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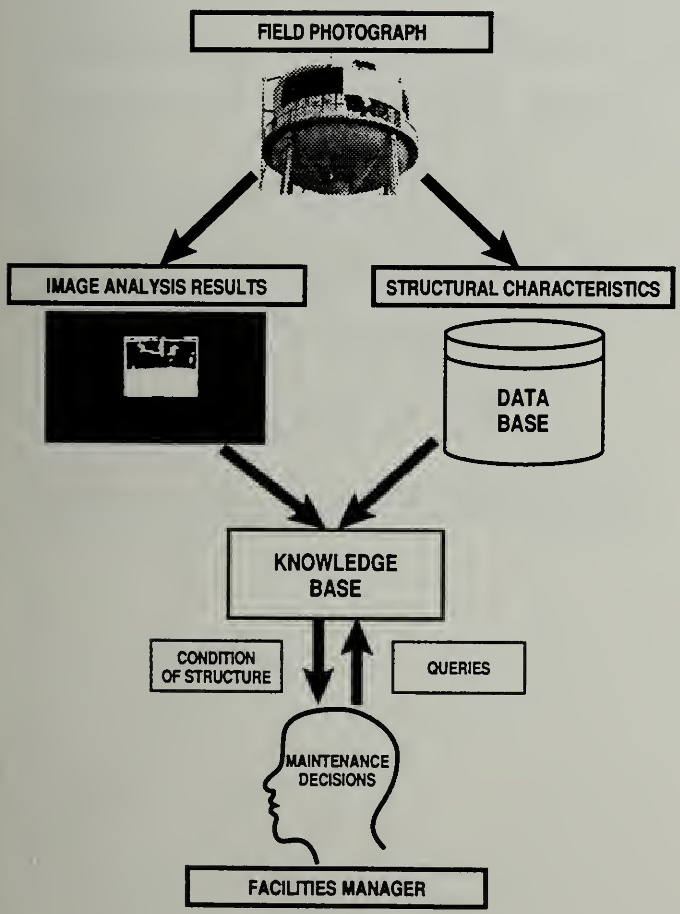
AN AUTOMATED MAINTENANCE MANAGEMENT PROGRAM PART II: THE INTEGRATION OF DATABASES AND IMAGE PROCESSING RESULTS FOR THE QUANTITATIVE ASSESSMENT OF THE EXTERIOR CONDITION OF METAL BUILDINGS



Lawrence J. Kaetzel
Jonathan W. Martin
Michael M. Hocker

U.S. DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
Center for Building Technology
Gaithersburg, MD 20899

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ABSTRACT

The establishment of an automated system for assessing the exterior condition of structures can provide facility managers with an important tool for making decisions. The integration of different forms of knowledge into a coherent system provides the fundamental basis for an expert system. This system can reduce the time required to analyze and interpret information, and provides a historical record of the rate of failure for building structures. This report discusses the feasibility of establishing an automated maintenance management program for making maintenance decisions using computer image processing to obtain quantitative results from field sites and information describing the characteristics of the structure. Relevant database technologies and the design and structure of the database for condition assessment are discussed. Image acquisition, processing, storage, and retrieval of images of a water tower are presented as a case study.

Keywords: Computer image processing, condition assessment, database, decision support system, integrated knowledge system.

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1. INTRODUCTION

Facilities managers are often responsible for a large inventory of buildings and structures. For example the U.S. Department of the Navy has 105,000 coated facilities at 586 locations and the average age of the Navy's buildings is 42 years. The facilities manager is often confronted with the problem of allocating scarce resources to maintain each building at an acceptable level of performance. Due to the complex nature of the condition assessment problem, and the lack of historical information, maintenance decisions are often made in response to a crisis situation.

In general, the complexity of the maintenance fund allocation process depends on the size of the building inventory. The larger the inventory, the more difficult the problem. Allocation of funds for a large inventory of buildings requires procedures for systematically evaluating and prioritizing the degradation state of each building in the inventory.

Current evaluation procedures seldom provide an unbiased assessment of the condition of a building because they are based largely on subjective visual criteria, and the level of expertise varies among building inspectors. Other factors affecting the evaluation process are the large amount of visual and descriptive data collected for each building in the inventory. Making comparisons of the degradation states of different buildings is difficult.

For these reasons, a fast, relatively simple and standardized method for systematically quantifying the condition of a building is needed. Researchers at The National Institute of Standards and Technology (NIST) have automated the maintenance decision steps for one building component; the condition of a protective coating. This automation has been possible due to a series of events arising from rapid developments in computer processing, storage, and retrieval of data. These include the availability of more powerful computers and the decreasing cost of computer hardware and software; the development of powerful database management systems for systematically categorizing the large data strings associated with a computerized condition assessment program, and rapidly evolving rule-based expert systems for managing and making decisions from data collected in database management and image processing programs.

The objective of this report is to describe efforts to combine computer image processing with database management systems for assessing the condition of organic coatings on steel structures. This technology is expected to relieve the facilities manager of the tedium in both assessing the condition of a building and processing data. The storage of images will permit the building manager to appraise the history of performance of different building materials and components. As a result, this technology should permit the facility's manager to spend more time on long-term maintenance planning as opposed to short-term, "put-the-fire-out" planning.

2. COMPUTERIZED ASSESSMENT OF THE EXTERIOR CONDITION OF A PAINTED STEEL BUILDING

2.1 COMPUTER IMAGE PROCESSING

Research conducted at NIST on assessing the condition of painted structures has demonstrated the value of being able to quantify defects that appear on metal and wood surfaces with organic coatings applied. Methods developed by Martin, McKnight and Bentz [1,2] demonstrated that through the use of computer image processing, an accurate and non-biased assessment can be made of the amount (percentage) of a building or structure's painted surface that has degraded. Computer image processing was used to obtain results by quantitatively evaluating the photographic visual standards for different defect types [3,4]. It was further demonstrated that the use of photographs obtained from the field were suitable for the visual determination of defects (e.g. blisters, peeling) and could be used as the source of input to the computer. Whereas assessments made by humans are often subjective, the computer can rapidly and repeatedly produce statistical information and retain the results in an historical record.. The procedure for conducting image processing operations can be defined in terms of the steps, as presented in Figure 1.

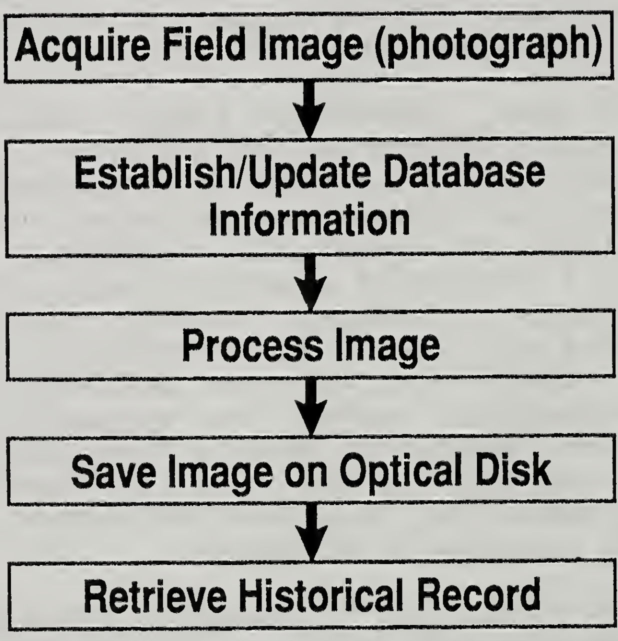

Figure 1. Image processing steps for condition assessment.

These steps provide the basis for the automated maintenance management system.

