NIST Scoring Package Cross-Reference for use with NIST Internal Reports 4950 and 5129

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NIST

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1. Introduction

The Image Recognition Group at NIST has developed a uniform method of evaluating the recognition of optical character readers used to process the information on electronically scanned forms. NIST Scoring Package Release 1.0, *NIST Special Software 1* (SS1)[1], is distributed on CD-ROM as a reference implementation of this uniform method and was successfully used in the First Census Optical Character Recognition Systems Conference.[2]

As with any effort related to technology development, the Scoring Package has evolved and matured over time. The Scoring Package was originally proposed in the draft, "Standard Method for Evaluating the Performance of Systems Intended to Recognize Hand-printed Characters from Image Data Scanned from Forms", which was submitted to ANSI X.3A1. Early implementations of the Scoring Package exposed various shortcomings and contradictions within the draft standard. A public version of SS1 was released in October of 1992 along with "NIST Scoring Package User's Guide Release 1.0" (NISTIR 4950).[1] The User's Guide describes the reference implementation in great detail, but it does not address the theory used to derive the implementation itself. In February of 1993, the paper, "Methods for Evaluating the Performance of Systems Intended to Recognize Characters from Image Data Scanned from Forms" (NISTIR 5129), replaced the draft standard. NISTIR 5129 formalizes the theory used in the Scoring Package and establishes a uniform method of evaluation.[3]

The Methods Paper outlines four general steps needed to assess the performance of an automated form processing system. Choosing an optical character recognition (OCR) application is the first step. Once an application is selected, the recognition tasks embodied in the application and the interactions between the tasks that impact system performance are identified. Based on these tasks and their interaction, a scoring flow is derived. Scoring accumulators designed to capture system performance statistics are defined within the scoring flow. Finally, recognition performance measures that use the scoring accumulators as input are defined. In order to formalize these steps, NISTIR 5129 introduced a standard nomenclature for accumulator names.

The purpose of this report is to map the nomenclature defined in the Methods Paper to the pre-existing User's Guide. The scoring flows, scoring accumulators, and performance measures defined in NISTIR 5129 are presented in Section 2. Section 3 documents the Scoring Package output files (summary report and fact sheet) defined in NIST 4950 using the new nomenclature.

2. Scoring Flows, Scoring Accumulators, and Performance Measures

The scoring flows illustrated in this section are a flexible framework by which form processing systems can be analyzed and compared. However, these scoring flows should not be mistaken as a model for implementing form processing systems. Three recognition tasks are identified in these flows: form identification, field recognition (character or icon), and character recognition. These tasks in no way limit the implementation of a form processing system by dictating a presumed set of algorithmic procedures. In general, the first step to processing a form requires proper identification of the form type. Based on the identified form type, the fields may be located through the use of a spatial template and recognized. The task of reporting a single response for an entire field is referred to as field recognition. If the field contains non-character information such as a box check mark or a signature, the task is referred to as icon-field recognition, and the recognition system is required only to determine if the field contains information or not. If the field contains characters, the task is referred to as character-field recognition. Character-field recognition is dependent upon the results from the character recognition task wherein single system responses, one for each character in a field, are reported.

Systems have the potential to reject the outcomes from each of these processing tasks. This is illustrated in the following scoring flows by variables and branches labeled (*A*) if a decision was accepted and labeled (*R*) if rejected. For example, in Figure 1, a

system may choose to reject the hypothesized form type assigned to a specific form image, and in Figure 2, a system may choose to reject the hypothesized classification assigned to a segmented character image. Rejecting outcomes gives a system the ability to flag low confidence decisions as unknown, so that they may be verified by human inspection. The scoring flows also include scoring outcomes that determine if the recognition system's decisions were correct (C) or incorrect (I) or whether information was missed (M) by the recognition system.

Task interactions of interest are those that impact system performance. In Figure 1, a system rejection of a form's identification results in all characters on the form being tallied as missed. In this case, a decision made within the form identification task influences performance within the character recognition task (characters are missed). In general, system responses at subsequent tasks are analyzed only when the recognition system's response at the current task has been accepted by the system and the response is correct. For example in Figure 2, only fields on forms that have been accepted and correctly identified are analyzed at the field recognition task.

