Wilson

NISTIR 4912

The First Census Optical Character Recognition System Conference

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August 1992

U.S. DEPARTMENT OF COMMERCE
Barbara Hackman Franklin, Secretary

TECHNOLOGY ADMINISTRATION
Robert M. White, Under Secretary for Technology

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
John W. Lyons, Director

The First Census Optical Character Recognition Systems Conference

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Christopher J. C. Burges, Robert Creecy, Bob Hammond,
Jonathan J. Hull, Norman W. Larsen, Thomas P. Vogl,
and Charles L. Wilson

Contents

List of Figures

List of Tables

1 Executive Summary

Bob Hammond

1.1 Background

Since 1790, the United States has conducted a decennial census, or head count, of the American population. Over the last century, growth in the population and demand for quicker tabulations have presented very strenuous tasks for data capture and information technology. In the late 1800's, tabulating machines with punched cards were invented for Census use. In the 1950's, staff at Census and NBS helped develop the UNIVAC for general purpose computing. About the same time, they jointly developed the first optical scanning device for high speed mark recognition of microfilm.

For almost three decades, staff at the Census Bureau have heard claims that machine recognition of handwriting was just around the technological corner. However, a careful review of most claims showed that the corner was still a long way off. Recent advances in recognition of machine print and improvements in microprocessor performance have renewed optimism for machine recognition of hand print. In the late 1980's, the Census Bureau enlisted the Image Recognition Group (IRG) at the National Institute for Standards and Technology (NIST) to help evaluate these claims more closely.

1.2 The Conference

After several years of research, the NIST/IRG had developed a working prototype along with various methods to measure the performance of other systems. After the 1990 Census, NIST and Census decided to sponsor a scientific experiment and conference (hereafter referred to as the Conference) to determine the state of the art in this industry. NIST and Census formed a Committee having representatives from government, industry, and academia to organize the Conference, and NIST personnel ran the Conference.

Twenty nine different groups from North America and Europe responded to the call for participation. Each party received an image data base of segmented, hand-printed, alpha and numeric characters for training their systems. Later, each party received a similar database for test purposes. Each attempted to recognize the characters, and all but three submitted their results to NIST for scoring. In late May 1992, all parties that submitted results convened in Gaithersburg, Maryland to discuss the results. Scientific and academic participation was encouraged, and marketing interests were discouraged. Attendance was strictly limited to sponsors, participants, and up to two associates designated by each participant, along with a few observers from federal agencies (FBI, IRS, USPS) that are currently sponsoring work in the field.

The Conference and related exercises focused on a single step in the process: machine recognition of individual (or segmented) characters with no context. With the single variable nature of this study, no valid comparisons can be made regarding cost or performance of systems designed to process entire forms or documents. Further, the efforts of participants were not proctored or monitored in any way by Census or NIST staff.

1.3 Conclusions

NIST and Census are in no way responsible for how these results may be used. NIST made every effort to assure the accuracy of the measures computed from the submissions by the participants. Nevertheless, NIST and Census are aware that different tests, which may be more pertinent to real applications, might give different results than those reported here, and that other analyses of the submissions might give more complete results than those reported here.

While some results from this Conference may appear in marketing literature, under no circumstances should potential buyers use data from this study as a primary basis for purchasing decisions. Census and NIST can make only one recommendation to potential buyers: use your own application-specific data to thoroughly test the performance of any system (or component) in a realistic setting.

The Conference resulted in the following general conclusions:

About half of the systems correctly recognized over 95% of the digits, over 90% of the upper case letters, and over 80% of the lower case letters in the test. For comparison, a human correctly recognized about 98.5% of the test digits. (Chapters 3 and 4 discuss the test data, scoring, and error rates in detail.)

While machine recognition of segmented digits appears to be approaching the level of human performance, one should not extrapolate this conclusion to the performance on unconstrained input, which is a much more difficult problem.

Further research, development, and testing on realistic sources of hand-printing is needed to determine the cost and practicality of this technology. Many participants said they learned of new techniques at the Conference that will help them improve their system's performances, but potential buyers should use their unique, application-specific data to thoroughly test the performance of any system (or component) in a realistic setting. Discussions about differences in the training data and the test data suggests that various systems may perform differently with only slight changes in the source data.

For scientific reasons, future efforts to measure performance of competing systems would isolate the source and extent of error resulting from each step of the recognition process. However, given the wide variety of approaches to various steps in the process, this incremental approach to the research may be impractical.

1.4 Organization of this Report

The Introduction in Chapter 2 provides an overview of the Conference, materials, theories, and methods used in the effort. Chapters 3 and 4 discuss in more technical detail the theory and results of metrics used for scoring and evaluation of results. Chapter 5 attempts to lay out a taxonomy of approaches to optical character recognition systems, while Chapter 6 qualifies and discusses various considerations on the speed measures of the Conference. The various appendices offer original copy from the initial call for participation and instructional material, discussions of lessons learned (and problems encountered), and detailed descriptions and scoring results of all 118 submissions.

2 Introduction

Jon Geist

The goals of the First Census Optical Character Recognition (OCR) Systems Conference were scientific in nature. The first goal was to gauge the state of the art of OCR of hand-printed characters with respect to the particular problems associated with entering census data into a computer database. The second was to learn what is currently limiting the state of the art. The third goal was to determine whether new databases of handprinted characters for use either in training or in testing could be expected to help to improve the state of the art of OCR for applications such as the census, and if so, what types of new databases are needed.

It was decided that a test open to organizations having strong OCR programs would be a cost-efficient tool for meeting these goals. This would allow comparison of the results from a wide variety of systems, algorithms, features, and preprocessing. Unfortunately, it would not be possible to control the variables as well as might otherwise be desirable with this type of experiment, but comparison of the results from a broad range of systems was thought to be more important than comparison of the results obtained from different variations of a single type of system.

The full Census OCR task consists of document handling, form identification, field isolation, character segmentation, character recognition, and context-based field correction. However, the recognition of segmented characters has been considered the bellwether of OCR progress for some time. Therefore, it seemed desirable to limit the test to this subtask, both to establish a baseline for this capability before considering more complex combinations of subtasks, and to test recent thinking that the recognition of segmented characters is no longer the accuracy-limiting subtask for hand-print OCR.

This decision required postponing tests that are more typical of the full Census OCR task for future conferences. The test that was implemented consisted of classifying about 85000 binary images of segmented characters that were distributed on a CD-ROM. All participants received identical tests, and none had seen any of the images on the CD before receiving it.

The Conference had no marketing goals. In particular, the test was not proctored, and neither the capabilities tested nor the test images were representative of any commercial application. Also, participants were implicitly encouraged to carry out experiments that promoted the scientific goals of the Conference, but which might not contribute to optimum system performance. For instance, a training CD that contained over 300000 binary images of segmented characters was provided to the participants in advance of the test CD, but the participants were not required to train their OCR systems on the characters on this CD. Instead they could use their own training data, and use the training CD only to experiment with the data formats that would be used on the test CD. Nevertheless, many of the participants chose to train on subsets of the characters on the training CD rather than on internal databases that might have given better results.

The results of this test should not be used as the basis for purchasing an OCR system. Anyone who does base a purchase on these results will probably encounter a number of serious problems. Decisions regarding applying an OCR system to some specific task should be based on the results of proctored tests with test materials that are typical of that task. On the other hand, the methodologies developed for this Conference and the results obtained from this Conference should prove quite useful in designing tests, both large and small, to support purchasing decisions.

2.1 Organization of the Conference

The Conference was organized by a Committee consisting of the following individuals:

Bob Hammond, Robert Creecy, and Norman W. Larsen, US Bureau of the Census

Charles L. Wilson and Jon Geist, National Institute of Standards and Technology

Dr. Jonathan J. Hull, Center of Excellence for Document Analysis And Recognition

Dr. Thomas P. Vogl, Environmental Research Institute of Michigan

Dr. Christopher J. C. Burges, AT&T Bell Laboratories

Jon Geist, the Committee Chariman, handled the planning of the Conference and the majority of the interaction with the participants. The Conference was run for the Committee by the Image Recognition Group (IRG) at the National Institute of Standards and Technology (NIST) under contract to the US Bureau of the Census. Bob Hammond administered the contract supporting this Conference.

The following individuals from the NIST IRG were instrumental in carrying out the work of the Conference. Charles Wilson, the Leader of the NIST IRG, assured that resources were available when needed. Allen Wilkinson coordinated the technical activities of the Conference including the preparation of training and test materials, the receipt of participant submissions, and software trouble shooting. Stan Janet scored all of the submissions. Michael Garris designed and helped implement a new procedure for classifying the character images on the test CD to take maximum advantage of the NIST IRG OCR system while still assuring that every classification was checked by a human. Patrick Grother provided valuable advice on various aspects of the Conference based on his role as a participant representing the NIST IRG OCR system.

A Call for Participation was prepared and issued on behalf of the Committee as the first activity of the Conference. A version of the Call is reproduced in Appendix C. NIST Special Database 3 (SD3)[1] was sent to the participants to familiarize them with the test data formats and for possible use as training data. A preprint of the documentation for that database was sent as instructional material at the same time. NIST Test Data 1 (TD1)[2] was sent to each of the participants as the test data. Instructions for the test phase of the Conference were sent with TD1. These are reproduced in Appendix D.

Twenty nine organizations agreed to participate in the Conference. Three organizations: HNC, San Diego, CA; Scan Optics, East Hartford, CT; and the University of Massachusetts at Lowell, chose not to return test results after receiving the training and test materials. The remaining twenty six participants, representing over 45 different systems, returned over 115 submissions for scoring. These participants, the names assigned by NIST to the systems for which they submitted results, the type of results submitted, and pertinent references where available are summarized in Tables 1 and 2. The detailed activities that occurred before the meeting phase of the Conference are described in the Appendices mentioned above.

Since this was the first conference of its kind being run by the NIST IRG, a number of problems were encountered. These are discussed in Appendices A and B of this report. The former is a list of issues raised by the participants during the Conference meeting. The latter presents, from the NIST perspective, a short list of problems along with possible solutions proposed by various individuals. A short discussion is also included for each problem, both to provide background information, and to indicate how practical each proposed solutions appears.

2.2 Summary of Results

Classification, rejection, confidence, and error are general ideas of importance in OCR. The following definitions of these and related terms will be used throughout this report.

A classification process assigns an ASCII character to an image of a character. The classification may be correct or incorrect.

A rejection process divides a set of classifications into rejected classifications and accepted classifications. Only the accepted classifications are considered useful.

Usually, the rejection mechanism is applied after the classification process. However, some rejection processes work in parallel with the classification process, and no classification is assigned when a character is rejected. Most systems that carry out the rejection process after the classification process produce what is called a confidence for each classification. This is a number (usually between zero and one) that orders the classifications according to expected reliability.

The rejection rate for a set of character classifications is defined as the ratio of the number of characters rejected by the rejection process to the total number of characters presented for classification. For convenience, this report will refer to classifications that are not rejected by the classification process at any given rejection rate as unrejected or accepted classifications.

If a confidence is associated with each classification, any desired rejection rate can be obtained by choosing the correct value for the confidence threshold and rejecting any classifications having confidences less than or equal to the threshold and accepting any classifications having confidences greater than the threshold.

The error rate for a set of classifications is defined as the fraction of the unrejected (accepted) characters that are classified incorrectly. Therefore, the error rate varies as a function of the rejection rate.

Table 3 lists the zero-rejection-rate error rates for all of the OCR results submitted to the Conference. As a very rough summary, about half of the systems produced error rates of less than 5% at zero rejection rate for digits, about half produced error rates of less than 10% at zero rejection rate for upper case letters, and about half produced error rates of less than 20% at zero rejection rate for lower case letters.

PARTICIPATING ORGANIZATION	SYSTEM	DIGIT	UPPER	LOWER	REFERENCES
AEG Electrocom GmbH Konstanz, Germany	AEG	X	X	X	
Adaptive Solutions, Inc. Beaverton, OR	ASOL	X	X	X	[3][4]
AT&T Bell Laboratories Holmdel, NJ	ATT_1	X	X	X	[5][6][7][8]
	ATT_2	X	X	X	[5][6][7][8]
	ATT_3	X	X	X	[9][10]
	ATT_4	X	X	X	[5][6][7][8]
Com Com Systems, Inc. Clearwater, FL	COMCOM	X	X	X	
ELSAG BAILEY, INC. Conshohocken, PA	ELSAGB_1	X			
	ELSAGB_2	X			
	ELSAGB_3	X			
Environmental Research Institute of Michigan Ann Arbor, MI	ERIM_1	X	X	X	[11][12][13][14]
	ERIM_2	X			[11][12][13][14]
Gesellschaft für Mathematik und Datenverarbeitung Sankt Augustin, Germany	GMD_1	X	X	X	[15][16]
	GMD_2	X	X	X	[17][18]
	GMD_3	X	X	X	[15][16]
	GMD_4	X	X	X	[15][16]
GTESS Corporation Richardson, TX	GTESS_1	X	X	X	
	GTESS_2	X	X	X	
Hughes Aircraft Company Canoga Park, CA	HUGHES_1	X	X	X	[19]
	HUGHES_2	X	X	X	[19]
IBM Almaden Research Center, San Jose, CA	IBM	X	X	X	[20][21][22] [23][24][25][26]
InterFax, Inc. Sunnyvale, CA	IFAX	X	X		
Kaman Sciences Corporation Utica, NY	KAMAN_1	X	X	X	
	KAMAN_2	X	X	X	
	KAMAN_3	X	X	X	
	KAMAN_4	X	X	X	
	KAMAN_5	X	X	X	

Table 1: List of participants, system names, tests, and references

PARTICIPATING ORGANIZATION	SYSTEM	DIGIT	UPPER	LOWER	REFERENCES
Eastman Kodak Co. Rochester, NY	KODAK_1 KODAK_2	X X	X	X	[5][27][28] [5][27][28]
Mimetics Chatenay Malabry, France	MIME	X	X		[29][30]
Nestor, Inc. Providence, RI	NESTOR	X	X	X	[19][31][32] [10][33][34][35] [36][37][38]
National Institute of Standards and Tech. Gaithersburg, MD	NIST_1 NIST_2 NIST_3 NIST_4	X X X X	X X X X	X X X X	[39] [40] [41] [42]
NYNEX Sciences & Technology, Inc. White Plains, NY	NYNEX	X	X	X	
OCR SYSTEMS, Inc. Huntingdon Valley, PA	OCRSYS	X	X	X	
Recognition Equip. Inc. Dallas, TX	REI	X	X		
Riso National Lab. Roskilde, Denmark	RISO	X	X	X	
Symbus Technology Waltham, MA	SYMBUS	X	X		
Thinking Machines Corporation Cambridge, MA	THINK_1 THINK_2	X X			
University of Bologna Bologna, Italy	UBOL	X	X	X	[43][44][45] [46][47][48] [49][12][6]
University of Michigan-Dearborn Dearborn, MI	UMICH_1		X	X	
University of Penn. Philadelphia, PA	UPENN	X	X	X	[50][51][37] [52][5][53] [54][55][56][57]
Universidad Politecnica de Valencia Valencia, Spain	VALEN_1 VALEN_2	X X	X	X	[58] [59]

Table 2: List of participants, system names, tests, and references

Entered	Percentage Classification Error		
System	Digits	Uppers	Lowers
AEG	3.43 ± 0.23	3.74 ± 0.82	12.74 ± 0.75
ASOL	8.91 ± 0.39	11.16 ± 1.05	21.25 ± 1.36
ATT_1	3.16 ± 0.29	6.55 ± 0.66	13.78 ± 0.90
ATT_2	3.67 ± 0.23	5.63 ± 0.63	14.06 ± 0.95
ATT_3	4.84 ± 0.24	6.83 ± 0.86	16.34 ± 1.11
ATT_4	4.10 ± 0.16	5.00 ± 0.79	14.28 ± 0.98
COMCOM	4.56 ± 0.91	16.94 ± 0.99	48.00 ± 1.87
ELSAGB_1	5.07 ± 0.32		
ELSAGB_2	3.38 ± 0.20		
ELSAGB_3	3.35 ± 0.21		
ERIM_1	3.88 ± 0.20	5.18 ± 0.67	13.79 ± 0.80
ERIM_2	3.92 ± 0.24		
GMD_1	8.73 ± 0.35	14.04 ± 1.00	22.54 ± 1.22
GMD_2	15.45 ± 0.64	24.57 ± 0.91	28.61 ± 1.25
GMD_3	8.13 ± 0.39	14.22 ± 1.09	20.85 ± 1.25
GMD_4	10.16 ± 0.35	15.85 ± 0.95	22.54 ± 1.22
GTESS_1	6.59 ± 0.18	8.01 ± 0.59	17.53 ± 0.75
GTESS_2	6.75 ± 0.30	8.14 ± 0.59	18.42 ± 1.09
HUGHES_1	4.84 ± 0.38	6.46 ± 0.52	15.39 ± 1.10
HUGHES_2	4.86 ± 0.35	6.73 ± 0.64	15.59 ± 1.08
IBM	3.49 ± 0.12	6.41 ± 0.80	15.42 ± 0.95
IFAX	17.07 ± 0.34	19.60 ± 1.26	
KAMAN_1	11.46 ± 0.41	15.03 ± 0.79	31.11 ± 1.15
KAMAN_2	13.38 ± 0.49	20.74 ± 0.88	35.11 ± 1.09
KAMAN_3	13.13 ± 0.45	19.78 ± 0.60	33.55 ± 1.37
KAMAN_4	20.72 ± 0.44	27.28 ± 1.30	46.25 ± 1.23
KAMAN_5	15.13 ± 0.41	33.95 ± 1.22	42.20 ± 0.96
KODAK_1	4.74 ± 0.37	6.92 ± 0.78	14.49 ± 0.77
KODAK_2	4.08 ± 0.26		
MIME	8.57 ± 0.34	10.07 ± 0.81	
NESTOR	4.53 ± 0.20	5.90 ± 0.68	15.39 ± 0.90
NIST_1	7.74 ± 0.31	13.85 ± 0.83	18.58 ± 1.12
NIST_2	9.19 ± 0.32	23.10 ± 0.88	31.20 ± 1.16
NIST_3	9.73 ± 0.29	16.93 ± 0.90	20.29 ± 0.99
NIST_4	4.97 ± 0.30	10.37 ± 1.28	20.01 ± 1.06
NYNEX	4.32 ± 0.22	4.91 ± 0.79	14.03 ± 0.96
OCRSYS	1.56 ± 0.19	5.73 ± 0.63	13.70 ± 0.93
REI	4.01 ± 0.26	11.74 ± 0.90	
RISO	10.55 ± 0.43	14.14 ± 0.88	21.72 ± 0.98
SYMBUS	4.71 ± 0.38	7.29 ± 1.07	
THINK_1	4.89 ± 0.24		
THINK_2	3.85 ± 0.33		
UBOL	4.35 ± 0.20	6.24 ± 0.66	15.48 ± 0.81
UMICH_1		5.11 ± 0.94	15.08 ± 0.92
UPENN	9.08 ± 0.37		
VALEN_1	17.95 ± 0.59	24.18 ± 1.00	31.60 ± 1.33
VALEN_2	15.75 ± 0.32		

Table 3: Mean zero-rejection-rate error rates and standard deviations in percent calculated over 10 partitions of TD1.

Figures 1 through 6 plot the error rate versus the rejection rate for digits, for upper case letters, and for lower case letters, respectively, for all of the systems. The odd numbered figures plot the error versus rejection curves that were obtained by applying thresholds to the confidence data provided for most of the systems. The even number figures plot the points obtained directly from rejection data provided for the remaining systems. Summaries describing the individual systems and more detailed results are included in Appendices E and F.

Table 3 contains uncertainties for the error rates presented there. These uncertainties were calculated by dividing the characters in Test Data 1 into ten sets of characters, each set being a contiguous block of the test materials. Each set contained a fixed number of classification hypotheses. Each set was scored separately for each submission and the mean and sample standard deviation of those means are recorded in the table. The recognition error percentages are the definitive scores for each conference participant. They are exact performance measures over the whole database. The standard deviation is a measure of the change expected for the given classifiers on alternative subsets of the test data. All results refer to zero-rejection-rate classification.

2.3 Differences between Test and Training Databases

Most participants pointed out that the characters in NIST TD1 seemed different from and harder to recognize than those in NIST SD3. One participant suggested a cross validation data study. The study is described in detail in Section 3. The results suggest that TD1 is significantly harder than SD3 for digits, but not significantly harder, only different, for upper and lower case letters. A more definitive study and supplemental studies using other systems seem warranted.

A possible explanation for the different levels of difficulty for the two sets of digit images is the different way that the two sets were obtained. NIST SD3 and NIST TD1 were obtained by segmenting the characters filled out in boxes on forms that were variations of that shown in Figure 7. The forms for SD3 were filled out and returned by 2100 of 3400 permanent Census field workers as part of the 1990 Census program. The forms for TD1 were filled out by math and science students in a high school as a short exercise during class. The 2100 Census workers who actually returned filled out forms to their employer were clearly more motivated than the 1300 who did not, and may be more motivated than the 500 high school students who were forced to fill out and return the forms in class. The attitudes of the high school students are probably more representative of the attitudes of the general population when filling out a Census form.

The individual characters on the forms obtained from the Census workers were isolated by a different segmenter than that used with the forms obtained from the high school students. The segmentor used for SD3 failed to successfully segment a much larger fraction of the characters presented to it than did the segmenter used to create TD1. If segmenters fail on the most difficult characters, then this could be another reason why TD1 appeared more difficult.

All participants who used NIST SD3 for training thought that their error rate for TD1 would have been lower had they used a better training set. The Kodak and AEG systems both demonstrated this point in different ways. The only difference between the KODAK_1 and KODAK_2 system results in Appendix E is the addition of sevens with crosses to SD3 for training. This one change reduced the zero-rejection-rate digit error rate from 4.7% to 4.1%. AEG used SD3 for the Conference submission, but reran the digit test after the Conference using an internal database. This reduced the zero-rejection-rate error rate from 3.4% to 2.9%. Both of these results are consistent with the cross validation results for digits described in Section 3.

2.4 Error Rates as a Function of Rejection Rates

A casual glance at the curves in Figures 1 through 6 suggests that they all have very similar shapes. Section 4 derives the ideal error rate versus rejection rate curve, fits an empirical equation to the data in Figures 1, 3, and 5, and derives the probability distributions that generate the ideal and empirical error rate versus rejection rate curves. As discussed in Section 4 there is a lot of room for improvement in the shapes of the error rate versus rejection rate curves produced by the OCR systems before they start to be limited by the ideal shape. First their slope at zero rejection rate is less negative than the ideal slope at zero rejection rate, and secondly the curvature on a log plot is in the wrong direction.

The last column in Tables 7, 8, and 9 in Section 4 lists the ratios of the slopes of the error rates at zero-rejection rate to the optimum slopes for all of the curves in Figures 1, 3, and 5. Notice that it apparently easy to get the ratio of the actual slope to the ideal slope greater than 30%, but quite difficult to get it greater than 80%.

The first 10000 digits of TD1 were presented without any indication as to the correct class and classified by a human. This process was carried out at about 2 characters per second for periods from one to two hours with many hours between the classification periods. The result was a zero-rejection-rate error rate of 1.57%, which is very close to the digit rate for all of the digits in TD1 for the OCRSYS system. It is very interesting that this system obtained approximately the same zero-rejection-rate error rate as a human, while producing an error rate versus rejection rate that is much less satisfactory than those for the other OCR systems in the Conference.

2.5 Other Topics

Many different types of classifiers, feature extractors, and preprocessors were used (including no feature extractors or preprocessors). The only general conclusion that is evident so far is that good people can make almost anything work. Section 5 presents a taxonomy for OCR systems and some more detailed observations about the different types of systems tested.

Determining the state of the art with respect to system speed was not a goal of the Conference. Nevertheless, the participants were asked to provide the time from first CD-ROM access to last CD-ROM access for their system runs. Some participants provided these times, some provided times that were associated only with the actual OCR recognition task, some provided both, and some provided some intermediate times. The results are not meaningful enough to warrant any figures, but some general conclusions are listed in Section 6.

2.6 Conclusion

Some preliminary conclusions of the Conference are listed below.

The state of the art of machine OCR of segmented, hand-printed digits is approaching human performance with respect to the zero-rejection-rate error rate. The results for upper case letters and lower case letters are probably not as good relative to human performance as the performance for digits, but no human classifications under the conditions of the Conference test have been conducted to address question.

The digits in NIST SD3 do not represent a heterogeneous enough sample of hand-printed digits for optimum training of OCR systems. The same is probably true for the letters in SD3, but studies comparable to that reported in Section 3 have yet to be carried out.

The fact that almost all of the systems give similar shape error rate versus rejection rate curves for the digit, upper case letter, and lower case letters suggests that these curves come about as close as can be expected to optimum with the data in NIST TD1. On the other hand, theoretical studies suggest that there is room for considerable improvement. Further research will be needed to resolve this paradox.

Many of the participants indicated that the Conference was a useful learning experience. This includes the NIST IRG. Following the Conference, several simple changes were made to the NIST_1 system. These changes converted a K-Nearest Neighbor (KNN) system to a Probabilistic Neural Network (PNN) system using Karhunen-Loève (KL) features on binary images obtained from simple preprocessing, and produced the NIST_4 system summarized in Appendix F. The improvement in performance, a 35% decrease in the zero-rejection-rate error rate for digits from 7.7% down to 5.0%, is striking. It is noteworthy that the changes giving this level of improvement were not only easily implemented, but they were more of the nature of improvements in what was already being done rather than the introduction of new or different approaches.

Most of the participants and Committee members believe that the results of this Conference were more than sufficient to justify a Conference on isolated fields, but there was less of a consensus on exactly what sort of isolated fields were appropriate for the next test. When forced to choose between two extremes, the participants overwhelmingly preferred digital images of the microfilmed occupation and industry fields on real Census forms along with a dictionary of allowed answers rather than artificial fields of random letters digitized from forms such as were used for NIST SD3 and TD1.

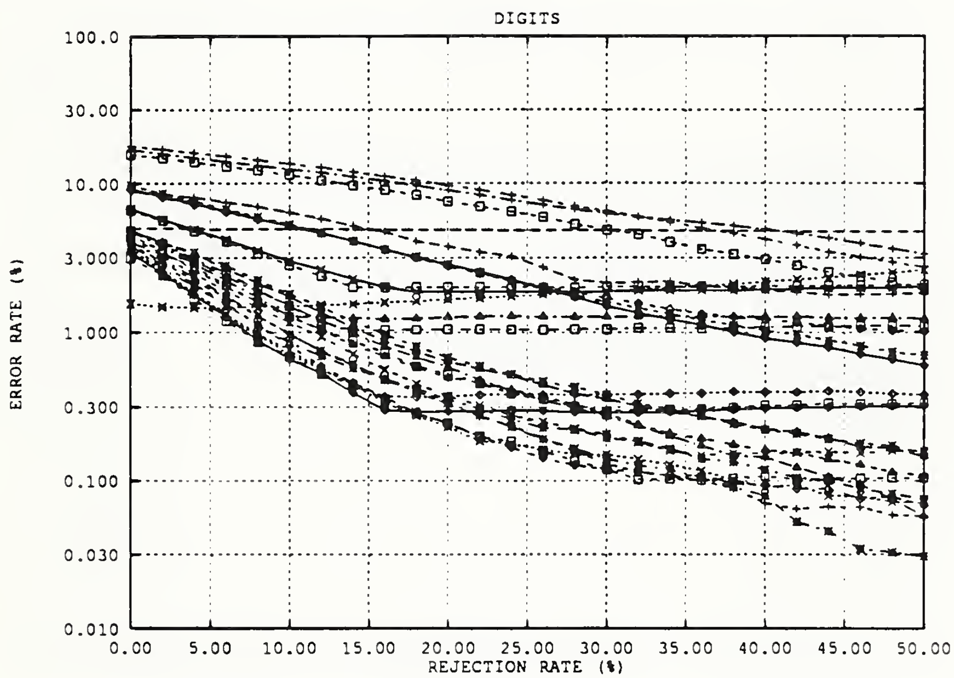


Figure 1: Error rate versus rejection rate for all systems providing confidence data with their classifications for the digit test.

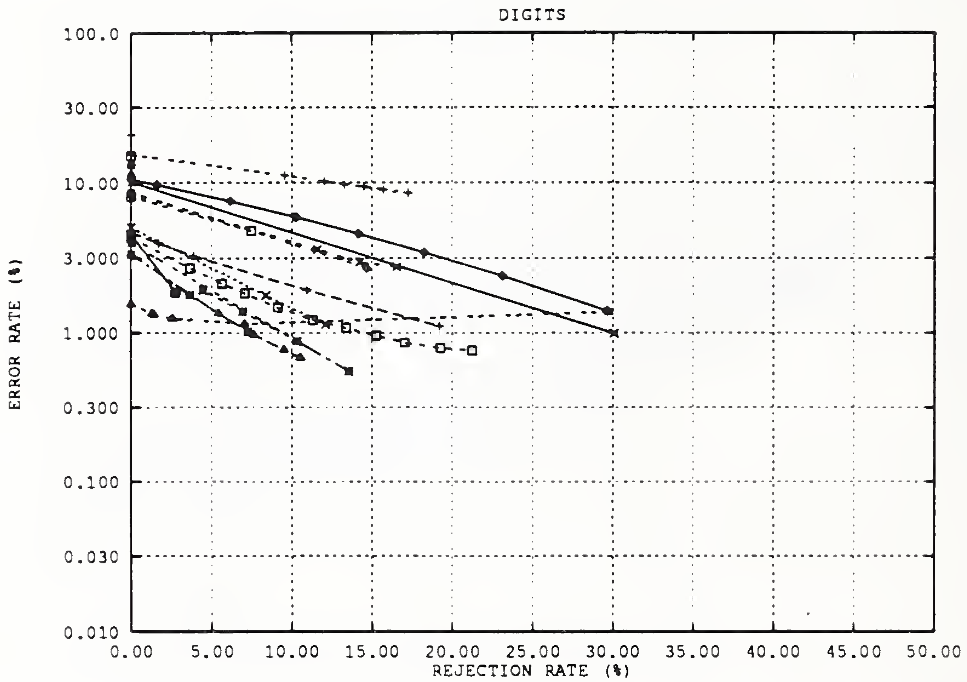


Figure 2: Error rate versus rejection rate for all systems providing rejection data with their classifications for the digit test.

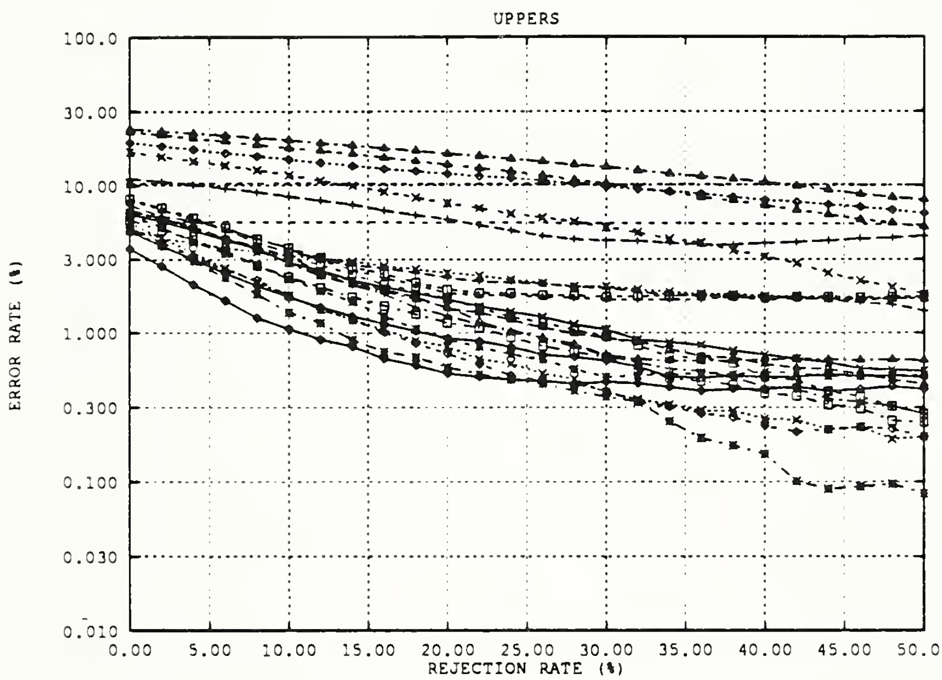


Figure 3: Error rate versus rejection rate for all systems providing confidence data with their classifications for the upper case test.

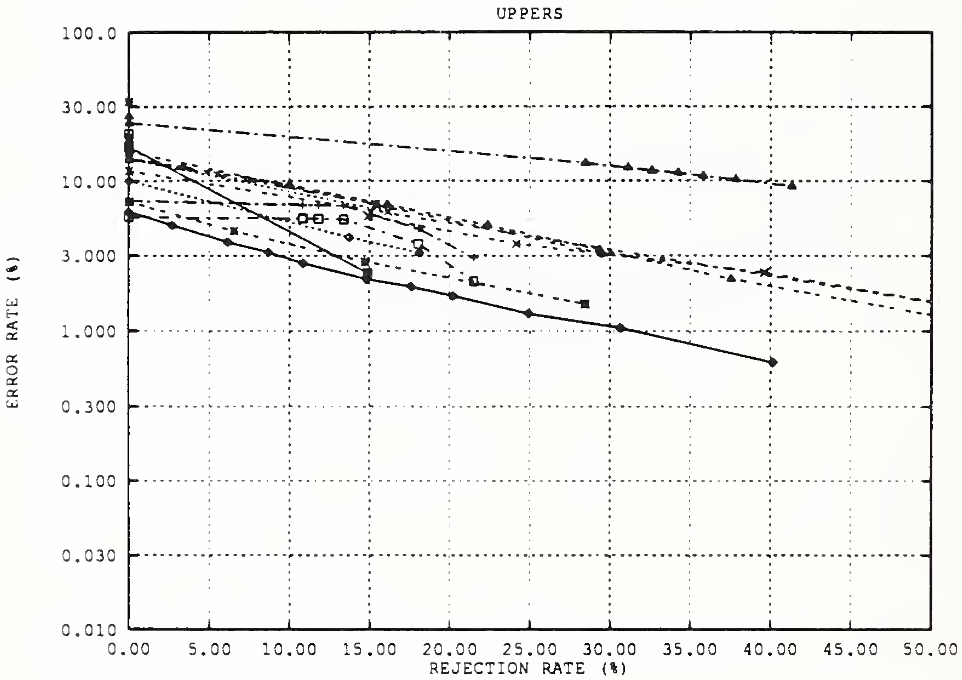


Figure 4: Error rate versus rejection rate for all systems providing rejection data with their classifications for the upper case test.

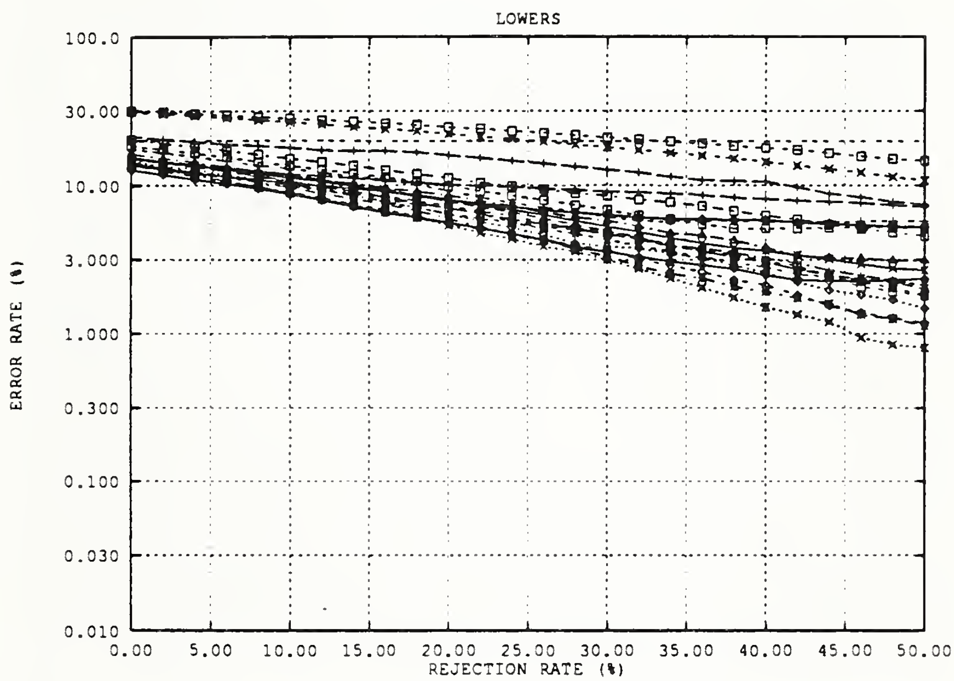


Figure 5: Error rate versus rejection rate for all systems providing confidence data with their classifications for the lower case test.

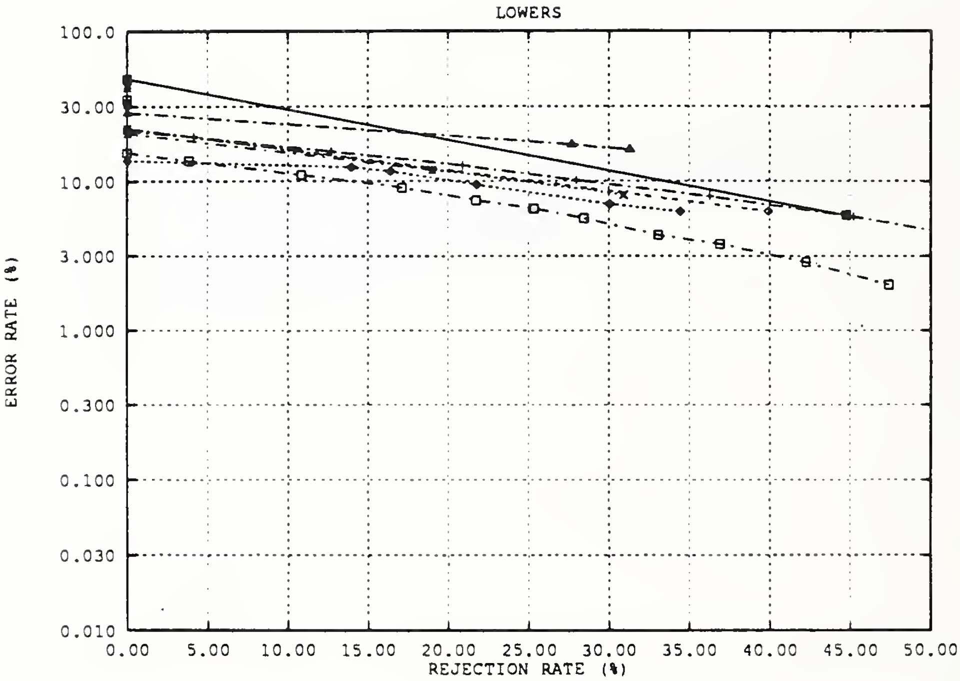
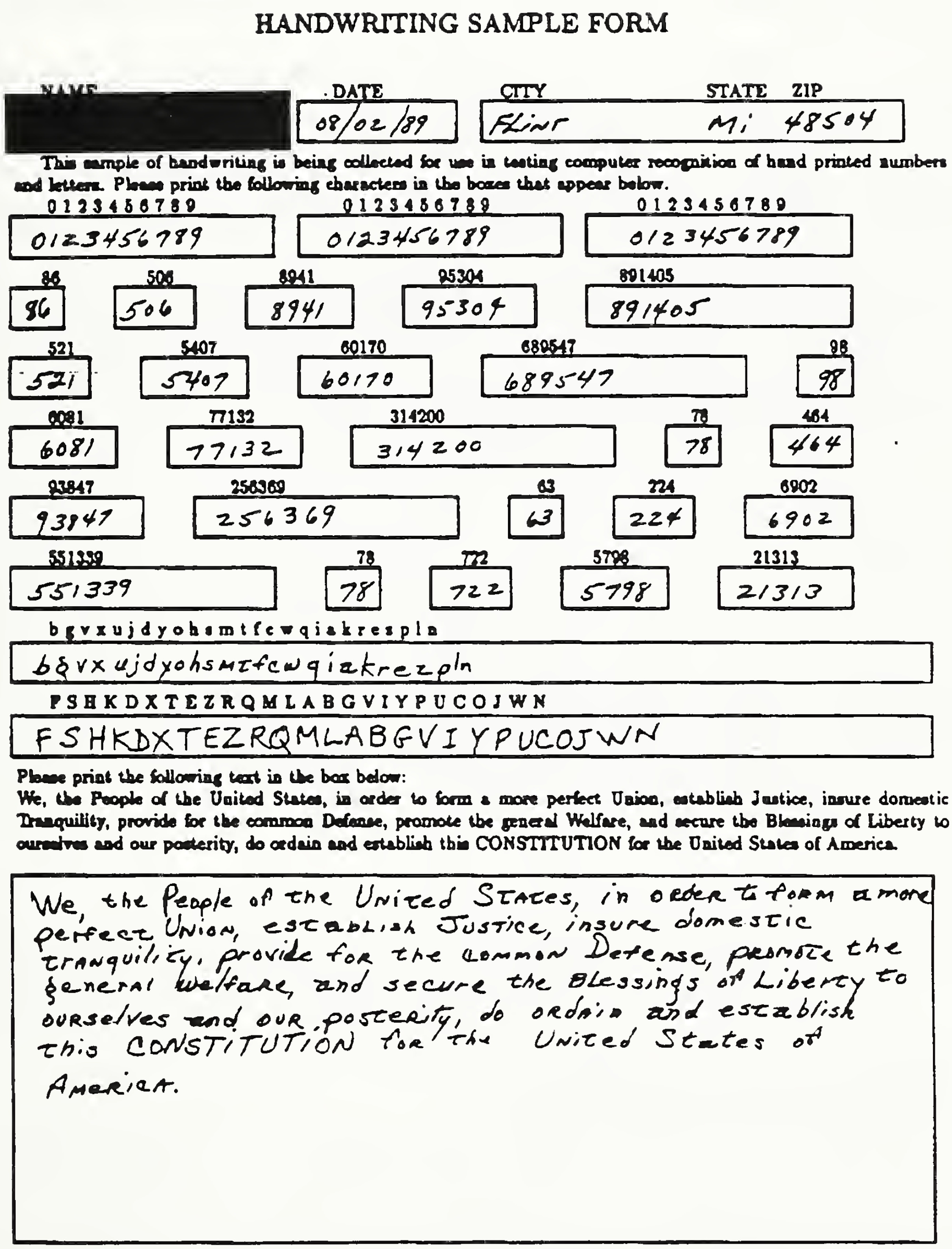


Figure 6: Error rate versus rejection rate for all systems providing rejection data with their classifications for the lower case test.



HANDWRITING SAMPLE FORM

NAME [redacted] DATE 08/02/89 CITY Flint STATE ZIP Mi 48504

This sample of handwriting is being collected for use in testing computer recognition of hand printed numbers and letters. Please print the following characters in the boxes that appear below.

0123456789 | 0123456789 | 0123456789

86 | 506 | 8941 | 95304 | 891405

521 | 5407 | 60170 | 689547 | 98

6081 | 77132 | 314200 | 78 | 464

93847 | 256369 | 63 | 724 | 6902

551339 | 78 | 722 | 5798 | 21313

bgvxujdyohsmtfcwqiakrezpln

FSHKDXTEZRQMLABGVIYPUCOJWN

Please print the following text in the box below:
We, the People of the United States, in order to form a more perfect Union, establish Justice, insure domestic Tranquility, provide for the common Defense, promote the general Welfare, and secure the Blessings of Liberty to ourselves and our posterity, do ordain and establish this CONSTITUTION for the United States of America.

Figure 7: A typical filled-out sample form

3 Cross Validation Studies

Patrick J. Grother

3.1 Introduction

Participants in the Conference agreed to classify unlabelled images using their own recognition systems and submit their classifications to NIST for scoring. NIST provided two databases to all entrants. The first, SD3, contained the segmented characters of 2100 writers and the "known" class files. This constituted an optional training set. The second database, TD1, contained unlabelled characters from 500 writers, and it constituted the test materials.

One result of the Conference was that those recognition systems trained solely on the SD3 database generally displayed inferior TD1 recognition to those trained on a superset of this data, i.e. one including SD3 as a subset, or other, possibly proprietary, datasets. The notion that SD3 was "clean" or "constrained" relative to the TD1 dataset was suggested by the writer profiles; SD3 was obtained from motivated permanent Census field personnel whereas TD1 was obtained from variously motivated, more diverse and cosmopolitan high school students. An example is that the European crossed seven is far more abundant in TD1 than SD3.

A study was initiated to formally investigate the relative differences between the two databases. The intent was to obtain some classifier-independent measures of the relative database difficulty - to obtain results that pertain to the properties of the data, and not the particular recognition algorithm. Cross validation [60] [61] has long been used as a method of obtaining more "mileage" from a data set. By partitioning the data into disjoint subsets, one for parameter estimation (i.e. training) and the other for performance measurement (i.e. testing), more robust estimates of performance statistics are available.

3.2 Theory

Cross validation is a method for accumulating a statistic, which in this section is the classification error obtained using a nearest neighbor classifier. Moody [62] expressed cross validation in terms of the mapping error associated between inputs and targets to a multilayer perceptron (MLP), but the concept of cross validation is in no way restricted to neural network classifiers or function approximators.

A problem associated with MLP networks is that patterns (for example, crossed sevens) present in a training set in small numbers are only weakly represented by the estimated weights, such that generalization is poor. Algorithms that do not aggregate information from the training data are not usually prone to this problem. Such a method is the ubiquitous K-Nearest Neighbor (KNN) algorithm [63]. The distances of an unknown pattern to elements of a prototype set are calculated using a suitable metric (often euclidean). Voting between the classes of the K-closest patterns implies the class of the unknown pattern. Numerous extensions to the scheme have been used effectively including an elaboration, termed "Probabilistic Neural Network" (PNN), developed by Donald Specht [42] in which all prototypes are included in a gaussian distance weighted metric. The advantage of the method is that an *a posteriori* probability is attached to each possible class; the unknown is classed as that with the highest probability. NIST has used nearest neighbor classifiers that significantly outperform MLP networks given identical features.

3.3 Classification

The first stage of classification for purposes of cross validation between the two sets used the Karhunen Loève (KL) expansion of the images as a reduced dimensionality, optimally compact, representation. The use of such features in OCR has been described[64] [39].

The hand printed binary characters are isolated and represented as the ± 1 elements of a column vector by some consistent ordering of the rectangular image. The mean vector of P such images is subtracted from each and an ensemble matrix, $\mathbf{U}$ is formed with the P vectors as its columns. The symmetric covariance matrix, $\mathbf{R}$, which can be expressed as

$$\mathbf{R} = \mathbf{U}\mathbf{U}^T, \tag{1}$$

gives the mean of all the interpixel correlations over all images in the ensemble. This can be used to statistically describe how handprinted character images vary. The covariance matrix $\mathbf{R}$ has eigenvectors as the columns of Ψ:

$$\mathbf{R}\Psi = \Psi\Lambda \tag{2}$$

where the only non-zero elements of Λ are the eigenvalues on its diagonal. The eigenvectors are the directions of maximum variance in the image space and form a complete orthonormal set termed the principal axes of a hyperellipse in that space. The eigenvalues define the statistical "length" of these axes; thus the first column of Ψ corresponding to the largest eigenvalue is the major axis. The eigensolution of the covariance matrix provides a variance expansion of the image ensemble ordered from largest to smallest eigenvectors. The eigenvectors having the smaller values and therefore describing very little variance in the images, are discarded, thus affording useful dimensionality reduction. *Any* image vector as a column of a new matrix $\mathbf{U}$ is a linear superposition of the basis vectors:

$$\mathbf{U} = \Psi\mathbf{V} \tag{3}$$

where the inversion of this formula, $\mathbf{V}$, defines the Karhunen Loève Transform (KLT) [65], the elements of which are the projection of the image vector onto the principal axes:

$$\mathbf{V} = \Psi^T\mathbf{U} \tag{4}$$

These feature vectors are classified using the PNN nearest neighbor technique[42]. Although many variations are described, the NIST_4 implementation reported in Appendix F is as follows. The square euclidean distance of an unknown pattern, τ, to the i^{th} prototype in the training set, t_i, is

$$d_i^2 = \sum_{j=1}^{N}(\tau_j - t_{ij})^2 \tag{5}$$

where the subscript j spans the N highest KL eigenvectors retained for the expansion. The distances d_i are expressed as a function of the standard deviations of normal distributions centered on each of the prototypes. A gaussian is applied as a kernel weighting function.

$$g_i = e^{-d_i^2/2\sigma^2} \tag{6}$$

The weighted distances are then accumulated by class over the K classes, to which the prototypes belong.

$$v_k = \sum_i^P g_i \delta_{ik} \tag{7}$$

where δ_{ik} is unity if the i^{th} prototype is of class k and zero otherwise. Interestingly this vector may be normalized to give *a posteriori* probabilities by dividing by $\sum_k v_k$. The unknown is assigned the class with the largest attached probability. For optimal classification it is necessary to survey over the gaussian width σ; for digits the best value was taken as 3.0, whereas for uppers and lowers a value of 4.0 was adopted.

Rather than use classifiability as a measure of database homogeneity it is possible to obtain *a priori* measures. Consider the databases as image ensembles for which the KLT is defined. The variances of the transform coefficients are the eigenvalues. Since the eigenvectors, the basis of the KLT, form a complete orthonormal set, *any* image (including those of the ensemble from which the covariance matrix is calculated) is exactly a linear superposition of those bases. If the eigenvalue spectrum is relatively flat, then the variance in an image ensemble is distributed over many eigenvectors and more eigenvectors are needed for an adequate representation, as for instance in achieving a low reconstruction mean square error level.

Interestingly, this total image variance is related to the scatter of the data, S, defined as

$$S = E\{\|\mathbf{u}_i - \mathbf{u}_j\|\} \tag{8}$$

where the expectation, $E\{\cdot\}$ of the underlying distribution is replaced by the sample mean whence

$$S = \frac{1}{P^2} \sum_{i=1}^P \sum_{j=1}^P (\mathbf{u}_i - \mathbf{u}_j)^T (\mathbf{u}_i - \mathbf{u}_j) \tag{9}$$

$$S = \frac{1}{P^2} \sum_{i=1}^P \sum_{j=1}^P \left(\mathbf{u}_i^T \mathbf{u}_i + \mathbf{u}_j^T \mathbf{u}_j\right) - \frac{1}{P^2} \sum_{i=1}^P \sum_{j=1}^P \left(\mathbf{u}_i^T \mathbf{u}_j + \mathbf{u}_j^T \mathbf{u}_i\right) - \tag{10}$$

Given that the $\mathbf{u}$ are mutually independent and from a single distribution the double sums are replaceable thus

$$S = \frac{2}{P} \sum_{i=1}^P \mathbf{u}_i^T \mathbf{u}_i - \frac{2}{P} \sum_{i=1}^P \mathbf{u}_\mathbf{i}^\mathbf{T} \frac{1}{P} \sum_{j=1}^P \mathbf{u}_\mathbf{j} \tag{11}$$

By considering these inner products as the traces of the outer products of the ensemble matrices then the scatter becomes twice the difference in the traces of the autocorrelation and mean outer product matrices. This matrix is identical to the covariance matrix of equation 1.

$$S = 2\, Trace\{\mathbf{U}\mathbf{U}^T\} \tag{12}$$

The diagonal elements of the covariance matrix are the variances of the image pixels. The total variance is conserved under any unitary transformation:

$$\sum_i \mathbf{R}_{ii} \equiv Trace\ \mathbf{R} = Trace\ \Lambda \tag{13}$$

It is found that the scatter statistic is proportional to the sum of the eigenvalues. Further expressing eigenvalues as a percentage of their total yields the percentage of the ensemble variance represented by a subset of N eigenvectors. For comparison of the two databases the difference in the percentages as a function of N is discussed. Some eigenfunctions describe image variance that is relevant to classification, and others describe variation that is representative of noise. If an eigenspectrum is wide, then the percentage variance described by the N leading eigenvectors will be small. If the cross validation percentage recognition is high, then the information discarded by using an incomplete KLT is irrelevant even though there is much of it. Alternatively, if the eigenspectrum is narrow, with much of the variance captured, then a low recognition rate implies that the discarded transform coefficients are valuable. This latter sensitivity to the high-order KL-transforms is undesirable since the motivation for feature extraction is reduced dimensionality.

3.4 Cross Validation Results

This study generated a *Validation Comparison Matrix*. The matrix has rank two and dimension equal to the number of databases in the comparison which in this case is also two. The row and column indices of the matrix denote, respectively, the databases used for training and testing. The absolute classification error rates in the matrix are taken as irrelevant since the entries were all produced using the same classifier which was not particularly well optimized. The interesting features are the relative percentages discussed below.

The on-diagonal terms, c_{ii}, indicate the mean error rates for standard v-fold cross validation of the i^{th} database. The off-diagonal elements, c_{ij} $i \neq j$, result from cross-cross validation. The first u partitions of database i are used as training sets for the v-fold cross validation of the j^{th} database. In the case of v-fold partitioning of the training set there will be uv results the mean of which is c_{ij}.

All mean elements have an attached sample standard deviation.

$$\sigma = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} (x_i - \mu)} \tag{14}$$

If an homogeneous dataset is large enough then this quantity will approach zero. The standard deviation is also a function of the data set redundancy. For instance, consider a database to which a copy of itself is appended, and which is classified with, for example, a single nearest neighbor algorithm. Perfect recognition could then be achieved if, as in the cross validation scheme used here, the partitions are contiguous blocks from the dataset.

The standard error is accessible by dividing the standard deviations by a further $\sqrt{N}$ where $N = 10$. The discussion of the comparisons of the means and the variances is aided by invoking the results of Student's "t test" and the "f test" (see for example [66]).

They are used to assess whether two distributions have the same mean and the same variances. The entire corpus of human hand-printed characters may be considered as one distribution of which SD3 and TD1 are subsets, but for this study the two sets are extracted from different distributions, namely the two social writer groups outlined in the introduction. The t-test quantifies the difference in two means as a function of their mutual root mean square standard error.

$$t = \frac{\mu_1 - \mu 2}{\sqrt{\frac{\sigma_1^2}{N_1} + \frac{\sigma_2^2}{N_2}}} \tag{15}$$

Attached to t is a significance, $0 \leq p \leq 1$, giving the probability that $|t|$ could be at least this large by chance. That is if p takes on a "small" value then the distributions have *significantly* different means. Similarly the f-test quantifies two variances as a ratio taken to be greater than 1 (i.e. either σ_1^2/σ_2^2 or its reciprocal). The value of f directly indicates differing variances. The attached significance, p is again a probability. Small values indicate significantly different variances.

The statistics are derived from the two samples obtained by testing the 10 partitions of SD3 and TD1 data using one or other training set. In all cases, digits, upper-case and lower-case letters, the calculated value of the t is found with very low significance indicating the mean differences are not at all spurious. However in no case does the attached probability for the f-test indicate that the variances are significantly different.

3.4.1 Digits

The handprinted digits of the first 500 writers of SD3 were partitioned into blocks each containing digits from 50 writers. The numbers of characters in these ten sets were not identical but varied by only 0.2%. The number of SD3 digits totalled 53449. The 500 writers of TD1 were similarly partitioned. The number of TD1 digits totalled 58646. The pure 10 fold cross validations for SD3 and TD1 were obtained using the characters of 90% of the writers as training prototypes with the characters of the remaining 10% used for testing. The mean of the zero-rejection-rate error rates for the cross validations are quoted on the diagonal of the Table below.

The first partition of SD3 (450 writers) was used as prototypes for the classification of all 10 sets of characters of TD1, and vice versa. The off-diagonal elements of the validation

Correct % ± σ	Test SD3 50 writers	Test TD1 50 writers	
Train SD3 450 writers	1.7% ± 0.3	6.8% ± 0.4	t = 28.5 p = 0.0 f = 1.5 p = 0.3
Train TD1 450 writers	3.5% ± 0.3	3.8% ± 0.5	t = 1.4 p = 0.2 f = 2.1 p = 0.3

Table 4: Inter and Intra database Cross Validation Recognition Errors for Digits

comparison matrix, so obtained, are also given in the Table below.

The most relevant result from this table is that, using the classifier as described above, training solely on SD3 implies a 5% loss when classifying TD1. This is effectively NIST's experience with its NIST_1 and NIST_3 systems reported in Appendix E.

The on-diagonal elements of the cross validation matrix show that SD3 is a less *diverse* digit set than TD1. That is the test partitions of SD3 are more like their training sets, in the nearest neighbor sense, than is the case with TD1. Greater on-diagonal terms indicate a higher intrinsic diversity for that database. If we relate the low TD1 classification to the width of the eigenvalue spectrum or the volume of the eigenspace, it is apparent that TD1 would benefit from the use of a more complete KLT as input to the classifier.

Figure 8 shows the eigenspectra of the SD3 and TD1 characters. Note in particular that the total variances for the 1024 pixel images are 575.5 (SD3) and 636.8 (TD1) indicating that TD1 is absolutely more diverse (larger scatter). Approximately 6.6% more of the variance of SD3 is described with 48 KL eigenvectors (as used by the classifier) than is the case for TD1.

The off-diagonal terms show that use of SD3 as a training set for testing with TD1 is markedly inferior to use of TD1 as a training set for testing with SD3. The implication is that TD1 is a superset of the SD3 set, i.e. TD1 contains sufficiently distributed prototypes to classify SD3 - whereas TD1 contains exemplars that are not "closely" present in SD3. That TD1 classifies itself and SD3 equally (to within one standard deviation) implies that TD1 is a more *general* dataset.

3.4.2 Uppers

Correct % ± σ	Test SD3 48 writers	Test TD1 50 writers	
Train SD3 432 writers	14.2% ± 1.4	19.4% ± 1.4	t = 7.9 p = 0.0 f = 1.0 p = 0.8
Train TD1 450 writers	19.3% ± 1.7	16.5% ± 1.4	t = 3.8 p = 0.0 f = 1.5 p = 0.4

Table 5: Inter and Intra database Cross Validation Recognition Errors for Uppers

The handprinted upper case letters of the first 480 [1] writers of SD3 were partitioned into blocks from 48 writers. The upper case letters totalled 10790 examples. The 500 writers of TD1, similarly partitioned, yielded 11941 characters. As in the case of digits, there is a 5% difference between the classification of SD3 on itself and on TD1. Again, TD1 is more diverse in classification of itself than is the case with SD3. On the other hand, the total variances are 734.0 (SD3) and 650.2 (TD1) indicating that SD3 is absolutely more diverse. With classification using 96 KL coefficients the percentage variance captured for SD3 was 4.8% *less* than that for TD1.

The off-diagonal elements, however, are the same indicating that neither set is more general than the other. That the off-diagonal elements are lower than the on-diagonals indicates the databases contain unique subsets that require specialist knowledge contained only in that database.

3.4.3 Lowers

The handprinted lower case letters of the first 490 [2] writers of SD3 were partitioned into blocks from 49 writers. The lower case letters totalled 10968. The 500 writers of TD1, similarly partitioned, yielded 12000 characters. As with the upper case letters, but not with the digits, the total variances are 740.4 (SD3) and 637.9 (TD1) indicating that SD3 is absolutely more diverse. With classification using 96 KL coefficients the percentage variance captured for SD3 was 2.3% less than the that for TD1. The cross validation matrix shows

[1] None of the upper case letters of twenty writers were segmented in the preparation of SD3. See subsection 3.5.

[2] None of the lowercase letters of 10 writers were segmented in the preparation of SD3. See subsection 3.5.

Correct % ± σ	Test SD3 49 writers	Test TD1 50 writers	
Train SD3 441 writers	19.6% ± 1.4	23.5% ± 1.4	t = 5.9 p = 0.0 f = 1.1 p = 0.8
Train TD1 450 writers	25.9% ± 1.8	19.2% ± 1.1	t = 9.6 p = 0.0 f = 2.5 p = 0.1

Table 6: Inter and Intra database Cross Validation Recognition Errors for Lowers

that the lower case datasets are equally difficult and yet different - they are insufficiently general to classify each other as well as they classify themselves.

3.5 Caveats

3.5.1 Segmentation

This initial study reports work NIST conducted immediately after the Conference. As such it is a provisional investigation of database quality; it is not experimentally flawless and therefore the conclusion that SD3 is cleaner than TD1, at least for digits, does not necessarily apply to the forms from which the two databases of characters were segmented.

One reason for this is that SD3 and TD1, both obtained from fields of full page forms, were arrived at with different character segmenters. From a possible 65000 characters on each 500 form set, final numbers of human-checked characters were 53449 (SD3) and 58646 (TD1). The SD3 segmentor, an old version, produced 9% fewer isolated characters than the updated model used for TD1. The principal reason for failure of the SD3 segmenter was the inability to segment connected or overlapping characters. If the characters from SD3 that were not segmented resemble the difficult digit images that apparently characterize TD1, then the difference between the two databases may not be writer-letter dependent at all. Instead it could represent writer-connectivity/overlap differences between the two different writer groups, or the differences in ability of the different segmenters to segment connected or overlapping characters that tend to be difficult in other ways as well.

This problem can be negated by resegmenting and rechecking the characters in SD3 using the identical algorithms applied to TD1. A new database, a superset of SD3, would then obtained, which could then be used in a more controlled comparison with TD1.

3.5.2 Classifier Dependence

The eigenvalue spectrum describes the information loss suffered when only the KL eigenvectors having the largest eigenvalues are used in classification. The classification of incomplete KLT's is peculiar in that variance ordered information is discarded. Using a much higher number of coefficients in the digit classification might equalize the on-diagonal cross validation entries. Even with a higher dimensional (but lower variance) KL space, aggregated functionally approximated MLP classifiers are not able to recognize minority patterns. Under these conditions, the nearest neighbor schemes do better.

Instead of using a "lossy" incomplete feature classifier it is possible to use a full description of the image; the complete KL transform. *Variance equalization* may be more reasonable - choose the number of KL features corresponding to either an absolute level of described variance or percentage thereof. Thus in the case of the digits in SD3, 43 eigenevectors describe 75% of the variance, whereas to reach this level with TD1, 70 KL coefficients are required. Alternatively, features that do not bias information loss may be used. For example, image row and column pixel histograms or orthogonal moments are known to be classifiable.

3.6 Conclusions

Given the experimental scheme described, it appears that TD1 does contain a more diverse and general digit set than SD3. The latter classified disjoint digit subsets of itself with a 5% lower error rate than that with which it classified TD1. Furthermore, TD1 yields a 3% improvement over SD3 in the classification of disjoint digit subsets of the former. The hypothesis that differing writer populations are responsible for this difference has not been proven. Indeed, the fact that the cross validations for the upper and lower case letters yield very different results seems to weaken this argument for digits.

Further, more controlled experimentation is necessary and on-going. The *a priori* measures of image variance are similarly inconclusive.

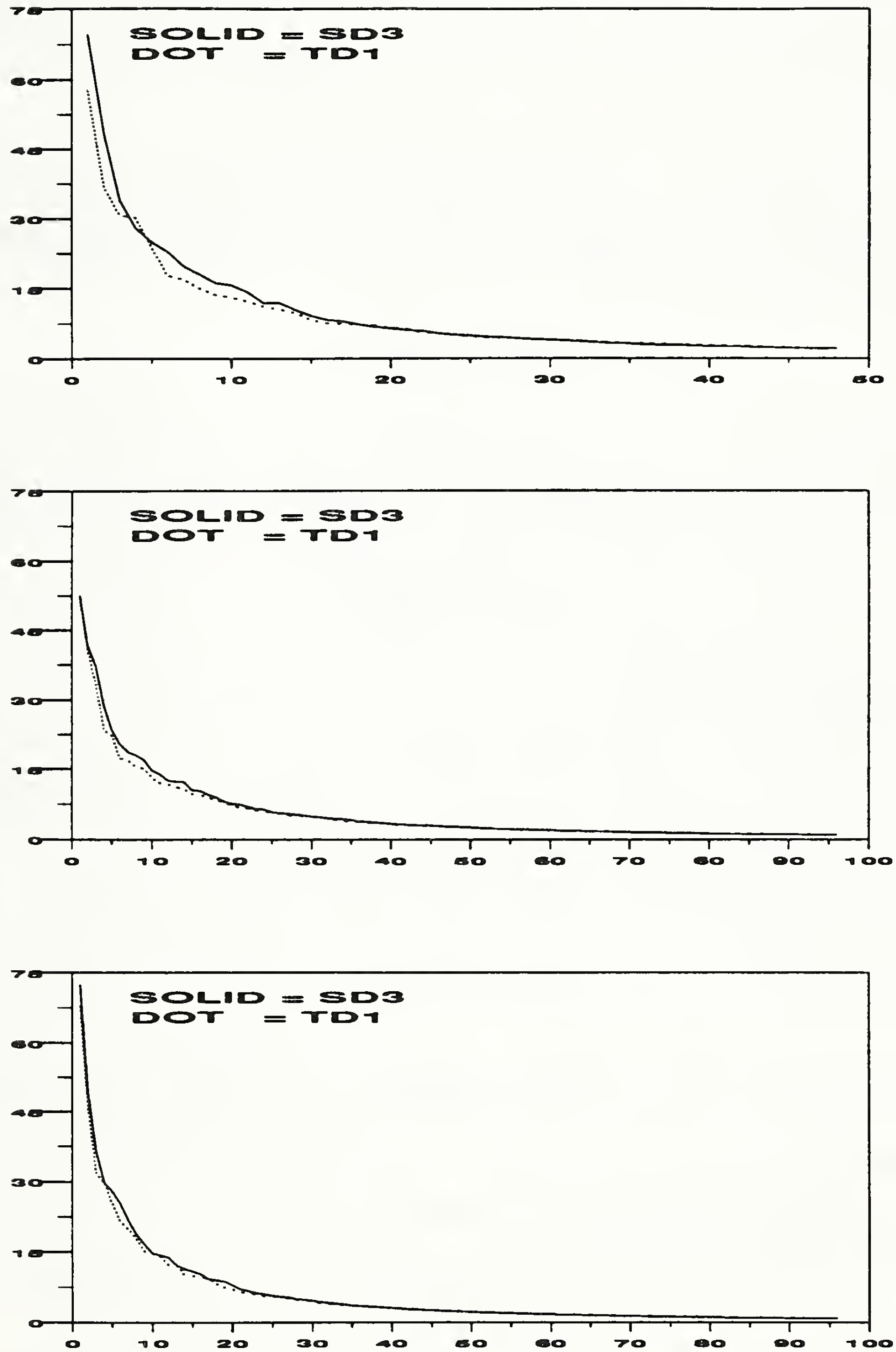


Figure 8: Eigenvalue vs Index for SD3 and TD1. From top: digits, uppers and lowers. All writers were used.

4 System Error Rates Versus Rejection Rates

Jon Geist and R. Allen Wilkinson

4.1 Theory

Let $q(r)$ be the probability as a function of rejection rate r that a rejected classification is an incorrect classification. In this case, the error rate $e(r)$, which is defined as the ratio of accepted (unrejected) classifications that are incorrect to the total number of accepted classifications, is given by

$$e(r) = \frac{e(0) - f(r)}{1 - r} \tag{16}$$

where

$$f(r) = \int_0^r q(s)ds, \tag{17}$$

is the fraction of the rejected classifications as a function of r that are actually incorrect. Equations 16 and 17 may be combined to give the slope of the error rate,

$$e'(r) = \frac{e(r) - q(r)}{1 - r} \tag{18}$$

If $e'(r)$ is zero in eq. 18 , then

$$q(r) = e(r) = e_0, \tag{19}$$

where e_0 is a constant. This means that the probability of rejecting an incorrect classification is equal to the fraction of incorrect classifications remaining in the unrejected sample. In this case, the rejection mechanism just rejects classifications at random.

If $q(r)$ is equal to the constant q_0 over some subrange of r, then

$$e(r) = \frac{e(0) - q_0 r}{1 - r} \tag{20}$$

and

$$e'(r) = \frac{-q_0 + e(0)}{(1 - r)^2} \tag{21}$$

over the same subrange.

Therefore, a perfect rejection mechanism is characterized by $q(r) = 1$ for $0 \leq r \leq e(0)$, and $q(r) = 0$, for $r > e(0)$, in which case,

$$e(r) = \frac{e(0) - r}{1 - r} \tag{22}$$

for $0 \leq r \leq e(0)$, and

$$e(r) = 0, \tag{23}$$

for $r > e(0)$.

It is clear from a cursory investigation of Figures 1 through 6 in Section 2 that none of the submissions to the Conference come close to a perfect rejection mechanism, yet all of their $e(r)$ curves seem to have similar shapes. The next section describes an experiment that was carried out to test this observation.

4.2 Fit of Model to Experimental Data

A visual examination of the curves in Figures 1 through 6 in Section 2 suggests that they might be well described by

$$e(r) = \frac{(e_0 - e_{min})exp(-r/r_0) + e_{min}}{1-r}. \tag{24}$$

To test this conjecture, we fit the logarithms of the measured $e(r)$ curves to the logarithm of eq. 24 over the range $0 \leq r \leq 0.14$, where e_0, e_{min}, and r_0 were adjusted in the fit. Logarithms were used to optimize the shape of the fits, rather than the values near the maximum of $e(r)$.

The results of the fits are summarized in Tables 7 , 8 , and 9 , which list for the digit, the upper case, and the lower case test, respectively, the values of e_0, e_{min}, and r_0 for each system that participated in each test. These tables also list the residual standard deviation of each fit, and the ratio of the actual value of $e'(0)$ for each system to the ideal value of $e'(0)$ for a perfect rejection process for that system. It is also noteworthy that it appears easy for a system to obtain a value of $e'(0)$ that is greater than 30% of the ideal value, but it appears very difficult for a system to obtain a value of $e'(0)$ that is greater than 80% of the ideal value.

Eight data points were used in each fit. Three parameters were estimated. This leaves five degrees of freedom in each fit. Because the fits were carried out on the logarithms of the data, the residual standard deviations of the fits are actually the standard deviations of the relative differences between the measured error rates and those predicted by eq. 24. Thus a residual standard deviation of 0.01 corresponds to a standard deviation of the relative errors of the fit of 1% over the range of the fit.

It is remakable how well eq. 24 can be fit to the $e(r)$ curves for the various different systems over the 0 to 14% subrange of r. In fact, most of the $e(r)$ curves are well described by eq. 24 over a subrange $0 \leq r \leq r_{s1}$, and by

$$e(r) = e_s, \tag{25}$$

over a subrange $r_{s1} \leq r \leq r_{s2}$, where e_s, r_{s1}, and r_{s2} are system dependent constants, $r_{s1} \leq r_{s2}$, and $r_{s2} \gg 14\%$.

4.3 Conclusion

Equation 25 corresponds to the case where the rejection process has degenerated to a random sampling of the unrejected classifications, as described in connection with eq. 19. Equation

24 , on the other hand, corresponds to the case where the probability of rejecting a classification that is actually incorrect is given by

$$q(r) = \frac{e_0 - e_{min}}{r_0} exp(-r/r_0), \tag{26}$$

which can be rewritten in terms of $e(r)$ as

$$q(r) = \frac{e(r)(1-r) - e_{min}}{r_0} \tag{27}$$

and which is bounded above by

$$q(r) = e(r)/r_0. \tag{28}$$

For most of the systems in the Conference, $e_{min} \ll e(0)$. Therefore, for small r, eq. 28 is a good approximation to to the probability distribution of eq. 27 for most of the systems. This distribution is an improvement by a factor of $1/r_0$ over the probability distribution for a completely random rejection process, but it is still greatly inferior to the ideal distribution. In fact, no probability distribution that is proportional to $e(r)$ can be efficient, because the very act of reducing $e(r)$ through the rejection process reduces the efficiency with which incorrect classifications are rejected.

The fact that eq. 24 describes all of the $e(r)$ curves reasonably well would seem to suggest that some limiting behavior is being approached. On the other hand, the fact that there is so much difference between the shapes of the $e(r)$ curves for the systems in the Conference and the ideal curve for a perfect rejection process suggests that there is considerable room for improvement. This is a paradox that will not be resolved without further research.

SYSTEM	sigma	e_0	e_{min}	r_0	ratio
AEG	0.028356	0.034726	0.001083	0.052480	0.585633
ASOL	0.031873	0.092238	0.000000	0.203180	0.241507
ATT_1	0.029338	0.032628	0.001808	0.050910	0.447927
ATT_2	0.015908	0.036287	0.001320	0.053330	0.673430
ATT_3	0.072066	0.050545	0.007738	0.048070	0.666328
ATT_4	0.019877	0.041735	0.001156	0.060660	0.583642
ERIM_1	0.020684	0.039069	0.000177	0.059683	0.634640
ERIM_2	0.015108	0.039497	0.000880	0.063479	0.561363
GTESS_1	0.012625	0.066724	0.000000	0.104407	0.560962
GTESS_2	0.006790	0.067664	0.002970	0.102696	0.592692
HUGHES_1	0.028769	0.050092	0.000000	0.084586	0.462246
HUGHES_2	0.029808	0.049664	0.000000	0.090055	0.519539
IBM	0.014380	0.034863	0.001592	0.052278	0.629884
IFAX	0.003250	0.170347	0.019570	0.206207	0.710072
KODAK_1	0.041515	0.049025	0.000850	0.076357	0.468308
KODAK_2	0.019072	0.041296	0.000600	0.070753	0.467999
NESTOR	0.016548	0.045243	0.002240	0.064995	0.609639
NIST_2	0.004107	0.091833	0.000004	0.146915	0.600810
NIST_3	0.005298	0.097302	0.000017	0.138602	0.691096
NYNEX	0.024356	0.044058	0.002230	0.067403	0.540163
OCRSYS	0.004160	0.015539	0.013377	0.034779	0.038724
THINK_1	0.009330	0.049349	0.001670	0.072030	0.586927
THINK_2	0.019543	0.038205	0.002250	0.053868	0.717975
UPENN	0.003870	0.090498	0.000393	0.148420	0.587952
VALEN_1	0.007752	0.181158	0.000001	0.252546	0.547717
VALEN_2	0.012972	0.159487	0.000000	0.222795	0.542634

Table 7: Parameters of fit over range from 0 to 14% of model to error versus rejection rate curves for systems submitting classifications and confidences values for the digit test.

SYSTEM	sigma	e_0	e_{min}	r_0	ratio
AEG	0.017454	0.038010	0.004459	0.053350	0.527693
ASOL	0.012070	0.113362	0.000000	0.248373	0.282966
ATT_1	0.011175	0.065826	0.000000	0.126673	0.487130
ATT_2	0.011336	0.056636	0.002750	0.071867	0.699079
ATT_3	0.032949	0.070109	0.000000	0.104839	0.530980
ATT_4	0.027155	0.050839	0.000950	0.070190	0.604783
ERIM_1	0.020207	0.051538	0.000940	0.083857	0.600994
GTESS_1	0.012625	0.066724	0.000000	0.104407	0.560962
GTESS_2	0.006790	0.067664	0.002970	0.102696	0.592692
HUGHES_1	0.027327	0.066304	0.000000	0.116388	0.420525
HUGHES_2	0.042265	0.070535	0.000000	0.111462	0.376435
IBM	0.005457	0.064087	0.001980	0.085055	0.700729
IFAX	0.001717	0.195923	0.017783	0.236433	0.697279
KODAK_1	0.023934	0.070835	0.000000	0.104786	0.561767
NESTOR	0.028858	0.060172	0.000000	0.100379	0.511940
NIST_2	0.001366	0.231152	0.014857	0.257046	0.759154
NIST_3	0.010560	0.170368	0.000000	0.205900	0.790337
NYNEX	0.005835	0.049212	0.004903	0.071414	0.584223
OCRSYS	0.000000	0.057283	0.010000	0.085924	0.006016
UMICH_1	0.013518	0.050340	0.020245	0.089622	0.386150
VALEN_1	0.007327	0.243245	0.000028	0.339330	0.560223

Table 8: Parameters of fit over range from 0 to 14% of model to error versus rejection rate curves for systems submitting classifications and confidences values for the upper case letter test.

SYSTEM	sigma	e_0	e_{min}	r_0	ratio
AEG	0.018673	0.129064	0.000002	0.197466	0.549637
ASOL	0.006330	0.212562	0.070999	0.219958	0.519595
ATT_1	0.011495	0.139576	0.000000	0.232988	0.431578
ATT_2	0.006518	0.141519	0.000000	0.175623	0.710256
ATT_3	0.006362	0.163227	0.000000	0.229147	0.733748
ATT_4	0.011273	0.144687	0.000000	0.195346	0.590847
ERIM_1	0.006800	0.137500	0.000000	0.185982	0.793400
GTESS_1	0.005090	0.176155	0.007665	0.229252	0.562496
GTESS_2	0.006994	0.185672	0.000000	0.240376	0.600176
HUGHES_1	0.009387	0.153990	0.000020	0.240259	0.690638
HUGHES_2	0.013273	0.156073	0.000000	0.247943	0.689370
IBM	0.004598	0.154840	0.000008	0.206804	0.674157
KODAK_1	0.013933	0.147603	0.000000	0.206858	0.493963
NESTOR	0.010327	0.155805	0.000003	0.207386	0.582884
NIST_2	0.004220	0.313207	0.000015	0.366355	0.720330
NIST_3	0.004278	0.203856	0.000000	0.251538	0.711280
NYNEX	0.008670	0.140270	0.000002	0.219168	0.581997
OCRSYS	0.002186	0.136838	0.038749	0.171823	0.500069
UMICH_1	0.002900	0.150510	0.043706	0.197158	0.489376
VALEN_1	0.003552	0.317315	0.000000	0.438767	0.514008

Table 9: Parameters of fit over range from 0 to 14% of model to error versus rejection rate curves for systems submitting classifications and confidences values for the lower case letter test.

5 Types of Algorithms Used

Charles L. Wilson

5.1 Rule-based versus Machine learning

In the past few years neural networks have become important as a possible method for constructing computer programs that can solve problems, such as speech and character recognition, where "human-like" response or artificial intelligence is needed. The most useful characteristics of neural networks are their ability to learn from examples, their ability to operate in parallel, and their ability to perform well using data that are noisy or incomplete. Many of these characteristics are shared by various statistical pattern recognition methods. These characteristics of pattern recognition systems are important for solving real problems from the field of character recognition exemplified by this report, as opposed to "toy" problems. The goal of this section is to summarize the different methods used at the Census OCR Conference in a way that will illustrate why neural networks and rule based methods achieved the level of performance that they did. The various methods used are summarized in Figure 9 for classification and feature extraction. Most of the systems presented at the Conference, but not all, used separate methods of feature extraction and classification. In the discussion presented here any image processing which preceded the feature extraction is combined with feature extraction.

The discriminant function and classification sections of the systems are of two types: adaptive learning based and rule-based. The most common approach to machine learning based systems used at the Conference was neural networks. The neural approach to machine learning was originally devised by Rosenblat [67] by connecting together a layer of artificial neurons [68] on a perceptron network. The weaknesses which were present in this approach were analyzed by Minski and Papert [69]. The results of this Conference suggest that many of these weaknesses are still important. The advent of new methods for network construction and training during the last ten years led to rapid expansions in neural network research in the late 1980s. Many of the methods referred to in Figure 9 were developed in this period.

Adaptive learning is further subdivided into two types, supervised learning and self-organization. The material presented in this report does not cover the mathematical detail of these methods, but the bibliographic references provided with many of the systems discuss these methods in detail. A good source of general information on neural networks is Lippmann's review [70]. The primary research sources for neural networks are available in Anderson and Rosenfeld [71]. More detailed information on the supervised learning methods discussed here is given in [72]; self-organizing methods are discussed by Kohonen [73] and Grossberg [74].

The principal difference between neural network methods and rule-based methods is that the former attempts to simulate intelligent behavior by using adaptive learning and the latter uses logical symbol manipulation. The two most common rule-based approaches at the Conference were those derived from mathematical image processing and those derived from statistics. With adaptive learning, once the learning phase has been completed the network response is automatic and similar in nature to reflex responses in living organisms. The processes where these methods have been most successful are in areas where human responses are automatic, such as touching ones nose or recognizing characters. With mathematical approaches, fixed operations are performed on individual images or on statistical samples of images.

The alternate approach to artificial intelligence is rule-based. Rather than teaching the program to differentiate between characters, a rule-based program is constructed to distinguish among the various characters by writing rules to be followed by the system. These are explicitly programmed in the system in the form of mathematical formulas.

Most of the OCR implementations discussed in this report combine several methods to carry out preprocessing (filtering) and feature extraction. Many of the filtering methods used are based on methods described in texts on image processing such as [65] and on a method based on KL transforms [39]. In these methods, the recognition is done using features extracted from the primary image by rule based techniques. The filtering and feature extraction processes start with an image of a character. The features produced are then used as the input for classification.

In a self-organizing method, such as [19], data is applied directly to the neural network and any filtering is learned as features are extracted. In a supervised method, the features are extracted using either rule-based or adaptive methods and classification is carried out using either type of method. Systems with all four possible combinations of rules and adaptive learning were used at the Conference.

5.2 Statistical Rules versus Mathematical Rules

In Figure 9, rules based on mathematical image processing are distinguished from rules based on statistics. These two types of rules are similar in that they both derive features based on a model of the images. Statistical rules derive these model parameters based on the data presented. For example, typical model parameters might be sample means and variances. Mathematical rules operate on the data based on external model parameters or on the specific data being analyzed. The model parameters might be designed to detect strokes, curvature, holes, or concave or convex surfaces.

5.3 Linear versus Non-linear Methods

All of the methods shown in Figure 9 can also be classed broadly into linear methods, such as perceptrons [67], and nonlinear methods, such as Multi-Layer Perceptrons (MLPs) [72]. This separation into linear and non-linear algorithms also extends to mathematical and statistical methods. Many of the convolution and transform methods, such as Walsh transforms [75] or combinations of Gabor transforms [28] are linear. Other method start with linear operations such as correlation matrices and become non-linear by removing information with low statistical significance; KL transforms [65] and principal component analysis (PCA) [64] are examples of this.

5.4 Statistical and Neural Methods

When training data is used to adjust statistical model parameters to train MLPs, certain methods may be classed as either neural network or statistical methods. The probabilistic neural network (PNN) is an example of this type of method. In another context PNN methods can be regarded as one class of a radial basis function (RBF) method. The information in Figure 9 classifies methods of this kind in an arbitrary way when statistical accumulation or neural network models of a given method are equivalent.

5.5 Role of Learning and Rules in Feature Extraction and Classification

The systems submitted for testing at the Conference used all of the four combinations of rule-based and learning-based feature extraction and classification. All possible combinations yielded at least one low error rate system. The most common combination was the use of a mathematically based feature extractor with a MLP classifier. At least one system combined feature extraction with classification [6]. One major surprise was that linear methods, such as Learned Vector Quantitatization (LVQ) [73] and PNN performed as well as highly non-linear methods such as MLPs.

A possible explanation for this can be found in Bayesian models of the learning and recognition process [76], [77], and [78]. The relationship between testing error, E_{tst} and training error E_{trn} is given by:

$$E_{tst} = E_{trn} + 2\sigma^2_{eff}\frac{p_{eff}}{n}$$

where σ^2_{eff} is the effective noise in the network variables, p_{eff} is the effective number of network parameters, and n is the size of the training sample.

The noise in the network is learned from the training sample and should be similar for all participants. Most participants achieved training errors of less than 0.5%. The strong similarity of accuracy results suggest that all of the methods used maintain a fixed ratio of complexity to sample size. This would suggest that, in noisy samples of the kind used in the Conference tests, learning can not remove sample noise injected into the classification system from the training data because the excess complexity of the network is used to track the noise in the data. This is not unexpected since the systems have no mechanism for evaluating "bad" writing except by statistical frequency.

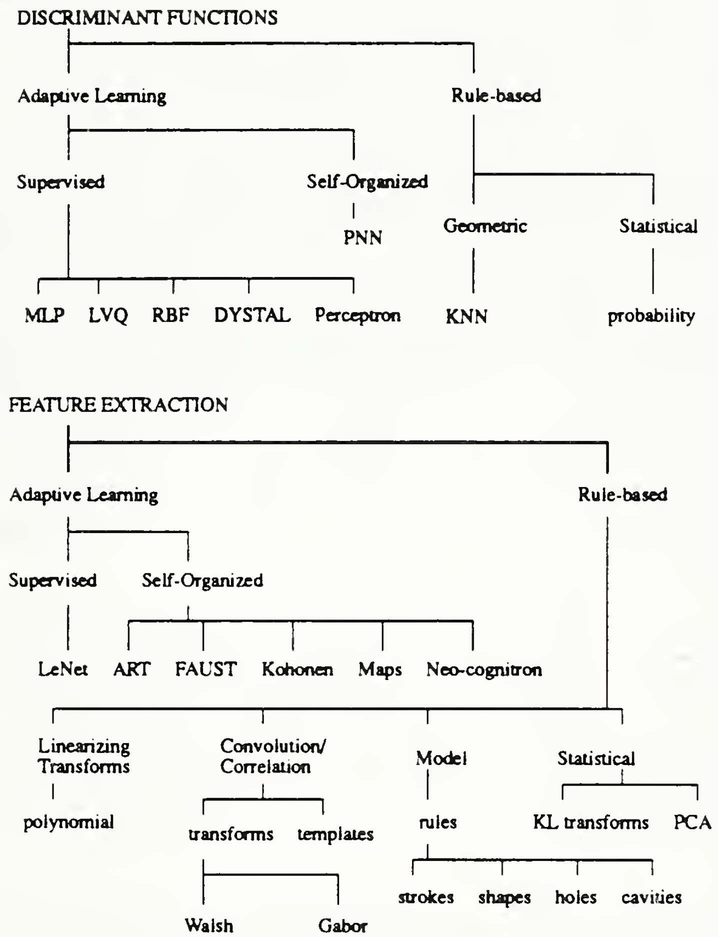


Figure 9: Types of methods used for feature extraction and classification.

6 System Speed

Charles L. Wilson

Figure 10 shows the flow of data through a typical page level OCR system. The details of the particular system are discussed in [79]. The tests run for this Conference were conducted on a simplified problem in which the characters were isolated and segmented prior to being used by the Conference participants so that the only modules used for Conference testing are normalization, filtering/feature extraction, recognition, and rejection. The load and store modules are present in either the full system or the simplified test system. This Conference did not address field isolation and character segmentation.

Typical timings for a system of the type shown in Figure 10 are given in Table 10. The dominant times in this table are image loading, field isolation, and character segmentation times. In the Conference systems, field isolation and character segmentation times were not required so that the dominant time for the Conference systems is the image loading time. In the system summaries in Appendices E and F, two rates are listed: the total system time and the recognition time. In most cases, total system rate is much longer than recognition rate. This speed difference increases as recognition time decreases. Most systems have similar load times but recognition times vary by several orders of magnitude. The minimum recognition time is less than 1ms/character. The typical load time is near 100ms/character. These two times place distinct bounds on system performance. The recognition rate of the faster systems is near the present state-of-the-art for recognition performance. The system rate is near the typical speed that can be achieved loading and decompressing image data on common present-day desk-top systems.

In order to evaluate the performance bounds of possible systems, some knowledge of both algorithmic complexity and the importance of the algorithm in the overall system performance are needed. This can not be accomplished without breaking the system into separate components each of which contains only one dominant algorithmic process. The importance of the scaling of algorithms has been known since the early work on neural networks [69]. The second factor which contributes to Table 10 is the data volume which each module encounters during operation.

Most theories of numerical algorithm complexity such as those given in [80], [69], and [81] express complexity results in notation of the form $O(n^p)$ where n is a measure of the size of a specific type of objects such as n weights, n pixels, or n classes and p is a measure of a specific polynomial complexity. As data flows through the recognition process, n decreases very rapidly. The characters used for testing in this Conference were scanned at six line pairs per mm. For a 5mm square character, this results in an input image having 3600 pixels. The system outputs were a single class. This reduces n from 3600 to one. In order to separate the $O(n^p)$ effects from changes in the size of n, the exact proportionality constant for each type of algorithm is important. A n^3 algorithm working on 10 data items may still be fast if compared to an linear algorithm working on 3600 data items.

The systems that were submitted to the Conference for testing used a wide variety of hardware. These ranged from PC's to a Connection Machine. Several types of special purpose systems were used. These included VLSI based hardware [10] and three kinds of massively parallel computer: Connection Machine, Adaptive Solutions, and AMT DAP. Several of these systems achieved recognition rates over 500 characters/second. At these rates, all of these systems were limited by image loading requirements. While high rates were achieved using special hardware, at least one system implemented on a PC platform achieved comparable speeds. This was possible by programing critical dot product routines as 8-bit calculations in assembly language. The algorithm used was a MLP with the usual complexity for this method but the speed achieved was dominated by reducing the basic calculation time.

The speed measurements presented in this report show that high recognition rates can be achieved either by using powerful hardware or by clever implementation. Algorithmic complexity cannot be separated from data flow requirements unless each algorithm is separated from the other system components during testing. High speed systems are limited by the ability to provide them with image data. None of these variables has been separated in the data presented here. NIST has measured system performance at the level of detail required to separate the effects of the various modules [79] but evaluation of such a system is much more complex than the bounding times given here. The Conference did show that systems on slow platforms or with slow implementations run at less than a character per second and that systems implemented on high speed hardware can run at 1000 character per second if images can be supplied at this rate.

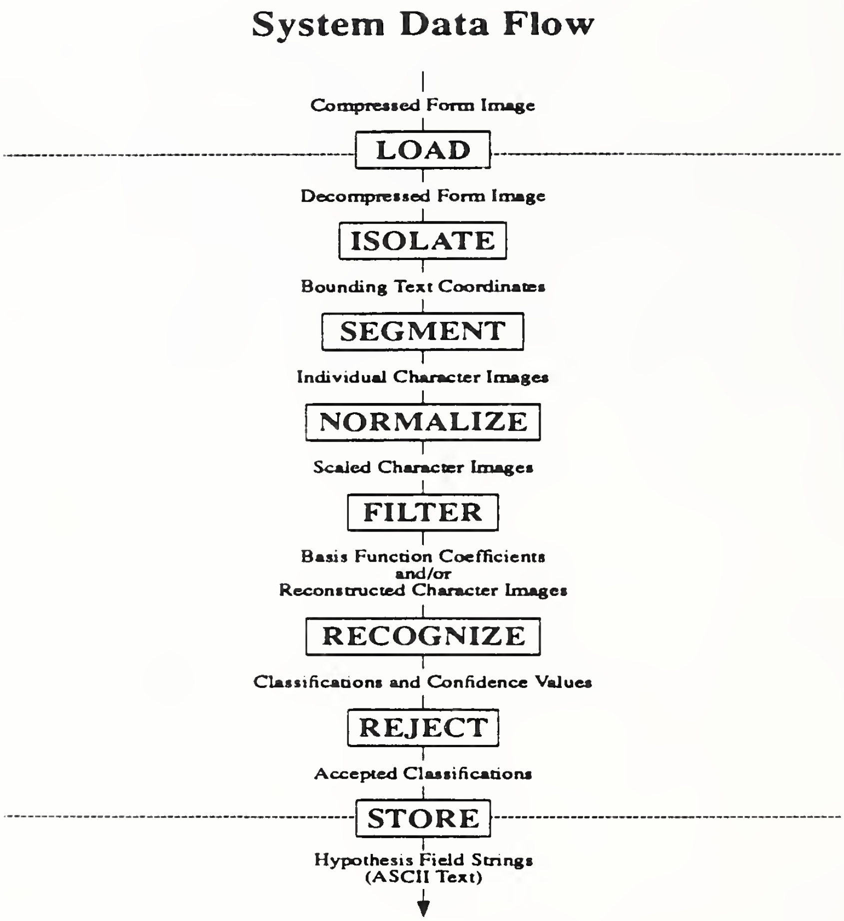


Figure 10: Data flow in a complete recognition system.

COMPONENT	OVERALL	PER FORM	
Load:	18668.328	8.889680	(58.54%)
Isolate:	3669.375	1.747321	(11.51%)
Segment:	4773.691	2.273186	(14.97%)
Normalize:	854.941	0.407115	(2.68%)
Filter:	3013.547	1.435023	(9.45%)
Recognize:	250.982	0.119515	(0.79%)
Reject:	50.900	0.024238	(0.16%)
Store:	609.079	0.290038	(1.91%)
Total:	31890.845	15.186117	(100.00%)

Table 10: System times in seconds for 2100 forms on a parallel computer.

