COMPUTER APPLICATIONS IN ARCHITECTURAL CONSERVATION

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ABSTRACT

The Center for Architectural Conservation, College of Architecture, Georgia Institute of Technology, is considered to be one of the leading exponents of computer-aided databases for the management of buildings of historical merit in the U.S. Through their involvement with the National Parks Service and other clients in North America, the Center has developed considerable expertise in the creation of computerized fabric and condition survey methods, and in the compilation of databases for components and materials used in the rehabilitation and conservation arena. In addition, exploratory research is currently being undertaken in the development of "expert systems" in the area of building diagnostics. This paper gives a brief historical background of the Center for Architectural Conservation, comments on the early establishment of the Center, and reviews the application of an expert system in the area of window diagnostic.

INTRODUCTION

The Center for Architectural Conservation (CAC) located at Georgia Institute of Technology was established in January 1982 to act as a research, information and design center concerned with all facets of building conservation technology. Services offered by the

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Center include research and development of specialized programs in facilities management and building conservation as well as the identification and interpretation of technical resources on architectural methods and materials. CAC staff work with research officers throughout the Georgia Tech community, including the Georgia Tech Research Corporation and laboratories across the campus. The development of the CAC is based on multilateral agreements among federal and state government, private industry and the Georgia Institute of Technology. The work of the CAC has developed over the past eight years and now includes extensive research capabilities in terms of building evaluation, information systems, publications, materials research, database design, architectural preservation and training.

For example, the CAC has worked for several years on the problems of evaluation, repair and maintenance of older, especially historic structures. Early work included a US$1.8 million contract with the United States National Park Service (NPS) to develop the Building Inventory Inspection Program (BIIP) for the inspection of all NPS buildings. BIIP is a comprehensive, microcomputer-based method of building condition assessment which results in a printed report for each building inspected. The program provides for the inspection of 150 elements related to the site and architectural and engineering systems. These elements include sections on public health, fire and life safety as well as handicapped accessibility. The building reports produced may be used in planning, budgeting, maintenance management and rehabilitation studies. In conjunction with the BIIP, the CAC has developed the Mobile Resource Laboratory (MRL), a self contained field-based office facility. The MRL is outfitted with computer facilities, drafting area, library, conference area and audio-visual equipment. Using the MRL, support staff are able to conduct orientation sessions, inspect buildings and enter inspection results to the computer system on site.

In addition to the National Parks Service, other CAC client include the U.S. Courts; U.S. Army; General Services Administration (GSA); Veteran's Association; and various city and State governments. In 1986 the Center was recognized for its formative work in the field by the Office of Technology Assessment (OTA) of the U.S. Congress. In 1988-89, the Director served on the National Academy of Sciences panel on Advanced Maintenance Concepts to address the state-of-the-art in Condition Assessment and Capital Renewal.

The Cultural Resources Assistance Information Network (CRAIN), presently under development within the CAC, is a computer-based system for collecting and disbursing information useful to those working in the conservation field. The network, designed to be accessible by computer-telephone link, aims to serve as a central resource for information on conservation issues. CRAIN is designed to maintain eight databases consisting of:

1. Laboratories  
2. Products  
3. Organizations  
4. Professionals  
5. Collections  
6. Training  
7. Non-Print  
8. Print

When the system is fully operational all eight databases will accessible by calling the CAC and requesting a search on a specific database. Information requested will be relayed by telephone in addition to a hard-copy mail-out. Currently all databases are operational with
the exception of Print and Non-Print. Information stored within CRAIN's databases has been gathered from many different sources, including periodicals and journals, organizations, product literature and individuals. It is envisaged that the final system will allow for keyword cross-searching of all databases.

Publications also form part of the CAC's operations. For example, working with the Preservation Assistance Division, NPS, the CAC has developed a new publication series, 'Preservation Technical Notes'. These short, illustrated case studies provide actual project details, costs, products and related data to assist property owners and developers in applying appropriate treatments to preservation projects. The initial series of 'Tech Notes' discusses planning, repair, replacement and energy consumption for windows (Fisher, 1986).

The CAC also coordinates research at Georgia Tech. in the assessment of the effects of acid rain on historic building materials. The work, which is on-going, includes the design of field assessment kits to evaluate the condition and deterioration of building materials. The ultimate aim of the project is to produce prototype testing kits that will enable the user to assess various potential preservation treatments. The work is part of a broad, federal government sponsored initiative to identify the impact of acid rain on building materials and to evaluate long-term solutions to the effects of acid rain. In addition, the CAC is currently developing a computer program for the 'Census of Treated Historic Masonry Buildings' as part of an international effort to identify preservation treatments applied to masonry buildings and to monitor the effects of these treatments over a long period of time. Recorded observations of conditions every 2-5 years will result in an international database to be used for planning and evaluation of the impact of monitored treatments. The CAC is designing and developing the microcomputer database to allow storage and analysis of the data by Census staff.