In order to accumulate performance statistics based on these tasks and their interaction, scoring variables must be defined. Performance statistics are accumulated at the form, character-field, icon-field, and character levels and are represented as the variable subscripts *form*, *chrfld*, *icofld*, and *char* respectively. The form processing task contributing to a particular statistical accumulator is denoted by the variable's superscript. Statistics accumulated for forms identification are denoted as *frmid*, field recognition as *fldrec*, and character recognition as *chrrec*.

Using this nomenclature, variable accumulators used to compute system performance measures are defined. For example, the variable AC_{form}^{frmid} can be used to represent the total number of correctly identified forms accepted by the recognition system. Likewise, a variable representing the total number of characters missed during character recognition is M_{char}^{chrrec}. Several other accumulators are also required for scoring. They include accumulators such as the total number of forms processed $total_{form}$ and the total number of reference characters known to be on the forms processed $total_{refchr}$.

Section 2.1 illustrates scoring flows, Section 2.2 defines scoring accumulators, and Section 2.3 lists performance measures.
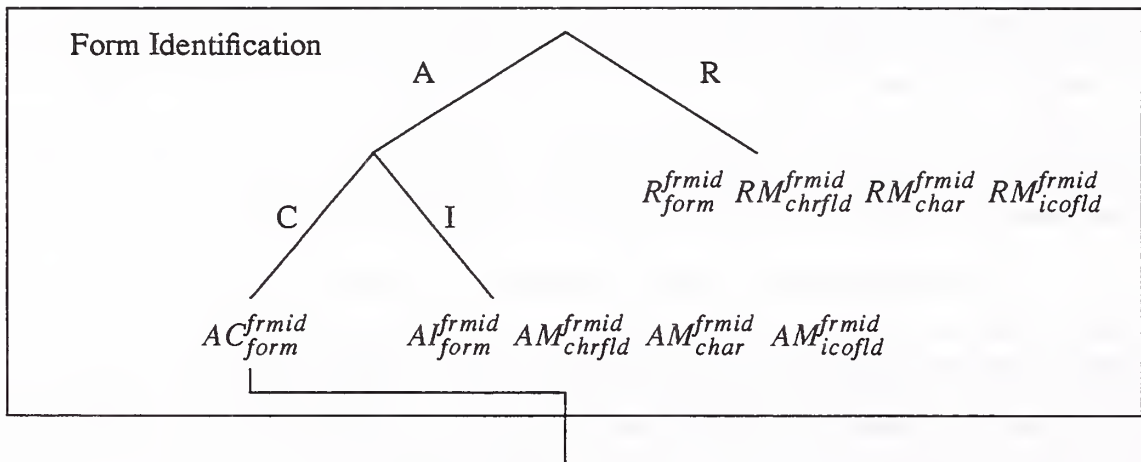
2.1 Scoring Flows

Figure 1: Scoring flow for form identifications.