2.2 COMPUTER ALGORITHMS FOR ASSESSING THE CONDITION OF THE COATING ON A WATER TOWER STRUCTURE

The development of computer programs to acquire, and process images for a specific application domain involves selecting a strategy or specific set of image processing operations for obtaining the statistical results from image processing. Examples of the computer image processing operations include:

- o enhance an image by rotation or color look-up tables
- o find objects in an image by thresholding
- o "painting" parts of an image to eliminate unwanted objects
- o unwrap a cylindrical shape
- o eliminate small defects
- o produce a histogram of the greylevels of an image
- o select an area of interest

Often these operations overlap between applications and the need to develop new computer programs is eliminated, thus saving staff time. The development of a multi-purpose image processing package for materials research was started at NIST in 1985 [5]. The software package has been enhanced significantly since that time and it has become the nucleus for providing image processing capability for materials research. Figure 2 identifies the current capabilities of the package. As new strategies are needed, programs are developed and incorporated into the software system.

Program Module	Function
active display	displays video signal from camera
freeze display	freezes image for processing
retrieve an image	restores an image to screen from disk
store an image	saves an image on disk
select area of interest (AOI)	selects a specific area of the image for further processing
histogram	generates a histogram of the distribution of greylevels for AOI
unwrap cylindrical shape	flattens a cylindrical object
eliminate small defects	removes unwanted objects from the image
sine wave analysis	produces a sine wave analysis to verify correct placement of photograph during acquisition
set contrast levels	enhances the image by changing # of displayed greylevels
get lookup table	retrieves a color lookup table from disk
activate lookup table	allows user to toggle between greylevel and color image format
map greylevel to color	enables the user to interactively create a color lookup table using the color intensity controller
convolve	performs a convolution filter on the image (used in detecting edges in the image)
% area	finds % area corresponding to a range (min to max)
crosshair select	places crosshairs on display to determine object coordinates, etc.
threshold	establishes greylevel values for defect areas vs. background area
rotate image	aligns image for processing to compensate for angles
translate	translate and expand-contract area of interest
variance	compute average greylevel and standard deviation
display temporal_average	time average a series of incoming images
defect_area	compute statistics for individual defects (size, etc.)

Figure 2. Image processing software capabilities.

An example of the use of such a system will be described for image processing of a water tower. Normally, several views of a structure are needed, thus several photographs are required. Figure 3a presents a single view shown in an original photograph of the water tower. Figure 3b presents an unwrapped view of the same image.

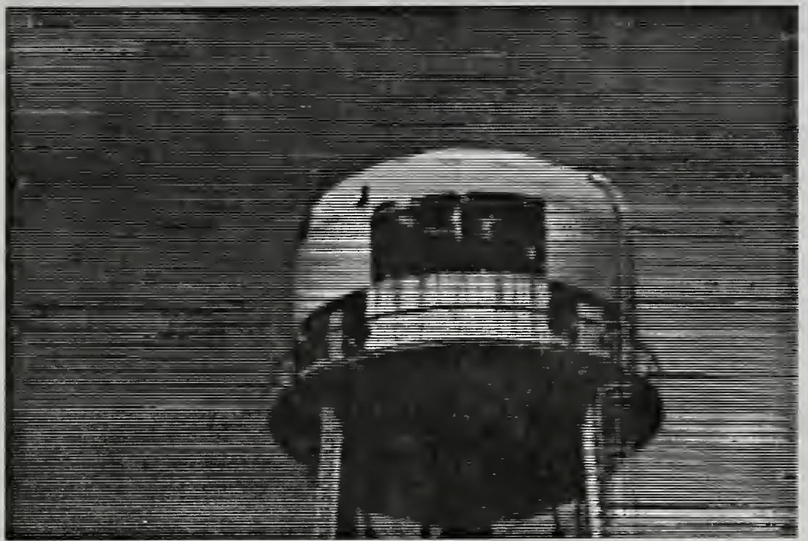

Figure 3a. Original image of water tower.

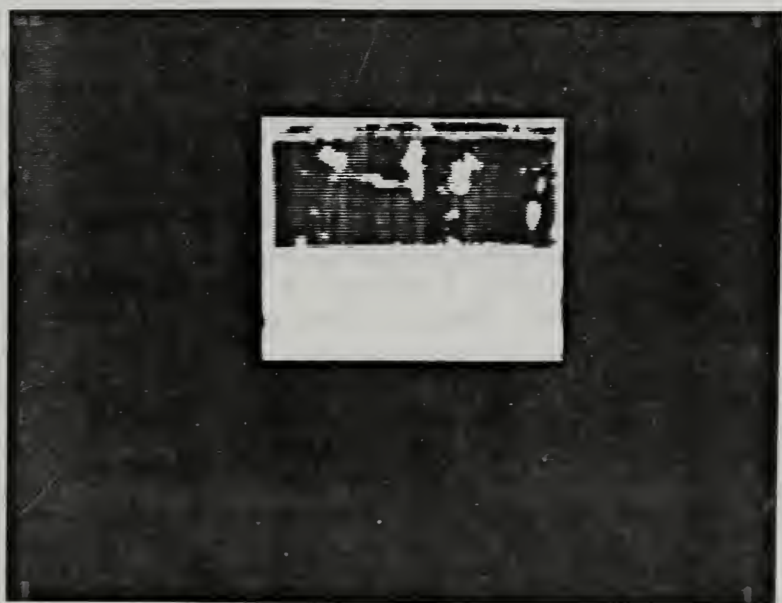

Figure 3b. Unwrapped image of water tower.

Three views or photographs were required to represent the structure in the computer. A view is represented by one or more sectors which represent areas of interest of the photograph that have been established by the operator. These sectors identify parts of the image that can be processed and distinguishes them from unwanted areas or areas that cannot be processed because of objects that interfere, such as trees or other vehicles. Statistical values obtained from each view were combined to produce a total percent peeled or blistered for coating on the tower. The formula for calculating the total percent degradation for a view is

$$\%\ \text{degradation in a view} = P_{1A}q_{1A} + P_{2A}q_{2A} + P_{3A}q_{3A}$$

where $$P_{1A} = \frac{\text{total no. pixels in Sector 1A}}{\text{total no. pixels in Sectors 1A+1B+2A}}$$

q_{1A} = percent of Area 1A which is degraded

Programs to digitize, threshold, and detect defects already existed [5]. However, an algorithm to compensate for the cylindrical shape of the tower was needed and developed. This algorithm "unwrapped" the cylindrical shape of the tower to create a flattened image.

Once the image was prepared for processing, existing programs to select the area of interest and distinguish defects (e.g. peeling, chipping) from the unblemished areas were used to determine the percent degradation. Figure 4 shows a single view of the water tower structure in its processed form. The percent degradation of this surface is 42%.

Figure 4. Processed image of water tower.

A key element in a maintenance management system is the ability to recall or track the condition of the structure over time. By storing the percent degradation of the surface of a structure and the image on optical disk, a historical record of the structure's condition is preserved. Using this information, facilities managers can query the system to determine the rate of deterioration or the current condition of the structure.

3. DATABASE MANAGEMENT SYSTEMS

3.1 THE CURRENT STATE OF DATABASE SYSTEMS AND THEIR USE

Databases are organized collections of information stored in the computer. The information is designed to represent the best description of a structure and contains relevant information needed for making decisions. This information is obtained from field inspections, existing records relating to the construction and maintenance of the structure, and statistical information obtained during image processing.

Numerous database systems are commercially available. Many could be used to implement a maintenance management system. However, these programs are only capable of storing building descriptions such as building type and dimensions, not digitized images. Those programs which do have the capability of storing photographs cannot process images. This limits the usefulness of these systems for integrating maintenance management information.