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A Issues Raised by Participants

Christopher J. C. Burges and Thomas P. Vogl

This section contains a list of issues that Conference participants raised during the course of their presentations. Feedback from participants is a very important part of our effort to make future Systems Conferences as effective and useful to the community as possible. The issues listed here will be seriously considered in the planning of the next System Conference. Some of these issues and possible problems anticipated in addressing them are described in the next appendix. It should be noted that the following does not represent a majority view of participants; it is merely a list of items that individual participants felt to be important.

(1) The long range goal of the enterprise should be "Goal Directed Document Understanding". Only when the overall goal is kept in mind will we have meaningful end-to-end performance measures.

(2) The next Systems Conference should involve recognition of isolated fields: strings of digits and printed, unsegmented words, perhaps including cursive words.

(3) Tests should be run at NIST, or somehow proctored by NIST, since whether we like it or not, results will be used extensively for marketing purposes.

(4) NIST should always provide a "submission received" message when materials are received from participants. This will prevent confusion in the event that, for example, electronic mail is lost.

(5) Participants should be given a mini-training set long before anything else happens, so that they can get their systems and software in place and ready to process large amounts of training/test materials in limited time. (In the test just passed, this process ate into the time available for training). Sufficient time should be given to participants so that all problems regarding data formatting and data exchange can be resolved, so that no time need be wasted in pursuing these issues at the following Conference.

(6) The NIST Test Data 1 should be split (by NIST) into training and test subsets, so that participants can compare the performance of systems trained on a portion of the test database.

(7) Two separate tests should be performed: one in which the test data is taken from the same distribution as the training data, and one in which it is not. This should be done because in some applications, the former may hold, while in others, the latter may hold.

(8) Participants should be told what part of the country and world the test samples are from, so that they might take advantage of (learned) "Handwriting Dialects".

(9) A writer index to databases should be provided, since in a real-world application like form reading, it is a good bet that the same writer filled out the whole form, and some systems might take advantage of this fact. Similarly, writer implement identification should be given.

(10) For word recognition, lexicons should be made available, even if they are as large as the English language. Nonsense words constructed from individual characters would not be

a useful test.

(11) Use of contextual information (in addition to lexical information) should eventually be tested. For example, in form recognition, there is often valuable contextual information available, such as how a particular writer prints the 1 and the 9 in a date.

(12) NIST, and other users, should settle on a standardized resolution for images so that results of tests performed elsewhere in the community (outside of OCR Systems Conferences) can be more easily compared.

(13) Single character OCR systems should also be tested for their rejection of NON-characters (junk), since that is extremely important when segmenting fields.

(14) Systems should be allowed to classify an image as ambiguous. Systems should give several top choice candidate answers for a given image. Such information could be used by a contextual-analysis "supersystem". In addition, a system that does not get the right top answer, but gets the right answer in the top few, should be given credit over a system that does not get the correct answer anywhere.

(15) A proposal was made for an error rate metric: error rate = Sum (F(character) $\times$ error (character)), where F(character) is the frequency of the character in the English language. Another proposal was to use the integral of the error rate as a function of rejection rate instead of the zero-rejection-rate error rate.

(16) Ranking test results by a single measurement was not a good idea; several measurements should be used to get fairer analyses (e.g. raw recognition rate, throughput, unit cost, punting, latency if any, flexibility to different applications). Tests should be done with and without both lexical and non-lexical context, and the scores for each reported.

(17) People who do NOT take part in a Conference should still be able to be subjected to the same kind of test by NIST, for example by some publicly acknowledged arrangement for submitting a request to NIST, getting test materials, and having to return the scored, OCR classified test materials within a fixed, short time. These "post conference" tests should support the just-completed segmented character tests for some reasonable minimum time (say 3 years). This would help many who would otherwise not be able to be involved, and would give a more accurate representation of the state of the art at any time.

(18) While it is likely that in future Conferences all applicants will be allowed to participate in the testing and scoring aspects of the Conference, only those who are willing to divulge information about their methods should be allowed to speak, or even to attend the meeting where other participants are going to describe their methods.

B NIST Perspective on Perceived Problems

Jon Geist

Some NIST staff members, some Conference Committee members, and some participants pointed out and suggested solutions to problems that occured at the first Conference. Problems of the most concern to the NIST personnel running the Conference are addressed in this Appendix. These are not necessarily the problems of the most concern to the participants. The information in this and Appendix A is included to help in the planning of future Conferences.

B.1 Perceived Problem 1

The plan to make all results public was inadequately formulated and inadequately stated in the Call for Participation.

B.1.1 Proposed Solutions

State this aspect of the plan very clearly in future Calls for Participation.

B.1.2 Discussion

From the earliest stages of planning for the Conference, it appeared that the goals of the Conference could not be met without disclosing the scores obtained by each system. Otherwise, it would not be possible to ask specific questions about aspects of the performance of a particular system. Therefore, there was at least a weak consensus among the Committee to distribute all of the scores for all of the systems to each participant, and to publish the results in a report that would enter the public domain. During the final preparations for the Conference meeting, the consensus grew in strength as the problems with keeping the scores confidential were brought clearly into focus.

B.2 Perceived Problem 2

The attempt to restrict the number of participants was a mistake.

B.2.1 Proposed Solutions

Open the Conferences to all applicants. If logistic considerations make it necessary, then restrict the actual number of attendees at the Conference meeting rather than the number of participants in the Conference test.

B.2.2 Discussion

Much more was learned by having 26 participants than would have been learned with only 15. It is unlikely that the Committee would have chosen an optimum combination of 15 participants from the 29 applications it received. By following a more relaxed schedule, it should be possible to close the application period before a room is reserved for the meeting. If not, actual attendance at the meeting can be limited based on factors listed in item 18 in Appendix A, on the basis of the scores obtained, or by further restricting the number of nonparticipant attendees, if necessary.

B.3 Perceived Problem 3

Too much time was required of each participant to prepare a proposal to participate and to respond to requests from the Committee for more information. In addition, the Committee and NIST staff found it very time consuming to abstract useful information from the proposals.

B.3.1 Proposed Solutions

A simple application form requesting all of the information desired by the Committee could be submitted by the participants. This form could be included in the Call for Participation.

B.3.2 Discussion

The proposals did not prove useful in choosing among the applicants for participation, and the effort the participants expended in preparing their proposals varied greatly. Futhermore, the Committee found it necessary to solicit more information from the participants in order to prepare the system summaries in Appendix C.

B.4 Perceived Problem 4

The test was not proctored.

B.4.1 Proposed Solutions

Possible solutions include:

1) Publicly disclose the participant's scores in such a way that no one can identify a specific score with a specific participant.

2) Privately disclose each participant's scores only to that participant.

3) Set up a means by which participants can have their tests proctored if they so desire.

B.4.2 Discussion

The idea behind the first and second proposed solutions is that there would be less motivation for the participants to cheat under these conditions. However, this proposal effectively prevents open discussion at the meeting, so there would be no point to the meeting. The Committee learned much at the meeting that would not have been learned otherwise, and many participants claimed that they learned a lot at the meeting. It seems that undisclosed or secretly disclosed scores without meetings, and meeting about openly disclosed scores are the only practical alternatives. Since one of the purposes of a systems conference is to stimulate improvements in the state of the art, the first two proposed solutions do not seem workable.

Also, secretly disclosed scores do not really remove the motivation to cheat, but only modify it. With unproctored tests and openly disclosed scores, the participants might be tempted to supplement their results with human classification in order to get a better score, so that they could advertise that score either to their sponsor to continue funding or to potential customers to encourage sales. With proctored tests and secretly disclosed scores, the participants might be tempted to lie about their scores to their sponsors or their potential customers for exactly the same reasons. This would be possible because there would be no independent way for anyone to verify that any particular participant actually received the score claimed unless the Committee were brought into all such discussions in a police role. This does not seem practical.

The idea behind the third proposed solution is that those participants who chose to enter the proctored section of the test would be protected from comparison with those who did not by the fact that the latter were apparently afraid to be proctored. Various ways that proctored tests could be conducted without requiring an undue amount of proctor time were proposed. For instance, the tests could be run on one or a limited number of different platforms, and they could be submitted as executable code with a (yet to be specified) standard interface to a (yet to be specified) central location where the test would be conducted. It remains an open question how practical this would actually be, but the developement of a standard interface for proctored tests might be a useful activity.

B.5 Perceived Problem 5

Some participants were not as open as they should have been for a Conference of this nature.

B.5.1 Proposed Solutions

Possible solutions include:

1) Request all information required of the participants in the application form, and reject any participants who do not provide it.

2) Make open discussion a prerequisite for attendence at the Conference meeting, but not for participation in the test, as discussed in item 18 of Appendix A.

B.5.2 Discussion

These solutions might reduce participation, particularly the first, which would reduce the usefulness of the Conference as discussed above under Perceived Problem 2. The Committee appreciates the openness that many participants showed, and hopes that their example will help other participants to be more open in the future.

B.6 Perceived Problem 6

E-mail did not prove suitable for returning test results to NIST.

B.6.1 Proposed Solutions

Possible solutions include:

1) Require all submissions on disk or tape.

2) Set up an anonymous FTP on a computer at NIST to receive the test results.

3) Set up participant accounts on a computer at NIST to receive the test results.

B.6.2 Discussion

It is most convenient for NIST IRG personnel to receive test results directly on a computer at NIST rather than to have to read a disk or tape. The people responsible for choosing E-mail did not know that DARPANET and BITNET E-mail network nodes truncate E-mail messages to 100k or 300k bytes and cannot handle the volume of messages that can be encountered from a number of different participants all submitting their returns at the same time through various network nodes. To use E-mail, some participants had to split tarred and uuencoded files into 190 separate files for submission. The E-mail spooler on the IRG network node cannot handle this many messages at one time. To solve this problem, a software switch was written to intercept Conference returns, and to redirect them to a large buffer. Unfortunately, the NIST IRG computers went down over the weekend before the last day to return the results. When the computers were restored many of the E-mailed returns were waiting at various E-mail nodes, and they all tried to enter the NIST node at the same time. This caused the buffer to crash. An anonymous FTP is clearly the best solution.

B.7 Perceived Problem 7

Some submissions and some corrections of errors in the format or content of CON and RJX (described in Appendices C and D files, that could not be easily carried out at NIST, were accepted and scored after April 27, which was the cutoff date for submission of test results.

B.7.1 Proposed Solutions

Possible solutions include:

1) Don't enforce any time limits.

2) Strictly enforce a time limit.

3) Provide all participants with C source code for a package that checks the structure of the results before they are submitted to NIST, and only score those submissions that are received on time at NIST and that pass the same check at NIST.

4) List all of the results that were obtained on time and in the correct format in one section, and all of the other results in a separate section to distinguish them in this respect.

B.7.2 Discussion

The third proposed solution seems the best compromise for addressing this problem for future Conferences. The fourth proposed solution was adopted for summarizing the results of this Conference. That section also contains a few results submitted after the Conference meeting to address specific questions brought up during the meeting.

The time limit was imposed mainly to assure that most of the results would be received in time for scoring at NIST before the Conference meeting. If the time limit is not enforced, then the participants will not make the effort to adhere to it, and it will not serve its main purpose. On the other hand, a number of useful submissions would have been rejected had the time limit been strictly enforced due to the problems that the participants had in conforming to the data formats specified for the classification results. Since this was the first Conference, and since the E-mail procedure for returning the results was fraught with its own problems, it was decided to request resubmissions of lost or incomplete results submitted by E-mail. This led to requests for resubmission in correct format of CON and RJX files that did not conform to the specified formats. This, in turn, led to a toleration for results that were submitted late, but before all of the CON and RJX were received in correct format.

C The Call for Participation

CALL FOR PARTICIPATION

FIRST CENSUS OPTICAL CHARACTER RECOGNITION SYSTEMS CONFERENCE

February 1992 - May 1992

Sponsored by:
US Bureau of the Census

Conducted by:
National Institute of Standards and Technology
(NIST)

1. Background of the CALL FOR PARTICIPATION:

The Bureau of the Census has requested the National Institute of Standards and Technology (NIST) to run a Systems Conference on Optical Character Recognition (OCR) of handprinted characters. One goal of the Systems Conference is to give the Bureau a sense of the current state-of-the-art in OCR of hand printed characters and the directions of near term R&D. Another goal is to provide a forum through which participants can influence 1) the creation of large data bases of hand printed characters for uniform testing of OCR systems, 2) the development of uniform methods for scoring tests based on such databases, and 3) the development of standards for evaluating the performance of OCR systems.

A registration fee of about $50 per person will be charged to cover lunches and coffees. All aspects of participation in this Systems Conference will be carried out at no cost to the Government. No contracts or grants will be awarded in connection with, or as a result of this Systems Conference. The Conference will be run through the First Census OCR Systems Conference Committee consisting of the following members:

Jon Geist, NIST, chairman

Charles Wilson, NIST
Bob Hammond, Census Bureau
Robert Creecy, Census Bureau
Tom Vogl, ERIM
Christopher Burges, ATT
Jonathan Hull, U. of Buffalo
Norman Larsen, Census Bureau

2. Activities of the Systems Conference:

2.1 The Committee will review with respect to the criteria stated in Section 6 below all applications for participation that are received at NIST before Close of Business (COB) on March 4, 1992. The Committee reserves the right to review applications received after this date.

2.2 The Committee will divide the applications into two categories with respect to the criteria stated in Section 6, qualified and unqualified.

2.3 If there are more than about fifteen qualified applications, the Committee will rank them according to the criteria stated in Section 6, and will select about fifteen applications for participation in the Conference. Otherwise, all qualified applications will be selected for participation.

2.4 NIST will inform the participants of their selection and will send them training materials on behalf of the Committee before COB March 23, 1992.

2.5 NIST will send test materials to the participants on behalf of the Committee before COB April 13, 1992.

2.6 The participants will return the completed test materials to NIST before COB April 27, 1992.

2.7 NIST will score the returned tests materials.

2.8 The participants and the Committee will attend a meeting on May 27 and 28, 1992. At this meeting

1) NIST will describe all participants' test results.

2) each participant will present a 15 minute talk outlining

the OCR approach used in completing the test, and any other information that they deem pertinent, and

3) the Committee and the participants will attempt to reach a consensus about what sort of test materials should be provided for the Second Census OCR Systems Conference, and what other issues should be addressed to make the second Conference more useful to the participants.

3. Specification of Formats:

3.1 Training and Test materials supplied by NIST:

Both the training and test materials will consist of digital images of segmented numbers, upper case letters, and lower case letters on an ISO-9660 formatted CD ROM disc. For the training and test materials, the numbers, the upper case letters, and the lower case letters will be in separate files. However, as many as 30% of the letters in the lower case training files will actually be little upper case letters that were printed when lower case letters were requested. The participants are requested to return their test results by E-Mail, but they may also return them on 8mm magnetic tape, or on IBM PC compatible 5.25 inch floppy disks.

The format for the image data for both the training and test materials will be in the Multiple Image Set (MIS) format, and the format for the classification data for the training materials will be the Multiple Feature Set (MFS) format. These formats are used by the NIST Image Recognition Group for Standard Reference Databases. More details of the MIS and MFS file formats, and the test result formats are given in the Appendix to this document.

3.2 Test Results supplied by Participants:

Participants will be required to return their test results in a Classification file (HYP) and either a Confidence file (CON) or a set of Rejection (RJX) file, if confidence levels are not readily available. All of theses files, HYP and CON or HYP and multiple RJX, must be in the MFS format. More details about the specifications for these files are given in the Appendix along with the specifications of the MIS and

MFS file formats. Participants will also be required to report the elapsed time for the OCR process and minimal specifications of the system used to obtain the results. Up to five different sets of test results will be accepted from each participant, but the participants must prioritize the results according to the format described in the Appendix.

4. Application Format:

Applications to participate in the First Census OCR Systems Conference should be no longer than 3 pages of text, and should conform to the following format:

4.1 The first section should briefly describe the proposing organization. This section should identify the person who will be the point of contact for the Systems Conference, including the mailing address, phone number, FAX number and E-Mail address, as appropriate, and up to two other attendees.

4.2 The second section of the application should state that the proposing organization agrees to participate by following instructions for the training, testing, and meeting phases of the Conference, provided that NIST supplies the materials before the dates stated in Section 2 of this CALL, as summarized below:

03/04 -- deadline for receipt of application at NIST
03/23 -- deadline for receipt of training material from NIST
04/13 -- deadline for receipt of testing material from NIST
04/27 -- deadline for return of completed test to NIST

4.3 The third section should concisely describe the state of the art in OCR of handprinted characters in the proposing organization by reporting at least one data point for the error rate and the rejection rate for some subset of NIST Special Database 1 or some other database of handprinted characters. The nature of the database used and exactly which OCR functions were performed automatically for the results presented should also be indicated.

4.4 The fourth section should concisely outline the approach to OCR used for the results reported in the third Section.

5. Submission of Applications:

Applications should be submitted to:

Jon Geist
B316/225
ASD/NCSL/NIST
Gaithersburg, MD 20899

Applications may be submitted by regular mail, express mail, courier service, FAX to (301) 948-4081, or E-Mail to geist@sed.eeel.nist.gov or geist@magi.ncsl.nist.gov.

6. Rating Criteria:

Applications not meeting the requirements stated in Section 4 of this CALL may be eliminated from further consideration at the discretion of the Committee. The remaining Applications will be be divided into qualified and unqualified categories on the basis of sections 4.3 and 4.4. These sections should demonstrate in a concise manner both a thorough understanding of the basic ideas of OCR of handwritten characters, and a state-of-the-art competence in this area.

If more than 15 qualified proposals are received, they will be divided into categories based on the similarity of the OCR techniques described, and the applications in each category will be ranked according to the performance claimed in the third section of each application. The fifteen applications will be selected by choosing the top ranked application from each category, then the second ranked, and so forth, until about 15 applications are chosen. The Committee reserves the right to reject all but one application from a single organization.

D Instructions to Participants

INDEX

1. INTRODUCTION

This report contains information about how to return the OCR test results obtained for the MIS files in subdirectory TEST1 to NIST for scoring.

For the purposes of this test you have been assigned the site name:

2. DIRECTORY FORMAT

The main directory on the CD-ROM called TEST DISK 1 has three subdirectories, DOS, DOC, and TEST1. DOS contains files that are needed only if the test results will be returned on an IBM PC compatible, 1.2 Mbyte, 5.25" floppy disk.

The actual test files are stored in subdirectory TEST1, which is organized as follows:

```
TEST1
|
-----------------------
|         |          |
|         |          DIGIT
|         |          |
|         |          ----------------------------
|         |          |          |          ...  |
|         |          D_001.MIS  D_002.MIS       D_293.MIS
|         |
|         |
|         UPPER
|         |
|         ----------------------------
|         |          |          ...  |
|         U_001.MIS  U_002.MIS       U_059.MIS
|
|
LOWER
|
----------------------------
|          |          ...  |
L_001.MIS  L_002.MIS       L_059.MIS
```

Each file except the last in each of the subdirectories DIGIT, UPPER, and LOWER has 200 images in it, while the last file has less than 200 images.

All of the information on the test file formats and programs to read these file formats was included on and/or with NIST Special Database 3, which was sent to you as the training materials for this test.

3. RETURN FILE FORMATS

This section explains the various file formats for use in returning your OCR classifications of the MIS file images in subdirectory TEST1 to NIST for scoring.

3.1 ASCII STRING (ASR) AND LINE (ALR) REPRESENTATIONS

An ASCII String Representation (ASR) is a buffer of variable length containing any number of printable ASCII characters, where the printable ASCII characters include all characters in the hexadecimal range 20 to 7E.

An ASCII Line Representation (ALR) is an ASR terminated by the ASCII LF character, hexadecimal 0A. This means that the ASCII CR character 0D cannot occur anywhere in an ALR, or in place of, or in combination with the ASCII LF character 0A at the end of the ALR.

3.2 MFS FILE FORMAT

A Multiple Feature Set (MFS) file is a file of ALRs. Each MFS file is associated with a unique MIS file. The first line of the MFS file contains the ASR of a decimal number, which is the number of lines in the file minus one, and which is also the number of images in the associated MIS file. No ASCII SPACE characters are allowed in the ASR for the first line. Each line following the first line of an MFS file is an ALR containing information about the corresponding image in the associated MIS file.

3.3 HYP FILE FORMAT

A Hypothesis (HYP) file is a file in the MFS file format. Each line following the first line contains an ASR of the correct class assigned to the corresponding image in the associated MIS file. The ASR in each line consists of two ASCII characters. These are the ASCII characters that represent the hexadecimal number that represents the ASCII character of the class. No space characters are allowed on any line of this type of file.

The name of a HYP file must be the same as the name of the associated MIS file, except that the extension must be .HYP. For example, consider an MIS file called ALPHAS.MIS that contains images of the five characters G, r, L, S, and w. An ASCII dump (that recognized the convention that 0A is the end of line marker) of the associated file ALPHAS.HYP would look like:

```
5
47
72
4C
53
77
```

Similarly, a HEX dump of the same CLS file would look like:

```
35 0A 34 37 0A 37 32 0A 34 63 0A 35 33 0A 37 37 0A
```

(A lower case "C" (hex 43 instead of hex 63) would be OK.)

You will return one HYP file for each MIS file in the subdirectory TEST1.

3.4 RJX FILE FORMAT

A Rejection (RJX) file is a file in the MFS file format in which the ASR on each line following the first line is an ASCII 0 or an ASCII 1. A 1 indicates that the classification should be scored as a Reject rather than as a Correct or an Incorrect. A 0 indicates that the classification should be scored Correct if identical with the correct classification and scored Incorrect otherwise.

The name of an RJX file must be the same as the name of the associated MIS file except that it must end in one of the ten extensions .RJ0, .RJ1, ..., .RJ8, .RJ9. Again as an example, consider the same MIS file used for the last example. An ASCII dump of one of the associated RJX files, ALPHAS.RJ3, for instance, might look like:

```
5
0
1
1
0
1
```

Similarly, a HEX dump of the same CON file would look like:

```
35 0A 30 0A 31 0A 31 0A 30 0A 31 0A
```

You may use the RJX file format to return information on the reliability of the hypothetical classifications obtained from your OCR system. This format is useful if your system does not provide confidence levels or activations. Also, if your system has an accept/reject criterion that is more complex than setting a threshold on the highest confidence level or activation, this is the preferred format. If you choose to use this format, you should provide up to ten RJX files for each MIS file, and should try to include some rejection rates in the range from 5% to 50%.

3.5 CON FILE FORMAT

A Confidence (CON) file is a file in the MFS file format in which the ASR on each line after the first line gives the decimal representation of the confidence level (or activation) assigned to the classification on the corresponding line of the HYP file that is associated with the same MIS file. The confidence level must be a number ranging from 0.0 through 1.0. The number of digits to the right of the decimal point must be less than 17.

The name of a CON file must be the same as the name of the associated MIS file except that the extension must be .CON. For example, consider the same MIS file used for the last example. An ASCII dump of the associated file ALPHAS.CON might look like:

```
5
0.375
.9
.7
```

```
.4
.8
```

Similarly, a HEX dump of the same CON file would look like:

```
35 0A 30 2E 33 37 35 0A 2E 39 0A 2E 37 0A 2E 34 0A 2E 38 0A
```

(Leading zeros are optional.)

You may use the CON file format to return the confidence levels assigned by your OCR system to the hypothetical classifications obtained from your OCR systems, provided that such information is available, and provided that your system makes it accept/reject decisions by comparing the contents of these files with a user specified threshold.

4. TEST RESULTS FORMAT

This section describes how the test results are to be returned to NIST. Three media are supported. The preferred media is E-Mail, the next choice is an Exabyte UNIX 8mm Magnetic Tape, and last choice is an IBM PC compatible 5.25" floppy disk.

No matter which format is used, the same directory tree structure will be used for organizing the test results. The tree will look as follows:

```
<SITE_NAME>
|
test1
|
------------------------------------
|                 |                |
|                 |                digit
|                 |                |
|                 lower
|                 |
upper
|
-----------------------------------------------------...
|                 |                |                |
u_000.hyp         u_000.con        u_000.rj0        <...
```

where <SITE_NAME> is the name assigned to your site in Section 1 above, if you are only reporting one set of results. If you are reporting more than one set of results (for instance, results for different systems, or results for the same system that are based on different sets of training materials such as your proprietary training materials and NIST Special Database 3, then <SITE_NAME> is obtained from the name assigned your site by adding an underscore followed by a single digit 1 through 5 to your assigned site name. For instance if your assigned site name is XYZ, and you are reporting only one set of results, then <SITE_NAME> = XYZ, but if you are reporting two sets of results, then <SITE_NAME> = XYZ_1 for the first set, and <SITE_NAME> = XYZ_2 for the second set. Note that NIST will assign a higher priority to XYZ_1 than to XYZ_2 for scoring and reporting purposes. Each separate set of results having a different <SITE_NAME> must be sent on a separate floppy disk, on a separate 8mm tape, or in a separate E-mail message. Your 8mm tapes (and floppy disks, if you want them back) will be returned at the Conference.

The next three sections describe how to send the test results to NIST. Of the following three options, E-Mail is preferred, 8mm tape is next, and 5.25" floppy disks can be used as a last resort. The results of each test are to be sent only once unless NIST requests that they be resent.

4.1 E-MAIL

This is the preferred way of getting the test results to NIST.

With a UNIX system, the directory tree described above will be turned into one file using a tar utility and a uuencode utility. The command line to turn the directory tree into one file is as follows and should be run from the directory above <SITE_NAME>:

```
tar -cvf <SITE_NAME>.tar ./<SITE_NAME>/test1
```

This command will generate a file, <SITE_NAME>.tar, containing everything in the directory test1.

The file must be uuencoded to send it by E-Mail. To uuencode the tar file use the following command:

```
uuencode <SITE_NAME>.tar <SITE_NAME>.uu > <SITE_NAME>.uu
```

This will create the file <SITE_NAME>.uu which can be E-mailed to NIST. The mail command may vary from machine to machine. Please be sure to include the subject line

```
"test1 results from <SITE_NAME>"
```

and to send the results to urt@magi.ncsl.nist.gov. On a Unix machine this can be done as follows:

```
mail -s "test1 results from <SITE_NAME>" \
            urt@magi.ncsl.nist.gov < <SITE_NAME>.uu
```

Refer to Section 4.3 to see how to use a MS-DOS based tar utility, which will be provided with the test materials, to prepare the directory tree for E-Mailing. Again, the mail command will vary from machine to machine.

4.2 EXABYTE UNIX 8MM MAGNETIC MEDIA

This option requires an Exabyte 8mm tape drive having no compress hardware, and a machine running UNIX.

The directory tree above will be turned into one file using a tar utility. The command line to turn the directory tree into one file is as follows and should be run from the directory above <SITE_NAME>:

```
tar -cvf <TAPE_DEVICE> ./<SITE_NAME>/test1
```

where, <TAPE_DEVICE> is the 8mm tape drive.

This command will generate a tar tape, containing everything in the directory test1.

Send the 8mm tape by Express Mail or Federal Express to:

R. Allen Wilkinson
Room A216 TECH

NIST/NCSL/ASD/IRG
Gaithersburg, MD 20899

4.3 IBM PC 1.2 MEGABYTE 5.25" FLOPPY DISK

This disk should be readable on an machine running MS-DOS.

The directory tree above will be turned into one file using a public domain, MS-DOS tar utility, which was tested and shown to produce directory structures that can be handled at NIST. This public domain utility can be found in the DOS subdirectory under the TEST1 directory on the TEST DATA 1 CD-ROM.

The command line to turn the directory tree into one file is as follows and should be run from the directory above <SITE_NAME>:

```
tar -cvf <SITE_NAME>.tar .\<SITE_NAME>\test1
```

This command will generate a file, <SITE_NAME>.tar, containing everything in the directory TEST1 only.

This file will be too large to put on the floppy. The PKware software that can be found in the DOS subdirectory under the TEST1 directory on the TEST DATA 1 CD-ROM will be used to compress the file into a size that should fit onto the floppy. The command to compress the file is

```
pkzip -ex <SITE_NAME>.zip <SITE_NAME>.tar
```

This will create a file <SITE_NAME>.zip which will contain the compressed version of <SITE_NAME>.tar

Copy the file <SITE_NAME>.zip to the floppy and send it by Express Mail or by Federal Express to:

R. Allen Wilkinson
Room A216 TECH
NIST/NCSL/ASD/IRG
Gaithersburg, MD 20899

E System Summaries For Results Submitted On Time

Jon Geist, Jonathan J. Hull, Stanley Janet, R. Allen Wilkinson, and Charles L. Wilson

This appendix contains summaries for all system results that were received on time. The first page of each summary lists pertinent information about the system such as the type of preprocessing, the type of feature extraction, the type of classification, and the training data used, whenever such information was provided by the participants. This page also summarizes the error rate as a function of rejection rate and the OCR rate in characters per second (CPS) for the digit, upper case, and lower case tests.

The second page of each system summary gives references to pertinent publications for the system and optional comments by the participants where such were provided. The DARPA Systems Conferences upon which this Conference was modeled provide a page for comments, so such a page was provided here. Very few participants in the Conference took advantage of this page, and some of those that did used it more for advertising than for information exchange. Bear in mind that the information given under the heading COMMENTS was provided by the participants, and does not necessarily represent the opinions of the Bureau of the Census, NIST, or the Committee.

The first graph on the third page of each system summary plots the logarithm of the system error rate versus the rejection rate for each test (digits = diamonds, upper case letters = plus signs, and lower case letters = squares) for which results were submitted.

The second graph on the third page of each summary is a little more difficult to explain. The abscissa of this graph is the zero-rejection-rate error rate for all of the test characters produced by a single writer for a given test (digits, upper case letters, lower case letters). The ordinate of this graph is the number of writers for which the single-writer zero-rejection-rate error rate is less than the percentage given on the abscissa. Again there is one curve for each test for which results were submitted. The three curves for digits, upper case letters, and lower case letters are not labeled, but they are readily distinguished. The curves for the upper and lower case letters are characterized by large steps near 4 and 8% rejection rate, corresponding to one and two incorrect characters out of a maximum of 26 letters per writer. The rounding of these steps is caused by the fact not all writers are represented by all 26 upper or lower case letters. Some letters were lost as a result of segmentation errors. The lower (upper) of the two curves with the large steps is always the curve for the upper (lower) case letters. The curve for digits has much smaller steps because there are many more digits (a maximum of 130) per writer than letters per writer.

The fourth through sixth pages of each summary contain three pseudo-correlation graphs. These show the correlations between the classifications produced by the system in question and the classifications produced by all of the other systems. The plus and minus signs in the graphs report two different correlation measures, whereas the continuous lines are for reference purposes. These graphs are also somewhat difficult to explain.

System number 1 in each graph is the system that is the subject of the particular system summary being read. Each plus sign reports the ratio of the zero-rejection-rate classifications that were identical for system number 1 and for the system corresponding to the number on the abscissa to the total number of characters to be classified . Each minus sign reports the ratio of the zero-rejection-rate classifications that were correct for system number 1 and for the system corresponding to the number on the abscissa to the total number of characters to be classified. The systems are ordered and numbered along the abscissa according to their plus-sign pseudo-correlation with system number 1. This means that the ordering could be different for the digit, upper case letter, and lower case letter tests within every system summary and between system summaries. Therefore, a key to the numbers on the abscissa and the correlation data is provided for each graph on the same page of the summary. The key also contains the numerical values for the pseudo correlations.

The upper continuous line in the pseudo-correlation graphs is the zero-rejection-rate accuracy rate (one minus the error rate) for each of the systems listed along the abscissa. The lower continuous line is the upper continuous line displaced downward by the zero-rejection-rate error rate for system number 1, the system in question. The lower and upper lines are lower and upper bounds, respectively, for the minus signs. The minus signs are lower bounds for the plus signs.

The pseudo-correlation graphs are useful for determining which systems might be used together to produce a lower error rate than either system alone. For example, there is little use to combining the two HUGHES_1 and HUGHES_2 systems, which produced virtually identical zero-rejection-rate error rates, because they are so strongly correlated. On the other hand, the U_PENN and NIST_2 systems also produce virtually identical results, but are much less strongly correlated. Therefore, combining their results might give a better system, at least as a function of rejection rate, if not for the zero-rejection-rate error rate.

The List of Figures and the List of Tables at the beginning of the Report following the Table of Contents can be used as an index of the system summaries given in this Appendix.

SYSTEM: AEG

PARTICIPANT: Juergen Franke

ORGANIZATION: AEG Electrocom GmbH, Konstanz, Germany

PREPROCESSING: normalization for size, stroke width, and slant

FEATURES: KL transform into 256 features

CLASSIFICATION: adaptive statistical polynomial classification (POLYFONT)

HARDWARE: VAX 6510 without 6510 vector processor

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	all	all	all	NSDB3

STATUS: on time

RESULTS:

-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
0.00	0.0343	0.00	0.0374	0.00	0.1274	
0.10	0.0067	0.10	0.0107	0.10	0.0876	
0.20	0.0029	0.20	0.0053	0.20	0.0562	
0.30	0.0029	0.30	0.0047	0.30	0.0358	
0.40	0.0031	0.40	0.0042	0.40	0.0249	
0.50	0.0032	0.50	0.0042	0.50	0.0237	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	not much lower than CPU rate		
CPU RATE:	33.70	4.42	3.77

(about 10 times faster with 6510 vector processor)

SYSTEM: AEG

BIBLIOGRAPHY:

The following references have been provided for this system:

none

COMMENTS: AEG

COMPANY CAPABILITIES:

AEG Electrocom GmbH is a Constance based subsidiary of the AEG Group. AEG represents one of the four main branches of the Daimler Benz Group. At AEG Electrocom currently approximately 1400 employees are responsible for an annual turnover of approximately 250 million DM.

AEG Electrcom's mission is to qualify as an efficient partner for high tech systems in automation, information technology and communications with precision mechanics, advanced electronics and customer specific software. AEG Electrocom is sharing R&D efforts for character recognition with the Daimler Benz Research Institute at Ulm, Germany.

The product range includes - Letter sorting systems - Parcel and flat sorters - Recognition systems: various form readers, reading electronics, scanners for OCR/ICR applications

Today, AEG is successfully addressing the US market with solutions for address and form reading (including hand print). AEG is represented in the US market by our subsidiary: AEG Washinton 1350 Connecticut Avenue NW Washington, DC 20036 Phone: (202) 835-2003 FAX : (202) 835-2022

STATE OF THE ART IN OCR OF HANDPRINTED CHARACTERS

AEG Electrocom has sold world-wide many thousands of systems for postal address reading and forms reading applications.

AEG'S CHARACTER RECOGNITION TECHNOLOGY

AEG's ICR technology, called POLYFONT, is based on a mathematical statistical approach and applies a polynomila classifier for the recognition task. The basis for the recognition process is a bit-map of the characters to be recognized. On this bit map, a primary segment calculation (black connected components) is applied. Primary segments are clustered together into compound objects which reflect single characters. These compound objects are normalized into a matrix. This matrix is represented afterwards by a vector with 256 dimensions. The vector is fed into the classifier. The classifier will produce a confidence level indicating the probability to which an input pattern does belong to a shape class which is stored in the classifier. The shape classes, which resemble the "typical" representation of a character to be recognized, are determined during the training of the classifier.

The core recognition algorithms are similar for the complete AEG product range. Performance of the different products varies in throughput and in the methods for image handling and preprocessing, as well as for the determination of the actual meaning of a shape class assigned by the recognizer. These processes are combined from a large toolbox to match customer requirements.

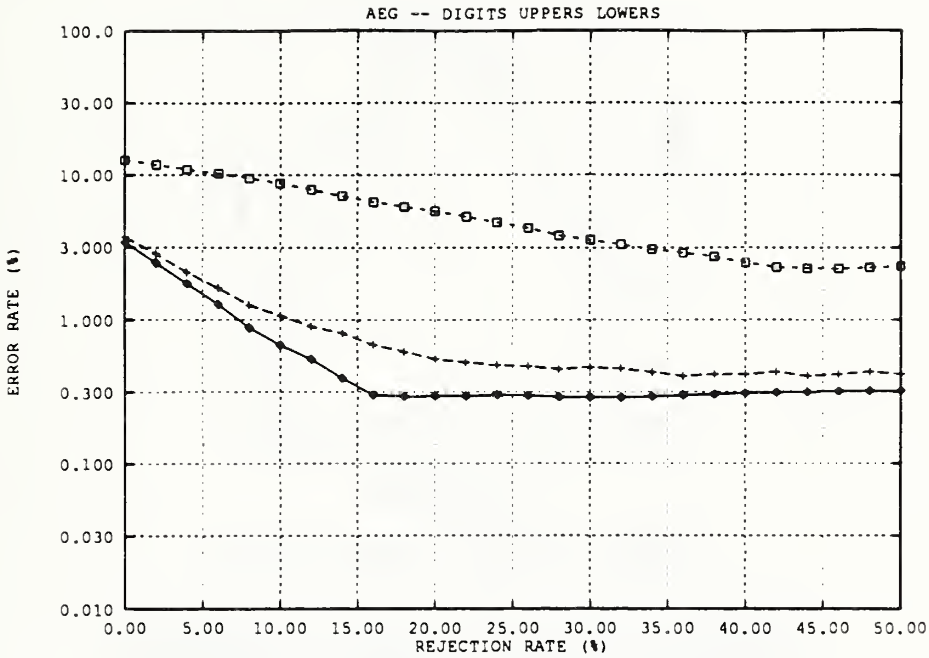

Figure 11: Error rate versus rejection rate for AEG

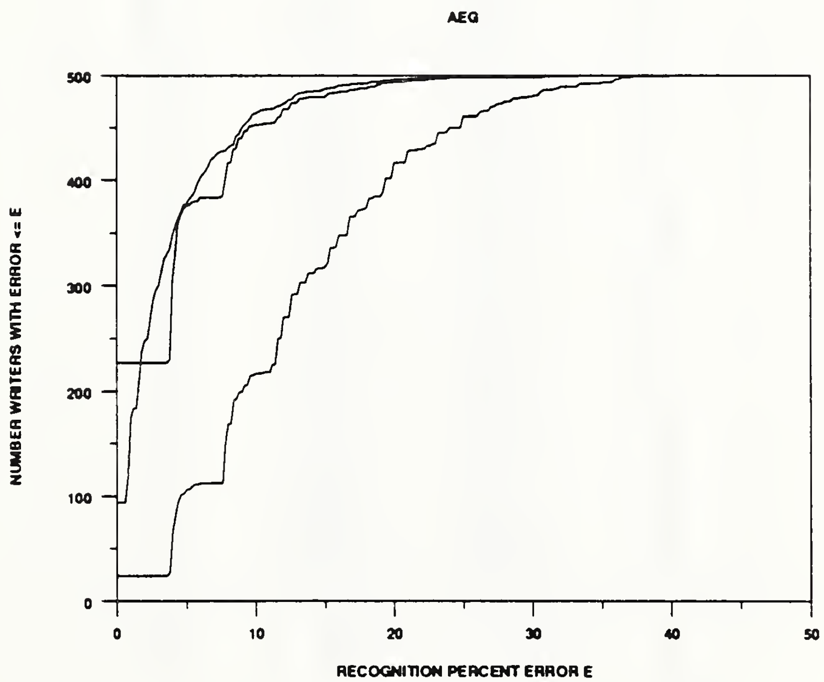

Figure 12: Error rate per writer of AEG

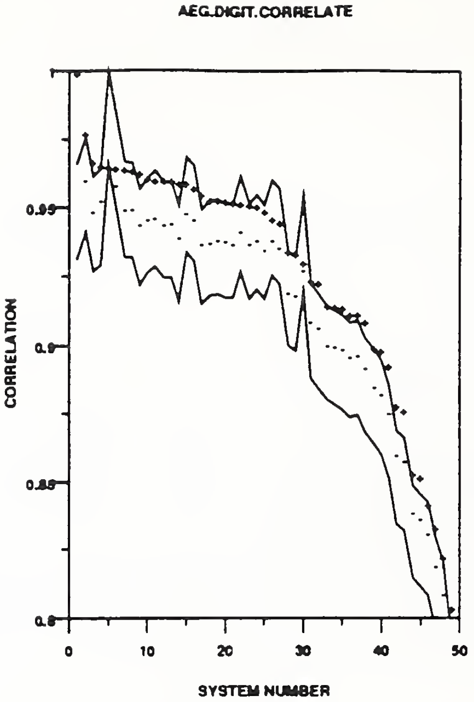

Figure 13: AEG - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	AEG	1.0000	1.0000
2	VOTE_M	0.9781	0.9606
3	ERIM_1	0.9674	0.9492
4	VOTE_P	0.9659	0.9534
5	REFERENCE	0.9657	0.9657
6	OCRSYS	0.9652	0.9586
7	ELSAGB_3	0.9645	0.9502
8	ELSAGB_2	0.9642	0.9499
9	UBOL	0.9632	0.9446
10	ERIM_2	0.9616	0.9465
11	ATT_2	0.9606	0.9469
12	KODAK_2	0.9605	0.9448
13	ATT_4	0.9605	0.9446
14	ATT_1	0.9598	0.9487
15	NIST_4	0.9598	0.9397
16	IBM	0.9578	0.9464
17	ELSAGB_1	0.9555	0.9378
18	SYMBUS	0.9536	0.9388
19	KODAK_1	0.9536	0.9383
20	ATT_3	0.9533	0.9384
21	HUGHES_1	0.9526	0.9378
22	THINK_2	0.9523	0.9420
23	HUGHES_2	0.9520	0.9375
24	NESTOR	0.9516	0.9389
25	THINK_1	0.9496	0.9356
26	REI	0.9466	0.9389
27	NYNEX	0.9454	0.9363
28	GTESS_1	0.9352	0.9203
29	GTESS_2	0.9346	0.9193
30	COMCOM	0.9314	0.9286
31	NIST_1	0.9247	0.9095
32	GMD_3	0.9239	0.9075
33	MIME	0.9155	0.9011
34	GMD_1	0.9152	0.9005
35	ASOL	0.9148	0.8996
36	UPENN	0.9124	0.8974
37	NIST_2	0.9124	0.8968
38	NIST_3	0.9096	0.8928
39	GMD_4	0.8998	0.8858
40	RISO	0.8990	0.8828
41	KAMAN_1	0.8937	0.8762
42	KAMAN_3	0.8789	0.8608
43	KAMAN_2	0.8768	0.8587
44	KAMAN_5	0.8540	0.8391
45	GMD_2	0.8525	0.8369
46	VALEN_2	0.8427	0.8315
47	IFAX	0.8336	0.8194
48	VALEN_1	0.8229	0.8093
49	KAMAN_4	0.8043	0.7867

Table 11: AEG correlation graph key for digits.

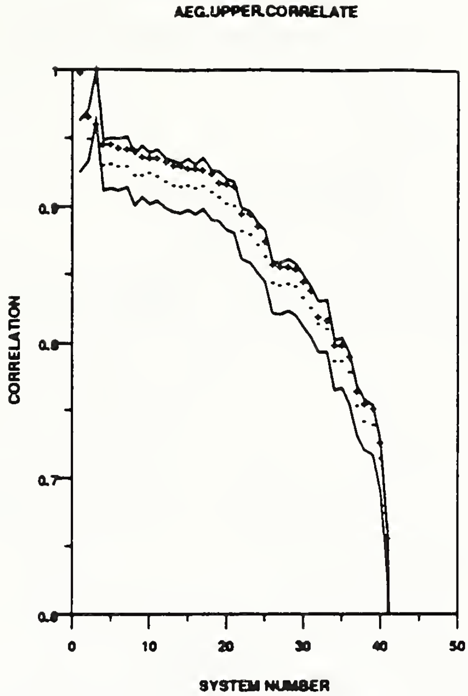

Figure 14: AEG - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	AEG	1.0000	1.0000
2	VOTE_M	0.9680	0.9518
3	REFERENCE	0.9626	0.9626
4	ERIM_1	0.9477	0.9323
5	ATT_4	0.9475	0.9330
6	UMICH_1	0.9450	0.9313
7	NYNEX	0.9440	0.9312
8	UBOL	0.9433	0.9246
9	ATT_2	0.9384	0.9252
10	VOTE_P	0.9374	0.9270
11	NESTOR	0.9374	0.9238
12	HUGHES_1	0.9348	0.9198
13	HUGHES_2	0.9324	0.9173
14	ATT_3	0.9322	0.9170
15	ATT_1	0.9305	0.9172
16	KODAK_1	0.9302	0.9158
17	IBM	0.9295	0.9173
18	SYMBUS	0.9268	0.9126
19	OCRSYS	0.9205	0.9091
20	GTESS_1	0.9189	0.9042
21	GTESS_2	0.9172	0.9024
22	MIME	0.8977	0.8841
23	NIST_4	0.8972	0.8820
24	ASOL	0.8885	0.8740
25	REI	0.8771	0.8658
26	GMD_1	0.8601	0.8467
27	RISO	0.8587	0.8446
28	NIST_1	0.8585	0.8457
29	GMD_3	0.8573	0.8444
30	KAMAN_1	0.8478	0.8354
31	GMD_4	0.8409	0.8282
32	COMCOM	0.8222	0.8168
33	NIST_3	0.8196	0.8125
34	KAMAN_3	0.8007	0.7892
35	IFAX	0.8007	0.7889
36	KAMAN_2	0.7922	0.7802
37	NIST_2	0.7667	0.7561
38	VALEN_1	0.7572	0.7450
39	GMD_2	0.7542	0.7424
40	KAMAN_4	0.7290	0.7169
41	KAMAN_5	0.6585	0.6491
42	UMICH_2	0.0337	0.0228

Table 12: AEG correlation graph key for uppers.

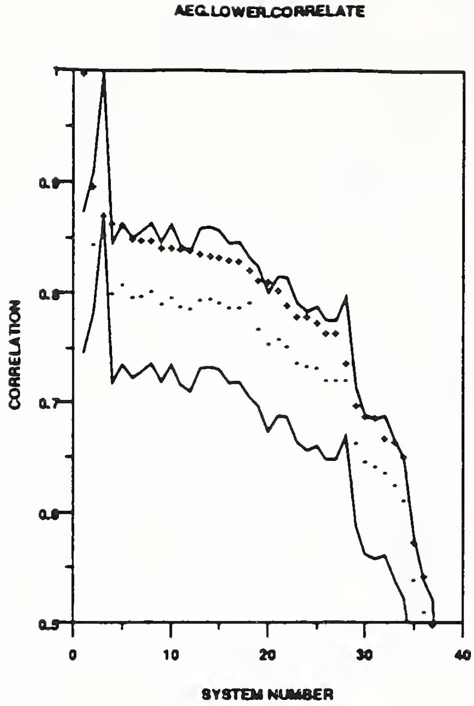

Figure 15: AEG - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	AEG	1.0000	1.0000
2	VOTE_M	0.8987	0.8468
3	REFERENCE	0.8726	0.8726
4	UBOL	0.8663	0.8026
5	ERIM_1	0.8644	0.8112
6	UMICH_1	0.8521	0.7987
7	OCRSYS	0.8508	0.8046
8	KODAK_1	0.8508	0.8006
9	HUGHES_1	0.8440	0.7933
10	ATT_1	0.8438	0.7989
11	HUGHES_2	0.8427	0.7916
12	ATT_3	0.8422	0.7886
13	ATT_2	0.8396	0.7975
14	NYNEX	0.8373	0.7979
15	ATT_4	0.8362	0.7946
16	IBM	0.8339	0.7897
17	NESTOR	0.8331	0.7900
18	VOTE_P	0.8247	0.7960
19	GTESS_1	0.8148	0.7702
20	NIST_4	0.8144	0.7565
21	GTESS_2	0.8067	0.7617
22	NIST_1	0.7924	0.7542
23	GMD_3	0.7826	0.7391
24	RISO	0.7817	0.7360
25	ASOL	0.7763	0.7347
26	GMD_4	0.7668	0.7235
27	GMD_1	0.7668	0.7235
28	NIST_3	0.7394	0.7235
29	GMD_2	0.7000	0.6659
30	KAMAN_1	0.6899	0.6487
31	VALEN_1	0.6885	0.6446
32	NIST_2	0.6702	0.6384
33	KAMAN_3	0.6677	0.6266
34	KAMAN_2	0.6531	0.6137
35	KAMAN_5	0.5755	0.5407
36	KAMAN_4	0.5438	0.5117
37	COMCOM	0.5011	0.4882
38	UMICH_2	0.0898	0.0505

Table 13: AEG correlation graph key for lowers.

SYSTEM: ASOL

PARTICIPANT: Thomas Baker

ORGANIZATION: Adaptive Solutions, Inc., Beaverton, OR

PREPROCESSING: size normalization to 8x8

FEATURES: Digits: raw
  Uppers: raw and histograms from four directions
  Lowers: raw and histograms from four directions

CLASSIFICATION: One layer Learning Vector Quantization NN

HARDWARE: CNAPS computer, digital SIMD processor array,
64 processors per chip, multiple chips per board.
Each processor is similar to DSP.

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	65000	44951	45313	NSDB3

STATUS: on time

RESULTS:

-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
0.00	0.0891	0.00	0.1116	0.00	0.2125	
0.10	0.0636	0.10	0.0842	0.10	0.1795	
0.20	0.0377	0.20	0.0592	0.20	0.1597	
0.30	0.0215	0.30	0.0423	0.30	0.1280	
0.40	0.0192	0.40	0.0407	0.40	0.1062	
0.50	0.0184	0.50	0.0457	0.50	0.0745	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	77.06	51.92	51.72
CPU RATE:	1303.24	459.27	461.54

NOTE: Output is the Euclidean distance between nodes in the network and the input vector. Net reported top three classes.

SYSTEM: ASOL

BIBLIOGRAPHY: [3][4]

COMMENTS:

System Description:

The OCR system submitted by Adaptive Solutions used a Learning Vector Quantization (LVQ) neural network classifier. LVQ is a single layer, winner-take-all network. Each weight vector in the network is assigned to a class. There can be more than one weight vector assigned to each class. The network uses the lowest euclidean distance between the weight vectors and the input vector to determine the winning class. The digit network had 224 output nodes, and the upper and lower case networks each had 416 output nodes.

The digits were normalized to an 8x8 array and input to the network. The inputs to the upper and lower case networks were a combination of the 8x8 normalized data and a histogram of the characters taken from the top, bottom, left and right of a 16x16 scale normalized array.

To report the confidence of the classification the three closest weight vectors were used. Statistics were accumulated based on the ordering of the outputs. The statistics were put into a table for reporting the confidence of the test data.

The neural network classifier was trained and tested on an Adaptive Solutions neurocomputer using a CNAPS parallel array of processors. The system that was used for the conference results had 32 processors. A system that used 64 processors for the preprocessing and classification of the test digits achieved a speed of over 1400 characters per second.

For questions or comments please contact:

Thomas Baker INTERNET: tom@asi.com Adaptive Solutions, Inc. UUCP: uunet!adaptive!tom 1400 N.W. Compton Drive, Suite 340 PHONE: (503) 690-1236 Beaverton, Oregon 97006 FAX: (503) 690-1249

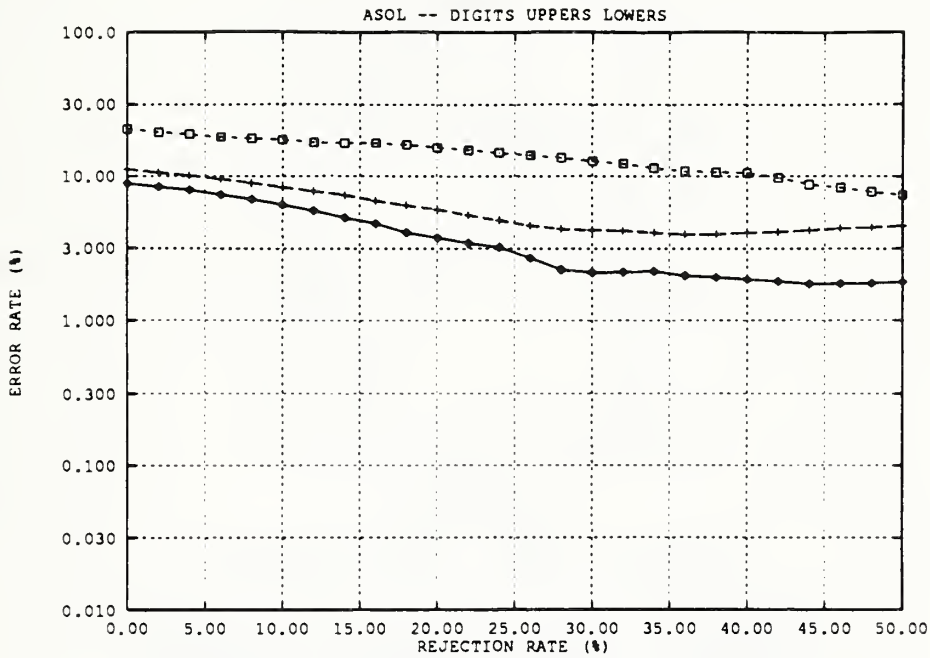

Figure 16: Error rate versus rejection rate for ASOL

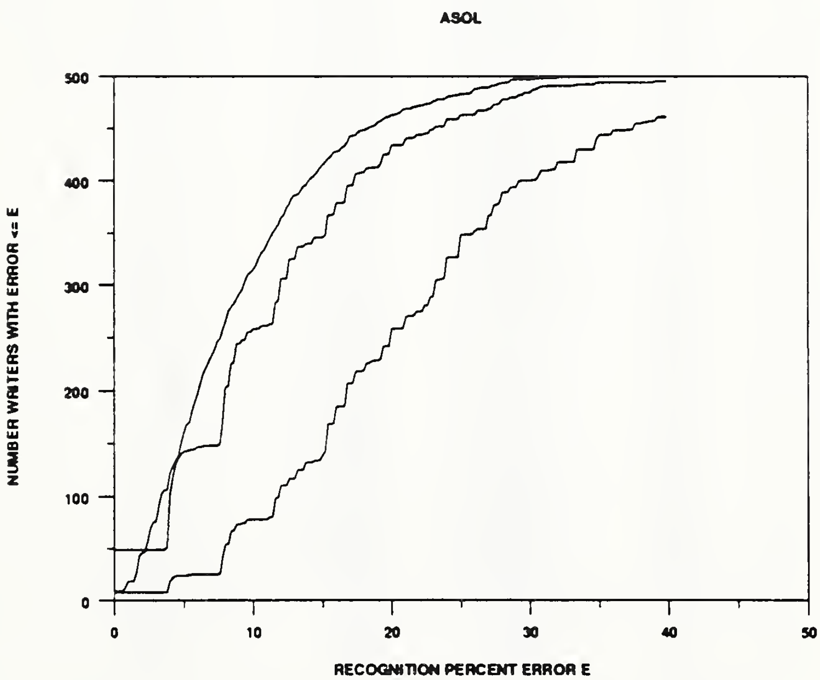

Figure 17: Error rate per writer of ASOL

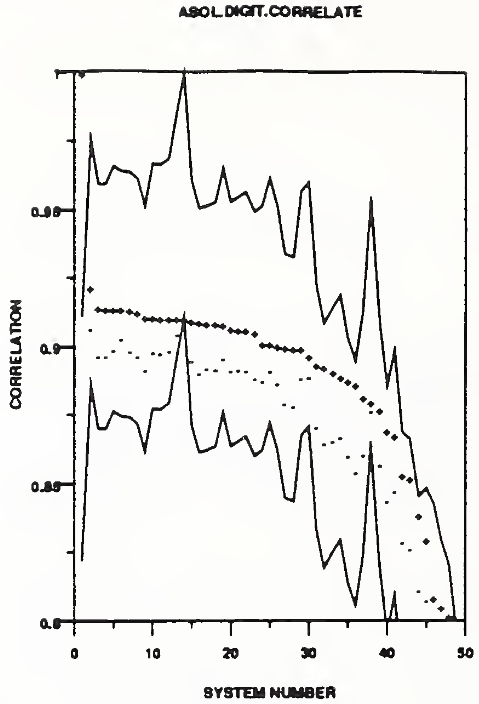

Figure 18: ASOL - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	ASOL	1.0000	1.0000
2	VOTE_M	0.9225	0.9071
3	ATT_4	0.9153	0.8974
4	AEG	0.9148	0.8996
5	KODAK_2	0.9148	0.8973
6	VOTE_P	0.9147	0.9037
7	ATT_2	0.9143	0.8989
8	ERIM_1	0.9134	0.8972
9	THINK_1	0.9115	0.8922
10	ELSAGB_3	0.9114	0.8985
11	ELSAGB_2	0.9112	0.8983
12	ATT_1	0.9111	0.8990
13	REFERENCE	0.9109	0.9109
14	OCRSYS	0.9109	0.9050
15	ERIM_2	0.9100	0.8954
16	NIST_4	0.9097	0.8907
17	ATT_3	0.9093	0.8924
18	KODAK_1	0.9093	0.8921
19	IBM	0.9085	0.8965
20	SYMBUS	0.9075	0.8915
21	NESTOR	0.9067	0.8921
22	UBOL	0.9067	0.8918
23	ELSAGB_1	0.9057	0.8890
24	THINK_2	0.9018	0.8917
25	HUGHES_1	0.9018	0.8878
26	HUGHES_2	0.9011	0.8873
27	GTESS_1	0.9006	0.8799
28	GTESS_2	0.9001	0.8790
29	NYNEX	0.9000	0.8889
30	REI	0.8972	0.8893
31	NIST_1	0.8942	0.8717
32	NIST_2	0.8929	0.8655
33	MIME	0.8913	0.8664
34	GMD_3	0.8893	0.8677
35	NIST_3	0.8881	0.8610
36	RISO	0.8867	0.8551
37	GMD_1	0.8821	0.8615
38	COMCOM	0.8802	0.8772
39	UPENN	0.8773	0.8577
40	KAMAN_1	0.8701	0.8446
41	GMD_4	0.8683	0.8479
42	KAMAN_3	0.8541	0.8291
43	KAMAN_2	0.8527	0.8271
44	GMD_2	0.8392	0.8116
45	KAMAN_5	0.8302	0.8080
46	VALEN_2	0.8092	0.7944
47	IFAX	0.8057	0.7860
48	VALEN_1	0.8028	0.7802
49	KAMAN_4	0.7865	0.7592

Table 14: ASOL correlation graph key for digits.

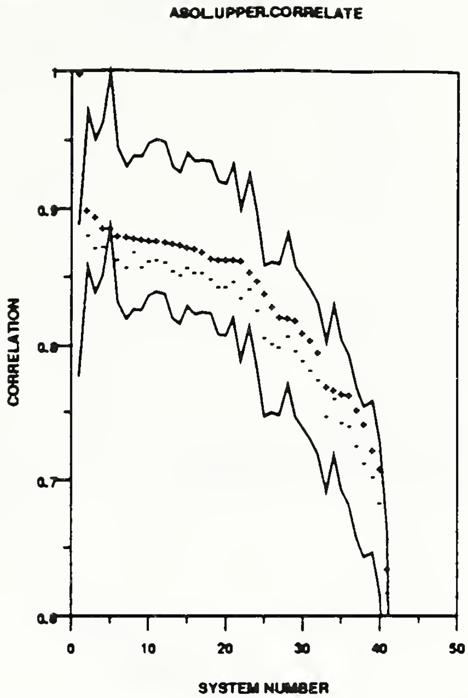

Figure 19: ASOL - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	ASOL	1.0000	1.0000
2	VOTE_M	0.9008	0.8827
3	ATT_4	0.8967	0.8734
4	AEG	0.8885	0.8740
5	REFERENCE	0.8884	0.8884
6	ATT_2	0.8824	0.8647
7	KODAK_1	0.8819	0.8592
8	VOTE_P	0.8809	0.8703
9	UBOL	0.8797	0.8598
10	ERIM_1	0.8789	0.8639
11	NYNEX	0.8787	0.8647
12	UMICH_1	0.8781	0.8633
13	ATT_3	0.8769	0.8570
14	SYMBUS	0.8761	0.8545
15	NESTOR	0.8747	0.8599
16	ATT_1	0.8735	0.8558
17	IBM	0.8712	0.8557
18	HUGHES_1	0.8673	0.8518
19	GTESS_1	0.8662	0.8462
20	GTESS_2	0.8658	0.8455
21	HUGHES_2	0.8656	0.8498
22	MIME	0.8648	0.8372
23	OCRSYS	0.8565	0.8441
24	NIST_4	0.8508	0.8283
25	RISO	0.8409	0.8085
26	NIST_1	0.8309	0.8036
27	GMD_1	0.8235	0.8004
28	REI	0.8225	0.8092
29	GMD_3	0.8208	0.7981
30	KAMAN_1	0.8116	0.7903
31	GMD_4	0.8061	0.7836
32	NIST_3	0.7972	0.7761
33	KAMAN_3	0.7711	0.7495
34	COMCOM	0.7684	0.7623
35	IFAX	0.7658	0.7449
36	KAMAN_2	0.7650	0.7421
37	NIST_2	0.7540	0.7270
38	GMD_2	0.7438	0.7148
39	VALEN_1	0.7249	0.7043
40	KAMAN_4	0.7107	0.6855
41	KAMAN_5	0.6360	0.6189
42	UMICH_2	0.0510	0.0188

Table 15: ASOL correlation graph key for uppers.

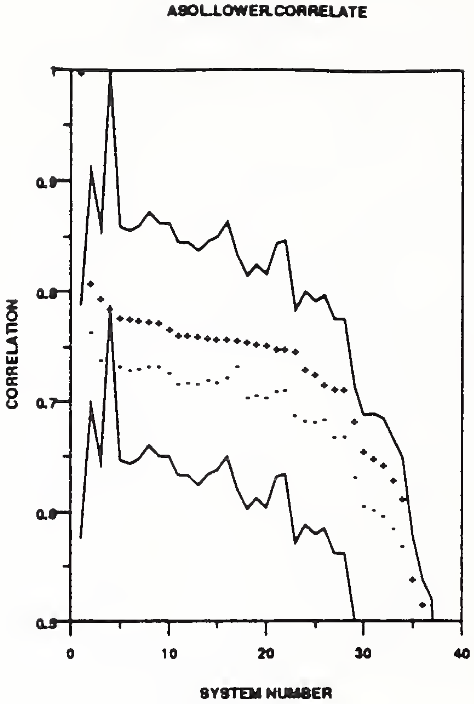

Figure 20: ASOL - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	ASOL	1.0000	1.0000
2	VOTE_M	0.8108	0.7660
3	ATT_4	0.7969	0.7408
4	REFERENCE	0.7875	0.7875
5	ATT_2	0.7801	0.7355
6	KODAK_1	0.7788	0.7320
7	NYNEX	0.7773	0.7328
8	AEG	0.7763	0.7347
9	ERIM_1	0.7757	0.7345
10	ATT_1	0.7690	0.7290
11	UBOL	0.7634	0.7189
12	IBM	0.7633	0.7203
13	ATT_3	0.7628	0.7193
14	NESTOR	0.7617	0.7222
15	UMICH_1	0.7603	0.7198
16	OCRSYS	0.7600	0.7242
17	VOTE_P	0.7593	0.7349
18	NIST_1	0.7581	0.7065
19	GTESS_1	0.7561	0.7084
20	GTESS_2	0.7547	0.7058
21	HUGHES_1	0.7512	0.7128
22	HUGHES_2	0.7512	0.7119
23	RISO	0.7493	0.6898
24	NIST_4	0.7323	0.6857
25	GMD_3	0.7283	0.6841
26	NIST_3	0.7187	0.6867
27	GMD_4	0.7146	0.6706
28	GMD_1	0.7146	0.6706
29	GMD_2	0.6852	0.6344
30	NIST_2	0.6581	0.6076
31	KAMAN_1	0.6506	0.6039
32	VALEN_1	0.6450	0.5987
33	KAMAN_3	0.6314	0.5863
34	KAMAN_2	0.6149	0.5710
35	KAMAN_5	0.5412	0.5042
36	KAMAN_4	0.5184	0.4772
37	COMCOM	0.4651	0.4545
38	UMICH_2	0.1101	0.0513

Table 16: ASOL correlation graph key for lowers.

SYSTEM: ATT_1

PARTICIPANT: Dr. Craig R. Nohl

ORGANIZATION: AT&T Bell Laboratories, Holmdel,NJ

FEATURES: gray levels in rescaled image

CLASSIFICATION: k-NN with specially-designed distance measure that can compensate for some common distortions such as translation.

HARDWARE: SPARC2

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	220000	44000	44000	NSDB3

STATUS: on time

RESULTS:

-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
0.00	0.0316	0.00	0.0655	0.00	0.1378	
0.10	0.0069	0.10	0.0331	0.10	0.1013	
0.20	0.0025	0.20	0.0171	0.20	0.0706	
0.30	0.0012	0.30	0.0094	0.30	0.0473	
0.40	0.0011	0.40	0.0050	0.40	0.0310	
0.50	0.0011	0.50	0.0028	0.50	0.0182	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	0.30	0.32	0.20
CPU RATE:			

SYSTEM: ATT_1

BIBLIOGRAPHY:

The following references have been provided for this system:

[5][6][7][8]

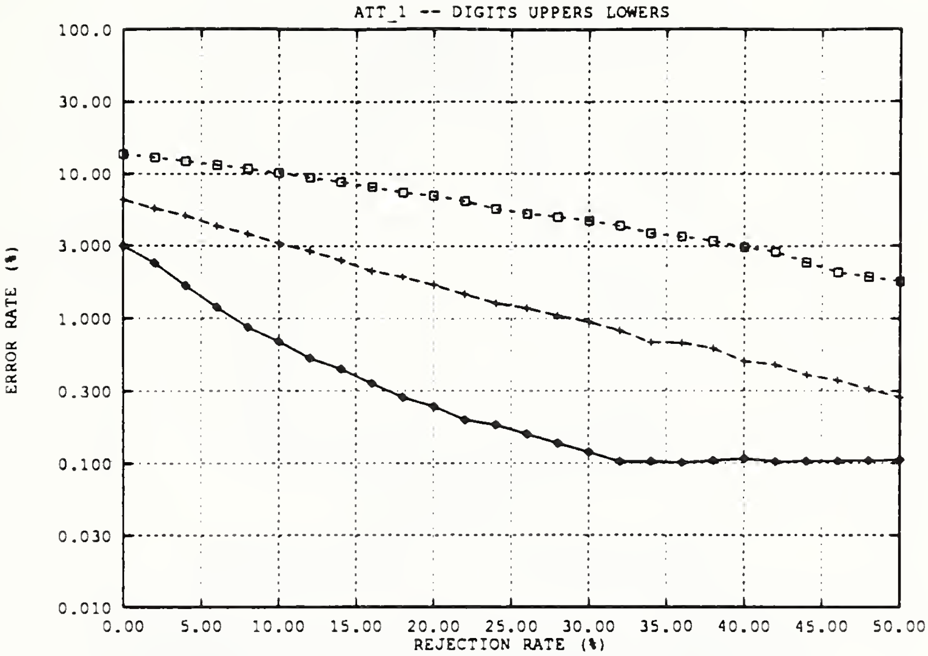

Figure 21: Error rate versus rejection rate for ATT_1

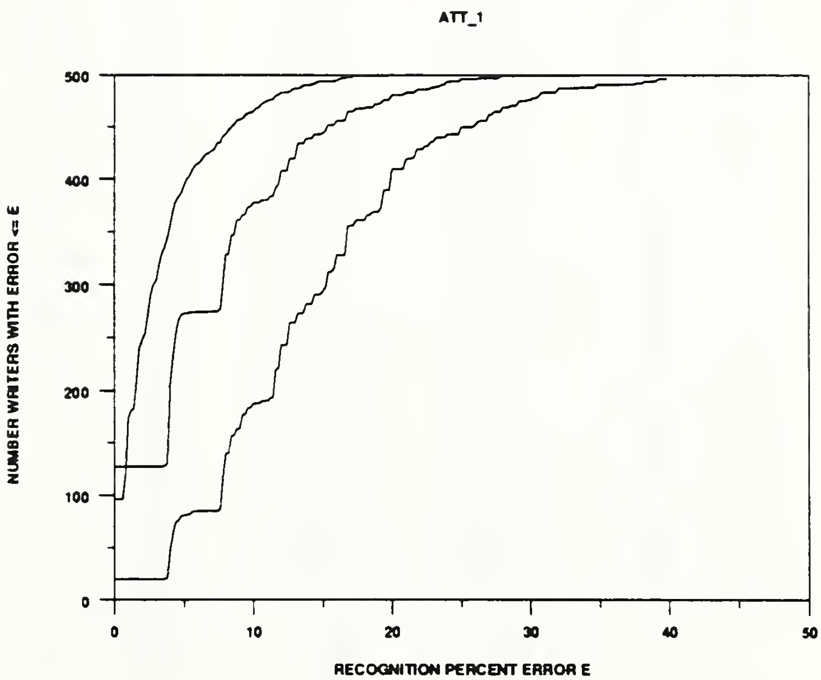

Figure 22: Error rate per writer of ATT_1

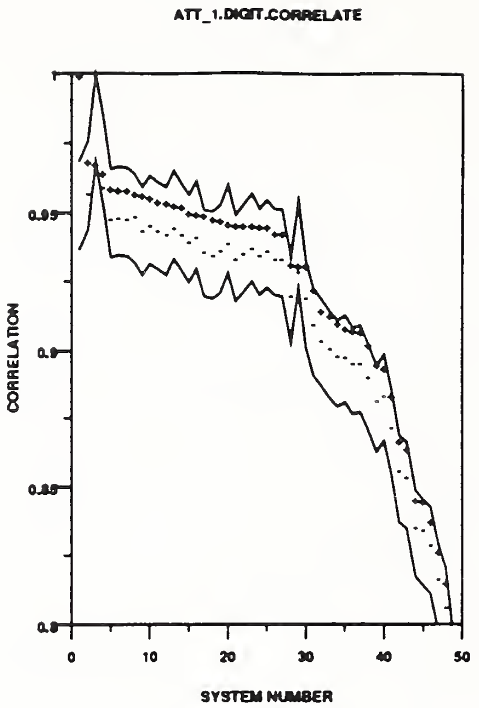

Figure 23: ATT_1 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	ATT_1	1.0000	1.0000
2	VOTE_M	0.9693	0.9580
3	REFERENCE	0.9684	0.9684
4	OCRSYS	0.9653	0.9601
5	AEG	0.9598	0.9487
6	ELSAGB_3	0.9594	0.9491
7	ELSAGB_2	0.9591	0.9488
8	VOTE_P	0.9580	0.9496
9	ATT_4	0.9573	0.9445
10	ATT_2	0.9566	0.9462
11	ERIM_1	0.9553	0.9446
12	KODAK_2	0.9544	0.9431
13	IBM	0.9535	0.9456
14	ERIM_2	0.9534	0.9433
15	UBOL	0.9511	0.9403
16	THINK_2	0.9506	0.9422
17	THINK_1	0.9500	0.9369
18	NIST_4	0.9485	0.9357
19	KODAK_1	0.9484	0.9371
20	REI	0.9467	0.9400
21	NYNEX	0.9462	0.9380
22	SYMBUS	0.9462	0.9361
23	ELSAGB_1	0.9462	0.9345
24	NESTOR	0.9459	0.9372
25	ATT_3	0.9459	0.9359
26	HUGHES_1	0.9435	0.9342
27	HUGHES_2	0.9434	0.9342
28	GTESS_1	0.9327	0.9209
29	COMCOM	0.9323	0.9298
30	GTESS_2	0.9322	0.9200
31	NIST_1	0.9235	0.9105
32	GMD_3	0.9155	0.9044
33	MIME	0.9139	0.9017
34	ASOL	0.9111	0.8990
35	GMD_1	0.9091	0.8985
36	NIST_2	0.9080	0.8961
37	UPENN	0.9079	0.8961
38	NIST_3	0.9032	0.8912
39	RISO	0.8959	0.8827
40	GMD_4	0.8946	0.8843
41	KAMAN_1	0.8845	0.8730
42	KAMAN_3	0.8679	0.8569
43	KAMAN_2	0.8651	0.8543
44	KAMAN_5	0.8463	0.8363
45	GMD_2	0.8457	0.8350
46	VALEN_2	0.8382	0.8298
47	IFAX	0.8275	0.8172
48	VALEN_1	0.8161	0.8071
49	KAMAN_4	0.7922	0.7821

Table 17: ATT_1 correlation graph key for digits.

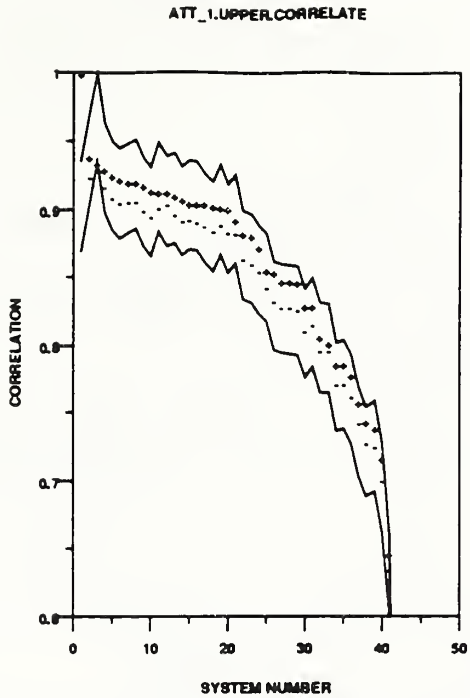

Figure 24: ATT_1 - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	ATT_1	1.0000	1.0000
2	VOTE_M	0.9397	0.9245
3	REFERENCE	0.9345	0.9345
4	AEG	0.9305	0.9172
5	ATT_4	0.9258	0.9094
6	ATT_2	0.9228	0.9051
7	ERIM_1	0.9215	0.9066
8	NYNEX	0.9209	0.9069
9	UBOL	0.9186	0.8998
10	KODAK_1	0.9143	0.8957
11	UMICH_1	0.9140	0.9022
12	VOTE_P	0.9139	0.9049
13	NESTOR	0.9111	0.8977
14	ATT_3	0.9085	0.8929
15	IBM	0.9059	0.8934
16	HUGHES_1	0.9053	0.8921
17	SYMBUS	0.9051	0.8887
18	GTESS_1	0.9034	0.8855
19	HUGHES_2	0.9032	0.8897
20	GTESS_2	0.9017	0.8841
21	OCRSYS	0.8938	0.8832
22	MIME	0.8839	0.8653
23	NIST_4	0.8818	0.8617
24	ASOL	0.8735	0.8558
25	REI	0.8571	0.8442
26	NIST_1	0.8550	0.8338
27	GMD_1	0.8485	0.8295
28	RISO	0.8484	0.8296
29	GMD_3	0.8474	0.8277
30	KAMAN_1	0.8304	0.8160
31	GMD_4	0.8304	0.8115
32	NIST_3	0.8076	0.7972
33	COMCOM	0.8031	0.7968
34	KAMAN_3	0.7872	0.7723
35	IFAX	0.7870	0.7723
36	KAMAN_2	0.7785	0.7628
37	NIST_2	0.7586	0.7441
38	GMD_2	0.7450	0.7291
39	VALEN_1	0.7404	0.7262
40	KAMAN_4	0.7178	0.7012
41	KAMAN_5	0.6478	0.6356
42	UMICH_2	0.0453	0.0234

Table 18: ATT_1 correlation graph key for uppers.

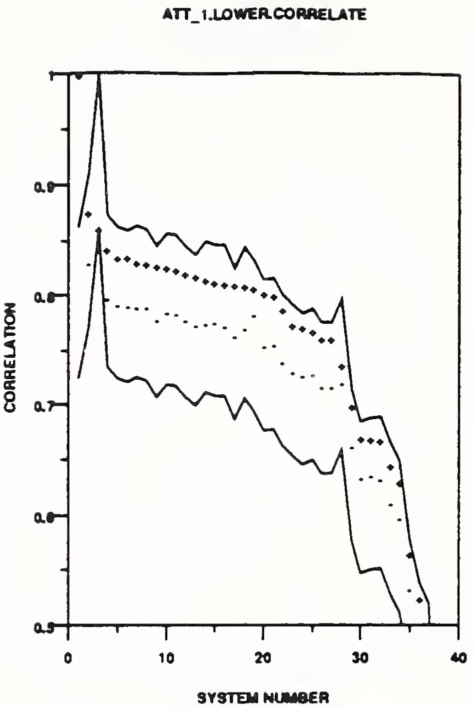

Figure 25: ATT_1 - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	ATT_1	1.0000	1.0000
2	VOTE_M	0.8773	0.8315
3	REFERENCE	0.8622	0.8622
4	AEG	0.8438	0.7989
5	ERIM_1	0.8375	0.7938
6	ATT_2	0.8370	0.7927
7	OCRSYS	0.8325	0.7908
8	NYNEX	0.8318	0.7912
9	UBOL	0.8288	0.7796
10	ATT_4	0.8275	0.7864
11	KODAK_1	0.8261	0.7853
12	IBM	0.8224	0.7793
13	ATT_3	0.8202	0.7749
14	UMICH_1	0.8168	0.7767
15	NESTOR	0.8142	0.7780
16	HUGHES_1	0.8129	0.7738
17	GTESS_1	0.8114	0.7647
18	HUGHES_2	0.8105	0.7717
19	VOTE_P	0.8088	0.7841
20	NIST_1	0.8035	0.7554
21	GTESS_2	0.8018	0.7563
22	NIST_4	0.7885	0.7403
23	GMD_3	0.7753	0.7320
24	RISO	0.7724	0.7281
25	ASOL	0.7690	0.7290
26	GMD_4	0.7623	0.7176
27	GMD_1	0.7623	0.7176
28	NIST_3	0.7383	0.7210
29	GMD_2	0.7010	0.6637
30	VALEN_1	0.6718	0.6346
31	NIST_2	0.6705	0.6374
32	KAMAN_1	0.6697	0.6336
33	KAMAN_3	0.6461	0.6118
34	KAMAN_2	0.6311	0.5983
35	KAMAN_5	0.5658	0.5338
36	KAMAN_4	0.5254	0.4979
37	COMCOM	0.4951	0.4848
38	UMICH_2	0.1023	0.0582

Table 19: ATT_1 correlation graph key for lowers.

SYSTEM: ATT_2

PARTICIPANT: Dr. Craig R. Nohl

ORGANIZATION: AT&T Bell Laboratories, Holmdel,NJ

FEATURES: raw?

CLASSIFICATION: five layer NN with local receptive fields and replicated weights

HARDWARE: SPARC2

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	156000	31000	31000	NSDB3

STATUS: on time

RESULTS: -- DIGITS -- -- UPPERS -- -- LOWERS -- DATABASE

REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
0.00	0.0367	0.00	0.0563	0.00	0.1406	
0.10	0.0076	0.10	0.0180	0.10	0.0893	
0.20	0.0023	0.20	0.0081	0.20	0.0538	
0.30	0.0015	0.30	0.0039	0.30	0.0317	
0.40	0.0009	0.40	0.0027	0.40	0.0151	
0.50	0.0007	0.50	0.0020	0.50	0.0080	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	5.10	1.95	1.99
CPU RATE:			

SYSTEM: ATT_2

BIBLIOGRAPHY:

The following references have been provided for this system:

[5][6][7][8]

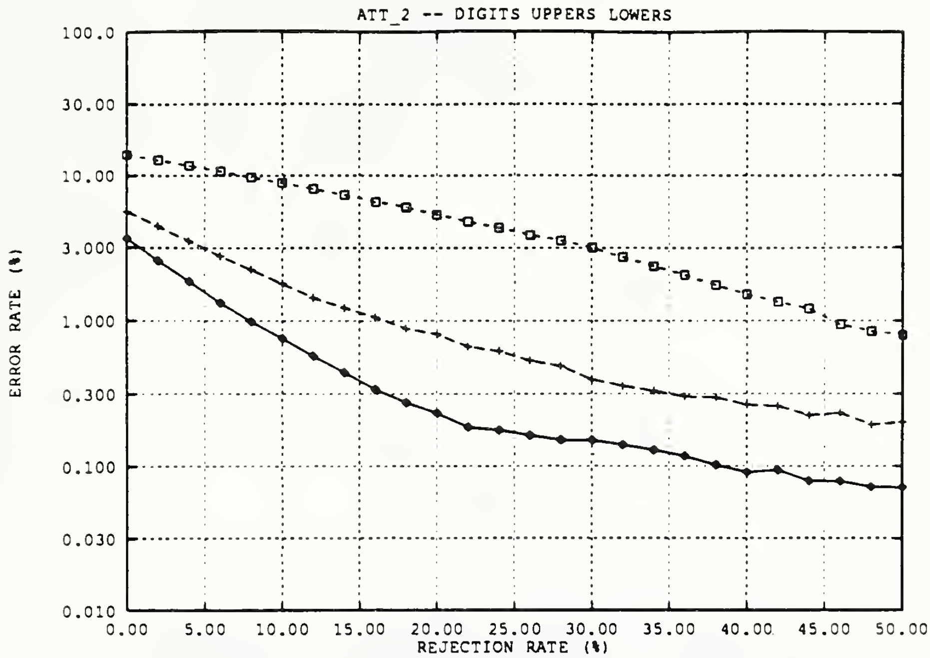

Figure 26: Error rate versus rejection rate for ATT_2

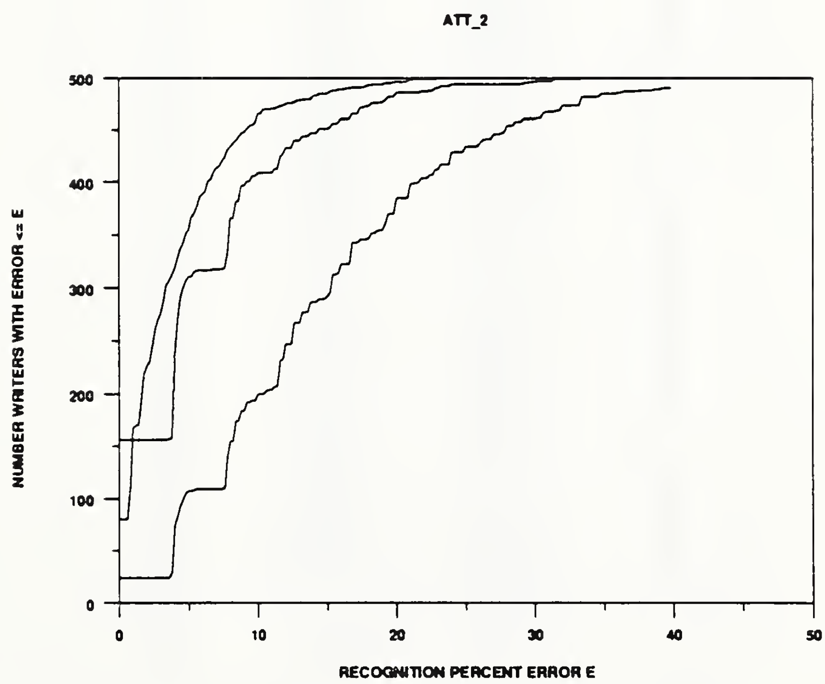

Figure 27: Error rate per writer of ATT_2

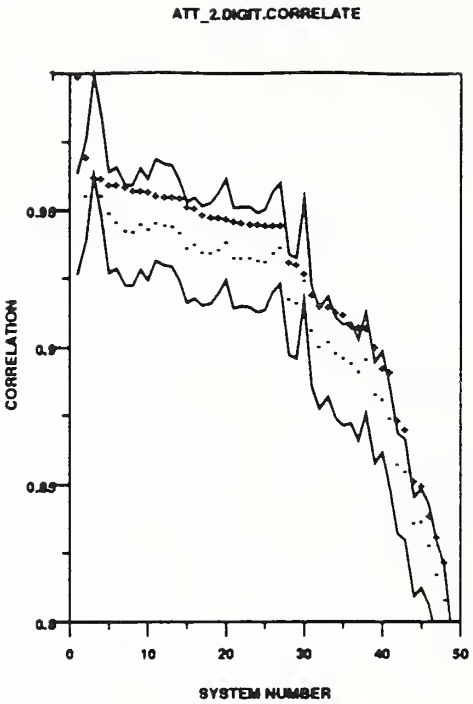

Figure 28: ATT_2 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	ATT_2	1.0000	1.0000
2	VOTE_M	0.9709	0.9566
3	REFERENCE	0.9633	0.9633
4	OCRSYS	0.9627	0.9563
5	VOTE_P	0.9606	0.9498
6	AEG	0.9606	0.9469
7	ATT_4	0.9595	0.9436
8	KODAK_2	0.9585	0.9431
9	IBM	0.9583	0.9460
10	ERIM_1	0.9580	0.9440
11	ATT_1	0.9566	0.9462
12	ELSAGB_3	0.9562	0.9454
13	ELSAGB_2	0.9558	0.9450
14	ERIM_2	0.9557	0.9428
15	KODAK_1	0.9523	0.9371
16	NESTOR	0.9518	0.9384
17	ATT_3	0.9497	0.9360
18	SYMBUS	0.9488	0 9356
19	UBOL	0.9486	0.9368
20	THINK_2	0.9484	0.9394
21	THINK_1	0.9474	0 9341
22	HUGHES_1	0.9468	0.9341
23	HUGHES_2	0.9464	0.9340
24	ELSAGB_1	0.9463	0.9328
25	NIST_4	0.9460	0.9327
26	REI	0.9459	0.9377
27	NYNEX	0.9459	0.9360
28	GTESS_1	0.9325	0.9186
29	GTESS_2	0.9318	0.9176
30	COMCOM	0.9285	0.9258
31	NIST_1	0.9204	0.9072
32	MIME	0.9163	0.9013
33	GMD_3	0.9161	0.9033
34	ASOL	0.9143	0.8989
35	NIST_2	0.9134	0.8974
36	UPENN	0.9091	0.8953
37	NIST_3	0.9089	0.8923
38	GMD_1	0.9082	0.8967
39	RISO	0.9015	0.8839
40	GMD_4	0 8933	0.8822
41	KAMAN_1	0.8922	0.8752
42	KAMAN_3	0.8747	0.8587
43	KAMAN_2	0.8715	0.8559
44	GMD_2	0.8525	0.8370
45	KAMAN_5	0.8508	0.8375
46	VALEN_2	0.8396	0.8288
47	IFAX	0.8319	0.8181
48	VALEN_1	0.8228	0.8091
49	KAMAN_4	0.7983	0.7834

Table 20: ATT_2 correlation graph key for digits.

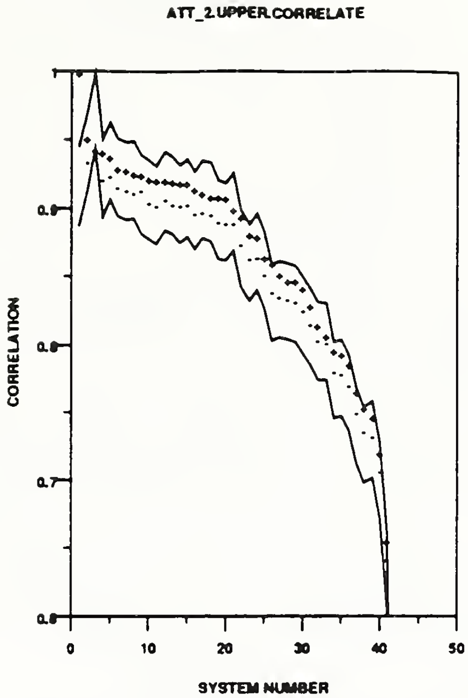

Figure 29: ATT_2 - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	ATT_2	1.0000	1.0000
2	VOTE_M	0.9528	0.9354
3	REFERENCE	0.9437	0.9437
4	ATT_4	0.9422	0.9223
5	AEG	0.9384	0.9252
6	NYNEX	0.9307	0.9165
7	ERIM_1	0.9290	0.9143
8	UMICH_1	0.9265	0.9131
9	VOTE_P	0.9254	0.9148
10	ATT_1	0.9228	0.9051
11	KODAK_1	0.9225	0.9039
12	NESTOR	0.9224	0.9080
13	UBOL	0.9210	0.9049
14	ATT_3	0.9206	0.9033
15	IBM	0.9198	0.9048
16	SYMBUS	0.9158	0.8985
17	HUGHES_1	0.9131	0.8995
18	HUGHES_2	0.9106	0.8969
19	GTESS_1	0.9101	0.8921
20	GTESS_2	0.9091	0.8912
21	OCRSYS	0.9010	0.8905
22	MIME	0.8952	0.8756
23	ASOL	0.8824	0.8647
24	NIST_4	0.8812	0.8658
25	REI	0.8658	0.8531
26	RISO	0.8619	0.8406
27	NIST_1	0.8529	0.8364
28	GMD_1	0.8488	0.8349
29	GMD_3	0.8482	0.8333
30	KAMAN_1	0.8429	0.8261
31	GMD_4	0.8303	0.8164
32	NIST_3	0.8159	0.8049
33	COMCOM	0.8084	0.8024
34	KAMAN_3	0.7973	0.7813
35	IFAX	0.7946	0.7799
36	KAMAN_2	0.7870	0.7712
37	NIST_2	0.7668	0.7511
38	GMD_2	0.7546	0.7376
39	VALEN_1	0.7487	0.7342
40	KAMAN_4	0.7222	0.7077
41	KAMAN_5	0.6562	0.6429
42	UMICH_2	0.0408	0.0231

Table 21: ATT_2 correlation graph key for uppers.

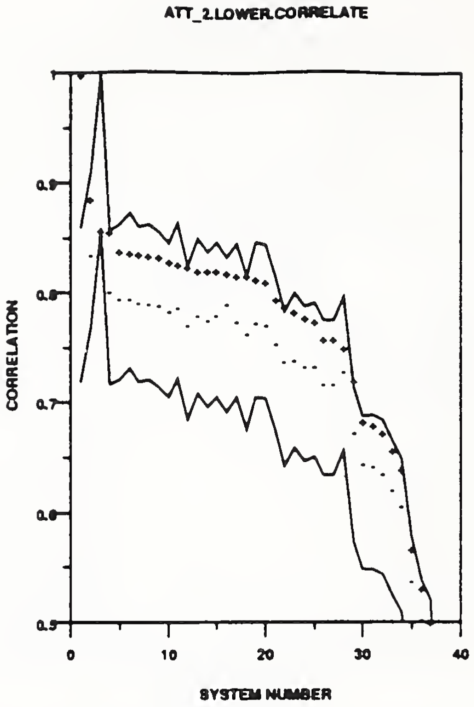

Figure 30: ATT_2 - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	ATT_2	1.0000	1.0000
2	VOTE_M	0.8879	0.8372
3	REFERENCE	0.8594	0.8594
4	ATT_4	0.8580	0.8033
5	ERIM_1	0.8405	0.7965
6	AEG	0.8396	0.7975
7	NYNEX	0.8378	0.7939
8	ATT_1	0.8370	0.7927
9	KODAK_1	0.8357	0.7911
10	IBM	0.8315	0.7858
11	OCRSYS	0.8291	0.7893
12	GTESS_1	0.8267	0.7734
13	UMICH_1	0.8239	0.7818
14	NESTOR	0.8235	0.7818
15	ATT_3	0.8235	0.7780
16	VOTE_P	0.8216	0.7928
17	UBOL	0 8188	0.7763
18	GTESS_2	0.8184	0.7652
19	HUGHES_1	0.8154	0.7747
20	HUGHES_2	0.8128	0.7728
21	NIST_1	0.7974	0.7552
22	RISO	0.7902	0.7393
23	NIST_4	0.7851	0.7402
24	ASOL	0.7801	0.7355
25	GMD_3	0.7762	0.7352
26	GMD_4	0.7597	0.7193
27	GMD_1	0.7597	0.7193
28	NIST_3	0.7527	0.7306
29	GMD_2	0.7219	0.6758
30	NIST_2	0.6860	0.6465
31	KAMAN_1	0.6825	0.6442
32	VALEN_1	0.6747	0.6376
33	KAMAN_3	0.6596	0.6227
34	KAMAN_2	0.6416	0.6075
35	KAMAN_5	0.5680	0.5385
36	KAMAN_4	0 5334	0.5045
37	COMCOM	0.5013	0.4896
38	UMICH_2	0 0944	0.0568

Table 22: ATT_2 correlation graph key for lowers.

SYSTEM: ATT_3

PARTICIPANT: Dr. Craig R. Nohl

ORGANIZATION: AT&T Bell Laboratories, Holmdel,NJ

FEATURES: raw?