Character-Field Recognition

A   R

C   I

RC_{chrfld}^{fldrec} $RI_{chrfld}^{fldrec} RM_{char}^{fldrec}$

Character Recognition

A   R

M_{char}^{chrrec}

C   I   C   I

AC_{char}^{chrrec} AI_{char}^{chrrec} RC_{char}^{chrrec} RI_{char}^{chrrec}

C   I

AC_{chrfld}^{fldrec} AI_{chrfld}^{fldrec}
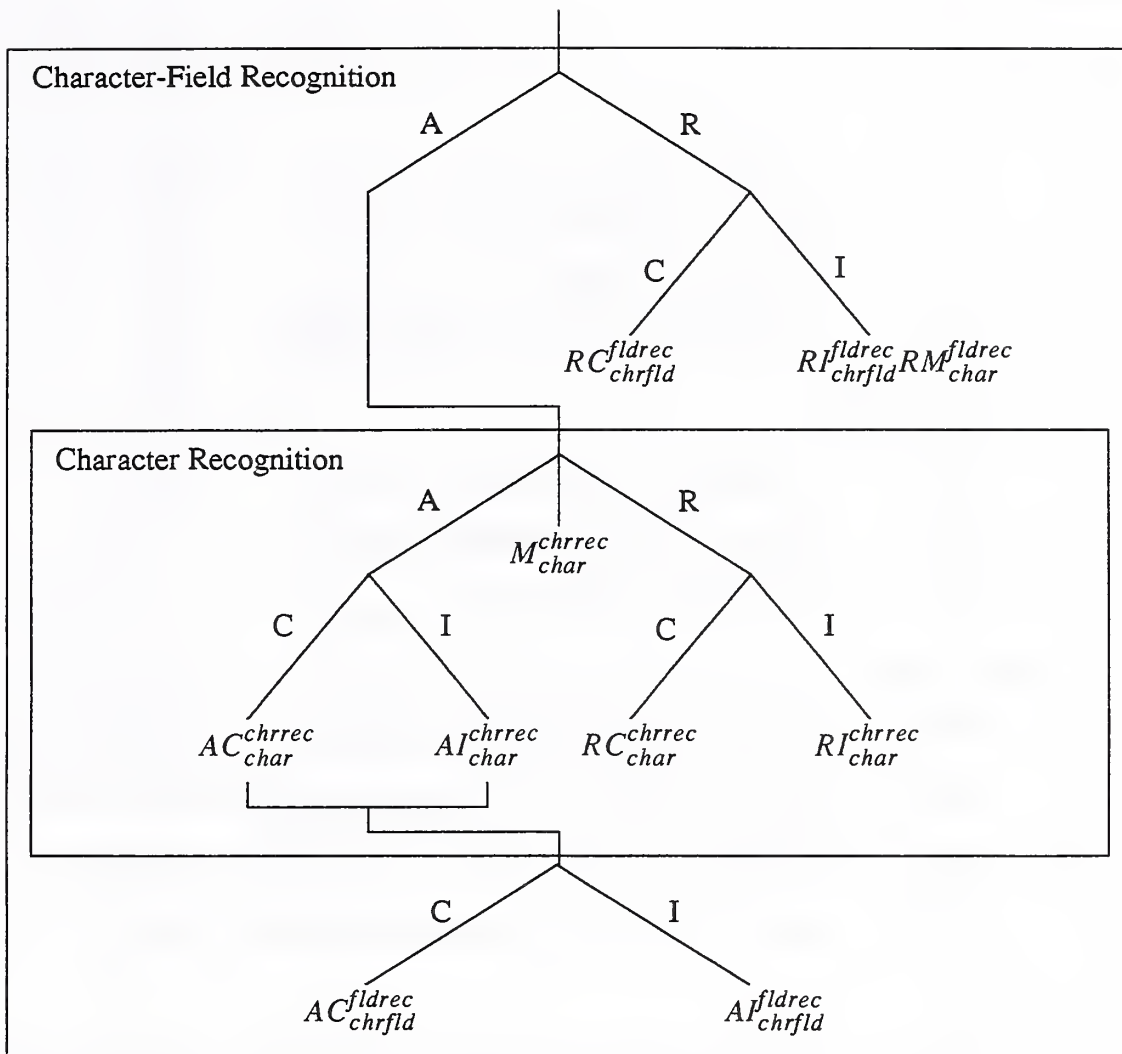
Figure 2: Scoring flow for character-field recognitions and character recognitions.

Icon-Field Recognition

A   R

C   I   C   I

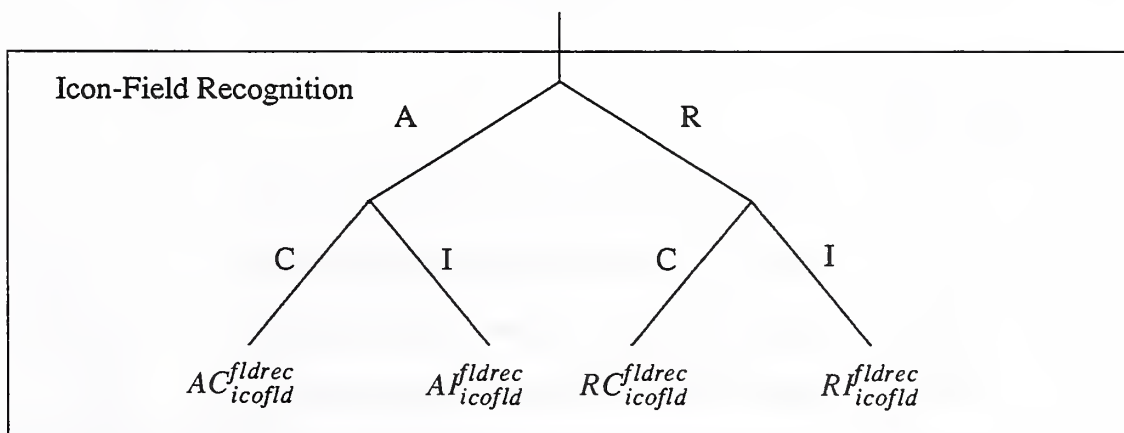AC_{icofld}^{fldrec} AI_{icofld}^{fldrec} RC_{icofld}^{fldrec} RI_{icofld}^{fldrec}