3.2 DATABASE ARCHITECTURES

There are four methods used in designing database systems: flat-file, network, hierarchical, and relational. Of these, the relational architecture is the most widely used. The criteria for selecting the database architecture that is appropriate for an application depends on factors such as the organization of the subject matter (whether it is centralized or de-centralized) and the way in which the information will be accessed (shared concurrently by multiple users or used by one user at a time).

3.2.1 DATABASE FILE STRUCTURES DEFINED

3.2.1.1 Flat File Database

The flat file database architecture is merely a file of information subdivided into fields. An example of this type of database is a file of names and addresses. Database systems that use this architecture tend to be primitive in nature or are developed for specialized, static applications. An example of a database containing information about buildings relating to a facility is shown in Figure 5.

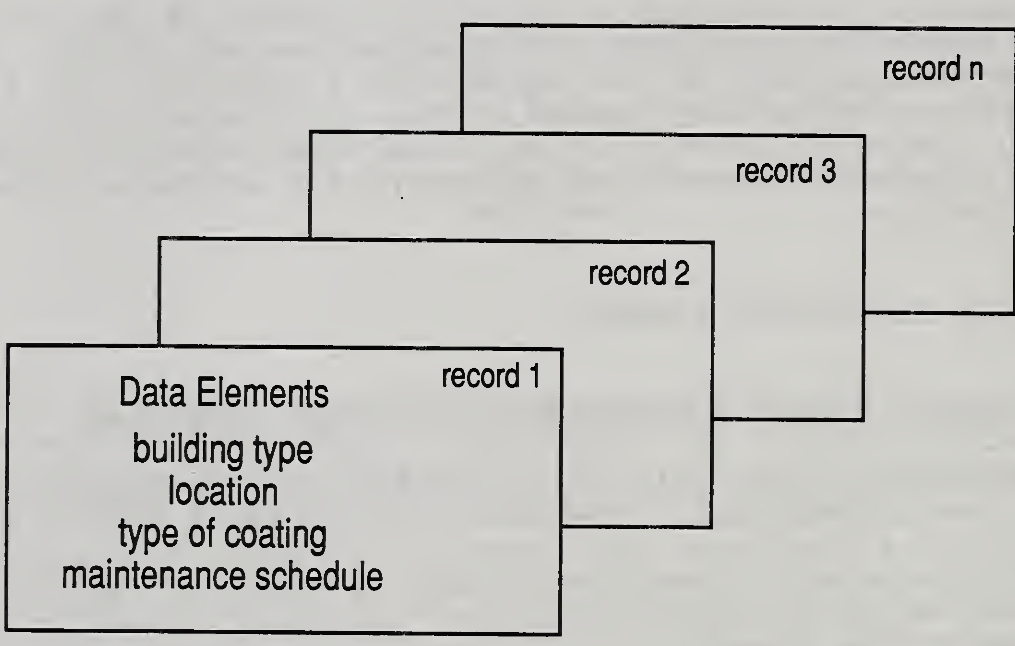

Figure 5. Flat file database architecture.

3.2.1.2 Network File Database

Network organizations represent graphs which may or may not be connected. Sets of records called chains are formed by attaching chain pointers between records to designate their interrelationships. Each chain has a header called the master and data records called details.

The network database design is used for applications that require periodic updating of a master file from remote sites. Each field site maintains a database file for its own use and communicates all or parts of the database to a central location to be merged with the central database. An example of a network database containing information about coatings performance is shown in Figure 6.

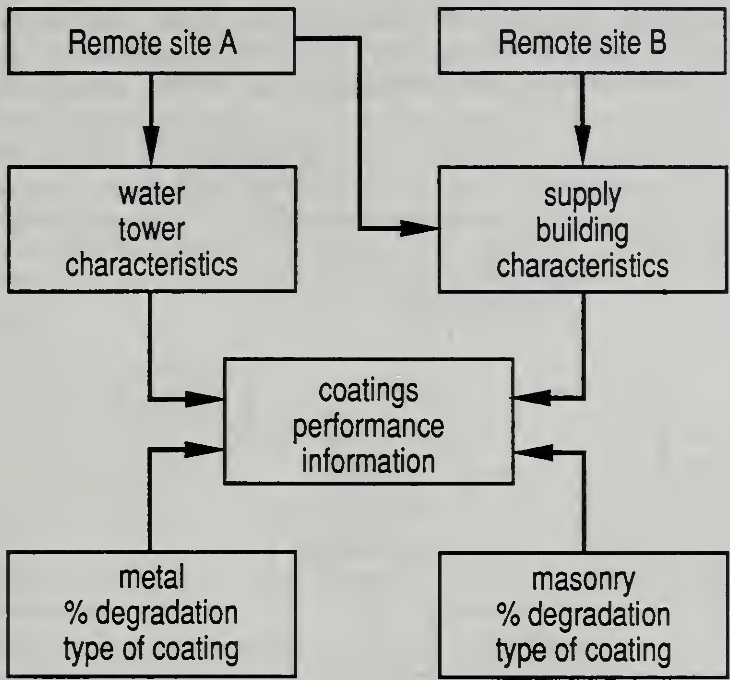

Figure 6. Network database file architecture.

3.2.1.3 Hierarchical File Database

In a hierarchical database system, the relationships between data elements are arranged vertically. For example, a building would be represented by many different types of information (e.g. performance, building design). Each category or data element would be sub-divided into sub data elements. An example of this architecture is shown in Figure 7.

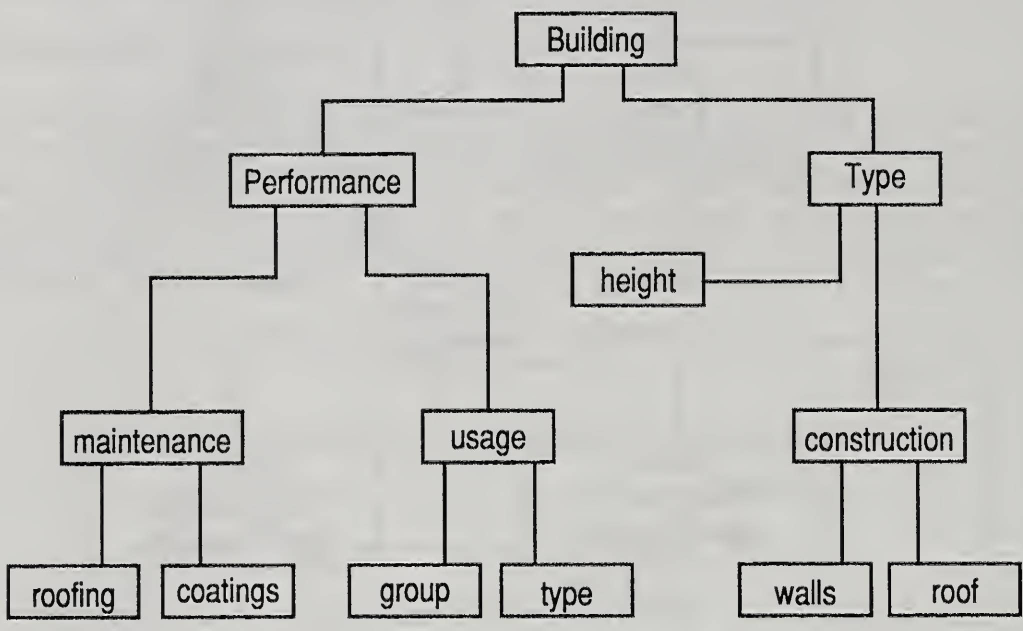

Figure 7. Hierarchical database file architecture.