CLASSIFICATION: hybrid of feature-based and NN classifiers.
The commercial NCR product.

HARDWARE: proprietary board based on Analog Devices 2901

TRAINING:

DIGITS	UPPERS	LOWERS	DATABASE
140000	26000	23000	NSDB3

STATUS: on time

RESULTS:

-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
0.00	0.0484	0.00	0.0683	0.00	0.1634	
0.10	0.0129	0.10	0.0297	0.10	0.1176	
0.20	0.0126	0.20	0.0150	0.20	0.0856	
0.30	0.0127	0.30	0.0071	0.30	0.0582	
0.40	0.0128	0.40	0.0066	0.40	0.0382	
0.50	0.0124	0.50	0.0065	0.50	0.0313	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	146.38	142.82	146.82
CPU RATE:			

SYSTEM: ATT_3

BIBLIOGRAPHY:

The following references have been provided for this system:

[9][10]

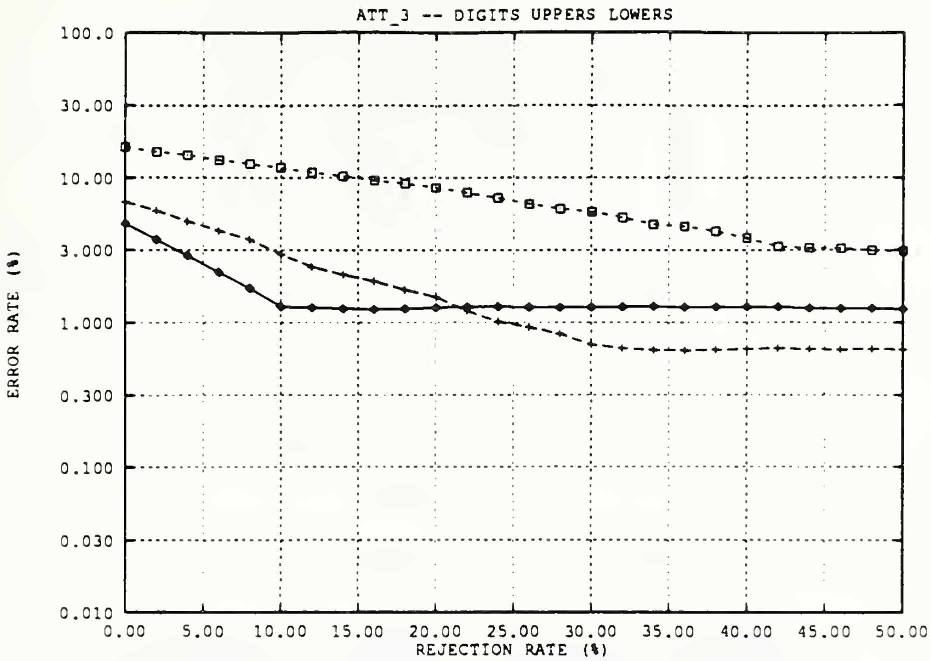

Figure 31: Error rate versus rejection rate for ATT_3

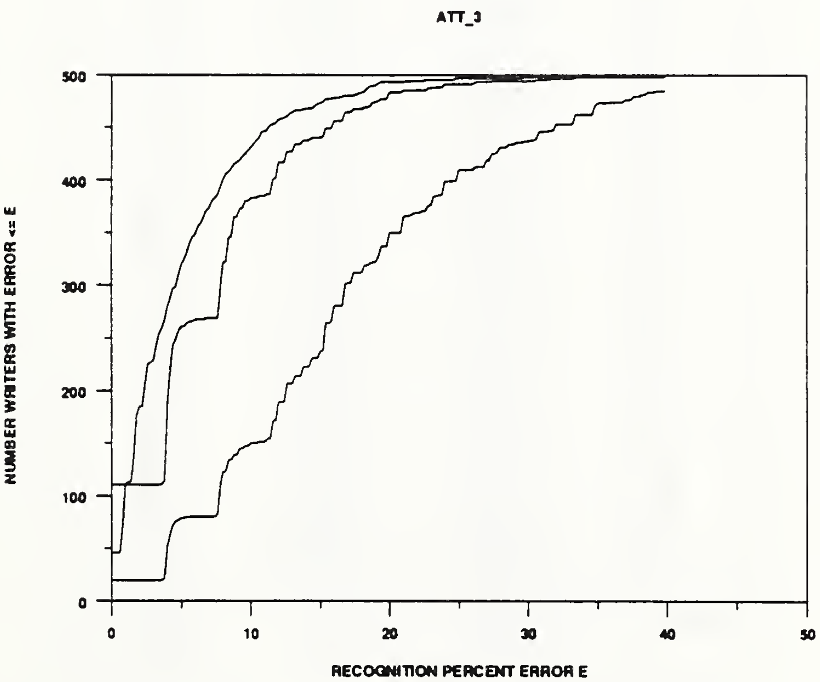

Figure 32: Error rate per writer of ATT_3

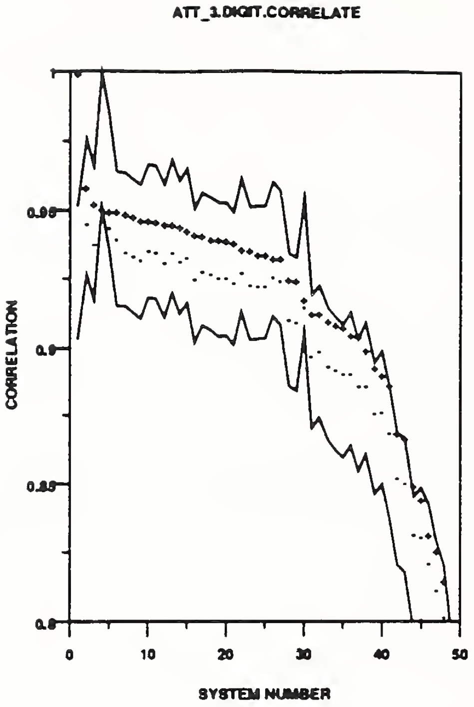

Figure 33: ATT_3 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	ATT_3	1.0000	1.0000
2	VOTE_M	0.9593	0.9457
3	AEG	0.9533	0.9384
4	REFERENCE	0.9516	0.9516
5	OCRSYS	0.9506	0.9447
6	VOTE_P	0.9503	0.9404
7	ATT_2	0.9497	0.9360
8	ERIM_1	0.9486	0.9345
9	ATT_4	0.9473	0.9329
10	ELSAGB_3	0.9472	0.9362
11	ELSAGB_2	0.9468	0.9358
12	KODAK_2	0.9460	0.9323
13	ATT_1	0.9459	0.9359
14	ERIM_2	0.9450	0.9326
15	IBM	0.9436	0.9338
16	NIST_4	0.9420	0.9262
17	UBOL	0.9417	0.9289
18	NESTOR	0.9404	0.9282
19	KODAK_1	0.9403	0.9267
20	SYMBUS	0.9399	0.9268
21	ELSAGB_1	0.9391	0.9247
22	THINK_2	0.9369	0.9284
23	THINK_1	0.9364	0.9240
24	HUGHES_2	0.9349	0.9235
25	HUGHES_1	0.9347	0.9235
26	REI	0.9337	0.9268
27	NYNEX	0.9336	0.9251
28	GTESS_1	0.9259	0.9111
29	GTESS_2	0.9252	0.9101
30	COMCOM	0.9181	0.9155
31	GMD_3	0.9133	0.8977
32	NIST_1	0.9132	0.8995
33	MIME	0.9103	0.8942
34	ASOL	0.9093	0.8924
35	NIST_2	0.9084	0.8911
36	GMD_1	0.9066	0.8911
37	NIST_3	0.9048	0.8866
38	UPENN	0.8998	0.8867
39	RISO	0.8936	0.8763
40	GMD_4	0.8907	0.8768
41	KAMAN_1	0.8869	0.8695
42	KAMAN_3	0.8696	0.8530
43	KAMAN_2	0.8680	0.8512
44	GMD_2	0.8504	0.8325
45	KAMAN_5	0.8455	0.8314
46	VALEN_2	0.8325	0.8219
47	IFAX	0.8264	0.8123
48	VALEN_1	0.8156	0.8026
49	KAMAN_4	0.7975	0.7802

Table 23: ATT_3 correlation graph key for digits.

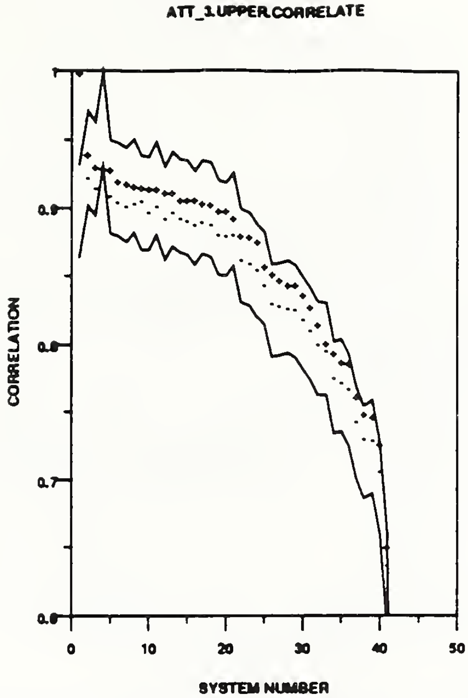

Figure 34: ATT_3 - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	ATT_3	1.0000	1.0000
2	VOTE_M	0.9415	0.9240
3	AEG	0.9322	0.9170
4	REFERENCE	0.9317	0.9317
5	ATT_4	0.9300	0.9111
6	ERIM_1	0.9223	0.9064
7	ATT_2	0.9206	0.9033
8	NYNEX	0.9185	0.9052
9	VOTE_P	0.9173	0.9070
10	UBOL	0.9169	0.8989
11	UMICH_1	0.9166	0.9034
12	KODAK_1	0.9141	0.8946
13	NESTOR	0.9139	0.8991
14	IBM	0.9087	0.8949
15	ATT_1	0.9085	0.8929
16	SYMBUS	0.9082	0.8897
17	HUGHES_1	0.9056	0.8916
18	HUGHES_2	0.9044	0.8896
19	GTESS_1	0.9005	0.8824
20	GTESS_2	0.8999	0.8815
21	OCRSYS	0.8943	0.8827
22	MIME	0.8813	0.8643
23	NIST_4	0.8807	0.8619
24	ASOL	0.8769	0.8570
25	REI	0.8696	0.8456
26	RISO	0.8537	0.8321
27	GMD_1	0.8493	0.8305
28	NIST_1	0.8463	0.8284
29	GMD_3	0.8457	0.8278
30	KAMAN_1	0.8385	0.8204
31	GMD_4	0.8294	0.8119
32	NIST_3	0.8168	0.8015
33	COMCOM	0.8029	0.7973
34	KAMAN_3	0.7951	0.7767
35	IFAX	0.7885	0.7731
36	KAMAN_2	0.7880	0.7684
37	NIST_2	0.7631	0.7452
38	GMD_2	0.7504	0.7322
39	VALEN_1	0.7489	0.7308
40	KAMAN_4	0.7286	0.7078
41	KAMAN_5	0.6516	0.6384
42	UMICH_2	0.0423	0.0210

Table 24: ATT_3 correlation graph key for uppers.

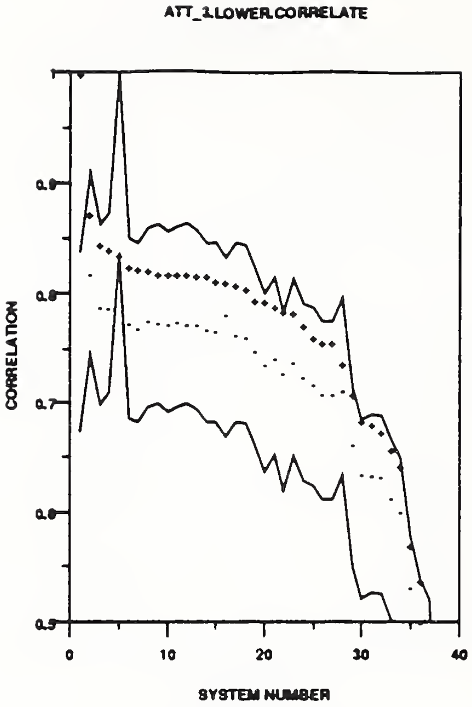

Figure 35: ATT_3 - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	ATT_3	1.0000	1.0000
2	VOTE_M	0.8740	0.8197
3	ERIM_1	0.8464	0.7899
4	AEG	0.8422	0.7886
5	REFERENCE	0.8366	0.8366
6	UMICH_1	0.8273	0.7747
7	UBOL	0.8248	0.7704
8	ATT_2	0.8235	0.7780
9	ATT_1	0.8202	0.7749
10	KODAK_1	0.8199	0.7735
11	NYNEX	0.8197	0.7768
12	OCRSYS	0.8194	0.7744
13	ATT_4	0.8192	0.7745
14	IBM	0.8183	0.7699
15	NESTOR	0.8141	0.7681
16	VOTE_P	0.8133	0.7827
17	HUGHES_1	0.8108	0.7648
18	HUGHES_2	0.8070	0.7622
19	GTESS_1	0.7972	0.7496
20	NIST_4	0.7960	0.7376
21	GTESS_2	0.7918	0.7431
22	RISO	0.7869	0.7289
23	NIST_1	0.7857	0.7390
24	GMD_3	0.7738	0.7260
25	ASOL	0.7628	0.7193
26	GMD_4	0.7574	0.7100
27	GMD_1	0.7574	0.7100
28	NIST_3	0.7382	0.7129
29	GMD_2	0.7100	0.6637
30	VALEN_1	0.6861	0.6359
31	KAMAN_1	0.6822	0.6355
32	NIST_2	0.6756	0.6342
33	KAMAN_3	0.6597	0.6146
34	KAMAN_2	0.6442	0.6013
35	KAMAN_5	0.5709	0.5332
36	KAMAN_4	0.5381	0.5007
37	COMCOM	0.4940	0.4818
38	UMICH_2	0.0852	0.0456

Table 25: ATT_3 correlation graph key for lowers.

SYSTEM: ATT_4

PARTICIPANT: Dr. Craig R. Nohl

ORGANIZATION: AT&T Bell Laboratories, Holmdel,NJ

FEATURES: raw?

CLASSIFICATION: vote of three ? layer NNs with local receptive fields and replicated weights

HARDWARE: SPARC2

TRAINING:

DIGITS	UPPERS	LOWERS	DATABASE
210000	40000	40000	NSDB3
10000	0	0	USPS

STATUS: on time

RESULTS:

-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
0.00	0.0410	0.00	0.0500	0.00	0.1428	
0.10	0.0098	0.10	0.0138	0.10	0.0968	
0.20	0.0034	0.20	0.0059	0.20	0.0596	
0.30	0.0014	0.30	0.0037	0.30	0.0334	
0.40	0.0008	0.40	0.0015	0.40	0.0193	
0.50	0.0003	0.50	0.0008	0.50	0.0113	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	1.15	1.03	1.50
CPU RATE:			

SYSTEM: ATT_4

BIBLIOGRAPHY:

The following references have been provided for this system:

[5][6][7][8]

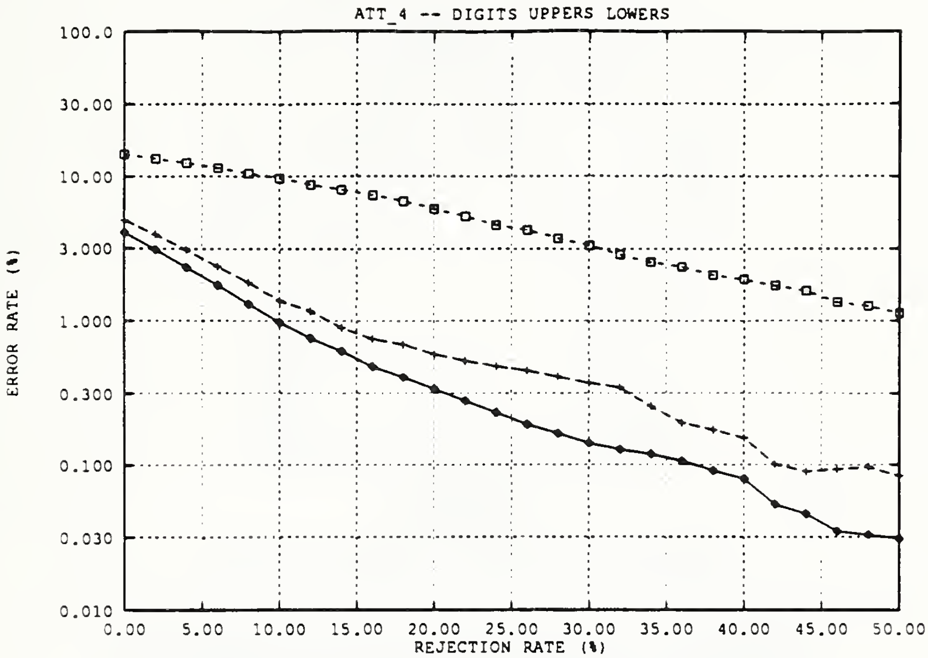

Figure 36: Error rate versus rejection rate for ATT_4

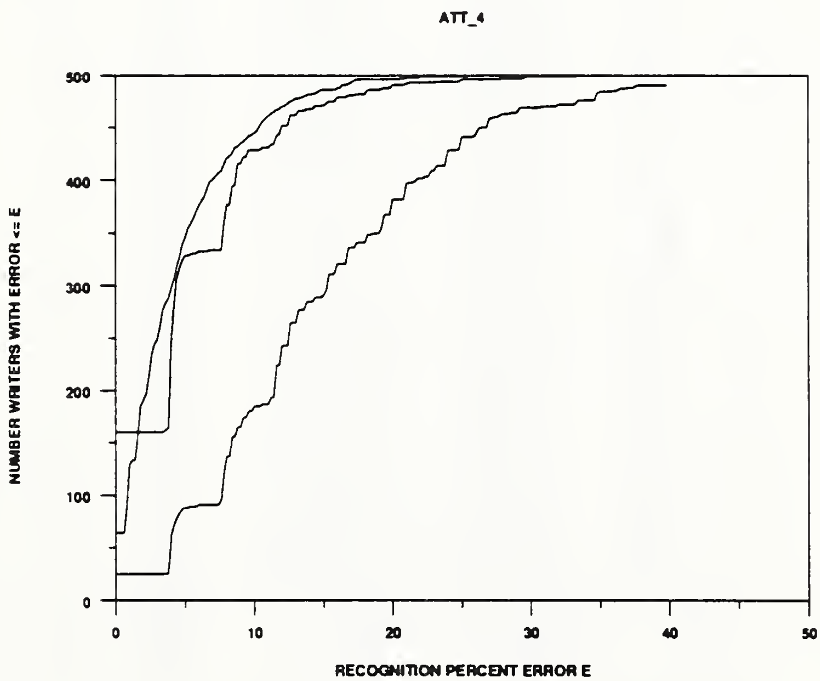

Figure 37: Error rate per writer of ATT_4

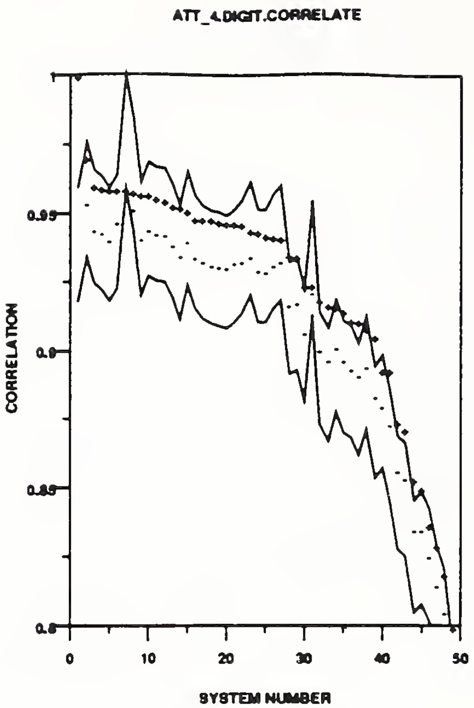

Figure 38: ATT_4 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	ATT_4	1.0000	1.0000
2	VOTE_M	0.9705	0.9541
3	AEG	0.9605	0.9446
4	ATT_2	0.9595	0.9436
5	VOTE_P	0.9591	0.9473
6	KODAK_2	0.9591	0.9410
7	REFERENCE	0.9590	0.9590
8	OCRSYS	0.9585	0.9520
9	ERIM_1	0.9574	0.9415
10	ATT_1	0.9573	0.9445
11	ELSAGB_3	0.9558	0.9432
12	ELSAGB_2	0.9552	0.9428
13	ERIM_2	0.9531	0.9391
14	KODAK_1	0.9526	0.9351
15	IBM	0.9514	0.9404
16	UBOL	0.9488	0.9348
17	SYMBUS	0.9486	0.9333
18	THINK_1	0.9485	0.9322
19	NIST_4	0.9479	0.9315
20	ELSAGB_1	0.9474	0.9311
21	ATT_3	0.9473	0.9329
22	NESTOR	0.9466	0.9334
23	THINK_2	0.9443	0.9351
24	HUGHES_1	0.9439	0.9305
25	HUGHES_2	0.9429	0.9299
26	NYNEX	0.9422	0.9321
27	REI	0.9417	0.9335
28	GTESS_2	0.9356	0.9175
29	GTESS_1	0.9355	0.9181
30	COMCOM	0.9247	0.9219
31	NIST_1	0.9247	0.9072
32	MIME	0.9193	0.9007
33	NIST_2	0.9172	0.8973
34	GMD_3	0.9170	0.9016
35	ASOL	0.9153	0.8974
36	UPENN	0.9120	0.8942
37	NIST_3	0.9114	0.8915
38	GMD_1	0.9090	0.8949
39	RISO	0.9060	0.8838
40	GMD_4	0.8935	0.8801
41	KAMAN_1	0.8934	0.8739
42	KAMAN_3	0.8746	0.8566
43	KAMAN_2	0.8721	0.8542
44	GMD_2	0.8535	0.8353
45	KAMAN_5	0.8503	0.8352
46	VALEN_2	0.8370	0.8257
47	IFAX	0.8297	0.8152
48	VALEN_1	0.8191	0.8052
49	KAMAN_4	0.8000	0.7826

Table 26: ATT_4 correlation graph key for digits.

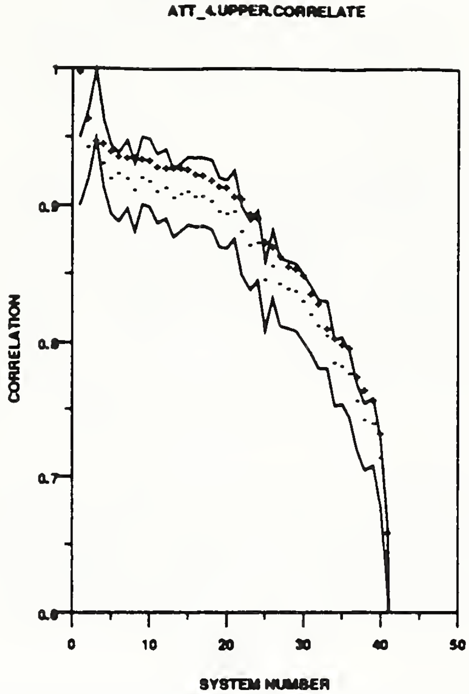

Figure 39: ATT_4 - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	ATT_4	1.0000	1.0000
2	VOTE_M	0.9663	0.9451
3	REFERENCE	0.9500	0.9500
4	AEG	0.9475	0.9330
5	ATT_2	0.9422	0.9223
6	VOTE_P	0.9385	0.9258
7	ERIM_1	0.9379	0.9219
8	KODAK_1	0.9374	0.9140
9	NYNEX	0.9371	0.9227
10	UMICH_1	0.9361	0.9206
11	UBOL	0.9313	0.9132
12	NESTOR	0.9308	0.9155
13	SYMBUS	0.9306	0.9081
14	ATT_3	0.9300	0.9111
15	IBM	0.9298	0.9127
16	ATT_1	0.9258	0.9094
17	HUGHES_1	0.9245	0.9088
18	HUGHES_2	0.9216	0.9060
19	GTESS_1	0.9168	0.8981
20	GTESS_2	0.9157	0.8967
21	OCRSYS	0.9091	0.8983
22	MIME	0.9077	0.8838
23	ASOL	0.8967	0.8734
24	NIST_4	0.8937	0.8755
25	RISO	0.8760	0.8488
26	REI	0.8726	0.8589
27	NIST_1	0.8664	0.8460
28	GMD_1	0.8587	0.8421
29	GMD_3	0.8570	0.8401
30	KAMAN_1	0.8523	0.8333
31	GMD_4	0.8386	0.8230
32	NIST_3	0.8307	0.8148
33	COMCOM	0.8132	0.8075
34	KAMAN_3	0.8053	0.7875
35	IFAX	0.8004	0.7846
36	KAMAN_2	0.7977	0.7789
37	NIST_2	0.7770	0.7586
38	GMD_2	0.7671	0.7452
39	VALEN_1	0.7596	0.7416
40	KAMAN_4	0.7351	0.7162
41	KAMAN_5	0.6616	0.6469
42	UMICH_2	0.0384	0.0218

Table 27: ATT_4 correlation graph key for uppers.

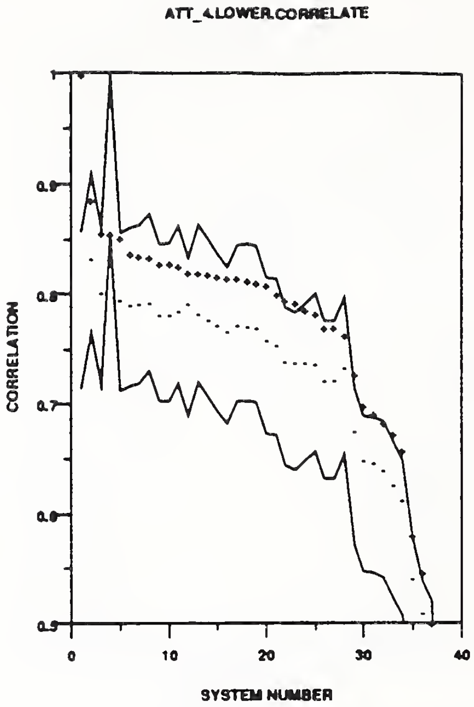

Figure 40: ATT_4 - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	ATT_4	1.0000	1.0000
2	VOTE_M	0.8873	0.8351
3	ATT_2	0.8580	0.8033
4	REFERENCE	0.8572	0.8572
5	KODAK_1	0.8529	0.7972
6	NYNEX	0.8395	0.7928
7	ERIM_1	0.8374	0.7934
8	AEG	0.8362	0.7946
9	IBM	0.8303	0.7828
10	NESTOR	0.8301	0.7837
11	ATT_1	0.8275	0.7864
12	VOTE_P	0.8223	0.7939
13	OCRSYS	0.8219	0.7849
14	UMICH_1	0.8210	0.7791
15	ATT_3	0.8192	0.7745
16	GTESS_1	0.8176	0.7678
17	UBOL	0.8173	0.7740
18	HUGHES_1	0.8153	0.7734
19	HUGHES_2	0.8130	0.7718
20	GTESS_2	0.8112	0.7605
21	NIST_1	0.8030	0.7559
22	ASOL	0.7969	0.7408
23	RISO	0.7947	0.7391
24	GMD_3	0.7878	0.7390
25	NIST_4	0.7847	0.7387
26	GMD_4	0.7718	0.7232
27	GMD_1	0.7718	0.7232
28	NIST_3	0.7650	0.7349
29	GMD_2	0.7287	0.6779
30	KAMAN_1	0.7004	0.6510
31	NIST_2	0.6933	0.6484
32	VALEN_1	0.6851	0.6419
33	KAMAN_3	0.6750	0.6283
34	KAMAN_2	0.6608	0.6148
35	KAMAN_5	0.5823	0.5420
36	KAMAN_4	0.5477	0.5107
37	COMCOM	0.5023	0.4896
38	UMICH_2	0.1065	0.0583

Table 28: ATT_4 correlation graph key for lowers.

SYSTEM: COMCOM

PARTICIPANTS: Mr. Eberhard Kuehl, Perry Riggs

ORGANIZATION: Com Com Systems, Inc., Clearwater, FL

PREPROCESSING: thinning.

FEATURES: ?

CLASSIFICATION: proprietary: not NN, not pixel comparison, nor vector analysis. Positional information and features matched against database of "tables".

HARDWARE: 386

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	---- Number used is proprietary ----			NSDB3
	---- Number used is proprietary ----			INTERNAL

STATUS: on time, 0's and 1's interchanged in RJX files

RESULTS:	-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
	0.00	0.0456	0.00	0.1694	0.00	0.4800	
	0.03	0.0186	0.15	0.0242	0.45	0.0590	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	12.68	11.71	9.09
CPU RATE:			

NOTE: Internal database contains 110000 hand printed digits, 220000 upper case letters, and at least 60000 mixed uppers and lowers.

SYSTEM: COMCOM

The following references have been provided for this system:

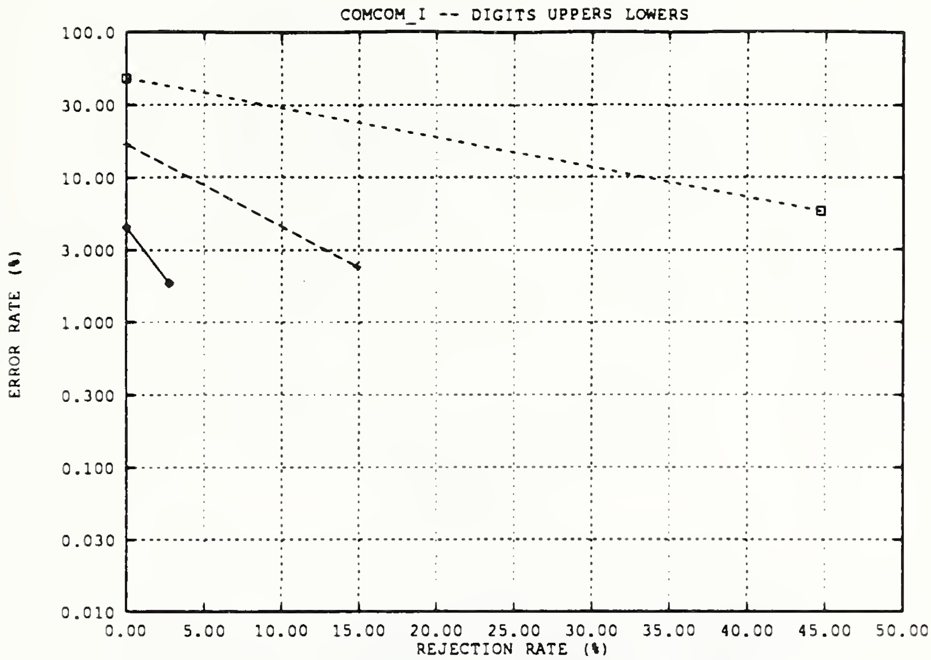

Figure 41: Error rate versus rejection rate for COMCOM

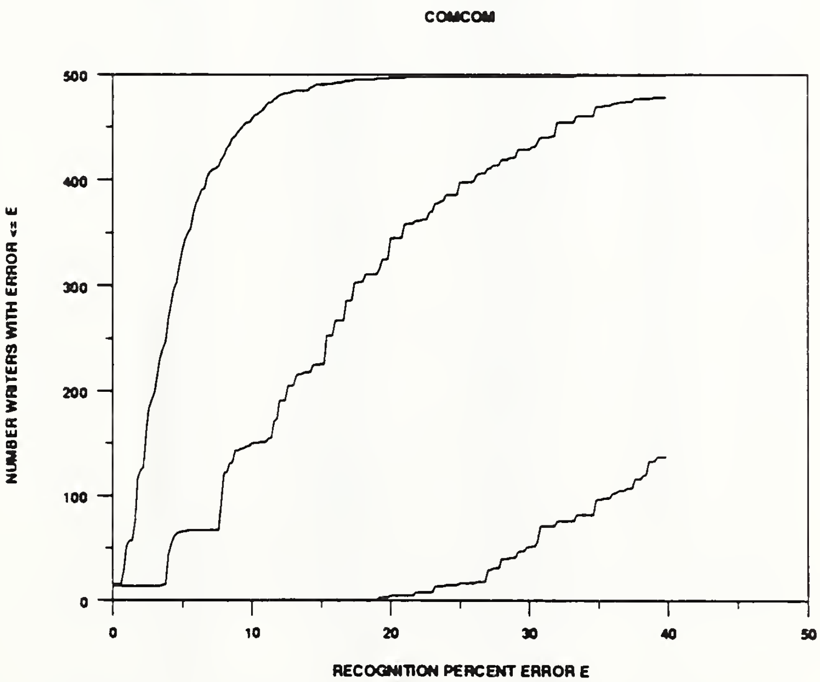

Figure 42: Error rate per writer of COMCOM

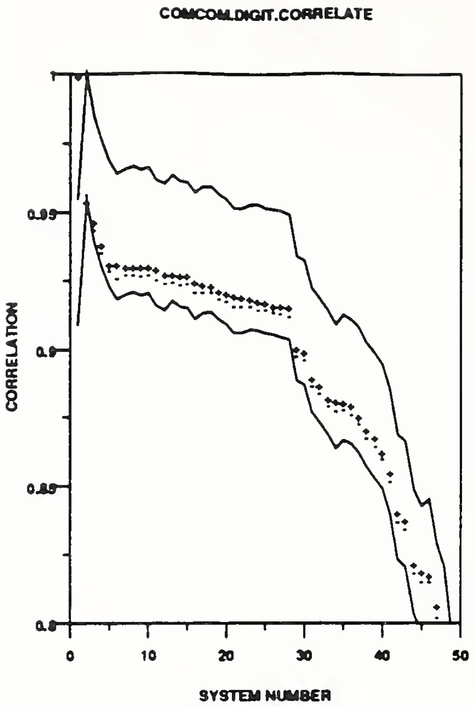

Figure 43: COMCOM - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	COMCOM	1.0000	1.0000
2	REFERENCE	0.9544	0.9544
3	OCRSYS	0.9471	0.9445
4	VOTE_M	0.9390	0.9364
5	ATT_1	0.9323	0.9298
6	VOTE_P	0.9321	0.9271
7	AEG	0.9314	0.9286
8	ELSAGB_3	0.9313	0.9286
9	ELSAGB_2	0.9311	0.9284
10	IBM	0.9311	0.9280
11	THINK_2	0.9302	0.9264
12	ATT_2	0.9285	0.9258
13	REI	0.9285	0.9251
14	ERIM_1	0.9279	0.9249
15	ERIM_2	0.9278	0.9250
16	NYNEX	0.9255	0.9219
17	ATT_4	0.9247	0.9219
18	KODAK_2	0.9244	0.9218
19	UBOL	0.9224	0.9198
20	NESTOR	0.9215	0.9186
21	HUGHES_1	0.9206	0.9170
22	HUGHES_2	0.9203	0.9168
23	SYMBUS	0.9197	0.9169
24	KODAK_1	0.9186	0.9158
25	ATT_3	0.9181	0.9155
26	THINK_1	0.9171	0.9145
27	NIST_4	0.9170	0.9141
28	ELSAGB_1	0.9163	0.9133
29	GTESS_1	0.9013	0.8986
30	GTESS_2	0.9000	0.8972
31	NIST_1	0.8903	0.8875
32	GMD_3	0.8875	0.8847
33	MIME	0.8831	0.8800
34	UPENN	0.8819	0.8782
35	GMD_1	0.8818	0.8789
36	ASOL	0.8802	0.8772
37	NIST_2	0.8762	0.8739
38	NIST_3	0.8713	0.8689
39	GMD_4	0.8686	0.8657
40	RISO	0.8633	0.8607
41	KAMAN_1	0.8557	0.8527
42	KAMAN_3	0.8410	0.8378
43	KAMAN_2	0.8386	0.8353
44	KAMAN_5	0.8223	0.8189
45	VALEN_2	0.8196	0.8159
46	GMD_2	0.8183	0.8159
47	IFAX	0.8072	0.8032
48	VALEN_1	0.7946	0.7914
49	KAMAN_4	0.7676	0.7646

Table 29: COMCOM correlation graph key for digits.

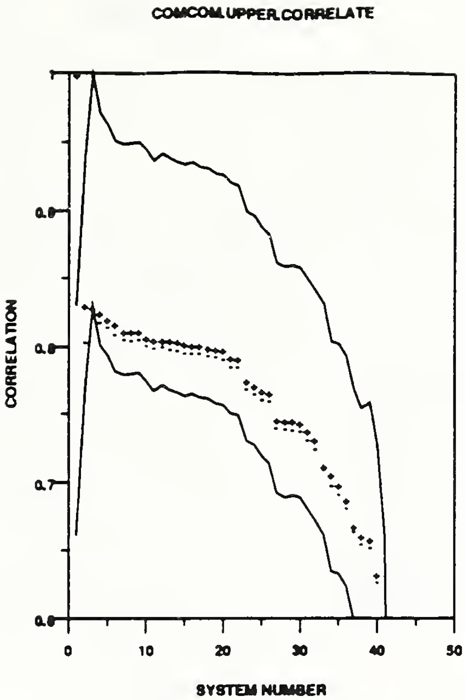

Figure 44: COMCOM - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	COMCOM	1.0000	1.0000
2	VOTE_P	0.8324	0.8052
3	REFERENCE	0.8306	0.8306
4	VOTE_M	0.8261	0.8205
5	AEG	0.8222	0.8168
6	NYNEX	0.8180	0.8113
7	ATT_4	0.8132	0.8075
8	ERIM_1	0.8132	0.8071
9	UMICH_1	0.8132	0.8066
10	ATT_2	0.8084	0.8024
11	NESTOR	0.8065	0.8014
12	IBM	0.8065	0.8004
13	UBOL	0.8060	0.7999
14	HUGHES_1	0.8053	0.7986
15	HUGHES_2	0.8040	0.7971
16	ATT_1	0.8031	0.7968
17	ATT_3	0.8029	0.7973
18	KODAK_1	0.8007	0.7949
19	SYMBUS	0.7995	0.7941
20	OCRSYS	0.7987	0.7927
21	GTESS_1	0.7931	0.7875
22	GTESS_2	0.7930	0.7870
23	MIME	0.7764	0.7709
24	NIST_4	0.7728	0.7669
25	ASOL	0.7684	0.7623
26	REI	0.7668	0.7612
27	NIST_1	0.7474	0.7421
28	RISO	0.7469	0.7409
29	GMD_1	0.7462	0.7402
30	GMD_3	0.7452	0.7391
31	KAMAN_1	0.7391	0.7327
32	GMD_4	0.7324	0.7261
33	NIST_3	0.7133	0.7119
34	IFAX	0.7068	0.6995
35	KAMAN_3	0.6997	0.6937
36	KAMAN_2	0.6890	0.6833
37	NIST_2	0.6697	0.6660
38	GMD_2	0.6618	0.6569
39	VALEN_1	0.6598	0.6540
40	KAMAN_4	0.6335	0.6282
41	KAMAN_5	0.5768	0.5718
42	UMICH_2	0.0274	0.0175

Table 30: COMCOM correlation graph key for uppers.

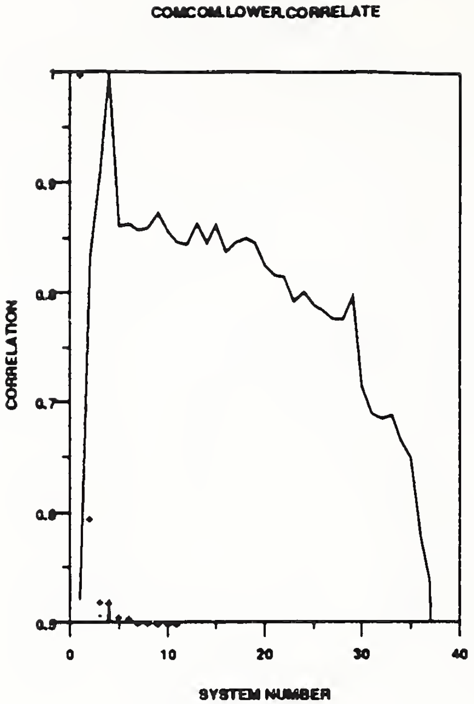

Figure 45: COMCOM - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	COMCOM	1.0000	1.0000
2	VOTE_P	0.5966	0.4902
3	VOTE_M	0.5209	0.5082
4	REFERENCE	0.5200	0.5200
5	NYNEX	0.5074	0.4937
6	ERIM_1	0.5061	0.4923
7	ATT_4	0.5023	0.4896
8	ATT_2	0.5013	0.4896
9	AEG	0.5011	0.4882
10	KODAK_1	0.5007	0.4876
11	HUGHES_1	0.5004	0.4886
12	HUGHES_2	0.4993	0.4872
13	OCRSYS	0.4980	0.4882
14	IBM	0.4965	0.4856
15	ATT_1	0.4951	0.4848
16	ATT_3	0.4940	0.4818
17	NESTOR	0.4933	0.4822
18	UMICH_1	0.4923	0.4823
19	UBOL	0.4919	0.4798
20	GTESS_1	0.4873	0.4757
21	GTESS_2	0.4830	0.4712
22	NIST_1	0.4782	0.4678
23	GMD_3	0.4712	0.4594
24	NIST_4	0.4688	0.4564
25	ASOL	0.4651	0.4545
26	RISO	0.4627	0.4540
27	GMD_4	0.4622	0.4513
28	GMD_1	0.4622	0.4513
29	NIST_3	0.4555	0.4523
30	GMD_2	0.4342	0.4247
31	KAMAN_1	0.4218	0.4098
32	VALEN_1	0.4204	0.4100
33	NIST_2	0.4168	0.4075
34	KAMAN_3	0.4097	0.3981
35	KAMAN_2	0.3975	0.3869
36	KAMAN_5	0.3582	0.3483
37	KAMAN_4	0.3302	0.3223
38	UMICH_2	0.0438	0.0306

Table 31: COMCOM correlation graph key for lowers.

SYSTEM: ELSAGB_1

PARTICIPANT: Mr. Francesco Fignoni

ORGANIZATION: ELSAG BAILEY, INC., Conshohocken, PA

PREPROCESSING: noise removal and size normalization to 24x36.

FEATURES: shape function of the character bit maps having the same size as the character.

CLASSIFICATION: KNN with respect to shape function distance from references representing clusters of shape functions in training sample

HARDWARE: 33 MHz 386 running tight assembly code

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	85491	NA	NA	NSDB3

STATUS: on time

RESULTS:	-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
	0.00	0.0507					
	0.08	0.0179					
	0.12	0.0114					

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:			
CPU RATE:	65.00	NA	NA

NOTE: This is the system used in their postal OCR. Few details of the recognition algorithm were provided.

SYSTEM: ELSAGB_1

BIBLIOGRAPHY:

The following references have been provided for this system:

none

COMMENTS: ELSAG BAILEY

SPECIFIC ABOUT ELSAG BAILEY

- AFTER receiving the TESTDATA1 CD ROM, that is the test set, Elsag Bailey neither modified in any part or tuned in any way the recognition units and associated data-bases produced from training for the tests ELSAGB_1, ELSAGB_2, and ELSAGB_3.

Elsag Bailey is aware of the fact that given the poor relationship between training and test sets, these countermeasures could prove useful.

- ELSAG_1 had some troubles dealing with the thickness range of characters: about 4% the training digits have an average thickness of less than 2 or more than 9 pixels.

GENERAL ABOUT THE CONFERENCE

- Elsag Bailey appreciated the way the test and Conference were set up by NIST. It was something between an acceptance test and a scientific conference and proved itself both useful and interesting.

- The test set for digits was both very difficult and very "far" from the training set; this fact produced rather conservative recognition results.

One reason is the fact that the training set did not contain examples of the difficult test characters. If it had, performance would have been higher. The other reason is that the test characters are poor in quality, probably representing the low end in a real environment.

While these points do not weaken the relative comparisons among the participants, nevertheless, they compromise the absolute meaning of the recognition performance.

- A good estimate of segmentation performance, that is, the next important part of the whole OCR process, is an open question.

In fact, the scoring procedure should be independent from the recognition unit and automatic. Otherwise, the two procedures are mixed together.

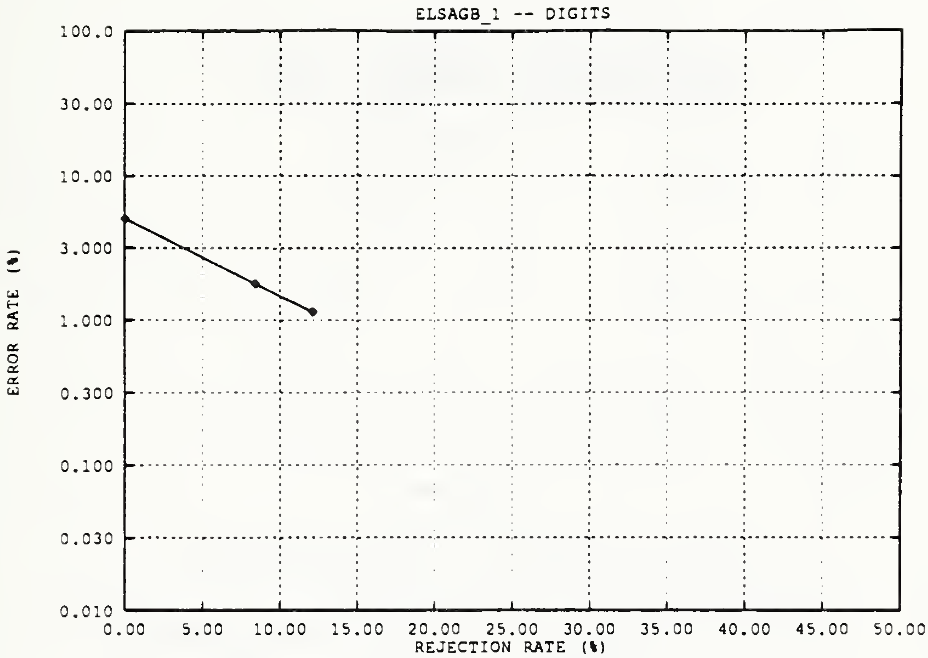

Figure 46: Error rate versus rejection rate for ELSAGB_1

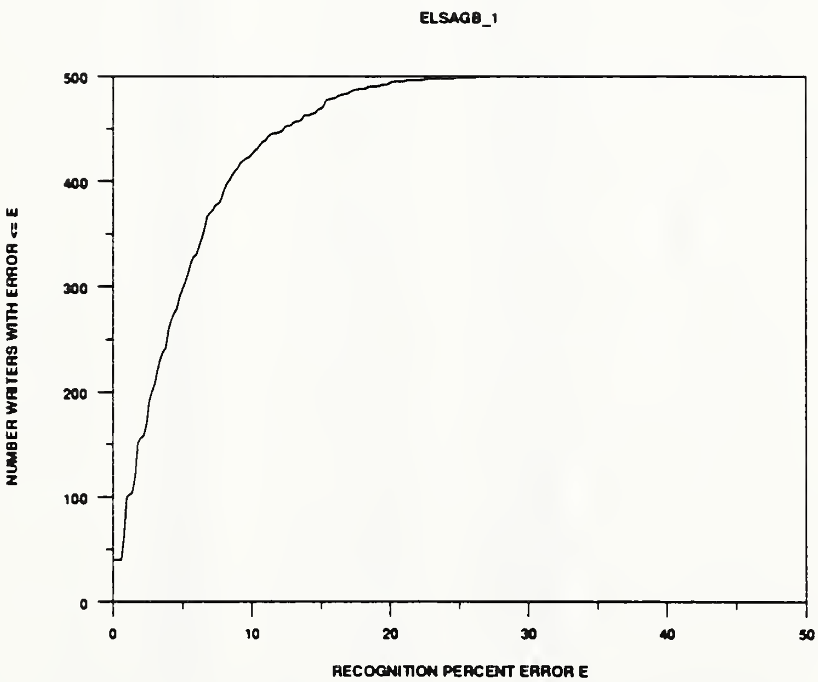

Figure 47: Error rate per writer of ELSAGB_1

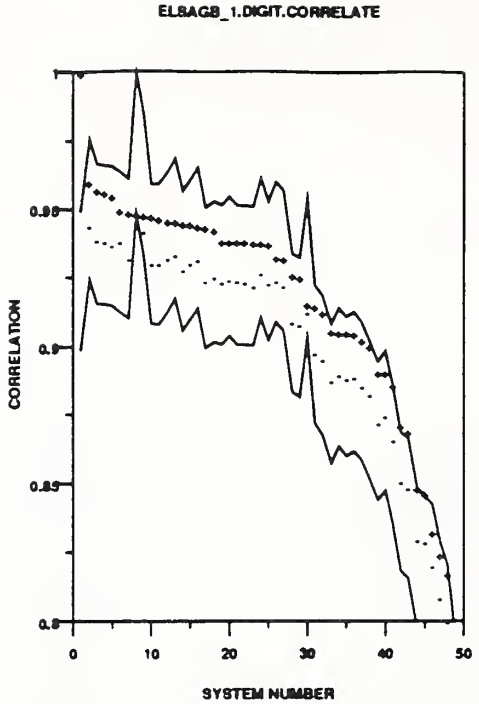

Figure 48: ELSAGB_1 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	ELSAGB_1	1.0000	1.0000
2	VOTE_M	0.9606	0.9444
3	ELSAGB_3	0.9578	0.9393
4	ELSAGB_2	0.9570	0.9388
5	AEG	0.9555	0.9378
6	VOTE_P	0.9506	0.9390
7	ERIM_1	0.9495	0.9331
8	REFERENCE	0.9493	0.9493
9	OCRSYS	0.9485	0.9425
10	KODAK_2	0.9480	0.9313
11	ATT_4	0.9474	0.9311
12	ATT_2	0.9463	0.9328
13	ATT_1	0.9462	0.9345
14	UBOL	0.9455	0.9287
15	ERIM_2	0.9454	0.9312
16	IBM	0.9447	0.9325
17	NIST_4	0.9439	0.9249
18	KODAK_1	0.9431	0.9260
19	NESTOR	0.9392	0.9254
20	HUGHES_1	0.9392	0.9243
21	ATT_3	0.9391	0.9247
22	HUGHES_2	0.9389	0.9241
23	THINK_1	0.9386	0.9228
24	THINK_2	0.9384	0.9277
25	SYMBUS	0.9379	0.9240
26	REI	0.9334	0.9249
27	NYNEX	0.9329	0.9228
28	GTESS_1	0.9270	0.9097
29	GTESS_2	0.9263	0.9087
30	COMCOM	0.9163	0.9133
31	NIST_1	0.9155	0.8981
32	GMD_3	0.9133	0.8958
33	NIST_2	0.9065	0.8881
34	MIME	0.9059	0.8902
35	ASOL	0.9057	0.8890
36	GMD_1	0.9056	0.8894
37	UPENN	0.9033	0.8861
38	NIST_3	0.9010	0.8830
39	RISO	0.8912	0.8730
40	GMD_4	0.8910	0.8751
41	KAMAN_1	0.8865	0.8666
42	KAMAN_3	0.8720	0.8513
43	KAMAN_2	0.8695	0.8490
44	KAMAN_5	0.8491	0.8303
45	GMD_2	0.8470	0.8291
46	VALEN_2	0.8327	0.8203
47	IFAX	0.8247	0.8092
48	VALEN_1	0.8178	0.8003
49	KAMAN_4	0.7964	0.7775

Table 32: ELSAGB_1 correlation graph key for digits.

No Data Available

Figure 49: ELSAGB_1 - upper case correlation

There was no data for this evaluation.

Table 33: ELSAGB_1 correlation graph key for uppers.

No Data Available

Figure 50: ELSAGB_1 - lower case correlation

There was no data for this evaluation.

Table 34: ELSAGB_1 correlation graph key for lowers.

SYSTEM: ELSAGB_2

PARTICIPANT: Mr. Francesco Fignoni

ORGANIZATION: ELSAG BAILEY, INC., Conshohocken, PA

PREPROCESSING: noise removal and size normalization to 24x36.

FEATURES: shape function of the character bit maps having the same size as the character.

CLASSIFICATION: KNN with respect to shape function distance from references representing clusters of shape functions in training sample (the classifier used with ELSAGB_1) for preclassification followed by the same classifier using a more sophisticated distance measure and many more references

HARDWARE: 33 MHz 386 running tight assembly for preclassification
VAX 6000/410 under VMS running FORTRAN for classification

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	85491	NA	NA	NSDB3

STATUS: on time

RESULTS:	-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
	0.00	0.0338					
	0.05	0.0135					
	0.08	0.0097					
	0.10	0.0077					
	0.11	0.0068					

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:			
CPU RATE:	0.30	NA	NA

NOTE: This is a laboratory research system. Few details of the recognition algorithm were provided.

SYSTEM: ELSAGB_2

BIBLIOGRAPHY:

The following references have been provided for this system:

none

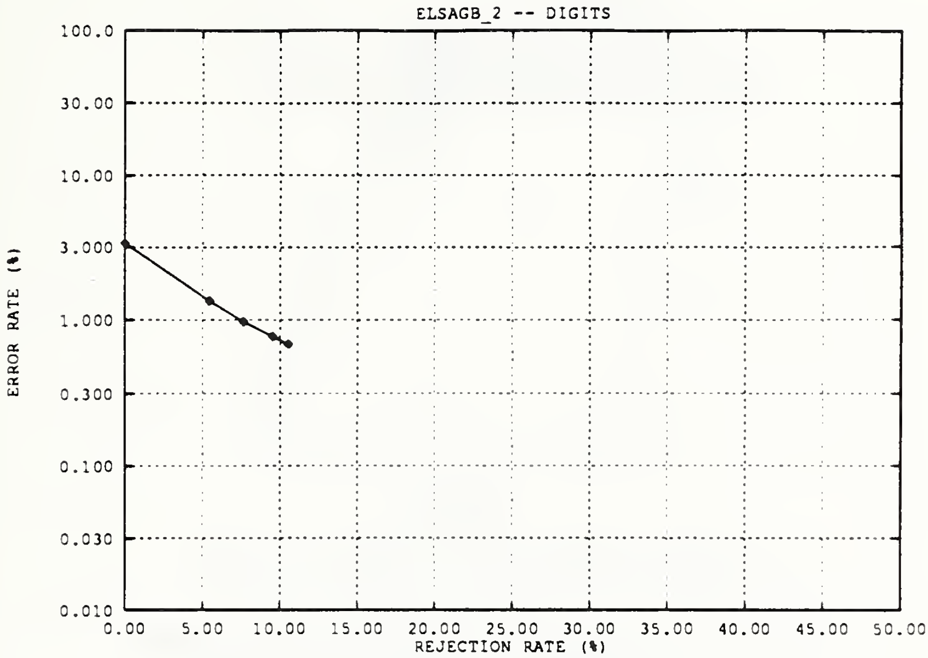

Figure 51: Error rate versus rejection rate for ELSAGB_2

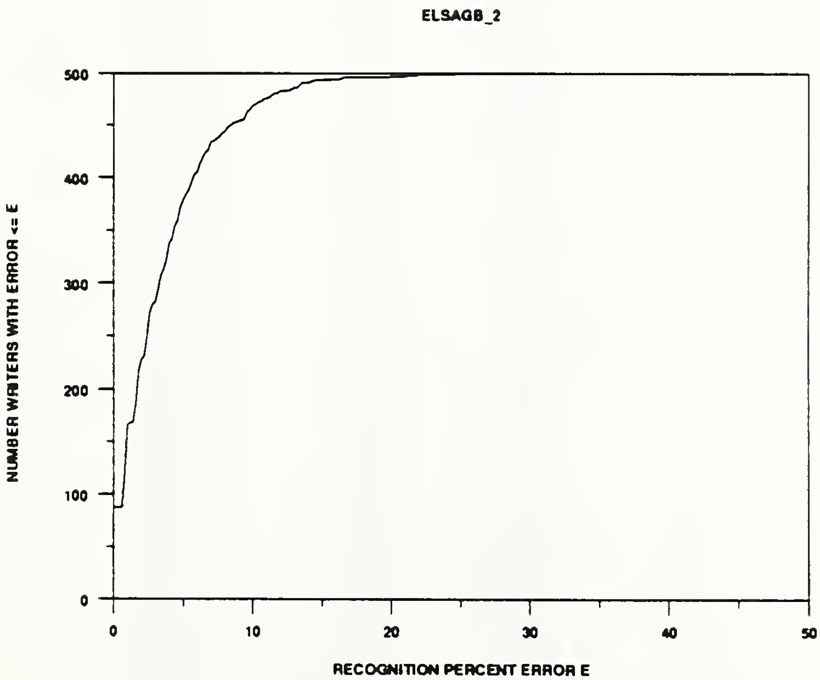

Figure 52: Error rate per writer of ELSAGB_2

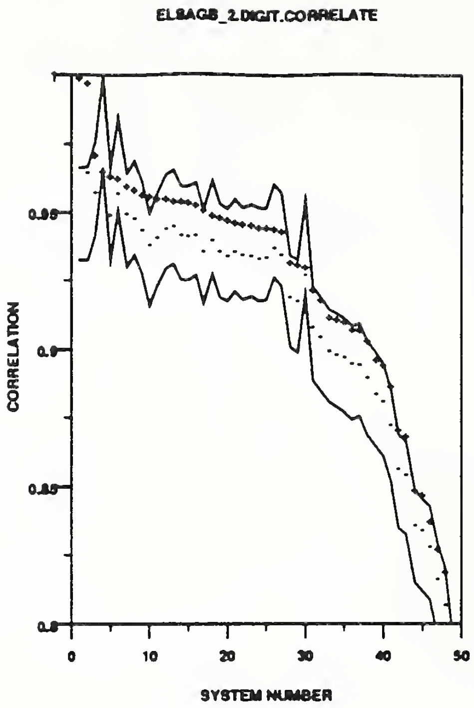

Figure 53: ELSAGB_2 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	ELSAGB_2	1.0000	1.0000
2	ELSAGB_3	0.9983	0.9655
3	VOTE_M	0.9721	0.9583
4	REFERENCE	0.9662	0.9662
5	AEG	0.9642	0.9499
6	OCRSYS	0.9632	0.9579
7	VOTE_P	0.9606	0.9506
8	ATT_1	0.9591	0.9488
9	ERIM_1	0.9572	0.9447
10	ELSAGB_1	0.9570	0.9388
11	UBOL	0.9561	0.9416
12	ATT_2	0.9558	0.9450
13	IBM	0.9553	0.9457
14	ATT_4	0.9552	0.9428
15	KODAK_2	0.9545	0.9423
16	ERIM_2	0.9535	0.9428
17	NIST_4	0.9517	0.9365
18	THINK_2	0.9499	0.9410
19	KODAK_1	0.9492	0.9368
20	THINK_1	0.9482	0.9352
21	NESTOR	0.9471	0.9368
22	ATT_3	0.9468	0.9358
23	SYMBUS	0.9462	0.9352
24	HUGHES_2	0.9454	0.9345
25	HUGHES_1	0.9453	0.9347
26	REI	0.9451	0.9383
27	NYNEX	0.9440	0.9360
28	GTESS_1	0.9328	0.9200
29	GTESS_2	0.9319	0.9186
30	COMCOM	0.9311	0.9284
31	NIST_1	0.9230	0.9090
32	GMD_3	0.9194	0.9055
33	MIME	0.9128	0.9006
34	GMD_1	0.9118	0.8990
35	ASOL	0.9112	0.8983
36	NIST_2	0.9083	0.8958
37	UPENN	0.9080	0.8953
38	NIST_3	0.9040	0.8909
39	GMD_4	0.8970	0.8846
40	RISO	0.8955	0.8820
41	KAMAN_1	0.8876	0.8739
42	KAMAN_3	0.8720	0.8579
43	KAMAN_2	0.8696	0.8554
44	KAMAN_5	0.8499	0.8369
45	GMD_2	0.8479	0.8354
46	VALEN_2	0.8384	0.8293
47	IFAX	0.8281	0.8172
48	VALEN_1	0.8201	0.8079
49	KAMAN_4	0.7965	0.7831

Table 35: ELSAGB_2 correlation graph key for digits.

No Data Available

Figure 54: ELSAGB_2 - upper case correlation

There was no data for this evaluation.

Table 36: ELSAGB_2 correlation graph key for uppers.

No Data Available

Figure 55: ELSAGB_2 - lower case correlation

There was no data for this evaluation

Table 37: ELSAGB_2 correlation graph key for lowers.

SYSTEM: ELSAGB_3

PARTICIPANT: Mr. Francesco Fignoni

ORGANIZATION: ELSAG BAILEY, INC., Conshohocken, PA

PREPROCESSING: noise removal and size normalization to 24x36.

FEATURES: shape function of the character bit maps having the same size as the character.

CLASSIFICATION: KNN with respect to shape function distance from references representing clusters of shape functions in training sample (the classifier used with ELSAGB_1) for preclassification followed by the same classifier using a more sophisticated distance measure and many more references

HARDWARE: 33 MHz 386 running tight assembly for preclassification
VAX 6000/410 under VMS running FORTRAN for classification

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	85491	NA	NA	NSDB3

STATUS: on time, lost at NIST until after Conference

RESULTS:	-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
	0.00	0.0335					
	0.04	0.0180					
	0.07	0.0102					

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:			
CPU RATE:	0.30	NA	NA

NOTE: This is a laboratory research system. Few details of the recognition algorithm were provided.

SYSTEM: ELSAGB_3

BIBLIOGRAPHY:

The following references have been provided for this system:

none

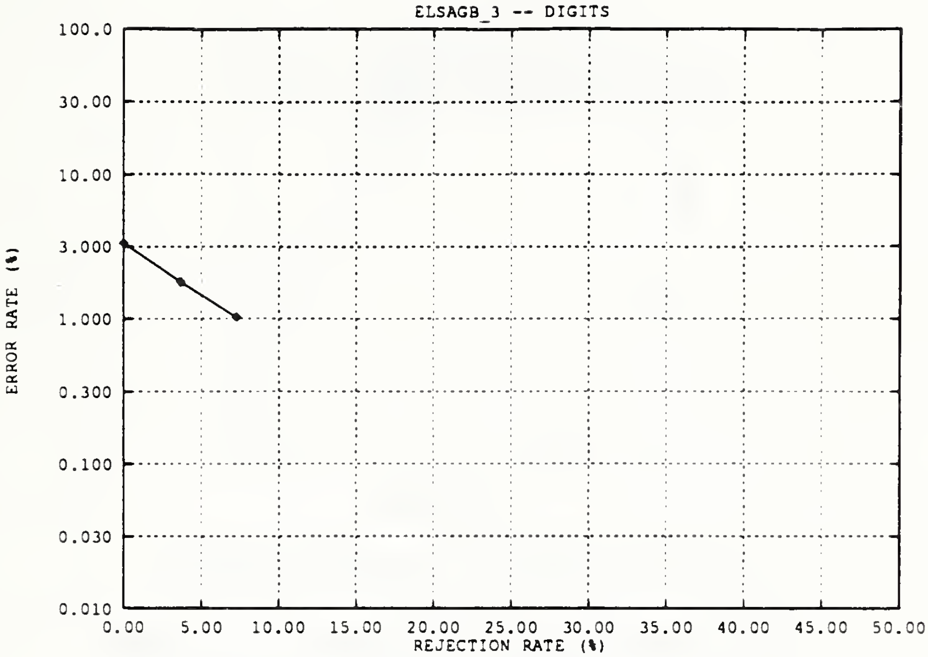

Figure 56: Error rate versus rejection rate for ELSAGB_3

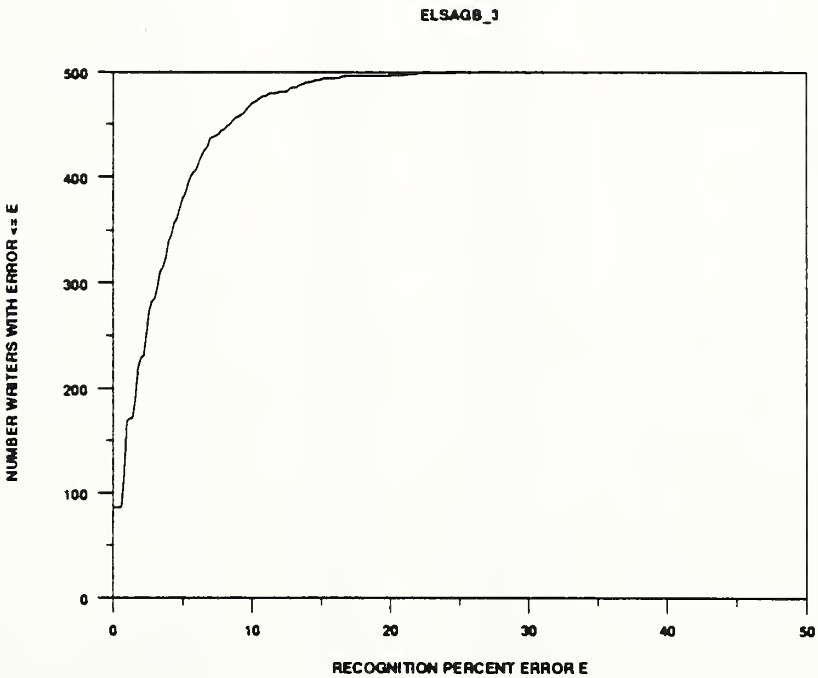

Figure 57: Error rate per writer of ELSAGB_3

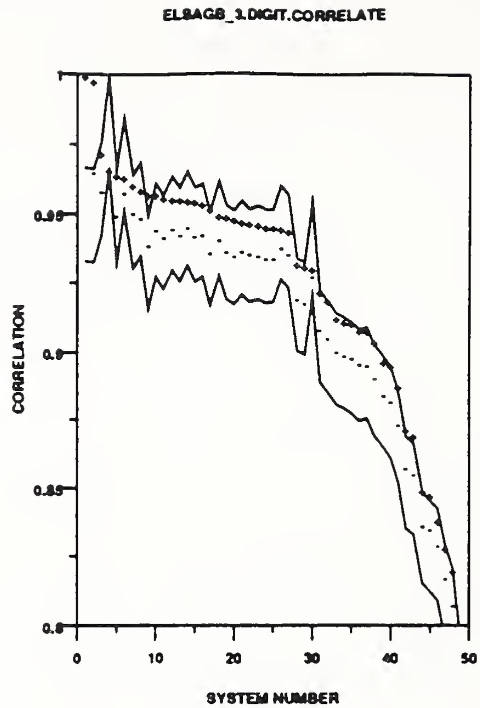

Figure 58: ELSAGB_3 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	ELSAGB_3	1.0000	1.0000
2	ELSAGB_2	0.9983	0.9655
3	VOTE_M	0.9726	0.9587
4	REFERENCE	0.9665	0.9665
5	AEG	0.9645	0.9502
6	OCRSYS	0.9636	0.9583
7	VOTE_P	0.9611	0.9510
8	ATT_1	0.9594	0.9491
9	ERIM_1	0.9578	0.9451
10	ELSAGB_1	0.9578	0.9393
11	UBOL	0.9566	0.9420
12	ATT_2	0.9562	0.9454
13	ATT_4	0.9558	0.9432
14	IBM	0.9556	0.9460
15	KODAK_2	0.9550	0.9427
16	ERIM_2	0.9543	0.9433
17	NIST_4	0.9522	0.9369
18	THINK_2	0.9502	0.9413
19	KODAK_1	0.9497	0.9371
20	THINK_1	0.9486	0.9356
21	NESTOR	0.9477	0.9373
22	ATT_3	0.9472	0.9362
23	SYMBUS	0.9467	0.9356
24	HUGHES_2	0.9459	0.9349
25	HUGHES_1	0.9457	0.9350
26	REI	0.9455	0.9387
27	NYNEX	0.9443	0.9363
28	GTESS_1	0.9330	0.9203
29	GTESS_2	0.9322	0.9189
30	COMCOM	0.9313	0.9286
31	NIST_1	0.9231	0.9092
32	GMD_3	0.9198	0.9059
33	MIME	0.9132	0.9010
34	GMD_1	0.9120	0.8993
35	ASOL	0.9114	0.8985
36	NIST_2	0.9087	0.8962
37	UPENN	0.9086	0.8958
38	NIST_3	0.9044	0.8913
39	GMD_4	0.8972	0.8849
40	RISO	0.8958	0.8823
41	KAMAN_1	0.8879	0.8742
42	KAMAN_3	0.8723	0.8582
43	KAMAN_2	0.8699	0.8557
44	KAMAN_5	0.8501	0.8371
45	GMD_2	0.8482	0.8356
46	VALEN_2	0.8387	0.8296
47	IFAX	0.8287	0.8177
48	VALEN_1	0.8204	0.8082
49	KAMAN_4	0.7968	0.7834

Table 38: ELSAGB_3 correlation graph key for digits.

No Data Available

Figure 59: ELSAGB_3 - upper case correlation

There was no data for this evaluation.

Table 39: ELSAGB_3 correlation graph key for uppers.

No Data Available

Figure 60: ELSAGB_3 - lower case correlation

There was no data for this evaluation.

Table 40: ELSAGB_3 correlation graph key for lowers.

SYSTEM: ERIM_1

PARTICIPANT: Steven Schlosser

ORGANIZATION: Environmental Research Institute of Michigan (ERIM)
Ann Arbor, Michigan

PREPROCESSING: filtering and size normalization

FEATURES: stroke detection, morphological feature extraction.

CLASSIFICATION: four layer NN with BP. For digits, 245 input units, and two hidden layers with 25 and 15 hidden units, 10 output units. For characters, 120 input units, and two hidden layers with 65 and 39 hidden units, 26 output units.

HARDWARE: SUN-4

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	61000	40300	36400	NSDB3

STATUS: on time, submitted as ERIM_0

RESULTS:

-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
0.00	0.0388	0.00	0.0518	0.00	0.1379	
0.10	0.0082	0.10	0.0180	0.10	0.0897	
0.20	0.0025	0.20	0.0072	0.20	0.0554	
0.30	0.0012	0.30	0.0041	0.30	0.0368	
0.40	0.0009	0.40	0.0024	0.40	0.0214	
0.50	0.0007	0.50	0.0020	0.50	0.0118	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	0.24	0.24	0.24
CPU RATE:	0.91	0.91	0.91

SYSTEM: ERIM_1

BIBLIOGRAPHY:

The following references have been provided for this system:

[11][12][13][14]

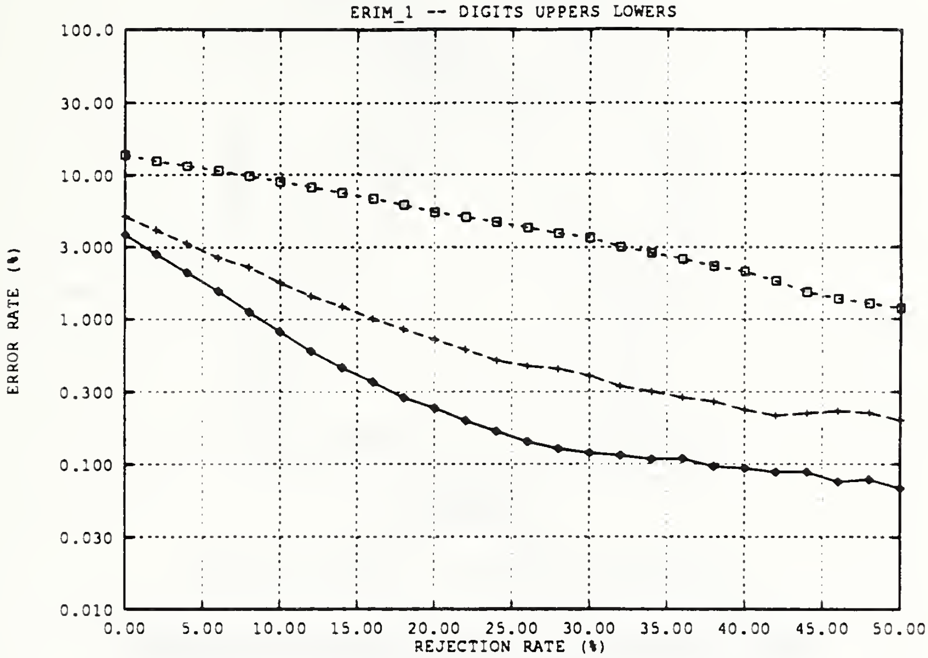

Figure 61: Error rate versus rejection rate for ERIM_1

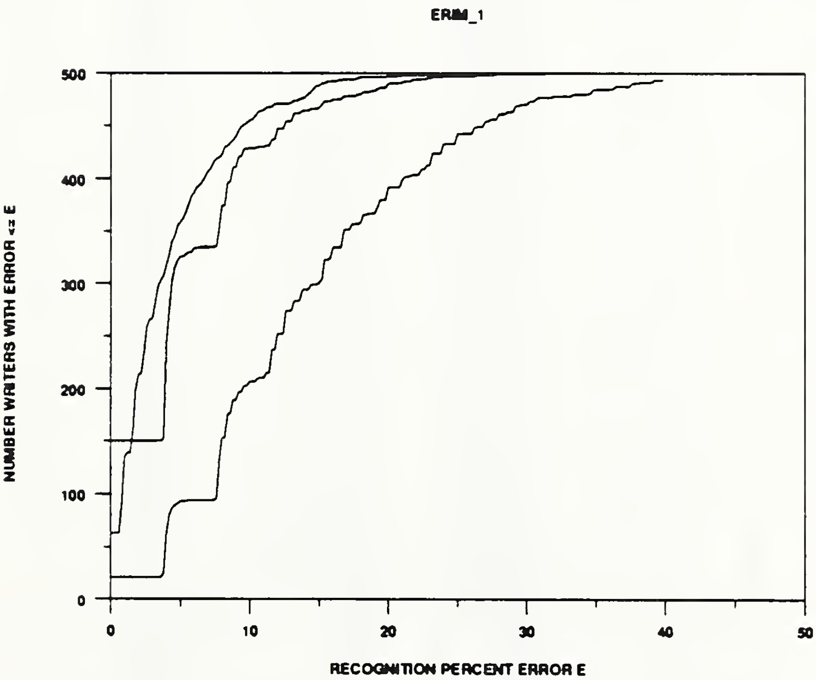

Figure 62: Error rate per writer of ERIM_1

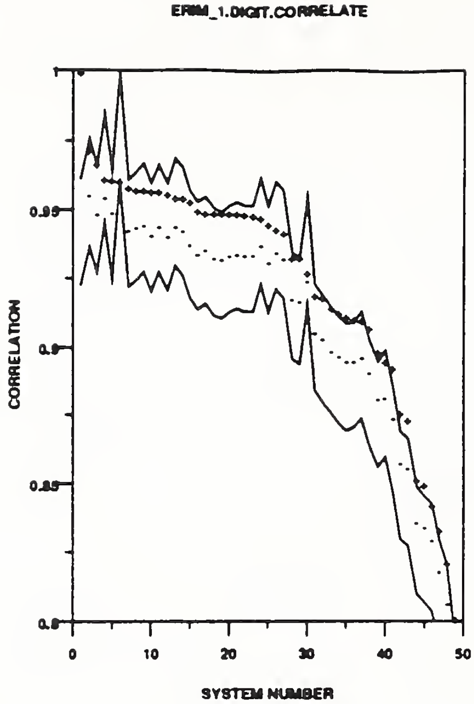

Figure 63: ERIM_1 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	ERIM_1	1.0000	1.0000
2	VOTE_M	0.9725	0.9561
3	AEG	0.9674	0.9492
4	OCRSYS	0.9619	0.9550
5	VOTE_P	0.9613	0.9494
6	REFERENCE	0.9612	0.9612
7	ERIM_2	0.9587	0.9433
8	ATT_2	0.9580	0.9440
9	ELSAGB_3	0.9578	0.9451
10	ATT_4	0.9574	0.9415
11	ELSAGB_2	0.9572	0.9447
12	KODAK_2	0.9566	0.9410
13	ATT_1	0.9553	0.9446
14	IBM	0.9549	0.9432
15	UBOL	0.9536	0.9382
16	KODAK_1	0.9504	0.9349
17	NESTOR	0.9497	0.9361
18	NIST_4	0.9496	0.9334
19	HUGHES_1	0.9495	0.9345
20	ELSAGB_1	0.9495	0.9331
21	SYMBUS	0.9494	0.9350
22	HUGHES_2	0.9491	0.9344
23	ATT_3	0.9485	0.9345
24	THINK_2	0.9477	0.9376
25	THINK_1	0.9453	0.9316
26	REI	0.9436	0.9355
27	NYNEX	0.9421	0.9331
28	GTESS_1	0.9334	0.9182
29	GTESS_2	0.9333	0.9175
30	COMCOM	0.9279	0.9249
31	NIST_1	0.9199	0.9057
32	GMD_3	0.9186	0.9036
33	MIME	0.9150	0.8992
34	ASOL	0.9134	0.8972
35	NIST_2	0.9117	0.8954
36	UPENN	0.9110	0.8952
37	GMD_1	0.9106	0.8968
38	NIST_3	0.9078	0.8910
39	RISO	0.8990	0.8818
40	GMD_4	0.8952	0.8821
41	KAMAN_1	0.8930	0.8746
42	KAMAN_3	0.8764	0.8583
43	KAMAN_2	0.8742	0.8561
44	KAMAN_5	0.8521	0.8367
45	GMD_2	0.8504	0.8347
46	VALEN_2	0.8429	0.8301
47	IFAX	0.8340	0.8185
48	VALEN_1	0.8217	0.8073
49	KAMAN_4	0.8016	0.7844

Table 41: ERIM_1 correlation graph key for digits.

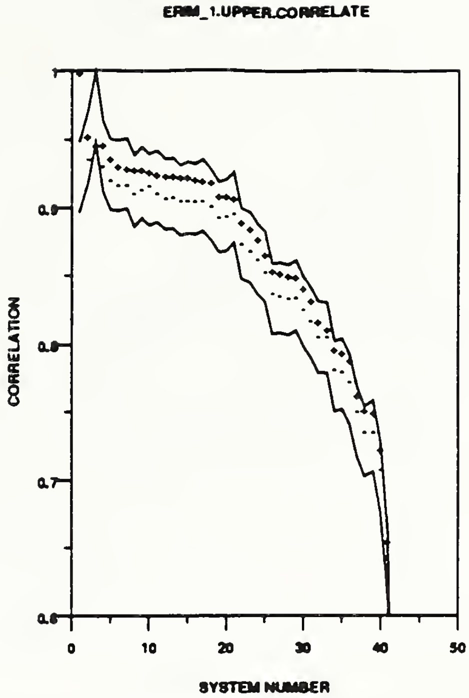

Figure 64: ERIM_1 - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	ERIM_1	1.0000	1.0000
2	VOTE_M	0.9539	0.9379
3	REFERENCE	0.9482	0.9482
4	AEG	0.9477	0.9323
5	ATT_4	0.9379	0.9219
6	UMICH_1	0.9323	0.9181
7	NYNEX	0.9305	0.9182
8	ATT_2	0.9290	0.9143
9	UBOL	0.9290	0.9116
10	VOTE_P	0.9278	0.9173
11	NESTOR	0.9255	0.9117
12	HUGHES_1	0.9252	0.9083
13	IBM	0.9245	0.9090
14	KODAK_1	0.9237	0.9066
15	HUGHES_2	0.9237	0.9063
16	ATT_3	0.9223	0.9064
17	ATT_1	0.9215	0.9066
18	SYMBUS	0.9200	0.9029
19	GTESS_1	0.9101	0.8950
20	GTESS_2	0.9101	0.8942
21	OCRSYS	0.9080	0.8972
22	MIME	0.8911	0.8750
23	NIST_4	0.8865	0.8705
24	ASOL	0.8789	0.8639
25	REI	0.8675	0.8552
26	RISO	0.8562	0.8390
27	GMD_1	0.8538	0.8375
28	GMD_3	0.8519	0.8358
29	NIST_1	0.8516	0.8371
30	KAMAN_1	0.8434	0.8279
31	GMD_4	0.8341	0.8192
32	NIST_3	0.8179	0.8072
33	COMCOM	0.8132	0.8071
34	KAMAN_3	0.7983	0.7833
35	IFAX	0.7949	0.7814
36	KAMAN_2	0.7901	0.7740
37	NIST_2	0.7640	0.7519
38	GMD_2	0.7529	0.7377
39	VALEN_1	0.7513	0.7372
40	KAMAN_4	0.7248	0.7097
41	KAMAN_5	0.6566	0.6441
42	UMICH_2	0.0390	0.0219

Table 42: ERIM_1 correlation graph key for uppers.

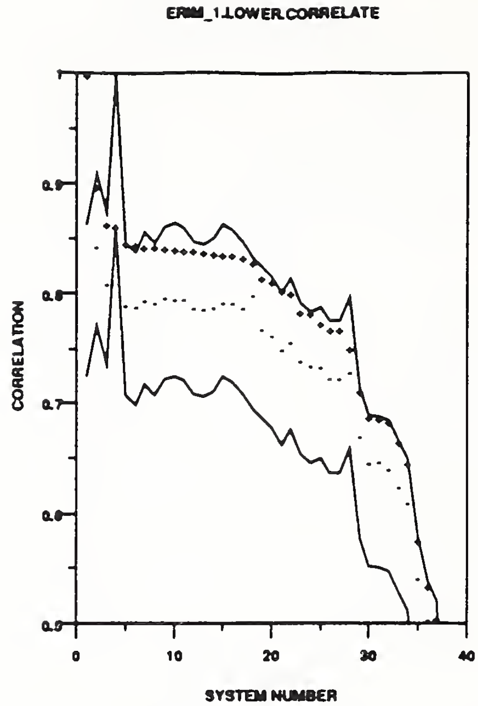

Figure 65: ERIM_1 - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	ERIM_1	1.0000	1.0000
2	VOTE_M	0.8993	0.8441
3	AEG	0.8644	0.8112
4	REFERENCE	0.8621	0.8621
5	UBOL	0.8471	0.7914
6	ATT_3	0.8464	0.7899
7	KODAK_1	0.8445	0.7961
8	IBM	0.8443	0.7932
9	NYNEX	0.8429	0.7985
10	OCRSYS	0.8417	0.7969
11	ATT_2	0.8405	0.7965
12	HUGHES_1	0.8404	0.7893
13	HUGHES_2	0.8399	0.7882
14	UMICH_1	0.8378	0.7885
15	ATT_1	0.8375	0.7938
16	ATT_4	0.8374	0.7934
17	NESTOR	0.8351	0.7889
18	VOTE_P	0.8308	0.7999
19	GTESS_1	0.8167	0.7691
20	GTESS_2	0.8125	0.7641
21	NIST_4	0.8052	0.7508
22	NIST_1	0.8030	0.7584
23	GMD_3	0.7855	0.7403
24	RISO	0.7838	0.7358
25	ASOL	0.7757	0.7345
26	GMD_4	0.7693	0.7247
27	GMD_1	0.7693	0.7247
28	NIST_3	0.7521	0.7307
29	GMD_2	0.7135	0.6723
30	KAMAN_1	0.6892	0.6481
31	NIST_2	0.6877	0.6485
32	VALEN_1	0.6859	0.6423
33	KAMAN_3	0.6668	0.6262
34	KAMAN_2	0.6482	0.6115
35	KAMAN_5	0.5763	0.5423
36	KAMAN_4	0.5356	0.5058
37	COMCOM	0.5061	0.4923
38	UMICH_2	0.0910	0.0539

Table 43: ERIM_1 correlation graph key for lowers.

SYSTEM: ERIM_2

PARTICIPANT: Steven Schlosser

ORGANIZATION: Environmental Research Institute of Michigan (ERIM)
Ann Arbor, Michigan

PREPROCESSING: filtering, size and slant normalization

FEATURES: morphological (cavities) and stroke features, whole digits for template matching

CLASSIFICATION: four layer NN and template matcher combined together for single result

HARDWARE: SUN-4

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	none	NA	NA	

STATUS: on time, submitted as ERIM_1

RESULTS:	-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
	0.00	0.0392					
	0.10	0.0099					
	0.20	0.0033					
	0.30	0.0013					
	0.40	0.0007					
	0.50	0.0006					

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	10.0	NA	NA
CPU RATE:			

SYSTEM: ERIM_2

BIBLIOGRAPHY:

The following references have been provided for this system:

[11][12][13][14]

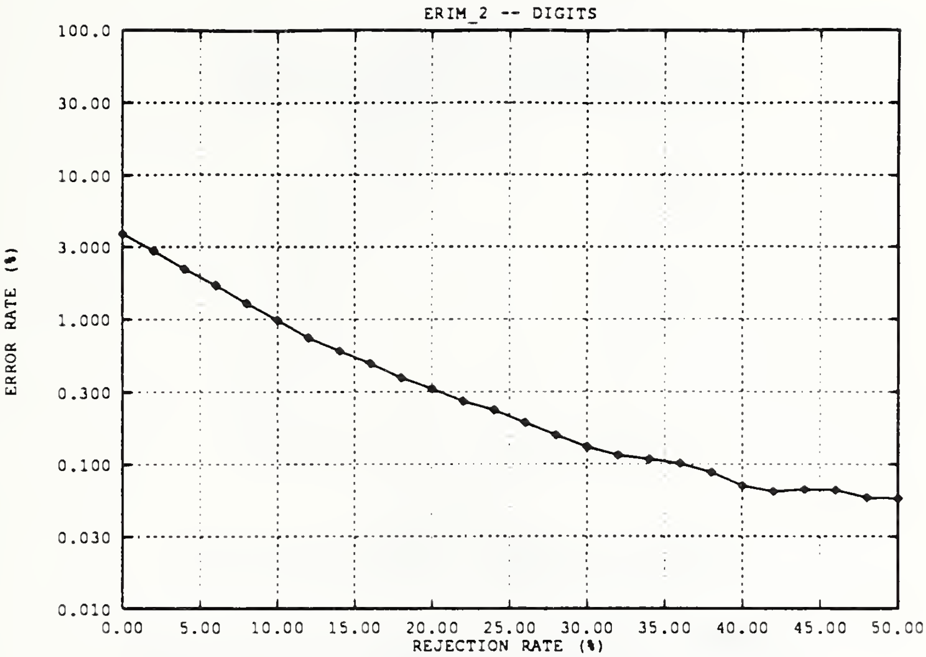

Figure 66: Error rate versus rejection rate for ERIM_2

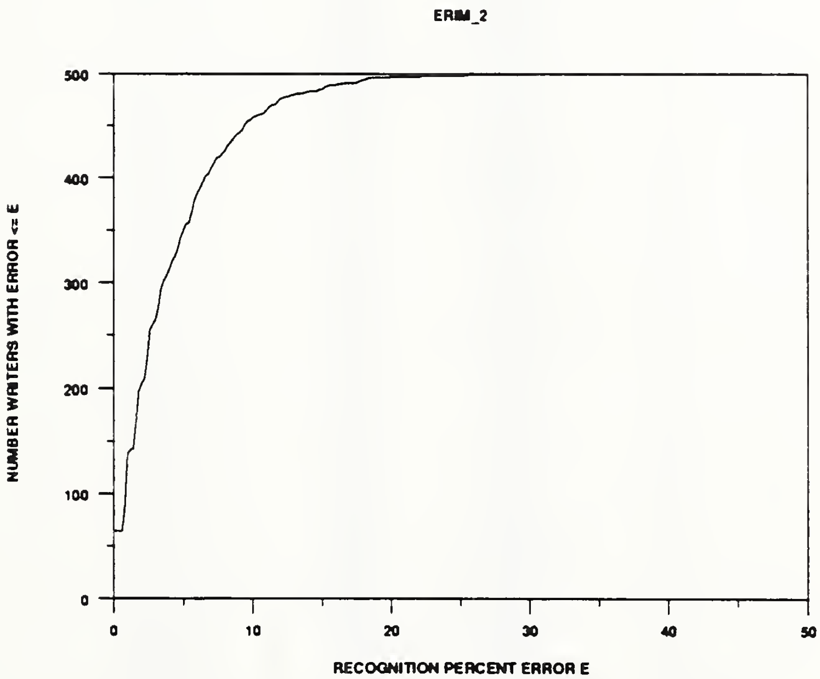

Figure 67: Error rate per writer of ERIM_2

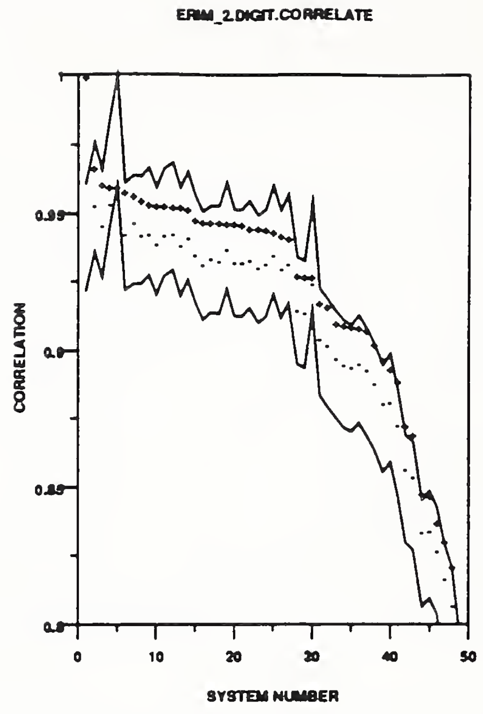

Figure 68: ERIM_2 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	ERIM_2	1.0000	1.0000
2	VOTE_M	0.9677	0.9537
3	AEG	0.9616	0.9465
4	REFERENCE	0.9608	0.9608
5	OCRSYS	0.9608	0.9542
6	ERIM_1	0.9587	0.9433
7	VOTE_P	0.9576	0.9472
8	ATT_2	0.9557	0.9428
9	ELSAGB_3	0.9543	0.9433
10	KODAK_2	0.9539	0.9396
11	ELSAGB_2	0.9535	0.9428
12	ATT_1	0.9534	0.9433
13	ATT_4	0.9531	0.9391
14	IBM	0.9523	0.9417
15	UBOL	0.9487	0.9359
16	SYMBUS	0.9479	0.9345
17	NIST_4	0.9479	0.9323
18	KODAK_1	0.9476	0.9335
19	THINK_2	0.9474	0.9375
20	HUGHES_1	0.9473	0.9329
21	HUGHES_2	0.9469	0.9328
22	NESTOR	0.9455	0.9339
23	ELSAGB_1	0.9454	0.9312
24	ATT_3	0.9450	0.9326
25	REI	0.9439	0.9357
26	THINK_1	0.9429	0.9306
27	NYNEX	0.9417	0.9325
28	GTESS_1	0.9283	0.9155
29	GTESS_2	0.9280	0.9147
30	COMCOM	0.9278	0.9250
31	NIST_1	0.9182	0.9049
32	GMD_3	0.9170	0.9026
33	MIME	0.9111	0.8976
34	ASOL	0.9100	0.8954
35	UPENN	0.9094	0.8945
36	GMD_1	0.9093	0.8960
37	NIST_2	0.9080	0.8936
38	NIST_3	0.9031	0.8885
39	RISO	0.8974	0.8812
40	GMD_4	0.8942	0.8815
41	KAMAN_1	0.8896	0.8735
42	KAMAN_3	0.8733	0.8572
43	KAMAN_2	0.8701	0.8545
44	GMD_2	0.8483	0.8341
45	KAMAN_5	0.8482	0.8349
46	VALEN_2	0.8379	0.8275
47	IFAX	0.8312	0.8173
48	VALEN_1	0.8218	0.8077
49	KAMAN_4	0.7976	0.7825

Table 44: ERIM_2 correlation graph key for digits.

No Data Available

Figure 69: ERIM_2 - upper case correlation

There was no data for this evaluation.

Table 45: ERIM_2 correlation graph key for uppers.

No Data Available

Figure 70: ERIM_2 - lower case correlation

There was no data for this evaluation.

Table 46: ERIM_2 correlation graph key for lowers.

SYSTEM: GMD_1

PARTICIPANT: Frank Smieja

ORGANIZATION: Gesellshcaft fuer Mathematik und Datenverarbeitung (GMD), Sankt Augustin, Germany

PREPROCESSING: size normalization to 16x24

FEATURES: genetically optimized polynomial filter, 384 features extracted. Feature optimization by PGA (parallel genetic algorithm).