Finally, the CAC is applying the concept of BIIP to the development of a program to evaluate National Historic Landmarks in the U.S.A. The program is part of a national effort to monitor U.S. cultural resources. The work is being coordinated through the NPS. At each threatened historic property, an in-depth, uniform report is completed that presents current, precise information on the physical condition of each building/structure inspected. The condition assessment is based on a comprehensive field inspection conducted by professional architects and engineers. Each report consists of the following information:

1. administrative data, e.g. location, size, historical significance.
2. inventory data, e.g. description of the major building elements and systems; condition assessment; priority evaluation.
3. inspection data, e.g. identified deficiencies and necessary remedial action.
4. management cost summary, e.g. matrix of approximate estimated costs for all recommended work.
5. graphic data, e.g. site sketch and plan; existing floor plans including current usage; historical development of the building form; color photographs of exterior and interior elevations.

Results from the Landmark's program will serve as a model for the Secretary of Interior's "Standards for Historic Preservation Projects".

THE DEVELOPMENT OF AN EXPERT SYSTEM

Faced with growing rehabilitation needs and limited sources of expertise in the area of preservation technology, the U.S. Department of the Army has undertaken a significant initiative to develop new methods and tools in the field of historic conservation. This initiative began with the U.S. Army Historic Preservation Officer based in the Army Engineering and Housing Support Center and the Construction Engineering Research Laboratory (CERL) working with the CAC. The focus of the initial effort is the development of a single historic preservation/rehabilitation "expert system" for the repair and replacement of windows in historic buildings. The initiative to develop an expert system that focuses on one problem will, it is hoped, create a model that may be used as a guide for future work in the field.

Decisions regarding the repair and replacement of windows are a constant source of concern for owners and managers of older and historic buildings. The decision making process requires a comprehensive understanding of many factors that influence the final settlement, e.g. a knowledge of preservation standards and philosophy; an understanding of preservation methods; an appreciation of contextual architectural history and construction technology; an awareness of energy issues; knowledge of local and regional codes; and finally, commercial information about supplier availability and related costs. Hence, with such a complex interrelationship, where judgement is required to evaluate and balance these multiple and often conflicting criteria, professional skills are essential. For example, there may be a need to arrive at solutions that (i) meet the Secretary of Interior's Standards, (ii) maintain the integrity of both the features and the building, and (iii) also satisfy the practical owner requirements for cost effectiveness, performance and maintenance.

Therefore, in an attempt to capture this professional knowledge, the CAC has developed an expert system that allows the user:

1. to assess the significance of windows within their historical setting both by type and location.
2. to evaluate the present condition of the windows.
3. to determine the need for repair and/or replacement of the windows.
4. to identify suitable designs (bespoke) or suppliers (generic) for the windows.
The program is fully supported by standards and guidelines to assist the user in performing the window design assessment in a logical, step-by-step approach. Although the current system utilizes a desk-top microcomputer based at the CAC, it is envisaged that the final version will be sufficiently automated and usable to be ported onto a lap-top microcomputer to be used by non-professionals (in terms of historic preservation) within the field. (Beta field-testing of a lap-top version of the system is currently under review.) The system prompts inspectors to examine significant areas of windows, provides written and graphic help and records and stores the assessment results for summary printouts. In addition, window manufacturer's capabilities are assessed, with the final report identifying by name potential suppliers and identifying proprietary names and/or codes where available.

The WINDOW EXPERT SYSTEM (WES) has been developed on the Personal Consultant Plus\(^4\) shell program, with extracted data transferred to a dBase III Plus\(^5\) file. Additional Clipper\(^6\) routines facilitate a more user friendly interface for data input. PC Plus is "a functional tool for developing expert system applications that offers the user a framework for handling multi-dimensional problems, techniques for imposing rule-order strategies, the ability to extend and customize the consultation environment, with large rule capacity".

The basic composition of the WES may be divided between:

A. the body of knowledge that includes the "facts"; rules about the relationship(s) between the facts; and strategies for making educated guesses, or rules-of-thumb, developed from those interrelationships. This may be termed the knowledge base.

B. a mechanism that perform the inference procedure that produces a solution to a particular problem. This may be termed the inference engine.

**The Knowledge Base**

The methodology for evaluating windows and developing planning level recommendations for repair and replacement must be based on reproducible techniques. Such techniques become the standards by which the program is operated, and they must be developed for the two major evaluation areas, i.e. significance and condition. The recommendations which result from the program are based upon a combination of these two factors. In general, a non-significant window in virtually any condition may be repaired or replaced, but a highly

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\(^4\)PC Plus by Texas Instruments - an expert system shell is used for rule-processing and to provide graphic and data interfacing.