3.2.1.4 Relational File Database

Relational database architecture is similar to the hierarchical database except that the data relationships between data files are horizontal. Relational database design is appropriate for data which can be subdivided into separate files each containing a common linkage or key. An example would be a database containing information about the performance of structures. A file would be needed to represent the building's description, location, performance, and images. Each file in the database would contain a field representing a linkage or key to another file or files. This information could further relate to locations within a geographic region or under a jurisdiction. Figure 8 presents an example of a relational database configuration.

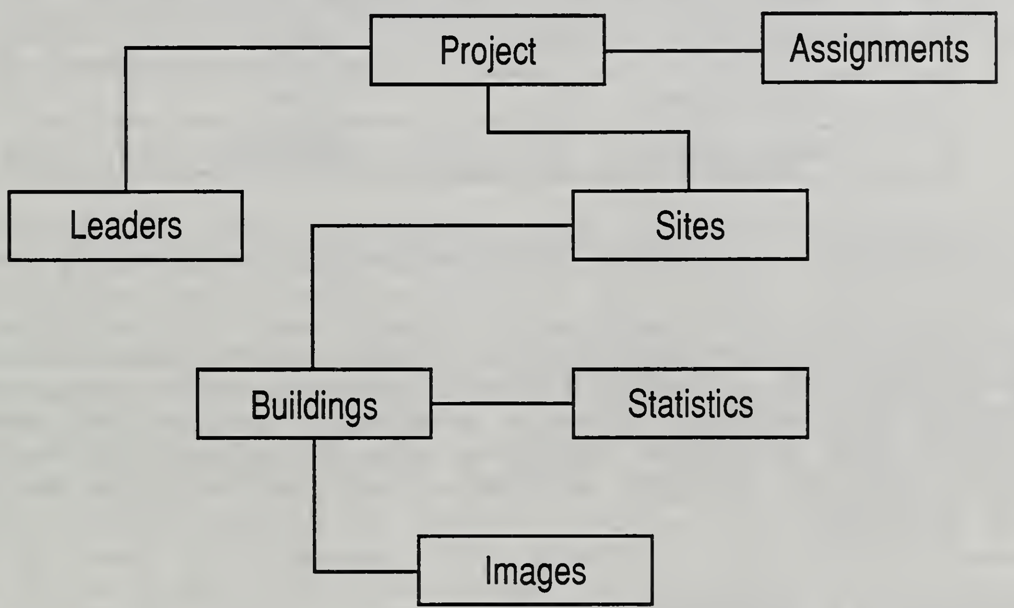

Figure 8. Relational database file architecture.

Figure 9 shows an example of the data necessary to catalogue the image.

Field	Contents
project_no	1
project_name	NAVFAC, TRI-SERV
site_no	2
site_name	Lakehurst Naval Air Sta
building_no	10
building_name	Water Tower Number 1
leader_no	1
leader_name	Jon Martin
image_no	01001
location_name	view 1
unique_fname	bld01001

Figure 9. Database information for cataloging image.

A major reason for the popularity of the relational architecture is the development of a Standard Query Language (SQL) [6]. This method of querying databases provides a consistent way of retrieving information from database systems. The impact of SQL is that a user is not required to relearn database query methods for different computer systems.

3.3 SELECTING A DATABASE SYSTEM

Choosing the most appropriate database system depends on the performance criteria (e.g. speed, query method), and the computer system used to implement the database. The designers of a database may choose from many database systems providing the capability to create, manipulate, and retrieve information. They may also include modules for report generation, import/export facilities, and a high level programming language used by the developer to perform cyclic operations under program control. Examples of the most popular database systems and their capabilities are described in Table 1. The strengths and weaknesses shown for the database systems relate to their application to an automated maintenance management system for condition assessment.

In addition to commercially available database systems, users may create their own database programs for managing information [7].

Unlike database systems which may be purchased, these systems require the resources of a computer programmer/analyst to develop the computer programs. Choosing this option is often predicated on the availability of database systems for the computer being used or the need to interface database operations with unique capabilities, such as image processing functions. Such is the case with the database for condition assessment of metal structures. The need to integrate the image processing functions with database operations required special programming. This design permitted the use of existing computer image processing algorithms which took several person years to develop. The C programming language was used to implement the database system. The database programs and their function are documented in Appendix A.

Wide-spread use of microcomputers for image processing will undoubtedly impact the future development of database systems which have interfacing capability to image processing functions. An example of these are information management systems being sold today for office systems that provide image capture, storage and efficient methods for image processing.

3.4 DATABASE OPERATIONS FOR CONDITION ASSESSMENT

Development of the condition assessment database began by first determining the type of information which was needed and then establishing the relationships between data sets. The relational database architecture was chosen to implement the maintenance management database because the information could easily be divided into sub-sets each having link to different connecting data files. Each of the sub-sets of data (e.g. project, sites, buildings) were created and the required fields defined. Figure 10 shows the database structure and identifies the fields for each data subset. By establishing relationships or keys to relate one structure to another, the query process is enhanced. For example, one can retrieve all BUILDINGS for a given SITE due to the relationship established through the field "site_no" which is contained in the data file "structure".

In designing the computer code for the database system, a major consideration was to combine the database manipulation features with the image processing function. This was accomplished by incorporating save and retrieve functions from the image processing menu. When the operator activates one of these functions, he is asked to supply the required database information for the structure. He need only supply the database structure relationships and the building specific information. An example of the input data required for a single view (image) of the water tower is shown in Figure 9.

Table 1. Popular database systems and their capabilities.[1]

Database Name	Software Company	Database Architecture	Computer System	Salient Features	Strengths	Weaknesses
dBASE III+	Ashton-Tate, Inc. 20101 Hamilton Ave. Torrance, CA 90502	quasi relational	IBM & compatible personal computers	programming language menu driven mode	widely used, import/export flexibility	slow performance
dBASE IV	Ashton-Tate, Inc. 20101 Hamilton Ave. Torrance, CA 90502	relational	IBM & compatible personal computers	programming language, menu driven mode, SQL capability	widely use, import/export flexibility, SQL capability	SQL is separate module
RBASE System V	Microrim, Inc. 3925-159th Ave., N.E. Redmond, WA 98073	relational	IBM & compatible personal computers	programming language automated forms, report and program generation, SQL query	very fast performance and program generation, query compatibility with mini and main-frames	limited translators for import/export of databases
DB2	IBM Corp.	relational	IBM System/370 mainframe	extensive program control language, SQL query capability, object definition of data elements	fast execution, extensive editing, dynamic means of creating database objects	mainframe computer based, required high level of knowledge to develop database
Oracle	Oracle Corp. 20 Davis Drive Belmont, CA 94002	relational	Personal, mini and mainframe computers running Unix operating system	programming language, SQL query language	fast performance, micro, mini, main-frame compatibility	relatively long time to learn
Focus	Information Builders 1250 Broadway New York, NY 10117	relational	Personal, mini and mainframe computers running various operating systems	portability between computer systems, SQL query capbility, 3-D graphics, screen painting and windowing	extremely powerful, decision support	relatively long time to learn
Cdata	generic database management algorithms [2,9]	relational	Personal, mini and mainframe computers maintaining C programing language	custom program interface capability	applicable to special purpose applications such as imaging	requires programmer to develop, contains only database manipulation facilities

[1] Trade names and company products are identified to specify adequately the work presented. In no case does such identification imply recommendation or endorsement by the National Institute of Standards and Technology.

