CAD-SPREADSHEET LINKAGES FOR DESIGN AND ANALYSIS

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ABSTRACT

This paper reports on two systems under development which link a CAD system with a spreadsheet. The first extracts areas and R-values from a special AutoCAD drawing and processes the information in a Lotus 1-2-3 spreadsheet to obtain total heat loss for a building. The second is a prototype expert system which uses space labels from an AutoCAD "bubble-diagram" to print lists of design recommendations extracted from a Lotus 1-2-3 data-base. These methods emphasize drawing as the primary design activity, while providing immediate factual feedback about the design proposal.

CAD-SPREADSHEET LINKAGES FOR DESIGN AND ANALYSIS

Our profession is called the "practice" of architecture, and for good reason. Apart from DOs and DON'Ts or SHOULDs and SHOULDN'Ts learned from teachers and colleagues or from reading and observation, much of the practicing architect's knowledge is gained from trial and error. One "tries" a design (at a client's expense) and hopes that the errors (there will be some!) are minor enough not to cause injury or prevent continuation of one's practice.

But that is the nature of architecture. Constructing prototypes or full-sized "test models" is generally unfeasible. Time for the research needed to gather sufficient information is limited. Analytic methods are available in certain objective areas, such as structures and energy performance, but the expense of these methods usually confines their use to a few basic proposals, not each scheme one sketches. If accurate information on building performance could easily be extracted from every drawing, the trial and error process would take place at that level, with great improvement in the product as well as the practice.

Here, of course, is where the computer can aid in the design process; by allowing one to do the trial and error on data models rather than real buildings. I have been working on this problem by linking CAD drawings with spreadsheets. My goal is to keep the input process as close to normal drawing techniques as possible,
while letting the spreadsheet process information extracted from
the drawing. This paper reports on some of my preliminary work.

Two on-going studies will be described, both of which link a
popular 2-D CAD program, AutoCAD (Autodesk, Inc.) with a popular
spreadsheet, Lotus 1-2-3 (Lotus Development Corp.) The first
analyzes building heat loss, and the second is a simple expert
system.

STUDY NUMBER ONE: HEAT LOSS ANALYSIS

AutoCAD has several capabilities beyond basic drafting:

1. Special menus can be developed for the screen.
2. These menus can consist of "macros" which concatenate
   multiple commands into one.
3. Entities (called blocks) can be constructed for later
   insertion as a single object.
4. These blocks can have attributes (ancillary
   information) attached to them.
5. The attributes can be extracted and saved in an ASCII
   file readable by other programs.

Taken together, these capabilities allow one to tailor the CAD
system for specialized use, while retaining drawing-focused methods
for recording information.

The system under development in this study allows one to draw a
floor plan showing walls, floors, roofs and openings, with R-value
and height (when appropriate) "attached" to each entity as
attributes. Information from the drawing can then be extracted and
incorporated into a Lotus spreadsheet, which calculates the
building's total (winter night) heat loss.

For brevity in the following description I assume the reader has
some knowledge of AutoCAD and Lotus 1-2-3. Refer to Figs.1 & 2:

```
[SETUP
LIMITS 0,0 60’,45’ SNAP R .001 GRID 4’ FILL OFF OSNAP NEA
[WALL-INTIINSERT WALL-1 \1\1TRACE 25;\1NODE 1\1
[WALL-RIGHTINSERT WALL10 \1\1TRACE 5;\1NODE 1\1
[WALL-RIGHTINSERT WALL19 \1\1TRACE 10;\1NODE 1\1
[WALL-OUTINSERT WALL28 \1\1TRACE 15;\1NODE 1\1
[SLABINSERT SLAB \1\1
[ROOF-RIGHTINSERT ROOF19 \1\1
[ROOF-LEFTINSERT ROOF26 \1\1
[DOORINSERT DOOR \1\1
[WINDOW-SPLITINSERT WDN1 \1\1\1\1\1
[WINDOW-SPLITINSERT WDN2 \1\1\1\1\1
[WINDOW-TRIPINSERT WDN3 \1\1\1\1\1
```

Fig.1 SPECIAL MENU FILE FOR THE AUTOCAD SCREEN
The ASCII file shown in Fig. 1 was constructed using a line editor (EDLIN). When called up from the main AutoCAD menu, the words in square brackets ([ ]) appear on the screen menu as commands. When a menu item is picked, the series of commands (macro) after the brackets is executed. Each INSERTed item is a block with its R-value attached in hidden form. Each "\" allows for mouse or keyboard entry at that point. These macros are carefully designed so that a minimum of information need be entered by keyboard. For instance, each wall has its R-value attached, but we must enter its average height from the keyboard. In the plan, we draw a wall by "picking" the wall type from the screen menu with mouse and cursor (WALL10, for instance, where 10 is the R-value) and locating the end points on the screen. The macro after the menu command then inserts the wall as a block with pairs of lines spaced by a distance roughly proportional to the R-value. (The interior wall has a large R-value, so that it shows no heat loss in the analysis. (No interior walls are shown in this drawing.)