\(^5\)dBASE III Plus by Ashton Tate - a microcomputer DBMS used to create file structures and to facilitate transfer of SDF files.

\(^6\)Clipper by Nantucket Software - a dBase compiler and procedural language used to improve the database management and reporting features.
significant window, even though it may be in a poor condition, should be repaired or retained wherever possible.

Architectural or historical significance is a qualitative term. It may be interpreted differently from one individual to another. Consequently, it is necessary to establish a "frame-of-reference" based on a common understanding. Significance may be determined by a number of factors, including:

1. period, or date of the window.
2. visual appropriateness.
3. special characteristics, e.g. shape, glass type, decoration, hardware etc.
4. building context.

Windows under review are assessed on a points basis for significance, i.e. one point is assigned for each significance factor, appendix 1. "Vintage" windows are those assessed with 4 points. Inappropriate windows, or "intrusions" are rated zero points with an automatic recommendation that these windows should be replaced. The actual condition assessment of intrusion windows may affect the timing or scheduling of the replacement.

In addition, a common measure related to window deterioration has been adopted and is based on the U.S. Department of Interior, "Preservation Brief #9" for the inspection of wood windows.

The classification system outlined in Preservation Brief #9 (PB9) consists of three levels of condition based upon the general types of repair actions required to restore the window(s) to a fully functional condition, with sound features and finishes. (Focusing on the types of repair required is thought to be more effective than classifying deterioration per se.) Repairs may be grouped into these broad groups depending on the amount of intervention required, the skill level necessary and the degree of removal and disassembly required. All of these are relevant to cost and feasibility.

**Condition level 1** is equivalent to "Repair Class I" of PB9, i.e:

1. some degree of interior and exterior paint removal.
2. removal and repair of sash.
3. minor repairs to the frame.
4. weather-stripping and reinstallation of the sash.
5. repainting.

**Condition level 2** applies to windows that require a greater level of effort and craft skill to repair than condition level 1. These may be characterized by the need for:

1. stabilization, patching or other craft techniques.
2. resealing, and/or the application of fillers and sealants.
Condition level 3 applies to windows with some of the above conditions but, in addition, have broken or missing parts, i.e. correction of these structural failures will always require skilled craftspeople, and the removal of components.

The Inference Engine

On-site evaluation of a building's windows requires a checklist of questions and "help" facilities which support the data collection. Currently, data collection and user interaction have been developed for (i) wooden windows and (ii) steel windows. The concepts of significance and condition for wooden and steel windows are equivalent. However, detailed questions are materials related.

The WES operates by prompting the user to determine essential information, i.e.:

1. basic information about the building, e.g. establish the building's name, location, and overall style; note important aspects of the building; identification of each window type within the building.

2. identify and evaluate the condition of each window type, e.g. the need for repainting and reglazing; sash and frame repair; replacement of incompatible windows.

3. determine the significance of the windows, e.g. establish the historical significance of the building and windows.

The eventual outcome of the program is the evaluation of items #1 - 3 above in terms of repair and/or replacement options and in the establishment of final recommendations through a systematic assessment of each window. Typically, the field assessor examines the outside face of the building noting any signs of deterioration. The WES prompts the user with regard to any data requirements. Procedures for the evaluation of the windows is completed by the expert system.

The WES is based on a three step procedure, i.e. (1) identification of the important aspects of the building, (2) identification and evaluation of each different type of window in the building, and (3) identification and evaluation of the condition of each window type. These three areas guide how the system runs, how questions are asked, how data is stored and the design of input forms and reports.

Typically, the first section determines the context in which the windows exist. The user is prompted to specify the type of building being examined, e.g. administrative office;

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7 For a more detailed description of the three level condition taxonomy used in assessing the condition rating of each window see - Preservation Briefs 9: "The Rehabilitation of Historic Wooden Windows", NPS publications, DOI.
auditorium; bank etc. (A list of twenty building types is included as guidance.) Next the user is asked to specify the style of the building, e.g. Adam.; art deco; beaux art etc. (A list of thirty different styles are available for review.) Continuing, the user is required to specify the construction date of the building (if known); the number of window styles; total number of windows per style; primary geographical elevation.

The second section assesses the significance for each window type. Significance may vary from one window type/style to another. Therefore, to accommodate these variations, a multi-level significance rating structure has been defined. Specific information required for each window includes operating type, e.g. fixed, single-hung, double-hung etc; size; distinguishing features, e.g. bulls eye glass, arched top etc; original? Y/N; conforms to prevailing pattern or style? Y/N; known builder/architect? Y/N.