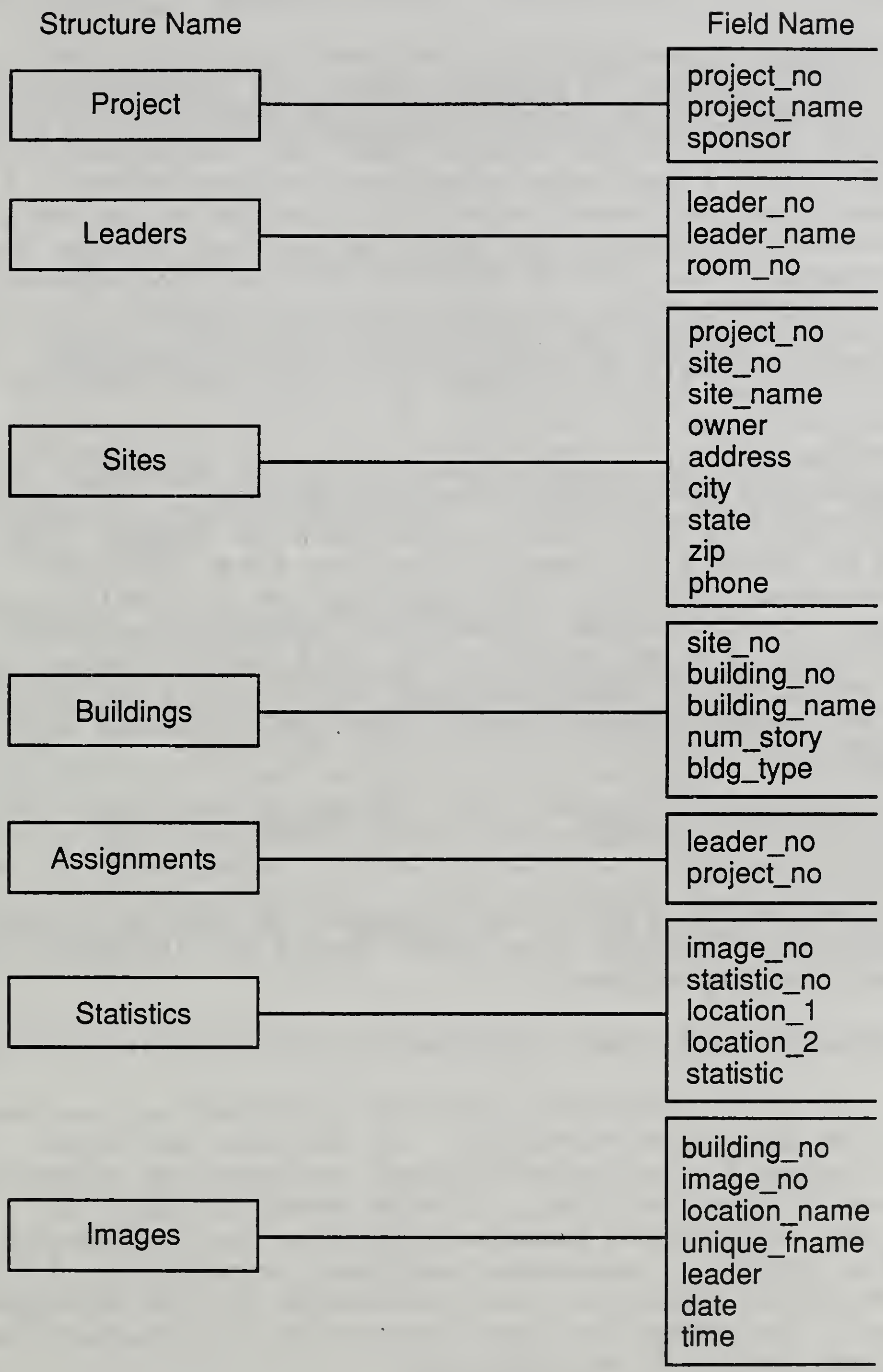

Figure 10. Condition assessment database structure.

4. AN INTEGRATED COMPUTER IMAGE PROCESSING/DATABASE MANAGEMENT SYSTEM FOR ASSESSING THE EXTERIOR CONDITION OF A COATED STEEL STRUCTURE

4.1 INTEGRATING IMAGE PROCESSING AND DATABASES

Inherent with image processing is the need to store large volumes of information. For example, a single image for condition assessment requires approximately one-quarter million characters of storage. This information tends to be static, that is, it is not likely to change once the source has been acquired and processed. For these reasons, images are good candidates for storage on an optical disk drive. These devices employ the WORM technology (Write Once Read Many). The storage capacity of optical disk drives approach 1 billion characters. A disadvantage of these devices however, is the access time required to retrieve the information from the disk. It typically is one-fourth to one-half the speed of a rotating magnetic disk drive.

Unlike image information, image descriptors or database information may change over time or require frequent editing. In addition, several records may be required to describe an image. For example, records would be needed for describing the site, project, and building. The need to search the database on a specific criterion requires higher speed devices to achieve optimum response. High speed seek and retrieval is a characteristic of rotating magnetic disk drives. The capacity of these devices may range from 10-300 million characters. An example query which uses the database and image knowledge would be:

> Retrieve BUILDING number X at SITE number Y under PROJECT Z.

The above command would result in a search of the relational database files and if found, the image would be displayed on the computer image display screen.

4.2 USE OF DATABASE AND IMAGE INFORMATION IN DECISION MAKING

A description of two different forms of information has been presented in the previous sections. By merging building description information and statistical information concerning the performance of the building, a very powerful tool is available to the facility's manager which is not currently available. For example, database retrieval system can be used to present a historical record of the structure to the manager in a concise manner. Tracking the performance of a structure can reveal important information such as:

- o the performance of a given type of coating
- o where the deterioration is most likely to appear (e.g. around windows, doors)

- o the rate of deterioration of a structure
- o the performance of buildings in one location versus another
- o responsibility for management and maintenance of structures

In addition to the textual and statistical information about the structure, interpreting the structure's condition is further enhanced by a visual presentation of the condition at a given time.

4.3 FIELD IMPLEMENTATION CONSIDERATIONS

Implementing an automated maintenance management program for condition assessment involves choosing a computer hardware and software system, designing the database, and selecting and training operations staff. In addition, it must be determined how the information is to be maintained. One may choose to establish a central database at a single site, or establish installations for each facility. These issues are addressed in the following text.

4.3.1 Computer Hardware and Software Platforms

The price of computer hardware is decreasing rapidly. This is evident by the number of microcomputers purchased for desktop workstations and the power available in each. The result of this proliferation has forced computer manufacturers to address specialized application needs. The design of computer hardware boards for image processing that are compatible with personal computers is an example. Three possible configurations are indicated in Figure 11a-11c. Each of these configurations has unique advantages and the selection would depend on the intended use of the system.

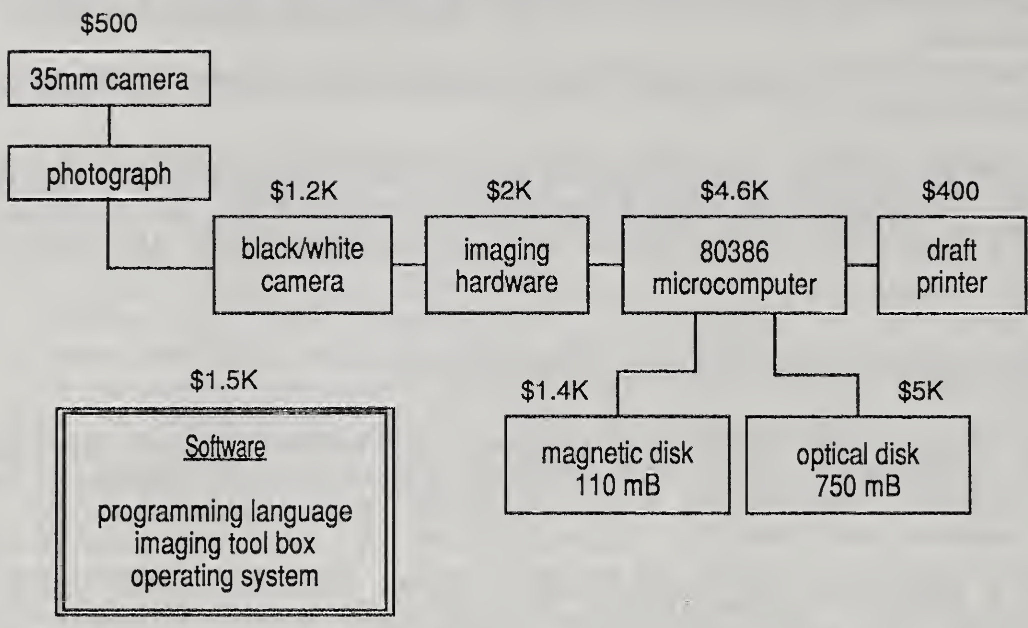

Figure 11a. Black/White image processing computer system configuration with approximate costs of components.