Figure 3: Scoring flow for icon-field recognitions.

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Totals

1. $total_{form}$ forms process

2. $total_{chrfld}$ character-fields processed

3. $total_{icofld}$ icon-fields processed

4. $total_{refchr}$ reference characters on all forms processed

Form Identification

5. AC_{form}^{frmid} accepted correctly identified forms

6. AI_{form}^{frmid} accepted incorrectly identified forms

7. R_{form}^{frmid} rejected form identifications

Character-Fields

8. AM_{chrfld}^{frmid} missed character-fields due to accepted incorrectly identified forms

9. AM_{char}^{frmid} missed characters due to accepted incorrectly identified forms

10. RM_{chrfld}^{frmid} missed character-fields due to rejected form identifications

11. RM_{char}^{frmid} missed characters due to rejected form identifications

Icon-Fields

12. AM_{icofld}^{frmid} accepted missed icon-fields due to accepted incorrectly identified forms

13. RM_{icofld}^{frmid} missed icon-fields due to rejected form identifications

Field Recognition

Character-Fields

14. AC_{chrfld}^{fldrec} accepted correctly recognized character-fields

15. AI_{chrfld}^{fldrec} accepted incorrectly recognized character-fields

16. RC_{chrfld}^{fldrec} correctly rejected character-field recognitions

17. RI_{chrfld}^{fldrec} incorrectly rejected character-field recognitions

18. RM_{char}^{fldrec} missing characters due to incorrectly rejected char. field recognitions

Field Recognition Cont'd

Icon-Fields

19. AC_{icofld}^{fldrec} accepted correctly recognized icon-fields

20. AI_{icofld}^{fldrec} accepted incorrectly recognized icon-fields

21. RC_{icofld}^{fldrec} rejected correctly recognized icon-fields

22. RI_{icofld}^{fldrec} rejected incorrectly recognized icon-fields

Character Recognition

23. AC_{char}^{chrrec} accepted correctly recognized characters

24. AI_{char}^{chrrec} accepted incorrectly recognized characters

25. M_{char}^{chrrec} missing characters

26. RC_{char}^{chrrec} rejected correctly recognized characters

27. RI_{char}^{chrrec} rejected incorrectly recognized characters

Figure 4: Table of scoring accumulators and their definitions.

Form-Based
    (1)   FORM1   fraction of all forms accepted and correctly identified
    (2)   FORM2   fraction of all forms not accepted and not correctly identified
    (3)   FORM3   fraction of accepted forms correctly identified
    (4)   FORM4   fraction of accepted forms incorrectly identified
    (5)   FORM5   fraction of all form identifications rejected

Character-Field Based
    (6)   CHRFLD1 fraction of all character-fields accepted and correctly recognized
    (7)   CHRFLD2 fraction of accepted character-fields correctly recognized
    (8)   CHRFLD3 fraction of all character-fields missed due to rejected form identifications
    (9)   CHRFLD4 fraction of all character-fields missed due to accepted incorrect form
                        identifications

Icon-Field Based
    (10) ICOFLD1   fraction of all accepted and correctly recognized icon-fields
    (11) ICOFLD2   fraction of accepted and correctly recognized icon-fields from all
                        accepted icon-field identifications
    (12) ICOFLD3   fraction of all icon-fields missed due to rejected form identifications
    (13) ICOFLD4   fraction of all icon-fields missed due to accepted incorrect form
                        identifications