CLASSIFICATION: statistical, nearest neighbor

HARDWARE: SPARC2

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	15000	22000	22000	NSDB3

STATUS: on time

RESULTS:	-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
	0.00	0.0873	0.00	0.1404	0.00	0.2254	
	0.15	0.0272	0.16	0.0625	0.31	0.0809	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	1.18	0.48	0.40
CPU RATE:			

SYSTEM: GMD_1

BIBLIOGRAPHY:

The following references have been provided for this system:

[15][16]

COMMENTS: GMD_1,3,4

PARTICIPANT: Frank Śmieja

ORGANIZATION: Gesellschaft für Mathematik und Datenverarbeitung (GMD), Sankt Augustin, Germany.

The algorithm works in several steps.

1. Normalization of the image to 16x24 pixels.
2. From a training set, 64 features are computed by Karhunen-Loeve transformation.
3. Distance and variance of the clusters are optimized by the genetic algorithm.

Future developments:

- Reduction of the training set required to be stored.
- Employment of geometric learning.

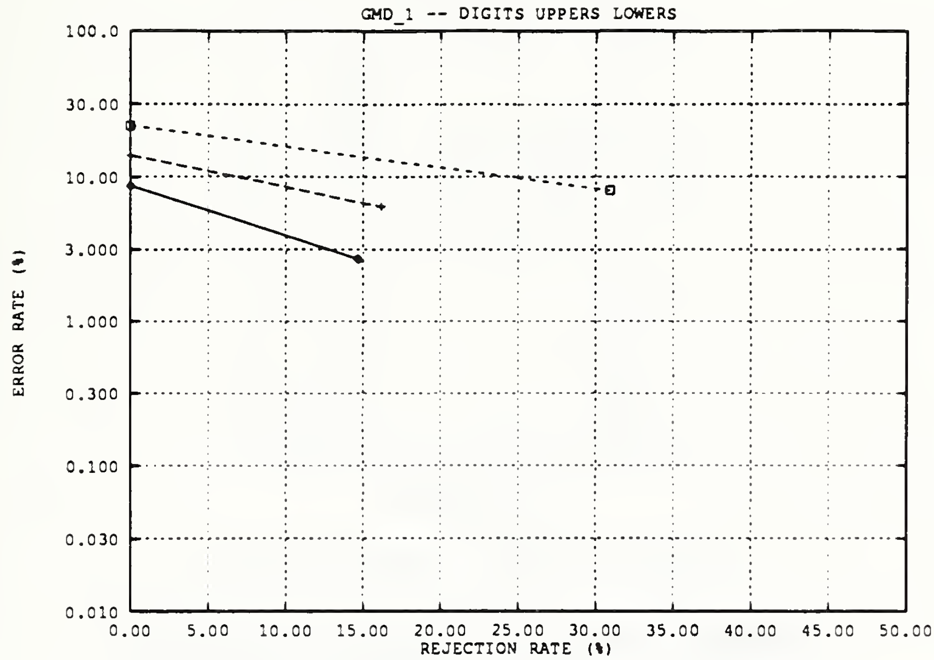

Figure 71: Error rate versus rejection rate for GMD_1

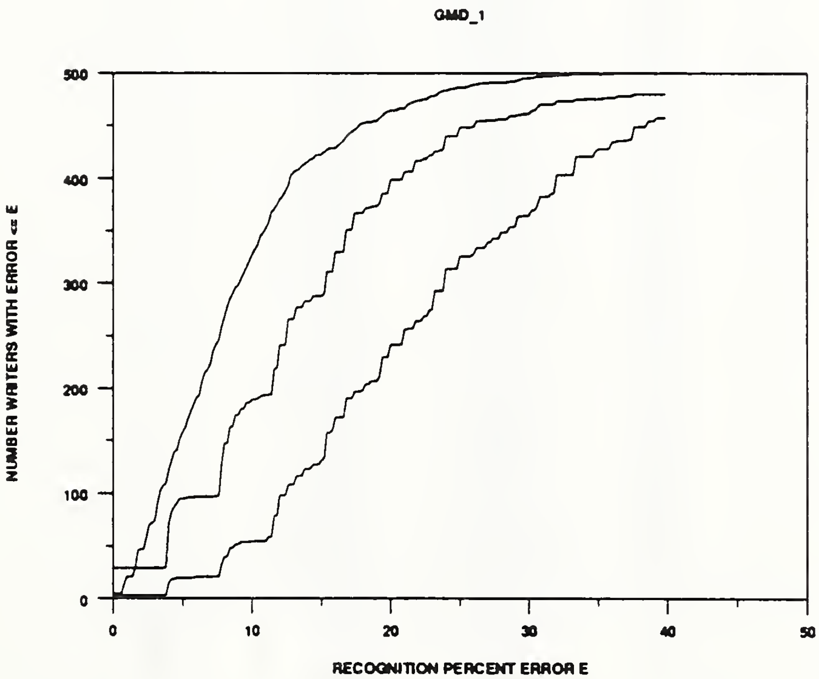

Figure 72: Error rate per writer of GMD_1

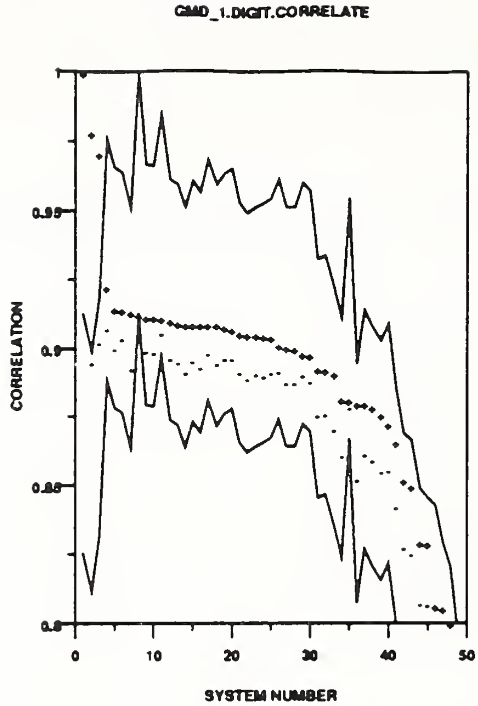

Figure 73: GMD_1 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	GMD_1	1.0000	1.0000
2	GMD_4	0.9786	0.8954
3	GMD_3	0.9712	0.9027
4	VOTE_M	0.9227	0.9079
5	AEG	0.9152	0.9005
6	VOTE_P	0.9146	0.9040
7	NIST_4	0.9138	0.8932
8	REFERENCE	0.9127	0.9127
9	ELSAGB_3	0.9120	0.8993
10	ELSAGB_2	0.9118	0.8990
11	OCRSYS	0.9114	0.9060
12	ERIM_1	0.9106	0.8968
13	KODAK_2	0.9096	0.8953
14	ERIM_2	0.9093	0.8960
15	THINK_1	0.9093	0.8916
16	ATT_1	0.9091	0.8985
17	UBOL	0.9091	0.8935
18	ATT_4	0.9090	0.8949
19	ATT_2	0.9082	0.8967
20	IBM	0.9075	0.8967
21	SYMBUS	0.9058	0.8915
22	ATT_3	0.9056	0.8911
23	ELSAGB_1	0.9056	0.8894
24	KODAK_1	0.9052	0.8904
25	NESTOR	0.9044	0.8916
26	THINK_2	0.9018	0.8920
27	HUGHES_1	0.9010	0.8881
28	HUGHES_2	0.9004	0.8879
29	REI	0.8984	0.8906
30	NYNEX	0.8982	0.8883
31	GTESS_2	0.8931	0.8761
32	GTESS_1	0.8924	0.8764
33	NIST_1	0.8913	0.8709
34	ASOL	0.8821	0.8615
35	COMCOM	0.8818	0.8789
36	MIME	0.8800	0.8620
37	RISO	0.8800	0.8526
38	NIST_2	0.8786	0.8596
39	NIST_3	0.8759	0.8556
40	UPENN	0.8727	0.8558
41	KAMAN_1	0.8659	0.8425
42	KAMAN_3	0.8520	0.8280
43	KAMAN_2	0.8498	0.8257
44	KAMAN_5	0.8297	0.8074
45	GMD_2	0.8291	0.8072
46	VALEN_2	0.8069	0.7934
47	IFAX	0.8059	0.7863
48	VALEN_1	0.8002	0.7782
49	KAMAN_4	0.7832	0.7585

Table 47: GMD_1 correlation graph key for digits.

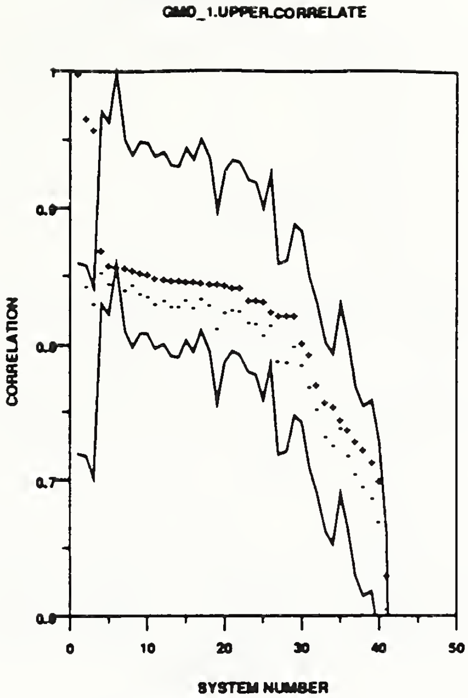

Figure 74: GMD_1 - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	GMD_1	1.0000	1.0000
2	GMD_3	0.9679	0.8446
3	GMD_4	0.9595	0.8318
4	VOTE_M	0.8715	0.8549
5	AEG	0.8601	0.8467
6	REFERENCE	0.8596	0.8596
7	ATT_4	0.8587	0.8421
8	VOTE_P	0.8570	0.8461
9	UMICH_1	0.8551	0.8390
10	ERIM_1	0.8538	0.8375
11	UBOL	0.8510	0.8324
12	NESTOR	0.8508	0.8350
13	ATT_3	0.8493	0.8305
14	KODAK_1	0.8491	0.8304
15	ATT_2	0.8488	0.8349
16	ATT_1	0.8485	0.8295
17	NYNEX	0.8478	0.8359
18	IBM	0.8470	0.8308
19	NIST_4	0.8464	0.8135
20	SYMBUS	0.8460	0.8253
21	HUGHES_1	0.8442	0.8272
22	HUGHES_2	0.8440	0.8261
23	GTESS_1	0.8350	0.8186
24	GTESS_2	0.8345	0.8178
25	MIME	0.8341	0.8095
26	OCRSYS	0.8267	0.8163
27	RISO	0.8241	0.7899
28	NIST_1	0.8239	0.7892
29	ASOL	0.8235	0.8004
30	REI	0.8037	0.7870
31	KAMAN_1	0.7949	0.7708
32	NIST_3	0.7719	0.7537
33	KAMAN_3	0.7597	0.7339
34	KAMAN_2	0.7555	0.7271
35	COMCOM	0.7462	0.7402
36	IFAX	0.7392	0.7198
37	NIST_2	0.7313	0.7063
38	GMD_2	0.7245	0.6968
39	VALEN_1	0.7152	0.6886
40	KAMAN_4	0.7012	0.6710
41	KAMAN_5	0.6319	0.6073
42	UMICH_2	0.0528	0.0154

Table 48: GMD_1 correlation graph key for uppers.

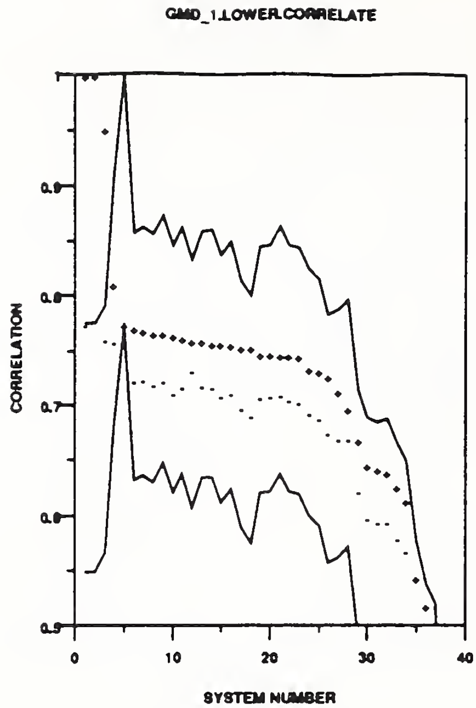

Figure 75: GMD_1 - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	GMD_1	1.0000	1 0000
2	GMD_4	1.0000	0 7746
3	GMD_3	0.9522	0.7613
4	VOTE_M	0.8117	0.7591
5	REFERENCE	0.7746	0.7746
6	ATT_4	0.7718	0.7232
7	ERIM_1	0 7693	0.7247
8	KODAK_1	0.7673	0 7199
9	AEG	0 7668	0 7235
10	UBOL	0 7644	0.7122
11	ATT_1	0.7623	0.7176
12	VOTE_P	0.7602	0.7325
13	ATT_2	0.7597	0.7193
14	NYNEX	0.7582	0 7182
15	ATT_3	0.7574	0 7100
16	UMICH_1	0.7571	0.7117
17	NIST_1	0 7542	0.6981
18	NIST_4	0 7541	0.6915
19	IBM	0 7489	0.7088
20	NESTOR	0.7485	0.7095
21	OCRSYS	0 7473	0.7110
22	HUGHES_1	0 7472	0.7057
23	HUGHES_2	0.7459	0.7040
24	GTESS_1	0.7352	0.6931
25	GTESS_2	0.7327	0.6888
26	RISO	0.7285	0.6765
27	ASOL	0.7146	0.6706
28	NIST_3	0.6983	0.6709
29	GMD_2	0 6692	0.6226
30	KAMAN_1	0.6470	0.5987
31	VALEN_1	0 6428	0.5945
32	NIST_2	0 6395	0.5954
33	KAMAN_3	0.6270	0.5795
34	KAMAN_2	0 6148	0.5684
35	KAMAN_5	0.5438	0 5020
36	KAMAN_4	0 5192	0.4757
37	COMCOM	0 4622	0.4513
38	UMICH_2	0.1098	0.0478

Table 49: GMD_1 correlation graph key for lowers.

SYSTEM: GMD_2

PARTICIPANT: Frank Smieja

ORGANIZATION: Gesellschaft fuer Mathematik und Datenverarbeitung
(GMD), Sankt Augustin, Germany

PREPROCESSING: scaled, centered, contrast filtered images?

FEATURES: pixel representation only

CLASSIFICATION: network of worker, monitor, and decision NN in pandemonium system of MINOS modules, "pandemonium reflective system". Output is chosen from network with maximum confidence value by decision NN.

HARDWARE: SPARC2

TRAINING:

	DIGITS	UPPERS	LOWERS	DATABASE
	4180	8979	9355	NSDB3
	~420	~420	~420	writers

STATUS: on time

RESULTS:

-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
0.00	0.1545	0.00	0.2457	0.00	0.2861	
0.10	0.1120	0.28	0.1321	0.28	0.1752	
0.12	0.1023	0.31	0.1219	0.31	0.1625	
0.13	0.0979	0.33	0.1172			
0.14	0.0941	0.34	0.1132			
C.16	0.0904	0.36	0.1080			
0.17	0.0855	0.38	0.1022			

OCR RATE (CPS):

	DIGITS	UPPERS	LOWERS
SYS RATE:	0.68	0.43	0.32
CPU RATE:			

SYSTEM: GMD_2

BIBLIOGRAPHY:

The following references have been provided for this system:

[17][18]

COMMENTS: GMD_2

PARTICIPANT: Frank Śmieja

ORGANIZATION: Gesellschaft für Mathematik und Datenverarbeitung (GMD), Sankt Augustin, Germany.

The data was learnt by a system of modular neural networks, described in the reports cited below. The individual patterns to be learnt are automatically decomposed over the modular system, such that the *Worker* neural network that learns to map a particular pattern to a target is the one that is most specialized *at that time* to learn it. In order that the appropriate network can be believed, when a test session is in process, a partner *Monitor* network is employed. The Monitor network partnered to the Worker network allocated the pattern to learn is trained to produce a positive output when it sees the pattern. The other Monitor networks, associated with Workers that do not learn the current pattern, are trained to produce a negative output on seeing this pattern.

Various confidence values are derived from the outputs from the Monitor networks during the test sessions. An ambiguity measure is also derived from degree of closeness of the two most positive Monitor outputs. Both the confidences and the ambiguity are then used to filter off the answers that are not provided with sufficient commitment (the "rejected" patterns).

Insofar as the NIST test results are concerned, it was observed that the training on so few examples (see above) was quite a disadvantage. The system was able to model the NIST training set well enough to produce good generalization for this set, but in general 10 worse for the NIST test sets.

BIBLIOGRAPHY:

F. J. Śmieja, Multiple network systems (MINOS) modules: task division and module discrimination, *Proc. 8th AISB conference on Artificial Intelligence*, Leeds, April 1991.

F. J Śmieja and H. Mühlenbein, Reflective modular neural networks, submitted to *Machine Learning*, available as GMD report number 633 (1992).

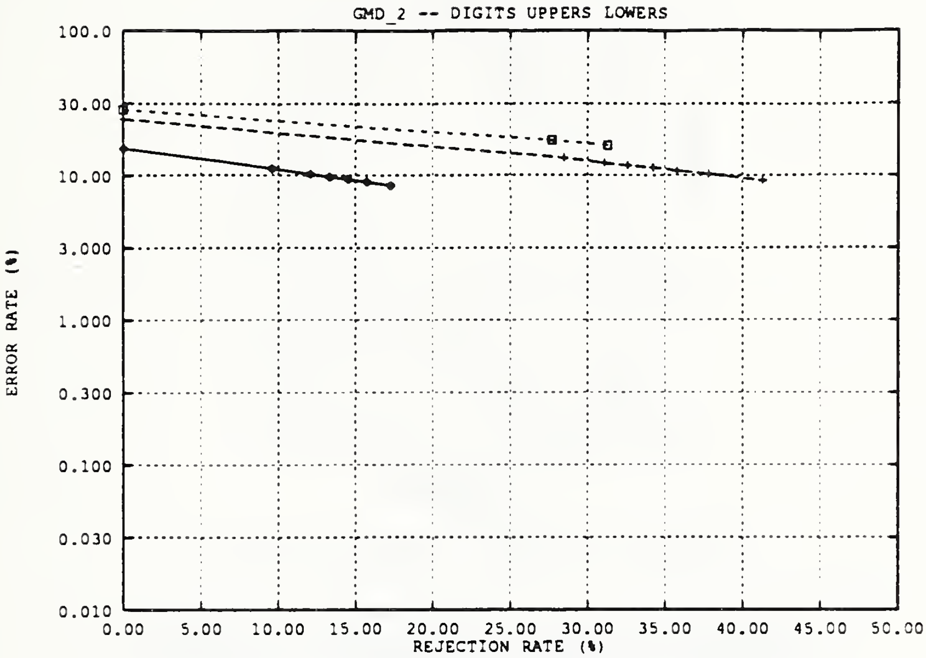

Figure 76: Error rate versus rejection rate for GMD_2

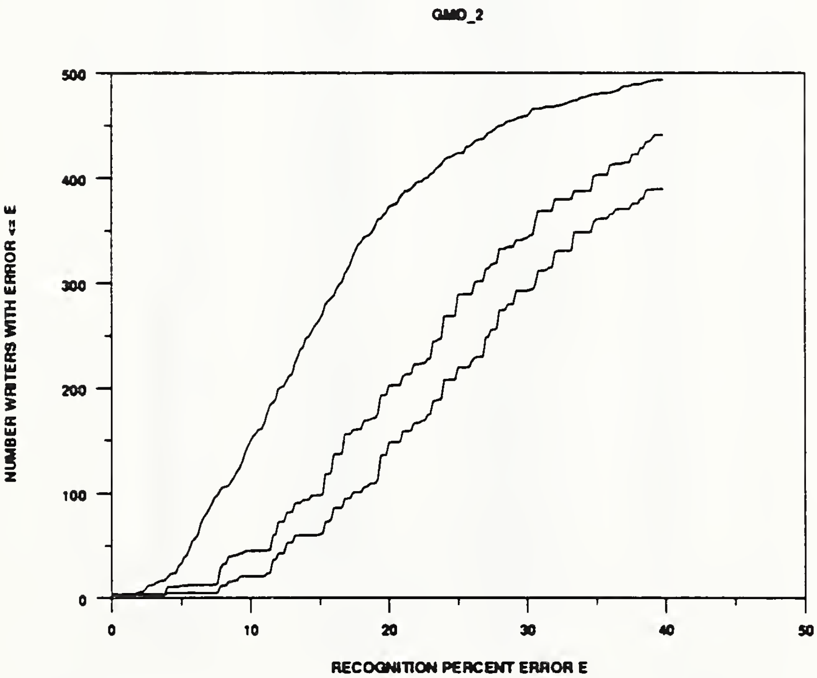

Figure 77: Error rate per writer of GMD_2

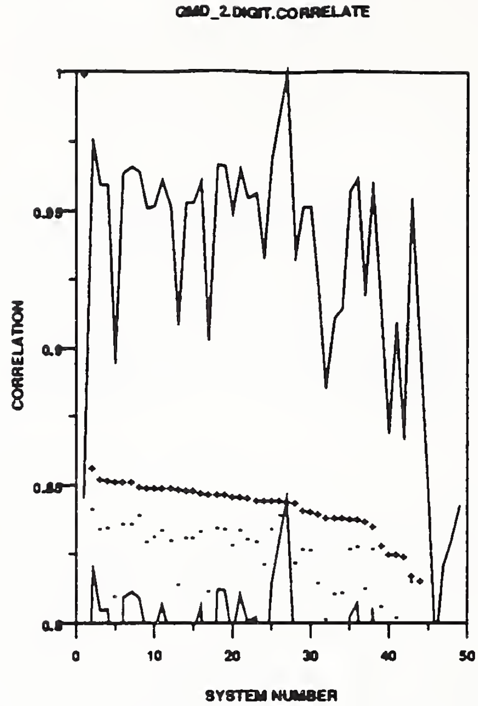

Figure 78: GMD_2 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	GMD_2	1.0000	1.0000
2	VOTE_M	0.8575	0.8425
3	ATT_4	0.8535	0.8353
4	KODAK_2	0.8530	0.8356
5	ATT_2	0.8525	0.8370
6	AEG	0.8525	0.8369
7	RISO	0.8525	0.8110
8	VOTE_P	0.8509	0.8402
9	ERIM_1	0.8504	0.8347
10	ATT_3	0.8504	0.8325
11	NIST_4	0.8504	0.8305
12	THINK_1	0.8502	0.8312
13	NIST_2	0.8497	0.8152
14	SYMBUS	0.8495	0.8320
15	KODAK_1	0.8494	0.8319
16	ERIM_2	0.8483	0.8341
17	ELSAGB_3	0.8482	0.8356
18	NIST_3	0.8482	0.8126
19	ELSAGB_2	0.8479	0.8354
20	ELSAGB_1	0.8470	0.8291
21	IBM	0.8469	0.8349
22	NESTOR	0.8466	0.8316
23	UBOL	0.8458	0.8307
24	OCRSYS	0.8457	0.8402
25	ATT_1	0.8457	0.8350
26	GTESS_2	0.8457	0.8225
27	REFERENCE	0.8455	0.8455
28	GTESS_1	0.8450	0.8226
29	HUGHES_2	0.8421	0.8278
30	HUGHES_1	0.8416	0.8275
31	NIST_1	0.8406	0.8155
32	KAMAN_1	0.8395	0.8024
33	ASOL	0.8392	0.8116
34	MIME	0.8391	0.8124
35	NYNEX	0.8389	0.8277
36	THINK_2	0.8387	0.8289
37	GMD_3	0.8381	0.8138
38	REI	0.8362	0.8280
39	GMD_1	0.8291	0.8072
40	UPENN	0.8258	0.8031
41	KAMAN_3	0.8258	0.7887
42	KAMAN_2	0.8249	0.7868
43	COMCOM	0.8183	0.8159
44	GMD_4	0.8165	0.7948
45	KAMAN_5	0.7975	0.7664
46	KAMAN_4	0.7727	0.7280
47	VALEN_1	0.7659	0.7377
48	IFAX	0.7631	0.7403
49	VALEN_2	0.7594	0.7438

Table 50: GMD_2 correlation graph key for digits.

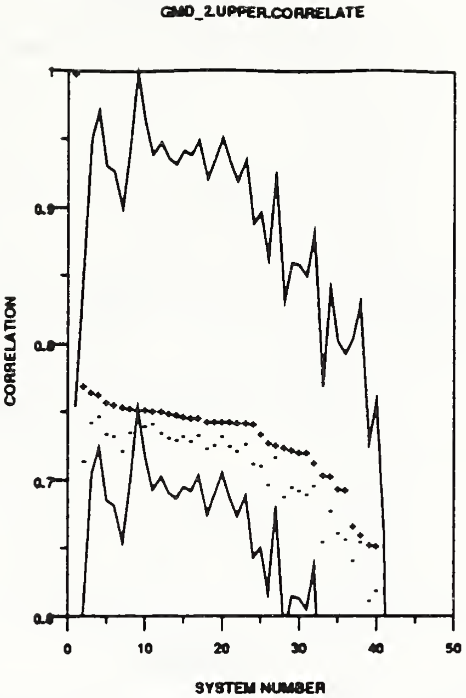

Figure 79: GMD_2 - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	GMD_2	1.0000	1.0000
2	RISO	0.7710	0.7165
3	ATT_4	0.7671	0.7452
4	VOTE_M	0.7649	0.7493
5	KODAK_1	0.7591	0.7364
6	SYMBUS	0.7579	0.7344
7	MIME	0.7561	0.7236
8	ATT_2	0.7546	0.7376
9	REFERENCE	0.7543	0.7543
10	AEG	0.7542	0.7424
11	VOTE_P	0.7532	0.7442
12	ERIM_1	0.7529	0.7377
13	IBM	0.7511	0.7334
14	ATT_3	0.7504	0.7322
15	NESTOR	0.7494	0.7343
16	UMICH_1	0.7488	0.7356
17	UBOL	0.7488	0.7311
18	GTESS_1	0.7459	0.7253
19	NYNEX	0.7457	0.7344
20	HUGHES_1	0.7457	0.7283
21	HUGHES_2	0.7454	0.7277
22	ATT_1	0.7450	0.7291
23	GTESS_2	0.7450	0.7239
24	ASOL	0.7438	0.7148
25	NIST_4	0.7363	0.7123
26	NIST_1	0.7304	0.6986
27	OCRSYS	0.7287	0.7187
28	NIST_3	0.7266	0.6895
29	GMD_1	0.7245	0.6968
30	GMD_3	0.7226	0.6947
31	KAMAN_1	0.7225	0.6917
32	REI	0.7154	0.6975
33	NIST_2	0.7063	0.6569
34	GMD_4	0.7051	0.6796
35	KAMAN_3	0.6963	0.6633
36	KAMAN_2	0.6954	0.6586
37	IFAX	0.6686	0.6429
38	COMCOM	0.6618	0.6569
39	KAMAN_4	0.6543	0.6134
40	VALEN_1	0.6540	0.6205
41	KAMAN_5	0.5801	0.5490
42	UMICH_2	0.0805	0.0143

Table 51: GMD_2 correlation graph key for uppers.

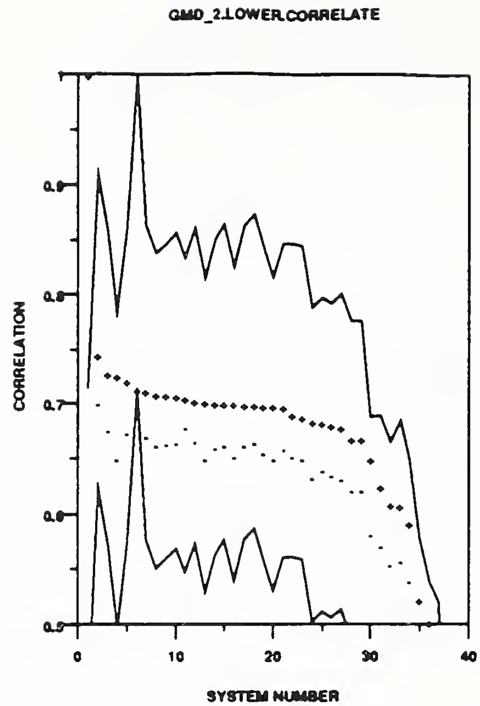

Figure 80: GMD_2 - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	GMD_2	1.0000	1.0000
2	VOTE_M	0.7470	0.7013
3	ATT_4	0 7287	0.6779
4	RISO	0.7265	0.6507
5	ATT_2	0.7219	0.6758
6	REFERENCE	0 7139	0.7139
7	ERIM_1	0 7135	0.6723
8	ATT_3	0 7100	0.6637
9	IBM	0.7097	0 6646
10	KODAK_1	0.7081	0.6662
11	VOTE_P	0.7068	0.6801
12	NYNEX	0.7035	0.6671
13	NIST_1	0.7031	0.6515
14	UMICH_1	0.7022	0.6610
15	OCRSYS	0.7021	0.6642
16	GTESS_1	0 7016	0.6537
17	ATT_1	0.7010	0.6637
18	AEG	0.7000	0.6659
19	UBOL	0 6998	0.6568
20	GTESS_2	0 6992	0.6507
21	NESTOR	0.6977	0.6598
22	HUGHES_1	0.6917	0 6536
23	HUGHES_2	0.6889	0.6511
24	ASOL	0 6852	0.6344
25	NIST_3	0 6850	0 6412
26	GMD_3	0.6822	0.6359
27	NIST_4	0.6798	0.6330
28	GMD_4	0 6692	0.6226
29	GMD_1	0 6692	0.6226
30	NIST_2	0.6515	0.5825
31	KAMAN_1	0 6262	0.5715
32	KAMAN_3	0.6093	0.5548
33	VALEN_1	0.6081	0 5585
34	KAMAN_2	0 5921	0.5398
35	KAMAN_5	0 5239	0 4779
36	KAMAN_4	0 5033	0 4527
37	COMCOM	0 4342	0.4247
38	UMICH_2	0.1047	0.0412

Table 52: GMD_2 correlation graph key for lowers.

SYSTEM: GMD_3

PARTICIPANT: Frank Smieja

ORGANIZATION: Gesellschaft fuer Mathematik und Datenverarbeitung (GMD), Sankt Augustin, Germany

FEATURES: genetically optimized polynomial filter

CLASSIFICATION: statistical

HARDWARE: SPARC2

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	15000	22000	22000	NSDB3

STATUS: on time

RESULTS:	-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
	0.00	0.0813	0.00	0.1422	0.00	0.2085	
	0.07	0.0479	0.15	0.0700	0.19	0.1187	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	1.18	0.48	0.40
CPU RATE:			

SYSTEM: GMD_3

BIBLIOGRAPHY:

The following references have been provided for this system:

[15][16]

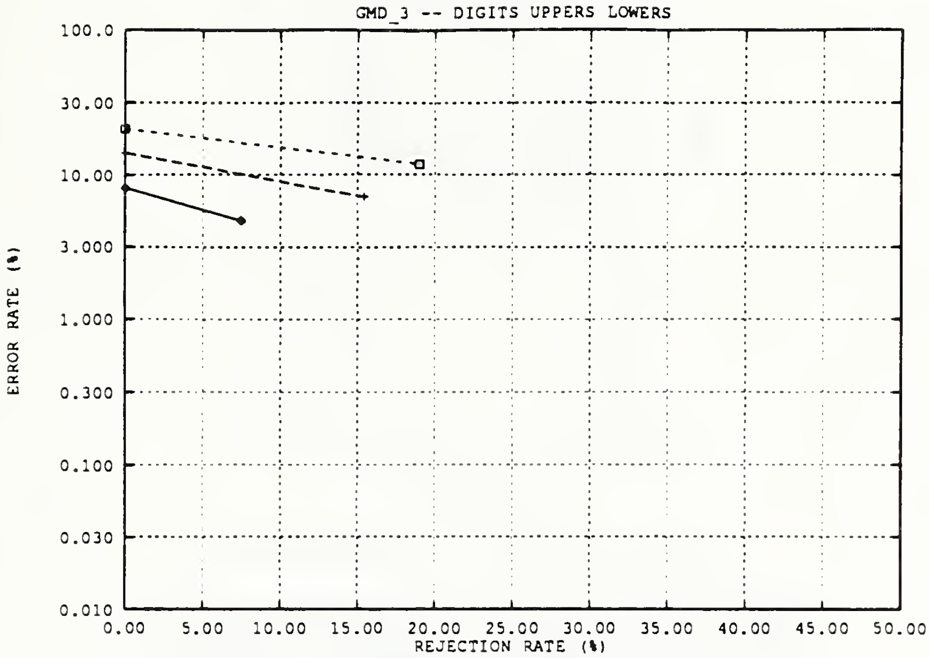

Figure 81: Error rate versus rejection rate for GMD_3

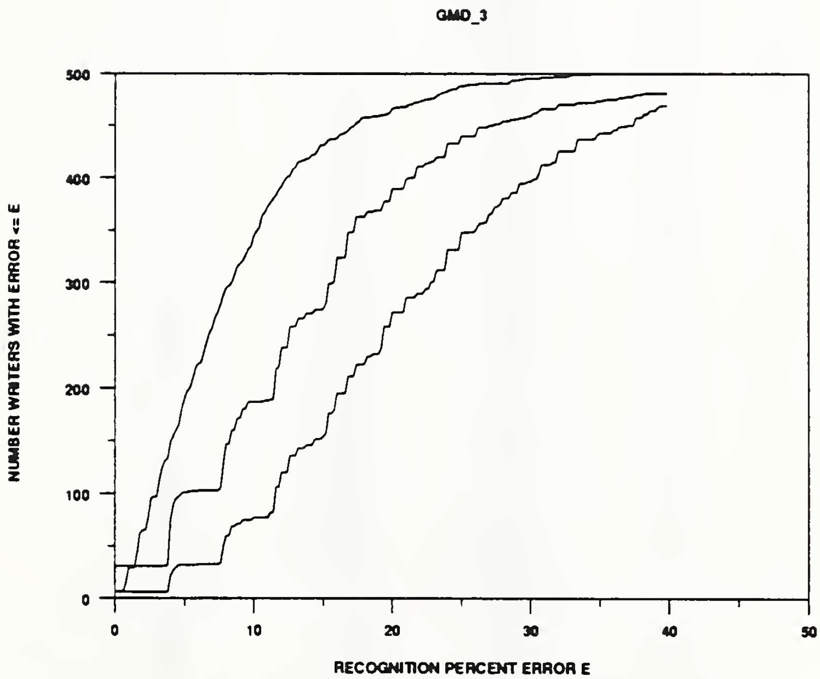

Figure 82: Error rate per writer of GMD_3

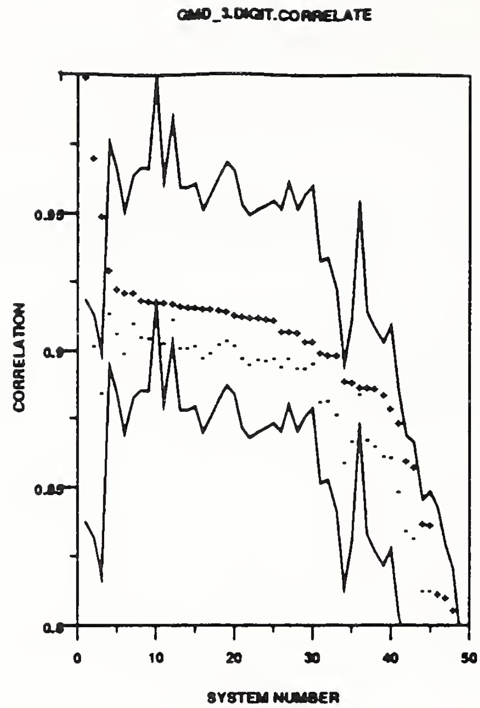

Figure 83: GMD_3 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	GMD_3	1.0000	1.0000
2	GMD_1	0.9712	0.9027
3	GMD_4	0.9498	0.8854
4	VOTE_M	0.9308	0.9146
5	AEG	0.9239	0.9075
6	NIST_4	0.9225	0.9001
7	VOTE_P	0.9224	0.9109
8	ELSAGB_3	0.9198	0.9059
9	ELSAGB_2	0.9194	0.9055
10	REFERENCE	0.9187	0.9187
11	ERIM_1	0.9186	0.9036
12	OCRSYS	0.9181	0.9122
13	KODAK_2	0.9172	0.9019
14	ERIM_2	0.9170	0.9026
15	ATT_4	0.9170	0.9016
16	THINK_1	0.9167	0.8979
17	UBOL	0.9165	0.8999
18	ATT_2	0.9161	0.9033
19	ATT_1	0.9155	0.9044
20	IBM	0.9141	0.9029
21	SYMBUS	0.9136	0.8981
22	ATT_3	0.9133	0.8977
23	ELSAGB_1	0.9133	0.8958
24	KODAK_1	0.9130	0.8973
25	NESTOR	0.9122	0.8982
26	HUGHES_1	0.9082	0.8947
27	THINK_2	0.9081	0.8980
28	HUGHES_2	0.9076	0.8944
29	NYNEX	0.9047	0.8944
30	REI	0.9046	0.8965
31	GTESS_2	0.9002	0.8821
32	GTESS_1	0.8996	0.8825
33	NIST_1	0.8995	0.8775
34	RISO	0.8899	0.8599
35	ASOL	0.8893	0.8677
36	COMCOM	0.8875	0.8847
37	MIME	0.8874	0.8683
38	NIST_2	0.8870	0.8661
39	NIST_3	0.8848	0.8624
40	UPENN	0.8798	0.8620
41	KAMAN_1	0.8745	0.8493
42	KAMAN_3	0.8610	0.8351
43	KAMAN_2	0.8586	0.8324
44	GMD_2	0.8381	0.8138
45	KAMAN_5	0.8374	0.8138
46	VALEN_2	0.8128	0.7990
47	IFAX	0.8113	0.7915
48	VALEN_1	0.8069	0.7839
49	KAMAN_4	0.7915	0.7646

Table 53: GMD_3 correlation graph key for digits.

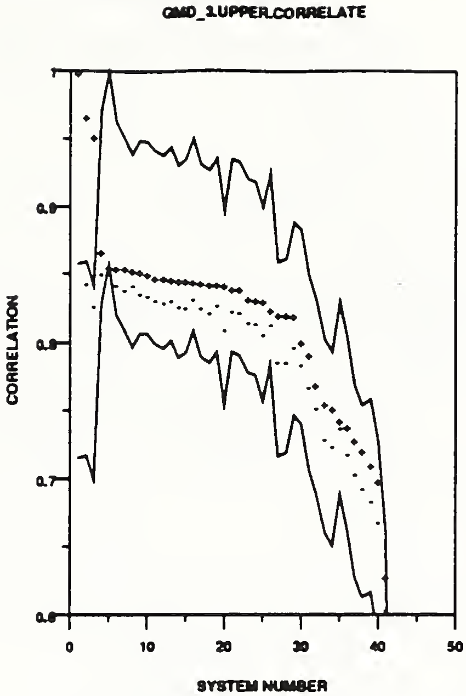

Figure 84: GMD_3 - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	GMD_3	1.0000	1.0000
2	GMD_1	0.9679	0.8446
3	GMD_4	0.9532	0.8280
4	VOTE_M	0.8689	0.8525
5	REFERENCE	0.8578	0.8578
6	AEG	0.8573	0.8444
7	ATT_4	0.8570	0.8401
8	VOTE_P	0.8547	0.8437
9	UMICH_1	0.8539	0.8372
10	ERIM_1	0.8519	0.8358
11	NESTOR	0.8497	0.8333
12	UBOL	0.8496	0.8308
13	ATT_2	0.8482	0.8333
14	KODAK_1	0.8478	0.8287
15	ATT_1	0.8474	0.8277
16	NYNEX	0.8467	0.8343
17	ATT_3	0.8457	0.8278
18	IBM	0.8453	0.8290
19	SYMBUS	0.8453	0.8240
20	NIST_4	0.8442	0.8113
21	HUGHES_1	0.8416	0.8250
22	HUGHES_2	0.8414	0.8238
23	GTESS_1	0.8341	0.8169
24	GTESS_2	0.8331	0.8158
25	MIME	0.8323	0.8076
26	OCRSYS	0.8259	0.8150
27	RISO	0.8220	0.7875
28	NIST_1	0.8215	0.7870
29	ASOL	0.8208	0.7981
30	REI	0.8015	0.7851
31	KAMAN_1	0.7927	0.7685
32	NIST_3	0.7705	0.7526
33	KAMAN_3	0.7564	0.7313
34	KAMAN_2	0.7535	0.7252
35	COMCOM	0.7452	0.7391
36	IFAX	0.7401	0.7196
37	NIST_2	0.7302	0.7050
38	GMD_2	0.7226	0.6947
39	VALEN_1	0.7117	0.6855
40	KAMAN_4	0.6998	0.6696
41	KAMAN_5	0.6286	0.6049
42	UMICH_2	0.0544	0.0149

Table 54: GMD_3 correlation graph key for uppers.

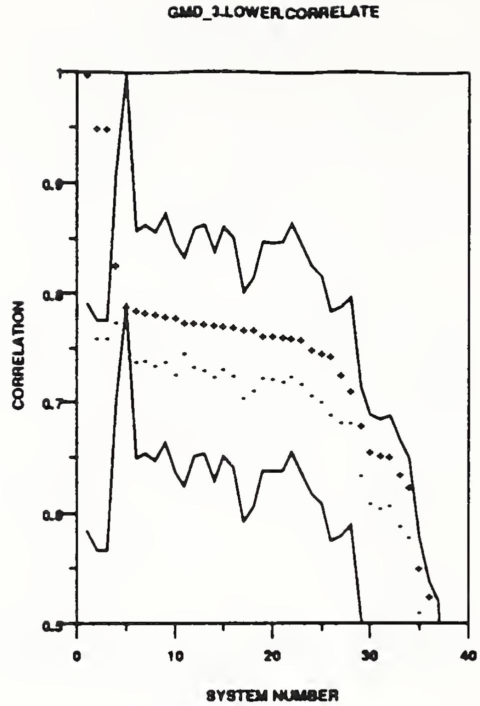

Figure 85: GMD_3 - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	GMD_3	1.0000	1.0000
2	GMD_4	0.9522	0.7613
3	GMD_1	0.9522	0.7613
4	VOTE_M	0.8292	0.7759
5	REFERENCE	0.7915	0.7915
6	ATT_4	0.7878	0.7390
7	ERIM_1	0.7855	0.7403
8	KODAK_1	0.7843	0.7362
9	AEG	0.7826	0.7391
10	UBOL	0.7809	0.7283
11	VOTE_P	0.7763	0.7477
12	ATT_2	0.7762	0.7352
13	ATT_1	0.7753	0.7320
14	ATT_3	0.7738	0.7260
15	NYNEX	0.7728	0.7327
16	UMICH_1	0.7713	0.7265
17	NIST_4	0.7698	0 7067
18	NIST_1	0.7692	0.7132
19	NESTOR	0.7642	0.7247
20	IBM	0.7636	0.7236
21	HUGHES_1	0.7629	0.7212
22	OCRSYS	0.7613	0.7256
23	HUGHES_2	0.7607	0.7190
24	GTESS_1	0.7515	0.7084
25	GTESS_2	0.7474	0.7032
26	RISO	0.7449	0.6917
27	ASOL	0.7283	0.6841
28	NIST_3	0.7129	0.6849
29	GMD_2	0.6822	0.6359
30	KAMAN_1	0.6584	0.6108
31	VALEN_1	0.6542	0.6062
32	NIST_2	0.6538	0.6083
33	KAMAN_3	0.6373	0.5907
34	KAMAN_2	0.6261	0.5800
35	KAMAN_5	0.5522	0.5116
36	KAMAN_4	0.5268	0.4839
37	COMCOM	0 4712	0.4594
38	UMICH_2	0.1073	0.0498

Table 55: GMD_3 correlation graph key for lowers.

SYSTEM: GMD_4

PARTICIPANT: Frank Smieja

ORGANIZATION: Gesellschaft fuer Mathematik und Datenverarbeitung
(GMD), Sankt Augustin, Germany

FEATURES: genetically optimized polynomial filter

CLASSIFICATION: statistical

HARDWARE: SPARC2

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	15000	22000	22000	NSDB3

STATUS: on time

RESULTS:	-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
	0.00	0.1016	0.00	0.1585	0.00	0.2254	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	1.18	0.48	0.40
CPU RATE:			

SYSTEM: GMD_4

BIBLIOGRAPHY:

The following references have been provided for this system:

[15][16]

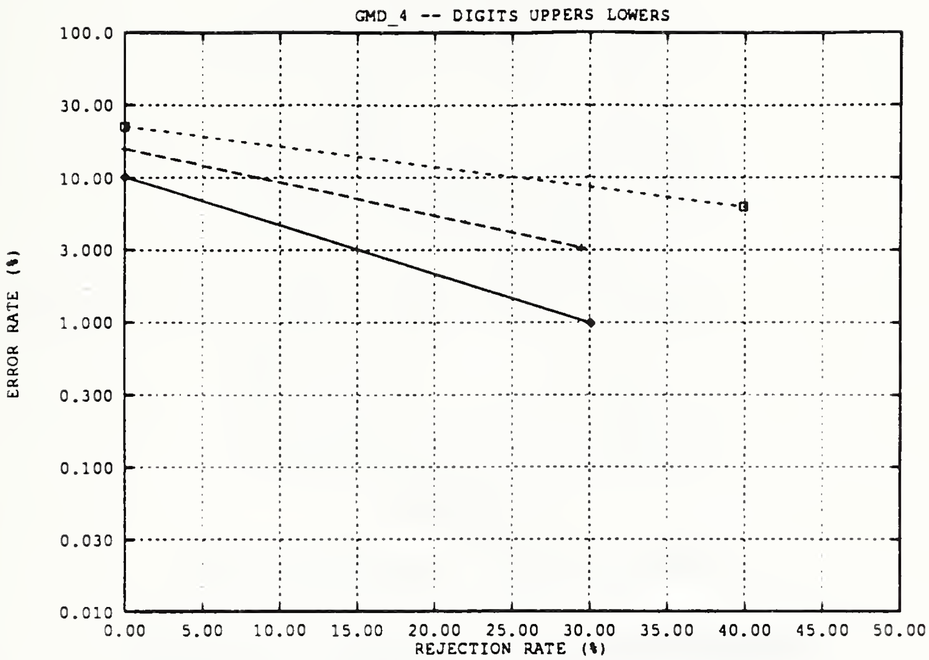

Figure 86: Error rate versus rejection rate for GMD_4

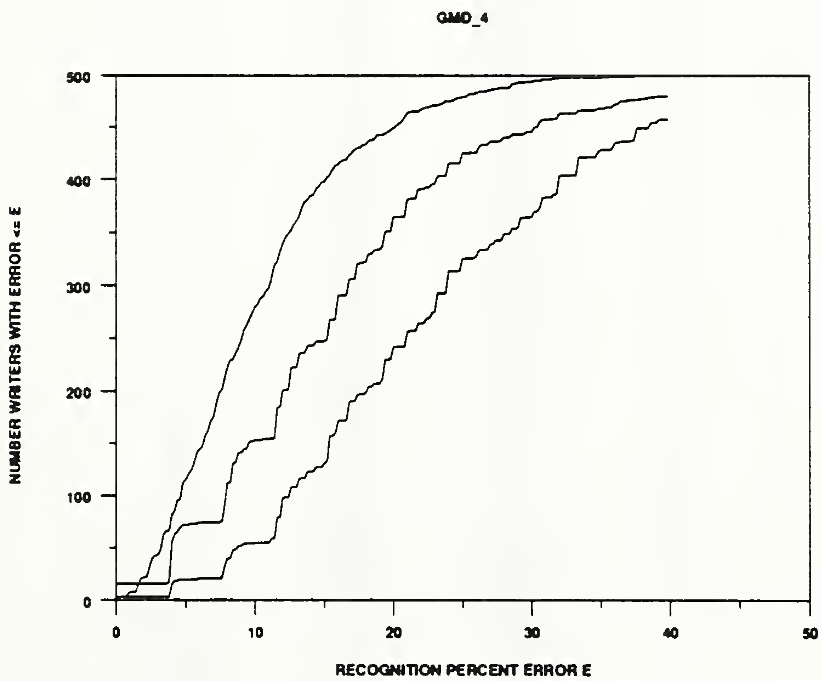

Figure 87: Error rate per writer of GMD_4

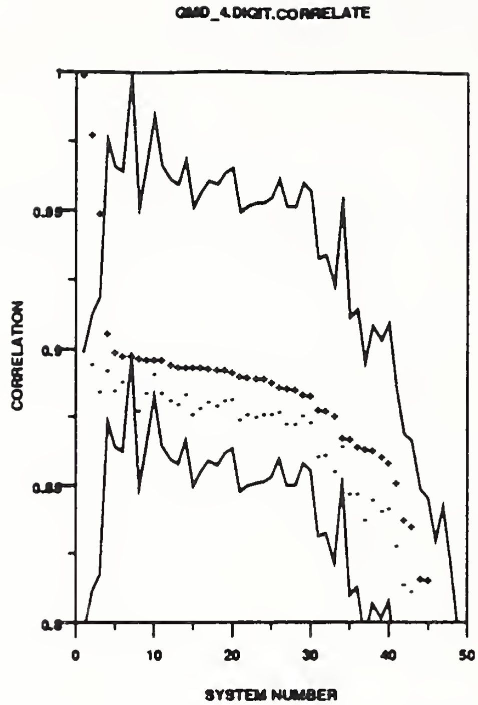

Figure 88: GMD_4 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	GMD_4	1.0000	1.0000
2	GMD_1	0.9786	0.8954
3	GMD_3	0.9498	0.8854
4	VOTE_M	0.9069	0.8930
5	AEG	0.8998	0.8858
6	VOTE_P	0.8988	0.8890
7	REFERENCE	0.8984	0.8984
8	NIST_4	0.8977	0.8783
9	ELSAGB_3	0.8972	0.8849
10	OCRSYS	0.8971	0.8918
11	ELSAGB_2	0.8970	0.8846
12	ERIM_1	0.8952	0.8821
13	ATT_1	0.8946	0.8843
14	KODAK_2	0.8946	0.8807
15	UBOL	0.8944	0.8792
16	THINK_1	0.8944	0.8771
17	ERIM_2	0.8942	0.8815
18	ATT_4	0.8935	0.8801
19	ATT_2	0.8933	0.8822
20	IBM	0.8928	0.8823
21	ELSAGB_1	0.8910	0.8751
22	ATT_3	0.8907	0.8768
23	SYMBUS	0.8904	0.8768
24	KODAK_1	0.8904	0.8760
25	NESTOR	0.8891	0.8769
26	THINK_2	0.8873	0.8778
27	HUGHES_1	0.8866	0.8740
28	HUGHES_2	0.8860	0.8738
29	REI	0.8844	0.8766
30	NYNEX	0.8840	0.8743
31	GTESS_2	0.8788	0.8620
32	GTESS_1	0.8783	0.8625
33	NIST_1	0.8763	0.8564
34	COMCOM	0.8686	0.8657
35	ASOL	0.8683	0.8479
36	MIME	0.8655	0.8480
37	RISO	0.8648	0.8382
38	NIST_2	0.8643	0.8456
39	NIST_3	0.8617	0.8417
40	UPENN	0.8594	0.8425
41	KAMAN_1	0.8520	0.8289
42	KAMAN_3	0.8384	0.8147
43	KAMAN_2	0.8363	0.8123
44	KAMAN_5	0.8170	0.7946
45	GMD_2	0.8165	0.7948
46	IFAX	0.7945	0.7744
47	VALEN_2	0.7944	0.7807
48	VALEN_1	0.7888	0.7662
49	KAMAN_4	0.7713	0.7463

Table 56: GMD_4 correlation graph key for digits.

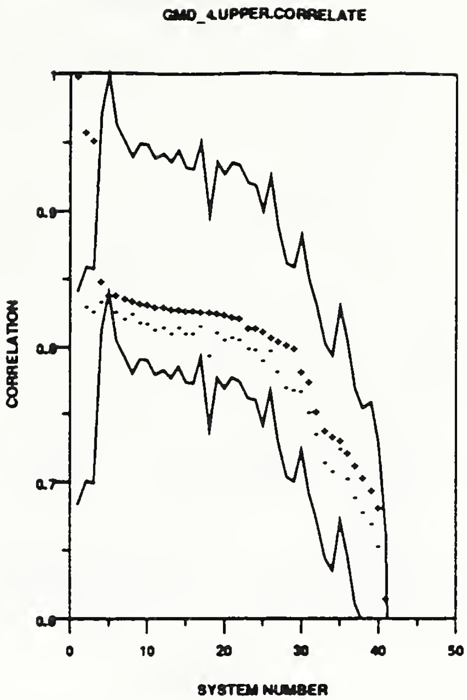

Figure 89: GMD_4 - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	GMD_4	1.0000	1.0000
2	GMD_1	0.9595	0.8318
3	GMD_3	0.9532	0.8280
4	VOTE_M	0.8513	0.8359
5	REFERENCE	0.8415	0.8415
6	AEG	0.8409	0.8282
7	ATT_4	0.8386	0.8230
8	VOTE_P	0.8369	0.8266
9	UMICH_1	0.8344	0.8197
10	ERIM_1	0.8341	0.8192
11	UBOL	0.8323	0.8144
12	NESTOR	0.8318	0.8166
13	ATT_1	0.8304	0.8115
14	ATT_2	0.8303	0.8164
15	ATT_3	0.8294	0.8119
16	KODAK_1	0.8292	0.8118
17	NYNEX	0.8288	0.8174
18	NIST_4	0.8282	0.7957
19	IBM	0.8277	0.8124
20	SYMBUS	0.8270	0.8070
21	HUGHES_1	0.8246	0.8089
22	HUGHES_2	0.8241	0.8076
23	GTESS_1	0.8166	0.8004
24	GTESS_2	0.8161	0.7996
25	MIME	0.8140	0.7913
26	OCRSYS	0.8090	0.7988
27	ASOL	0.8061	0.7836
28	NIST_1	0.8035	0.7711
29	RISO	0.8009	0.7697
30	REI	0.7834	0.7688
31	KAMAN_1	0.7763	0.7532
32	NIST_3	0.7542	0.7370
33	KAMAN_3	0.7406	0.7166
34	KAMAN_2	0.7360	0.7097
35	COMCOM	0.7324	0.7261
36	IFAX	0.7240	0.7042
37	NIST_2	0.7142	0.6904
38	GMD_2	0.7051	0.6796
39	VALEN_1	0.6965	0.6716
40	KAMAN_4	0.6836	0.6550
41	KAMAN_5	0.6171	0.5928
42	UMICH_2	0.0605	0.0159

Table 57: GMD_4 correlation graph key for uppers.

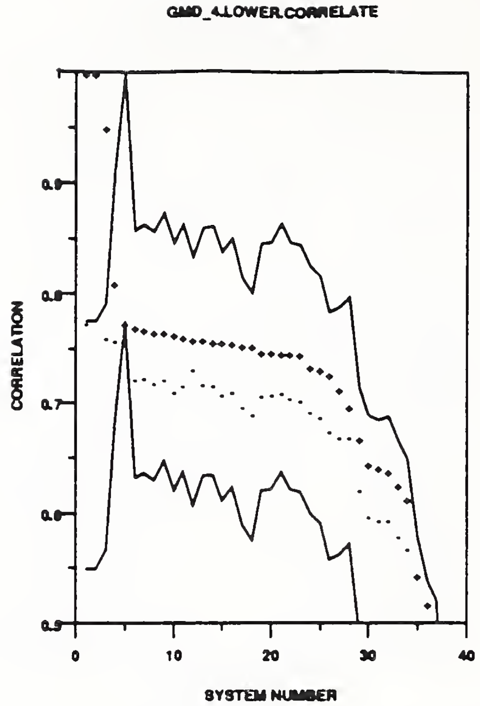

Figure 90: GMD_4 - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	GMD_4	1.0000	1.0000
2	GMD_1	1.0000	0.7746
3	GMD_3	0.9522	0.7613
4	VOTE_M	0.8117	0.7591
5	REFERENCE	0.7746	0.7746
6	ATT_4	0.7718	0.7232
7	ERIM_1	0.7693	0.7247
8	KODAK_1	0.7673	0.7199
9	AEG	0.7668	0.7235
10	UBOL	0.7644	0.7122
11	ATT_1	0.7623	0.7176
12	VOTE_P	0.7602	0.7325
13	ATT_2	0.7597	0.7193
14	NYNEX	0.7582	0.7182
15	ATT_3	0.7574	0.7100
16	UMICH_1	0.7571	0.7117
17	NIST_1	0.7542	0.6981
18	NIST_4	0.7541	0.6915
19	IBM	0.7489	0.7088
20	NESTOR	0.7485	0.7095
21	OCRSYS	0.7473	0.7110
22	HUGHES_1	0.7472	0.7057
23	HUGHES_2	0.7459	0.7040
24	GTESS_1	0.7352	0.6931
25	GTESS_2	0.7327	0.6888
26	RISO	0.7285	0.6765
27	ASOL	0.7146	0.6706
28	NIST_3	0.6983	0.6709
29	GMD_2	0.6692	0.6226
30	KAMAN_1	0.6470	0.5987
31	VALEN_1	0.6428	0.5945
32	NIST_2	0.6395	0.5954
33	KAMAN_3	0.6270	0.5795
34	KAMAN_2	0.6148	0.5684
35	KAMAN_5	0.5438	0.5020
36	KAMAN_4	0.5192	0.4757
37	COMCOM	0.4622	0.4513
38	UMICH_2	0.1098	0.0478

Table 58: GMD_4 correlation graph key for lowers.

SYSTEM: GTESS_1

PARTICIPANT: Dr. Vadim Anshelevich

ORGANIZATION: GTESS CORPORATION, Richardson, TX

PREPROCESSING: size normalization, deskewing, and dimension reduction.

FEATURES: vectors from non-linear transformations, result is 200-400 dimensional vector.

CLASSIFICATION: MLP, training performed with variant of perceptron training algorithm modified for feed-forward network.

HARDWARE: 50 MHz 486

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	1/4	3/4	3/4	NSDB3
	4983 ~70	8217 ~70	7103 ~70	INTERNAL writers

STATUS: on time, corrected CON files 9 days late

RESULTS: -- DIGITS -- -- UPPERS -- -- LOWERS -- DATABASE

REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
0.00	0.0659	0.00	0.0801	0.00	0.1753	
0.10	0.0284	0.10	0.0374	0.10	0.1296	
0.20	0.0202	0.20	0.0186	0.20	0.0918	
0.30	0.0202	0.30	0.0169	0.30	0.0613	
0.40	0.0205	0.40	0.0167	0.40	0.0575	
0.50	0.0210	0.50	0.0172	0.50	0.0580	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	15.51	3.43	3.51
CPU RATE:			

SYSTEM: GTESS_1

BIBLIOGRAPHY:

The following references have been provided for this system:

none

COMMENTS: GTESS

COMPANY INFORMATION

GTESS Corporation was founded in January, 1991. It currently employs 6 people and is in the business of providing inexpensive PC-based hand print and machine print form recognition systems. Areas of interest are: character recognition, character segmentation, form pre-processing, form post-processing (context), case independence (lower/upper), style independence (machine/hand).

RECOGNITION TECHNOLOGY DESCRIPTION SUMMARY

We use a two stage isolated character recognition engine composed of 1) reduction and normalization 2) neural classification

Instead of back propagation, we use a modified perceptron training algorithm which allows us to retrain our network in a matter of hours rather than weeks. Training and production algorithms do not require floating point, are portable, run on PC platforms without special hardware and recognize at the rate of 10-100 characters/sec on a 50 MHz 486, depending upon the alphabet. Inexpensive DSP implementations are also being developed for high performance systems.

INTERPRETATION OF NIST CONFERENCE RESULTS

We feel that our current algorithms offer an attractive compromise between reliability of recognition and economy of implementation. The Conference results indicate to us that we are able to achieve one of the best overall reliability recognition rates among the participants which relied only on NIST supplied training data.

PRODUCTS

Within the next few months, GTESS will start distributing two products:

1) A PC-based, all software form recognition subsystem;

2) A field recognition engine under Windows 3.x to be used in form processing applications.

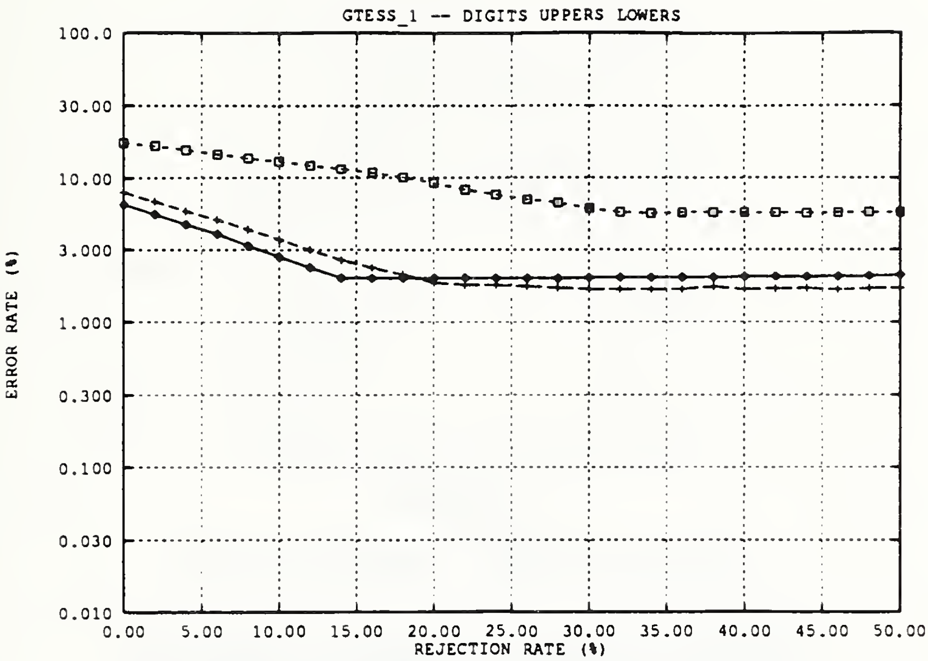

Figure 91: Error rate versus rejection rate for GTESS_1

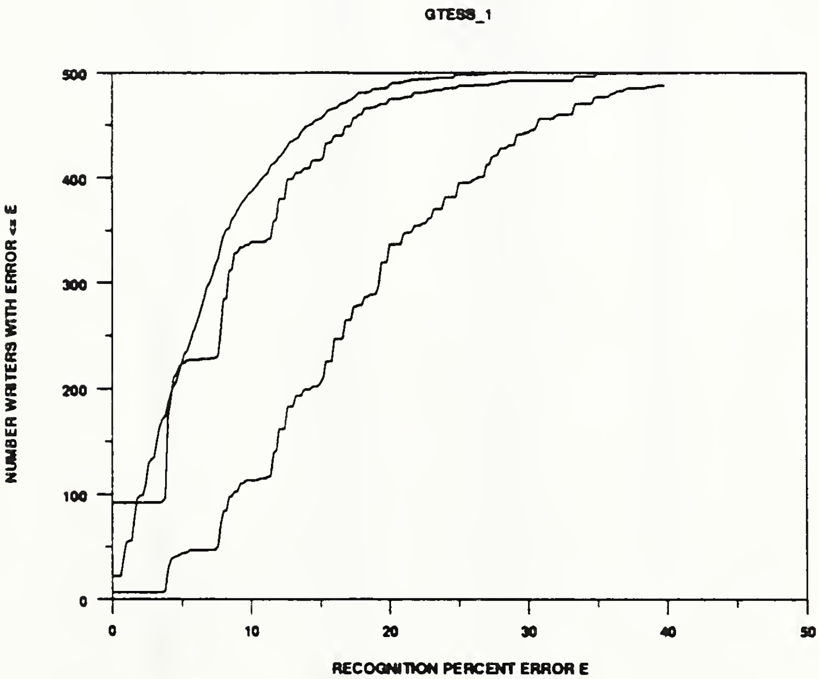

Figure 92: Error rate per writer of GTESS_1

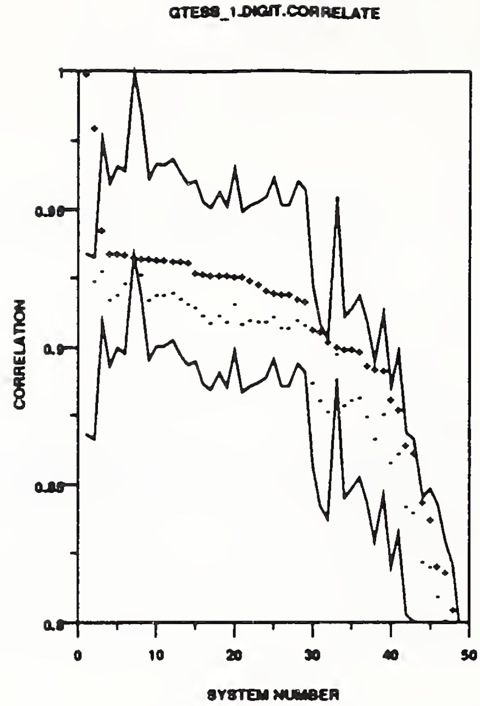

Figure 93: GTESS_1 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	GTESS_1	1.0000	1.0000
2	GTESS_2	0.9806	0.9250
3	VOTE_M	0.9435	0.9287
4	ATT_4	0.9355	0.9181
5	AEG	0.9352	0.9203
6	VOTE_P	0.9347	0.9244
7	REFERENCE	0.9341	0.9341
8	OCRSYS	0.9336	0.9277
9	ERIM_1	0.9334	0.9182
10	ELSAGB_3	0.9330	0.9203
11	ELSAGB_2	0.9328	0.9200
12	ATT_1	0.9327	0.9209
13	ATT_2	0.9325	0.9186
14	KODAK_2	0.9322	0.9170
15	ERIM_2	0.9283	0.9155
16	KODAK_1	0.9279	0.9126
17	NIST_4	0.9277	0.9101
18	UBOL	0.9276	0.9129
19	THINK_1	0.9273	0.9107
20	IBM	0.9272	0.9170
21	ELSAGB_1	0.9270	0.9097
22	ATT_3	0.9259	0.9111
23	SYMBUS	0.9243	0.9105
24	NESTOR	0.9222	0.9107
25	THINK_2	0.9213	0.9124
26	HUGHES_1	0.9207	0.9081
27	HUGHES_2	0.9207	0.9080
28	REI	0.9188	0.9109
29	NYNEX	0.9179	0.9093
30	NIST_1	0.9077	0.8882
31	NIST_2	0.9068	0.8816
32	NIST_3	0.9032	0.8773
33	COMCOM	0.9013	0.8986
34	ASOL	0.9006	0.8799
35	MIME	0.9004	0.8814
36	GMD_3	0.8996	0.8825
37	UPENN	0.8945	0.8754
38	RISO	0.8929	0.8677
39	GMD_1	0.8924	0.8764
40	KAMAN_1	0.8821	0.8593
41	GMD_4	0.8783	0.8625
42	KAMAN_3	0.8653	0.8432
43	KAMAN_2	0.8626	0.8406
44	GMD_2	0.8450	0.8226
45	KAMAN_5	0.8382	0.8211
46	VALEN_2	0.8212	0.8102
47	IFAX	0.8192	0.8015
48	VALEN_1	0.8058	0.7899
49	KAMAN_4	0.7946	0.7713

Table 59: GTESS_1 correlation graph key for digits.

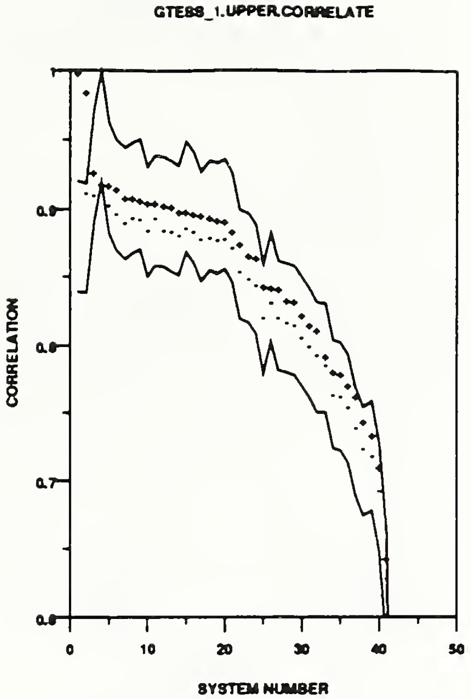

Figure 94: GTESS_1 - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	GTESS_1	1.0000	1.0000
2	GTESS_2	0.9864	0.9139
3	VOTE_M	0.9286	0.9119
4	REFERENCE	0.9199	0.9199
5	AEG	0.9189	0.9042
6	ATT_4	0.9168	0.8981
7	ERIM_1	0.9101	0.8950
8	ATT_2	0.9101	0.8921
9	NYNEX	0.9079	0.8942
10	KODAK_1	0.9064	0.8864
11	VOTE_P	0.9063	0.8959
12	UBOL	0.9044	0.8865
13	ATT_1	0.9034	0.8855
14	ATT_3	0.9005	0.8824
15	UMICH_1	0.8997	0.8883
16	NESTOR	0.8985	0.8855
17	SYMBUS	0.8977	0.8794
18	HUGHES_1	0.8956	0.8812
19	HUGHES_2	0.8940	0.8791
20	IBM	0.8926	0.8802
21	OCRSYS	0.8858	0.8737
22	MIME	0.8764	0.8558
23	NIST_4	0.8683	0.8501
24	ASOL	0.8662	0.8462
25	RISO	0.8449	0.8219
26	REI	0.8442	0.8327
27	NIST_1	0.8429	0.8217
28	GMD_1	0.8350	0.8186
29	GMD_3	0.8341	0.8169
30	KAMAN_1	0.8240	0.8076
31	GMD_4	0.8166	0.8004
32	NIST_3	0.8125	0.7944
33	COMCOM	0.7931	0.7875
34	IFAX	0.7822	0.7649
35	KAMAN_3	0.7807	0.7643
36	KAMAN_2	0.7725	0.7554
37	NIST_2	0.7643	0.7414
38	GMD_2	0.7459	0.7253
39	VALEN_1	0.7357	0.7196
40	KAMAN_4	0.7116	0.6939
41	KAMAN_5	0.6443	0.6303
42	UMICH_2	0.0497	0.0231

Table 60: GTESS_1 correlation graph key for uppers.

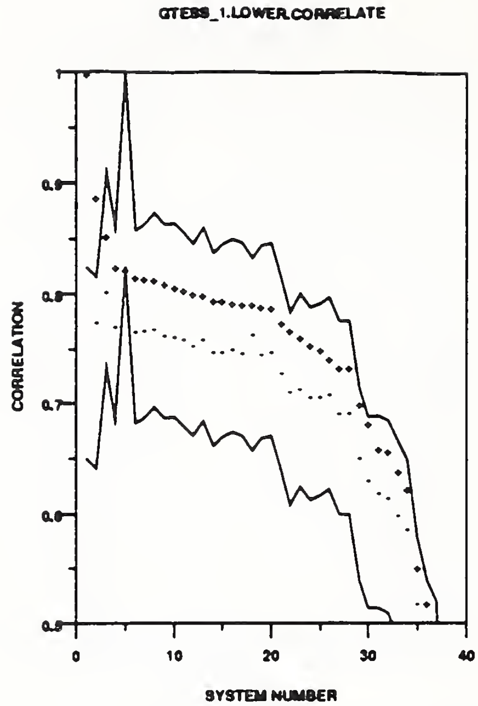

Figure 95: GTESS_1 - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	GTESS_1	1.0000	1.0000
2	GTESS_2	0.8892	0.7779
3	VOTE_M	0.8547	0.8048
4	ATT_2	0.8267	0.7734
5	REFERENCE	0.8248	0.8248
6	ATT_4	0.8176	0.7678
7	ERIM_1	0.8167	0.7691
8	AEG	0.8148	0.7702
9	ATT_1	0.8114	0.7647
10	OCRSYS	0.8083	0.7641
11	KODAK_1	0.8058	0.7612
12	IBM	0.8023	0.7556
13	NYNEX	0.8015	0.7619
14	ATT_3	0.7972	0.7496
15	UBOL	0.7965	0.7504
16	UMICH_1	0.7943	0.7517
17	HUGHES_1	0.7937	0.7493
18	VOTE_P	0.7931	0.7662
19	HUGHES_2	0.7917	0.7473
20	NESTOR	0.7898	0.7498
21	NIST_1	0.7763	0.7307
22	RISO	0.7690	0.7131
23	NIST_4	0.7628	0.7153
24	ASOL	0.7561	0.7084
25	GMD_3	0.7515	0.7084
26	NIST_3	0.7429	0.7107
27	GMD_4	0.7352	0.6931
28	GMD_1	0.7352	0.6931
29	GMD_2	0.7016	0.6537
30	NIST_2	0.6843	0.6331
31	KAMAN_1	0.6619	0.6208
32	VALEN_1	0.6587	0.6168
33	KAMAN_3	0.6413	0.6007
34	KAMAN_2	0.6245	0.5880
35	KAMAN_5	0.5527	0.5203
36	KAMAN_4	0.5203	0.4888
37	COMCOM	0.4873	0.4757
38	UMICH_2	0.1026	0.0518

Table 61: GTESS_1 correlation graph key for lowers.

SYSTEM: GTESS_2

PARTICIPANT: Dr. Vadim Anshelevich

ORGANIZATION: GTESS CORPORATION, Richardson, TX

FEATURES: vectors from non-linear transformations

CLASSIFICATION: MLP

HARDWARE: 50 MHz 486

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	1/4	3/4	3/4	NSDB3
	4983 ~70	8217 ~70	7103 ~70	INTERNAL writers

STATUS: on time, corrected CON files 9 days late

RESULTS: -- DIGITS -- -- UPPERS -- -- LOWERS -- DATABASE

DIGITS REJ. RATE	DIGITS ERR. RATE--	UPPERS REJ. RATE	UPPERS ERR. RATE--	LOWERS REJ. RATE	LOWERS ERR. RATE--	TESTDATA1
0.00	0.0675	0.00	0.0814	0.00	0.1842	
0.10	0.0301	0.10	0.0381	0.10	0.1358	
0.20	0.0188	0.20	0.0198	0.20	0.0992	
0.30	0.0189	0.30	0.0176	0.30	0.0684	
0.40	0.0194	0.40	0.0173	0.40	0.0515	
0.50	0.0203	0.50	0.0176	0.50	0.0522	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	18.80	3.37	3.39
CPU RATE:			

SYSTEM: GTESS_2

BIBLIOGRAPHY:

The following references have been provided for this system:

none

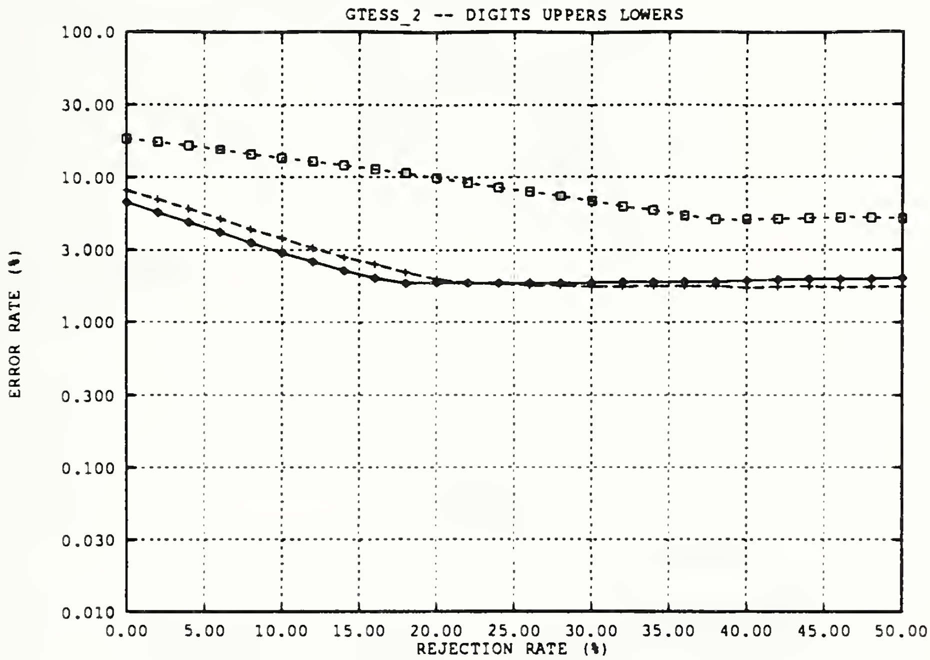

Figure 96: Error rate versus rejection rate for GTESS_2

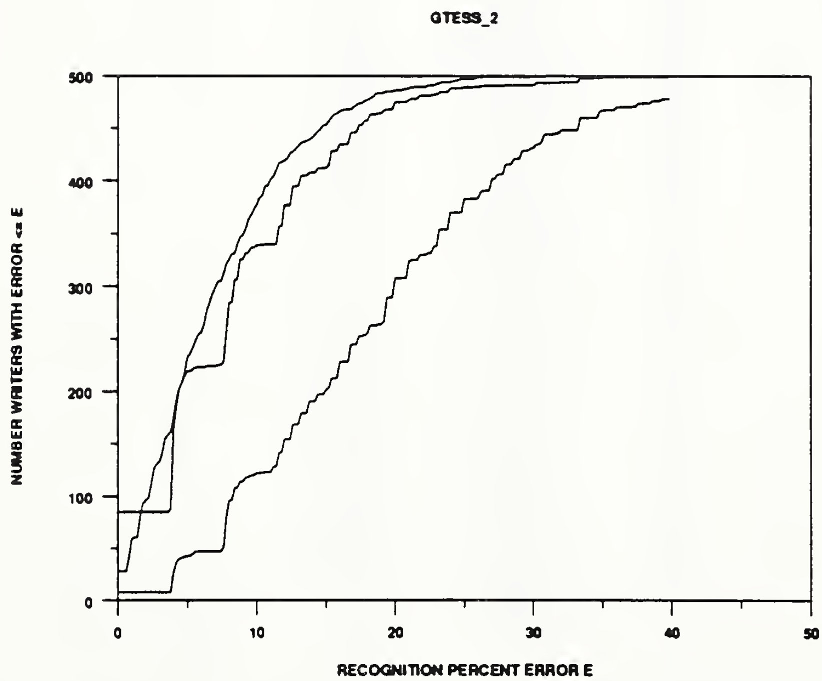

Figure 97: Error rate per writer of GTESS_2

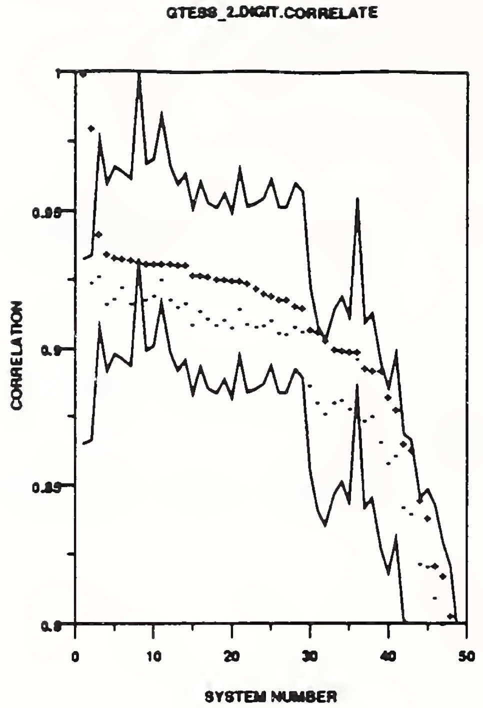

Figure 98: GTESS_2 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	GTESS_2	1.0000	1.0000
2	GTESS_1	0.9806	0.9250
3	VOTE_M	0.9429	0.9277
4	ATT_4	0.9356	0.9175
5	AEG	0.9346	0.9193
6	VOTE_P	0.9341	0.9234
7	ERIM_1	0.9333	0.9175
8	REFERENCE	0.9325	0.9325
9	ATT_1	0.9322	0.9200
10	ELSAGB_3	0.9322	0.9189
11	OCRSYS	0.9320	0.9261
12	ELSAGB_2	0.9319	0.9186
13	ATT_2	0.9318	0.9176
14	KODAK_2	0.9318	0.9162
15	ERIM_2	0.9280	0.9147
16	NIST_4	0.9280	0.9096
17	KODAK_1	0.9275	0.9119
18	THINK_1	0.9268	0.9098
19	UBOL	0.9265	0.9116
20	ELSAGB_1	0.9263	0.9087
21	IBM	0.9262	0.9157
22	ATT_3	0.9252	0.9101
23	SYMBUS	0.9234	0.9093
24	NESTOR	0.9215	0.9096
25	THINK_2	0.9206	0.9113
26	HUGHES_1	0.9193	0.9067
27	HUGHES_2	0.9192	0.9066
28	REI	0.9169	0.9092
29	NYNEX	0.9159	0.9074
30	NIST_1	0.9080	0.8876
31	NIST_2	0.9071	0.8810
32	NIST_3	0.9043	0.8772
33	MIME	0.9007	0.8809
34	GMD_3	0.9002	0.8821
35	ASOL	0.9001	0.8790
36	COMCOM	0.9000	0.8972
37	UPENN	0.8941	0.8748
38	GMD_1	0.8931	0.8761
39	RISO	0.8930	0.8669
40	KAMAN_1	0.8833	0.8593
41	GMD_4	0.8788	0.8620
42	KAMAN_3	0.8662	0.8432
43	KAMAN_2	0.8642	0.8408
44	GMD_2	0.8457	0.8225
45	KAMAN_5	0.8392	0.8212
46	VALEN_2	0.8220	0.8102
47	IFAX	0.8183	0.8007
48	VALEN_1	0.8040	0.7884
49	KAMAN_4	0.7963	0.7715

Table 62: GTESS_2 correlation graph key for digits.

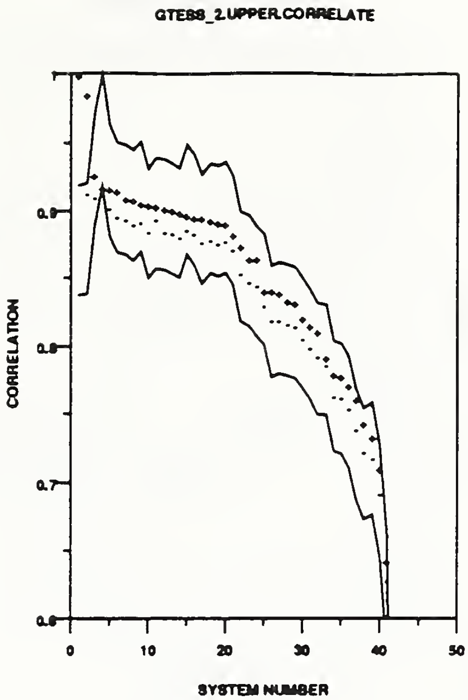

Figure 99: GTESS_2 - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	GTESS_2	1.0000	1.0000
2	GTESS_1	0.9864	0.9139
3	VOTE_M	0.9274	0.9107
4	REFERENCE	0.9186	0.9186
5	AEG	0.9172	0.9024
6	ATT_4	0.9157	0.8967
7	ERIM_1	0.9101	0.8942
8	ATT_2	0.9091	0.8912
9	NYNEX	0.9065	0.8928
10	KODAK_1	0.9060	0.8854
11	VOTE_P	0.9044	0.8943
12	UBOL	0.9031	0.8849
13	ATT_1	0.9017	0.8841
14	ATT_3	0.8999	0.8815
15	UMICH_1	0.8986	0.8869
16	NESTOR	0.8968	0.8840
17	SYMBUS	0.8965	0.8781
18	HUGHES_1	0.8946	0.8798
19	HUGHES_2	0.8924	0.8775
20	IBM	0.8914	0.8791
21	OCRSYS	0.8839	0.8723
22	MIME	0.8751	0.8546
23	NIST_4	0.8663	0.8488
24	ASOL	0.8658	0.8455
25	REI	0.8426	0.8312
26	RISO	0.8425	0.8204
27	NIST_1	0.8404	0.8203
28	GMD_1	0.8345	0.8178
29	GMD_3	0.8331	0.8158
30	KAMAN_1	0.8223	0.8065
31	GMD_4	0.8161	0.7996
32	NIST_3	0.8117	0.7934
33	COMCOM	0.7930	0.7870
34	IFAX	0.7808	0.7640
35	KAMAN_3	0.7792	0.7633
36	KAMAN_2	0.7722	0.7546
37	NIST_2	0.7625	0.7406
38	GMD_2	0.7450	0.7239
39	VALEN_1	0.7350	0.7187
40	KAMAN_4	0.7117	0.6933
41	KAMAN_5	0.6434	0.6294
42	UMICH_2	0.0491	0.0229

Table 63: GTESS_2 correlation graph key for uppers.

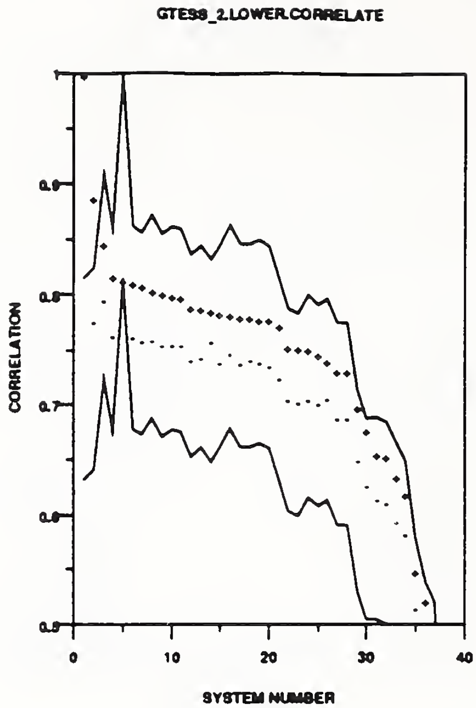

Figure 100: GTESS_2 - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	GTESS_2	1.0000	1.0000
2	GTESS_1	0.8892	0.7779
3	VOTE_M	0.8470	0.7965
4	ATT_2	0.8184	0.7652
5	REFERENCE	0.8158	0.8158
6	ERIM_1	0.8125	0.7641
7	ATT_4	0.8112	0.7605
8	AEG	0.8067	0.7617
9	KODAK_1	0.8040	0.7573
10	ATT_1	0.8018	0.7563
11	NYNEX	0.8000	0.7570
12	ATT_3	0.7918	0.7431
13	IBM	0.7900	0.7456
14	VOTE_P	0.7878	0.7601
15	UBOL	0.7851	0.7410
16	OCRSYS	0.7843	0.7483
17	NESTOR	0.7822	0.7429
18	HUGHES_1	0.7822	0.7393
19	UMICH_1	0.7799	0.7407
20	HUGHES_2	0.7796	0.7370
21	NIST_1	0.7740	0.7262
22	ASOL	0.7547	0.7058
23	RISO	0.7538	0.7039
24	NIST_4	0.7523	0.7067
25	GMD_3	0.7474	0.7032
26	NIST_3	0.7413	0.7079
27	GMD_4	0.7327	0.6888
28	GMD_1	0.7327	0.6888
29	GMD_2	0.6992	0.6507
30	NIST_2	0.6783	0.6279
31	KAMAN_1	0.6571	0.6157
32	VALEN_1	0.6550	0.6117
33	KAMAN_3	0.6363	0.5949
34	KAMAN_2	0.6198	0.5828
35	KAMAN_5	0.5490	0.5156
36	KAMAN_4	0.5224	0.4880
37	COMCOM	0.4830	0.4712
38	UMICH_2	0.1070	0.0542

Table 64: GTESS_2 correlation graph key for lowers.

SYSTEM: HUGHES_1

PARTICIPANT: Tony Baraghimian

ORGANIZATION: Hughes Aircraft Company, Canoga Park, CA

FEATURES: ?

CLASSIFICATION: fusion of results of multiple nonparametric algorithms (neocognitron)

HARDWARE: single Intel i860 in a Datacube computer

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	10000	7800	7800	NSDB3

STATUS: on time

RESULTS:	-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
	0.00	0.0484	0.00	0.0646	0.00	0.1539	
	0.10	0.0173	0.10	0.0301	0.10	0.1129	
	0.20	0.0064	0.20	0.0169	0.20	0.0806	
	0.30	0.0036	0.30	0.0105	0.30	0.0529	
	0.40	0.0022	0.40	0.0071	0.40	0.0362	
	0.50	0.0015	0.50	0.0055	0.50	0.0270	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:			
CPU RATE:	21.00	19.00	19.00

NOTE: proprietary architecture using a neural net classifier. Few details of recognition algorithm provided.

SYSTEM: HUGHES_1

BIBLIOGRAPHY:

The following references have been provided for this system:

[19]

COMMENTS: HUGHES

HUGHES Recognition Systems brings complete document image processing solutions based on its proven success in advanced imaging and recognition technology. We provide a wide range of technology, solutions, and services from system analysis through system integration, training, and support.

HUGHES develops sophisticated subsystem solutions easily tailorable to your application for pre-processing, intelligent recognition, contextual analysis, and more. We accommodate image lift from a variety of sources directly into our pre-processing subcomponent. We apply unique pre-processing techniques such as image quality control, registration, and enhancement, as well as form identification, suppression, and field isolation. The result feeds immediately into HIGHES' intelligent recognition subcomponent, or any other you provide. With technologies such as artificial networks and fuzzy logic, our pre-processing in concert with our intelligent recognizer provides maximum performance. The flexible pre-processing also enables higher performance of your own recognition system. Further enhancements to recognition performance is accomplished by contextual analysis in our post-processing subcomponent.

We also offer traditional subsystems for image acquisition, format conversion, work flow, forms editing, image storage, and much more.

HUGHES Recognition Systems participating in the First Census OCR Systems Conference in May 1992. Our test results were highly competitive, among the top performing group of participants.

For more information, please contact Tony Baraghimian at (818) 702-1580.