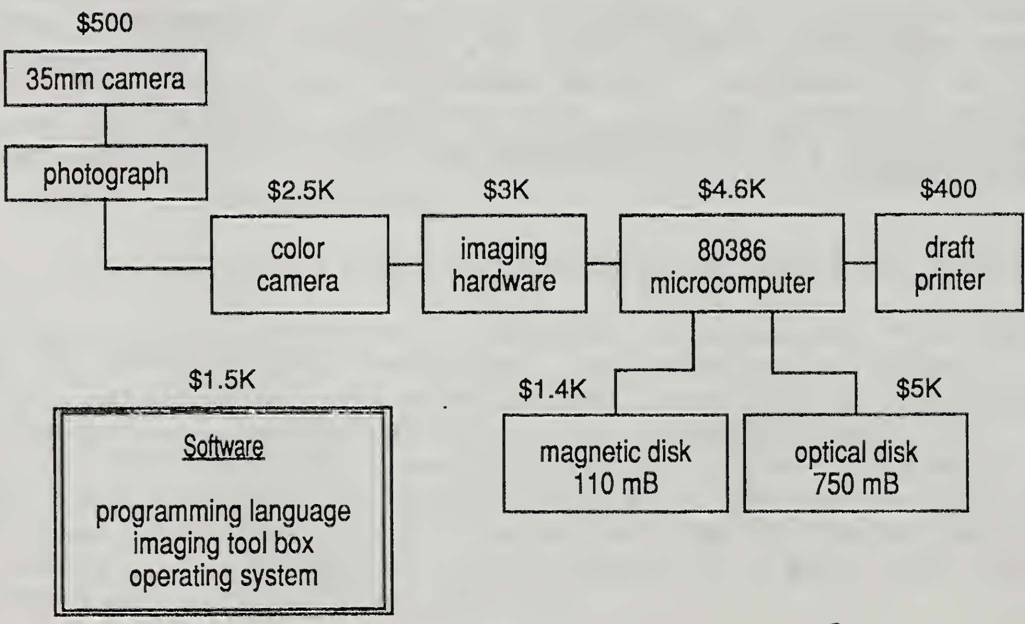

Figure 11b. Color image processing computer system configuration with approximate costs of components.

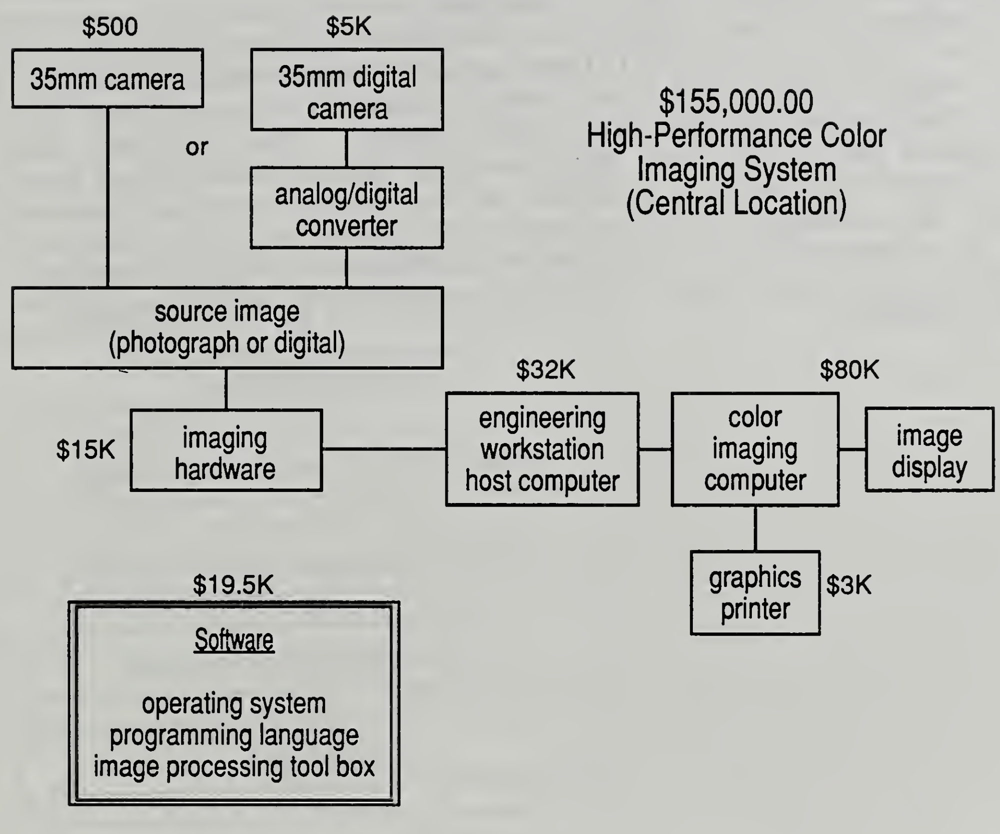

Figure 11c. High-performance Color Image Processing Computer system configuration with approximate costs of components.

4.3.2 Staff Requirements for System Design

Staffing for an automated maintenance management system requires an engineer with computer experience. Initially, the efforts will involve the design of the system. This requires input from the facilities manager, and field inspectors who work closely with a staff member or consultants knowledgeable in techniques for designing databases and the selection and implementation of computer hardware and software. Rarely will these skills exist in a single individual in a production environment. This effort is estimated to require from 6 months to 2 years to develop a production system. Two important factors determine this wide span in time: 1) the availability of information about the structure, and 2) the required image analysis functions which need to be developed to process the image. The obvious best case scenario would be a limited application dealing with a single facility (inventory of buildings) where the building descriptive information is already on file and the imaging requirements can be met by a commercially available software system. Figure 12 presents the required steps in establishing a maintenance management system.