Combined Field-Based
    (14) FIELD1   fraction of all fields accepted and correctly recognized
    (15) FIELD2   fraction of accepted and correctly identified fields correctly recognized
    (16) FIELD3   fraction of all fields missed due to rejected form identifications
    (17) FIELD4   fraction of all fields missed due to accepted incorrect form
                        identifications

Character-Based
    (18) CHAR1   fraction of correctly recognized characters including characters missed
                        due to rejection
    (19) CHAR2   fraction of correctly recognized characters from all accepted field recognitions
    (20) CHAR3   fraction of accepted correctly recognized characters
    (21) CHAR4   fraction of all character recognitions rejected
    (22) CHAR5   fraction of characters rejected from all accepted field recognitions
    (23) CHAR6   fraction of correctly recognized characters rejected
    (24) CHAR7   fraction of characters missed due to rejected form identifications
    (25) CHAR8   fraction of all accepted and correctly recognized characters
    (26) CHAR9   fraction of accepted and correctly recognized characters from all accepted
                        field recognitions
    (27) CHAR10   fraction of all characters missed due to accepted incorrect field
                        identifications

Figure 5: Table of recognition system performance measures and their definitions.

2.3.1 Form-Based Performance Measures

$$FORM1 = \frac{AC_{form}^{frmid}}{total_{form}} \tag{1}$$

$$FORM2 = \frac{AI_{form}^{frmid} + R_{form}^{frmid}}{total_{form}} \tag{2}$$

$$FORM3 = \frac{AC_{form}^{frmid}}{AC_{form}^{frmid} + AI_{form}^{frmid}} \tag{3}$$

$$FORM4 = \frac{AI_{form}^{frmid}}{AC_{form}^{frmid} + AI_{form}^{frmid}} \tag{4}$$

$$FORM5 = \frac{R_{form}^{frmid}}{total_{form}} \tag{5}$$

2.3.2 Character-Field Based Performance Measures

$$CHRFLD1 = \frac{AC_{chrfld}^{fldrec}}{total_{chrfld}} \tag{6}$$

$$CHRFLD2 = \frac{AC_{chrfld}^{fldrec}}{AC_{chrfld}^{fldrec} + AI_{chrfld}^{fldrec}} \tag{7}$$

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$$CHRFLD3 = \frac{RM_{chrfld}^{frmid}}{total_{chrfld}} \qquad (8)$$

$$CHRFLD4 = \frac{AM_{chrfld}^{frmid}}{total_{chrfld}} \qquad (9)$$

2.3.3 Icon-Field Based Performance Measures

$$ICOFLD1 = \frac{AC_{icofld}^{fldrec}}{total_{icofld}} \qquad (10)$$

$$ICOFLD2 = \frac{AC_{icofld}^{fldrec}}{AC_{icofld}^{fldrec} + AI_{icofld}^{fldrec} + RC_{icofld}^{fldrec} + RI_{icofld}^{fldrec}} \qquad (11)$$

$$ICOFLD3 = \frac{RM_{icofld}^{frmid}}{total_{icofld}} \qquad (12)$$

$$ICOFLD4 = \frac{AM_{icofld}^{frmid}}{total_{icofld}} \qquad (13)$$

2.3.4 Combined Field-Based Performance Measures

$$FIELD1 = \frac{AC_{chrfld}^{fldrec} + AC_{icofld}^{fldrec}}{total_{chrfld} + total_{icofld}} \qquad (14)$$

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$$FIELD2 = \frac{AC_{chrfld}^{fldrec} + AC_{icofld}^{fldrec}}{AC_{chrfld}^{fldrec} + AI_{chrfld}^{fldrec} + RC_{chrfld}^{fldrec} + RI_{chrfld}^{fldrec} + AC_{icofld}^{fldrec} + AI_{icofld}^{fldrec} + RC_{icofld}^{fldrec} + RI_{icofld}^{fldrec}} \quad (15)*$$

$$FIELD3 = \frac{RM_{chrfld}^{frmid} + RM_{icofld}^{frmid}}{total_{chrfld} + total_{icofld}} \quad (16)$$

$$FIELD4 = \frac{AM_{chrfld}^{frmid} + AM_{icofld}^{frmid}}{total_{chrfld} + total_{icofld}} \quad (17)$$