Finally, a condition assessment of each window is undertaken. The procedure follows a systematic visual inspection of both the outside and inside face of all windows. Typically, the user is required to assess the condition of all glazing; glazing putty; wood condition; exterior paint-work; frame condition.

Currently the data is collected on site using manual window condition inspection forms. Subsequently the data is transferred to the WES in the office.

REVIEW

It is acknowledged that funding levels for the repair and replacement of windows are finite and subject to competition with other components. Therefore, compromise on funding allocation will normally be necessary with most projects. Additional work is currently related to seeking and identifying consistency and compatibility between NPS, the user, and the WES. This work is on-going.

Further work relates to attempts to improve the user-interface to the current system through the utilization of an AutoCAD\(^8\) interface. In this instance, drawing files have been generated to represent common window styles, figure 1. These are stored as drawing blocks. Custom screen and icon menu’s have been written for ease of user selection, figure 2. In addition, attributes have been attached to the window blocks. [Attributes contain text and numeric data related to each window in terms of reference codes, identity, location and condition assessment.] A separate set of drawing blocks contain a pictorial representation of the various conditions, e.g. replace glazing, repaint, repair fixture etc. It is anticipated that each window’s condition will be identified directly using the AutoCAD interface. Each repair/replacement requirement is tagged with a numerical code that may be extracted using AutoCAD’s attribute data extraction facility. This data may subsequently be transferred directly to the WES.

\(^8\)AutoCAD, by Autodesk, Inc - an industry standard 2- and 3-D drawing package.
Fig. 1
Fig. 2
One of the main advantage of identifying and transferring data through a graphic interface is the medium itself, i.e. current condition survey methods frequently utilize simple drawings to identify location and the need for repair/replacement work. This data has to be subsequently reinterpreted in order to facilitate its entry into a DBMS package. It is this current need for reinterpretation that a direct graphic interface overcomes. This aspect of the work is at an exploratory stage of investigation, but early results are encouraging.

REFERENCES

APPENDIX 1

Wooden Window Decision Matrix

<table>
<thead>
<tr>
<th>Condition Level</th>
<th>Significance Level</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>0 1 2 3 4</td>
</tr>
<tr>
<td>1</td>
<td>1 4 4 4 4</td>
</tr>
<tr>
<td>2</td>
<td>2 7/8 9 14 13</td>
</tr>
<tr>
<td>3</td>
<td>2 7/8 7/8 12 8</td>
</tr>
<tr>
<td>4</td>
<td>3 3 3 3 11</td>
</tr>
</tbody>
</table>

**Condition Level:**
- 0 = Perfect
- 1 = Good
- 2 = Deteriorated
- 3 = Damaged
- 4 = Missing

**Significance Level:**
- 0 = Intrusion
- 1 = Important
- 2 = Significant
- 3 = Distinctive
- 4 = Vintage

Rules corresponding to matrix:

1. Because this window is an intrusion you should replace it with a visually appropriate new window. Since the window is in a good condition, however, the schedule of replacement may depend upon project economics.

2. Because this window is an intrusion in a deteriorated or damaged condition, you should replace it with a visually appropriate new window.

3. Because this window is missing, you should replace it with a visually appropriate new window.

4. Because this window is important and in a good condition, you should re-glaze and/or repaint it as necessary. All windows should be routinely inspected and maintained after repair.

5. Because this window is in perfect repair, no work is necessary. It should be cleaned as required and put on a preventative maintenance program.

6. Because this distinctive or vintage window is in perfect repair, no work is necessary. It should be cleaned as required and put on a preventative maintenance program. Special care should be taken to preserve this window.
7. This window is important or significant and in a deteriorated condition. Because it is located in a primary elevation to the building, you should reglaze, repaint and repair as necessary. All windows should be routinely inspected and maintained after repair.

8. This window is important and significant and in a deteriorated condition. It is not located in a primary elevation of the building. Repair is desirable, but if project economics do not allow, the window may be replaced with a visually appropriate new window. All windows should be routinely inspected and maintained after repair.

9. This window is significant and in a deteriorated condition; reglaze, repaint and repair it as necessary. All windows should be routinely inspected and maintained after repair.

10. This window is vintage but in a damaged condition. Repair this window, regardless of the cost. Should that be impossible, it should be replaced with an exact copy.

11. This missing window was a vintage window. You should replace this window with an exact copy, regardless of cost.

12. This window is distinctive but in a damaged condition. Repair this window, regardless of the cost. Should that be impossible, it should be replaced with an exact copy.

13. Because this window is vintage but in a deteriorated condition you should repair this window, regardless of the cost. Should that be impossible, it should be replaced with an exact copy.

14. Because this window is distinctive but in a deteriorated condition you should repair, reglaze and repaint as necessary. All windows should be routinely inspected and maintained after repair.