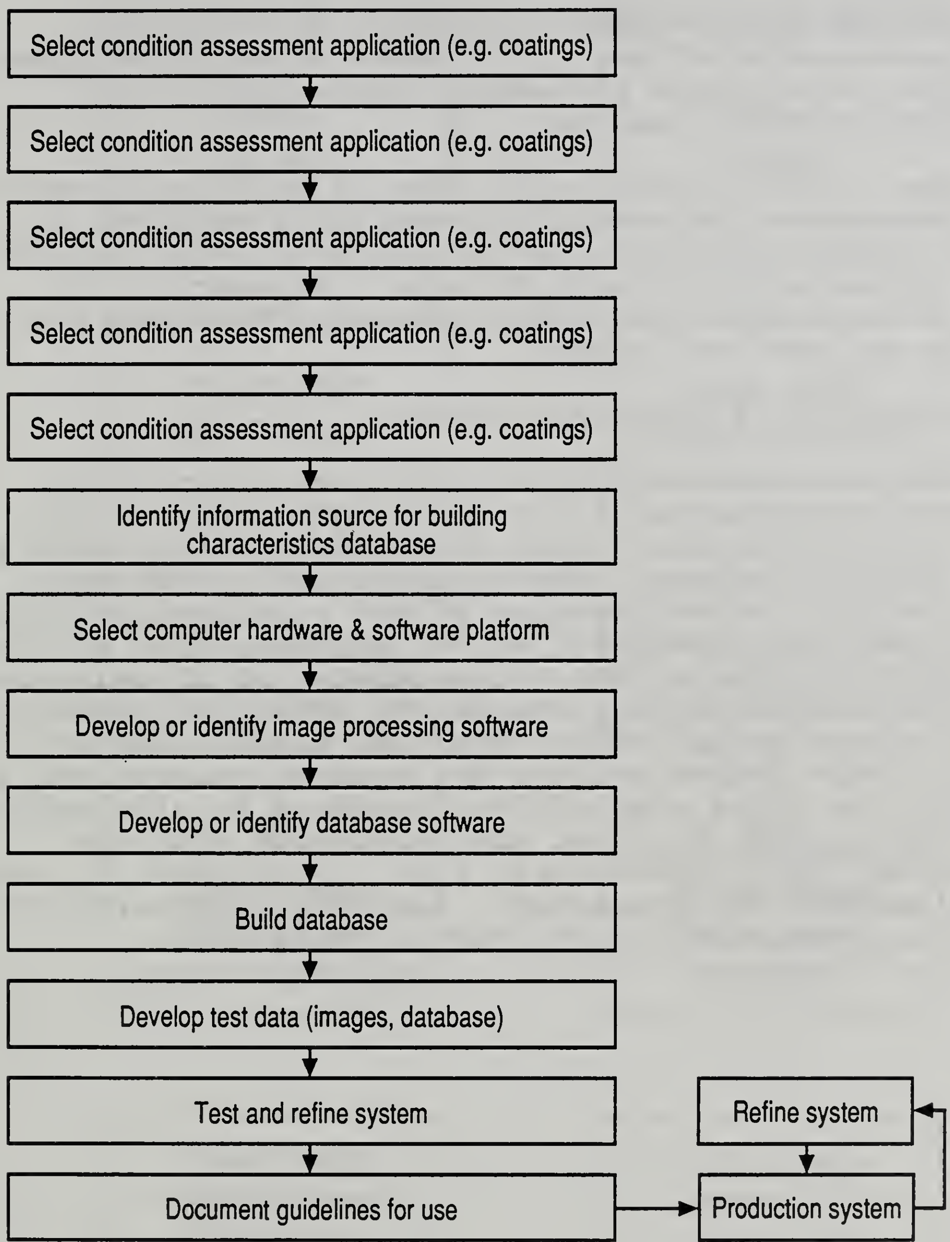

Figure 12. Required steps in establishing a maintenance management system.

4.3.3 Staff Requirements for Operability

To successfully maintain a maintenance management system for condition assessment the following tasks must be performed by its operating staff:

- o acquisition of field photographs
- o routine updating of building characteristics database
- o performance of image processing operations
- o interpretation of results

Since the scope of the system (e.g. size of building inventory) ultimately determines the amount of staff time required to maintain the system, estimates of the amount of time required to operate the system are difficult to make. However, it is possible to identify the procedures necessary to accomplish the tasks. These are outlined below.

4.3.3.1 Acquisition of Field Photographs

This task involves obtaining photographs from field sites. It replaces visual assessments of the building's condition by inspectors. Instead of the visual inspection, the process is aid through the use of a camera. Accomplishing this task may involve: 1) taking 35mm photographs of the structure sufficient to obtain an adequate assessment of the surface, then developing these for acquisition using the video camera, or 2) using one of the recently developed digital cameras to obtain the necessary views of the structure for direct entry as digital images into the computer. This method reduces the need to process the film and simplifies the image acquisition procedure by eliminating the need for a video camera to input the photograph into the computer. It may also reduce staff time. In Figure 13, examples of these two methods are presented. Sampling considerations for field images have been defined by Martin, et al. [1].

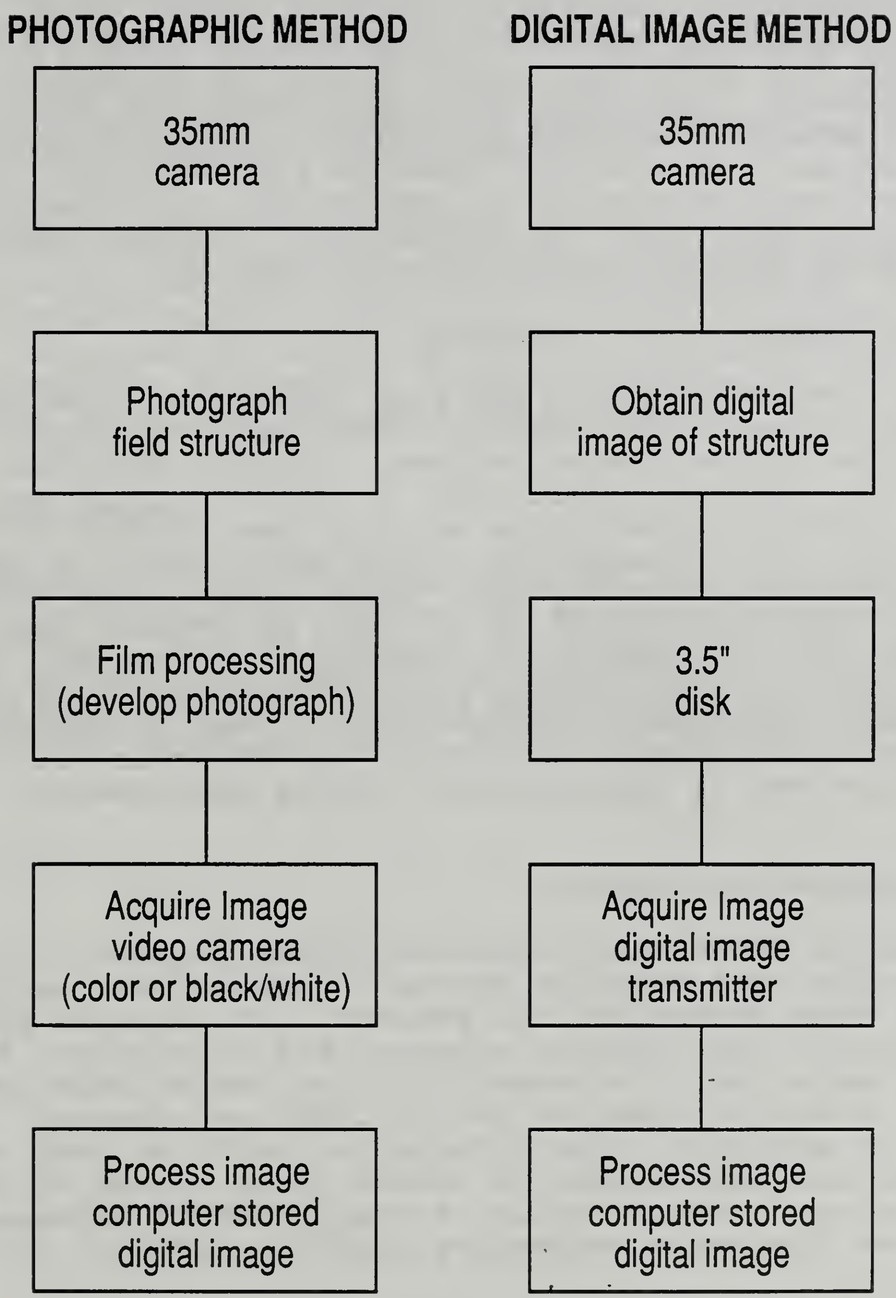

Figure 13. Image acquisition methods.