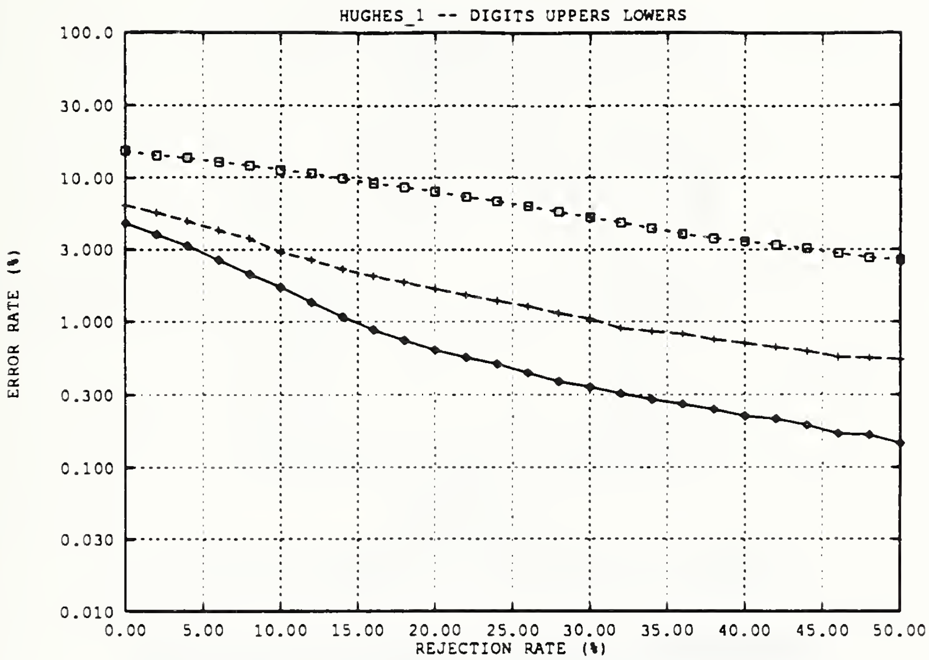

Figure 101: Error rate versus rejection rate for HUGHES_1

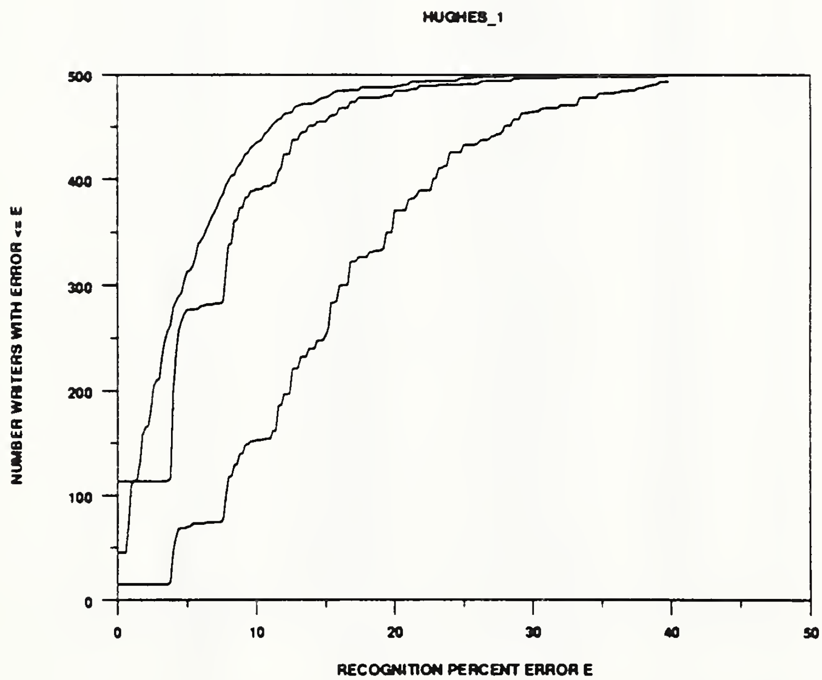

Figure 102: Error rate per writer of HUGHES_1

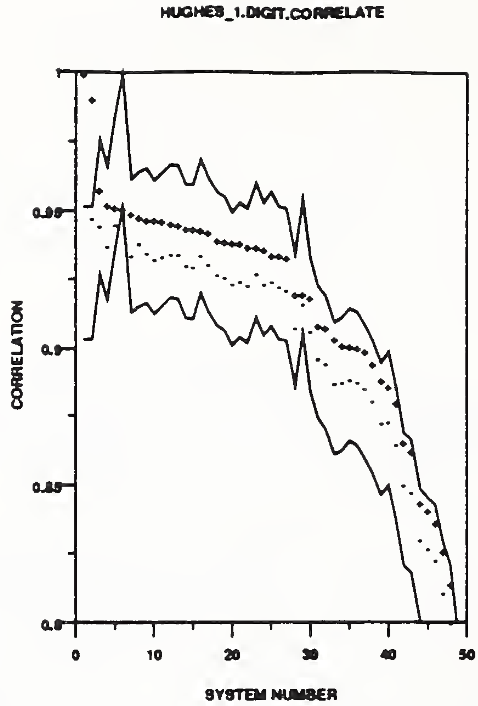

Figure 103: HUGHES_1 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	HUGHES_1	1.0000	1.0000
2	HUGHES_2	0.9915	0.9479
3	VOTE_M	0.9583	0.9448
4	AEG	0.9526	0.9378
5	OCRSYS	0.9520	0.9453
6	REFERENCE	0.9516	0.9516
7	ERIM_1	0.9495	0.9345
8	VOTE_P	0.9483	0.9385
9	IBM	0.9474	0.9351
10	ERIM_2	0.9473	0.9329
11	ATT_2	0.9468	0.9341
12	ELSAGB_3	0.9457	0.9350
13	ELSAGB_2	0.9453	0.9347
14	KODAK_2	0.9442	0.9306
15	ATT_4	0.9439	0.9305
16	ATT_1	0.9435	0.9342
17	THINK_2	0.9426	0.9311
18	UBOL	0.9401	0.9275
19	NESTOR	0.9393	0.9268
20	ELSAGB_1	0.9392	0.9243
21	KODAK_1	0.9388	0.9251
22	REI	0.9377	0.9282
23	NIST_4	0.9377	0.9237
24	SYMBUS	0.9366	0.9242
25	NYNEX	0.9349	0.9250
26	ATT_3	0.9347	0.9235
27	THINK_1	0.9341	0.9220
28	GTESS_1	0.9207	0.9081
29	COMCOM	0.9206	0.9170
30	GTESS_2	0.9193	0.9067
31	NIST_1	0.9091	0.8966
32	GMD_3	0.9082	0.8947
33	UPENN	0.9043	0.8877
34	ASOL	0.9018	0.8878
35	MIME	0.9014	0.8890
36	GMD_1	0.9010	0.8881
37	NIST_2	0.8995	0.8857
38	NIST_3	0.8949	0.8811
39	RISO	0.8890	0.8732
40	GMD_4	0.8866	0.8740
41	KAMAN_1	0.8805	0.8655
42	KAMAN_3	0.8664	0.8508
43	KAMAN_2	0.8631	0.8480
44	KAMAN_5	0.8443	0.8304
45	GMD_2	0.8416	0.8275
46	VALEN_2	0.8371	0.8234
47	IFAX	0.8266	0.8115
48	VALEN_1	0.8144	0.8003
49	KAMAN_4	0.7894	0.7760

Table 65: HUGHES_1 correlation graph key for digits.

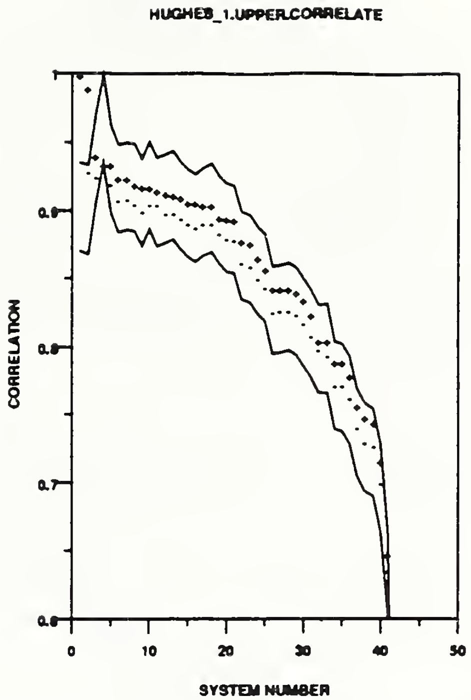

Figure 104: HUGHES_1 - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	HUGHES_1	1.0000	1.0000
2	HUGHES_2	0.9907	0.9296
3	VOTE_M	0.9411	0.9254
4	REFERENCE	0.9354	0.9354
5	AEG	0.9348	0.9198
6	ERIM_1	0.9252	0.9083
7	ATT_4	0.9245	0.9088
8	UMICH_1	0.9199	0.9056
9	UBOL	0.9188	0.8997
10	NYNEX	0.9182	0.9060
11	VOTE_P	0.9158	0.9055
12	NESTOR	0.9140	0.8991
13	ATT_2	0.9131	0.8995
14	IBM	0.9114	0.8959
15	KODAK_1	0.9073	0.8917
16	SYMBUS	0.9070	0.8893
17	ATT_3	0.9056	0.8916
18	ATT_1	0.9053	0.8921
19	OCRSYS	0.8967	0.8848
20	GTESS_1	0.8956	0.8812
21	GTESS_2	0.8946	0.8798
22	MIME	0.8793	0.8631
23	NIST_4	0.8774	0.8602
24	ASOL	0.8673	0.8518
25	REI	0.8591	0.8447
26	RISO	0.8443	0.8263
27	GMD_1	0.8442	0.8272
28	NIST_1	0.8439	0.8275
29	GMD_3	0.8416	0.8250
30	KAMAN_1	0.8361	0.8184
31	GMD_4	0.8246	0.8089
32	COMCOM	0.8053	0.7986
33	NIST_3	0.8051	0.7947
34	IFAX	0.7898	0.7727
35	KAMAN_3	0.7894	0.7728
36	KAMAN_2	0.7798	0.7633
37	NIST_2	0.7573	0.7421
38	VALEN_1	0.7496	0.7309
39	GMD_2	0.7457	0.7283
40	KAMAN_4	0.7174	0.7010
41	KAMAN_5	0.6481	0.6360
42	UMICH_2	0.0458	0.0204

Table 66: HUGHES_1 correlation graph key for uppers.

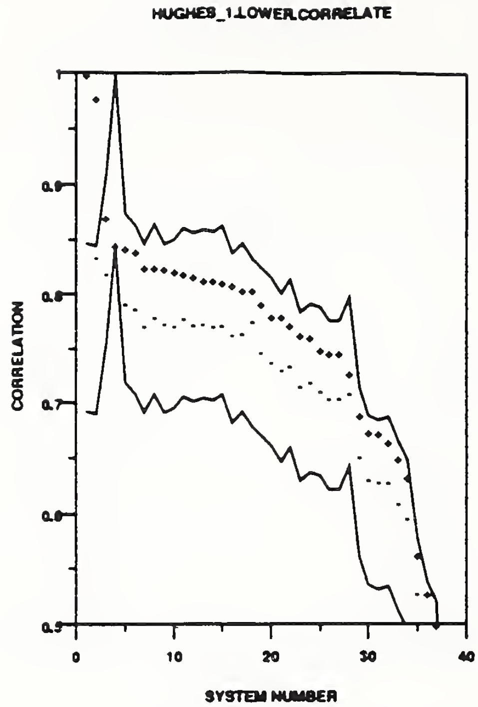

Figure 105: HUGHES_1 - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	HUGHES_1	1.0000	1.0000
2	HUGHES_2	0.9800	0.8363
3	VOTE_M	0.8715	0.8215
4	REFERENCE	0.8461	0.8461
5	AEG	0.8440	0.7933
6	ERIM_1	0.8404	0.7893
7	UBOL	0.8273	0.7732
8	OCRSYS	0.8267	0.7810
9	IBM	0.8252	0.7747
10	UMICH_1	0.8232	0.7732
11	NYNEX	0.8209	0.7795
12	KODAK_1	0.8183	0.7738
13	ATT_2	0.8154	0.7747
14	ATT_4	0.8153	0.7734
15	ATT_1	0.8129	0.7738
16	ATT_3	0.8108	0.7648
17	NESTOR	0.8062	0.7664
18	VOTE_P	0.8056	0.7771
19	GTESS_1	0.7937	0.7493
20	GTESS_2	0.7822	0.7393
21	NIST_4	0.7817	0.7323
22	NIST_1	0.7744	0.7364
23	RISO	0.7647	0.7173
24	GMD_3	0.7629	0.7212
25	ASOL	0.7512	0.7128
26	GMD_4	0.7472	0.7057
27	GMD_1	0.7472	0.7057
28	NIST_3	0.7293	0.7105
29	GMD_2	0.6917	0.6536
30	KAMAN_1	0.6762	0.6332
31	VALEN_1	0.6757	0.6309
32	NIST_2	0.6675	0.6302
33	KAMAN_3	0.6525	0.6112
34	KAMAN_2	0.6351	0.5970
35	KAMAN_5	0.5642	0.5293
36	KAMAN_4	0.5293	0.4966
37	COMCOM	0.5004	0.4886
38	UMICH_2	0.1015	0.0514

Table 67: HUGHES_1 correlation graph key for lowers.

SYSTEM: HUGHES_2

PARTICIPANT: Tony Baraghimian

ORGANIZATION: Hughes Aircraft Company, Missiles Systems Group,
Canoga Park, CA

FEATURES:

CLASSIFICATION: fusion of results of multiple nonparametric
algorithms (neocognitron)

HARDWARE: single Intel i860 in a Datacube computer

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	NIST SPECIAL DATABASE 3			
	10000	7800	7800	random

STATUS: on time

RESULTS:	-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
	0.00	0.0486	0.00	0.0673	0.00	0.1559	
	0.10	0.0181	0.10	0.0332	0.10	0.1176	
	0.20	0.0068	0.20	0.0147	0.20	0.0781	
	0.30	0.0038	0.30	0.0092	0.30	0.0493	
	0.40	0.0022	0.40	0.0061	0.40	0.0307	
	0.50	0.0015	0.50	0.0045	0.50	0.0202	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:			
CPU RATE:	21.00	19.00	19.00

SYSTEM: HUGHES_2

BIBLIOGRAPHY:

The following references have been provided for this system:

[19]

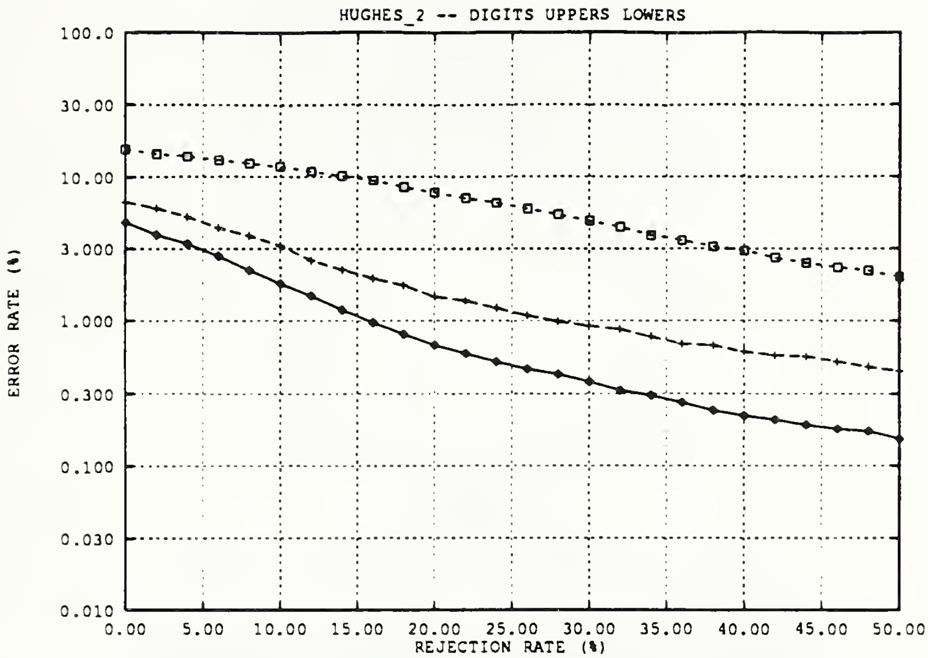

Figure 106: Error rate versus rejection rate for HUGHES_2

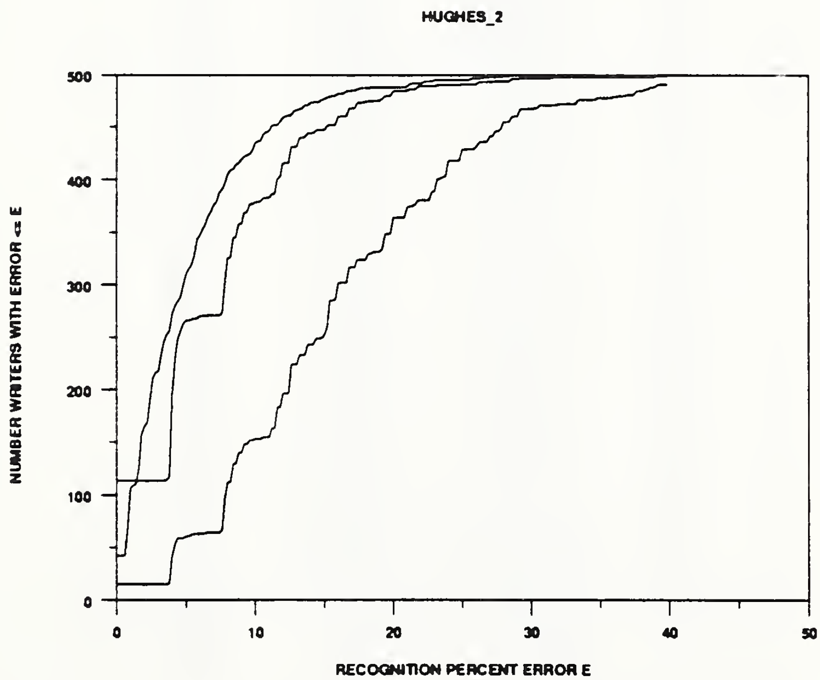

Figure 107: Error rate per writer of HUGHES_2

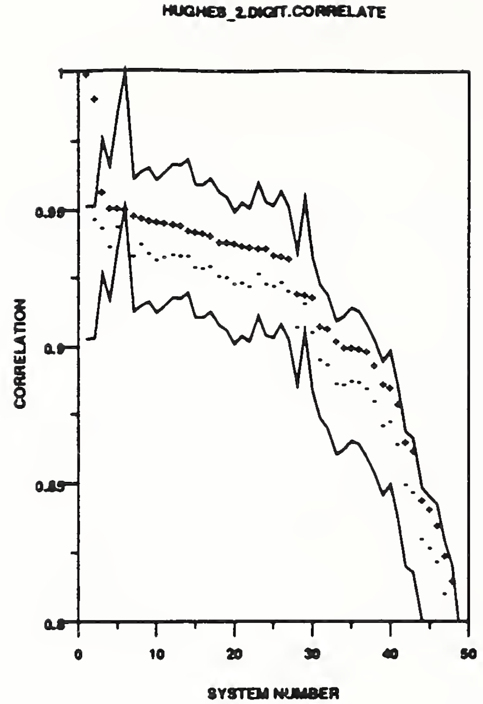

Figure 108: HUGHES_2 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	HUGHES_2	1.0000	1.0000
2	HUGHES_1	0.9915	0.9479
3	VOTE_M	0.9578	0.9446
4	AEG	0.9520	0.9375
5	OCRSYS	0.9519	0.9451
6	REFERENCE	0.9514	0.9514
7	ERIM_1	0.9491	0.9344
8	VOTE_P	0.9480	0.9384
9	IBM	0.9474	0.9351
10	ERIM_2	0.9469	0.9328
11	ATT_2	0.9464	0.9340
12	ELSAGB_3	0.9459	0.9349
13	ELSAGB_2	0.9454	0.9345
14	ATT_1	0.9434	0.9342
15	KODAK_2	0.9432	0.9301
16	ATT_4	0.9429	0.9299
17	THINK_2	0.9416	0.9306
18	UBOL	0.9396	0.9272
19	NESTOR	0.9395	0.9268
20	ELSAGB_1	0.9389	0.9241
21	KODAK_1	0.9379	0.9248
22	NIST_4	0.9374	0.9235
23	REI	0.9372	0.9278
24	SYMBUS	0.9370	0.9244
25	ATT_3	0.9349	0.9235
26	NYNEX	0.9344	0.9247
27	THINK_1	0.9336	0.9217
28	GTESS_1	0.9207	0.9080
29	COMCOM	0.9203	0.9168
30	GTESS_2	0.9192	0.9066
31	NIST_1	0.9089	0.8965
32	GMD_3	0.9076	0.8944
33	UPENN	0.9031	0.8874
34	ASOL	0.9011	0.8873
35	MIME	0.9008	0.8887
36	GMD_1	0.9004	0.8879
37	NIST_2	0.8996	0.8857
38	NIST_3	0.8945	0.8809
39	RISO	0.8875	0.8725
40	GMD_4	0.8860	0.8738
41	KAMAN_1	0.8802	0.8653
42	KAMAN_3	0.8663	0.8507
43	KAMAN_2	0.8630	0.8480
44	KAMAN_5	0.8452	0.8309
45	GMD_2	0.8421	0.8278
46	VALEN_2	0.8360	0.8228
47	IFAX	0.8253	0.8111
48	VALEN_1	0.8157	0.8010
49	KAMAN_4	0.7891	0.7759

Table 68: HUGHES_2 correlation graph key for digits.

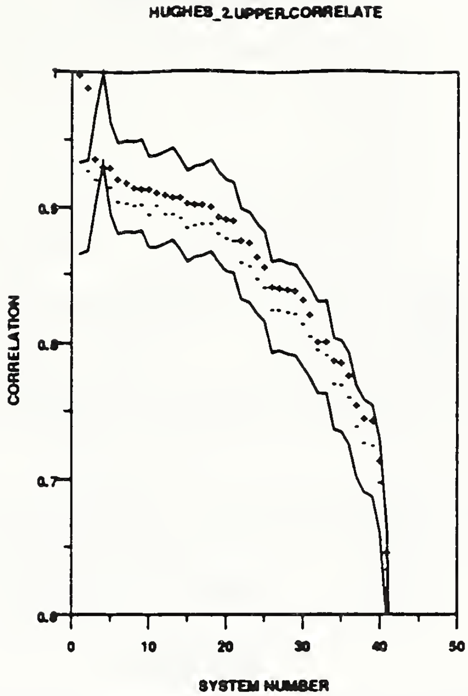

Figure 109: HUGHES_2 - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	HUGHES_2	1.0000	1.0000
2	HUGHES_1	0.9907	0.9296
3	VOTE_M	0.9389	0.9230
4	REFERENCE	0.9327	0.9327
5	AEG	0.9324	0.9173
6	ERIM_1	0.9237	0.9063
7	ATT_4	0.9216	0.9060
8	UMICH_1	0.9179	0.9034
9	NYNEX	0.9169	0.9042
10	UBOL	0.9168	0.8975
11	VOTE_P	0.9138	0.9034
12	NESTOR	0.9121	0.8970
13	ATT_2	0.9106	0.8969
14	IBM	0.9105	0.8945
15	SYMBUS	0.9054	0.8872
16	KODAK_1	0.9047	0.8891
17	ATT_3	0.9044	0.8896
18	ATT_1	0.9032	0.8897
19	OCRSYS	0.8952	0.8829
20	GTESS_1	0.8940	0.8791
21	GTESS_2	0.8924	0.8775
22	MIME	0.8778	0.8612
23	NIST_4	0.8759	0.8584
24	ASOL	0.8656	0.8498
25	REI	0.8587	0.8433
26	GMD_1	0.8440	0.8261
27	NIST_1	0.8427	0.8261
28	RISO	0.8425	0.8245
29	GMD_3	0.8414	0.8238
30	KAMAN_1	0.8349	0.8168
31	GMD_4	0.8241	0.8076
32	COMCOM	0.8040	0.7971
33	NIST_3	0.8034	0.7931
34	IFAX	0.7901	0.7723
35	KAMAN_3	0.7881	0.7714
36	KAMAN_2	0.7792	0.7622
37	NIST_2	0.7571	0.7409
38	VALEN_1	0.7479	0.7293
39	GMD_2	0.7454	0.7277
40	KAMAN_4	0.7162	0.6997
41	KAMAN_5	0.6479	0.6351
42	UMICH_2	0.0458	0.0203

Table 69: HUGHES_2 correlation graph key for uppers.

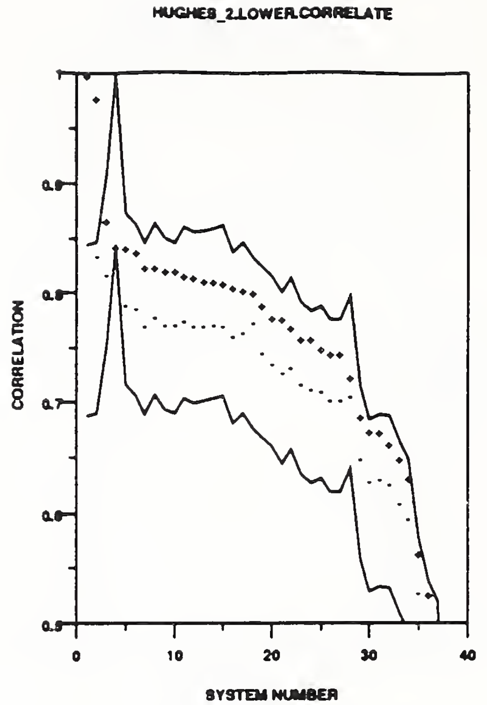

Figure 110: HUGHES_2 - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	HUGHES_2	1.0000	1.0000
2	HUGHES_1	0.9800	0.8363
3	VOTE_M	0.8679	0.8190
4	REFERENCE	0.8441	0.8441
5	AEG	0.8427	0.7916
6	ERIM_1	0.8399	0.7882
7	UBOL	0.8257	0.7715
8	OCRSYS	0.8252	0.7794
9	UMICH_1	0.8227	0.7723
10	IBM	0.8220	0.7724
11	NYNEX	0.8172	0.7768
12	KODAK_1	0.8163	0.7719
13	ATT_4	0.8130	0.7718
14	ATT_2	0.8128	0.7728
15	ATT_1	0.8105	0.7717
16	ATT_3	0.8070	0.7622
17	NESTOR	0.8052	0.7654
18	VOTE_P	0.8028	0.7748
19	GTESS_1	0.7917	0.7473
20	GTESS_2	0.7796	0.7370
21	NIST_4	0.7782	0.7295
22	NIST_1	0.7707	0.7337
23	GMD_3	0.7607	0.7190
24	RISO	0.7602	0.7145
25	ASOL	0.7512	0.7119
26	GMD_4	0.7459	0.7040
27	GMD_1	0.7459	0.7040
28	NIST_3	0.7251	0.7074
29	GMD_2	0.6889	0.6511
30	VALEN_1	0.6769	0.6308
31	KAMAN_1	0.6747	0.6324
32	NIST_2	0.6653	0.6284
33	KAMAN_3	0.6515	0.6109
34	KAMAN_2	0.6342	0.5968
35	KAMAN_5	0.5648	0.5293
36	KAMAN_4	0.5288	0.4958
37	COMCOM	0.4993	0.4872
38	UMICH_2	0.1008	0.0503

Table 70: HUGHES_2 correlation graph key for lowers.

SYSTEM: IBM

PARTICIPANT: Dr. K. M. Mohiuddin

ORGANIZATION: IBM Almaden Research Center, San Jose, CA

FEATURES: geometrical and zonal patterns, including bending points and areas of significant direction change around the contour.

CLASSIFICATION: 3-layer NN: 184 input units (96 for bending points and 88 for direction changes), 40 hidden units (static for all experiments), 10 output units for digits, 26 for upper case and 26 for lower case.

HARDWARE: RS/6000 Model 530 running AIX

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	80\%	100\%	100\%	NSDB3

STATUS: on time

RESULTS:

-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
0.00	0.0349	0.00	0.0641	0.00	0.1542	
0.10	0.0071	0.10	0.0234	0.10	0.1061	
0.20	0.0037	0.20	0.0090	0.20	0.0730	
0.30	0.0038	0.30	0.0050	0.30	0.0482	
0.40	0.0040	0.40	0.0054	0.40	0.0307	
0.50	0.0038	0.50	0.0052	0.50	0.0183	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	86.95	80.97	89.04
CPU RATE:	200.	194.17	194.17

SYSTEM: IBM

BIBLIOGRAPHY:

The following references have been provided for this system:

[20][24][21][22][23] [24] [25][26]

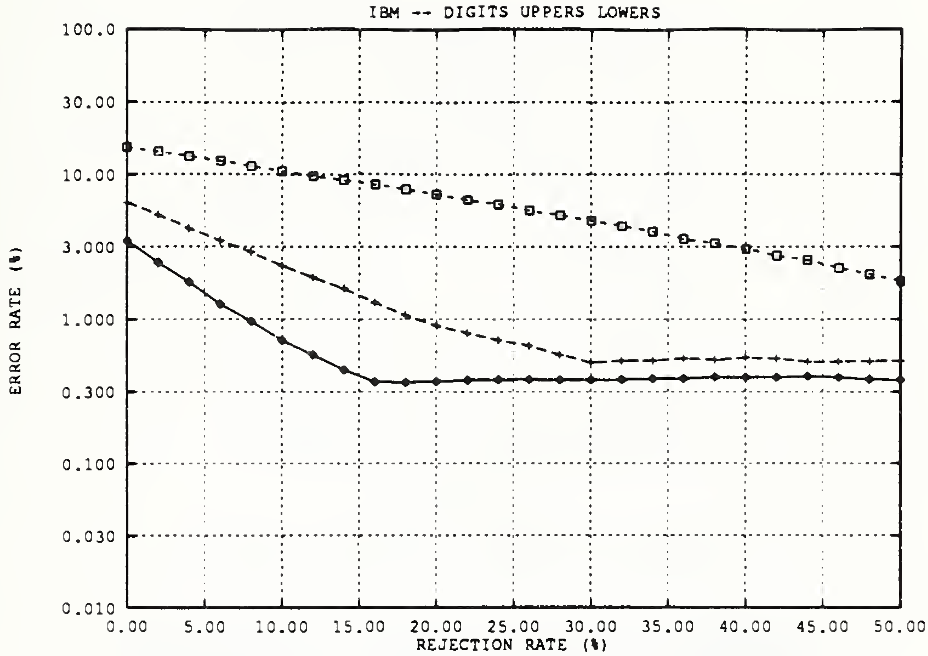

Figure 111: Error rate versus rejection rate for IBM

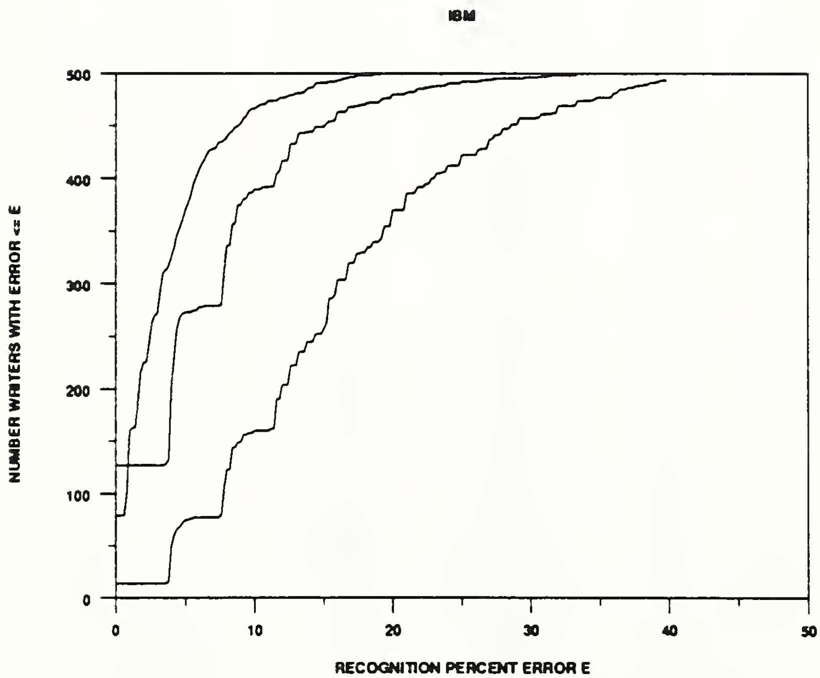

Figure 112: Error rate per writer of IBM

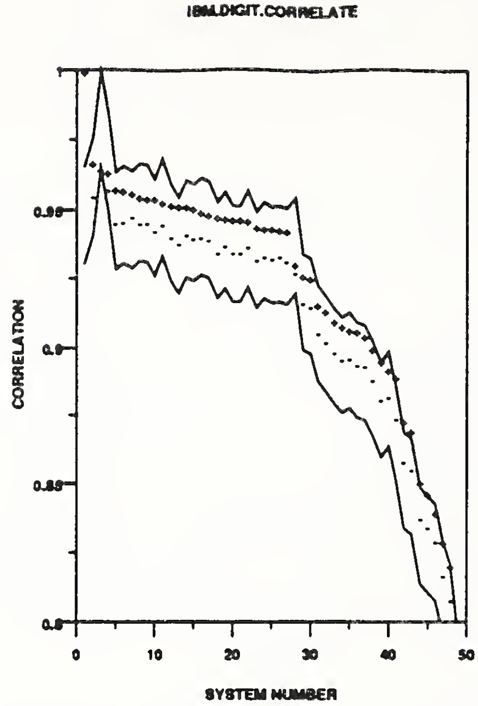

Figure 113: IBM - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	IBM	1.0000	1.0000
2	VOTE_M	0.9677	0.9557
3	REFERENCE	0.9651	0.9651
4	OCRSYS	0.9641	0.9577
5	ATT_2	0.9583	0.9460
6	AEG	0.9578	0.9464
7	VOTE_P	0.9570	0.9483
8	ELSAGB_3	0.9556	0.9460
9	ELSAGB_2	0.9553	0.9457
10	ERIM_1	0.9549	0.9432
11	ATT_1	0.9535	0.9456
12	KODAK_2	0.9529	0.9408
13	ERIM_2	0.9523	0.9417
14	NESTOR	0.9523	0.9386
15	ATT_4	0.9514	0.9404
16	THINK_2	0.9501	0.9407
17	REI	0.9489	0.9400
18	KODAK_1	0.9480	0.9354
19	UBOL	0.9477	0.9374
20	HUGHES_2	0.9474	0.9351
21	HUGHES_1	0.9474	0.9351
22	NYNEX	0.9470	0.9371
23	ELSAGB_1	0.9447	0.9325
24	SYMBUS	0.9442	0.9341
25	THINK_1	0.9440	0.9328
26	ATT_3	0.9436	0.9338
27	NIST_4	0.9433	0.9323
28	COMCOM	0.9311	0.9280
29	GTESS_1	0.9272	0.9170
30	GTESS_2	0.9262	0.9157
31	NIST_1	0.9163	0.9059
32	GMD_3	0.9141	0.9029
33	MIME	0.9105	0.8989
34	ASOL	0.9085	0.8965
35	GMD_1	0.9075	0.8967
36	UPENN	0.9069	0.8945
37	NIST_2	0.9051	0.8939
38	NIST_3	0.9003	0.8889
39	RISO	0.8957	0.8816
40	GMD_4	0.8928	0.8823
41	KAMAN_1	0.8898	0.8745
42	KAMAN_3	0.8737	0.8584
43	KAMAN_2	0.8701	0.8558
44	KAMAN_5	0.8513	0.8380
45	GMD_2	0.8469	0.8349
46	VALEN_2	0.8403	0.8296
47	IFAX	0.8295	0.8174
48	VALEN_1	0.8209	0.8086
49	KAMAN_4	0.7945	0.7824

Table 71: IBM correlation graph key for digits.

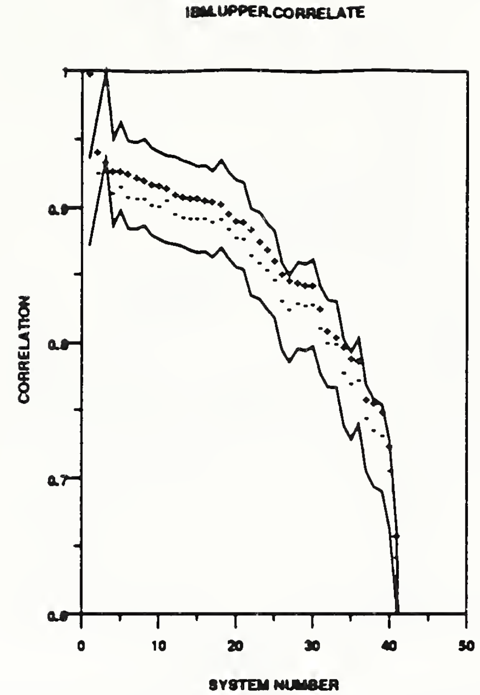

Figure 114: IBM - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	IBM	1.0000	1.0000
2	VOTE_M	0.9430	0.9272
3	REFERENCE	0.9359	0.9359
4	ATT_4	0.9298	0.9127
5	AEG	0.9295	0.9173
6	UMICH_1	0.9274	0.9106
7	ERIM_1	0.9245	0.9090
8	NYNEX	0.9231	0.9094
9	ATT_2	0.9198	0.9048
10	NESTOR	0.9191	0.9038
11	VOTE_P	0.9178	0.9081
12	UBOL	0.9126	0.8979
13	HUGHES_1	0.9114	0.8959
14	HUGHES_2	0.9105	0.8945
15	KODAK_1	0.9101	0.8947
16	ATT_3	0.9087	0.8949
17	SYMBUS	0.9071	0.8915
18	ATT_1	0.9059	0.8934
19	OCRSYS	0.8982	0.8866
20	GTESS_1	0.8926	0.8802
21	GTESS_2	0.8914	0.8791
22	MIME	0.8860	0.8673
23	NIST_4	0.8775	0.8617
24	ASOL	0.8712	0.8557
25	REI	0.8634	0.8490
26	RISO	0.8528	0.8331
27	KAMAN_1	0.8482	0.8269
28	GMD_1	0.8470	0.8308
29	GMD_3	0.8453	0.8290
30	NIST_1	0.8449	0.8302
31	GMD_4	0.8277	0.8124
32	NIST_3	0.8112	0.8013
33	COMCOM	0.8065	0.8004
34	KAMAN_3	0.7988	0.7801
35	KAMAN_2	0.7905	0.7710
36	IFAX	0.7893	0.7746
37	NIST_2	0.7607	0.7463
38	VALEN_1	0.7574	0.7378
39	GMD_2	0.7511	0.7334
40	KAMAN_4	0.7264	0.7076
41	KAMAN_5	0.6603	0.6435
42	UMICH_2	0.0408	0.0193

Table 72: IBM correlation graph key for uppers.

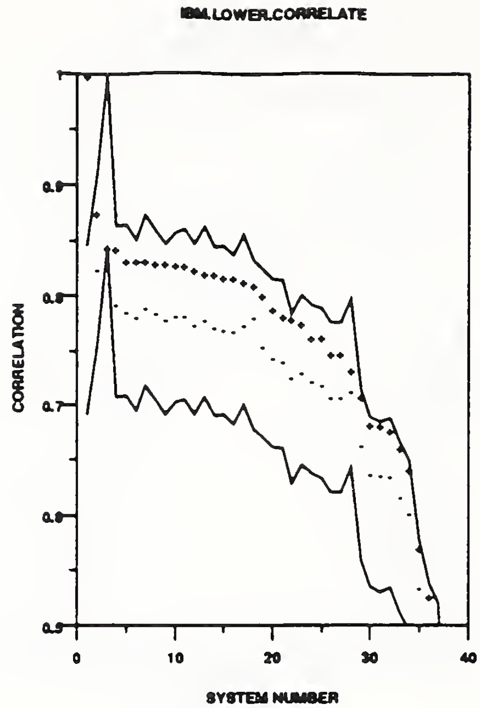

Figure 115: IBM - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	IBM	1.0000	1.0000
2	VOTE_M	0.8760	0.8254
3	REFERENCE	0.8457	0.8457
4	ERIM_1	0.8443	0.7932
5	OCRSYS	0.8342	0.7863
6	AEG	0.8339	0.7897
7	UMICH_1	0.8339	0.7817
8	ATT_2	0.8315	0.7858
9	NESTOR	0.8311	0.7797
10	ATT_4	0.8303	0.7828
11	NYNEX	0.8296	0.7837
12	HUGHES_1	0.8252	0.7747
13	ATT_1	0.8224	0.7793
14	HUGHES_2	0.8220	0.7724
15	UBOL	0.8184	0.7706
16	ATT_3	0.8183	0.7699
17	KODAK_1	0.8150	0.7749
18	VOTE_P	0.8114	0.7825
19	GTESS_1	0.8023	0.7556
20	GTESS_2	0.7900	0.7456
21	NIST_1	0.7828	0.7413
22	RISO	0.7811	0.7272
23	NIST_4	0.7762	0.7312
24	GMD_3	0.7636	0.7236
25	ASOL	0.7633	0.7203
26	GMD_4	0.7489	0.7088
27	GMD_1	0.7489	0.7088
28	NIST_3	0.7337	0.7142
29	GMD_2	0.7097	0.6646
30	KAMAN_1	0.6848	0.6390
31	VALEN_1	0.6837	0.6368
32	NIST_2	0.6783	0.6357
33	KAMAN_3	0.6624	0.6177
34	KAMAN_2	0.6436	0.6032
35	KAMAN_5	0.5724	0.5352
36	KAMAN_4	0.5284	0.4976
37	COMCOM	0.4965	0.4856
38	UMICH_2	0.0922	0.0482

Table 73: IBM correlation graph key for lowers.

SYSTEM: IFAX

PARTICIPANT: Leonid Nilva

ORGANIZATION: InterFax, Inc., Sunnyvale, CA

FEATURES: Shape and Histogram based,
adaptively selected relevant subset of over 500 features

CLASSIFICATION: series of adaptive affine transformations

HARDWARE:

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	?	?	NA	NSDB3

STATUS: on time

RESULTS:

-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
0.00	0.1707	0.00	0.1960			
0.10	0.1249	0.10	0.1498			
0.20	0.0897	0.20	0.1198			
0.30	0.0626	0.30	0.0974			
0.40	0.0491	0.40	0.0794			
0.50	0.0335	0.50	0.0648			

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	20.00	12.00	NA
CPU RATE:			

NOTE: Few details of features or classification provided.

SYSTEM: IFAX

BIBLIOGRAPHY:

The following references have been provided for this system:

none

COMMENTS:

InterFax, headquartered in Sunnyvale, California, develops and markets an integrated family of robust application development tools for fax information processing.

One of InterFax's new products, code-named Harvest, is an object-oriented development environment that automates the reading and entering of data from faxed forms into host transaction systems. These forms can have hand-printed numbers or letters, machine-printed characters, mark sense boxes, graphics, or other images. Harvest reads and interprets forms from fax machines or scanners. Once a form is read and verified, the information is automatically sent to the host computer application and a fax response or confirmation is generated.

Harvest will be available for commercial use in the fourth quarter of 1992. Initial release of the product will support IBM mainframe and AS/400 host computers. The implementation platform is 486 IBM compatible computers with OS/2 2.0 operating system and C++ programming language.

The hand-printed character recognition used in the First Census OCR Systems Conference is a prototype algorithm, one of a couple that InterFax may pursue. The engine utilizes geometric feature extraction and modified a k-nearest neighbor classifier.

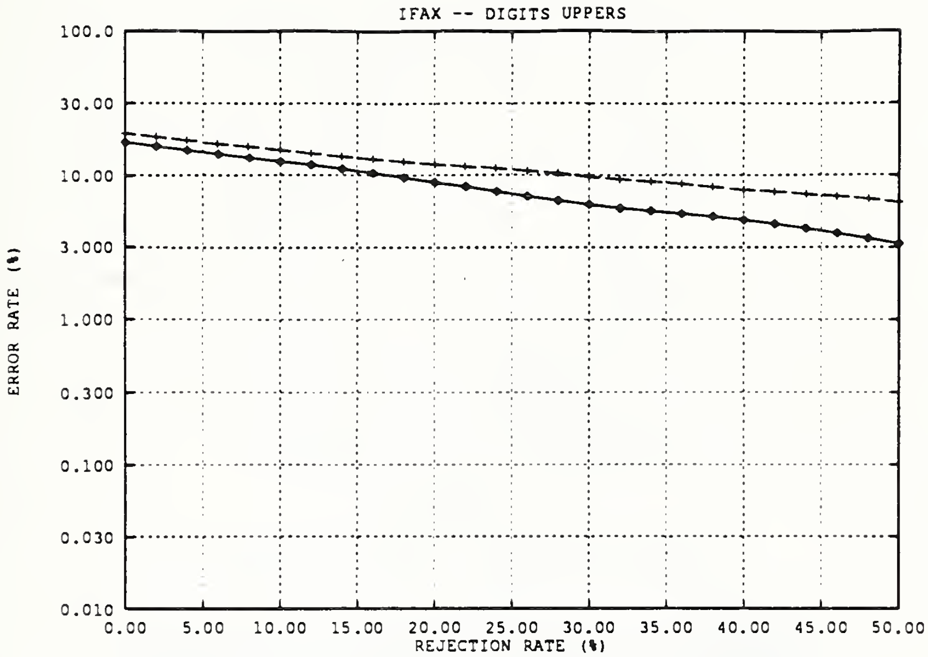

Figure 116: Error rate versus rejection rate for IFAX

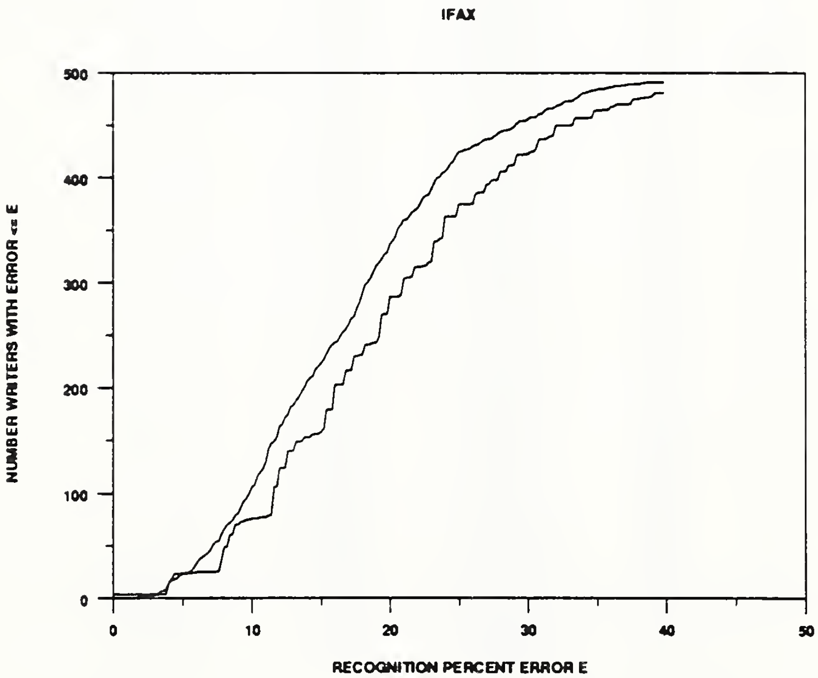

Figure 117: Error rate per writer of IFAX

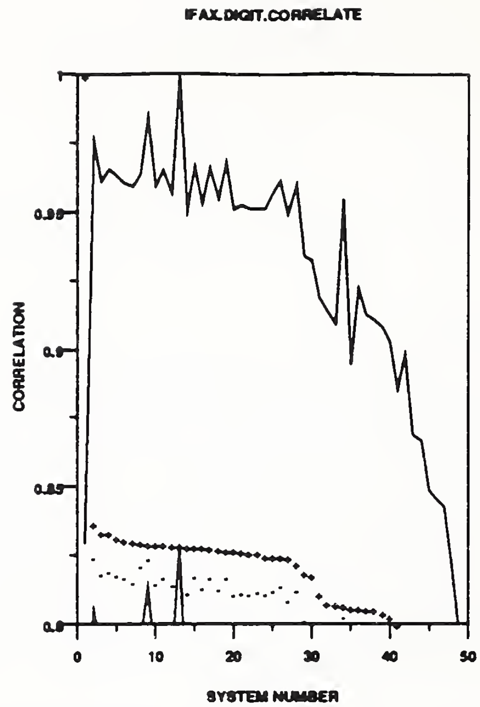

Figure 118: IFAX - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	IFAX	1.0000	1.0000
2	VOTE_M	0.8370	0.8248
3	ERIM_1	0.8340	0.8185
4	AEG	0.8336	0.8194
5	ATT_2	0.8319	0.8181
6	ERIM_2	0.8312	0.8173
7	KODAK_2	0.8304	0.8155
8	VOTE_P	0.8301	0.8212
9	OCRSYS	0.8298	0.8241
10	ATT_4	0.8297	0.8152
11	IBM	0.8295	0.8174
12	REFERENCE	0.8293	0.8293
13	UBOL	0.8293	0.8143
14	NIST_4	0.8289	0.8118
15	ELSAGB_3	0.8287	0.8177
16	SYMBUS	0.8286	0.8134
17	ELSAGB_2	0.8281	0.8172
18	NESTOR	0.8279	0.8131
19	ATT_1	0.8275	0.8172
20	THINK_1	0.8273	0.8114
21	KODAK_1	0.8271	0.8117
22	HUGHES_1	0.8266	0.8115
23	ATT_3	0.8264	0.8123
24	HUGHES_2	0.8253	0.8111
25	NYNEX	0.8252	0.8127
26	THINK_2	0.8249	0.8139
27	ELSAGB_1	0.8247	0.8092
28	REI	0.8221	0.8128
29	GTESS_1	0.8192	0.8015
30	GTESS_2	0.8183	0.8007
31	GMD_3	0.8113	0.7915
32	MIME	0.8082	0.7881
33	UPENN	0.8078	0.7862
34	COMCOM	0.8072	0.8032
35	RISO	0.8064	0.7802
36	NIST_1	0.8062	0.7898
37	GMD_1	0.8059	0.7863
38	ASOL	0.8057	0.7860
39	NIST_2	0.8044	0.7843
40	NIST_3	0.8029	0.7825
41	KAMAN_1	0.8003	0.7734
42	GMD_4	0.7945	0.7744
43	KAMAN_3	0.7878	0.7603
44	KAMAN_2	0.7848	0.7581
45	KAMAN_5	0.7653	0.7412
46	GMD_2	0.7631	0.7403
47	VALEN_2	0.7625	0.7391
48	VALEN_1	0.7479	0.7196
49	KAMAN_4	0.7267	0.6971

Table 74: IFAX correlation graph key for digits.

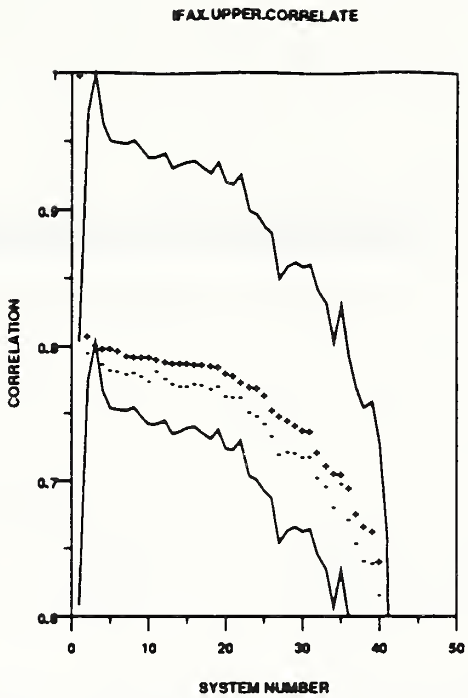

Figure 119: IFAX - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	IFAX	1.0000	1.0000
2	VOTE_M	0.8100	0.7967
3	REFERENCE	0.8040	0.8040
4	AEG	0.8007	0.7889
5	ATT_4	0.8004	0.7846
6	UMICH_1	0.7992	0.7834
7	ERIM_1	0.7949	0.7814
8	NYNEX	0.7947	0.7828
9	ATT_2	0.7946	0.7799
10	UBOL	0.7945	0.7762
11	VOTE_P	0.7927	0.7836
12	NESTOR	0.7909	0.7775
13	KODAK_1	0.7901	0.7738
14	HUGHES_2	0.7901	0.7723
15	HUGHES_1	0.7898	0.7727
16	IBM	0.7893	0.7746
17	ATT_3	0.7885	0.7731
18	SYMBUS	0.7877	0.7706
19	ATT_1	0.7870	0.7723
20	GTESS_1	0.7822	0.7649
21	GTESS_2	0.7808	0.7640
22	OCRSYS	0.7758	0.7642
23	MIME	0.7726	0.7529
24	NIST_4	0.7715	0.7507
25	ASOL	0.7658	0.7449
26	REI	0.7549	0.7357
27	KAMAN_1	0.7501	0.7217
28	RISO	0.7479	0.7241
29	NIST_1	0.7436	0.7231
30	GMD_3	0.7401	0.7196
31	GMD_1	0.7392	0.7198
32	GMD_4	0.7240	0.7042
33	NIST_3	0.7140	0.6981
34	KAMAN_3	0.7081	0.6824
35	COMCOM	0.7068	0.6995
36	KAMAN_2	0.6973	0.6731
37	NIST_2	0.6773	0.6556
38	GMD_2	0.6686	0.6429
39	VALEN_1	0.6650	0.6406
40	KAMAN_4	0.6431	0.6176
41	KAMAN_5	0.5874	0.5646
42	UMICH_2	0.0837	0.0157

Table 75: IFAX correlation graph key for uppers.

No Data Available

Figure 120: IFAX - lower case correlation

There was no data for this evaluation.

Table 76: IFAX correlation graph key for lowers.

SYSTEM: KAMAN_1

PARTICIPANT: Mark G. Costello

ORGANIZATION: Kaman Sciences Corporation, Utica, NY

FEATURES:

CLASSIFICATION:

HARDWARE: SPARC2, multiuser

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	800	2080	2080	NSDB1?

STATUS: on time

RESULTS:	-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
	0.00	0.1146	0.00	0.1503	0.00	0.3111	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	0.50	0.38	0.43
CPU RATE:			

NOTE: The CON files for the KAMAN systems had numbers greater than 1, which is not allowed by the NIST scoring package, so no rejection-rate data was calculated.

NOTE: No details of recognition algorithms provided.

SYSTEM: KAMAN_1

BIBLIOGRAPHY:

The following references have been provided for this system:

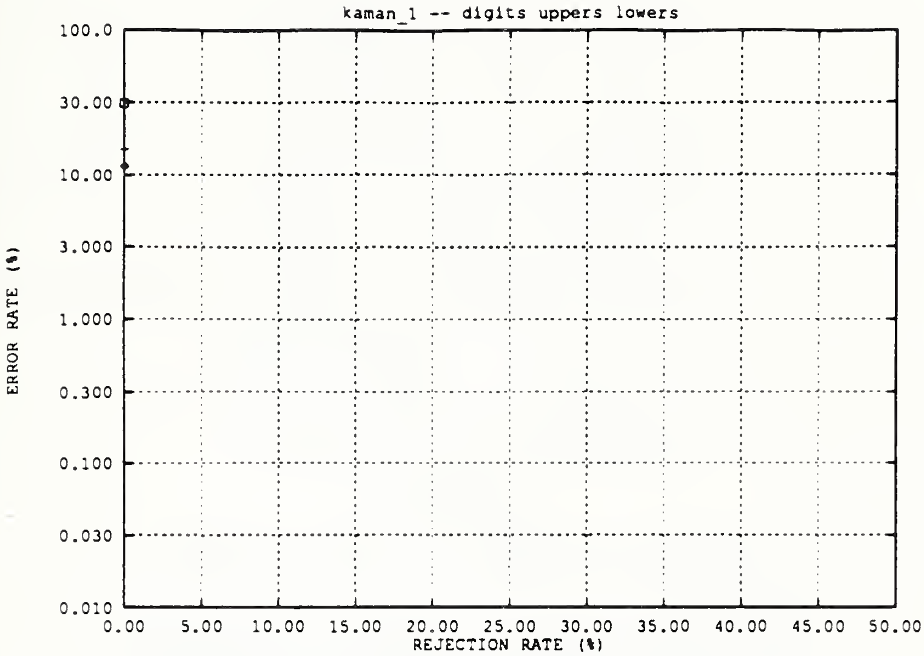

Figure 121: Error rate versus rejection rate for KAMAN_1

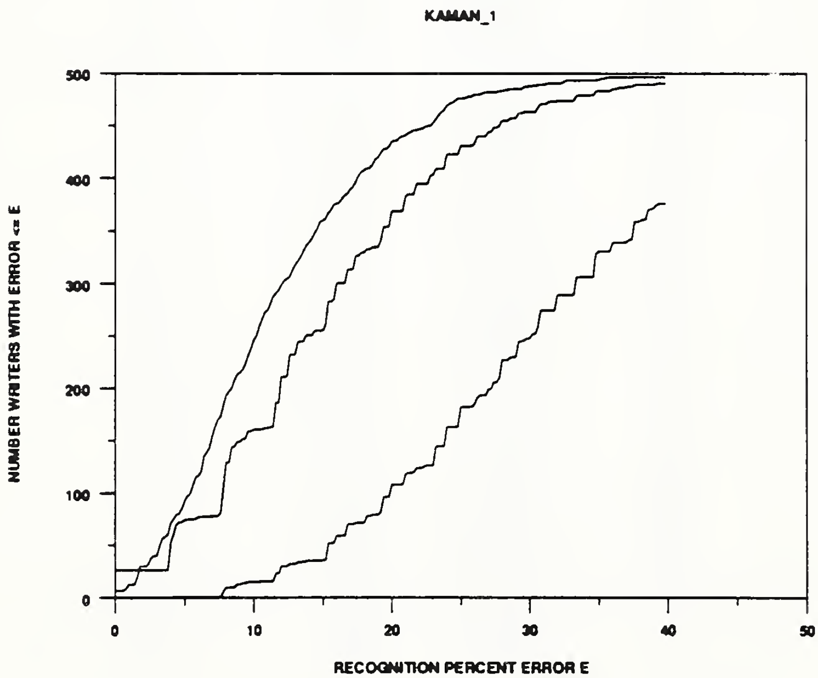

Figure 122: Error rate per writer of KAMAN_1

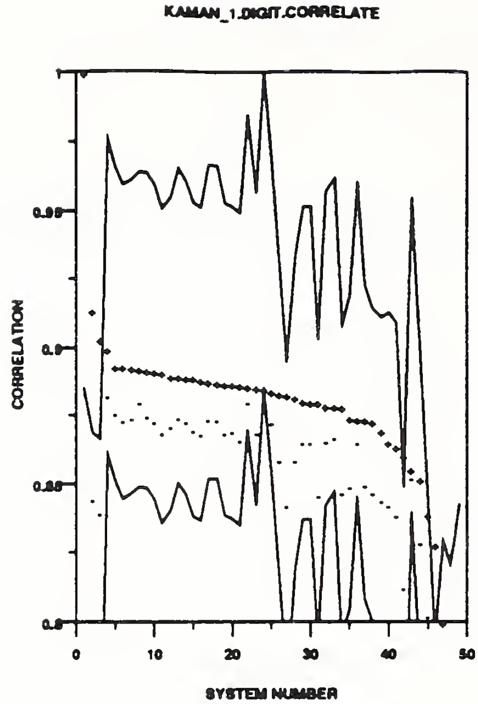

Figure 123: KAMAN_1 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	KAMAN_1	1.0000	1.0000
2	KAMAN_3	0.9142	0.8448
3	KAMAN_2	0.9036	0.8398
4	VOTE_M	0.8998	0.8827
5	AEG	0.8937	0.8762
6	ATT_4	0.8934	0.8739
7	ERIM_1	0.8930	0.8746
8	VOTE_P	0.8924	0.8804
9	ATT_2	0.8922	0.8752
10	KODAK_2	0.8918	0.8733
11	NIST_4	0.8914	0.8694
12	IBM	0.8898	0.8745
13	NESTOR	0.8898	0.8713
14	ERIM_2	0.8896	0.8735
15	KODAK_1	0.8893	0.8699
16	THINK_1	0.8887	0.8687
17	ELSAGB_3	0.8879	0.8742
18	ELSAGB_2	0.8876	0.8739
19	SYMBUS	0.8873	0.8693
20	ATT_3	0.8869	0.8695
21	ELSAGB_1	0.8865	0.8666
22	OCRSYS	0.8864	0.8800
23	UBOL	0.8857	0.8691
24	REFERENCE	0.8854	0.8854
25	ATT_1	0.8845	0.8730
26	GTESS_2	0.8833	0.8593
27	RISO	0.8828	0.8426
28	GTESS_1	0.8821	0.8593
29	HUGHES_1	0.8805	0.8655
30	HUGHES_2	0.8802	0.8653
31	NIST_3	0.8801	0.8463
32	THINK_2	0.8786	0.8674
33	NYNEX	0.8786	0.8660
34	NIST_2	0.8785	0.8470
35	GMD_3	0.8745	0.8493
36	REI	0.8743	0.8655
37	NIST_1	0.8741	0.8498
38	MIME	0.8733	0.8469
39	ASOL	0.8701	0.8446
40	GMD_1	0.8659	0.8425
41	UPENN	0.8640	0.8387
42	KAMAN_5	0.8610	0.8127
43	COMCOM	0.8557	0.8527
44	GMD_4	0.8520	0.8289
45	GMD_2	0.8395	0.8024
46	KAMAN_4	0.8284	0.7696
47	IFAX	0.8003	0.7734
48	VALEN_1	0.7973	0.7678
49	VALEN_2	0.7961	0.7782

Table 77: KAMAN_1 correlation graph key for digits.

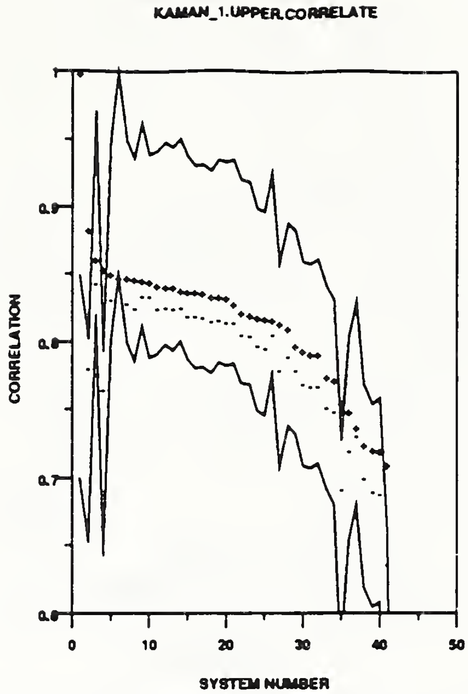

Figure 124: KAMAN_1 - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	KAMAN_1	1.0000	1.0000
2	KAMAN_3	0.8844	0.7818
3	VOTE_M	0.8636	0.8452
4	KAMAN_2	0.8558	0.7661
5	ATT_4	0.8523	0.8333
6	REFERENCE	0.8497	0.8497
7	UMICH_1	0.8491	0.8306
8	IBM	0.8482	0.8269
9	AEG	0.8478	0.8354
10	VOTE_P	0.8470	0.8360
11	NESTOR	0.8436	0.8268
12	ERIM_1	0.8434	0.8279
13	ATT_2	0.8429	0.8261
14	NYNEX	0.8400	0.8272
15	UBOL	0.8395	0.8213
16	KODAK_1	0.8393	0.8209
17	ATT_3	0.8385	0.8204
18	HUGHES_1	0.8361	0.8184
19	SYMBUS	0.8361	0.8175
20	HUGHES_2	0.8349	0.8168
21	ATT_1	0.8304	0.8160
22	GTESS_1	0.8240	0.8076
23	GTESS_2	0.8223	0.8065
24	MIME	0.8204	0.7987
25	NIST_4	0.8189	0.7967
26	OCRSYS	0.8180	0.8070
27	RISO	0.8153	0.7803
28	ASOL	0.8116	0.7903
29	REI	0.7991	0.7803
30	GMD_1	0.7949	0.7708
31	GMD_3	0.7927	0.7685
32	NIST_1	0.7921	0.7689
33	GMD_4	0.7763	0.7532
34	NIST_3	0.7729	0.7499
35	KAMAN_4	0.7566	0.6932
36	IFAX	0.7501	0.7217
37	COMCOM	0.7391	0.7327
38	NIST_2	0.7268	0.7012
39	GMD_2	0.7225	0.6917
40	VALEN_1	0.7219	0.6901
41	KAMAN_5	0.7117	0.6372
42	UMICH_2	0.0648	0.0149

Table 78: KAMAN_1 correlation graph key for uppers.

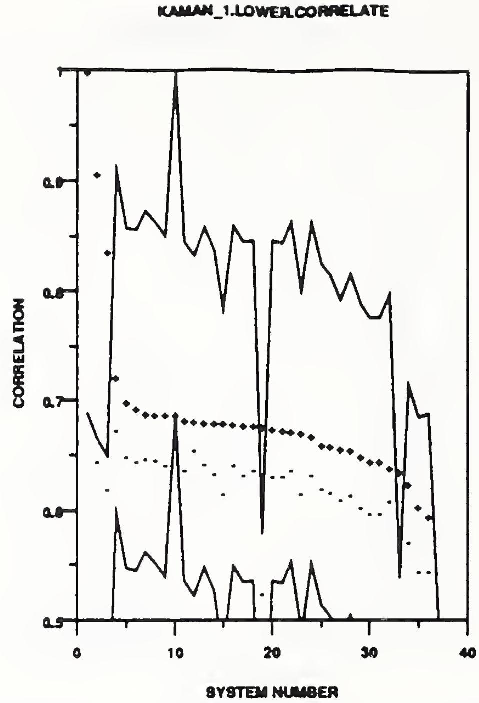

Figure 125: KAMAN_1 - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	KAMAN_1	1.0000	1.0000
2	KAMAN_3	0.9089	0.6464
3	KAMAN_2	0.8382	0.6208
4	VOTE_M	0.7229	0.6749
5	ATT_4	0.7004	0.6510
6	KODAK_1	0.6947	0.6460
7	AEG	0.6899	0.6487
8	ERIM_1	0.6892	0.6481
9	UMICH_1	0.6890	0.6428
10	REFERENCE	0.6889	0.6889
11	IBM	0.6848	0.6390
12	VOTE_P	0.6834	0.6568
13	ATT_2	0.6825	0.6442
14	ATT_3	0.6822	0.6355
15	RISO	0.6821	0.6172
16	NYNEX	0.6809	0.6431
17	UBOL	0.6802	0.6338
18	NESTOR	0.6800	0.6382
19	KAMAN_5	0.6787	0.5261
20	HUGHES_1	0.6762	0.6332
21	HUGHES_2	0.6747	0.6324
22	OCRSYS	0.6744	0.6381
23	NIST_4	0.6733	0.6166
24	ATT_1	0.6697	0.6336
25	GTESS_1	0.6619	0.6208
26	NIST_1	0.6604	0.6181
27	GMD_3	0.6584	0.6108
28	GTESS_2	0.6571	0.6157
29	ASOL	0.6506	0.6039
30	GMD_4	0.6470	0.5987
31	GMD_1	0.6470	0.5987
32	NIST_3	0.6411	0.6094
33	KAMAN_4	0.6373	0.4952
34	GMD_2	0.6262	0.5715
35	VALEN_1	0.6057	0.5458
36	NIST_2	0.5961	0.5460
37	COMCOM	0.4218	0.4098
38	UMICH_2	0.1265	0.0362

Table 79: KAMAN_1 correlation graph key for lowers.

SYSTEM: KAMAN_2

PARTICIPANT: Mark G. Costello

ORGANIZATION: Kaman Sciences Corporation, Utica, NY

FEATURES:

CLASSIFICATION:

HARDWARE: SPARC2, multiuser

TRAINING:

	DIGITS	UPPERS	LOWERS	DATABASE
	800	2080	2080	NSDB1?

STATUS: on time

RESULTS:

-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
0.00	0.1338	0.00	0.2074	0.00	0.3511	

OCR RATE (CPS):

	DIGITS	UPPERS	LOWERS
SYS RATE:	0.76	0.47	0.47
CPU RATE:			

SYSTEM: KAMAN_2

BIBLIOGRAPHY:

The following references have been provided for this system:

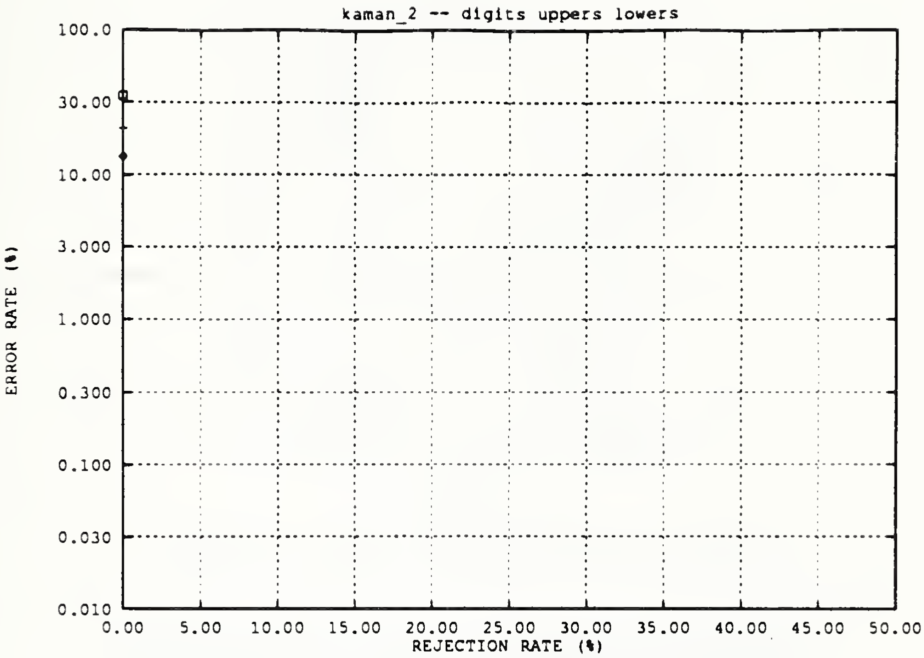

Figure 126: Error rate versus rejection rate for KAMAN_2

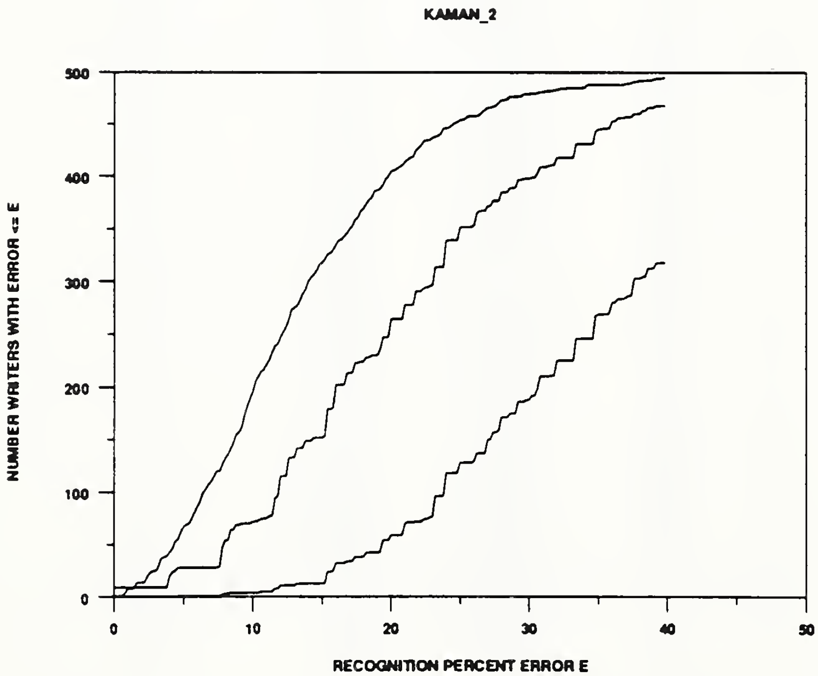

Figure 127: Error rate per writer of KAMAN_2

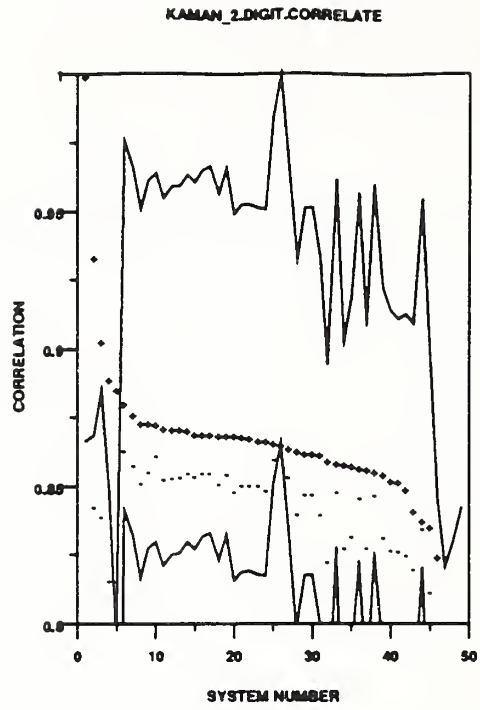

Figure 128: KAMAN_2 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	KAMAN_2	1.0000	1.0000
2	KAMAN_3	0.9343	0.8436
3	KAMAN_1	0.9036	0.8398
4	KAMAN_5	0.8899	0.8162
5	KAMAN_4	0.8864	0.7807
6	VOTE_M	0.8809	0.8639
7	AEG	0.8768	0.8587
8	ERIM_1	0.8742	0.8561
9	NIST_4	0.8742	0.8520
10	VOTE_P	0.8739	0.8621
11	NESTOR	0.8726	0.8537
12	ATT_4	0.8721	0.8542
13	KODAK_2	0.8718	0.8546
14	ATT_2	0.8715	0.8559
15	IBM	0.8701	0.8558
16	ERIM_2	0.8701	0.8545
17	ELSAGB_3	0.8699	0.8557
18	UBOL	0.8698	0.8519
19	ELSAGB_2	0.8696	0.8554
20	ELSAGB_1	0.8695	0.8490
21	KODAK_1	0.8692	0.8512
22	SYMBUS	0.8685	0.8512
23	ATT_3	0.8680	0.8512
24	THINK_1	0.8678	0.8494
25	OCRSYS	0.8671	0.8608
26	REFERENCE	0.8662	0.8662
27	ATT_1	0.8651	0.8543
28	GTESS_2	0.8642	0.8408
29	HUGHES_1	0.8631	0.8480
30	HUGHES_2	0.8630	0.8480
31	GTESS_1	0.8626	0.8406
32	RISO	0.8605	0.8233
33	THINK_2	0.8595	0.8489
34	NIST_3	0.8591	0.8284
35	GMD_3	0.8586	0.8324
36	NYNEX	0.8576	0.8468
37	NIST_2	0.8571	0.8283
38	REI	0.8564	0.8476
39	NIST_1	0.8556	0.8319
40	MIME	0.8530	0.8276
41	ASOL	0.8527	0.8271
42	GMD_1	0.8498	0.8257
43	UPENN	0.8423	0.8205
44	COMCOM	0.8386	0.8353
45	GMD_4	0.8363	0.8123
46	GMD_2	0.8249	0.7868
47	VALEN_1	0.7921	0.7567
48	IFAX	0.7848	0.7581
49	VALEN_2	0.7834	0.7656

Table 80: KAMAN_2 correlation graph key for digits.

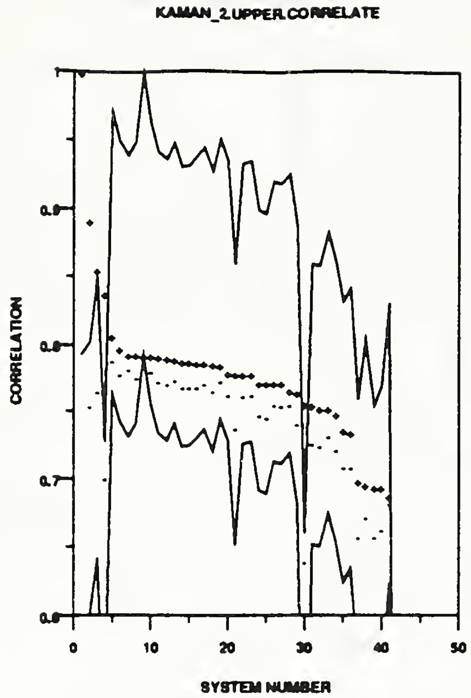

Figure 129: KAMAN_2 - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	KAMAN_2	1.0000	1.0000
2	KAMAN_3	0.8915	0.7546
3	KAMAN_1	0.8558	0.7661
4	KAMAN_4	0.8382	0.7018
5	VOTE_M	0.8069	0.7889
6	ATT_4	0.7977	0.7789
7	VOTE_P	0.7935	0.7826
8	UMICH_1	0.7931	0.7756
9	REFERENCE	0.7926	0.7926
10	AEG	0.7922	0.7802
11	NESTOR	0.7916	0.7736
12	IBM	0.7905	0.7710
13	ERIM_1	0.7901	0.7740
14	KODAK_1	0.7884	0.7685
15	ATT_3	0.7880	0.7684
16	ATT_2	0.7870	0.7712
17	UBOL	0.7870	0.7684
18	SYMBUS	0.7862	0.7659
19	NYNEX	0.7856	0.7731
20	HUGHES_1	0.7798	0.7633
21	HUGHES_2	0.7792	0.7622
22	RISO	0.7792	0.7381
23	ATT_1	0.7785	0.7628
24	MIME	0.7728	0.7488
25	NIST_4	0.7726	0.7470
26	GTESS_1	0.7725	0.7554
27	GTESS_2	0.7722	0.7546
28	OCRSYS	0.7672	0.7555
29	ASOL	0.7650	0.7421
30	KAMAN_5	0.7566	0.6400
31	GMD_1	0.7555	0.7271
32	GMD_3	0.7535	0.7252
33	REI	0.7533	0.7328
34	NIST_1	0.7494	0.7229
35	NIST_3	0.7374	0.7100
36	GMD_4	0.7360	0.7097
37	VALEN_1	0.6998	0.6588
38	IFAX	0.6973	0.6731
39	GMD_2	0.6954	0.6586
40	NIST_2	0.6953	0.6640
41	COMCOM	0.6890	0.6833
42	UMICH_2	0.0728	0.0131

Table 81: KAMAN_2 correlation graph key for uppers.

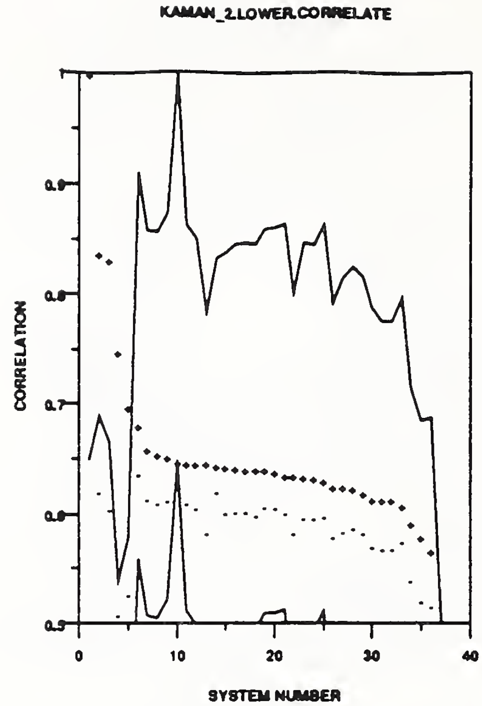

Figure 130: KAMAN_2 - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	KAMAN_2	1.0000	1.0000
2	KAMAN_1	0.8382	0.6208
3	KAMAN_3	0.8320	0.6050
4	KAMAN_4	0.7484	0.5091
5	KAMAN_5	0.6985	0.5269
6	VOTE_M	0.6818	0.6378
7	ATT_4	0.6608	0.6148
8	KODAK_1	0.6556	0.6112
9	AEG	0.6531	0.6137
10	REFERENCE	0.6489	0.6489
11	ERIM_1	0.6482	0.6115
12	UMICH_1	0.6476	0.6062
13	RISO	0.6472	0.5833
14	VOTE_P	0.6457	0.6209
15	ATT_3	0.6442	0.6013
16	IBM	0.6436	0.6032
17	NESTOR	0.6418	0.6028
18	UBOL	0.6417	0.5992
19	ATT_2	0.6416	0.6075
20	NYNEX	0.6398	0.6059
21	OCRSYS	0.6362	0.6022
22	NIST_4	0.6360	0.5839
23	HUGHES_1	0.6351	0.5970
24	HUGHES_2	0.6342	0.5968
25	ATT_1	0.6311	0.5983
26	GMD_3	0.6261	0.5800
27	NIST_1	0.6255	0.5847
28	GTESS_1	0.6245	0.5880
29	GTESS_2	0.6198	0.5828
30	ASOL	0.6149	0.5710
31	GMD_4	0.6148	0.5684
32	GMD_1	0.6148	0.5684
33	NIST_3	0.6083	0.5755
34	GMD_2	0.5921	0.5398
35	VALEN_1	0.5794	0.5218
36	NIST_2	0.5675	0.5173
37	COMCOM	0.3975	0.3869
38	UMICH_2	0.1227	0.0334

Table 82: KAMAN_2 correlation graph key for lowers.

SYSTEM: KAMAN_3

PARTICIPANT: Mark G. Costello

ORGANIZATION: Kaman Sciences Corporation, Utica, NY

FEATURES:

CLASSIFICATION:

HARDWARE: SPARC2, multiuser

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	800	2080	2080	NSDB1?

STATUS: on time

RESULTS:	-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
	0.00	0.1313	0.00	0.1978	0.00	0.3355	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	0.76	0.47	0.47
CPU RATE:			

SYSTEM: KAMAN_3

BIBLIOGRAPHY:

The following references have been provided for this system:

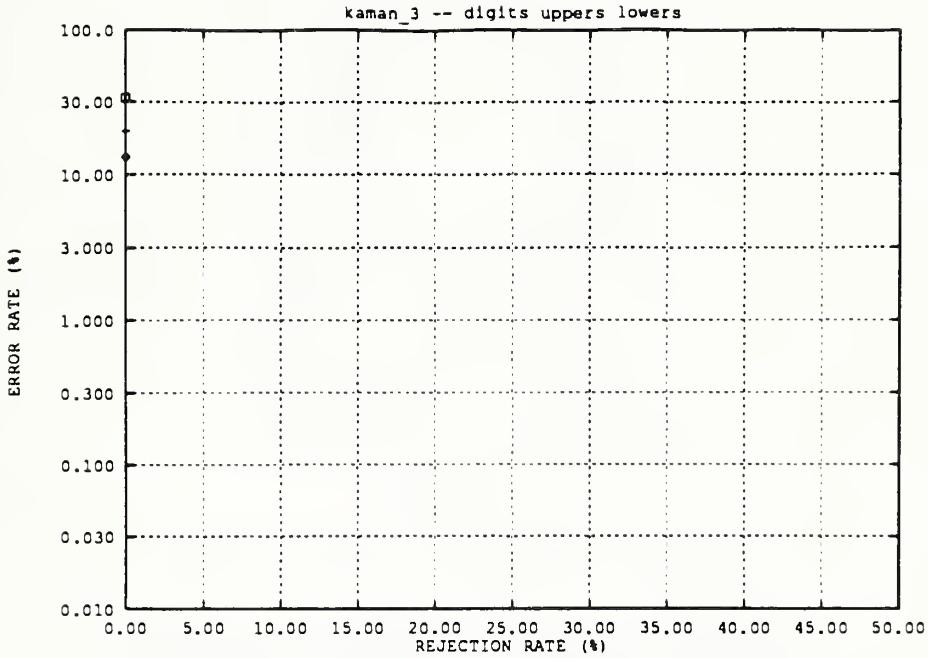

Figure 131: Error rate versus rejection rate for KAMAN_3

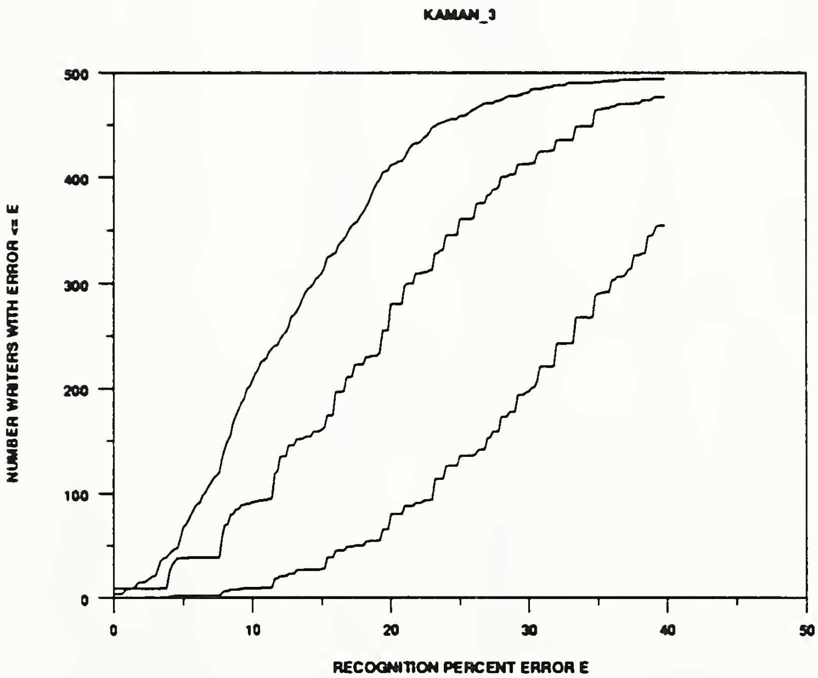

Figure 132: Error rate per writer of KAMAN_3

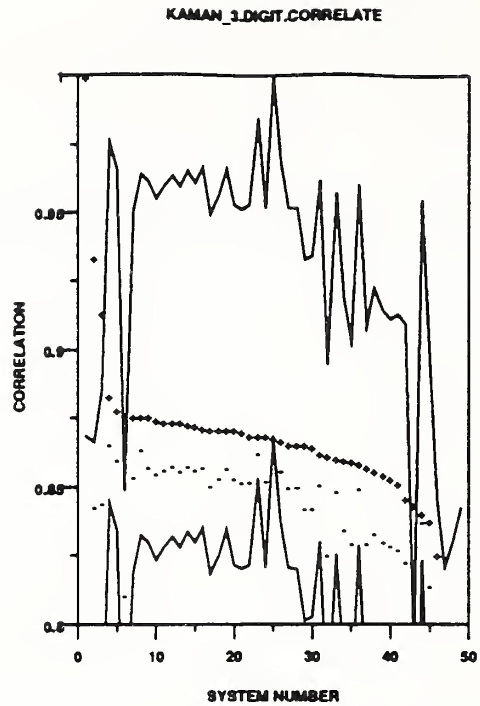

Figure 133: KAMAN_3 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	KAMAN_3	1.0000	1.0000
2	KAMAN_2	0.9343	0.8436
3	KAMAN_1	0.9142	0.8448
4	VOTE_M	0.8837	0.8664
5	AEG	0.8789	0.8608
6	KAMAN_5	0.8770	0.8111
7	NIST_4	0.8766	0.8544
8	VOTE_P	0.8765	0.8645
9	ERIM_1	0.8764	0.8583
10	NESTOR	0.8753	0.8559
11	ATT_2	0.8747	0.8587
12	KODAK_2	0.8747	0.8572
13	ATT_4	0.8746	0.8566
14	IBM	0.8737	0.8584
15	ERIM_2	0.8733	0.8572
16	ELSAGB_3	0.8723	0.8582
17	ELSAGB_2	0.8720	0.8579
18	UBOL	0 8720	0.8542
19	ELSAGB_1	0.8720	0.8513
20	KODAK_1	0.8718	0.8538
21	THINK_1	0.8710	0.8525
22	SYMBUS	0.8698	0.8528
23	OCRSYS	0.8697	0.8633
24	ATT_3	0.8696	0.8530
25	REFERENCE	0 8687	0.8687
26	ATT_1	0.8679	0.8569
27	HUGHES_1	0.8664	0.8508
28	HUGHES_2	0.8663	0.8507
29	GTESS_2	0.8662	0.8432
30	GTESS_1	0.8653	0.8432
31	THINK_2	0.8630	0.8518
32	RISO	0.8625	0.8258
33	NYNEX	0.8614	0.8496
34	GMD_3	0.8610	0.8351
35	NIST_3	0.8604	0.8303
36	REI	0 8596	0.8503
37	NIST_2	0.8580	0.8303
38	NIST_1	0.8570	0.8340
39	MIME	0.8555	0.8306
40	ASOL	0.8541	0.8291
41	GMD_1	0.8520	0.8280
42	UPENN	0.8466	0.8232
43	KAMAN_4	0.8445	0.7683
44	COMCOM	0.8410	0.8378
45	GMD_4	0.8384	0.8147
46	GMD_2	0.8258	0.7887
47	VALEN_1	0.7926	0.7584
48	IFAX	0.7878	0.7603
49	VALEN_2	0.7847	0.7670

Table 83: KAMAN_3 correlation graph key for digits.

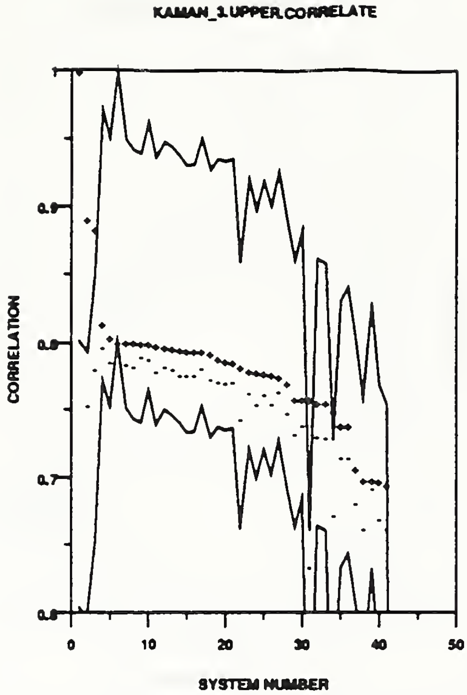

Figure 134: KAMAN_3 - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	KAMAN_3	1.0000	1.0000
2	KAMAN_2	0.8915	0.7546
3	KAMAN_1	0.8844	0.7818
4	VOTE_M	0.8151	0.7983
5	ATT_4	0.8053	0.7875
6	REFERENCE	0.8022	0.8022
7	UMICH_1	0.8018	0.7849
8	NESTOR	0.8013	0.7837
9	VOTE_P	0.8012	0.7910
10	AEG	0.8007	0.7892
11	IBM	0.7988	0.7801
12	ERIM_1	0.7983	0.7833
13	ATT_2	0.7973	0.7813
14	UBOL	0.7958	0.7774
15	KODAK_1	0.7952	0.7769
16	ATT_3	0.7951	0.7767
17	NYNEX	0.7949	0.7827
18	SYMBUS	0.7934	0.7741
19	HUGHES_1	0.7894	0.7728
20	HUGHES_2	0.7881	0.7714
21	ATT_1	0.7872	0.7723
22	RISO	0.7835	0.7449
23	GTESS_1	0.7807	0.7643
24	NIST_4	0.7797	0.7558
25	GTESS_2	0.7792	0.7633
26	MIME	0.7782	0.7560
27	OCRSYS	0.7756	0.7646
28	ASOL	0.7711	0.7495
29	REI	0.7597	0.7399
30	GMD_1	0.7597	0.7339
31	KAMAN_5	0.7594	0.6348
32	NIST_1	0.7570	0.7315
33	GMD_3	0.7564	0.7313
34	KAMAN_4	0.7499	0.6728
35	GMD_4	0.7406	0.7166
36	NIST_3	0.7406	0.7164
37	IFAX	0.7081	0.6824
38	VALEN_1	0.6998	0.6628
39	COMCOM	0.6997	0.6937
40	NIST_2	0.6990	0.6706
41	GMD_2	0.6963	0.6633
42	UMICH_2	0.0718	0.0137

Table 84: KAMAN_3 correlation graph key for uppers.

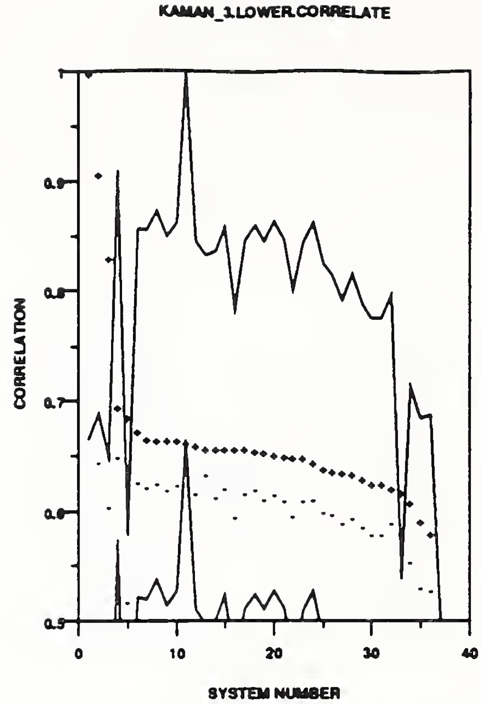

Figure 135: KAMAN_3 - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	KAMAN_3	1.0000	1.0000
2	KAMAN_1	0 9089	0.6464
3	KAMAN_2	0.8320	0.6050
4	VOTE_M	0.6968	0.6508
5	KAMAN_5	0.6873	0.5186
6	ATT_4	0.6750	0.6283
7	KODAK_1	0 6685	0.6230
8	AEG	0.6677	0.6266
9	UMICH_1	0.6670	0.6216
10	ERIM_1	0 6668	0.6262
11	REFERENCE	0.6645	0.6645
12	IBM	0.6624	0.6177
13	VOTE_P	0.6597	0.6345
14	ATT_3	0.6597	0.6146
15	ATT_2	0.6596	0.6227
16	NESTOR	0.6593	0.6179
17	RISO	0 6593	0.5964
18	NYNEX	0.6566	0.6209
19	UBOL	0.6562	0.6116
20	OCRSYS	0.6529	0.6169
21	HUGHES_1	0.6525	0.6112
22	NIST_4	0.6516	0.5969
23	HUGHES_2	0.6515	0.6109
24	ATT_1	0.6461	0.6118
25	GTESS_1	0.6413	0.6007
26	NIST_1	0.6388	0.5978
27	GMD_3	0.6373	0.5907
28	GTESS_2	0.6363	0.5949
29	ASOL	0.6314	0.5863
30	GMD_4	0.6270	0.5795
31	GMD_1	0.6270	0.5795
32	NIST_3	0.6222	0.5898
33	KAMAN_4	0.6184	0.4792
34	GMD_2	0.6093	0.5548
35	VALEN_1	0.5921	0.5312
36	NIST_2	0 5806	0.5297
37	COMCOM	0 4097	0.3981
38	UMICH_2	0.1213	0.0336

Table 85: KAMAN_3 correlation graph key for lowers.