2.3.5 Character-Based Performance Measures

$$CHAR1 = \frac{AC_{char}^{chrrec} + RC_{char}^{chrrec}}{AC_{char}^{chrrec} + AI_{char}^{chrrec} + RC_{char}^{chrrec} + RI_{char}^{chrrec} + RM_{char}^{frmid} + RM_{char}^{fldrec}} \quad (18)$$

$$CHAR2 = \frac{AC_{char}^{chrrec} + RC_{char}^{chrrec}}{AC_{char}^{chrrec} + AI_{char}^{chrrec} + RC_{char}^{chrrec} + RI_{char}^{chrrec}} \quad (19)$$

$$CHAR3 = \frac{AC_{char}^{chrrec}}{AC_{char}^{chrrec} + AI_{char}^{chrrec}} \quad (20)$$

$$CHAR4 = \frac{RC_{char}^{chrrec} + RI_{char}^{chrrec}}{total_{refchr}} \quad (21)$$

* Note that *FIELD2* was incorrect in NISTIR 5129. The corrections have been included in this cross-reference.

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$$CHAR5 = \frac{RC_{char}^{chrrec} + RI_{char}^{chrrec}}{AC_{char}^{chrrec} + AI_{char}^{chrrec} + RC_{char}^{chrrec} + RI_{char}^{chrrec}} \qquad (22)$$

$$CHAR6 = \frac{RC_{char}^{chrrec}}{AC_{char}^{chrrec} + RC_{char}^{chrrec}} \qquad (23)$$

$$CHAR7 = \frac{RM_{char}^{frmid}}{total_{refchr}} \qquad (24)$$

$$CHAR8 = \frac{AC_{char}^{chrrec}}{total_{refchr}} \qquad (25)$$

$$CHAR9 = \frac{AC_{char}^{chrrec}}{AC_{char}^{chrrec} + AI_{char}^{chrrec} + RC_{char}^{chrrec} + RI_{char}^{chrrec} + M_{char}^{chrrec}} \qquad (26)*$$

$$CHAR10 = \frac{AM_{char}^{frmid}}{total_{refchr}} \qquad (27)$$

* Note that *CHAR9* was incorrect in NISTIR 5129. The corrections have been included in this cross-reference.

3. Scoring Package Output Files

The Scoring Package generates two output files defined in the User's Guide (NISTIR 4950). The first file, a summary report, lists the performance measures computed by the Scoring Package, and the second file, a fact sheet, gives a detailed accounting of various event statistics. The summary report is documented in Section 3.1, and the fact sheet is documented in Section 3.2. Comments delimited by "<" and ">" have been added to the file listings for the purpose of documentation. Where appropriate, the statistics reported in these two files have been cross-referenced to scoring accumulators and performance measures defined in the Methods Paper (NISTIR 5129).

3.1 Summary Report Description

Summary: < beginning of summary report >
  TOTALS (output=FCItdA,of=form.sum,cf=form.fct)   < scoring profile options selected >

Draft standard measures:

< fundamental accumulators : $\quad$ $\mathbf{TP} = AC_{char}^{chrrec} + RC_{char}^{chrrec}$ $\quad$ >

< $\quad$ $\mathbf{FP} = AI_{char}^{chrrec} + RI_{char}^{chrrec}$ $\quad$ >

< $\quad$ $\mathbf{M} = M_{char}^{chrrec} + AM_{char}^{frmid}$ $\quad$ >

< $\quad$ $\mathbf{RT} = RC_{char}^{chrrec}$ $\quad$ >

< $\quad$ $\mathbf{RF} = RI_{char}^{chrrec}$ $\quad$ >

< $\quad$ $\mathbf{RM} = RM_{char}^{frmid}$ $\quad$ >

Accumulators: TP=1648 FP=43 M=36 RT=45 RF=18 RM=164
  Character recognition decision:
< CHAR1 (18) >
    : $\qquad$ accuracy: 88.8410% (1648 / 1855)
< CHAR2 (19) >
    : $\qquad$ accuracy (form right): 97.4571% (1648 / 1691)
  Character output:
< CHAR3 (20) >
    : $\qquad$ accuracy: 98.4644% (1603 / 1628)
  Field accuracy:
< FIELD1 (14) >
    : $\qquad$ accuracy (including icons): 81.2762% (777 / 956)