4.3.3.2 Routine Updating of Building Characteristics Database

This task involves obtaining information about the facility's structures and entering it into the computer. An example of the type of information is shown in Figure 10. Normally, this task would be performed by a data entry person, and is highly recommended, especially when large building inventories are involved, e.g., 50 buildings. If the number of buildings in the inventory is small, this task could be performed by the facility manager or a person designated to operate the maintenance management system. As with all database applications, it is important that the information be represented in a consistent form (e.g. building types, pre-established location names) form so that database queries produce precise results.

4.3.3.3 Performing Image Processing Functions

This task is the most complex and most important. The operator of the image processing system must understand the capabilities and limitations of the imaging system. Factors affecting the accuracy of the imaging results are: 1) ability to detect defect areas from the source photograph or digitized source; 2) adequate percent surface area represented in the photographs to make a visual determination of condition. These issues were addressed in research conducted at NIST [1,2,8] and by Trimber and Neal [9], and must be described in the operating procedures. Statistical information obtained from this procedure is stored in the maintenance management database and is used to determine the rate of deterioration and condition of the structure at a point in time. It serves as the basis for making maintenance decisions.

4.3.3.4 Interpreting Results

This function is performed by the facilities manager. It involves querying the computer system to obtain the condition of a structure, both historical and present. It requires knowledge of how to operate the computer programs and to retrieve results in text and image form. An example of the use of this operation would be to obtain information for periodic maintenance schedules. In addition, this information could be used to project costs for maintenance in future years, based on the rate of deterioration. This function is significantly enhanced by the ability to see the image processing results stored in the computer.

5. CONCLUSIONS

Computer image processing and database techniques have been successfully applied to the condition assessment of structures. By integrating images with databases, one can determine the current condition of a coated surface (e.g. percent degradation) of a structure or groupings of structures. The system can also be used to determine the rate of deterioration by retrieving images of the same structure at different time periods. The automated system described here provided several advantages over previous systems: 1) it recorded an historical record of a structure in a consistent method; 2) it stored large volumes of information using optical disk technology; 3) it provided the framework for intelligent queries of the database to obtain critical information about the structures.

The automated maintenance management system will allow facilities managers to make more accurate and timely maintenance decisions. It will serve as the basis for further development of decision support or expert systems which will incorporate additional knowledge forms such as facts, guidelines and expert opinion. By incorporating this information, expert knowledge will be preserved and made available to a wider audience.

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Appendix A: Database Programs and Their Function

This appendix presents a listing of the database programs needed to create, edit, and manipulate information for an automated maintenance management system for structures. There are four distinct program entities which are used:

1) database initialization
2) database indexing
3) database updating
4) database and image processing

The origin of the programs described in this appendix are as follows. Database programs are taken from the Cdata model described by Stevens [7]. Image processing programs were designed and developed at NIST to meet the needs of image processing and computer system utilities required to perform computer image analysis. These operations are described in Figure 2.

Program	Function
SCHEMA.C	Reads the Cdata data definition language and compiles it into a set of three C language source files that comply with the schema requirements of Cdata.
SYS.C	Performs screen cursor movement and clearing operations.
BTREE.C	Defines the index structure. It is a balanced tree of key values used to locate the data file record that matches a specified key argument.
CLIST.C	Used to list the contents of database files.
DATABASE.C	Defines the functions to be used by Cdata that determine the methods of database storage and retrieval.
DATAFILE.C	Defines the functions to be used by Cdata that determine the file management operations to create, add, change and delete records in the data files.
DBINIT.C	Builds initial copies of data and index files. These files contain no data.
DBLIST.C	Display the contents of a file on the screen.

Appendix A: Database Programs and Their Function

Program	Function
DBSIZE.C	Calculates the disk space requirements for Cdata from estimates of file sizes.
DS.C	Database file report program for printing reports from the database.
ELLIST.C	Handles program input parameters specified on command lines.
INDEX.C	Repairs Cdata index files by closing B-trees. This measure is necessary after a system failure.
QD.C	Specifies a file, constructs a data entry screen, and displays it.
SCREEN.C	Builds screen templates to manage the display of information on the screen.
UPDATE.C	Query program to update database files based on user input from keyboard.
RDWRIMAG.C	Reads and writes images from optical disk drive.
OPTOIO.C	Transfers file to and from imaging computer and optical disk drive interface.
OPTOIMAGE.FTN	Master program that calls image processing, and database programs to read, store, and process images and database information.

Appendix B: Terminology

Term	Definition
Database	Organized collections of information stored in the computer.
Field	A data element which is the smallest quantum of information in a database.
Record	A set of fields and/or groups that contain database information.
File	A set of database records.
Schema	A definition of the database described within the Data Description Language (DDL) that describes the design of the database data -items (fields), sets (records), areas (one or more records and sets).
Data Description Language (DDL)	A standard method developed by the CODASYL Language Committee to allow databases to be described within and independent of a programming language.
Data Manipulation Language (DML)	A standard method developed by the CODASYL Language Committee to allow for manipulation (open, get, close, remove records) of databases within and independent of a programming language.
Query	A request made of a database system by the database operator to retrieve information based on selection criteria defined in the command.
Standard Query Language (SQL)	A standard method for querying a database to retrieve information [6].
Database Architecture	The method used to implement the data base which defines the relationships between files.
Flat File Database	A type of database architecture. All data about the database is contained in a single file.

Appendix B: Terminology

Term	Definition
Network Database	A type of database architecture. Files are connected through sets of records called chains which define their relationship.
Hierarchical Database	A type of database architecture. The relationships between data elements in the database are arranged vertically.
Relational Database	A type of database architecture. The relationships between data elements in the database are arranged horizontally. Keys provide links between data files.
Cdata	A computer software model and programs used for the development of custom database management systems [10].
Centralized Database	A method of implementing a database management system. Information is maintained at a single point.
Distributed Database	A method of implementing a database management system. Information is maintained at remote locations and communicated between a central location and field sites.
Expert System	An interactive computerized system that uses knowledge and inference procedures to solve specialized problems that require the knowledge of an expert.
Frame Buffer	The memory allocated for the storage of the greylevel values of all the pixels in a digitized image.
Image Enhancement	The modification of an image to produce a resultant image in which features of interest are easily detectable.
Inference	The process of matching or linking knowledge (facts or data) to rules to form conclusions specific to the problem.
Knowledge Integration	The process of combining two or more forms of knowledge, such database information, and images into a coherent automated system.

Appendix B: Terminology

Term	Definition
Knowledge Base	Facts and rules contained in an automated maintenance management system for use in making decisions.
Thresholding	An image processing point operation in which each pixel is assigned one output value (e.g. 0) if its original greylevel value is within a specified threshold value and a second value (e.g. 255) if its original output value not in this range. The result is a binary image.
Binary Image	A high-contrast image in which each pixel is assigned one of two values (e.g. 0-black and 255-white).

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The establishment of and automated system for assessing the exterior condition of structures can provide facility managers with an important tool for making decisions. The integration of different forms of knowledge into a coherent system provides the fundamental basis for an expert system. This system can reduce the time required to analyze and interpret information, and provides a historical record of the rate of failure for building structures. This report discusses the feasibility of establishing and automated maintenance management program for making maintenance decisions using computer image processing to obtain quantitative results from field sites and information describing the characteristics of the structure. Relevant database technologies and the design and structure of the database for condition assessment are discussed. Image acquisition, processing, storage, and retrieval of images of a water tower are presented as a case study.

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

computer image processing; condition assessment; database; decision support system; integrated knowledge system.

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