SYSTEM: KAMAN_4

PARTICIPANT: Mark G. Costello

ORGANIZATION: Kaman Sciences Corporation, Utica, NY

FEATURES:

CLASSIFICATION:

HARDWARE: SPARC2, multiuser

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	800	2080	2080	NSDB1?

STATUS: on time

RESULTS:	-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
	0.00	0.2072	0.00	0.2728	0.00	0.4625	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	0.94	0.56	0.56
CPU RATE:			

SYSTEM: KAMAN_4

BIBLIOGRAPHY:

The following references have been provided for this system:

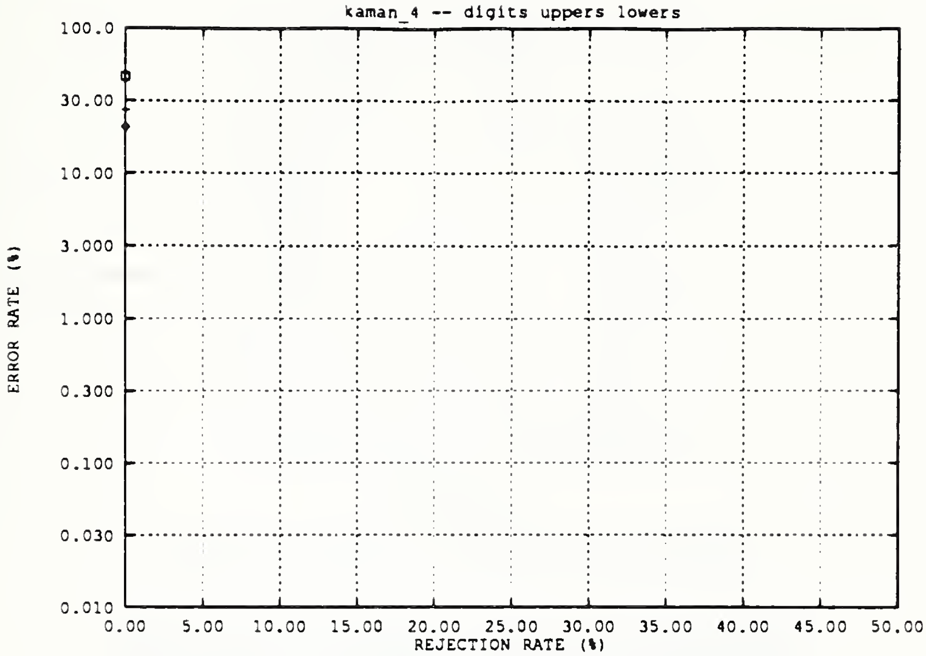

Figure 136: Error rate versus rejection rate for KAMAN_4

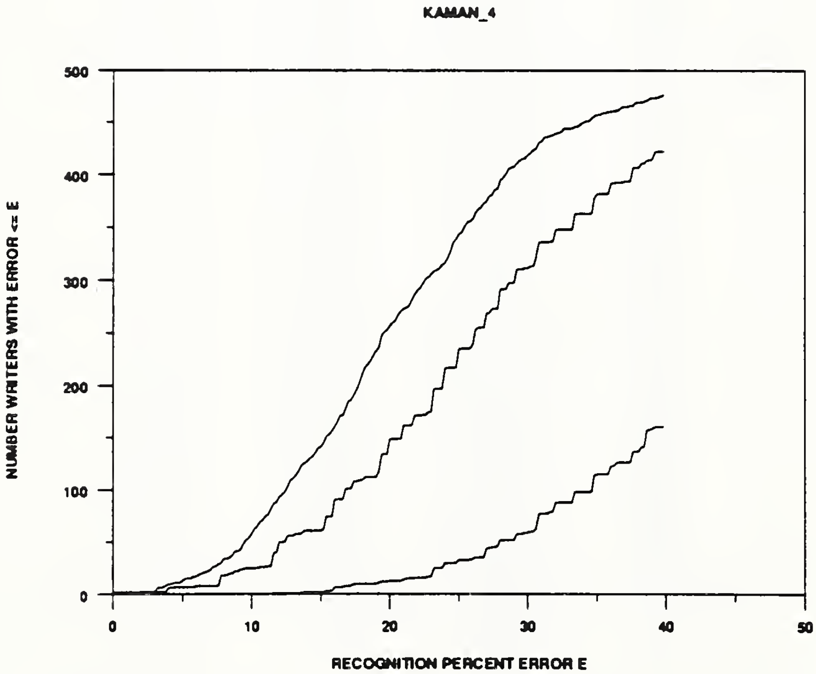

Figure 137: Error rate per writer of KAMAN_4

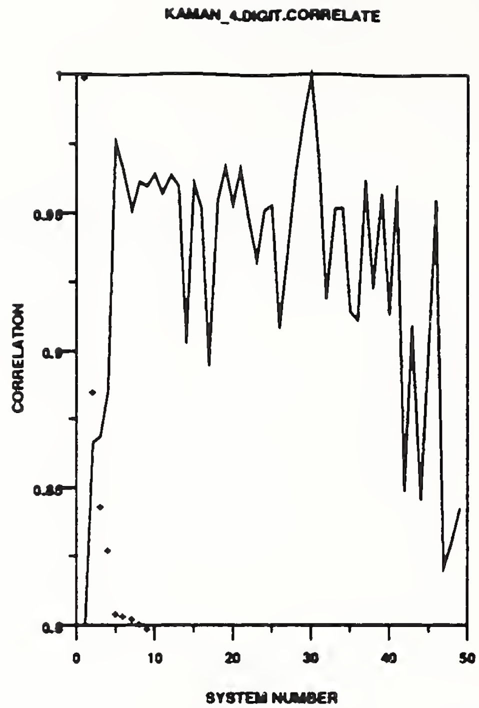

Figure 138: KAMAN_4 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	KAMAN_4	1.0000	1.0000
2	KAMAN_2	0.8864	0.7807
3	KAMAN_3	0.8445	0.7683
4	KAMAN_1	0.8284	0.7696
5	VOTE_M	0.8054	0.7903
6	AEG	0.8043	0.7867
7	NIST_4	0.8036	0.7813
8	ERIM_1	0.8016	0.7844
9	ATT_4	0.8000	0.7826
10	VOTE_P	0.7993	0.7885
11	UBOL	0.7990	0.7809
12	ATT_2	0.7983	0.7834
13	KODAK_2	0.7978	0.7819
14	ERIM_2	0.7976	0.7825
15	NIST_3	0.7976	0.7628
16	ATT_3	0.7975	0.7802
17	RISO	0.7974	0.7582
18	NESTOR	0.7971	0.7807
19	ELSAGB_3	0.7968	0.7834
20	ELSAGB_2	0.7965	0.7831
21	SYMBUS	0.7965	0.7800
22	ELSAGB_1	0.7964	0.7775
23	GTESS_2	0.7963	0.7715
24	THINK_1	0.7962	0.7780
25	KODAK_1	0.7955	0.7788
26	NIST_2	0.7950	0.7624
27	GTESS_1	0.7946	0.7713
28	IBM	0.7945	0.7824
29	OCRSYS	0.7933	0.7875
30	REFERENCE	0.7928	0.7928
31	ATT_1	0.7922	0.7821
32	GMD_3	0.7915	0.7646
33	HUGHES_1	0.7894	0.7760
34	HUGHES_2	0.7891	0.7759
35	MIME	0.7882	0.7606
36	THINK_2	0.7865	0.7766
37	ASOL	0.7865	0.7592
38	NIST_1	0.7863	0.7623
39	NYNEX	0.7853	0.7750
40	REI	0.7832	0.7755
41	GMD_1	0.7832	0.7585
42	KAMAN_5	0.7763	0.7307
43	UPENN	0.7740	0.7517
44	GMD_2	0.7727	0.7280
45	GMD_4	0.7713	0.7463
46	COMCOM	0.7676	0.7646
47	VALEN_1	0.7310	0.6954
48	IFAX	0.7267	0.6971
49	VALEN_2	0.7180	0.7006

Table 86: KAMAN_4 correlation graph key for digits.

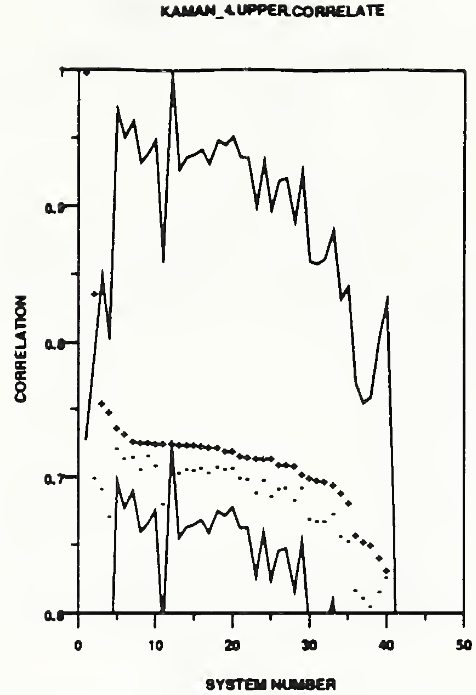

Figure 139: KAMAN_4 - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	KAMAN_4	1.0000	1.0000
2	KAMAN_2	0.8382	0.7018
3	KAMAN_1	0.7566	0.6932
4	KAMAN_3	0.7499	0.6728
5	VOTE_M	0.7397	0.7232
6	ATT_4	0.7351	0.7162
7	AEG	0.7290	0.7169
8	ATT_3	0.7286	0.7078
9	VOTE_P	0.7279	0.7177
10	UMICH_1	0.7275	0.7108
11	REFERENCE	0.7272	0.7272
12	RISO	0.7272	0.6826
13	SYMBUS	0.7267	0.7056
14	IBM	0.7264	0.7076
15	UBOL	0.7262	0.7070
16	NESTOR	0.7258	0.7091
17	KODAK_1	0.7249	0.7054
18	ERIM_1	0.7248	0.7097
19	ATT_2	0.7222	0.7077
20	NYNEX	0.7215	0.7094
21	ATT_1	0.7178	0.7012
22	HUGHES_1	0.7174	0.7010
23	MIME	0.7163	0.6904
24	HUGHES_2	0.7162	0.6997
25	NIST_4	0.7159	0.6880
26	GTESS_2	0.7117	0.6933
27	GTESS_1	0.7116	0.6939
28	ASOL	0.7107	0.6855
29	OCRSYS	0.7047	0.6945
30	GMD_1	0.7012	0.6710
31	GMD_3	0.6998	0.6696
32	NIST_1	0.6986	0.6691
33	REI	0.6958	0.6750
34	NIST_3	0.6910	0.6583
35	GMD_4	0.6836	0.6550
36	NIST_2	0.6592	0.6189
37	GMD_2	0.6543	0.6134
38	VALEN_1	0.6519	0.6074
39	IFAX	0.6431	0.6176
40	COMCOM	0.6335	0.6282
41	KAMAN_5	0.5948	0.5491
42	UMICH_2	0.0855	0.0126

Table 87: KAMAN_4 correlation graph key for uppers.

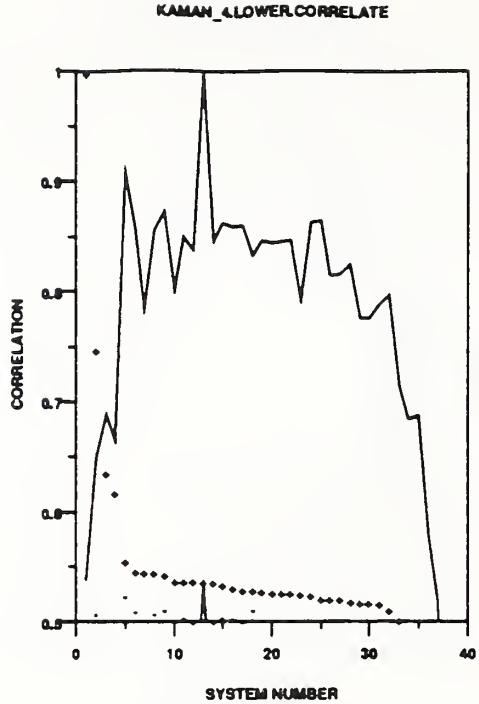

Figure 140: KAMAN_4 - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	KAMAN_4	1.0000	1.0000
2	KAMAN_2	0.7484	0.5091
3	KAMAN_1	0.6373	0.4952
4	KAMAN_3	0.6184	0.4792
5	VOTE_M	0.5572	0.5249
6	ATT_4	0.5477	0.5107
7	RISO	0.5463	0.4889
8	KODAK_1	0.5461	0.5091
9	AEG	0.5438	0.5117
10	NIST_4	0.5388	0.4908
11	UMICH_1	0.5384	0.5052
12	ATT_3	0.5381	0.5007
13	REFERENCE	0.5375	0.5375
14	UBOL	0.5372	0.5010
15	ERIM_1	0.5356	0.5058
16	ATT_2	0.5334	0.5045
17	NYNEX	0.5311	0.5022
18	VOTE_P	0.5306	0.5124
19	HUGHES_1	0.5293	0.4966
20	HUGHES_2	0.5288	0.4958
21	IBM	0.5284	0.4976
22	NESTOR	0.5280	0.4996
23	GMD_3	0.5268	0.4839
24	ATT_1	0.5254	0.4979
25	OCRSYS	0.5228	0.4985
26	NIST_1	0.5225	0.4866
27	GTESS_2	0.5224	0.4880
28	GTESS_1	0.5203	0.4888
29	GMD_4	0.5192	0.4757
30	GMD_1	0.5192	0.4757
31	ASOL	0.5184	0.4772
32	NIST_3	0.5127	0.4796
33	GMD_2	0.5033	0.4527
34	VALEN_1	0.4939	0.4405
35	NIST_2	0.4865	0.4370
36	KAMAN_5	0.4469	0.3871
37	COMCOM	0.3302	0.3223
38	UMICH_2	0.1213	0.0243

Table 88: KAMAN_4 correlation graph key for lowers.

SYSTEM: KAMAN_5

PARTICIPANT: Mark G. Costello

ORGANIZATION: Kaman Sciences Corporation, Utica, NY

FEATURES:

CLASSIFICATION:

HARDWARE: SPARC2, multiuser

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	800	2080	2080	NSDB1?

STATUS: on time

RESULTS:	-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
	0.00	0.1513	0.00	0.3395	0.00	0.4220	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	6.57	3.74	3.74
CPU RATE:			

SYSTEM: KAMAN_5

BIBLIOGRAPHY:

The following references have been provided for this system:

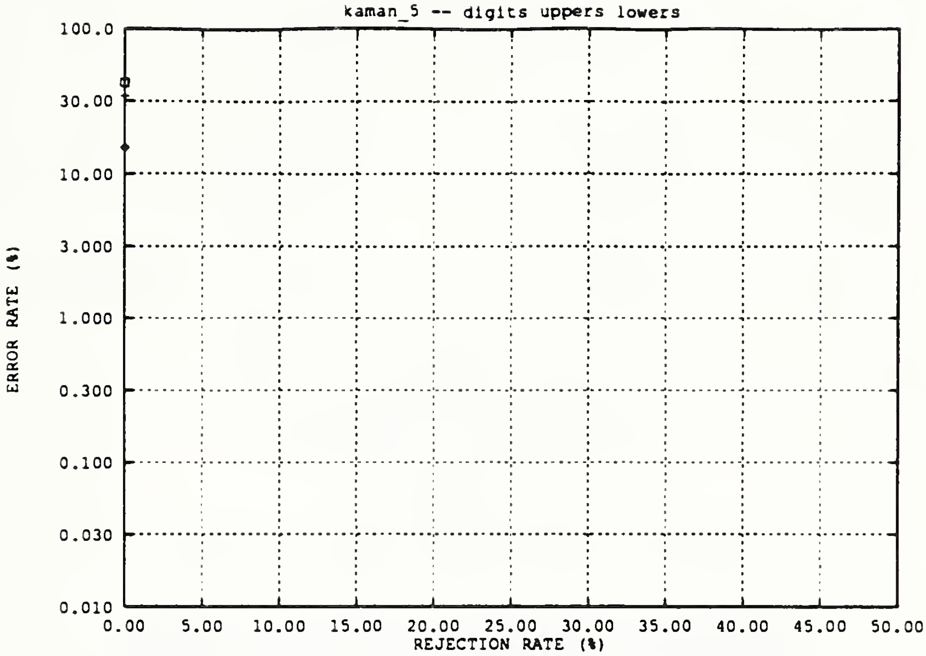

Figure 141: Error rate versus rejection rate for KAMAN_5

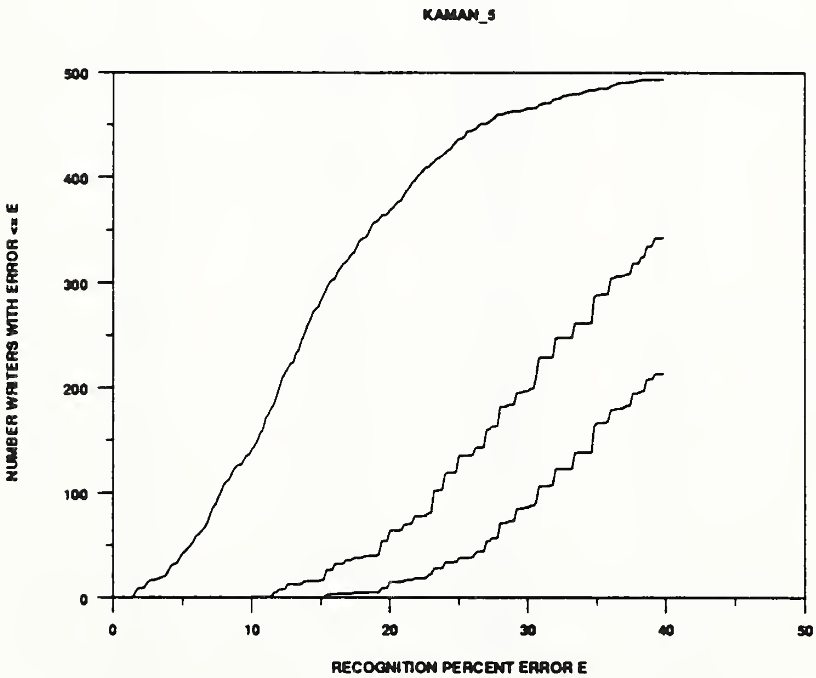

Figure 142: Error rate per writer of KAMAN_5

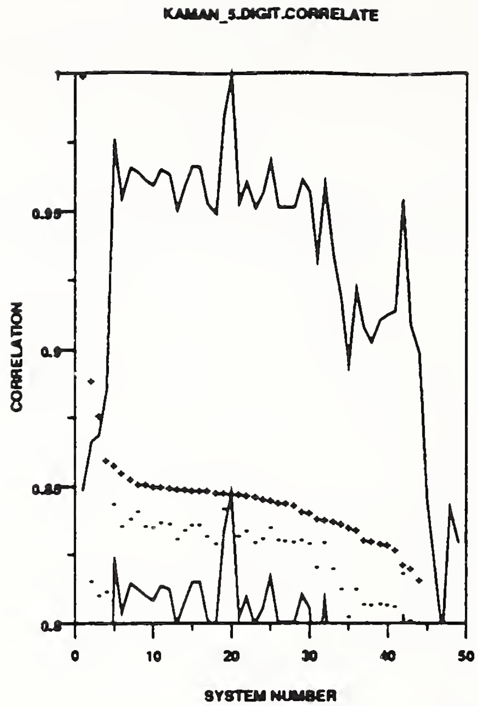

Figure 143: KAMAN_5 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	KAMAN_5	1.0000	1.0000
2	KAMAN_2	0.8899	0.8162
3	KAMAN_3	0.8770	0.8111
4	KAMAN_1	0.8610	0.8127
5	VOTE_M	0.8590	0.8448
6	NESTOR	0.8561	0.8364
7	AEG	0.8540	0.8391
8	VOTE_P	0.8522	0.8423
9	ERIM_1	0.8521	0.8367
10	KODAK_2	0.8514	0.8361
11	IBM	0.8513	0.8380
12	ATT_2	0.8508	0.8375
13	ATT_4	0.8503	0.8352
14	NIST_4	0.8503	0.8319
15	ELSAGB_3	0.8501	0.8371
16	ELSAGB_2	0.8499	0.8369
17	KODAK_1	0.8497	0.8330
18	ELSAGB_1	0.8491	0.8303
19	OCRSYS	0.8489	0.8431
20	REFERENCE	0.8487	0.8487
21	SYMBUS	0.8484	0.8327
22	ERIM_2	0.8482	0.8349
23	THINK_1	0.8474	0.8307
24	UBOL	0.8467	0.8321
25	ATT_1	0.8463	0.8363
26	ATT_3	0.8455	0.8314
27	HUGHES_2	0.8452	0.8309
28	HUGHES_1	0.8443	0.8304
29	THINK_2	0.8420	0.8317
30	NYNEX	0.8414	0.8303
31	GTESS_2	0.8392	0.8212
32	REI	0.8389	0.8305
33	GTESS_1	0.8382	0.8211
34	GMD_3	0.8374	0.8138
35	RISO	0.8359	0.8035
36	NIST_1	0.8350	0.8138
37	NIST_2	0.8313	0.8080
38	NIST_3	0.8310	0.8074
39	ASOL	0.8302	0.8080
40	GMD_1	0.8297	0.8074
41	MIME	0.8279	0.8071
42	COMCOM	0.8223	0.8189
43	UPENN	0.8211	0.8022
44	GMD_4	0.8170	0.7946
45	GMD_2	0.7975	0.7664
46	VALEN_1	0.7828	0.7440
47	KAMAN_4	0.7763	0.7307
48	VALEN_2	0.7695	0.7506
49	IFAX	0.7653	0.7412

Table 89: KAMAN_5 correlation graph key for digits.

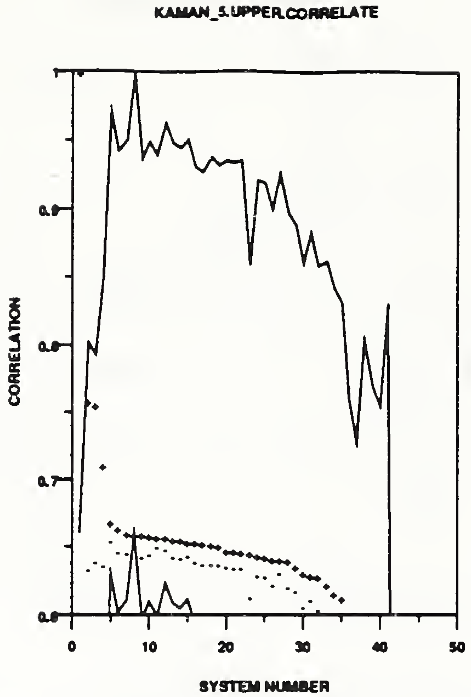

Figure 144: KAMAN_5 - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	KAMAN_5	1.0000	1.0000
2	KAMAN_3	0.7594	0.6348
3	KAMAN_2	0.7566	0.6400
4	KAMAN_1	0.7117	0.6372
5	VOTE_M	0 6690	0.6560
6	NESTOR	0.6648	0.6473
7	ATT_4	0.6616	0.6469
8	REFERENCE	0.6605	0.6605
9	IBM	0.6603	0.6435
10	UMICH_1	0.6592	0.6458
11	VOTE_P	0 6587	0.6508
12	AEG	0.6585	0.6491
13	ERIM_1	0.6566	0.6441
14	ATT_2	0.6562	0.6429
15	NYNEX	0.6551	0.6450
16	KODAK_1	0.6546	0.6399
17	SYMBUS	0.6542	0.6381
18	UBOL	0.6531	0.6386
19	ATT_3	0.6516	0.6384
20	HUGHES_1	0.6481	0.6360
21	HUGHES_2	0.6479	0.6351
22	ATT_1	0.6478	0.6356
23	RISO	0.6464	0.6143
24	GTESS_1	0.6443	0.6303
25	GTESS_2	0 6434	0.6294
26	MIME	0.6422	0.6234
27	OCRSYS	0.6417	0.6314
28	NIST_4	0.6414	0.6215
29	ASOL	0.6360	0.6189
30	GMD_1	0.6319	0.6073
31	REI	0.6303	0.6121
32	GMD_3	0.6286	0.6049
33	NIST_1	0.6239	0.6022
34	GMD_4	0 6171	0.5928
35	NIST_3	0.6135	0.5922
36	VALEN_1	0.5987	0.5595
37	KAMAN_4	0.5948	0.5491
38	IFAX	0.5874	0.5646
39	NIST_2	0.5829	0.5580
40	GMD_2	0.5801	0.5490
41	COMCOM	0.5768	0.5718
42	UMICH_2	0.0927	0.0113

Table 90: KAMAN_5 correlation graph key for uppers.

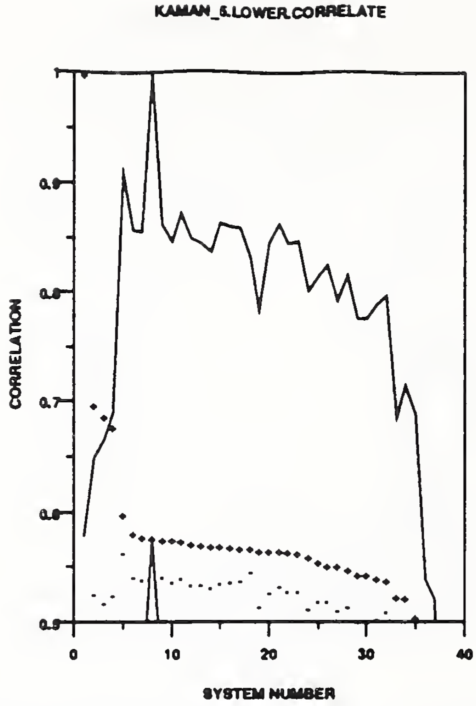

Figure 145: KAMAN_5 - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	KAMAN_5	1.0000	1.0000
2	KAMAN_2	0.6985	0.5269
3	KAMAN_3	0.6873	0.5186
4	KAMAN_1	0.6787	0.5261
5	VOTE_M	0.6000	0.5641
6	ATT_4	0.5823	0.5420
7	KODAK_1	0.5787	0.5397
8	REFERENCE	0.5780	0.5780
9	ERIM_1	0.5763	0.5423
10	NESTOR	0.5761	0.5374
11	AEG	0.5755	0.5407
12	UMICH_1	0.5727	0.5353
13	IBM	0.5724	0.5352
14	ATT_3	0.5709	0.5332
15	OCRSYS	0.5707	0.5365
16	NYNEX	0.5693	0.5378
17	ATT_2	0.5680	0.5385
18	VOTE_P	0.5679	0.5470
19	UBOL	0.5667	0.5284
20	RISO	0.5667	0.5158
21	ATT_1	0.5658	0.5338
22	HUGHES_2	0.5648	0.5293
23	HUGHES_1	0.5642	0.5293
24	NIST_4	0.5602	0.5135
25	NIST_1	0.5562	0.5202
26	GTESS_1	0.5527	0.5203
27	GMD_3	0.5522	0.5116
28	GTESS_2	0.5490	0.5156
29	GMD_4	0.5438	0.5020
30	GMD_1	0.5438	0.5020
31	ASOL	0.5412	0.5042
32	NIST_3	0.5383	0.5111
33	VALEN_1	0.5253	0.4665
34	GMD_2	0.5239	0.4779
35	NIST_2	0.5059	0.4600
36	KAMAN_4	0.4469	0.3871
37	COMCOM	0.3582	0.3483
38	UMICH_2	0.1276	0.0333

Table 91: KAMAN_5 correlation graph key for lowers.

SYSTEM: KODAK_1

PARTICIPANT: Dr. Arun Rao

ORGANIZATION: Eastman Kodak Company, Rochester, NY

FEATURES: Gabor functions, polynomial, and local receptor fields

CLASSIFICATION: four layer NN with local receptive fields and proprietary BP

HARDWARE: HP/Apollo 730

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	180000	36000	4400022	NSDB3

STATUS: on time

RESULTS:	-- DIGITS --		-- UPPERS --		-- LOWERS --	DATABASE
REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
0.00	0.0474	0.00	0.0692	0.00	0.1449	
0.10	0.0151	0.10	0.0300	0.10	0.1014	
0.20	0.0105	0.20	0.0131	0.20	0.0643	
0.30	0.0105	0.30	0.0071	0.30	0.0388	
0.40	0.0109	0.40	0.0043	0.40	0.0261	
0.50	0.0110	0.50	0.0028	0.50	0.0148	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	14.82	11.68	8.95
CPU RATE:	27.35	12.47	11.78

NOTE: Some upper case characters were added for training lowers.

SYSTEM: KODAK_1

BIBLIOGRAPHY:

The following references have been provided for this system:

[5][27][28]

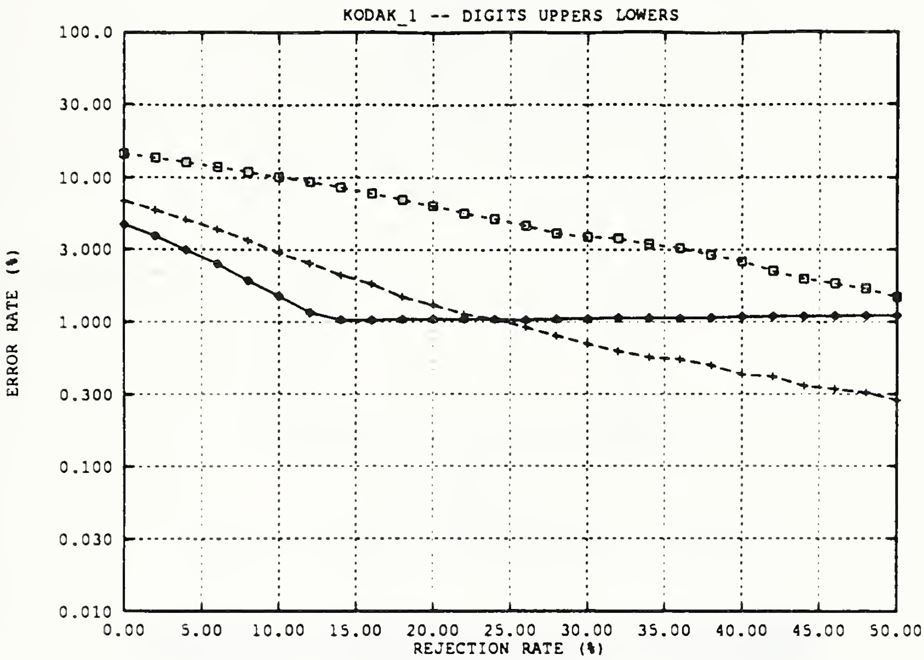

Figure 146: Error rate versus rejection rate for KODAK_1

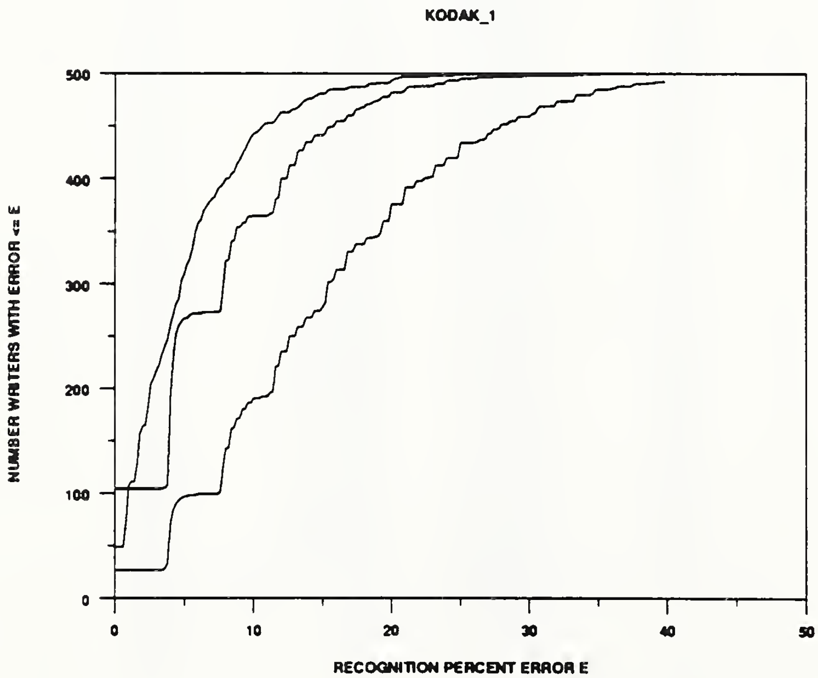

Figure 147: Error rate per writer of KODAK_1

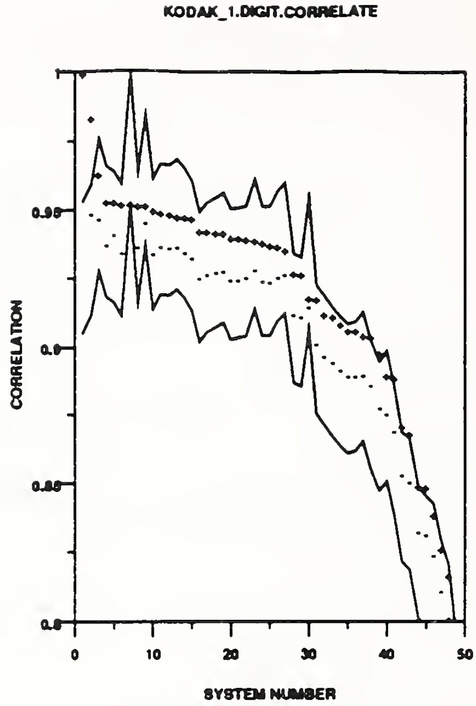

Figure 148: KODAK_1 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	KODAK_1	1.0000	1.0000
2	KODAK_2	0.9841	0.9489
3	VOTE_M	0.9637	0.9474
4	AEG	0.9536	0.9383
5	VOTE_P	0.9535	0.9418
6	REFERENCE	0.9526	0.9526
7	ATT_4	0.9526	0.9351
8	ATT_2	0.9523	0.9371
9	OCRSYS	0.9522	0.9458
10	ERIM_1	0.9504	0.9349
11	ELSAGB_3	0.9497	0.9371
12	ELSAGB_2	0.9492	0.9368
13	ATT_1	0.9484	0.9371
14	IBM	0.9480	0.9354
15	ERIM_2	0.9476	0.9335
16	ELSAGB_1	0.9431	0.9260
17	SYMBUS	0.9430	0.9273
18	NESTOR	0.9427	0.9286
19	UBOL	0.9425	0.9290
20	THINK_1	0.9409	0.9255
21	NIST_4	0.9409	0.9255
22	ATT_3	0.9403	0.9267
23	THINK_2	0.9397	0.9295
24	HUGHES_1	0.9388	0.9251
25	HUGHES_2	0.9379	0.9248
26	NYNEX	0.9374	0.9265
27	REI	0.9363	0.9276
28	GTESS_1	0.9279	0.9126
29	GTESS_2	0.9275	0.9119
30	COMCOM	0.9186	0.9158
31	NIST_1	0.9182	0.9016
32	GMD_3	0.9130	0.8973
33	MIME	0.9119	0.8948
34	ASOL	0.9093	0.8921
35	NIST_2	0.9070	0.8899
36	UPENN	0.9070	0.8897
37	GMD_1	0.9052	0.8904
38	NIST_3	0.9046	0.8868
39	RISO	0.8985	0.8785
40	GMD_4	0.8904	0.8760
41	KAMAN_1	0.8893	0.8699
42	KAMAN_3	0.8718	0.8538
43	KAMAN_2	0.8692	0.8512
44	KAMAN_5	0.8497	0.8330
45	GMD_2	0.8494	0.8319
46	VALEN_2	0.8393	0.8247
47	IFAX	0.8271	0.8117
48	VALEN_1	0.8172	0.8020
49	KAMAN_4	0.7955	0.7788

Table 92: KODAK_1 correlation graph key for digits.

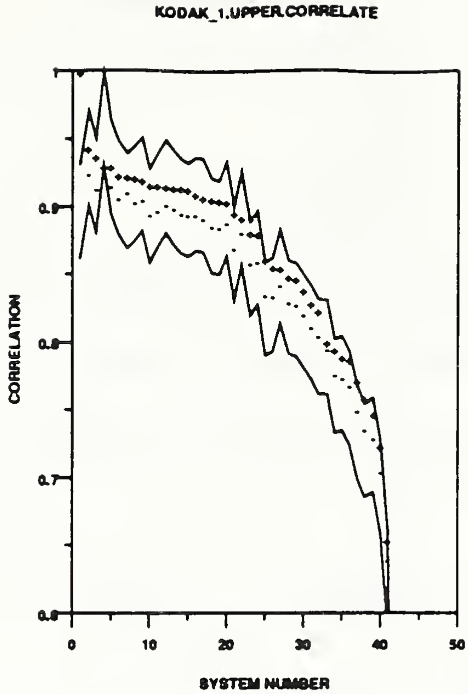

Figure 149: KODAK_1 - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	KODAK_1	1.0000	1.0000
2	VOTE_M	0.9439	0.9249
3	ATT_4	0.9374	0.9140
4	REFERENCE	0.9308	0.9308
5	AEG	0.9302	0.9158
6	ERIM_1	0.9237	0.9066
7	VOTE_P	0.9229	0.9108
8	ATT_2	0.9225	0.9039
9	NYNEX	0.9203	0.9060
10	SYMBUS	0.9170	0.8941
11	UBOL	0.9168	0.8977
12	UMICH_1	0.9160	0.9022
13	NESTOR	0.9144	0.8992
14	ATT_1	0.9143	0.8957
15	ATT_3	0.9141	0.8946
16	IBM	0.9101	0.8947
17	HUGHES_1	0.9073	0.8917
18	GTESS_1	0.9064	0.8864
19	GTESS_2	0.9060	0.8854
20	HUGHES_2	0.9047	0.8891
21	MIME	0.8965	0.8711
22	OCRSYS	0.8925	0.8820
23	ASOL	0.8819	0.8592
24	NIST_4	0.8807	0.8608
25	RISO	0.8625	0.8359
26	NIST_1	0.8565	0.8344
27	REI	0.8556	0.8428
28	GMD_1	0.8491	0.8304
29	GMD_3	0.8478	0.8287
30	KAMAN_1	0.8393	0.8209
31	GMD_4	0.8292	0.8118
32	NIST_3	0.8241	0.8056
33	COMCOM	0.8007	0.7949
34	KAMAN_3	0.7952	0.7769
35	IFAX	0.7901	0.7738
36	KAMAN_2	0.7884	0.7685
37	NIST_2	0.7720	0.7500
38	GMD_2	0.7591	0.7364
39	VALEN_1	0.7484	0.7303
40	KAMAN_4	0.7249	0.7054
41	KAMAN_5	0.6546	0.6399
42	UMICH_2	0.0431	0.0222

Table 93: KODAK_1 correlation graph key for uppers.

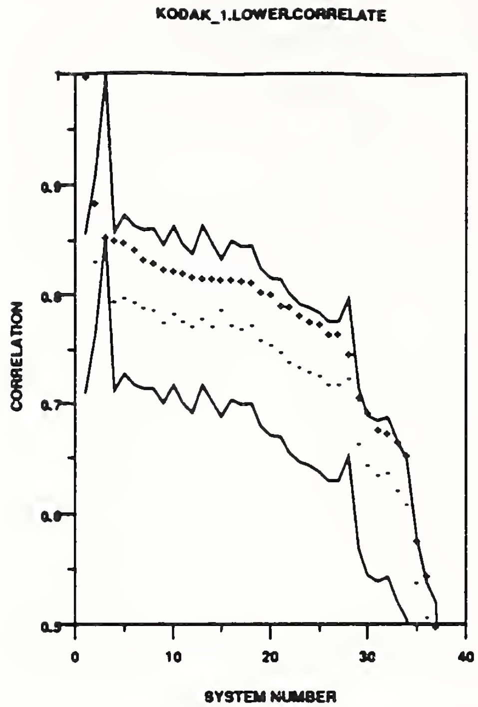

Figure 150: KODAK_1 - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	KODAK_1	1.0000	1.0000
2	VOTE_M	0.8866	0.8336
3	REFERENCE	0.8551	0.8551
4	ATT_4	0.8529	0.7972
5	AEG	0.8508	0.8006
6	ERIM_1	0.8445	0.7961
7	ATT_2	0.8357	0.7911
8	NYNEX	0.8320	0.7888
9	UBOL	0.8267	0.7778
10	ATT_1	0.8261	0.7853
11	NESTOR	0.8235	0.7791
12	ATT_3	0.8199	0.7735
13	OCRSYS	0.8184	0.7811
14	HUGHES_1	0.8183	0.7738
15	VOTE_P	0.8177	0.7884
16	UMICH_1	0.8174	0.7755
17	HUGHES_2	0.8163	0.7719
18	IBM	0.8150	0.7749
19	GTESS_1	0.8058	0.7612
20	GTESS_2	0.8040	0.7573
21	NIST_1	0.7934	0.7503
22	NIST_4	0.7921	0.7408
23	GMD_3	0.7843	0.7362
24	ASOL	0.7788	0.7320
25	RISO	0.7761	0.7279
26	GMD_4	0.7673	0.7199
27	GMD_1	0.7673	0.7199
28	NIST_3	0.7485	0.7257
29	GMD_2	0.7081	0.6662
30	KAMAN_1	0.6947	0.6460
31	VALEN_1	0.6798	0.6371
32	NIST_2	0.6765	0.6399
33	KAMAN_3	0.6685	0.6230
34	KAMAN_2	0.6556	0.6112
35	KAMAN_5	0.5787	0.5397
36	KAMAN_4	0.5461	0.5091
37	COMCOM	0.5007	0.4876
38	UMICH_2	0.1031	0.0591

Table 94: KODAK_1 correlation graph key for lowers.

SYSTEM: KODAK_2

PARTICIPANT: Dr. Arun Rao

ORGANIZATION: Eastman Kodak Company, Rochester, NY

FEATURES: Gabor functions, polynomial, and local receptor fields

CLASSIFICATION: four layer NN with local receptive fields and proprietary BP

HARDWARE: HP/Apollo 730

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	180000	NA	NA	NSDB3
	2310 sevens with crosses			INTERNAL

STATUS: on time

RESULTS:

-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
0.00	0.0408					
0.10	0.0117					
0.20	0.0037					
0.30	0.0021					
0.40	0.0015					
0.50	0.0016					

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	8.01	NA	NA
CPU RATE:			

NOTE: Crossed sevens were added to training set after determining need for them from results of KODAK_1.

SYSTEM: KODAK_2

BIBLIOGRAPHY:

The following references have been provided for this system:

[5][27][28]

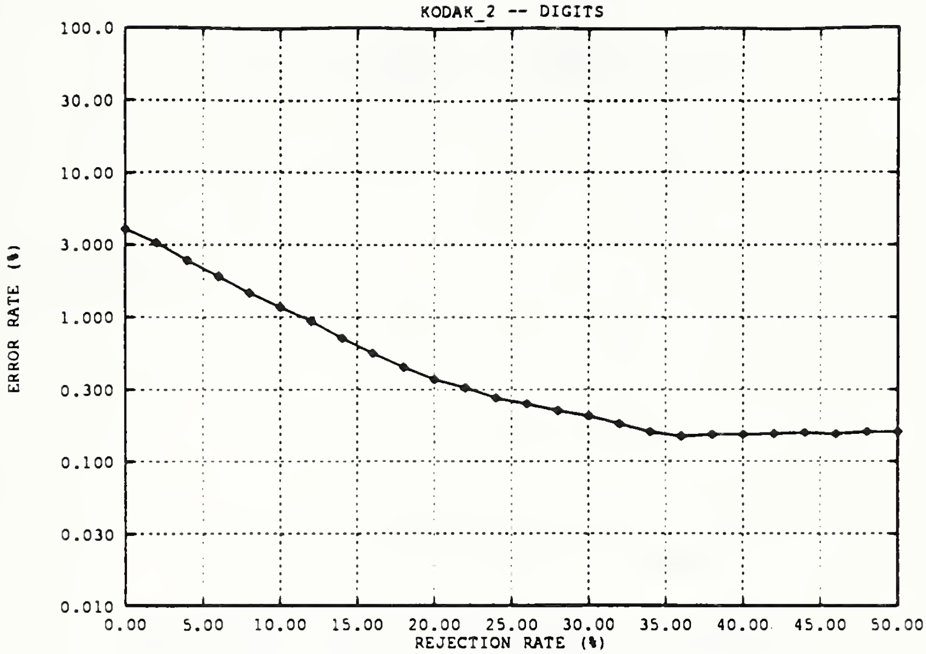

Figure 151: Error rate versus rejection rate for KODAK_2

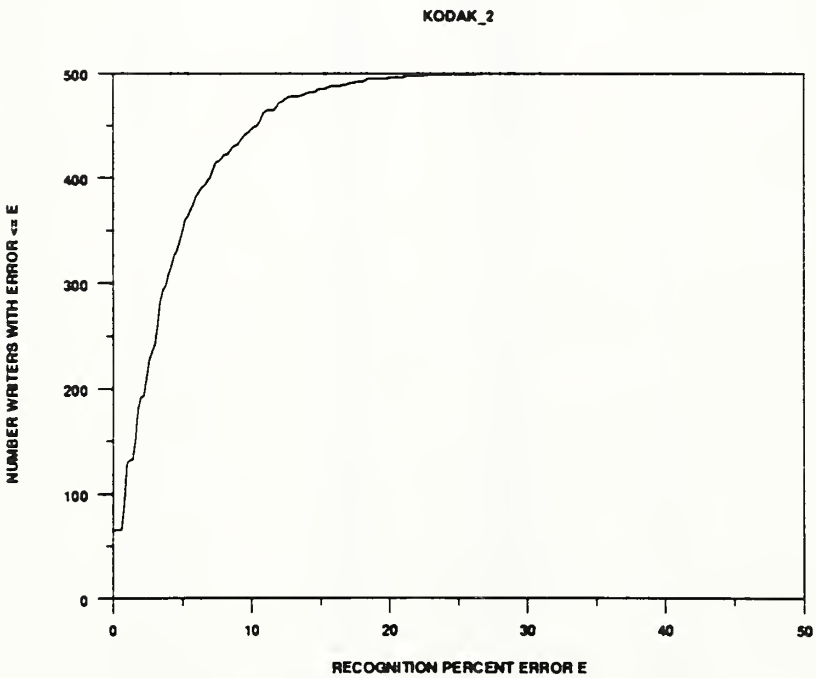

Figure 152: Error rate per writer of KODAK_2

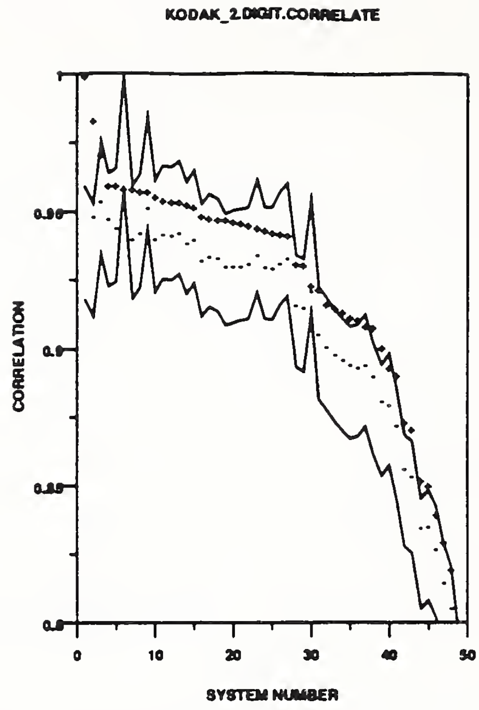

Figure 153: KODAK_2 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	KODAK_2	1.0000	1.0000
2	KODAK_1	0.9841	0.9489
3	VOTE_M	0.9716	0.9545
4	VOTE_P	0.9605	0.9482
5	AEG	0.9605	0.9448
6	REFERENCE	0.9592	0.9592
7	ATT_4	0.9591	0.9410
8	ATT_2	0.9585	0.9431
9	OCRSYS	0.9584	0.9521
10	ERIM_1	0.9566	0.9410
11	ELSAGB_3	0.9550	0.9427
12	ELSAGB_2	0.9545	0.9423
13	ATT_1	0.9544	0.9431
14	ERIM_2	0.9539	0.9396
15	IBM	0.9529	0.9408
16	SYMBUS	0.9494	0.9337
17	UBOL	0.9485	0.9349
18	NESTOR	0.9481	0.9343
19	ELSAGB_1	0.9480	0.9313
20	NIST_4	0.9471	0.9314
21	THINK_1	0.9466	0.9312
22	ATT_3	0.9460	0.9323
23	THINK_2	0.9450	0.9352
24	HUGHES_1	0.9442	0.9306
25	HUGHES_2	0.9432	0.9301
26	NYNEX	0.9429	0.9323
27	REI	0.9424	0.9338
28	GTESS_1	0.9322	0.9170
29	GTESS_2	0.9318	0.9162
30	COMCOM	0.9244	0.9218
31	NIST_1	0.9227	0.9063
32	GMD_3	0.9172	0.9019
33	MIME	0.9160	0.8992
34	ASOL	0.9148	0.8973
35	NIST_2	0.9127	0.8952
36	UPENN	0.9119	0.8945
37	GMD_1	0.9096	0.8953
38	NIST_3	0.9093	0.8912
39	RISO	0.9017	0.8821
40	GMD_4	0.8946	0.8807
41	KAMAN_1	0.8918	0.8733
42	KAMAN_3	0.8747	0.8572
43	KAMAN_2	0.8718	0.8546
44	GMD_2	0.8530	0.8356
45	KAMAN_5	0.8514	0.8361
46	VALEN_2	0.8409	0.8279
47	IFAX	0.8304	0.8155
48	VALEN_1	0.8207	0.8061
49	KAMAN_4	0.7978	0.7819

Table 95: KODAK_2 correlation graph key for digits.

No Data Available

Figure 154: KODAK_2 - upper case correlation

There was no data for this evaluation.

Table 96: KODAK_2 correlation graph key for uppers.

No Data Available

Figure 155: KODAK_2 - lower case correlation

There was no data for this evaluation.

Table 97: KODAK_2 correlation graph key for lowers.

SYSTEM: MIME

PARTICIPANT: Francoise Fogelman

ORGANIZATION: MIMETICS, Chatenay Malabry, France

FEATURES: multi-layer TDNN

CLASSIFICATION: LVQ

HARDWARE: SUN 4, SPARC 1

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	45000	16000		

STATUS: on time, submitted as MIME_1

RESULTS:

-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
0.00	0.0857	0.00	0.1007			
0.12	0.0361	0.14	0.0419			
0.14	0.0298	0.18	0.0331			
0.17	0.0276					

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	5.0	3.0	
CPU RATE:			

NOTE: classification is effectively nearest-neighbor

SYSTEM: MIME

BIBLIOGRAPHY:

The following references have been provided for this system:

[29][30]

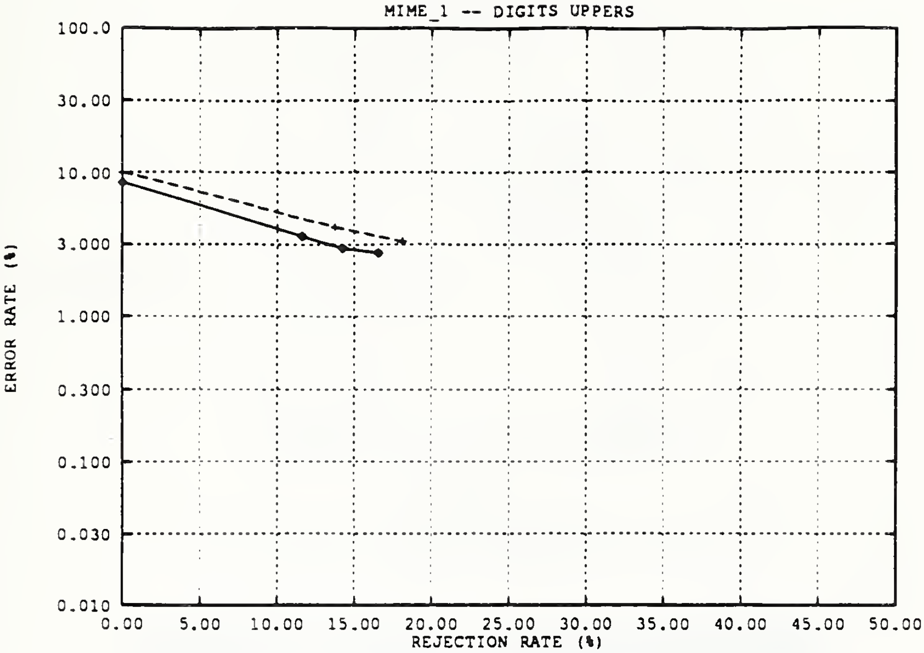

Figure 156: Error rate versus rejection rate for MIME

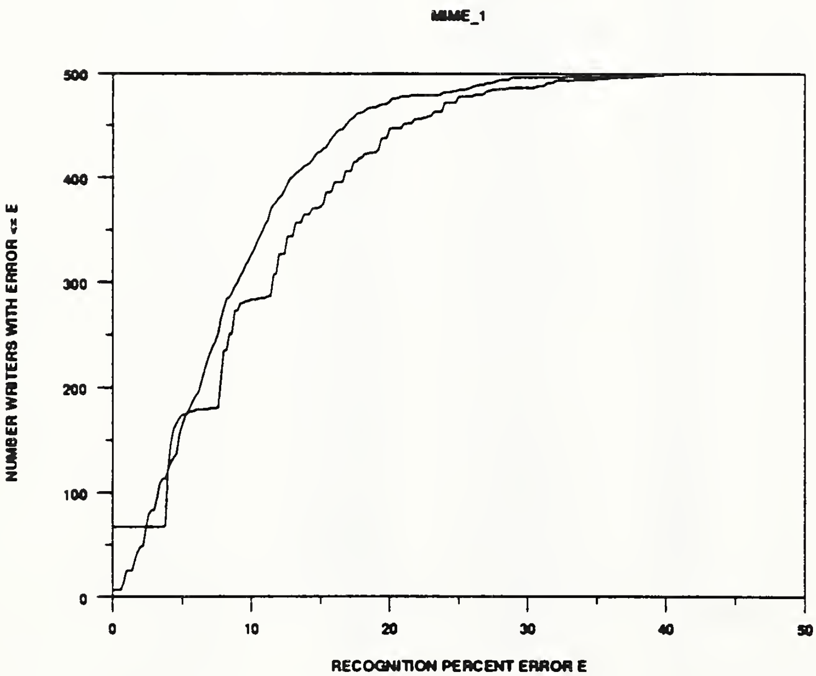

Figure 157: Error rate per writer of MIME

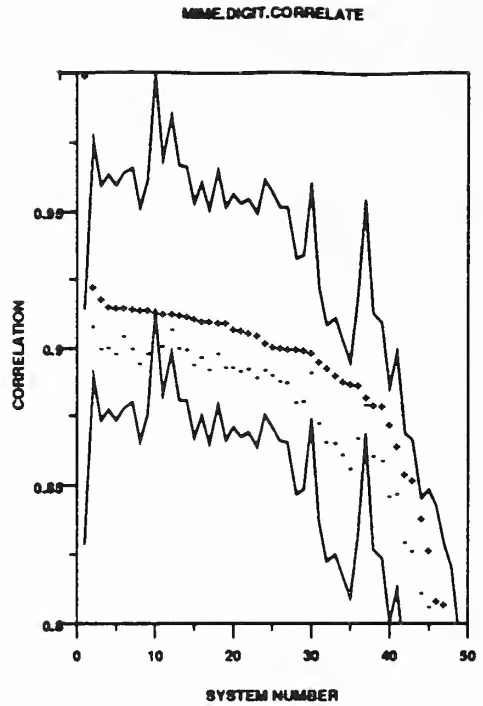

Figure 158: MIME - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	MIME	1.0000	1.0000
2	VOTE_M	0.9239	0.9093
3	ATT_4	0.9193	0.9007
4	ATT_2	0.9163	0.9013
5	KODAK_2	0.9160	0.8992
6	VOTE_P	0.9159	0.9054
7	AEG	0.9155	0.9011
8	ERIM_1	0.9150	0.8992
9	THINK_1	0.9150	0.8952
10	REFERENCE	0.9143	0.9143
11	ATT_1	0.9139	0.9017
12	OCRSYS	0.9138	0.9079
13	ELSAGB_3	0.9132	0.9010
14	ELSAGB_2	0.9128	0.9006
15	KODAK_1	0.9119	0.8948
16	ERIM_2	0.9111	0.8976
17	NIST_4	0.9110	0.8930
18	IBM	0.9105	0.8989
19	ATT_3	0.9103	0.8942
20	UBOL	0.9081	0.8941
21	SYMBUS	0.9079	0.8927
22	NESTOR	0.9069	0.8935
23	ELSAGB_1	0.9059	0.8902
24	THINK_2	0.9030	0.8932
25	NYNEX	0.9020	0.8914
26	HUGHES_1	0.9014	0.8890
27	HUGHES_2	0.9008	0.8887
28	GTESS_2	0.9007	0.8809
29	GTESS_1	0.9004	0.8814
30	REI	0.8997	0.8920
31	NIST_1	0.8962	0.8739
32	NIST_2	0.8940	0.8670
33	ASOL	0.8913	0.8664
34	NIST_3	0.8889	0.8624
35	RISO	0.8882	0.8571
36	GMD_3	0.8874	0.8683
37	COMCOM	0.8831	0.8800
38	GMD_1	0.8800	0.8620
39	UPENN	0.8797	0.8599
40	KAMAN_1	0.8733	0.8469
41	GMD_4	0.8655	0.8480
42	KAMAN_3	0.8555	0.8306
43	KAMAN_2	0.8530	0.8276
44	GMD_2	0.8391	0.8124
45	KAMAN_5	0.8279	0.8071
46	VALEN_2	0.8096	0.7950
47	IFAX	0.8082	0.7881
48	VALEN_1	0.7997	0.7789
49	KAMAN_4	0.7882	0.7606

Table 98: MIME correlation graph key for digits.

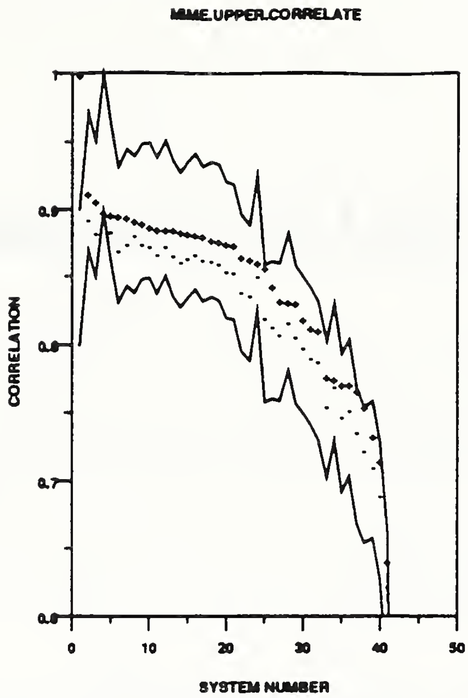

Figure 159: MIME - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	MIME	1.0000	1.0000
2	VOTE_M	0.9131	0.8939
3	ATT_4	0.9077	0.8838
4	REFERENCE	0.8993	0.8993
5	AEG	0.8977	0.8841
6	KODAK_1	0.8965	0.8711
7	ATT_2	0.8952	0.8756
8	VOTE_P	0.8931	0.8818
9	ERIM_1	0.8911	0.8750
10	UMICH_1	0.8879	0.8731
11	UBOL	0.8867	0.8681
12	NYNEX	0.8864	0.8734
13	IBM	0.8860	0.8673
14	SYMBUS	0.8843	0.8622
15	ATT_1	0.8839	0.8653
16	NESTOR	0.8828	0.8683
17	ATT_3	0.8813	0.8643
18	HUGHES_1	0.8793	0.8631
19	HUGHES_2	0.8778	0.8612
20	GTESS_1	0.8764	0.8558
21	GTESS_2	0.8751	0.8546
22	NIST_4	0.8669	0.8401
23	ASOL	0.8648	0.8372
24	OCRSYS	0.8627	0.8521
25	RISO	0.8585	0.8210
26	NIST_1	0.8453	0.8149
27	GMD_1	0.8341	0.8095
28	REI	0.8332	0.8176
29	GMD_3	0.8323	0.8076
30	KAMAN_1	0.8204	0.7987
31	GMD_4	0.8140	0.7913
32	NIST_3	0.8122	0.7886
33	KAMAN_3	0.7782	0.7560
34	COMCOM	0.7764	0.7709
35	KAMAN_2	0.7728	0.7488
36	IFAX	0.7726	0.7529
37	NIST_2	0.7673	0.7375
38	GMD_2	0.7561	0.7236
39	VALEN_1	0.7349	0.7113
40	KAMAN_4	0.7163	0.6904
41	KAMAN_5	0.6422	0.6234
42	UMICH_2	0.0532	0.0193

Table 99: MIME correlation graph key for uppers.

No Data Available

Figure 160: MIME - lower case correlation

There was no data for this evaluation

Table 100: MIME correlation graph key for lowers.

SYSTEM: NESTOR

PARTICIPANT: Christopher L. Scofield

ORGANIZATION: Nestor, Inc., Providence, RI

FEATURES: neocognitron - convolution, 120 dimensional feature vector.

CLASSIFICATION: MLP. Two nets used in parallel, outputs averaged to generate overall confidence value. Training with gradient descent.

HARDWARE: IBM RS6000 Model 320H development environment

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	40000	20000	20000	NSDB1
	1800	1800	1800	writers
	200000	40000	40000	NSDB1
	1800	1800	1800	writers
	15000	0	0	INTERNAL
	800	0	0	writers

STATUS: on time

RESULTS: -- DIGITS -- -- UPPERS -- -- LOWERS -- DATABASE

REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
0.00	0.0453	0.00	0.0590	0.00	0.1539	
0.10	0.0129	0.10	0.0240	0.10	0.1074	
0.20	0.0050	0.20	0.0117	0.20	0.0704	
0.30	0.0029	0.30	0.0068	0.30	0.0469	
0.40	0.0016	0.40	0.0039	0.40	0.0325	
0.50	0.0011	0.50	0.0025	0.50	0.0213	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	14.10	16.80	13.10
CPU RATE:			

SYSTEM: NESTOR

BIBLIOGRAPHY:

The following references have been provided for this system:

[19][31][34][32] [36][37][10] [33][34][35][38]

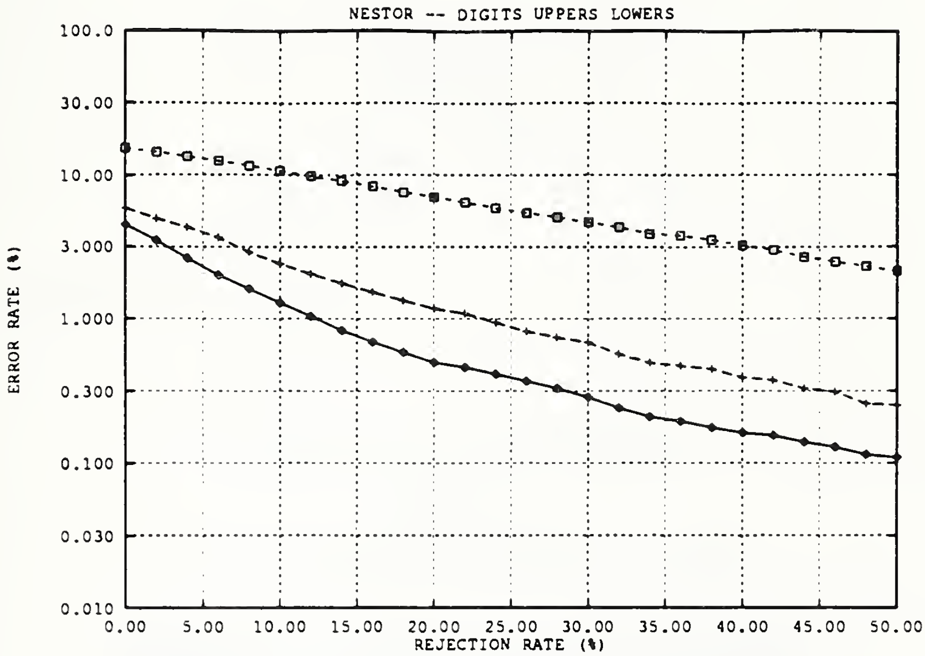

Figure 161: Error rate versus rejection rate for NESTOR

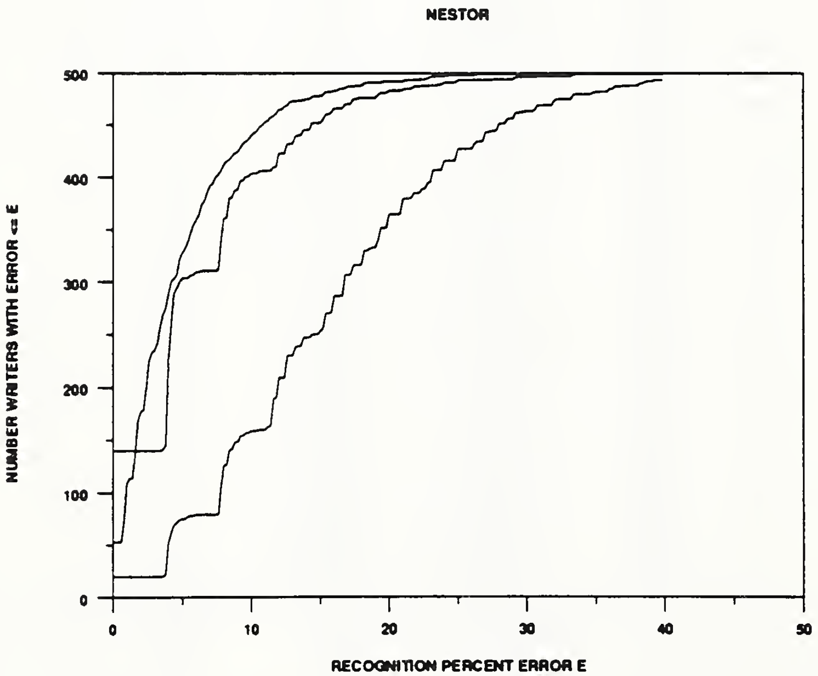

Figure 162: Error rate per writer of NESTOR

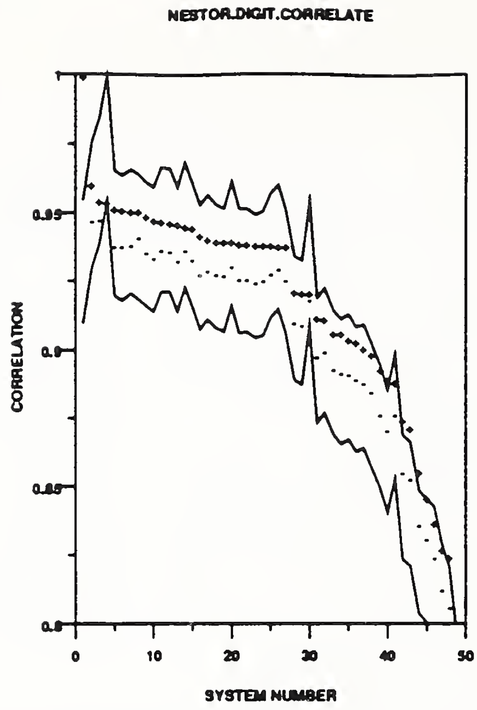

Figure 163: NESTOR - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	NESTOR	1.0000	1.0000
2	VOTE_M	0.9609	0.9478
3	OCRSYS	0.9552	0.9483
4	REFERENCE	0.9547	0.9547
5	IBM	0.9523	0.9386
6	ATT_2	0.9518	0.9384
7	AEG	0.9516	0.9389
8	VOTE_P	0.9515	0.9419
9	ERIM_1	0.9497	0.9361
10	KODAK_2	0.9481	0.9343
11	ELSAGB_3	0.9477	0.9373
12	ELSAGB_2	0.9471	0.9368
13	ATT_4	0.9466	0.9334
14	ATT_1	0.9459	0.9372
15	ERIM_2	0.9455	0.9339
16	KODAK_1	0.9427	0.9286
17	UBOL	0.9415	0.9299
18	SYMBUS	0.9406	0.9283
19	THINK_2	0.9404	0.9311
20	ATT_3	0.9404	0.9282
21	HUGHES_2	0.9395	0.9268
22	HUGHES_1	0.9393	0.9268
23	NIST_4	0.9392	0.9260
24	ELSAGB_1	0.9392	0.9254
25	NYNEX	0.9388	0.9286
26	REI	0.9386	0.9303
27	THINK_1	0.9384	0.9261
28	GTESS_1	0.9222	0.9107
29	COMCOM	0.9215	0.9186
30	GTESS_2	0.9215	0.9096
31	GMD_3	0.9122	0.8982
32	NIST_1	0.9117	0.8998
33	MIME	0.9069	0.8935
34	ASOL	0.9067	0.8921
35	GMD_1	0.9044	0.8916
36	NIST_2	0.9035	0.8897
37	UPENN	0.9013	0.8884
38	NIST_3	0.8992	0.8853
39	RISO	0.8935	0.8772
40	KAMAN_1	0.8898	0.8713
41	GMD_4	0.8891	0.8769
42	KAMAN_3	0.8753	0.8559
43	KAMAN_2	0.8726	0.8537
44	KAMAN_5	0.8561	0.8364
45	GMD_2	0.8466	0.8316
46	VALEN_2	0.8375	0.8245
47	IFAX	0.8279	0.8131
48	VALEN_1	0.8251	0.8068
49	KAMAN_4	0.7971	0.7807

Table 101: NESTOR correlation graph key for digits.

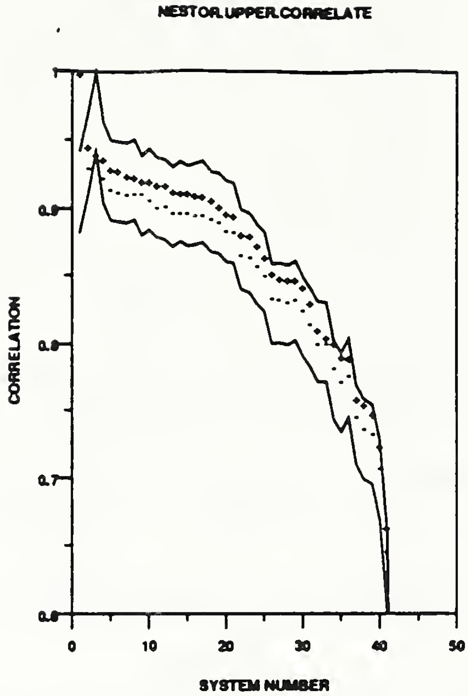

Figure 164: NESTOR - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	NESTOR	1.0000	1.0000
2	VOTE_M	0.9466	0.9310
3	REFERENCE	0.9410	0.9410
4	AEG	0.9374	0.9238
5	ATT_4	0.9308	0.9155
6	UMICH_1	0.9297	0.9141
7	ERIM_1	0.9255	0.9117
8	NYNEX	0.9252	0.9126
9	VOTE_P	0.9225	0.9132
10	ATT_2	0.9224	0.9080
11	UBOL	0.9194	0.9030
12	IBM	0.9191	0.9038
13	KODAK_1	0.9144	0.8992
14	HUGHES_1	0.9140	0.8991
15	ATT_3	0.9139	0.8991
16	HUGHES_2	0.9121	0.8970
17	ATT_1	0.9111	0.8977
18	SYMBUS	0.9082	0.8943
19	OCRSYS	0.9036	0.8917
20	GTESS_1	0.8985	0.8855
21	GTESS_2	0.8968	0.8840
22	MIME	0.8828	0.8683
23	NIST_4	0.8815	0.8658
24	ASOL	0.8747	0.8599
25	REI	0.8665	0.8527
26	RISO	0.8545	0.8361
27	GMD_1	0.8508	0.8350
28	GMD_3	0.8497	0.8333
29	NIST_1	0.8492	0.8344
30	KAMAN_1	0.8436	0.8268
31	GMD_4	0.8318	0.8166
32	NIST_3	0.8122	0.8020
33	COMCOM	0.8065	0.8014
34	KAMAN_3	0.8013	0.7837
35	KAMAN_2	0.7916	0.7736
36	IFAX	0.7909	0.7775
37	NIST_2	0.7604	0.7473
38	VALEN_1	0.7555	0.7385
39	GMD_2	0.7494	0.7343
40	KAMAN_4	0.7258	0.7091
41	KAMAN_5	0.6648	0.6473
42	UMICH_2	0.0389	0.0205

Table 102: NESTOR correlation graph key for uppers.

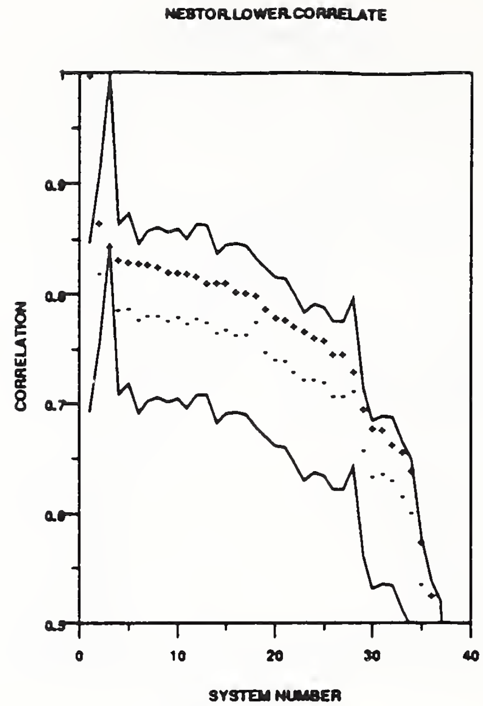

Figure 165: NESTOR - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	NESTOR	1.0000	1.0000
2	VOTE_M	0.8668	0.8225
3	REFERENCE	0.8461	0.8461
4	ERIM_1	0.8351	0.7889
5	AEG	0.8331	0.7900
6	IBM	0.8311	0.7797
7	ATT_4	0.8301	0.7837
8	NYNEX	0.8276	0.7837
9	ATT_2	0.8235	0.7818
10	KODAK_1	0.8235	0.7791
11	UMICH_1	0.8221	0.7761
12	OCRSYS	0.8205	0.7809
13	ATT_1	0.8142	0.7780
14	ATT_3	0.8141	0.7681
15	UBOL	0.8137	0.7701
16	HUGHES_1	0.8062	0.7664
17	HUGHES_2	0.8052	0.7654
18	VOTE_P	0.8030	0.7779
19	GTESS_1	0.7898	0.7498
20	GTESS_2	0.7822	0.7429
21	NIST_1	0.7803	0.7423
22	NIST_4	0.7744	0.7317
23	RISO	0.7694	0.7243
24	GMD_3	0.7642	0.7247
25	ASOL	0.7617	0.7222
26	GMD_4	0.7485	0.7095
27	GMD_1	0.7485	0.7095
28	NIST_3	0.7322	0.7143
29	GMD_2	0.6977	0.6598
30	VALEN_1	0.6812	0.6363
31	KAMAN_1	0.6800	0.6382
32	NIST_2	0.6657	0.6322
33	KAMAN_3	0.6593	0.6179
34	KAMAN_2	0.6418	0.6028
35	KAMAN_5	0.5761	0.5374
36	KAMAN_4	0.5280	0.4996
37	COMCOM	0.4933	0.4822
38	UMICH_2	0.0962	0.0531

Table 103: NESTOR correlation graph key for lowers.

SYSTEM: NIST_1

PARTICIPANT: Patrick J. Grother

ORGANIZATION: NIST, Gaithersburg, MD

PREPROCESSING: Size (preserving aspect ratio), Slant Normalization.
Subtraction from binary image of mean of training images.

FEATURES: Projection onto principal components of training set.
32 leading elements of KL transform.

CLASSIFICATION: K Nearest Neighbour. K not fixed; Distance weighted voting among prototypes within 1.1 * distance of the closest prototype.

HARDWARE: AMT 510C Array (32x32) Processor with Sparc IO host.

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	~22000	~22000	~22000	NSDB3
	2100	2100	2100	WRITERS

STATUS: On time

RESULTS:	-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
	0.00	0.0774	0.00	0.1385	0.00	0.1858	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
OCR RATE:			
CPU RATE:	4.8	4.8	4.8

SYSTEM: NIST_1

BIBLIOGRAPHY:

The following references have been provided for this system:

[39]

COMMENTS: NIST_1

See Cross Validation Section on Inadequacies of NIST Special Database 3 for the classification of NIST Test Data 1.

The late system NIST_4 outperforms this system on digits on the basis of further preprocessing, a larger training set, and more KL coefficients.

Very Slow Classification.

No exemplar pruning or aggregation.

Does not suffer from "minority" problems of perceptrons (e.g. crossed sevens).

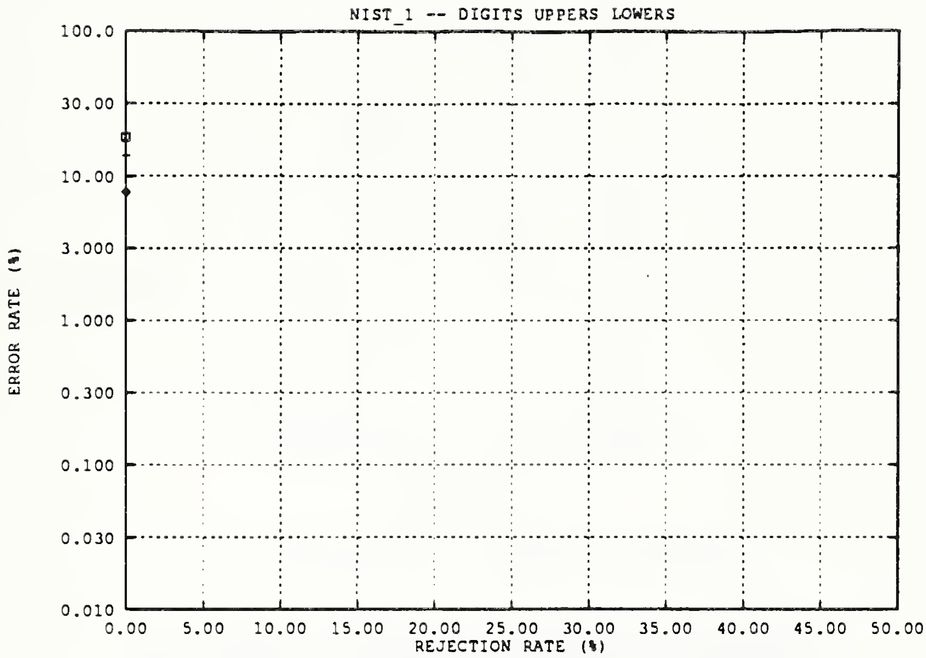

Figure 166: Error rate versus rejection rate for NIST_1

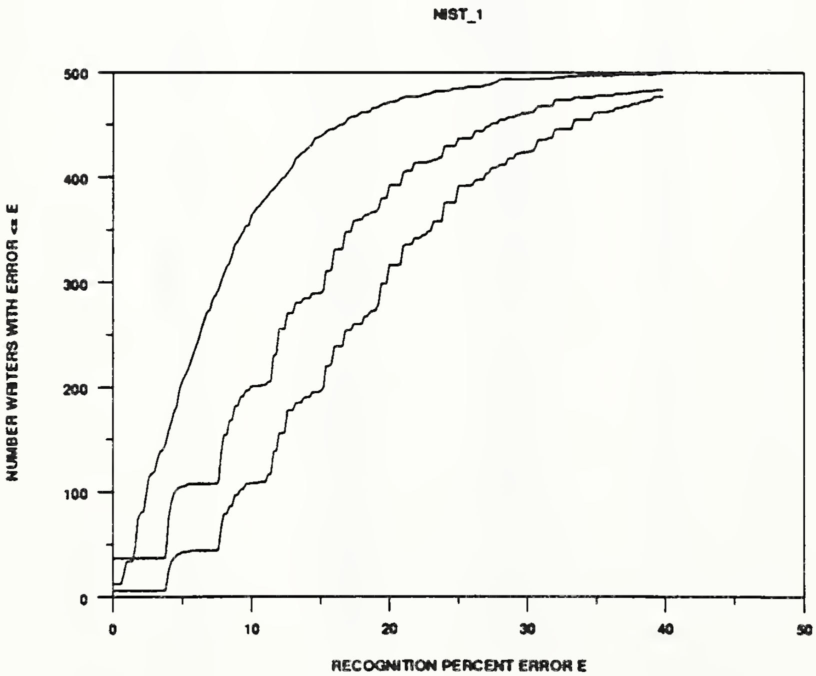

Figure 167: Error rate per writer of NIST_1

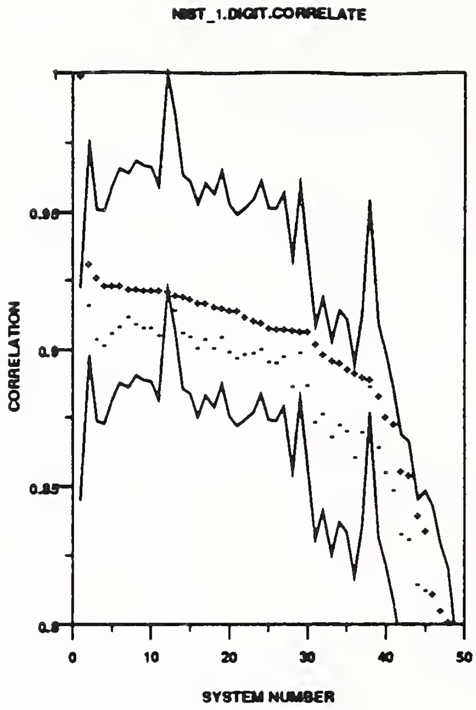

Figure 168: NIST_1 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	NIST_1	1.0000	1.0000
2	VOTE_M	0.9325	0.9174
3	THINK_1	0.9277	0.9048
4	AEG	0.9247	0.9095
5	ATT_4	0.9247	0.9072
6	NIST_4	0.9247	0.9028
7	VOTE_P	0.9235	0.9131
8	ATT_1	0.9235	0.9105
9	ELSAGB_3	0.9231	0.9092
10	ELSAGB_2	0.9230	0.9090
11	KODAK_2	0.9227	0.9063
12	REFERENCE	0.9225	0.9225
13	OCRSYS	0.9211	0.9156
14	ATT_2	0.9204	0.9072
15	ERIM_1	0.9199	0.9057
16	ERIM_2	0.9182	0.9049
17	KODAK_1	0.9182	0.9016
18	UBOL	0.9170	0.9018
19	IBM	0.9163	0.9059
20	SYMBUS	0.9157	0.9006
21	ELSAGB_1	0.9155	0.8981
22	ATT_3	0.9132	0.8995
23	NESTOR	0.9117	0.8998
24	THINK_2	0.9108	0.9012
25	HUGHES_1	0.9091	0.8966
26	HUGHES_2	0.9089	0.8965
27	NYNEX	0.9087	0.8988
28	GTESS_2	0.9080	0.8876
29	REI	0.9078	0.8999
30	GTESS_1	0.9077	0.8882
31	NIST_2	0.9032	0.8748
32	GMD_3	0.8995	0.8775
33	NIST_3	0.8974	0.8691
34	MIME	0.8962	0.8739
35	ASOL	0.8942	0.8717
36	RISO	0.8926	0.8618
37	GMD_1	0.8913	0.8709
38	COMCOM	0.8903	0.8875
39	UPENN	0.8845	0.8654
40	GMD_4	0.8763	0.8564
41	KAMAN_1	0.8741	0.8498
42	KAMAN_3	0.8570	0.8340
43	KAMAN_2	0.8556	0.8319
44	GMD_2	0.8406	0.8155
45	KAMAN_5	0.8350	0.8138
46	VALEN_2	0.8121	0.7997
47	IFAX	0.8062	0.7898
48	VALEN_1	0.8019	0.7826
49	KAMAN_4	0.7863	0.7623

Table 104: NIST_1 correlation graph key for digits.

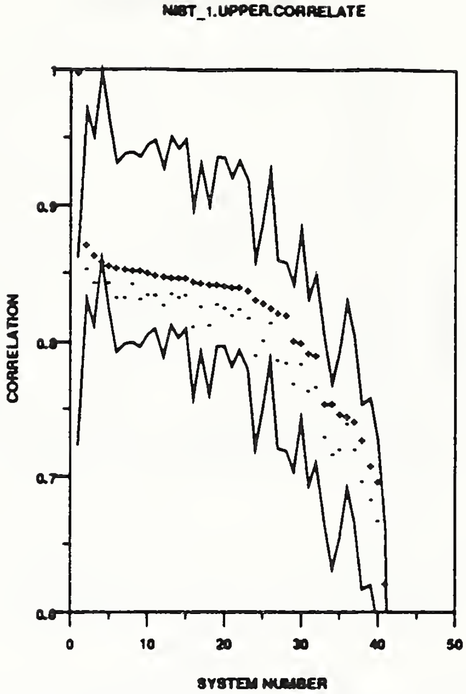

Figure 169: NIST_1 - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	NIST_1	1.0000	1.0000
2	VOTE_M	0.8730	0.8555
3	ATT_4	0.8664	0.8460
4	REFERENCE	0.8615	0.8615
5	AEG	0.8585	0.8457
6	KODAK_1	0.8565	0.8344
7	UBOL	0.8557	0.8346
8	VOTE_P	0.8551	0.8453
9	ATT_1	0.8550	0.8338
10	ATT_2	0.8529	0.8364
11	ERIM_1	0.8516	0.8371
12	SYMBUS	0.8504	0.8291
13	NYNEX	0.8498	0.8375
14	NESTOR	0.8492	0.8344
15	UMICH_1	0.8491	0.8362
16	NIST_4	0.8467	0.8135
17	ATT_3	0.8463	0.8284
18	MIME	0.8453	0.8149
19	IBM	0.8449	0.8302
20	HUGHES_1	0.8439	0.8275
21	GTESS_1	0.8429	0.8217
22	HUGHES_2	0.8427	0.8261
23	GTESS_2	0.8404	0.8203
24	RISO	0.8338	0.7925
25	ASOL	0.8309	0.8036
26	OCRSYS	0.8277	0.8166
27	GMD_1	0.8239	0.7892
28	GMD_3	0.8215	0.7870
29	GMD_4	0.8035	0.7711
30	REI	0.8013	0.7860
31	NIST_3	0.7945	0.7658
32	KAMAN_1	0.7921	0.7689
33	KAMAN_3	0.7570	0.7315
34	NIST_2	0.7569	0.7193
35	KAMAN_2	0.7494	0.7229
36	COMCOM	0.7474	0.7421
37	IFAX	0.7436	0.7231
38	GMD_2	0.7304	0.6986
39	VALEN_1	0.7111	0.6850
40	KAMAN_4	0.6986	0.6691
41	KAMAN_5	0.6239	0.6022
42	UMICH_2	0.0616	0.0185

Table 105: NIST_1 correlation graph key for uppers.

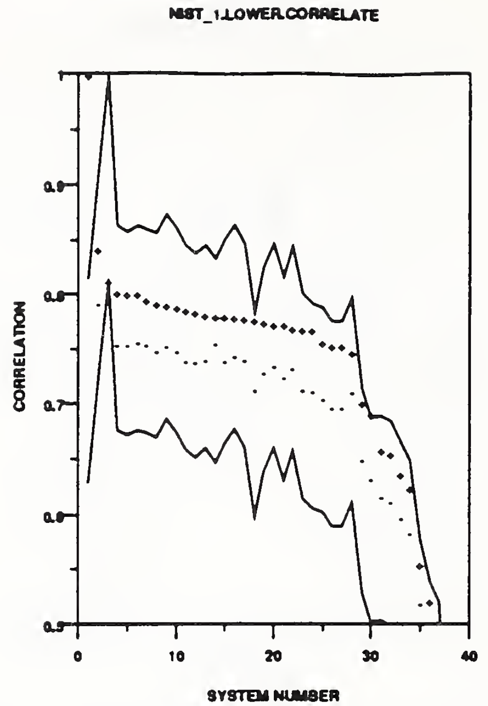

Figure 170: NIST_1 - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	NIST_1	1.0000	1.0000
2	VOTE_M	0.8425	0.7937
3	REFERENCE	0.8142	0.8142
4	ATT_1	0.8035	0.7554
5	ERIM_1	0.8030	0.7584
6	ATT_4	0.8030	0.7559
7	ATT_2	0.7974	0.7552
8	KODAK_1	0.7934	0.7503
9	AEG	0.7924	0.7542
10	NYNEX	0.7897	0.7498
11	UBOL	0.7883	0.7409
12	ATT_3	0.7857	0.7390
13	IBM	0.7828	0.7413
14	VOTE_P	0.7822	0.7573
15	UMICH_1	0.7820	0.7408
16	OCRSYS	0.7809	0.7448
17	NESTOR	0.7803	0.7423
18	RISO	0.7784	0.7145
19	GTESS_1	0.7763	0.7307
20	HUGHES_1	0.7744	0.7364
21	GTESS_2	0.7740	0.7262
22	HUGHES_2	0.7707	0.7337
23	NIST_4	0.7699	0.7144
24	GMD_3	0.7692	0.7132
25	ASOL	0.7581	0.7065
26	GMD_4	0.7542	0.6981
27	GMD_1	0.7542	0.6981
28	NIST_3	0.7493	0.7122
29	GMD_2	0.7031	0.6515
30	NIST_2	0.6919	0.6340
31	KAMAN_1	0.6604	0.6181
32	VALEN_1	0.6572	0.6127
33	KAMAN_3	0.6388	0.5978
34	KAMAN_2	0.6255	0.5847
35	KAMAN_5	0.5562	0.5202
36	KAMAN_4	0.5225	0.4866
37	COMCOM	0.4782	0.4678
38	UMICH_2	0.1046	0.0534

Table 106: NIST_1 correlation graph key for lowers.

SYSTEM: NIST_2

PARTICIPANT: Patrick J. Grother

ORGANIZATION: NIST, Gaithersburg, MD

PREPROCESSING: Size (preserving aspect ratio), Slant Normalization.

FEATURES: Projection onto 4 quadrant gabor wavelets. One frequency, two phases, four angles gives 32 element "Gabor Transform". Least squares fitting.

CLASSIFICATION: Scaled conjugate gradient trained 32:48:{10,26} perceptron.

HARDWARE: AMT 510C Array (32x32) Processor with Sparc IO host.

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	~102000	~45000	~46000	NSDB3
	2100	2100	2100	WRITERS

STATUS: On time

RESULTS: -- DIGITS -- -- UPPERS -- -- LOWERS -- DATABASE

REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
0.00	0.0919	0.00	0.2310	0.00	0.3120	
0.10	0.0519	0.10	0.1793	0.10	0.2657	
0.20	0.0285	0.20	0.1384	0.20	0.2220	
0.30	0.0150	0.30	0.1028	0.30	0.1805	
0.40	0.0092	0.40	0.0728	0.40	0.1440	
0.50	0.0060	0.50	0.0524	0.50	0.1078	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
OCR RATE:			
CPU RATE:	81.0	81.0	81.0

SYSTEM: NIST_2

BIBLIOGRAPHY:

The following references have been provided for this system:

[40]

COMMENTS: NIST_2

See Cross Validation Section on Inadequacies of NIST Special Database 3 for the classification of NIST Test Data 1.