Character rejection rates:
< CHAR4 (21) >
    : $\qquad$ all: 3.3475% (63 / 1882)
< CHAR5 (22) >
    : $\qquad$ all hypotheses: 3.7256% (63 / 1691)
< CHAR6 (23) >
    : $\qquad$ matches: 2.7306% (45 / 1648)
< percentage of substituted characters rejected >
    : $\qquad$ substitutions: 44.1176% (15 / 34)
< percentage of inserted characters rejected >
    : $\qquad$ insertions: 33.3333% (3 / 9)
< CHAR7 (24) >
    : $\qquad$ all (due to form type): 8.7141% (164 / 1882)

Fields (excluding icons):
< CHRFLD1 (6) >
    : $\qquad$ accuracy: 81.7010% (634 / 776)
< CHRFLD2 (7) >
    : $\qquad$ accuracy (with form right): 90.1849% (634 / 703)
< CHRFLD3 (8) >
    : $\qquad$ rejected (due to form type): 9.4072% (73 / 776)
< CHRFLD4 (9) >
    : $\qquad$ deleted (due to form wrong): 0.0000% (0 / 776)

Fields (including icons):
< FIELD1 (14) >
:   accuracy: 81.2762% (777 / 956)
< FIELD2 (15) >
:   accuracy (with form right): 89.8266% (777 / 865)
< FIELD3 (16) >
:   rejected (due to form type): 9.5188% (91 / 956)
< FIELD4 (17) >
:   deleted (due to form wrong): 0.0000% (0 / 956)

Characters:
< CHAR8 (25) >
:   accuracy: 85.1753% (1603 / 1882)
< CHAR9 (26) >
:   accuracy (with form right): 94.7960% (1603 / 1691)
< CHAR7 (24) >
:   rejected (due to form type): 8.7141% (164 / 1882)
< CHAR10 (27) >
:   deleted (due to form wrong): 0.0000% (0 / 1882)

Icons:
< ICOFLD1 (10) >
:   accuracy: 79.4444% (143 / 180)
< ICOFLD2 (11) >
:   accuracy (with form right): 88.2716% (143 / 162)
< ICOFLD3 (12) >
:   rejected (due to form type): 10.0000% (18 / 180)
< ICOFLD4 (13) >
:   deleted (due to form wrong): 0.0000% (0 / 180)

Form type identification:
< FORM1 (1) >
:   accuracy: 90.9091% (10 / 11)
< FORM2 (2) >
:   failure rate: 9.0909% (1 / 11)
< FORM3 (3) >
:   accuracy (excluding rejected): 100.0000% (10 / 10)
< FORM4 (4) >
: failure rate (excluding rejected): 0.0000% (0 / 10)
< FORM5 (5) >
:   rejected: 9.0909% (1 / 11)

3.2 Fact Sheet Description

form type:	< form-level accumulators >
count: 11	$< total_{form} >$
rejected: 1	$< R_{form}^{frmid} >$
not rejected, right: 10	$< AC_{form}^{frmid} >$
not rejected, wrong: 0	$< AI_{form}^{frmid} >$

icon fields:	< icon field accumulators >
count: 180	$< total_{icofld} >$

< indented counts are subsets of all icon fields scored >

form type rejected: 18	$< RM_{icofld}^{frmid} >$
form type wrong and not rejected: 0	$< AM_{icofld}^{frmid} >$
form type right and not rejected: 162	$< AC_{icofld}^{fldrec} + AI_{icofld}^{fldrec} + RC_{icofld}^{fldrec} + RI_{icofld}^{fldrec} >$

< indented counts are subsets of all forms correctly identified and not rejected >

right: 143	$< AC_{icofld}^{fldrec} >$
wrong: 19	$< AI_{icofld}^{fldrec} + RC_{icofld}^{fldrec} + RI_{icofld}^{fldrec} >$
rejected: 15	$< RC_{icofld}^{fldrec} + RI_{icofld}^{fldrec} >$
not rejected: 147	$< AC_{icofld}^{fldrec} + AI_{icofld}^{fldrec} >$
matches: 157	$< AC_{icofld}^{fldrec} + RC_{icofld}^{fldrec} >$