Insufficient / Inappropriate Gabor Bases.

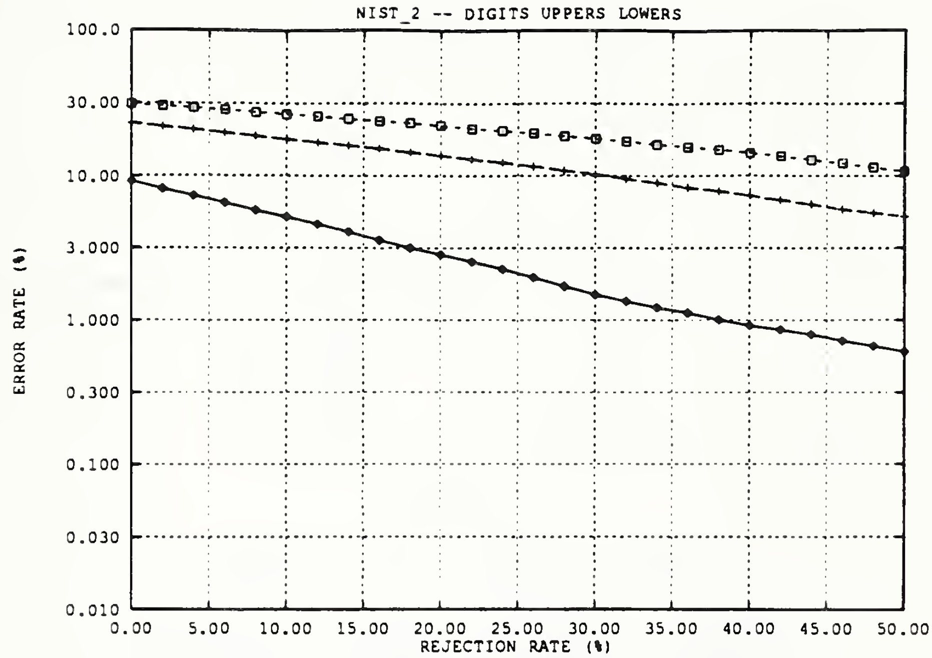

Figure 171: Error rate versus rejection rate for NIST_2

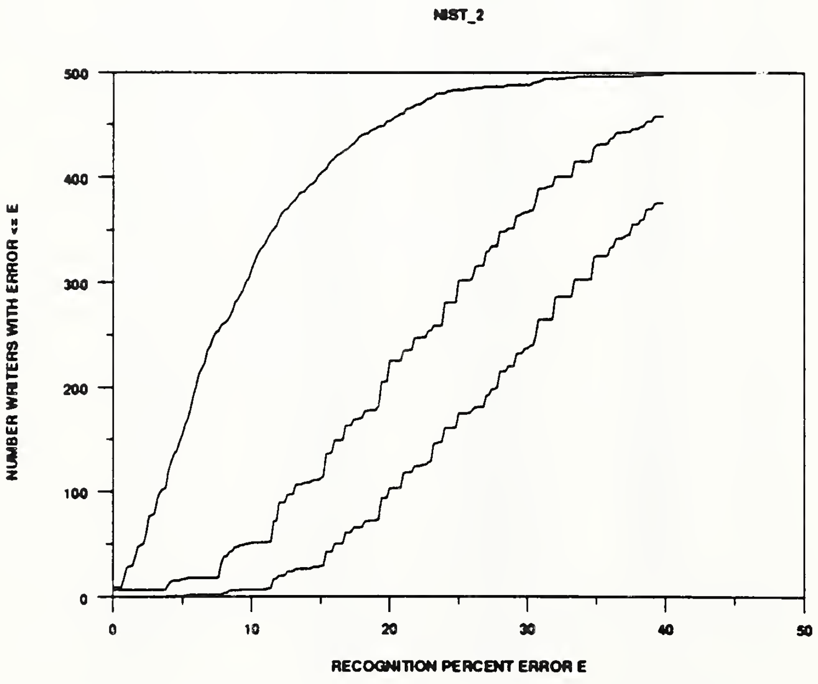

Figure 172: Error rate per writer of NIST_2

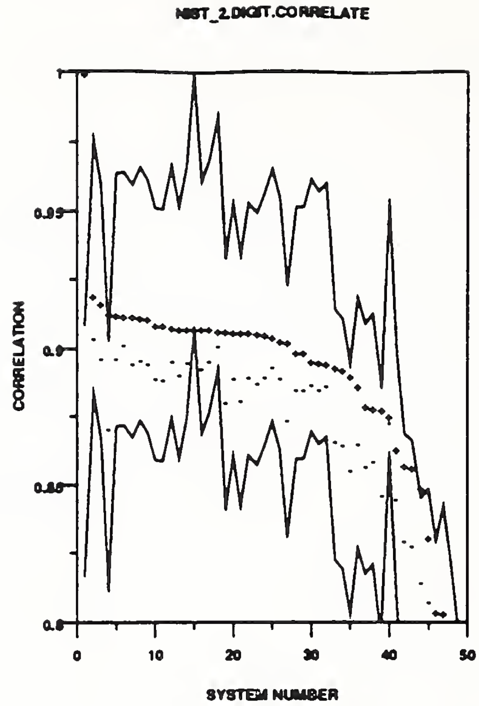

Figure 173: NIST_2 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	NIST_2	1.0000	1.0000
2	VOTE_M	0.9201	0.9046
3	ATT_4	0.9172	0.8973
4	NIST_3	0.9138	0.8715
5	ATT_2	0.9134	0.8974
6	VOTE_P	0.9130	0.9021
7	KODAK_2	0.9127	0.8952
8	AEG	0.9124	0.8968
9	ERIM_1	0.9117	0.8954
10	THINK_1	0.9097	0.8900
11	NIST_4	0.9094	0.8896
12	ELSAGB_3	0.9087	0.8962
13	ATT_3	0.9084	0.8911
14	ELSAGB_2	0.9083	0.8958
15	REFERENCE	0.9081	0.9081
16	ATT_1	0.9080	0.8961
17	ERIM_2	0.9080	0.8936
18	OCRSYS	0.9074	0.9016
19	GTESS_2	0.9071	0.8810
20	KODAK_1	0.9070	0.8899
21	SYMBUS	0.9068	0.8902
22	GTESS_1	0.9068	0.8816
23	ELSAGB_1	0.9065	0.8881
24	UBOL	0.9059	0.8902
25	IBM	0.9051	0.8939
26	NESTOR	0.9035	0.8897
27	NIST_1	0.9032	0.8748
28	HUGHES_2	0.8996	0.8857
29	HUGHES_1	0.8995	0.8857
30	THINK_2	0.8964	0.8876
31	NYNEX	0.8956	0.8859
32	REI	0.8952	0.8870
33	MIME	0.8940	0.8670
34	ASOL	0.8929	0.8655
35	RISO	0.8909	0.8561
36	GMD_3	0.8870	0.8661
37	UPENN	0.8797	0.8576
38	GMD_1	0.8786	0.8596
39	KAMAN_1	0.8785	0.8470
40	COMCOM	0.8762	0.8739
41	GMD_4	0.8643	0.8456
42	KAMAN_3	0.8580	0.8303
43	KAMAN_2	0.8571	0.8283
44	GMD_2	0.8497	0.8152
45	KAMAN_5	0.8313	0.8080
46	IFAX	0.8044	0.7843
47	VALEN_2	0.8039	0.7909
48	VALEN_1	0.7972	0.7766
49	KAMAN_4	0.7950	0.7624

Table 107: NIST_2 correlation graph key for digits.

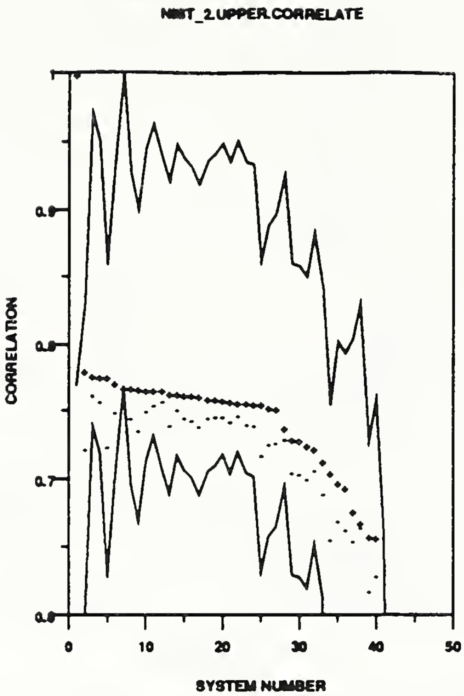

Figure 174: NIST_2 - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	NIST_2	1.0000	1.0000
2	NIST_3	0.7818	0.7235
3	VOTE_M	0.7780	0.7634
4	ATT_4	0.7770	0.7586
5	RISO	0.7765	0.7253
6	KODAK_1	0.7720	0.7500
7	REFERENCE	0.7690	0.7690
8	SYMBUS	0.7688	0.7463
9	MIME	0.7673	0.7375
10	ATT_2	0.7668	0.7511
11	AEG	0.7667	0.7561
12	VOTE_P	0.7664	0.7582
13	GTESS_1	0.7643	0.7414
14	ERIM_1	0.7640	0.7519
15	UBOL	0.7633	0.7465
16	ATT_3	0.7631	0.7452
17	GTESS_2	0.7625	0.7406
18	IBM	0.7607	0.7463
19	NESTOR	0.7604	0.7473
20	UMICH_1	0.7598	0.7478
21	ATT_1	0.7586	0.7441
22	NYNEX	0.7579	0.7485
23	HUGHES_1	0.7573	0.7421
24	HUGHES_2	0.7571	0.7409
25	NIST_1	0.7569	0.7193
26	ASOL	0.7540	0.7270
27	NIST_4	0.7535	0.7278
28	OCRSYS	0.7396	0.7311
29	GMD_1	0.7313	0.7063
30	GMD_3	0.7302	0.7050
31	KAMAN_1	0.7268	0.7012
32	REI	0.7232	0.7083
33	GMD_4	0.7142	0.6904
34	GMD_2	0.7063	0.6569
35	KAMAN_3	0.6990	0.6706
36	KAMAN_2	0.6953	0.6640
37	IFAX	0.6773	0.6556
38	COMCOM	0.6697	0.6660
39	KAMAN_4	0.6592	0.6189
40	VALEN_1	0.6581	0.6298
41	KAMAN_5	0.5829	0.5580
42	UMICH_2	0.0672	0.0157

Table 108: NIST_2 correlation graph key for uppers.

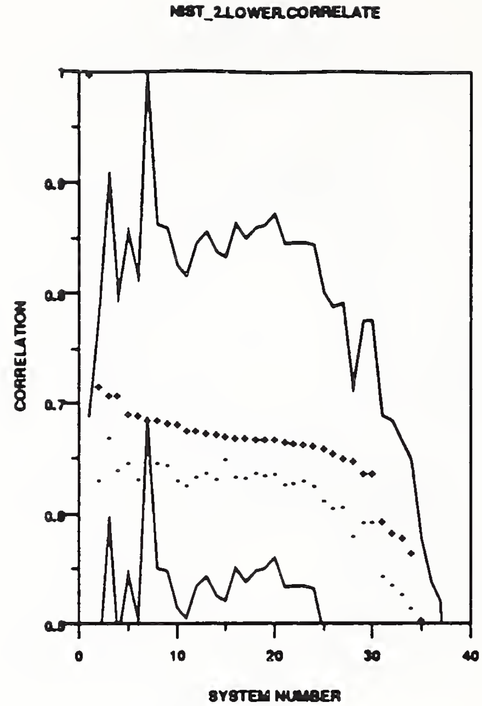

Figure 175: NIST_2 - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	NIST_2	1.0000	1.0000
2	RISO	0.7193	0.6332
3	VOTE_M	0.7112	0.6715
4	NIST_3	0.7107	0.6415
5	ATT_4	0.6933	0.6484
6	NIST_1	0.6919	0.6340
7	REFERENCE	0.6880	0.6880
8	ERIM_1	0.6877	0.6485
9	ATT_2	0.6860	0.6465
10	GTESS_1	0.6843	0.6331
11	IBM	0.6783	0.6357
12	GTESS_2	0.6783	0.6279
13	KODAK_1	0.6765	0.6399
14	ATT_3	0.6756	0.6342
15	VOTE_P	0.6733	0.6521
16	OCRSYS	0.6722	0.6364
17	UMICH_1	0.6718	0.6354
18	NYNEX	0.6707	0.6391
19	ATT_1	0 6705	0.6374
20	AEG	0.6702	0.6384
21	UBOL	0.6684	0.6291
22	HUGHES_1	0.6675	0.6302
23	NESTOR	0.6657	0.6322
24	HUGHES_2	0.6653	0.6284
25	NIST_4	0.6631	0.6140
26	ASOL	0.6581	0.6076
27	GMD_3	0.6538	0.6083
28	GMD_2	0.6515	0.5825
29	GMD_4	0.6395	0.5954
30	GMD_1	0.6395	0.5954
31	KAMAN_1	0.5961	0.5460
32	VALEN_1	0.5858	0.5372
33	KAMAN_3	0.5806	0.5297
34	KAMAN_2	0.5675	0.5173
35	KAMAN_5	0.5059	0.4600
36	KAMAN_4	0.4865	0.4370
37	COMCOM	0.4168	0.4075
38	UMICH_2	0.1052	0.0382

Table 109: NIST_2 correlation graph key for lowers.

SYSTEM: NIST_3

PARTICIPANT: Patrick J. Grother

ORGANIZATION: NIST, Gaithersburg, MD

PREPROCESSING: Size (preserving aspect ratio), Slant Normalization.
Subtraction from binary image of mean of training images.

FEATURES: Projection onto principal components of training set.
32 leading elements of KL transform.

CLASSIFICATION: Scaled conjugate gradient trained 32:48:{10,26} perceptron.

HARDWARE: AMT 510C Array (32x32) Processor with Sparc IO host.

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	~77000	~26000	~26000	NSDB3
	2100	2100	2100	WRITERS

STATUS: On time, submitted as NIST_0

RESULTS: -- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
REJ.	ERR.	REJ.	ERR.	REJ.	ERR.	TESTDATA1
RATE	RATE--	RATE	RATE--	RATE	RATE--	
0.00	0.0973	0.00	0.1693	0.00	0.2029	
0.10	0.0529	0.10	0.1172	0.10	0.1521	
0.20	0.0286	0.20	0.0757	0.20	0.1122	
0.30	0.0160	0.30	0.0520	0.30	0.0853	
0.40	0.0103	0.40	0.0331	0.40	0.0629	
0.50	0.0070	0.50	0.0184	0.50	0.0458	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
OCR RATE:			
CPU RATE:	142.6	64.3	64.3

SYSTEM: NIST_3

BIBLIOGRAPHY:

The following references have been provided for this system:

[41]

COMMENTS: NIST_3

See Cross Validation Section on Inadequacies of NIST Special Database 3 for the classification of NIST Test Data 1.

Small training set. Small number of KL coefficients. KL basis and first MLP layer both perform linear affine transformation. Therefore premultiply them. Algorithmic complexity is low: dominated by two matrix multiplies. Very fast.

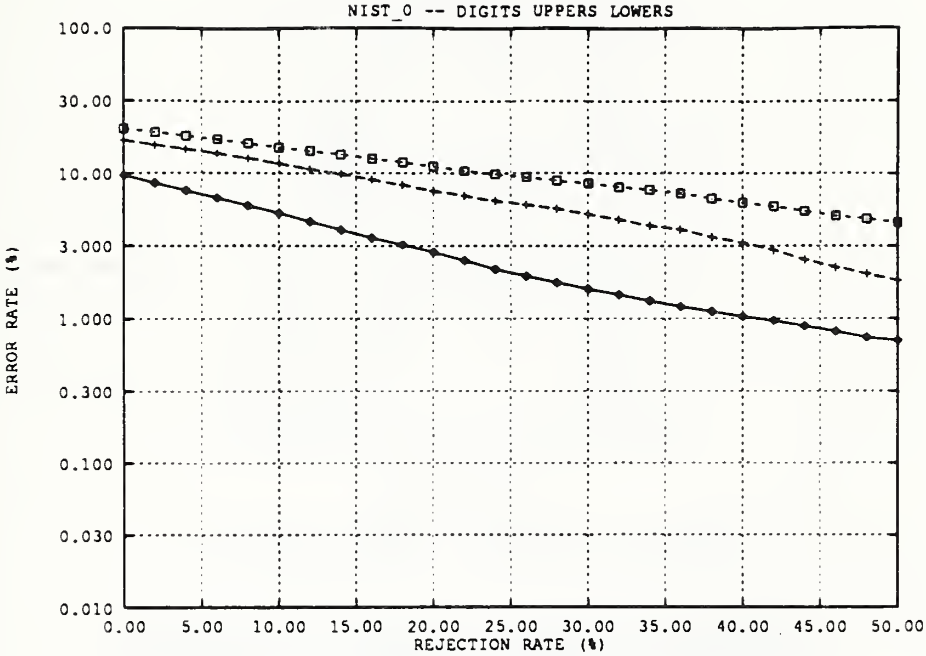

Figure 176: Error rate versus rejection rate for NIST_3

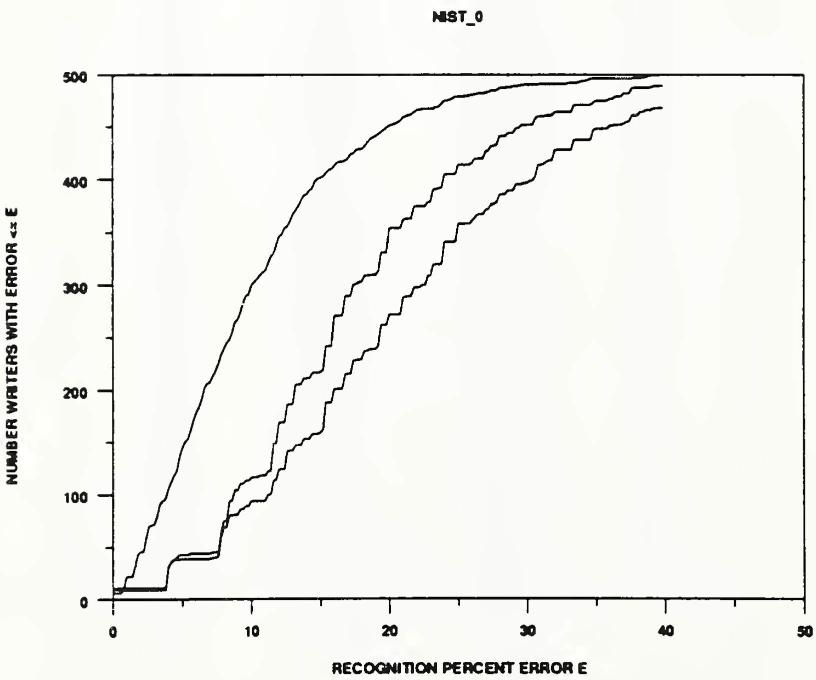

Figure 177: Error rate per writer of NIST_3

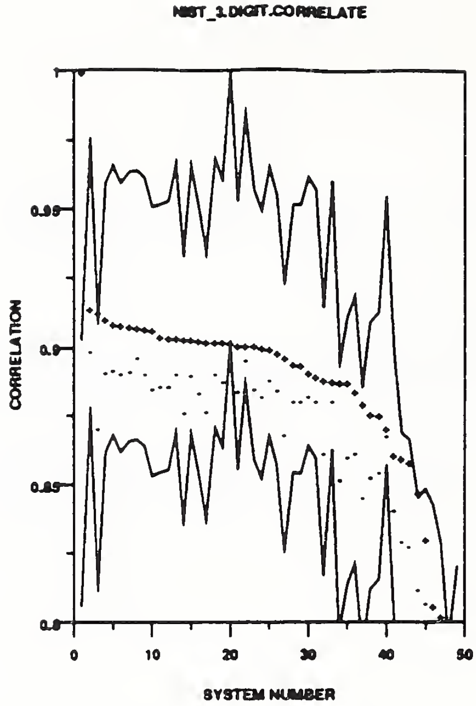

Figure 178: NIST_3 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	NIST_3	1.0000	1.0000
2	VOTE_M	0.9151	0.8994
3	NIST_2	0.9138	0.8715
4	ATT_4	0.9114	0.8915
5	AEG	0.9096	0.8928
6	KODAK_2	0.9093	0.8912
7	ATT_2	0.9089	0.8923
8	VOTE_P	0.9081	0.8971
9	ERIM_1	0.9078	0.8910
10	NIST_4	0.9071	0.8858
11	ATT_3	0.9048	0.8866
12	KODAK_1	0.9046	0.8868
13	ELSAGB_3	0.9044	0.8913
14	GTESS_2	0.9043	0.8772
15	ELSAGB_2	0.9040	0.8909
16	THINK_1	0.9037	0.8845
17	ATT_1	0.9032	0.8912
18	GTESS_1	0.9032	0.8773
19	ERIM_2	0.9031	0.8885
20	REFERENCE	0.9027	0.9027
21	OCRSYS	0.9017	0.8963
22	SYMBUS	0.9017	0.8850
23	UBOL	0.9016	0.8857
24	ELSAGB_1	0.9010	0.8830
25	IBM	0.9003	0.8889
26	NESTOR	0.8992	0.8853
27	NIST_1	0.8974	0.8691
28	HUGHES_1	0.8949	0.8811
29	HUGHES_2	0.8945	0.8809
30	THINK_2	0.8916	0.8828
31	NYNEX	0.8905	0.8809
32	MIME	0.8889	0.8624
33	REI	0.8887	0.8812
34	RISO	0.8882	0.8526
35	ASOL	0.8881	0.8610
36	GMD_3	0.8848	0.8624
37	KAMAN_1	0.8801	0.8463
38	UPENN	0.8763	0.8537
39	GMD_1	0.8759	0.8556
40	COMCOM	0.8713	0.8689
41	GMD_4	0.8617	0.8417
42	KAMAN_3	0.8604	0.8303
43	KAMAN_2	0.8591	0.8284
44	GMD_2	0.8482	0.8126
45	KAMAN_5	0.8310	0.8074
46	VALEN_2	0.8066	0.7922
47	IFAX	0.8029	0.7825
48	KAMAN_4	0.7976	0.7628
49	VALEN_1	0.7929	0.7729

Table 110: NIST_3 correlation graph key for digits.

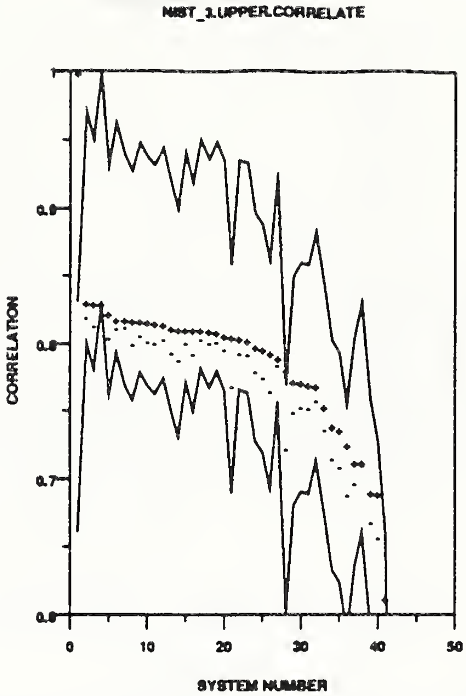

Figure 179: NIST_3 - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	NIST_3	1.0000	1.0000
2	VOTE_M	0.8318	0.8210
3	REFERENCE	0.8307	0.8307
4	ATT_4	0.8307	0.8148
5	KODAK_1	0.8241	0.8056
6	AEG	0.8196	0.8125
7	VOTE_P	0.8189	0.8137
8	ERIM_1	0.8179	0.8072
9	SYMBUS	0.8179	0.8005
10	UBOL	0.8172	0.8028
11	ATT_3	0.8168	0.8015
12	ATT_2	0.8159	0.8049
13	GTESS_1	0.8125	0.7944
14	NESTOR	0.8122	0.8020
15	MIME	0.8122	0.7886
16	GTESS_2	0.8117	0.7934
17	NYNEX	0.8116	0.8048
18	IBM	0.8112	0.8013
19	UMICH_1	0.8100	0.8024
20	ATT_1	0.8076	0.7972
21	RISO	0.8062	0.7692
22	HUGHES_1	0.8051	0.7947
23	HUGHES_2	0.8034	0.7931
24	NIST_4	0.7991	0.7803
25	ASOL	0.7972	0.7761
26	NIST_1	0.7945	0.7658
27	OCRSYS	0.7908	0.7853
28	NIST_2	0.7818	0.7235
29	KAMAN_1	0.7729	0.7499
30	GMD_1	0.7719	0.7537
31	GMD_3	0.7705	0.7526
32	REI	0.7694	0.7583
33	GMD_4	0.7542	0.7370
34	KAMAN_3	0.7406	0.7164
35	KAMAN_2	0.7374	0.7100
36	GMD_2	0.7266	0.6895
37	IFAX	0.7140	0.6981
38	COMCOM	0.7133	0.7119
39	VALEN_1	0.6918	0.6691
40	KAMAN_4	0.6910	0.6583
41	KAMAN_5	0.6135	0.5922
42	UMICH_2	0.0601	0.0204

Table 111: NIST_3 correlation graph key for uppers.

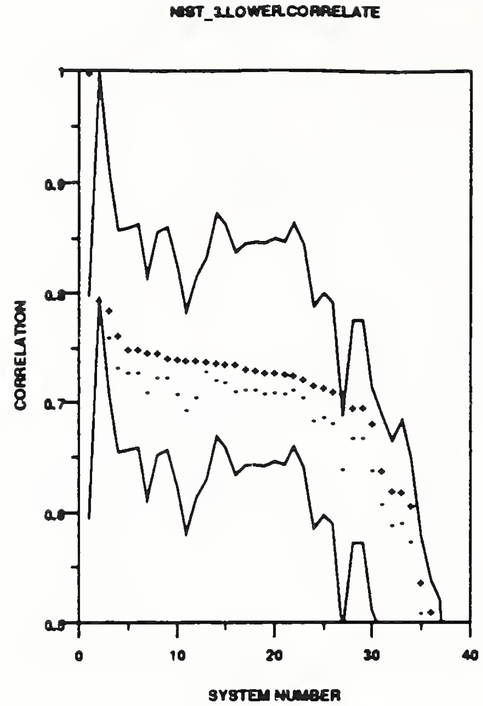

Figure 180: NIST_3 - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	NIST_3	1.0000	1.0000
2	REFERENCE	0.7971	0.7971
3	VOTE_M	0.7874	0.7628
4	ATT_4	0.7650	0.7349
5	ATT_2	0.7527	0.7306
6	ERIM_1	0.7521	0.7307
7	NIST_1	0.7493	0.7122
8	KODAK_1	0.7485	0.7257
9	NYNEX	0.7443	0.7258
10	GTESS_1	0.7429	0.7107
11	RISO	0.7418	0.6964
12	GTESS_2	0.7413	0.7079
13	VOTE_P	0.7412	0.7312
14	AEG	0.7394	0.7235
15	ATT_1	0.7383	0.7210
16	ATT_3	0.7382	0.7129
17	IBM	0.7337	0.7142
18	NESTOR	0.7322	0.7143
19	UBOL	0.7305	0.7105
20	UMICH_1	0.7301	0.7120
21	HUGHES_1	0.7293	0.7105
22	OCRSYS	0.7278	0.7138
23	HUGHES_2	0.7251	0.7074
24	ASOL	0.7187	0.6867
25	NIST_4	0.7171	0.6888
26	GMD_3	0.7129	0.6849
27	NIST_2	0.7107	0.6415
28	GMD_4	0.6983	0.6709
29	GMD_1	0.6983	0.6709
30	GMD_2	0.6850	0.6412
31	KAMAN_1	0.6411	0.6094
32	KAMAN_3	0.6222	0.5898
33	VALEN_1	0.6208	0.5924
34	KAMAN_2	0.6083	0.5755
35	KAMAN_5	0.5383	0.5111
36	KAMAN_4	0.5127	0.4796
37	COMCOM	0.4555	0.4523
38	UMICH_2	0.1058	0.0629

Table 112: NIST_3 correlation graph key for lowers.

SYSTEM: NYNEX

PARTICIPANT: Atul Chhabra

ORGANIZATION: Nynex Sciences & Technology, Inc., White Plains, NY

FEATURES: model or stroke, automatic feature selection. A large number of pre-segmentation points are first generated. The algorithm effectively chooses a subset of them that provide the most confident recognition.

CLASSIFICATION: MLP

HARDWARE: SPARC2 with 40 Mbyte ram, coded in C.

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	40000	45000		INTERNAL
	0	0	35000	NSDB3

STATUS: on time

RESULTS:

-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
0.00	0.0432	0.00	0.0491	0.00	0.1403	
0.10	0.0128	0.10	0.0175	0.10	0.0994	
0.20	0.0052	0.20	0.0092	0.20	0.0646	
0.30	0.0029	0.30	0.0065	0.30	0.0433	
0.40	0.0032	0.40	0.0050	0.40	0.0283	
0.50	0.0034	0.50	0.0050	0.50	0.0215	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	22.00	12.00	12.00
CPU RATE:			

NOTE: Internal database includes digits and upper case letters from NSDB1. NOTE: Suggested that NIST be involved in proctoring future tests.

SYSTEM: NYNEX

BIBLIOGRAPHY:

The following references have been provided for this system:

none

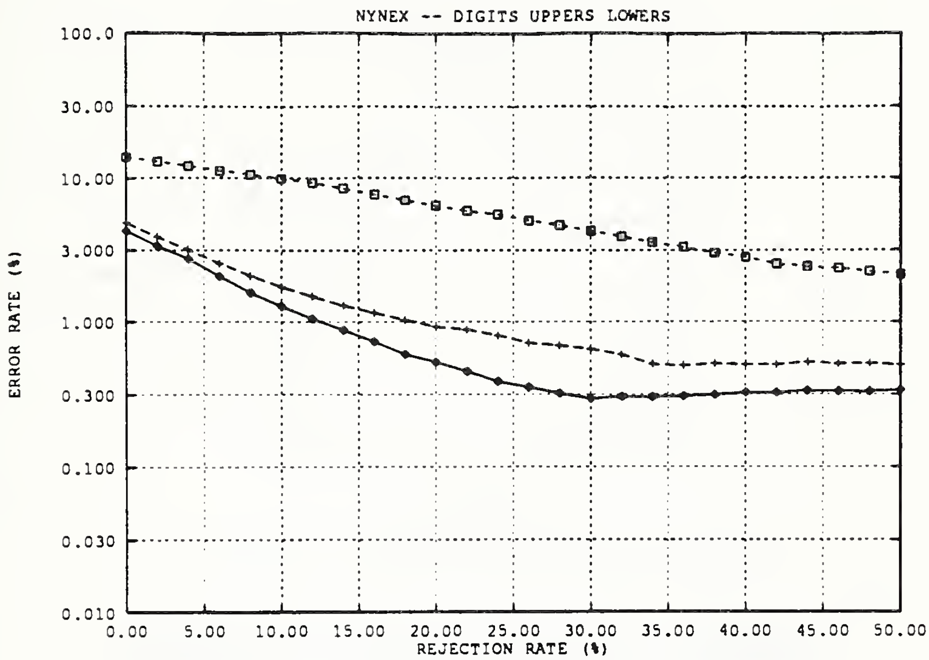

Figure 181: Error rate versus rejection rate for NYNEX

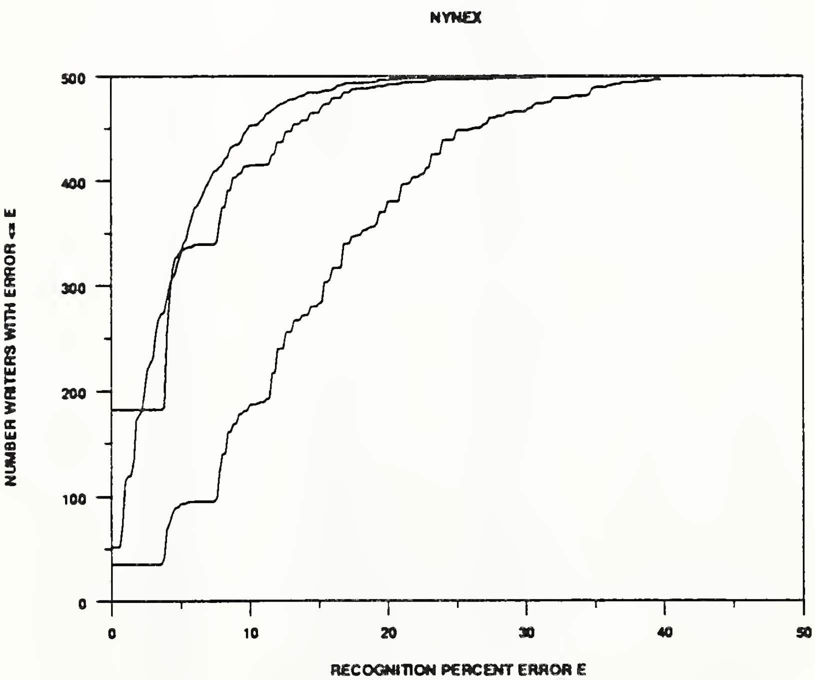

Figure 182: Error rate per writer of NYNEX

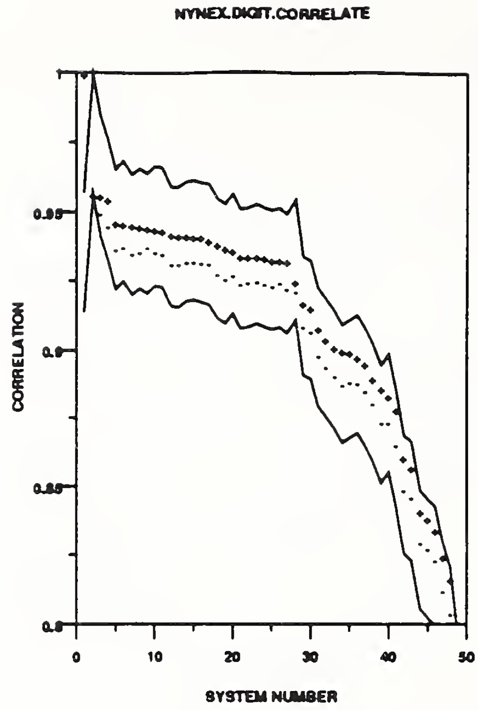

Figure 183: NYNEX - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	NYNEX	1.0000	1.0000
2	REFERENCE	0.9568	0.9568
3	OCRSYS	0.9564	0.9501
4	VOTE_M	0.9550	0.9456
5	IBM	0.9470	0.9371
6	ATT_1	0.9462	0.9380
7	ATT_2	0.9459	0.9360
8	AEG	0.9454	0.9363
9	VOTE_P	0.9450	0.9379
10	ELSAGB_3	0.9443	0.9363
11	ELSAGB_2	0.9440	0.9360
12	KODAK_2	0.9429	0.9323
13	ATT_4	0.9422	0.9321
14	ERIM_1	0.9421	0.9331
15	THINK_2	0.9419	0.9328
16	ERIM_2	0.9417	0.9325
17	REI	0.9406	0.9323
18	NESTOR	0.9388	0.9286
19	KODAK_1	0.9374	0.9265
20	UBOL	0.9366	0.9282
21	THINK_1	0.9360	0.9247
22	HUGHES_1	0.9349	0.9250
23	SYMBUS	0.9348	0.9256
24	HUGHES_2	0.9344	0.9247
25	NIST_4	0.9337	0.9238
26	ATT_3	0.9336	0.9251
27	ELSAGB_1	0.9329	0.9228
28	COMCOM	0.9255	0.9219
29	GTESS_1	0.9179	0.9093
30	GTESS_2	0.9159	0.9074
31	NIST_1	0.9087	0.8988
32	GMD_3	0.9047	0.8944
33	MIME	0.9020	0.8914
34	UPENN	0.9002	0.8880
35	ASOL	0.9000	0.8889
36	GMD_1	0.8982	0.8883
37	NIST_2	0.8956	0.8859
38	NIST_3	0.8905	0.8809
39	RISO	0.8867	0.8741
40	GMD_4	0.8840	0.8743
41	KAMAN_1	0.8786	0.8660
42	KAMAN_3	0.8614	0.8496
43	KAMAN_2	0.8576	0.8468
44	KAMAN_5	0.8414	0.8303
45	GMD_2	0.8389	0.8277
46	VALEN_2	0.8345	0.8237
47	IFAX	0.8252	0.8127
48	VALEN_1	0.8170	0.8042
49	KAMAN_4	0.7853	0.7750

Table 113: NYNEX correlation graph key for digits.

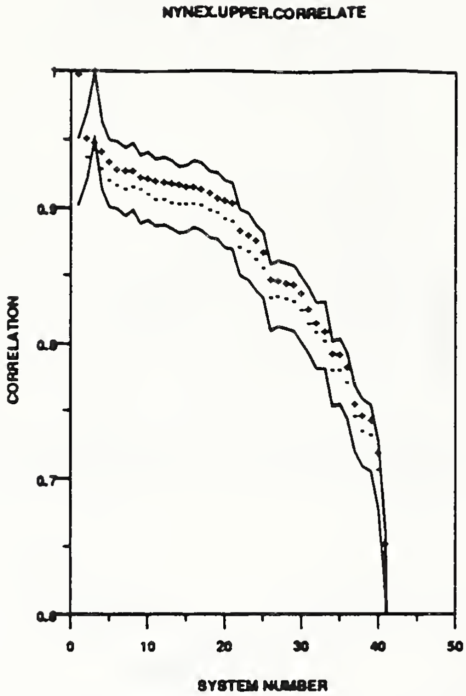

Figure 184: NYNEX - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	NYNEX	1.0000	1.0000
2	VOTE_M	0.9533	0.9393
3	REFERENCE	0.9509	0.9509
4	AEG	0.9440	0.9312
5	ATT_4	0.9371	0.9227
6	UMICH_1	0.9311	0.9190
7	ATT_2	0.9307	0.9165
8	ERIM_1	0.9305	0.9182
9	VOTE_P	0.9254	0.9163
10	NESTOR	0.9252	0.9126
11	IBM	0.9231	0.9094
12	UBOL	0.9225	0.9091
13	ATT_1	0.9209	0.9069
14	KODAK_1	0.9203	0.9060
15	ATT_3	0.9185	0.9052
16	HUGHES_1	0.9182	0.9060
17	HUGHES_2	0.9169	0.9042
18	SYMBUS	0.9137	0.9008
19	OCRSYS	0.9104	0.8989
20	GTESS_1	0.9079	0.8942
21	GTESS_2	0.9065	0.8928
22	MIME	0.8864	0.8734
23	NIST_4	0.8829	0.8704
24	ASOL	0.8787	0.8647
25	REI	0.8704	0.8586
26	RISO	0.8503	0.8369
27	NIST_1	0.8498	0.8375
28	GMD_1	0.8478	0.8359
29	GMD_3	0.8467	0.8343
30	KAMAN_1	0.8400	0.8272
31	GMD_4	0.8288	0.8174
32	COMCOM	0.8180	0.8113
33	NIST_3	0.8116	0.8048
34	KAMAN_3	0.7949	0.7827
35	IFAX	0.7947	0.7828
36	KAMAN_2	0.7856	0.7731
37	NIST_2	0.7579	0.7485
38	VALEN_1	0.7495	0.7375
39	GMD_2	0.7457	0.7344
40	KAMAN_4	0.7215	0.7094
41	KAMAN_5	0.6551	0.6450
42	UMICH_2	0.0407	0.0237

Table 114: NYNEX correlation graph key for uppers.

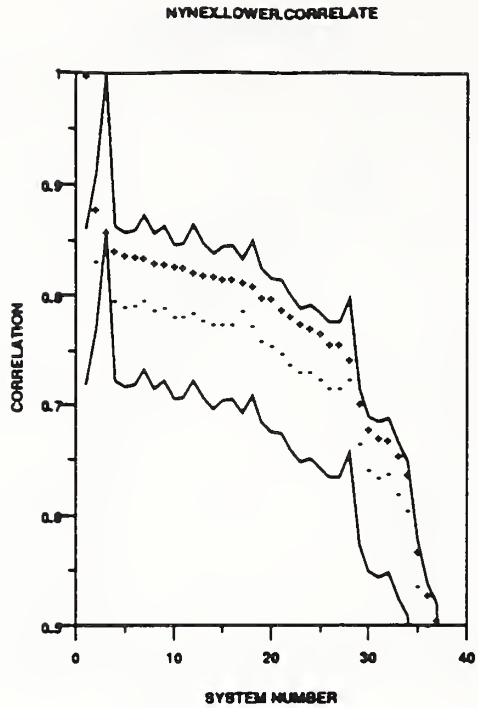

Figure 185: NYNEX - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	NYNEX	1.0000	1.0000
2	VOTE_M	0.8805	0.8339
3	REFERENCE	0.8597	0.8597
4	ERIM_1	0.8429	0.7985
5	ATT_4	0.8395	0.7928
6	ATT_2	0.8378	0.7939
7	AEG	0.8373	0.7979
8	KODAK_1	0.8320	0.7888
9	ATT_1	0.8318	0.7912
10	IBM	0.8296	0.7837
11	NESTOR	0.8276	0.7837
12	OCRSYS	0.8232	0.7866
13	HUGHES_1	0.8209	0.7795
14	ATT_3	0.8197	0.7768
15	HUGHES_2	0.8172	0.7768
16	UBOL	0.8172	0.7761
17	VOTE_P	0.8152	0.7887
18	UMICH_1	0.8121	0.7757
19	GTESS_1	0.8015	0.7619
20	GTESS_2	0.8000	0.7570
21	NIST_1	0.7897	0.7498
22	NIST_4	0.7843	0.7396
23	ASOL	0.7773	0.7328
24	GMD_3	0.7728	0.7327
25	RISO	0.7677	0.7258
26	GMD_4	0.7582	0.7182
27	GMD_1	0.7582	0.7182
28	NIST_3	0.7443	0.7258
29	GMD_2	0.7035	0.6671
30	KAMAN_1	0.6809	0.6431
31	VALEN_1	0.6728	0.6359
32	NIST_2	0.6707	0.6391
33	KAMAN_3	0.6566	0.6209
34	KAMAN_2	0.6398	0.6059
35	KAMAN_5	0.5693	0.5378
36	KAMAN_4	0.5311	0.5022
37	COMCOM	0.5074	0.4937
38	UMICH_2	0.1028	0.0606

Table 115: NYNEX correlation graph key for lowers.

SYSTEM: OCRSYS

PARTICIPANT: Harry S. Gierhart

ORGANIZATION: OCR Systems, Inc., Huntingdon Valley, PA

FEATURES: convolution with hand-coded filters

CLASSIFICATION: MLP, top three choices and confidence value that discriminates between them are calculated.

HARDWARE:

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	---- number used is proprietary ----			INTERNAL

STATUS: on time

RESULTS:

-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
0.00	0.0156	0.00	0.0573	0.00	0.1370	
0.10	0.0150	0.10	0.0224	0.10	0.1042	
0.20	0.0166	0.20	0.0144	0.20	0.0800	
0.30	0.0188	0.30	0.0123	0.30	0.0636	
0.40	0.0219	0.40	0.0106	0.40	0.0586	
0.50	0.0262	0.50	0.0080	0.50	0.0528	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:			
CPU RATE:	300.00	220.00	220.00

NOTE: Internal database is very large.

NOTE: HYP files for upper case letters included letters classified as lower case letters. These were scored as incorrect for Conference giving a zero rejection rate score of 0.0738. The score given above for UPPERS is case insensitive.

NOTE: Used a beta test version of an off-the-shelf system for this submission.

NOTE: Recently purchased by Adobe Systems.

SYSTEM: OCRSYS

BIBLIOGRAPHY:

The following references have been provided for this system:

none

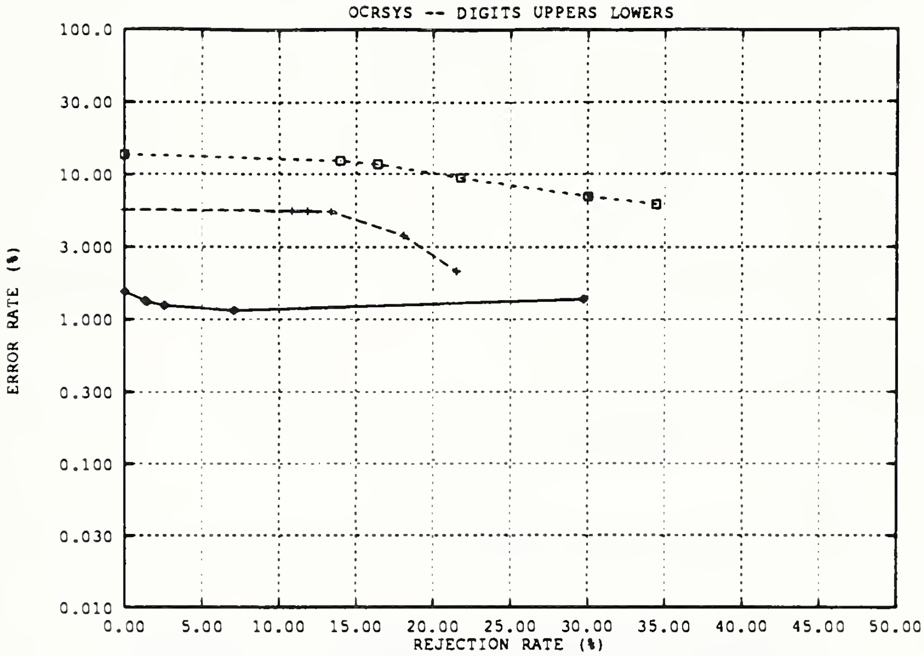

Figure 186: Error rate versus rejection rate for OCRSYS

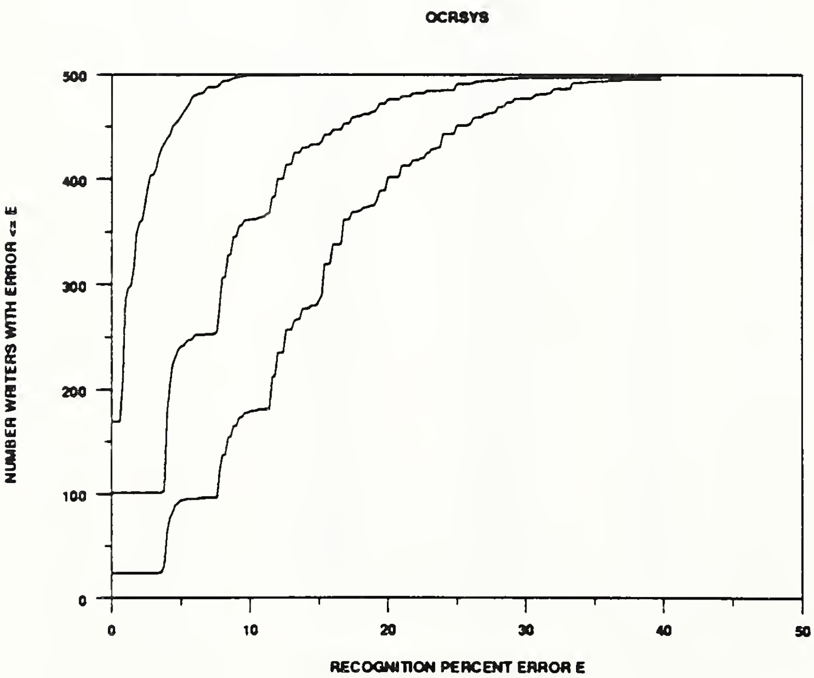

Figure 187: Error rate per writer of OCRSYS

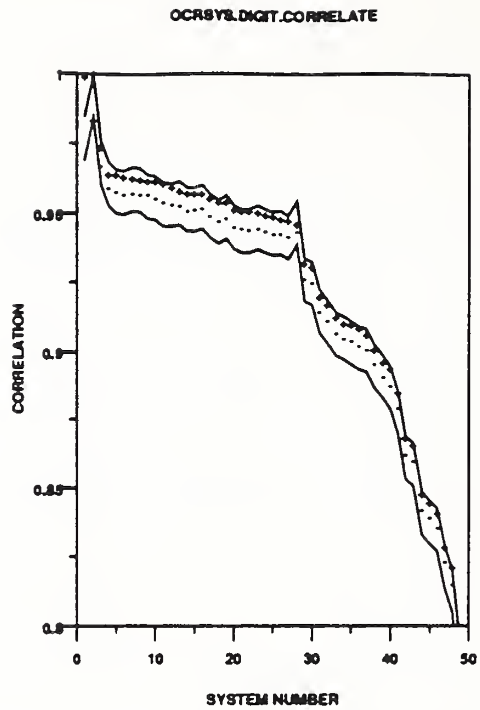

Figure 188: OCRSYS - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	OCRSYS	1.0000	1.0000
2	REFERENCE	0.9844	0.9844
3	VOTE_M	0.9746	0.9681
4	ATT_1	0.9653	0.9601
5	AEG	0.9652	0.9586
6	IBM	0.9641	0.9577
7	ELSAGB_3	0.9636	0.9583
8	ELSAGB_2	0.9632	0.9579
9	VOTE_P	0.9629	0.9579
10	ATT_2	0.9627	0.9563
11	ERIM_1	0.9619	0.9550
12	ERIM_2	0.9608	0.9542
13	THINK_2	0.9591	0.9537
14	ATT_4	0.9585	0.9520
15	KODAK_2	0.9584	0.9521
16	REI	0.9581	0.9528
17	NYNEX	0.9564	0.9501
18	UBOL	0.9552	0.9492
19	NESTOR	0.9552	0.9483
20	KODAK_1	0.9522	0.9458
21	HUGHES_1	0.9520	0.9453
22	HUGHES_2	0.9519	0.9451
23	SYMBUS	0.9512	0.9456
24	ATT_3	0.9506	0.9447
25	NIST_4	0.9499	0.9435
26	THINK_1	0.9492	0.9435
27	ELSAGB_1	0.9485	0.9425
28	COMCOM	0.9471	0.9445
29	GTESS_1	0.9336	0.9277
30	GTESS_2	0.9320	0.9261
31	NIST_1	0.9211	0.9156
32	GMD_3	0.9181	0.9122
33	MIME	0.9138	0.9079
34	GMD_1	0.9114	0.9060
35	ASOL	0.9109	0.9050
36	UPENN	0.9094	0.9031
37	NIST_2	0.9074	0.9016
38	NIST_3	0.9017	0.8963
39	GMD_4	0.8971	0.8918
40	RISO	0.8948	0.8884
41	KAMAN_1	0.8864	0.8800
42	KAMAN_3	0.8697	0.8633
43	KAMAN_2	0.8671	0.8608
44	KAMAN_5	0.8489	0.8431
45	GMD_2	0.8457	0.8402
46	VALEN_2	0.8419	0.8366
47	IFAX	0.8298	0.8241
48	VALEN_1	0.8222	0.8159
49	KAMAN_4	0.7933	0.7875

Table 116: OCRSYS correlation graph key for digits.

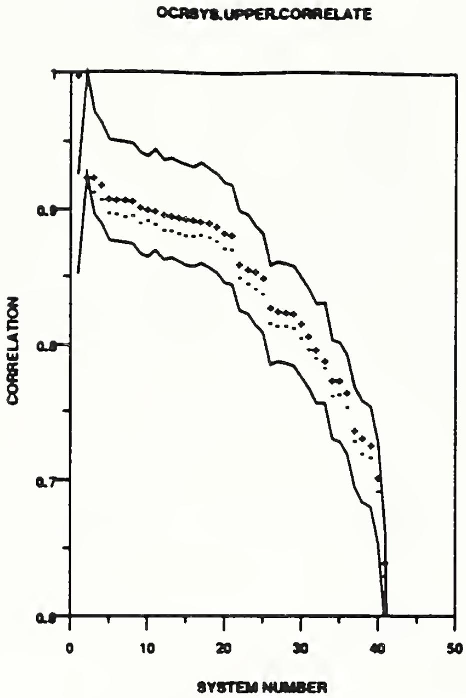

Figure 189: OCRSYS - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	OCRSYS	1.0000	1.0000
2	REFERENCE	0.9262	0.9262
3	VOTE_M	0.9259	0.9147
4	AEG	0.9205	0.9091
5	NYNEX	0.9104	0.8989
6	ATT_4	0.9091	0.8983
7	UMICH_1	0.9088	0.8968
8	ERIM_1	0.9080	0.8972
9	NESTOR	0.9036	0.8917
10	VOTE_P	0.9019	0.8940
11	ATT_2	0.9010	0.8905
12	IBM	0.8982	0.8866
13	UBOL	0.8972	0.8861
14	HUGHES_1	0.8967	0.8848
15	HUGHES_2	0.8952	0.8829
16	ATT_3	0.8943	0.8827
17	ATT_1	0.8938	0.8832
18	KODAK_1	0.8925	0.8820
19	SYMBUS	0.8901	0.8792
20	GTESS_1	0.8858	0.8737
21	GTESS_2	0.8839	0.8723
22	MIME	0.8627	0.8521
23	NIST_4	0.8587	0.8476
24	ASOL	0.8565	0.8441
25	REI	0.8523	0.8404
26	RISO	0.8298	0.8179
27	NIST_1	0.8277	0.8166
28	GMD_1	0.8267	0.8163
29	GMD_3	0.8259	0.8150
30	KAMAN_1	0.8180	0.8070
31	GMD_4	0.8090	0.7988
32	COMCOM	0.7987	0.7927
33	NIST_3	0.7908	0.7853
34	IFAX	0.7758	0.7642
35	KAMAN_3	0.7756	0.7646
36	KAMAN_2	0.7672	0.7555
37	NIST_2	0.7396	0.7311
38	VALEN_1	0.7334	0.7216
39	GMD_2	0.7287	0.7187
40	KAMAN_4	0.7047	0.6945
41	KAMAN_5	0.6417	0.6314
42	UMICH_2	0.0358	0.0217

Table 117: OCRSYS correlation graph key for uppers.

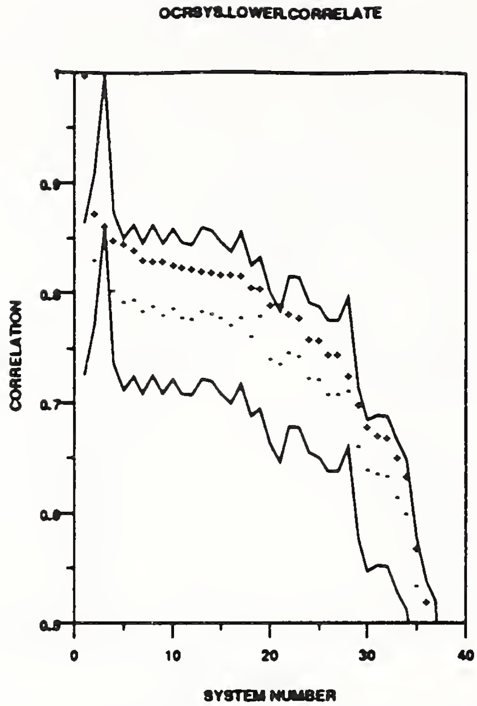

Figure 190: OCRSYS - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	OCRSYS	1.0000	1.0000
2	VOTE_M	0.8745	0.8327
3	REFERENCE	0.8630	0.8630
4	AEG	0.8508	0.8045
5	UMICH_1	0.8472	0.7941
6	ERIM_1	0.8417	0.7969
7	IBM	0.8342	0.7863
8	ATT_1	0.8325	0.7908
9	UBOL	0.8320	0.7828
10	ATT_2	0.8291	0.7893
11	HUGHES_1	0.8267	0.7810
12	HUGHES_2	0.8252	0.7794
13	NYNEX	0.8232	0.7866
14	ATT_4	0.8219	0.7849
15	NESTOR	0.8205	0.7809
16	ATT_3	0.8194	0.7744
17	KODAK_1	0.8184	0.7811
18	GTESS_1	0.8083	0.7641
19	VOTE_P	0.8068	0.7822
20	NIST_4	0.7928	0.7431
21	RISO	0.7908	0.7379
22	GTESS_2	0.7843	0.7483
23	NIST_1	0.7809	0.7448
24	GMD_3	0.7613	0.7256
25	ASOL	0.7600	0.7242
26	GMD_4	0.7473	0.7110
27	GMD_1	0.7473	0.7110
28	NIST_3	0.7278	0.7138
29	GMD_2	0.7021	0.6642
30	VALEN_1	0.6817	0.6418
31	KAMAN_1	0.6744	0.6381
32	NIST_2	0.6722	0.6364
33	KAMAN_3	0.6529	0.6169
34	KAMAN_2	0.6362	0.6022
35	KAMAN_5	0.5707	0.5365
36	KAMAN_4	0.5228	0.4985
37	COMCOM	0.4980	0.4882
38	UMICH_2	0.0827	0.0451

Table 118: OCRSYS correlation graph key for lowers.

SYSTEM: REI

PARTICIPANT: David L. Cauthron

ORGANIZATION: Recognition Equipment Inc. (REI),

FEATURES: model-based

CLASSIFICATION: MLP

HARDWARE: VAX simulation of 386 with coprocessor boards ICR handprint recognizer

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	245000	100000	NA	INTERNAL

STATUS: on time

RESULTS:	-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
	0.00	0.0401	0.00	0.1174			
	0.14	0.0055	0.57	0.0117			
	0.10	0.0088	0.40	0.0244			
	0.07	0.0139	0.24	0.0379			
	0.04	0.0194	0.15	0.0582			

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	1.97	2.06	
CPU RATE:			

NOTE: Internal database contains approximately 245000 digits and 100000 upper case letters.

NOTE: Few details of system description provided. Did not train on NIST data.

SYSTEM: REI

BIBLIOGRAPHY:

The following references have been provided for this system:

none

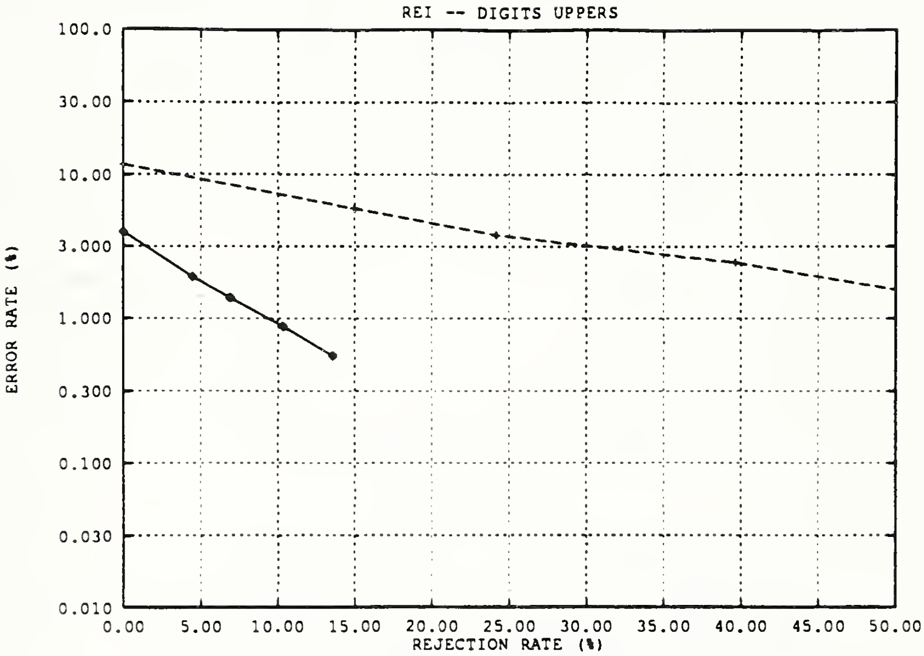

Figure 191: Error rate versus rejection rate for REI

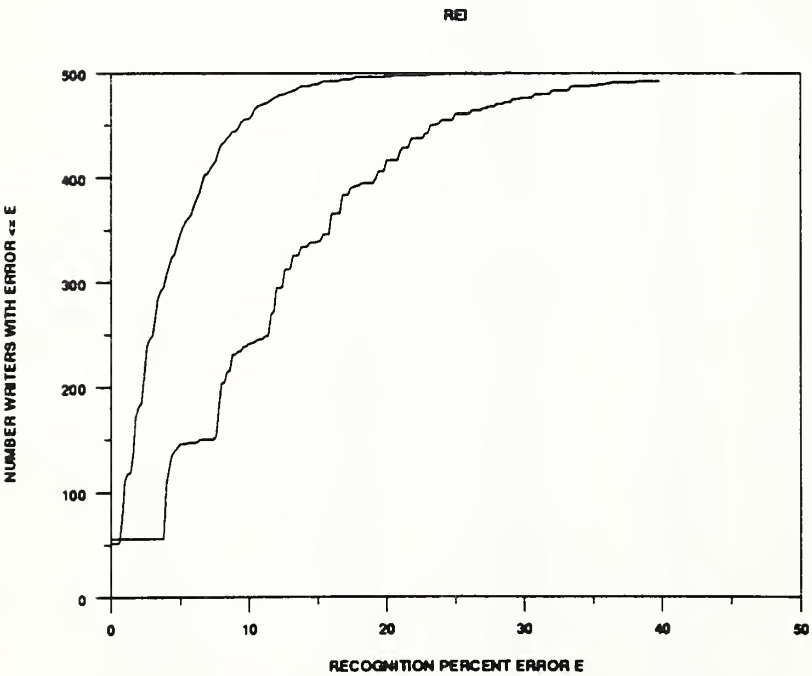

Figure 192: Error rate per writer of REI

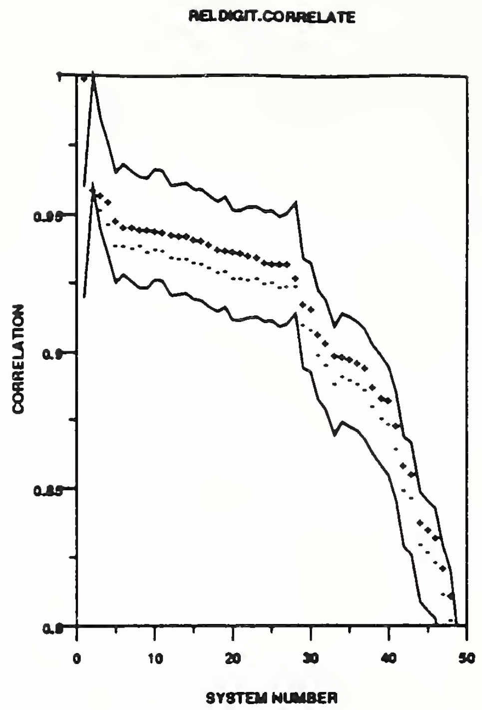

Figure 193: REI - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	REI	1.0000	1.0000
2	REFERENCE	0.9599	0.9599
3	OCRSYS	0.9581	0.9528
4	VOTE_M	0.9561	0.9479
5	IBM	0.9489	0.9400
6	ATT_1	0.9467	0.9400
7	AEG	0.9466	0.9389
8	VOTE_P	0.9460	0.9401
9	ATT_2	0.9459	0.9377
10	ELSAGB_3	0.9455	0.9387
11	ELSAGB_2	0.9451	0.9383
12	ERIM_2	0.9439	0.9357
13	ERIM_1	0.9436	0.9355
14	THINK_2	0.9434	0.9355
15	KODAK_2	0.9424	0.9338
16	ATT_4	0.9417	0.9335
17	NYNEX	0.9406	0.9323
18	NESTOR	0.9386	0.9303
19	UBOL	0.9379	0.9307
20	HUGHES_1	0.9377	0.9282
21	HUGHES_2	0.9372	0.9278
22	KODAK_1	0.9363	0.9276
23	SYMBUS	0.9357	0.9280
24	THINK_1	0.9339	0.9263
25	ATT_3	0.9337	0.9268
26	NIST_4	0.9334	0.9253
27	ELSAGB_1	0.9334	0.9249
28	COMCOM	0.9285	0.9251
29	GTESS_1	0.9188	0.9109
30	GTESS_2	0.9169	0.9092
31	NIST_1	0.9078	0.8999
32	GMD_3	0.9046	0.8965
33	UPENN	0.8998	0.8896
34	MIME	0.8997	0.8920
35	GMD_1	0.8984	0.8906
36	ASOL	0.8972	0.8893
37	NIST_2	0.8952	0.8870
38	NIST_3	0.8887	0.8812
39	GMD_4	0.8844	0.8766
40	RISO	0.8836	0.8745
41	KAMAN_1	0.8743	0.8655
42	KAMAN_3	0.8596	0.8503
43	KAMAN_2	0.8564	0.8476
44	KAMAN_5	0.8389	0.8305
45	GMD_2	0.8362	0.8280
46	VALEN_2	0.8332	0.8241
47	IFAX	0.8221	0.8128
48	VALEN_1	0.8122	0.8032
49	KAMAN_4	0.7832	0.7755

Table 119: REI correlation graph key for digits.

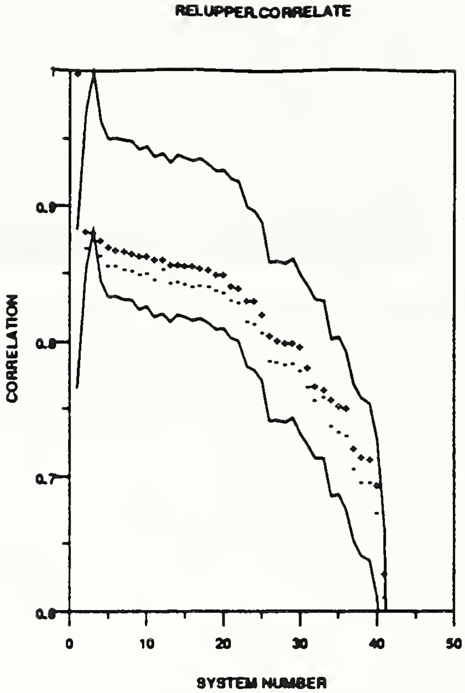

Figure 194: REI - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	REI	1.0000	1.0000
2	VOTE_M	0.8836	0.8715
3	REFERENCE	0.8826	0.8826
4	AEG	0.8771	0.8658
5	ATT_4	0.8726	0.8589
6	NYNEX	0.8704	0.8586
7	UMICH_1	0.8694	0.8561
8	ERIM_1	0.8675	0.8552
9	NESTOR	0.8665	0.8527
10	ATT_2	0.8658	0.8531
11	VOTE_P	0.8634	0.8556
12	IBM	0.8634	0.8490
13	UBOL	0.8596	0.8465
14	ATT_3	0.8596	0.8456
15	HUGHES_1	0.8591	0.8447
16	HUGHES_2	0.8587	0.8433
17	ATT_1	0.8571	0.8442
18	KODAK_1	0.8555	0.8428
19	OCRSYS	0.8523	0.8404
20	SYMBUS	0.8519	0.8388
21	GTESS_1	0.8442	0.8327
22	GTESS_2	0.8426	0.8312
23	MIME	0.8332	0.8176
24	NIST_4	0.8328	0.8153
25	ASOL	0.8225	0.8092
26	RISO	0.8075	0.7876
27	GMD_1	0.8037	0.7870
28	GMD_3	0.8015	0.7851
29	NIST_1	0.8013	0.7860
30	KAMAN_1	0.7991	0.7803
31	GMD_4	0.7834	0.7688
32	NIST_3	0.7694	0.7583
33	COMCOM	0.7668	0.7612
34	KAMAN_3	0.7597	0.7399
35	IFAX	0.7549	0.7357
36	KAMAN_2	0.7533	0.7328
37	NIST_2	0.7232	0.7083
38	VALEN_1	0.7169	0.6983
39	GMD_2	0.7154	0.6975
40	KAMAN_4	0.6958	0.6750
41	KAMAN_5	0.6303	0.6121
42	UMICH_2	0.0550	0.0204

Table 120: REI correlation graph key for uppers.

No Data Available

Figure 195: REI - lower case correlation

There was no data for this evaluation.

Table 121: REI correlation graph key for lowers.

SYSTEM: RISO

PARTICIPANT: Christian Liisberg

ORGANIZATION: Riso National Laboratories, Roskilde, Denmark

PREPROCESSING: size normalization to 16x16, no deskewing.
The normalized image is directly input to the neural net.

FEATURES: receptor field (LVT)

CLASSIFICATION: self-organizing geometric, ensembles of look-up table networks used.

HARDWARE: 33 MHz 486 with 16 Mbyte RAM

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	210000	40000	40000	NSDB3

1 to 2ambiguous characters removed by hand

STATUS: on time

RESULTS: -- DIGITS -- -- UPPERS -- -- LOWERS -- DATABASE

REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
0.00	0.1055	0.00	0.1414	0.00	0.2172	
0.02	0.0975	0.03	0.1244	0.04	0.1979	
0.06	0.0759	0.10	0.0943	0.13	0.1580	
0.10	0.0594	0.16	0.0694	0.21	0.1273	
0.14	0.0460	0.22	0.0504	0.28	0.1013	
0.18	0.0345	0.29	0.0347	0.36	0.0790	
0.23	0.0241	0.38	0.0221	0.45	0.0578	
0.30	0.0141	0.55	0.0105	0.61	0.0288	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	4.67	2.00	?
CPU RATE:	6.79	2.31	?

SYSTEM: RISO

PARTICIPANT: Christian Liisberg

BIBLIOGRAPHY:

The following references have been provided for this system:

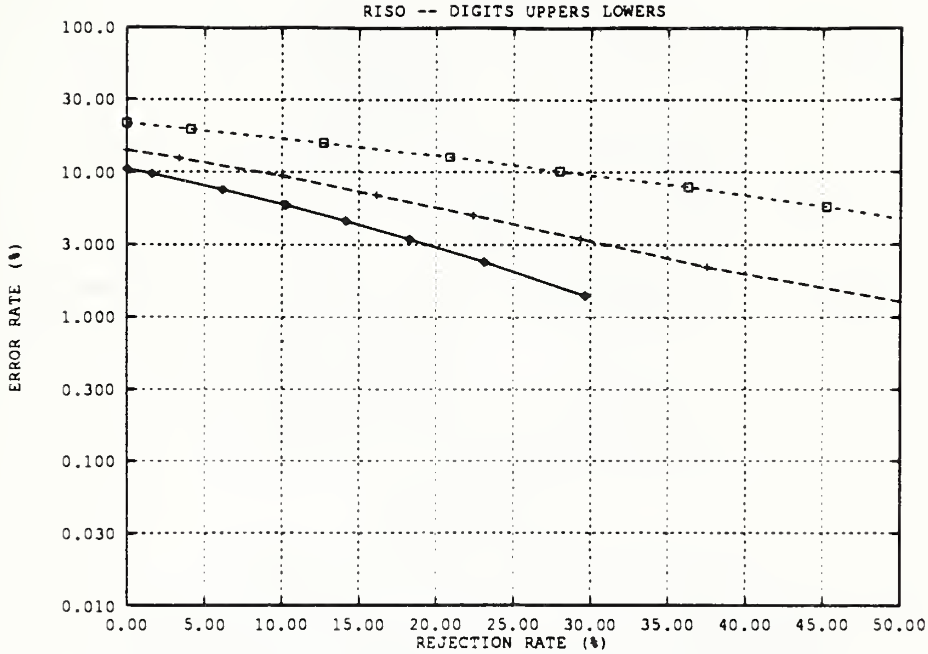

Figure 196: Error rate versus rejection rate for RISO

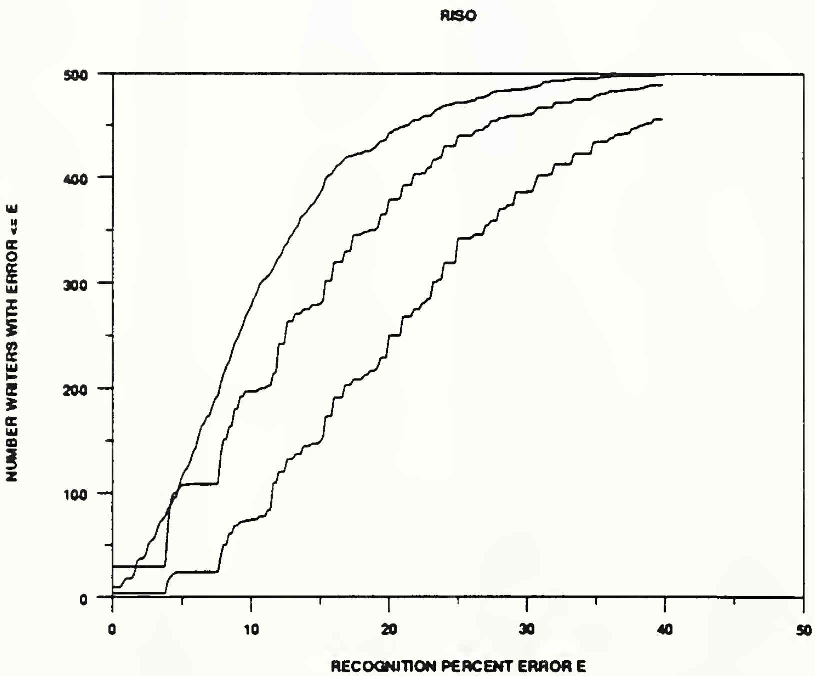

Figure 197: Error rate per writer of RISO

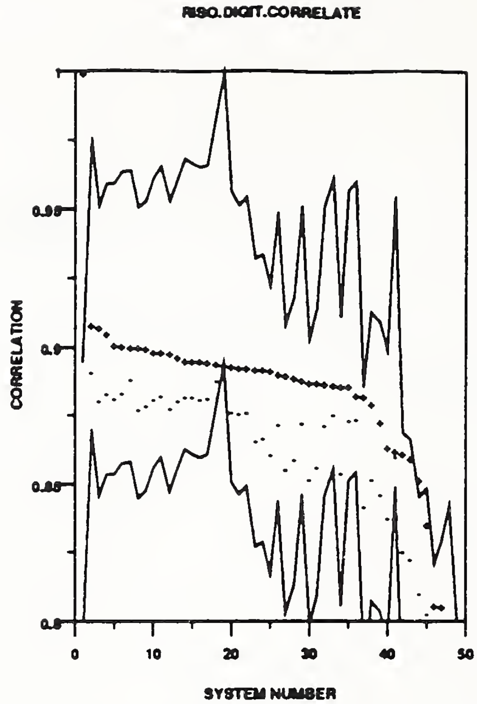

Figure 198: RISO - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	RISO	1.0000	1.0000
2	VOTE_M	0.9091	0.8916
3	THINK_1	0.9080	0.8812
4	ATT_4	0.9060	0.8838
5	KODAK_2	0.9017	0.8821
6	ATT_2	0.9015	0.8839
7	VOTE_P	0.9011	0.8889
8	NIST_4	0.9008	0.8777
9	SYMBUS	0.9002	0.8794
10	AEG	0.8990	0.8828
11	ERIM_1	0.8990	0.8818
12	KODAK_1	0.8985	0.8785
13	ERIM_2	0.8974	0.8812
14	ATT_1	0.8959	0.8827
15	ELSAGB_3	0.8958	0.8823
16	IBM	0.8957	0.8816
17	ELSAGB_2	0.8955	0.8820
18	OCRSYS	0.8948	0.8884
19	REFERENCE	0.8945	0.8945
20	UBOL	0.8941	0.8771
21	ATT_3	0.8936	0.8763
22	NESTOR	0.8935	0.8772
23	GTESS_2	0.8930	0.8669
24	GTESS_1	0.8929	0.8677
25	NIST_1	0.8926	0.8618
26	ELSAGB_1	0.8912	0.8730
27	NIST_2	0.8909	0.8561
28	GMD_3	0.8899	0.8599
29	HUGHES_1	0.8890	0.8732
30	MIME	0.8882	0.8571
31	NIST_3	0.8882	0.8526
32	HUGHES_2	0.8875	0.8725
33	THINK_2	0.8869	0.8759
34	NYNEX	0.8867	0.8741
35	ASOL	0.8867	0.8551
36	REI	0.8836	0.8745
37	KAMAN_1	0.8828	0.8426
38	GMD_1	0.8800	0.8526
39	UPENN	0.8739	0.8470
40	GMD_4	0.8648	0.8382
41	COMCOM	0.8633	0.8607
42	KAMAN_3	0.8625	0.8258
43	KAMAN_2	0.8605	0.8233
44	GMD_2	0.8525	0.8110
45	KAMAN_5	0.8359	0.8035
46	VALEN_1	0.8068	0.7739
47	IFAX	0.8064	0.7802
48	VALEN_2	0.7994	0.7832
49	KAMAN_4	0.7974	0.7582

Table 122: RISO correlation graph key for digits.

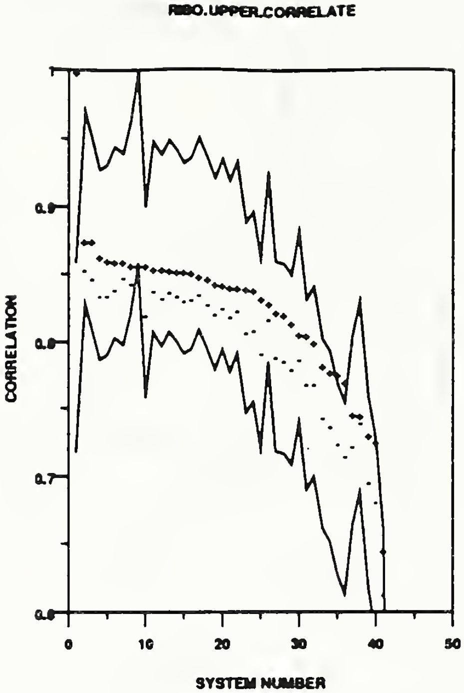

Figure 199: RISO - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	RISO	1.0000	1.0000
2	VOTE_M	0.8761	0.8554
3	ATT_4	0.8760	0.8488
4	SYMBUS	0.8653	0.8353
5	KODAK_1	0.8625	0.8359
6	ATT_2	0.8619	0.8406
7	VOTE_P	0.8614	0.8496
8	AEG	0.8587	0.8446
9	REFERENCE	0.8586	0.8586
10	MIME	0.8585	0.8210
11	ERIM_1	0.8562	0.8390
12	UBOL	0.8557	0.8337
13	UMICH_1	0.8552	0.8383
14	NESTOR	0.8545	0.8361
15	ATT_3	0.8537	0.8321
16	IBM	0.8528	0.8331
17	NYNEX	0.8503	0.8369
18	ATT_1	0.8484	0.8296
19	GTESS_1	0.8449	0.8219
20	HUGHES_1	0.8443	0.8263
21	HUGHES_2	0.8425	0.8245
22	GTESS_2	0.8425	0.8204
23	ASOL	0.8409	0.8085
24	NIST_4	0.8405	0.8096
25	NIST_1	0.8338	0.7925
26	OCRSYS	0.8298	0.8179
27	GMD_1	0.8241	0.7899
28	GMD_3	0.8220	0.7875
29	KAMAN_1	0.8153	0.7803
30	REI	0.8075	0.7876
31	NIST_3	0.8062	0.7692
32	GMD_4	0.8009	0.7697
33	KAMAN_3	0.7835	0.7449
34	KAMAN_2	0.7792	0.7381
35	NIST_2	0.7765	0.7253
36	GMD_2	0.7710	0.7165
37	IFAX	0.7479	0.7241
38	COMCOM	0.7469	0.7409
39	VALEN_1	0.7320	0.6968
40	KAMAN_4	0.7272	0.6826
41	KAMAN_5	0.6464	0.6143
42	UMICH_2	0.0641	0.0161

Table 123: RISO correlation graph key for uppers.

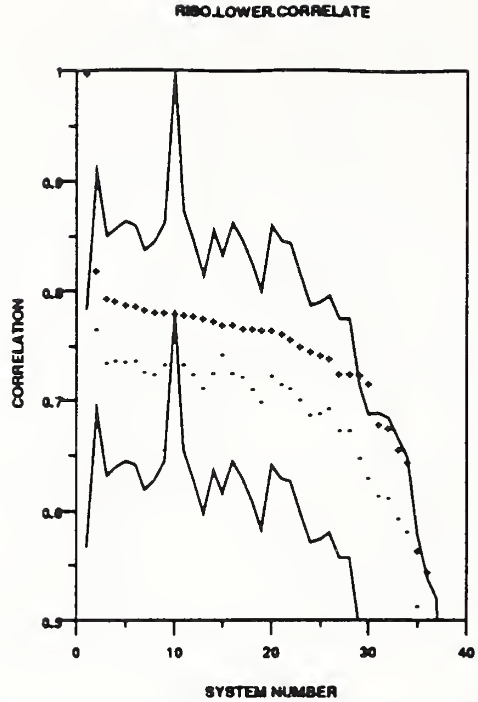

Figure 200: RISO - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	RISO	1.0000	1.0000
2	VOTE_M	0.8227	0.7683
3	UMICH_1	0.7968	0.7369
4	ATT_4	0.7947	0.7391
5	OCRSYS	0.7908	0.7379
6	ATT_2	0.7902	0.7393
7	ATT_3	0.7869	0.7289
8	UBOL	0.7843	0.7269
9	ERIM_1	0.7838	0.7358
10	REFERENCE	0.7828	0.7828
11	AEG	0.7817	0.7360
12	IBM	0.7811	0.7272
13	NIST_1	0.7784	0.7145
14	KODAK_1	0.7761	0.7279
15	VOTE_P	0.7732	0.7450
16	ATT_1	0.7724	0.7281
17	NESTOR	0.7694	0.7243
18	GTESS_1	0.7690	0.7131
19	NIST_4	0.7678	0.7017
20	NYNEX	0.7677	0.7258
21	HUGHES_1	0.7647	0.7173
22	HUGHES_2	0.7602	0.7145
23	GTESS_2	0.7538	0.7039
24	ASOL	0.7493	0.6898
25	GMD_3	0.7449	0.6917
26	NIST_3	0.7418	0.6964
27	GMD_4	0.7285	0.6765
28	GMD_1	0.7285	0.6765
29	GMD_2	0.7265	0.6507
30	NIST_2	0.7193	0.6332
31	KAMAN_1	0.6821	0.6172
32	VALEN_1	0.6790	0.6148
33	KAMAN_3	0.6593	0.5964
34	KAMAN_2	0.6472	0.5833
35	KAMAN_5	0.5667	0.5158
36	KAMAN_4	0.5463	0.4889
37	COMCOM	0.4627	0.4540
38	UMICH_2	0.0906	0.0335

Table 124: RISO correlation graph key for lowers.

SYSTEM: SYMBUS

PARTICIPANT: Jerry Fisher

ORGANIZATION: Symbus Technology, Brookline, MA

FEATURES: output of preprocessing

CLASSIFICATION: cascaded self-organizing NNs

HARDWARE:

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	number used is proprietary		NA	INTERNAL

STATUS: on time, three RJX files missing

RESULTS:

-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
0.00	0.0471	0.00	0.0729			
0.00	0.0470	0.00	0.0727			
0.02	0.0397	0.07	0.0462			
0.04	0.0327	0.15	0.0289			
0.11	0.0194	0.28	0.0151			
0.19	0.0111					

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	NA	NA	NA
CPU RATE:			

NOTE: Some of the HYP files contained tildes to indicate that no classification was attempted. Every classification in the whole file, rather than just the tilde was inadvertently converted to a question mark at NIST before scoring for the Conference. This gave zero rejection rate error rates of 7.0% and 12.0% for digits and uppers, respectively. The scores above reflect the correction of this NIST error.

NOTE: Few if any details provided about features or recognition algorithm.

NOTE: Internal database includes NSDB1.

SYSTEM: SYMBUS

BIBLIOGRAPHY:

The following references have been provided for this system:

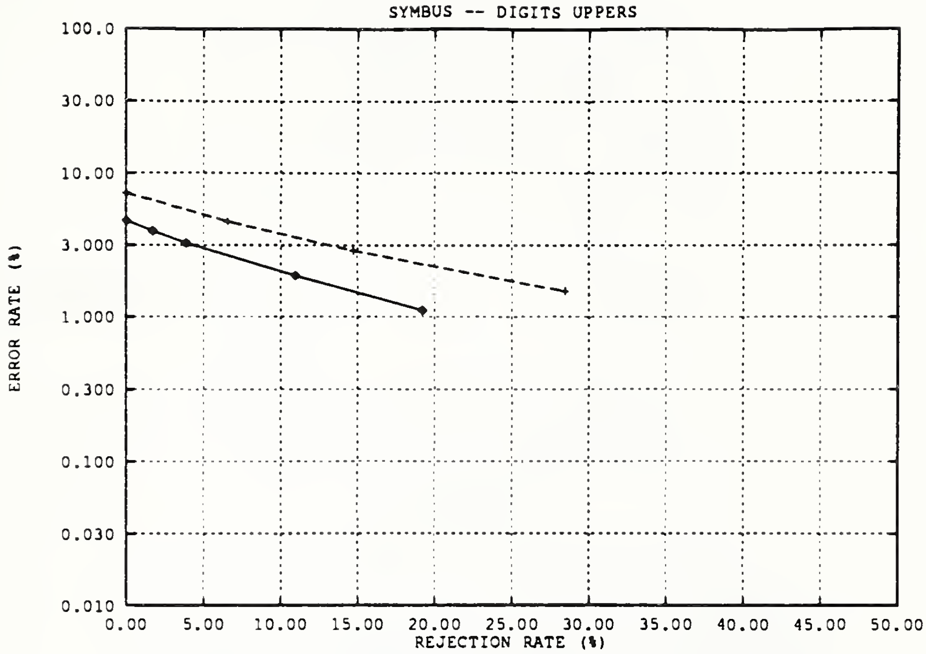

Figure 201: Error rate versus rejection rate for SYMBUS

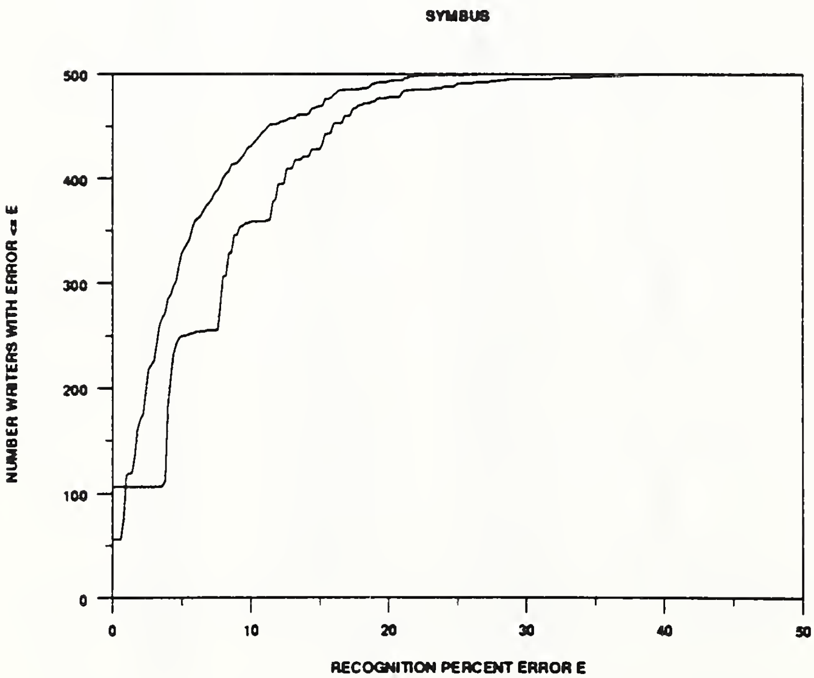

Figure 202: Error rate per writer of SYMBUS

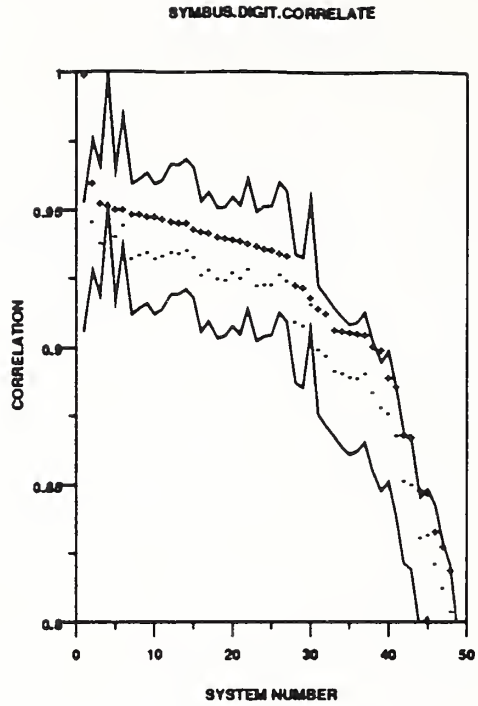

Figure 203: SYMBUS - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	SYMBUS	1.0000	1.0000
2	VOTE_M	0.9611	0.9468
3	AEG	0.9536	0.9388
4	REFERENCE	0.9529	0.9529
5	OCRSYS	0.9512	0.9456
6	VOTE_P	0.9512	0.9411
7	ERIM_1	0.9494	0.9350
8	KODAK_2	0.9494	0.9337
9	ATT_2	0.9488	0.9356
10	ATT_4	0.9486	0.9333
11	ERIM_2	0.9479	0.9345
12	ELSAGB_3	0.9467	0.9356
13	ATT_1	0.9462	0.9361
14	ELSAGB_2	0.9462	0.9352
15	IBM	0.9442	0.9341
16	KODAK_1	0.9430	0.9273
17	UBOL	0.9425	0.9294
18	NIST_4	0.9411	0.9260
19	THINK_1	0.9407	0.9259
20	NESTOR	0.9406	0.9283
21	ATT_3	0.9399	0.9268
22	THINK_2	0.9389	0.9297
23	ELSAGB_1	0.9379	0.9240
24	HUGHES_2	0.9370	0.9244
25	HUGHES_1	0.9366	0.9242
26	REI	0.9357	0.9280
27	NYNEX	0.9348	0.9256
28	GTESS_1	0.9243	0.9105
29	GTESS_2	0.9234	0.9093
30	COMCOM	0.9197	0.9169
31	NIST_1	0.9157	0.9006
32	GMD_3	0.9136	0.8981
33	MIME	0.9079	0.8927
34	ASOL	0.9075	0.8915
35	NIST_2	0.9068	0.8902
36	UPENN	0.9065	0.8900
37	GMD_1	0.9058	0.8915
38	NIST_3	0.9017	0.8850
39	RISO	0.9002	0.8794
40	GMD_4	0.8904	0.8768
41	KAMAN_1	0.8873	0.8693
42	KAMAN_3	0.8698	0.8528
43	KAMAN_2	0.8685	0.8512
44	GMD_2	0.8495	0.8320
45	KAMAN_5	0.8484	0.8327
46	VALEN_2	0.8341	0.8223
47	IFAX	0.8286	0.8134
48	VALEN_1	0.8201	0.8048
49	KAMAN_4	0.7965	0.7800

Table 125: SYMBUS correlation graph key for digits.

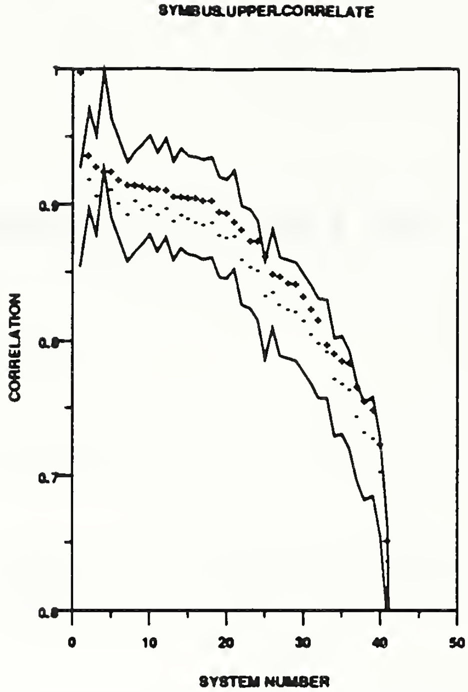

Figure 204: SYMBUS - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	SYMBUS	1.0000	1.0000
2	VOTE_M	0.9382	0.9204
3	ATT_4	0.9306	0.9081
4	REFERENCE	0.9271	0.9271
5	AEG	0.9268	0.9126
6	ERIM_1	0.9200	0.9029
7	KODAK_1	0.9170	0.8941
8	VOTE_P	0.9165	0.9049
9	ATT_2	0.9158	0.8985
10	NYNEX	0.9137	0.9008
11	UBOL	0.9136	0.8942
12	UMICH_1	0.9133	0.8993
13	NESTOR	0.9082	0.8943
14	ATT_3	0.9082	0.8897
15	IBM	0.9071	0.8915
16	HUGHES_1	0.9070	0.8893
17	HUGHES_2	0.9054	0.8872
18	ATT_1	0.9051	0.8887
19	GTESS_1	0.8977	0.8794
20	GTESS_2	0.8965	0.8781
21	OCRSYS	0.8901	0.8792
22	MIME	0.8843	0.8622
23	NIST_4	0.8764	0.8567
24	ASOL	0.8761	0.8545
25	RISO	0.8653	0.8353
26	REI	0.8519	0.8388
27	NIST_1	0.8504	0.8291
28	GMD_1	0.8460	0.8253
29	GMD_3	0.8453	0.8240
30	KAMAN_1	0.8361	0.8175
31	GMD_4	0.8270	0.8070
32	NIST_3	0.8179	0.8005
33	COMCOM	0.7995	0.7941
34	KAMAN_3	0.7934	0.7741
35	IFAX	0.7877	0.7706
36	KAMAN_2	0.7862	0.7659
37	NIST_2	0.7688	0.7[illegible]63
38	GMD_2	0.7579	0.7344
39	VALEN_1	0.7509	0.7301
40	KAMAN_4	0.7267	0.7056
41	KAMAN_5	0.6542	0.6381
42	UMICH_2	0.0424	0.0204

Table 126: SYMBUS correlation graph key for uppers.

No Data Available

Figure 205: SYMBUS - lower case correlation

There was no data for this evaluation.

Table 127: SYMBUS correlation graph key for lowers.

SYSTEM: THINK_1

PARTICIPANT: Stephen Smith

ORGANIZATION: Thinking Machines Corporation, Cambridge, MA

PREPROCESSING: size normalization

FEATURES: template, model, including arcs extracted from a 32x32 image after normalization.

CLASSIFICATION: distance maps, modified nearest neighbor, modified Hamming distance used where each pixel is represented by its distance to the nearest matching pixel.

HARDWARE: 32,768 processor CM2 with SUN front end

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	all	NA	NA	NSDB3

STATUS: on time

RESULTS:	-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
	0.00	0.0489					
	0.10	0.0152					
	0.20	0.0059					
	0.30	0.0027					
	0.40	0.0014					
	0.50	0.0006					

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	0.67		
CPU RATE:			

SYSTEM: THINK_1

BIBLIOGRAPHY:

The following references have been provided for this system:

none

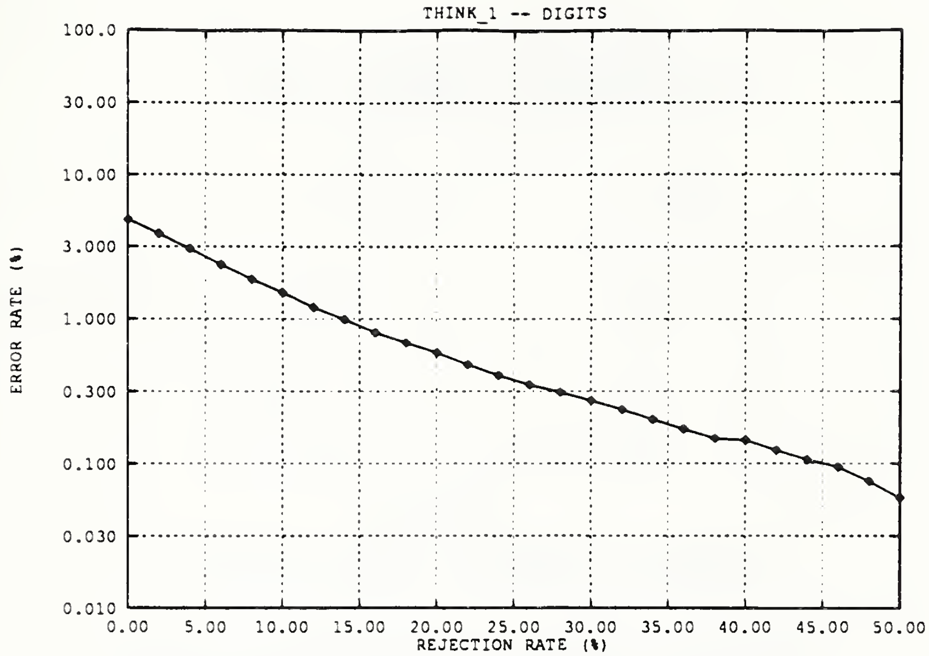

Figure 206: Error rate versus rejection rate for THINK_1

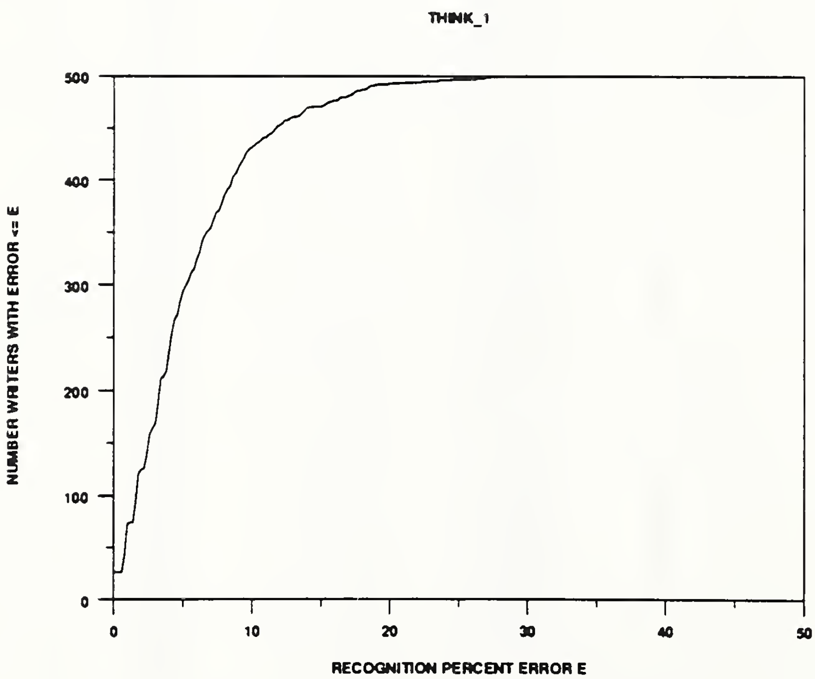

Figure 207: Error rate per writer of THINK_1

THINK_1.DIGIT.CORRELATE

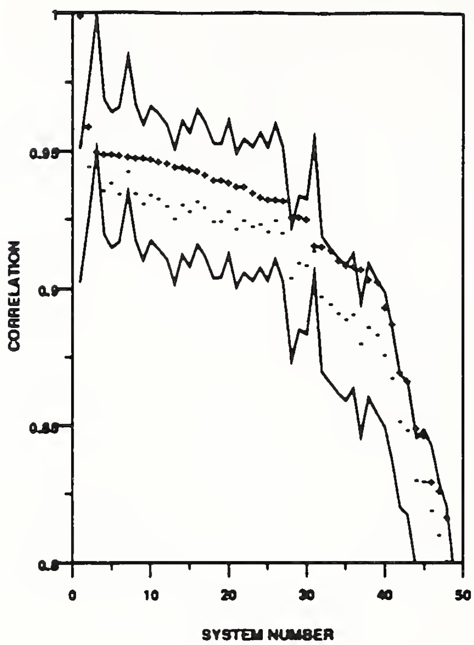

Figure 208: THINK_1 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	THINK_1	1.0000	1.0000
2	VOTE_M	0.9603	0.9452
3	REFERENCE	0.9511	0.9511
4	ATT_1	0.9500	0.9369
5	VOTE_P	0.9499	0.9394
6	AEG	0.9496	0.9356
7	OCRSYS	0.9492	0.9435
8	ELSAGB_3	0.9486	0.9356
9	ATT_4	0.9485	0.9322
10	ELSAGB_2	0.9482	0.9352
11	ATT_2	0.9474	0.9341
12	KODAK_2	0.9466	0.9312
13	NIST_4	0.9454	0.9265
14	ERIM_1	0.9453	0.9316
15	UBOL	0.9445	0.9292
16	IBM	0.9440	0.9328
17	ERIM_2	0.9429	0.9306
18	KODAK_1	0.9409	0.9255
19	SYMBUS	0.9407	0.9259
20	THINK_2	0.9401	0.9293
21	ELSAGB_1	0.9386	0.9228
22	NESTOR	0.9384	0.9261
23	ATT_3	0.9364	0.9240
24	NYNEX	0.9350	0.9247
25	HUGHES_1	0.9341	0.9220
26	REI	0.9339	0.9263
27	HUGHES_2	0.9336	0.9217
28	NIST_1	0.9277	0.9048
29	GTESS_1	0.9273	0.9107
30	GTESS_2	0.9268	0.9098
31	COMCOM	0.9171	0.9145
32	GMD_3	0.9167	0.8979
33	MIME	0.9150	0.8952
34	ASOL	0.9115	0.8922
35	NIST_2	0.9097	0.8900
36	GMD_1	0.9093	0.8916
37	RISO	0.9080	0.8812
38	UPENN	0.9047	0.8873
39	NIST_3	0.9037	0.8845
40	GMD_4	0.8944	0.8771
41	KAMAN_1	0.8887	0.8687
42	KAMAN_3	0.8710	0.8525
43	KAMAN_2	0.8678	0.8494
44	GMD_2	0.8502	0.8312
45	KAMAN_5	0.8474	0.8307
46	VALEN_2	0.8308	0.8201
47	IFAX	0.8273	0.8114
48	VALEN_1	0.8178	0.8015
49	KAMAN_4	0.7962	0.7780

Table 128: THINK_1 correlation graph key for digits.

No Data Available

Figure 209: THINK_1 - upper case correlation

There was no data for this evaluation.

Table 129: THINK_1 correlation graph key for uppers.

No Data Available

Figure 210: THINK_1 - lower case correlation

There was no data for this evaluation.

Table 130: THINK_1 correlation graph key for lowers.

SYSTEM: UBOL

PARTICIPANT: Dr. Zsolt M. Kovacs-V.

ORGANIZATION: University of Bologna, Bologna, Italy

PREPROCESSING: noise removal, slant normalization, thinning, and size normalization to 32x32. Then a distance transform is performed on the background and a further reduction is performed to 8x8. This provides a 64-dimensional feature vector.

FEATURES: rule-based distance transform

CLASSIFICATION: KNN with novel metric

HARDWARE: simulation of CM2 with 64K processors on SPARC

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	72000	all	all	NSDB3

STATUS: on time

RESULTS:

-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
0.00	0.0435	0.00	0.0624	0.00	0.1548	
0.04	0.0271	0.03	0.0506	0.04	0.1365	
0.06	0.0215	0.06	0.0390	0.11	0.1107	
0.07	0.0184	0.09	0.0334	0.17	0.0909	
0.09	0.0148	0.11	0.0282	0.22	0.0745	
0.11	0.0122	0.15	0.0221	0.25	0.0655	
0.13	0.0108	0.18	0.0197	0.28	0.0564	
0.15	0.0096	0.20	0.0171	0.33	0.0436	
0.17	0.0086	0.25	0.0130	0.37	0.0379	
0.19	0.0079	0.31	0.0105	0.42	0.0287	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	0.06	0.09	0.04
CPU RATE:	0.08	0.10	0.05

SYSTEM: UBOL

BIBLIOGRAPHY:

The following references have been provided for this system:

[43][44][45][46][47] [12][6][48][49]

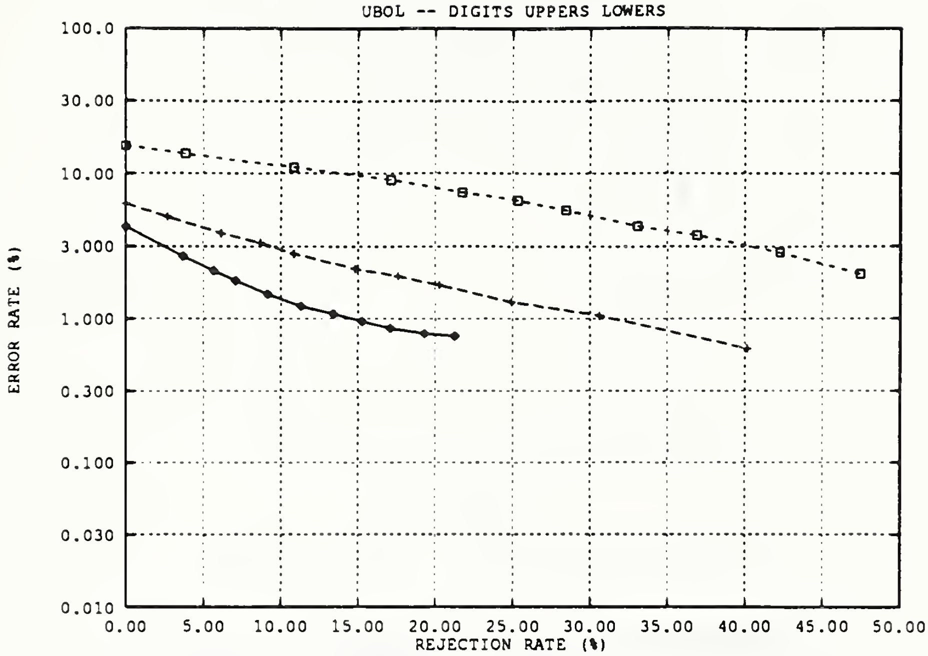

Figure 211: Error rate versus rejection rate for UBOL

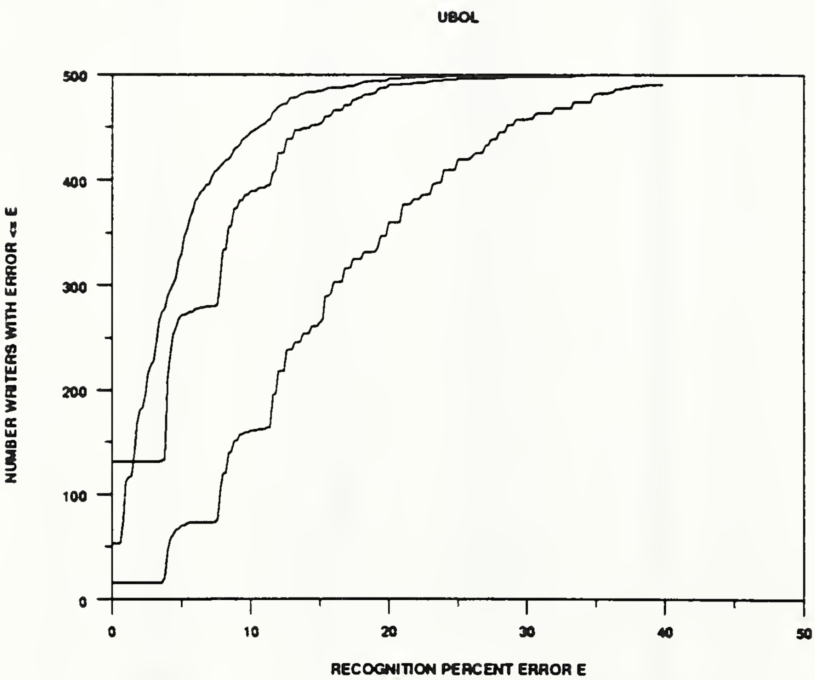

Figure 212: Error rate per writer of UBOL

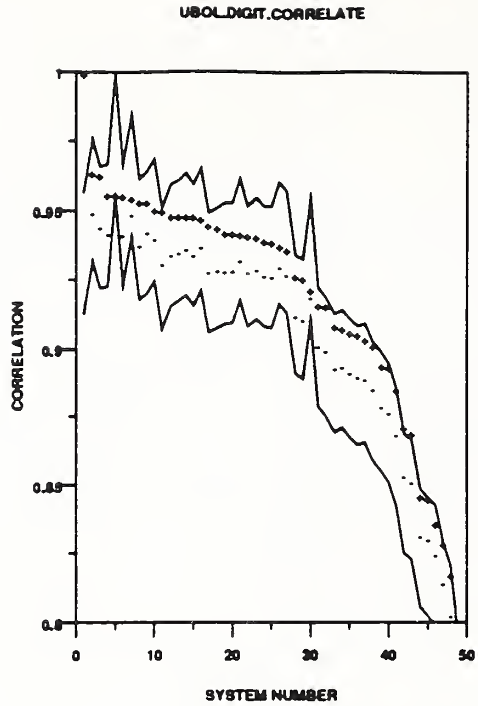

Figure 213: UBOL - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	UBOL	1.0000	1.0000
2	VOTE_M	0.9644	0.9496
3	AEG	0.9632	0.9446
4	ELSAGB_3	0.9566	0.9420
5	REFERENCE	0.9565	0.9565
6	ELSAGB_2	0.9561	0.9416
7	OCRSYS	0.9552	0.9492
8	ERIM_1	0.9536	0.9382
9	VOTE_P	0.9535	0.9429
10	ATT_1	0.9511	0.9403
11	NIST_4	0.9506	0.9316
12	ATT_4	0.9488	0.9348
13	ERIM_2	0.9487	0.9359
14	ATT_2	0.9486	0.9368
15	KODAK_2	0.9485	0.9349
16	IBM	0.9477	0.9374
17	ELSAGB_1	0.9455	0.9287
18	THINK_1	0.9445	0.9292
19	SYMBUS	0.9425	0.9294
20	KODAK_1	0.9425	0.9290
21	THINK_2	0.9423	0.9328
22	ATT_3	0.9417	0.9289
23	NESTOR	0.9415	0.9299
24	HUGHES_1	0.9401	0.9275
25	HUGHES_2	0.9396	0.9272
26	REI	0.9379	0.9307
27	NYNEX	0.9366	0.9282
28	GTESS_1	0.9276	0.9129
29	GTESS_2	0.9265	0.9116
30	COMCOM	0.9224	0.9198
31	NIST_1	0.9170	0.9018
32	GMD_3	0.9165	0.8999
33	GMD_1	0.9091	0.8935
34	MIME	0.9081	0.8941
35	ASOL	0.9067	0.8918
36	NIST_2	0.9059	0.8902
37	UPENN	0.9041	0.8896
38	NIST_3	0.9016	0.8857
39	GMD_4	0.8944	0.8792
40	RISO	0.8941	0.8771
41	KAMAN_1	0.8857	0.8691
42	KAMAN_3	0.8720	0.8542
43	KAMAN_2	0.8698	0.8519
44	KAMAN_5	0.8467	0.8321
45	GMD_2	0.8458	0.8307
46	VALEN_2	0.8365	0.8251
47	IFAX	0.8293	0.8143
48	VALEN_1	0.8177	0.8031
49	KAMAN_4	0.7990	0.7809

Table 131: UBOL correlation graph key for digits.

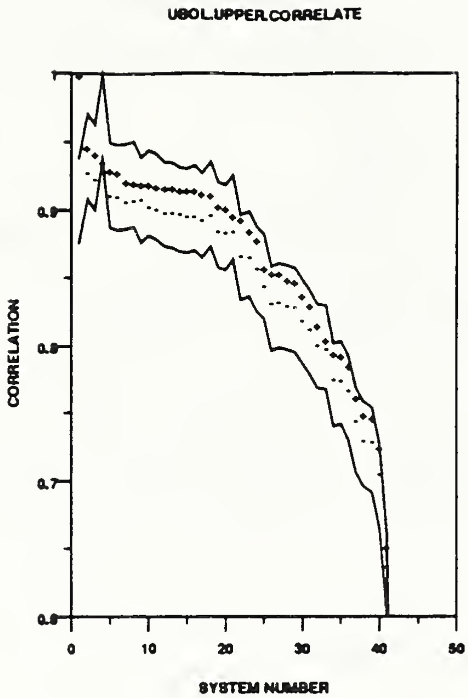

Figure 214: UBOL - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	UBOL	1.0000	1.0000
2	VOTE_M	0.9481	0.9299
3	AEG	0.9433	0.9246
4	REFERENCE	0.9376	0.9376
5	ATT_4	0.9313	0.9132
6	ERIM_1	0.9290	0.9116
7	UMICH_1	0.9231	0.9080
8	NYNEX	0.9225	0.9091
9	VOTE_P	0.9215	0.9104
10	ATT_2	0.9210	0.9049
11	NESTOR	0.9194	0.9030
12	HUGHES_1	0.9188	0.8997
13	ATT_1	0.9186	0.8998
14	ATT_3	0.9169	0.8989
15	KODAK_1	0.9168	0.8977
16	HUGHES_2	0.9168	0.8975
17	SYMBUS	0.9136	0.8942
18	IBM	0.9126	0.8979
19	GTESS_1	0.9044	0.8865
20	GTESS_2	0.9031	0.8849
21	OCRSYS	0.8972	0.8861
22	NIST_4	0.8941	0.8692
23	MIME	0.8867	0.8681
24	ASOL	0.8797	0.8598
25	REI	0.8596	0.8465
26	NIST_1	0.8557	0.8346
27	RISO	0.8557	0.8337
28	GMD_1	0.8510	0.8324
29	GMD_3	0.8496	0.8308
30	KAMAN_1	0.8395	0.8213
31	GMD_4	0.8323	0.8144
32	NIST_3	0.8172	0.8028
33	COMCOM	0.8060	0.7999
34	KAMAN_3	0.7958	0.7774
35	IFAX	0.7945	0.7762
36	KAMAN_2	0.7870	0.7684
37	NIST_2	0.7633	0.7465
38	VALEN_1	0.7503	0.7315
39	GMD_2	0.7488	0.7311
40	KAMAN_4	0.7262	0.7070
41	KAMAN_5	0.6531	0.6386
42	UMICH_2	0.0448	0.0211

Table 132: UBOL correlation graph key for uppers.

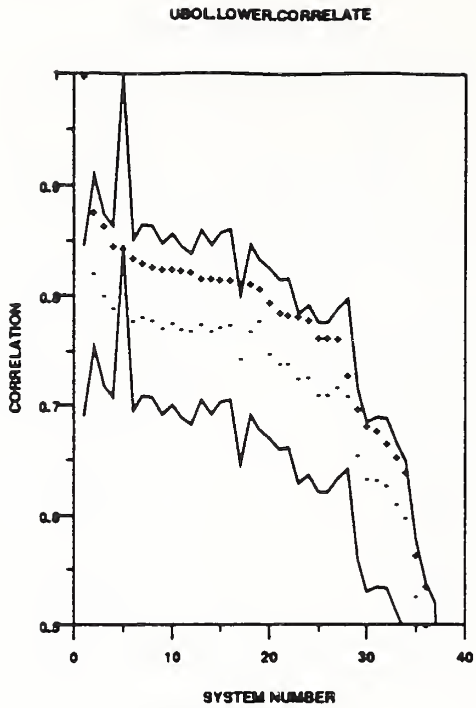

Figure 215: UBOL - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	UBOL	1.0000	1.0000
2	VOTE_M	0.8784	0.8238
3	AEG	0.8663	0.8026
4	ERIM_1	0.8471	0.7914
5	REFERENCE	0.8452	0.8452
6	UMICH_1	0.8373	0.7800
7	OCRSYS	0.8320	0.7828
8	ATT_1	0.8288	0.7796
9	HUGHES_1	0.8273	0.7732
10	KODAK_1	0.8267	0.7778
11	HUGHES_2	0.8257	0.7715
12	ATT_3	0.8248	0.7704
13	ATT_2	0.8188	0.7763
14	IBM	0.8184	0.7706
15	ATT_4	0.8173	0.7740
16	NYNEX	0.8172	0.7761
17	NIST_4	0.8145	0.7449
18	NESTOR	0.8137	0.7701
19	VOTE_P	0.8097	0.7793
20	GTESS_1	0.7965	0.7504
21	NIST_1	0.7883	0.7409
22	GTESS_2	0.7851	0.7410
23	RISO	0.7843	0.7269
24	GMD_3	0.7809	0.7283
25	GMD_4	0.7644	0.7122
26	GMD_1	0.7644	0.7122
27	ASOL	0.7634	0.7189
28	NIST_3	0.7305	0.7105
29	GMD_2	0.6998	0.6568
30	VALEN_1	0.6848	0.6347
31	KAMAN_1	0.6802	0.6338
32	NIST_2	0.6684	0.6291
33	KAMAN_3	0.6562	0.6116
34	KAMAN_2	0.6417	0.5992
35	KAMAN_5	0.5667	0.5284
36	KAMAN_4	0.5372	0.5010
37	COMCOM	0.4919	0.4798
38	UMICH_2	0.0966	0.0467

Table 133: UBOL correlation graph key for lowers.

SYSTEM: UPENN

PARTICIPANT: Thomas Fontaine

ORGANIZATION: University of Pennsylvania, Philadelphia, PA

FEATURES: local receptor fields

CLASSIFICATION: Spatio-temporal connectionist model. Learning using a gradient-based technique. Shift invariance is achieved along temporalized directions.

HARDWARE: IBM RS/6000

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	5400			USPS

STATUS: on time

RESULTS:	-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
	0.00	0.0908					
	0.10	0.0517					
	0.20	0.0277					
	0.30	0.0169					
	0.40	0.0122					
	0.50	0.0102					

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	0.50	NA	NA
CPU RATE:			

SYSTEM: UPENN

BIBLIOGRAPHY:

The following references have been provided for this system:

[50][51][37][56][57][52][5][53] [54][55]

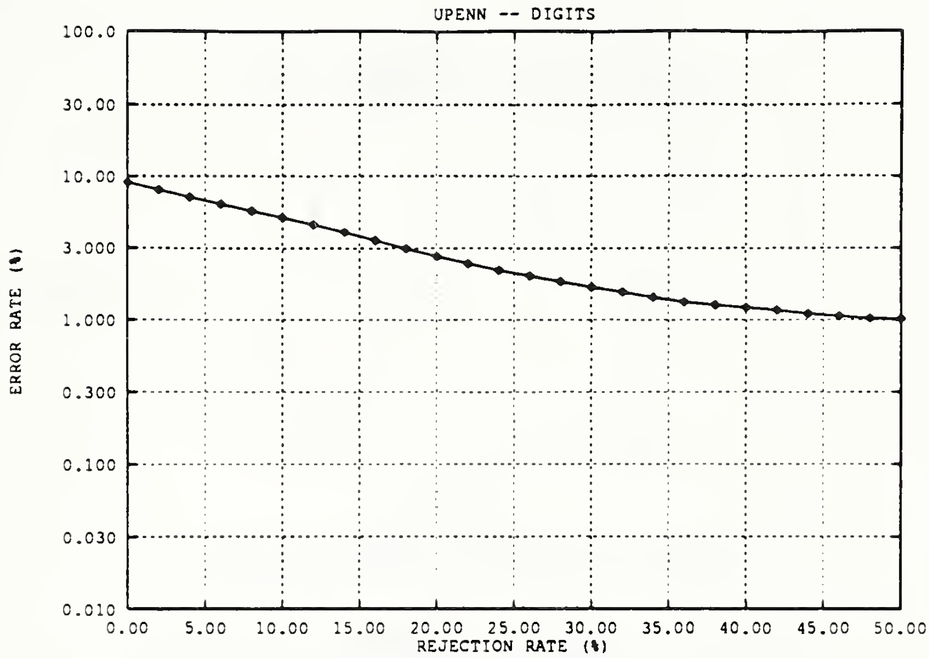

Figure 216: Error rate versus rejection rate for UPENN

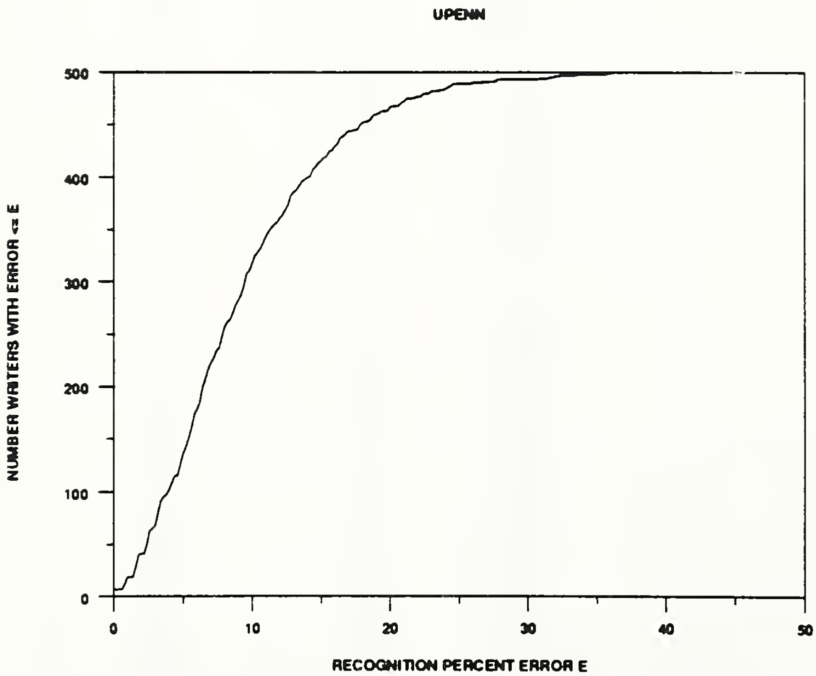

Figure 217: Error rate per writer of UPENN

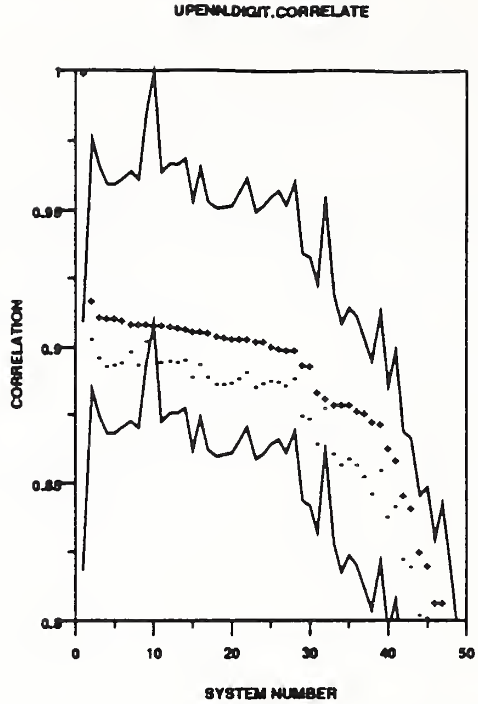

Figure 218: UPENN - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	UPENN	1.0000	1.0000
2	VOTE_M	0.9183	0.9041
3	AEG	0.9124	0.8974
4	ATT_4	0.9120	0.8942
5	KODAK_2	0.9119	0.8945
6	ERIM_1	0.9110	0.8952
7	VOTE_P	0.9096	0.8995
8	OCRSYS	0.9094	0.9031
9	ERIM_2	0.9094	0.8945
10	REFERENCE	0.9092	0.9092
11	ATT_2	0.9091	0.8953
12	ELSAGB_3	0.9086	0.8958
13	ELSAGB_2	0.9080	0.8953
14	ATT_1	0.9079	0.8961
15	KODAK_1	0.9070	0.8897
16	IBM	0.9069	0.8945
17	SYMBUS	0.9065	0.8900
18	NIST_4	0.9051	0.8873
19	THINK_1	0.9047	0.8873
20	HUGHES_1	0.9043	0.8877
21	THINK_2	0.9041	0.8915
22	UBOL	0.9041	0.8896
23	ELSAGB_1	0.9033	0.8861
24	HUGHES_2	0.9031	0.8874
25	NESTOR	0.9013	0.8884
26	NYNEX	0.9002	0.8880
27	REI	0.8998	0.8896
28	ATT_3	0.8998	0.8867
29	GTESS_1	0.8945	0.8754
30	GTESS_2	0.8941	0.8748
31	NIST_1	0.8845	0.8654
32	COMCOM	0.8819	0.8782
33	GMD_3	0.8798	0.8620
34	MIME	0.8797	0.8599
35	NIST_2	0.8797	0.8576
36	ASOL	0.8773	0.8577
37	NIST_3	0.8763	0.8537
38	RISO	0.8739	0.8470
39	GMD_1	0.8727	0.8558
40	KAMAN_1	0.8640	0.8387
41	GMD_4	0.8594	0.8425
42	KAMAN_3	0.8466	0.8232
43	KAMAN_2	0.8423	0.8205
44	GMD_2	0.8258	0.8031
45	KAMAN_5	0.8211	0.8022
46	IFAX	0.8078	0.7862
47	VALEN_2	0.8076	0.7929
48	VALEN_1	0.7936	0.7739
49	KAMAN_4	0.7740	0.7517

Table 134: UPENN correlation graph key for digits.

No Data Available

Figure 219: UPENN - upper case correlation

There was no data for this evaluation.

Table 135: UPENN correlation graph key for uppers.

No Data Available

Figure 220: UPENN - lower case correlation

There was no data for this evaluation.

Table 136: UPENN correlation graph key for lowers.

SYSTEM: VALEN_1

PARTICIPANT: Enrique Vidal

ORGANIZATION: Universidad Politecnica de Valencia, Valencia, Spain

FEATURES: line fit features

CLASSIFICATION: KNN or NN with BP

HARDWARE: model 380 HP-9000

TRAINING: DIGITS UPPERS LOWERS DATABASE

STATUS: on time

RESULTS: -- DIGITS -- -- UPPERS -- -- LOWERS -- DATABASE

REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
0.00	0.1795	0.00	0.2418	0.00	0.3160	
0.10	0.1358	0.10	0.2023	0.10	0.2813	
0.20	0.0971	0.20	0.1633	0.20	0.2460	
0.30	0.0647	0.30	0.1331	0.30	0.2096	
0.40	0.0422	0.40	0.1048	0.40	0.1786	
0.50	0.0275	0.50	0.0799	0.50	0.1468	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	5.15	3.14	3.14
CPU RATE:	18.18	5.58	5.58

SYSTEM: VALEN_1

The following references have been provided for this system:

[58]

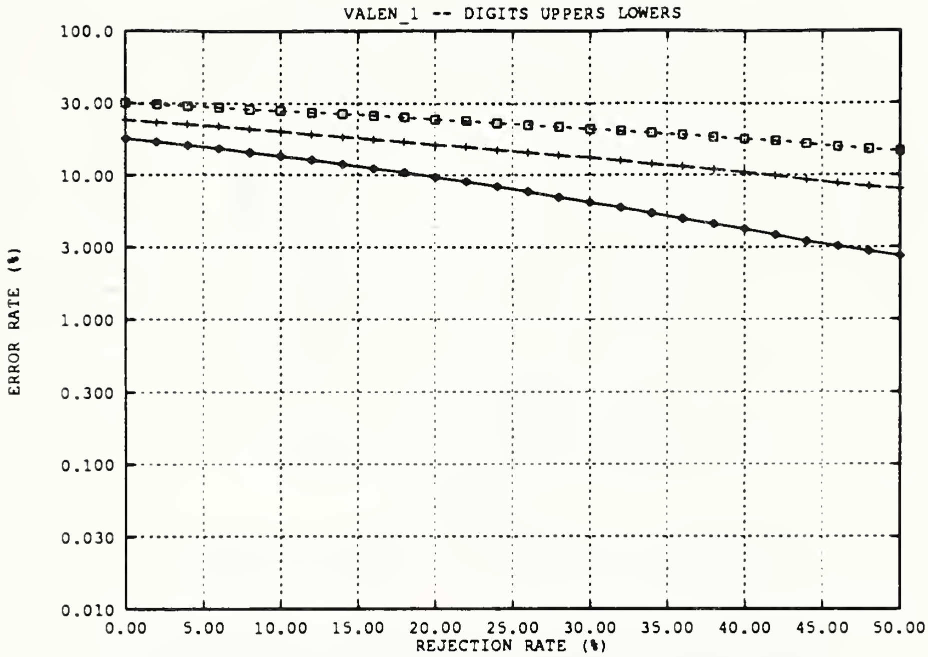

Figure 221: Error rate versus rejection rate for VALEN_1

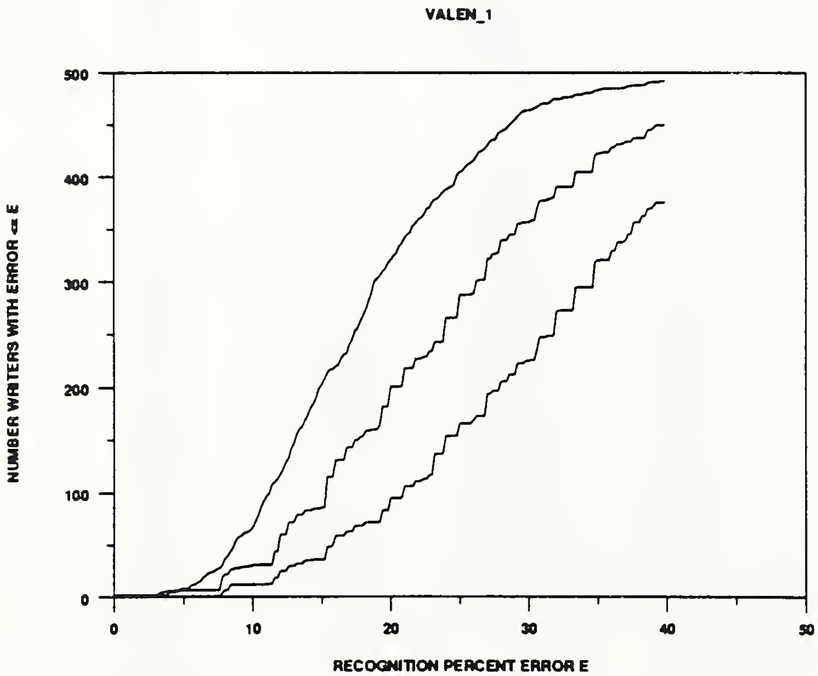

Figure 222: Error rate per writer of VALEN_1

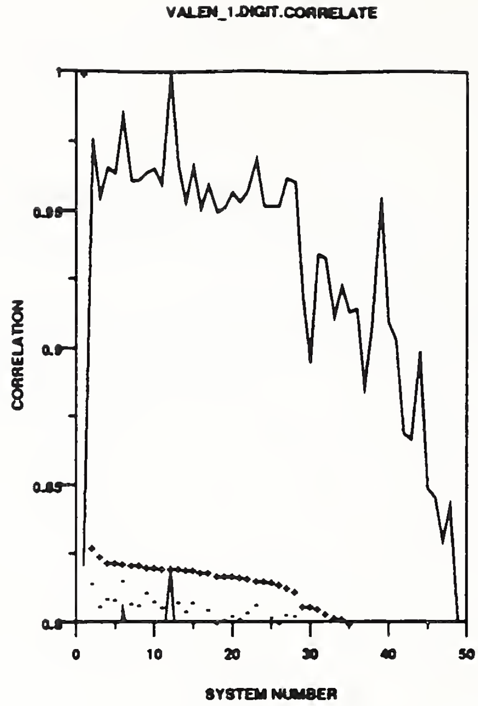

Figure 223: VALEN_1 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	VALEN_1	1.0000	1.0000
2	VOTE_M	0.8281	0.8152
3	NESTOR	0.8251	0.8068
4	AEG	0.8229	0.8093
5	ATT_2	0.8228	0.8091
6	OCRSYS	0.8222	0.8159
7	ERIM_2	0.8218	0.8077
8	ERIM_1	0.8217	0.8073
9	VOTE_P	0.8210	0.8118
10	IBM	0.8209	0.8086
11	KODAK_2	0.8207	0.8061
12	REFERENCE	0.8205	0.8205
13	ELSAGB_3	0.8204	0.8082
14	ELSAGB_2	0.8201	0.8079
15	SYMBUS	0.8201	0.8048
16	NIST_4	0.8192	0.8014
17	ATT_4	0.8191	0.8052
18	THINK_1	0.8178	0.8015
19	ELSAGB_1	0.8178	0.8003
20	UBOL	0.8177	0.8031
21	KODAK_1	0.8172	0.8020
22	NYNEX	0.8170	0.8042
23	ATT_1	0.8161	0.8071
24	HUGHES_2	0.8157	0.8010
25	ATT_3	0.8156	0.8026
26	HUGHES_1	0.8144	0.8003
27	THINK_2	0.8138	0.8033
28	REI	0.8122	0.8032
29	GMD_3	0.8069	0.7839
30	RISO	0.8068	0.7739
31	GTESS_1	0.8058	0.7899
32	GTESS_2	0.8040	0.7884
33	ASOL	0.8028	0.7802
34	NIST_1	0.8019	0.7826
35	GMD_1	0.8002	0.7782
36	MIME	0.7997	0.7789
37	KAMAN_1	0.7973	0.7678
38	NIST_2	0.7972	0.7766
39	COMCOM	0.7946	0.7914
40	UPENN	0.7936	0.7739
41	NIST_3	0.7929	0.7729
42	KAMAN_3	0.7926	0.7584
43	KAMAN_2	0.7921	0.7567
44	GMD_4	0.7888	0.7662
45	KAMAN_5	0.7828	0.7440
46	GMD_2	0.7659	0.7377
47	IFAX	0.7479	0.7196
48	VALEN_2	0.7348	0.7179
49	KAMAN_4	0.7310	0.6954

Table 137: VALEN_1 correlation graph key for digits.

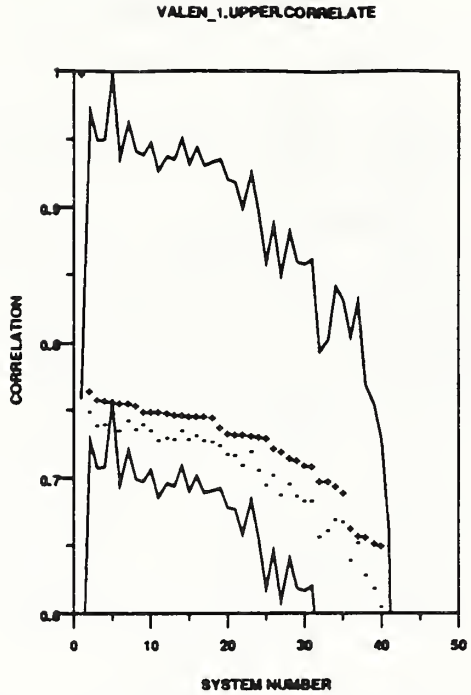

Figure 224: VALEN_1 - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	VALEN_1	1.0000	1.0000
2	VOTE_M	0.7664	0.7512
3	UMICH_1	0.7605	0.7413
4	ATT_4	0.7596	0.7416
5	REFERENCE	0.7582	0.7582
6	IBM	0.7574	0.7378
7	AEG	0.7572	0.7450
8	NESTOR	0.7555	0.7385
9	VOTE_P	0.7513	0.7421
10	ERIM_1	0.7513	0.7372
11	SYMBUS	0.7509	0.7301
12	UBOL	0.7503	0.7315
13	HUGHES_1	0.7496	0.7309
14	NYNEX	0.7495	0.7375
15	ATT_3	0.7489	0.7308
16	ATT_2	0.7487	0.7342
17	KODAK_1	0.7484	0.7303
18	HUGHES_2	0.7479	0.7293
19	ATT_1	0.7404	0.7262
20	GTESS_1	0.7357	0.7196
21	GTESS_2	0.7350	0.7187
22	MIME	0.7349	0.7113
23	OCRSYS	0.7334	0.7216
24	NIST_4	0.7329	0.7076
25	RISO	0.7320	0.6968
26	ASOL	0.7249	0.7043
27	KAMAN_1	0.7219	0.6901
28	REI	0.7169	0.6983
29	GMD_1	0.7152	0.6886
30	GMD_3	0.7117	0.6855
31	NIST_1	0.7111	0.6850
32	KAMAN_3	0.6998	0.6628
33	KAMAN_2	0.6998	0.6588
34	GMD_4	0.6965	0.6716
35	NIST_3	0.6918	0.6691
36	IFAX	0.6650	0.6406
37	COMCOM	0.6598	0.6540
38	NIST_2	0.6581	0.6298
39	GMD_2	0.6540	0.6205
40	KAMAN_4	0.6519	0.6074
41	KAMAN_5	0.5987	0.5595
42	UMICH_2	0.0987	0.0134

Table 138: VALEN_1 correlation graph key for uppers.

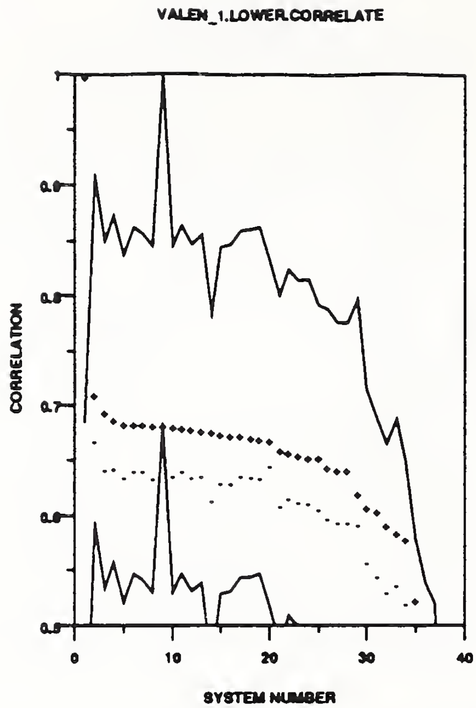

Figure 225: VALEN_1 - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	VALEN_1	1.0000	1.0000
2	VOTE_M	0.7122	0.6693
3	UMICH_1	0.6957	0.6426
4	AEG	0.6885	0.6446
5	ATT_3	0.6861	0.6359
6	ERIM_1	0.6859	0.6423
7	ATT_4	0.6851	0.6419
8	UBOL	0.6848	0.6347
9	REFERENCE	0.6840	0.6840
10	IBM	0.6837	0.6368
11	OCRSYS	0.6817	0.6418
12	NESTOR	0.6812	0.6363
13	KODAK_1	0.6798	0.6371
14	RISO	0.6790	0.6148
15	HUGHES_2	0.6769	0.6308
16	HUGHES_1	0.6757	0.6309
17	ATT_2	0.6747	0.6376
18	NYNEX	0.6728	0.6359
19	ATT_1	0.6718	0.6346
20	VOTE_P	0.6701	0.6461
21	NIST_4	0.6611	0.6096
22	GTESS_1	0.6587	0.6168
23	NIST_1	0.6572	0.6127
24	GTESS_2	0.6550	0.6117
25	GMD_3	0.6542	0.6062
26	ASOL	0.6450	0.5987
27	GMD_4	0.6428	0.5945
28	GMD_1	0.6428	0.5945
29	NIST_3	0.6208	0.5924
30	GMD_2	0.6081	0.5585
31	KAMAN_1	0.6057	0.5458
32	KAMAN_3	0.5921	0.5312
33	NIST_2	0.5858	0.5372
34	KAMAN_2	0.5794	0.5218
35	KAMAN_5	0.5253	0.4665
36	KAMAN_4	0.4939	0.4405
37	COMCOM	0.4204	0.4100
38	UMICH_2	0.1189	0.0321

Table 139: VALEN_1 correlation graph key for lowers.

F System Summaries For Late Submitted Results

Jon Geist, Jonathan J. Hull, Stanley Janet, R. Allen Wilkinson, and Charles L. Wilson

This appendix contains summaries for most systems whose HYP files were received late. Some results that were received late were not included because they would not add anything to the report even though in some cases the results are interesting. In such cases the results are mentioned in the body of the report. The summary format is exactly the same as that used for the summaries in Appendix E.

SYSTEM: NIST_4

PARTICIPANT: Patrick J. Grother

ORGANIZATION: NIST, Gaithersburg, MD

PREPROCESSING: Size (both height and width), Slant, Stroke Width, Normalization.
Subtraction from binary image of mean of training images.

FEATURES: Projection onto principal components of training set.
48 leading elements of "KL" transform. Digits
96 leading elements of "KL" transform. Uppers
96 leading elements of "KL" transform. Lowers

CLASSIFICATION: PNN: Gaussian distance weighted voting among all prototypes.
Equivalent to KNN algorithm of NIST_1.

HARDWARE: Sparc 2 running optimized C code.

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	~56000	~11000	~11000	NSDB3
	500	500	500	WRITERS

STATUS: submitted after Conference

RESULTS:

-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
0.00	0.0497	0.00	0.1037	0.00	0.2001	
0.10	0.0105	0.10	0.0614	0.10	0.1570	
0.20	0.0064	0.20	0.0346	0.20	0.1199	
0.30	0.0035	0.30	0.0214	0.30	0.0889	
0.40	0.0021	0.40	0.0141	0.40	0.0610	
0.50	0.0014	0.50	0.0092	0.50	0.0420	

OCR RATE (CPS): DIGITS UPPERS LOWERS

OCR RATE:

CPU RATE:

SYSTEM: NIST_4

The following references have been provided for this system:

[42]

COMMENTS: NIST_4

See Cross Validation Section on Inadequacies of NIST Special Database 3 for the classification of NIST Test Data 1.

Very Slow Classification. No exemplar pruning or aggregation. Does not suffer from "minority" problems of perceptrons (e.g. crossed sevens).

Size normalization enforces 32 pixel height 24 pixel width, does not preserve aspect ratio. Dilation / erosion used to normalize stroke widths. Significant recognition gains over NIST_1.

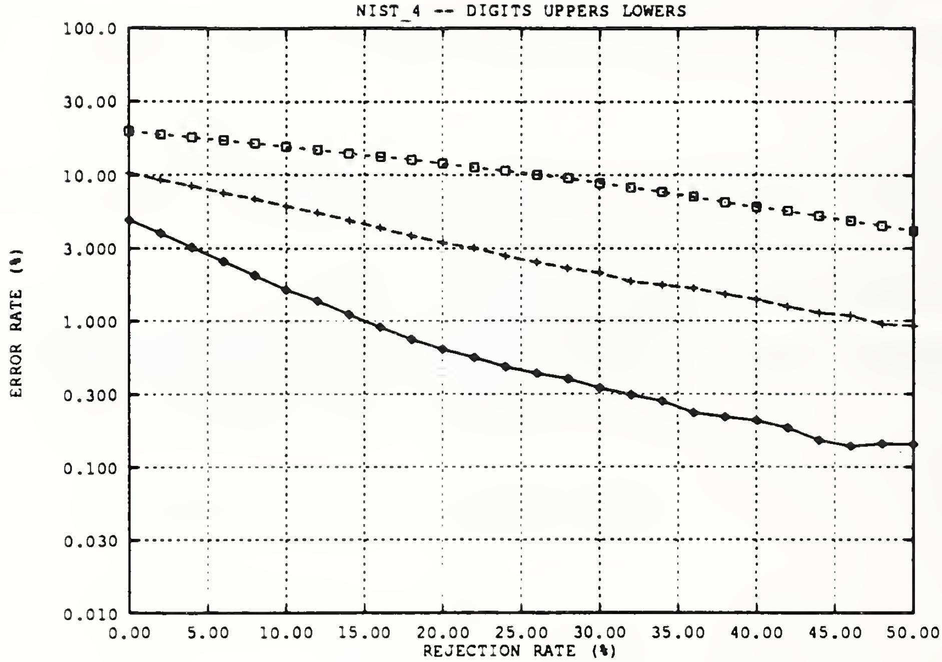

Figure 226: Error rate versus rejection rate for NIST_4

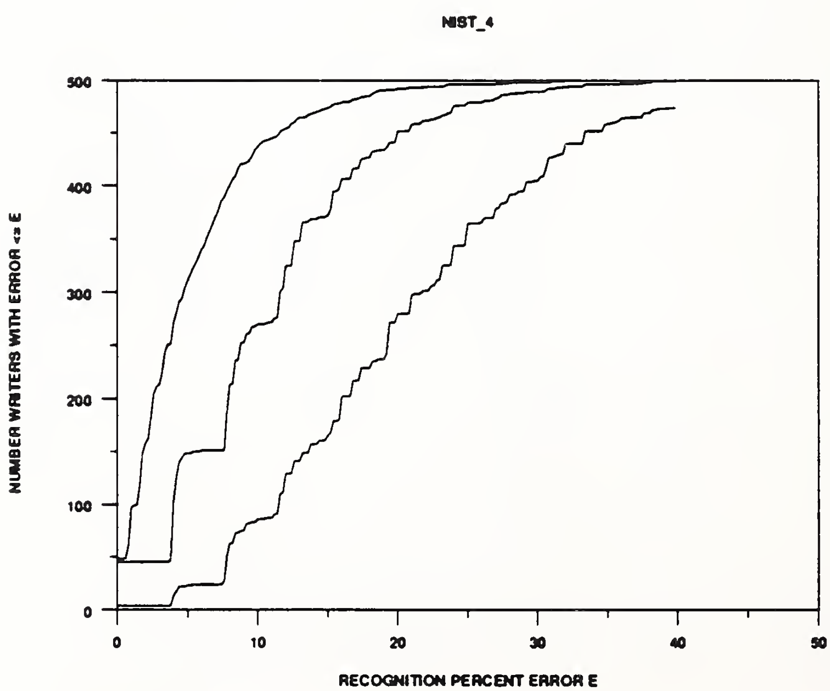

Figure 227: Error rate per writer of NIST_4

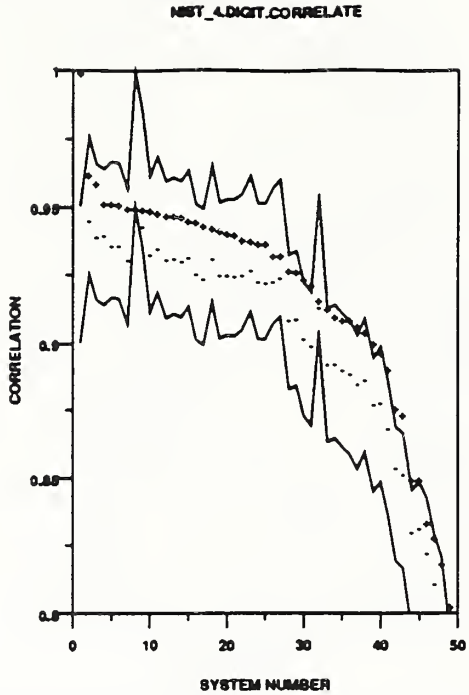

Figure 228: NIST_4 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	NIST_4	1.0000	1.0000
2	VOTE_M	0.9630	0.9457
3	AEG	0.9598	0.9397
4	VOTE_P	0.9524	0.9403
5	ELSAGB_3	0.9522	0.9369
6	ELSAGB_2	0.9517	0.9365
7	UBOL	0.9506	0.9316
8	REFERENCE	0.9503	0.9503
9	OCRSYS	0.9499	0.9435
10	ERIM_1	0.9496	0.9334
11	ATT_1	0.9485	0.9357
12	ERIM_2	0.9479	0.9323
13	ATT_4	0.9479	0.9315
14	KODAK_2	0.9471	0.9314
15	ATT_2	0.9460	0.9327
16	THINK_1	0.9454	0.9265
17	ELSAGB_1	0.9439	0.9249
18	IBM	0.9433	0.9323
19	ATT_3	0.9420	0.9262
20	SYMBUS	0.9411	0.9260
21	KODAK_1	0.9409	0.9255
22	NESTOR	0.9392	0.9260
23	THINK_2	0.9385	0.9280
24	HUGHES_1	0.9377	0.9237
25	HUGHES_2	0.9374	0.9235
26	NYNEX	0.9337	0.9238
27	REI	0.9334	0.9253
28	GTESS_2	0.9280	0.9096
29	GTESS_1	0.9277	0.9101
30	NIST_1	0.9247	0.9028
31	GMD_3	0.9225	0.9001
32	COMCOM	0.9170	0.9141
33	GMD_1	0.9138	0.8932
34	MIME	0.9110	0.8930
35	ASOL	0.9097	0.8907
36	NIST_2	0.9094	0.8896
37	NIST_3	0.9071	0.8858
38	UPENN	0.9051	0.8873
39	RISO	0.9008	0.8777
40	GMD_4	0.8977	0.8783
41	KAMAN_1	0.8914	0.8694
42	KAMAN_3	0.8766	0.8544
43	KAMAN_2	0.8742	0.8520
44	GMD_2	0.8504	0.8305
45	KAMAN_5	0.8503	0.8319
46	VALEN_2	0.8343	0.8227
47	IFAX	0.8289	0.8118
48	VALEN_1	0.8192	0.8014
49	KAMAN_4	0.8036	0.7813

Table 140: NIST_4 correlation graph key for digits.

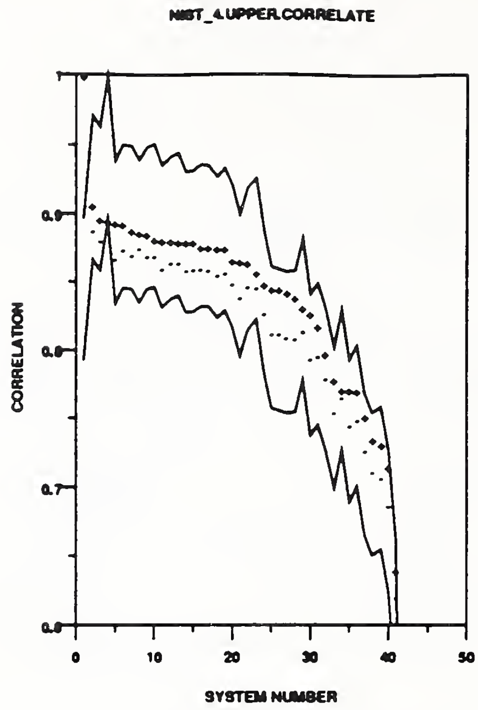

Figure 229: NIST_4 - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	NIST_4	1.0000	1.0000
2	VOTE_M	0.9070	0.8893
3	AEG	0.8972	0.8820
4	REFERENCE	0.8963	0.8963
5	UBOL	0.8941	0.8692
6	ATT_4	0.8937	0.8755
7	UMICH_1	0.8886	0.8714
8	VOTE_P	0.8871	0.8765
9	ERIM_1	0.8865	0.8705
10	NYNEX	0.8829	0.8704
11	ATT_1	0.8818	0.8617
12	NESTOR	0.8815	0.8658
13	ATT_2	0.8812	0.8658
14	ATT_3	0.8807	0.8619
15	KODAK_1	0.8807	0.8608
16	IBM	0.8775	0.8617
17	HUGHES_1	0.8774	0.8602
18	SYMBUS	0.8764	0.8567
19	HUGHES_2	0.8759	0.8584
20	GTESS_1	0.8683	0.8501
21	MIME	0.8669	0.8401
22	GTESS_2	0.8663	0.8488
23	OCRSYS	0.8587	0.8476
24	ASOL	0.8508	0.8283
25	NIST_1	0.8467	0.8135
26	GMD_1	0.8464	0.8135
27	GMD_3	0.8442	0.8113
28	RISO	0.8405	0.8096
29	REI	0.8328	0.8153
30	GMD_4	0.8282	0.7957
31	KAMAN_1	0.8189	0.7967
32	NIST_3	0.7991	0.7803
33	KAMAN_3	0.7797	0.7558
34	COMCOM	0.7728	0.7669
35	KAMAN_2	0.7726	0.7470
36	IFAX	0.7715	0.7507
37	NIST_2	0.7535	0.7278
38	GMD_2	0.7363	0.7123
39	VALEN_1	0.7329	0.7076
40	KAMAN_4	0.7159	0.6880
41	KAMAN_5	0.6414	0.6215
42	UMICH_2	0.0547	0.0177

Table 141: NIST_4 correlation graph key for uppers.

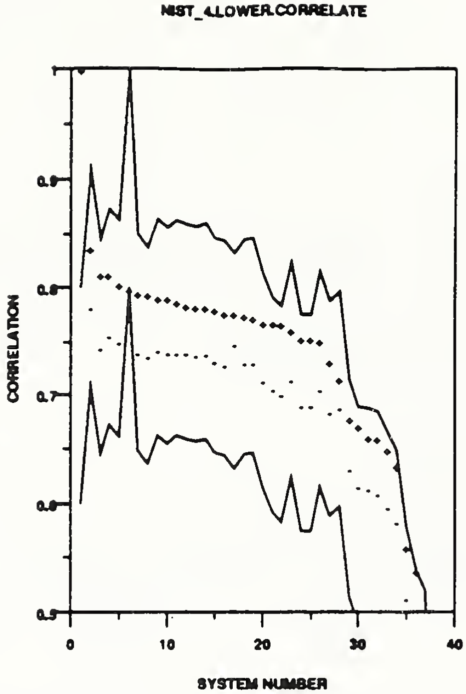

Figure 230: NIST_4 - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	NIST_4	1.0000	1.0000
2	VOTE_M	0.8378	0.7830
3	UBOL	0.8146	0.7449
4	AEG	0.8144	0.7565
5	ERIM_1	0.8052	0.7508
6	REFERENCE	0.7999	0.7999
7	UMICH_1	0.7971	0.7402
8	ATT_3	0.7960	0.7376
9	OCRSYS	0.7928	0.7431
10	KODAK_1	0.7921	0.7408
11	ATT_1	0.7885	0.7403
12	ATT_2	0.7851	0.7402
13	ATT_4	0.7847	0.7387
14	NYNEX	0.7843	0.7396
15	HUGHES_1	0.7817	0.7323
16	HUGHES_2	0.7782	0.7295
17	VOTE_P	0.7781	0.7492
18	IBM	0.7762	0.7312
19	NESTOR	0.7744	0.7317
20	NIST_1	0 7699	0.7144
21	GMD_3	0.7698	0.7067
22	RISO	0.7678	0.7017
23	GTESS_1	0.7628	0.7153
24	GMD_4	0.7541	0.6915
25	GMD_1	0.7541	0.6915
26	GTESS_2	0.7523	0.7067
27	ASOL	0.7323	0.6857
28	NIST_3	0.7171	0.6888
29	GMD_2	0.6798	0.6330
30	KAMAN_1	0.6733	0.6166
31	NIST_2	0.6631	0.6140
32	VALEN_1	0.6611	0.6096
33	KAMAN_3	0.6516	0.5969
34	KAMAN_2	0.6360	0.5839
35	KAMAN_5	0.5602	0.5135
36	KAMAN_4	0.5388	0.4908
37	COMCOM	0.4688	0.4564
38	UMICH_2	0.1091	0.0434

Table 142: NIST_4 correlation graph key for lowers.

SYSTEM: THINK_2

PARTICIPANT: Stephen Smith

ORGANIZATION: Thinking Machines Corporation, Cambridge, MA

PREPROCESSING: Thinning and normalization.

FEATURES: contour model of arc

CLASSIFICATION: KNN for variable length vectors

HARDWARE: 32,768 processor CM2 with SUN front end

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	all	NA	NA	NSDB3

STATUS: one day late

RESULTS: -- DIGITS -- -- UPPERS -- -- LOWERS -- DATABASE

-- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
0.00	0.0385					
0.10	0.0086					
0.20	0.0036					
0.30	0.0019					
0.40	0.0012					
0.50	0.0008					

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:	0.67		
CPU RATE:			

SYSTEM: THINK_2

BIBLIOGRAPHY:

The following references have been provided for this system:

none

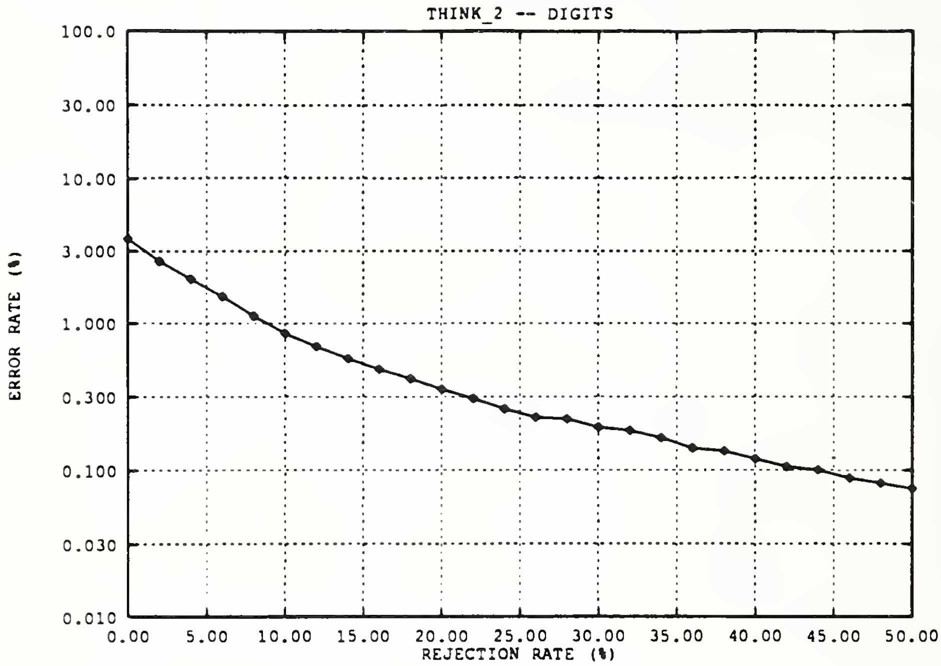

Figure 231: Error rate versus rejection rate for THINK_2

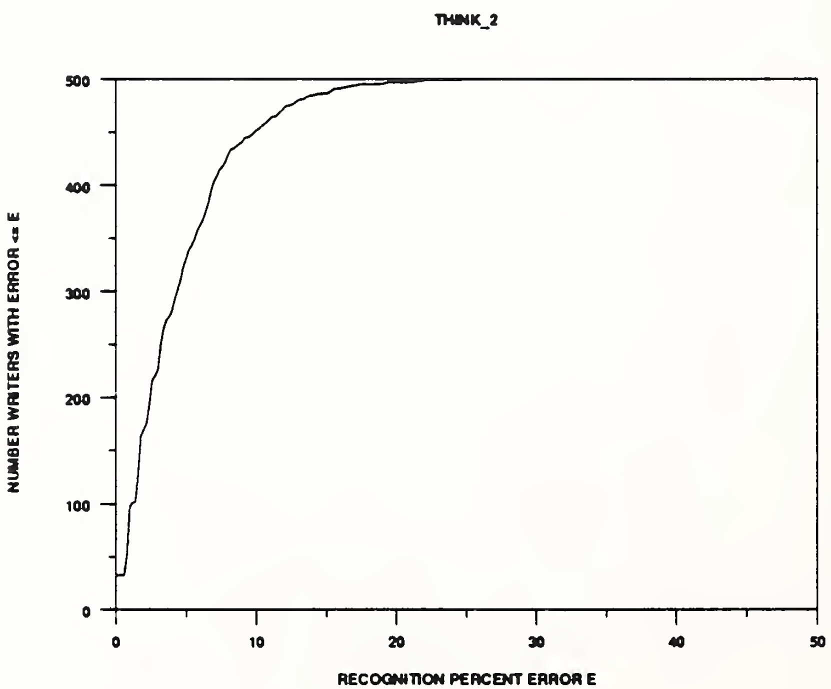

Figure 232: Error rate per writer of THINK_2

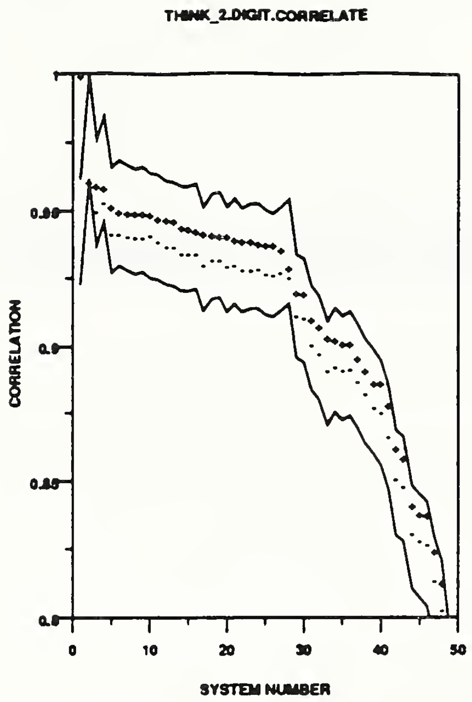

Figure 233: THINK_2 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	THINK_2	1.0000	1.0000
2	REFERENCE	0.9615	0.9615
3	VOTE_M	0.9600	0.9504
4	OCRSYS	0.9591	0.9537
5	AEG	0.9523	0.9420
6	ATT_1	0.9506	0.9422
7	ELSAGB_3	0.9502	0.9413
8	IBM	0.9501	0.9407
9	ELSAGB_2	0.9499	0.9410
10	VOTE_P	0.9494	0.9419
11	ATT_2	0.9484	0.9394
12	ERIM_1	0.9477	0.9376
13	ERIM_2	0.9474	0.9375
14	KODAK_2	0.9450	0.9352
15	ATT_4	0.9443	0.9351
16	REI	0.9434	0.9355
17	HUGHES_1	0.9426	0.9311
18	UBOL	0.9423	0.9328
19	NYNEX	0.9419	0.9328
20	HUGHES_2	0.9416	0.9306
21	NESTOR	0.9404	0.9311
22	THINK_1	0.9401	0.9293
23	KODAK_1	0.9397	0.9295
24	SYMBUS	0.9389	0.9297
25	NIST_4	0.9385	0.9280
26	ELSAGB_1	0.9384	0.9277
27	ATT_3	0.9369	0.9284
28	COMCOM	0.9302	0.9264
29	GTESS_1	0.9213	0.9124
30	GTESS_2	0.9206	0.9113
31	NIST_1	0.9108	0.9012
32	GMD_3	0.9081	0.8980
33	UPENN	0.9041	0.8915
34	MIME	0.9030	0.8932
35	GMD_1	0.9018	0.8920
36	ASOL	0.9018	0.8917
37	NIST_2	0.8964	0.8876
38	NIST_3	0.8916	0.8828
39	GMD_4	0.8873	0.8778
40	RISO	0.8869	0.8759
41	KAMAN_1	0.8786	0.8674
42	KAMAN_3	0.8630	0.8518
43	KAMAN_2	0.8595	0.8489
44	KAMAN_5	0.8420	0.8317
45	GMD_2	0.8387	0.8289
46	VALEN_2	0.8385	0.8272
47	IFAX	0.8249	0.8139
48	VALEN_1	0.8138	0.8033
49	KAMAN_4	0.7865	0.7766

Table 143: THINK_2 correlation graph key for digits.

No Data Available

Figure 234: THINK_2 - upper case correlation

There was no data for this evaluation.

Table 144: THINK_2 correlation graph key for uppers.

No Data Available

Figure 235: THINK_2 - lower case correlation

There was no data for this evaluation.

Table 145: THINK_2 correlation graph key for lowers.

SYSTEM: UMICH_1

PARTICIPANT: M. Shridhar

ORGANIZATION: University of Michigan, Dearborn, MI

PREPROCESSING: size normalization.

FEATURES: rule-based features of all sorts, histogram of direction vectors (4 directions) evaluated in 16 zones. Provides a 64 dimensional feature vector.

CLASSIFICATION: hybrid statistical, structural, and NN. Used modified quadratic discriminant function.

HARDWARE:

TRAINING:	DIGITS	UPPERS	LOWERS	DATABASE
	600	600	600	NSDB3?

STATUS: five days late

RESULTS:	DIGITS	UPPERS	LOWERS	DATABASE

RESULTS: -- DIGITS --		-- UPPERS --		-- LOWERS --		DATABASE
REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
		0.00	0.0511	0.00	0.1508	
		0.10	0.0337	0.10	0.1198	
		0.20	0.0256	0.20	0.1012	
		0.30	0.0207	0.30	0.0912	
		0.40	0.0179	0.40	0.0811	
		0.50	0.0172	0.50	0.0720	

OCR RATE (CPS):	DIGITS	UPPERS	LOWERS
SYS RATE:			
CPU RATE:			

SYSTEM: UMICH_1

The following references have been provided for this system:

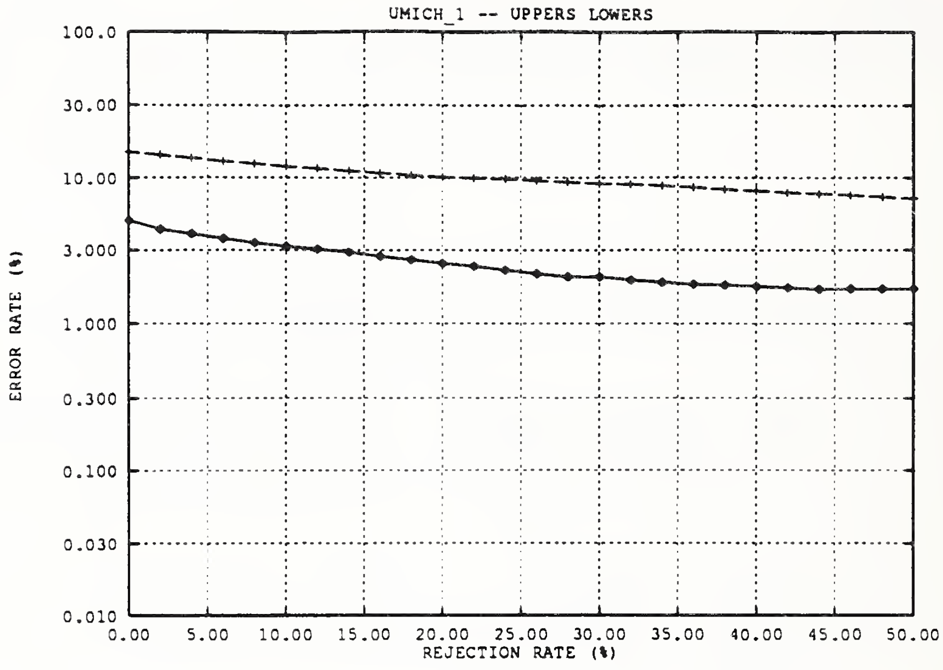

Figure 236: Error rate versus rejection rate for UMICH_1

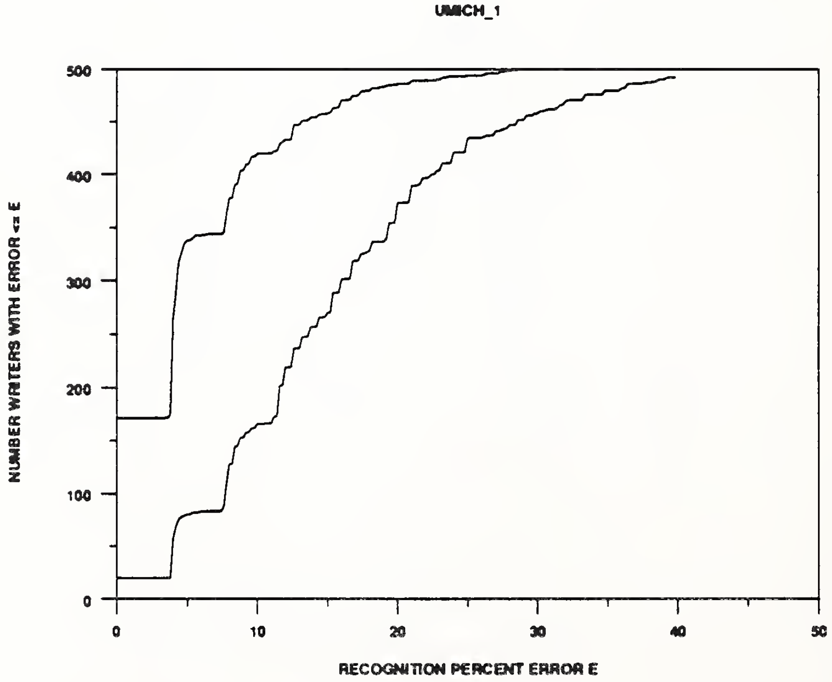

Figure 237: Error rate per writer of UMICH_1

No Data Available

Figure 238: UMICH_1 - digit correlation

There was no data for this evaluation.

Table 146: UMICH_1 correlation graph key for digits.

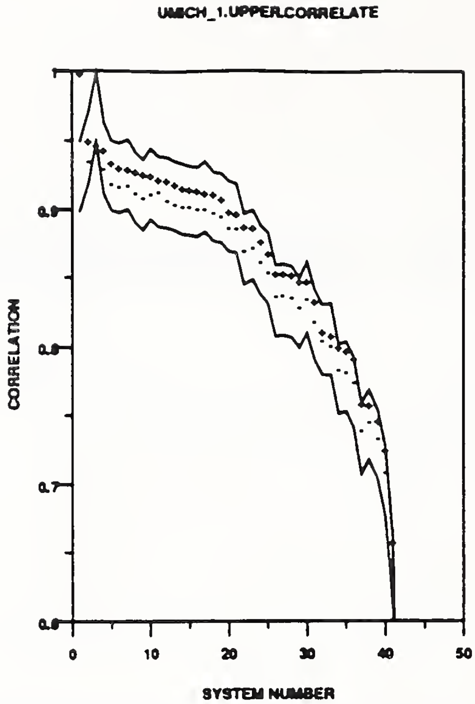

Figure 239: UMICH_1 - upper case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	UMICH_1	1.0000	1.0000
2	VOTE_M	0.9513	0.9369
3	REFERENCE	0.9489	0.9489
4	AEG	0.9450	0.9313
5	ATT_4	0.9361	0.9206
6	ERIM_1	0.9323	0.9181
7	NYNEX	0.9311	0.9190
8	NESTOR	0.9297	0.9141
9	IBM	0.9274	0.9106
10	ATT_2	0.9265	0.9131
11	VOTE_P	0.9240	0.9149
12	UBOL	0.9231	0.9080
13	HUGHES_1	0.9199	0.9056
14	HUGHES_2	0.9179	0.9034
15	ATT_3	0.9166	0.9034
16	KODAK_1	0.9160	0.9022
17	ATT_1	0.9140	0.9022
18	SYMBUS	0.9133	0.8993
19	OCRSYS	0.9088	0.8968
20	GTESS_1	0.8997	0.8883
21	GTESS_2	0.8986	0.8869
22	NIST_4	0.8886	0.8714
23	MIME	0.8879	0.8731
24	ASOL	0.8781	0.8633
25	REI	0.8694	0.8561
26	RISO	0.8552	0.8383
27	GMD_1	0.8551	0.8390
28	GMD_3	0.8539	0.8372
29	NIST_1	0.8491	0.8362
30	KAMAN_1	0.8491	0.8306
31	GMD_4	0.8344	0.8197
32	COMCOM	0.8132	0.8066
33	NIST_3	0.8100	0.8024
34	KAMAN_3	0.8018	0.7849
35	IFAX	0.7992	0.7834
36	KAMAN_2	0.7931	0.7756
37	VALEN_1	0.7605	0.7413
38	NIST_2	0.7598	0.7478
39	GMD_2	0.7488	0.7356
40	KAMAN_4	0.7275	0.7108
41	KAMAN_5	0.6592	0.6458
42	UMICH_2	0.0000	0.0000

Table 147: UMICH_1 correlation graph key for uppers.

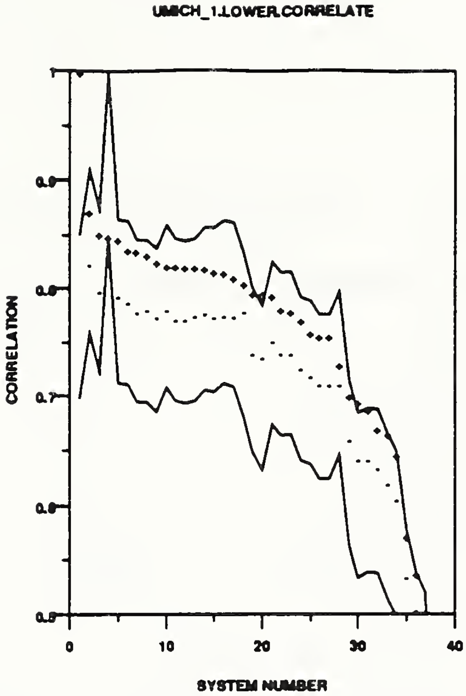

Figure 240: UMICH_1 - lower case correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	UMICH_1	1.0000	1.0000
2	VOTE_M	0.8728	0.8245
3	AEG	0.8521	0.7987
4	REFERENCE	0.8493	0.8493
5	OCRSYS	0.8472	0.7941
6	ERIM_1	0.8378	0.7885
7	UBOL	0.8373	0.7800
8	IBM	0.8339	0.7817
9	ATT_3	0.8273	0.7747
10	ATT_2	0.8239	0.7818
11	HUGHES_1	0.8232	0.7732
12	HUGHES_2	0.8227	0.7723
13	NESTOR	0.8221	0.7761
14	ATT_4	0.8210	0.7791
15	KODAK_1	0.8174	0.7755
16	ATT_1	0.8168	0.7767
17	NYNEX	0.8121	0.7757
18	VOTE_P	0.8062	0.7803
19	NIST_4	0.7971	0.7402
20	RISO	0.7968	0.7369
21	GTESS_1	0.7943	0.7517
22	NIST_1	0.7820	0.7408
23	GTESS_2	0.7799	0.7407
24	GMD_3	0.7713	0.7265
25	ASOL	0.7603	0.7198
26	GMD_4	0.7571	0.7117
27	GMD_1	0.7571	0.7117
28	NIST_3	0.7301	0.7120
29	GMD_2	0.7022	0.6610
30	VALEN_1	0.6957	0.6426
31	KAMAN_1	0.6890	0.6428
32	NIST_2	0.6718	0.6354
33	KAMAN_3	0.6670	0.6216
34	KAMAN_2	0.6476	0.6062
35	KAMAN_5	0.5727	0.5353
36	KAMAN_4	0.5384	0.5052
37	COMCOM	0.4923	0.4823
38	UMICH_2	0.0000	0.0000

Table 148: UMICH_1 correlation graph key for lowers.

SYSTEM: VALEN_2

PARTICIPANT: Enrique Vidal

ORGANIZATION: Universidad Politecnica de Valencia, Valencia, Spain

FEATURES: line fit features

CLASSIFICATION: k-NN or NN with BP

HARDWARE: model 380 HP-9000

TRAINING: DIGITS UPPERS LOWERS DATABASE

STATUS: seven days late

RESULTS: -- DIGITS -- -- UPPERS -- -- LOWERS -- DATABASE

REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	REJ. RATE	ERR. RATE--	TESTDATA1
0.00	0.1575					
0.10	0.1144					
0.20	0.0756					
0.30	0.0488					
0.40	0.0307					
0.50	0.0192					

OCR RATE (CPS): DIGITS UPPERS LOWERS

SYS RATE:

CPU RATE:

SYSTEM: VALEN_2

The following references have been provided for this system:

[59]

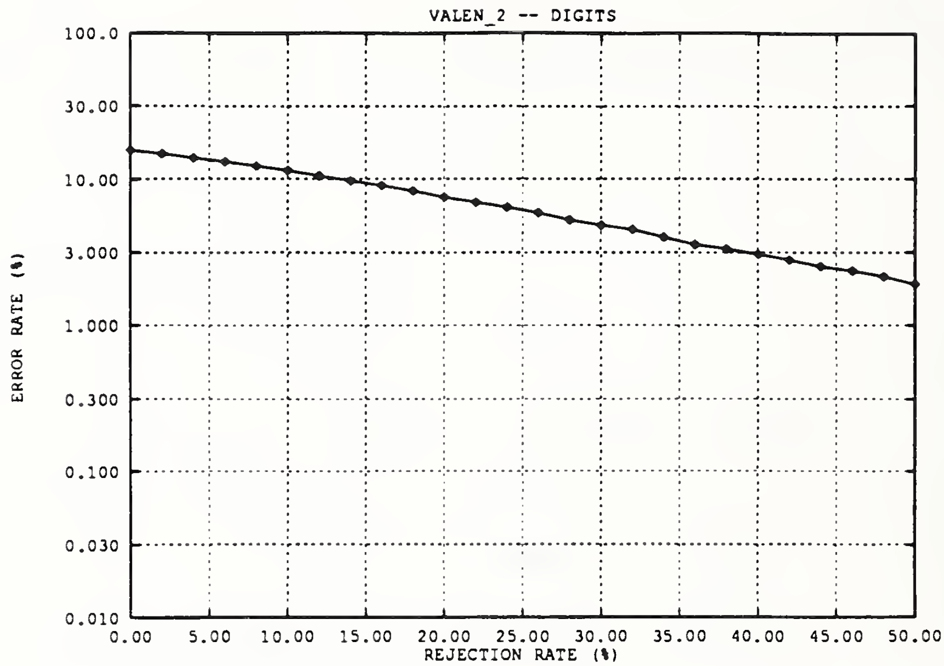

Figure 241: Error rate versus rejection rate for VALEN_2

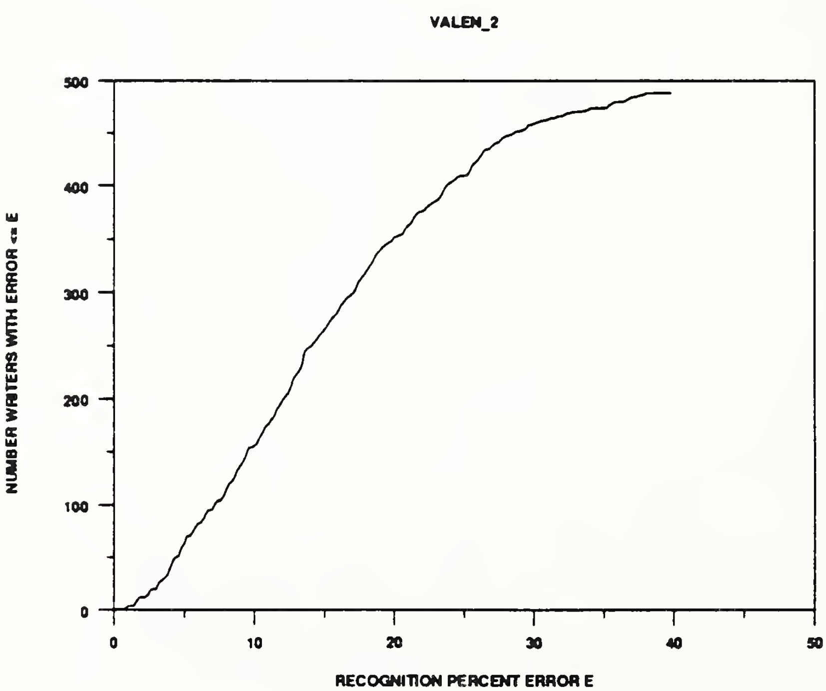

Figure 242: Error rate per writer of VALEN_2

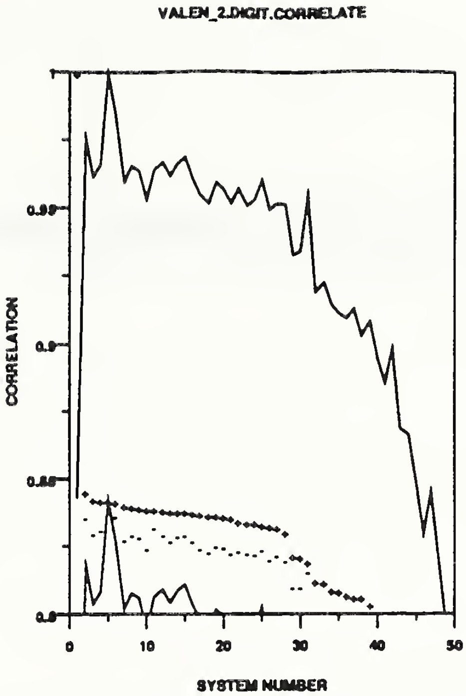

Figure 243: VALEN_2 - digit correlation

System Number	System Name	Correlation (all)	Correlation (correct)
1	VALEN_2	1.0000	1.0000
2	VOTE_M	0.8457	0.8362
3	ERIM_1	0.8429	0.8301
4	AEG	0.8427	0.8315
5	REFERENCE	0.8425	0.8425
6	OCRSYS	0.8419	0.8366
7	KODAK_2	0.8409	0.8279
8	IBM	0.8403	0.8296
9	ATT_2	0.8396	0.8288
10	KODAK_1	0.8393	0.8247
11	VOTE_P	0.8392	0.8323
12	ELSAGB_3	0.8387	0.8296
13	THINK_2	0.8385	0.8272
14	ELSAGB_2	0.8384	0.8293
15	ATT_1	0.8382	0.8298
16	ERIM_2	0.8379	0.8275
17	NESTOR	0.8375	0.8245
18	HUGHES_1	0.8371	0.8234
19	ATT_4	0.8370	0.8257
20	UBOL	0.8365	0.8251
21	HUGHES_2	0.8360	0.8228
22	NYNEX	0.8345	0.8237
23	NIST_4	0.8343	0.8227
24	SYMBUS	0.8341	0.8223
25	REI	0.8332	0.8241
26	ELSAGB_1	0.8327	0.8203
27	ATT_3	0.8325	0.8219
28	THINK_1	0.8308	0.8201
29	GTESS_2	0.8220	0.8102
30	GTESS_1	0.8212	0.8102
31	COMCOM	0.8196	0.8159
32	GMD_3	0.8128	0.7990
33	NIST_1	0.8121	0.7997
34	MIME	0.8096	0.7950
35	ASOL	0.8092	0.7944
36	UPENN	0.8076	0.7929
37	GMD_1	0.8069	0.7934
38	NIST_3	0.8066	0.7922
39	NIST_2	0.8039	0.7909
40	RISO	0.7994	0.7832
41	KAMAN_1	0.7961	0.7782
42	GMD_4	0.7944	0.7807
43	KAMAN_3	0.7847	0.7670
44	KAMAN_2	0.7834	0.7656
45	KAMAN_5	0.7695	0.7506
46	IFAX	0.7625	0.7391
47	GMD_2	0.7594	0.7438
48	VALEN_1	0.7348	0.7179
49	KAMAN_4	0.7180	0.7006

Table 149: VALEN_2 correlation graph key for digits.

No Data Available

Figure 244: VALEN_2 - upper case correlation

There was no data for this evaluation.

Table 150: VALEN_2 correlation graph key for uppers.

No Data Available

Figure 245: VALEN_2 - lower case correlation

There was no data for this evaluation.

Table 151: VALEN_2 correlation graph key for lowers.

NIST-114A (REV. 3-90)	U.S. DEPARTMENT OF COMMERCE NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY	1. PUBLICATION OR REPORT NUMBER NISTIR 4912
	BIBLIOGRAPHIC DATA SHEET	2. PERFORMING ORGANIZATION REPORT NUMBER
		3. PUBLICATION DATE SEPTEMBER 1992

4. TITLE AND SUBTITLE

The First Census Optical Character Recognition Systems Conference

5. AUTHOR(S)

R. Allen Wilkinson, Jon Geist, Stanley Janet, Christopher J. C. Burges, Robert Creecy, Bob Hammond, Jonathan J. Hull, Norman W. Larsen, Thomas P. Vogl, and Charles L. Wilson

6. PERFORMING ORGANIZATION (IF JOINT OR OTHER THAN NIST, SEE INSTRUCTIONS)	7. CONTRACT/GRANT NUMBER
U.S. DEPARTMENT OF COMMERCE NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY GAITHERSBURG, MD 20899	8. TYPE OF REPORT AND PERIOD COVERED

9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS (STREET, CITY, STATE, ZIP)

U. S. Bureau of the Census
Washington, DC 20233

10. SUPPLEMENTARY NOTES

11. ABSTRACT (A 200-WORD OR LESS FACTUAL SUMMARY OF MOST SIGNIFICANT INFORMATION. IF DOCUMENT INCLUDES A SIGNIFICANT BIBLIOGRAPHY OR LITERATURE SURVEY, MENTION IT HERE.)

The First Census Optical Character Recognition (OCR) Systems Conference tested a number of systems developed by different commercial, educational, and government organizations in the OCR of segmented hand-printed digits, upper case letters, and lower case letters. This report discusses the results, conclusions, and open questions of the Conference.

12. KEY WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)

digits; hand print; lower case; OCR; optical character recognition; upper case.

13. AVAILABILITY		14. NUMBER OF PRINTED PAGES
X	UNLIMITED	373
	FOR OFFICIAL DISTRIBUTION. DO NOT RELEASE TO NATIONAL TECHNICAL INFORMATION SERVICE (NTIS).	
	ORDER FROM SUPERINTENDENT OF DOCUMENTS, U.S. GOVERNMENT PRINTING OFFICE, WASHINGTON, DC 20402.	15. PRICE
X	ORDER FROM NATIONAL TECHNICAL INFORMATION SERVICE (NTIS), SPRINGFIELD, VA 22161.	A16

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