< indented counts are subsets of all correct icon fields ignoring rejection >

rejected: 14	$< RC_{icofld}^{fldrec} >$
not rejected: 143	$< AC_{icofld}^{fldrec} >$
mismatches: 5	$< AI_{icofld}^{fldrec} + RI_{icofld}^{fldrec} >$

< indented counts are subsets of all incorrect icon fields ignoring rejection >

rejected: 1	$< RI_{icofld}^{fldrec} >$
not rejected: 4	$< AI_{icofld}^{fldrec} >$
not present / not found: 115	< # of empty icon fields detected correctly >
not present / found: 3	< # of empty icon fields detected incorrectly >
present / not found: 2	< # of non-empty icon fields detected incorrectly >
present / found: 42	< # of non-empty icon fields detected correctly >

character fields: < character field accumulators >

count: 776 $< total_{chrfld} >$

   < indented counts are subsets of all character fields scored >

form type rejected: 73 $< RM^{frmid}_{chrfld} >$

form type wrong and not rejected: 0 $< AM^{frmid}_{chrfld} >$

form type right and not rejected: 703 $< AC^{fldrec}_{chrfld} + AI^{fldrec}_{chrfld} + RC^{fldrec}_{chrfld} + RI^{fldrec}_{chrfld} >$

   < indented counts are subsets of all character fields on forms correctly identified and not rejected >

right: 634 $< AC^{fldrec}_{chrfld} >$

wrong: 69 $< AI^{fldrec}_{chrfld} + RC^{fldrec}_{chrfld} + RI^{fldrec}_{chrfld} >$

characters: < character-level accumulators >

   < indented counts are subsets of all character scored >

in alignments: 1891   < # of character alignment positions >

hypothesis: 1691   < # of hypothesized characters >

reference: 1882 $< total_{refchr} >$

   < indented counts are subsets of all reference characters scored >

form type rejected: 164 $< RM^{frmid}_{char} >$

form type wrong and not rejected: 0 $< AM^{frmid}_{char} >$

form type right and not rejected: 1691 $< AC^{chrrec}_{char} + AI^{chrrec}_{char} + RC^{chrrec}_{char} + RI^{chrrec}_{char} >$

   < indented counts are subsets of all reference characters on forms correctly identified and not rejected >

rejected: 63 $< RC^{chrrec}_{char} + RI^{chrrec}_{char} >$

not rejected: 1628 $< AC^{chrrec}_{char} + AI^{chrrec}_{char} >$

correct: 1648 $< AC^{chrrec}_{char} + RC^{chrrec}_{char} >$

   < indented counts are subsets of all correct characters ignoring rejection >

rejected: 45 $< RC^{chrrec}_{char} >$

not rejected: 1603 $< AC^{chrrec}_{char} >$

substitutions: 34   < # of substituted characters ignoring rejection >

   < indented counts are subsets of all substituted characters ignoring rejection >

rejected: 15   < # of substituted characters rejected >

not rejected: 19   < # of substituted characters accepted >

insertions: 9   < # of inserted characters ignoring rejection >

   < indented counts are subsets of all inserted characters ignoring rejection >

rejected: 3   < # of inserted characters rejected >

not rejected: 6   < # of inserted characters accepted >

deletions: 36 $< M^{chrrec}_{char} >$

Accumulators: TP=1648 FP=43 M=36 RT=45 RF=18 RM=164 < fundamental accumulators >

4. References

[1] M. D. Garris and S. A. Janet. NIST Scoring Package User's Guide Release 1.0. Technical Report NISTIR 4950, National Institute of Standards and Technology, October 1992.

[2] R. A. Wilkinson, et al. The first Census optical character recognition systems conference. Technical Report NISTIR 4912, National Institute of Standards and Technology, July 1992.

[3] M. D. Garris. Methods for Evaluating the Performance of Systems Intended to Recognize Characters from Image Data Scanned from Forms. Technical Report NISTIR 5129, National Institute of Standards and Technology, February 1993.