After picking their locations, both dimensions of the openings must be entered by keyboard. Windows and doors show in a symbolic way on the plan; only their identification with a certain wall, not their position in that wall, affects the heat-loss calculations. Slabs (dotted outlines) and roofs, (dashed outlines) for the present must be divided into rectangular sections, picking opposite corners on the screen.

Once all the entities are drawn on the plan, desired information can be extracted by AutoCAD and written to an ASCII file. A template file (in the form of a d-BASE II template, Fig. 3) specifies the information to be extracted for each block, whether to use single or double quotes as delimiters for string information, and the data-separator symbol desired. The extracted file for the plan of Fig. 2 is shown in Fig. 4.
Fig. 3 TEMPLATE FILE

Fig. 4 EXTRACTED FILE

Fig. 5 SPREADSHEET SUMMARY AND IMPORTED FILE

At this point we exit AutoCAD and enter Lotus 1-2-3, calling up a special spreadsheet template, importing the extracted file into the spreadsheet (Fig. 5). Using Data-Query commands, we now copy the data for walls, openings, and horizontal surfaces to appropriate areas of the spreadsheet (Fig. 6A & 6B). Formulas built into the sheet (in AREA and HT LOSS columns) do the appropriate calculations, heat-loss being based upon the temperature difference entered at the left. There is one exception; the area of the openings must be subtracted from the walls in which they are located. This requires some Lotus "programming" (called "the typing alternative" by Lotus), in
<table>
<thead>
<tr>
<th>No.</th>
<th>Data 1</th>
<th>Data 2</th>
<th>Data 3</th>
<th>Data 4</th>
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<tr>
<td>1</td>
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<td>3.00</td>
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<tr>
<td>2</td>
<td>5.00</td>
<td>6.00</td>
<td>7.00</td>
<td>8.00</td>
</tr>
<tr>
<td>3</td>
<td>9.00</td>
<td>10.00</td>
<td>11.00</td>
<td>12.00</td>
</tr>
</tbody>
</table>

**Figure 7: Lotus Macros**

- **Diagram Description**: Diagram showing the relationship between various elements in Lotus Macros.

**Table 1: Data Overview**

<table>
<thead>
<tr>
<th>Column 1</th>
<th>Column 2</th>
<th>Column 3</th>
<th>Column 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data1</td>
<td>Data2</td>
<td>Data3</td>
<td>Data4</td>
</tr>
<tr>
<td>0.50</td>
<td>1.50</td>
<td>2.50</td>
<td>3.50</td>
</tr>
<tr>
<td>4.50</td>
<td>5.50</td>
<td>6.50</td>
<td>7.50</td>
</tr>
</tbody>
</table>

**Figure 6B: Openings and Horizontal Elements**

- **Data Representation**: Table showing the horizontal elements with their respective values.

<table>
<thead>
<tr>
<th>Element</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>B</td>
<td>1.00</td>
<td>2.00</td>
<td>3.00</td>
</tr>
<tr>
<td>C</td>
<td>4.00</td>
<td>5.00</td>
<td>6.00</td>
</tr>
</tbody>
</table>
effect a series of macros. The macros shown in Fig.7 perform this
task, examining the x- and y-coordinates of each opening and wall,
and matching them up. Once matched, formulas in the spreadsheet do
the subtracting.

By changing the temperature difference one can immediately see a
new value for the heat-losses. Fuel cost calculations will soon be
added. Other "experiments" such as changing the R-value of a wall
or opening can now be done directly in the spreadsheet, or the
drawing can be revised and the process repeated. Unfortunately,
there is no way currently to send information back to AutoCAD, a
very desirable feature, but one not likely to be developed. This
may be possible, however, in future CAD systems which incorporate a
spreadsheet. (At least one CAD system currently does this, but I
believe information flow is still one-way).

Many future enhancements to this system are needed and planned,
and its usefulness must be tested in classroom trials. The goal
is to make this and related systems automated enough for students
to get several forms of accurate feedback about their proposals
while they are still in a sketch stage of design.

STUDY NUMBER TWO: A SIMPLE "EXPERT SYSTEM"

This system uses the capabilities of AutoCAD and Lotus 1-2-3
listed above, but at an earlier stage of design, the analysis or
"bubble diagram" stage. I believe bubble diagrams should be
scale-less and used primarily to discover and examine the
interrelationships among the spaces in a building program. When
one begins organizing the spaces into a design scheme, they should
be sketched at correct scale, and the relationships should be
known and well-understood in order to guide the organizing
process. Little or no effort should be made to optimize the
location of bubbles at the analysis stage.

For this system I have automated the bubble-and-link drawing
process using the INSERT/BLOCK methods of AutoCAD. To this I have
overlaid a Lotus 1-2-3 routine which extracts, from a database in
the spreadsheet, recommendations about the spaces in the diagram.
For the example below, the recommendations are elementary ones
about a simple house, used only to test the working of the system.
I shall discuss the development of more sophisticated sets after
outlining how the system works.

A special menu (Fig.8), is appended to the standard AutoCAD menu.
The blocks available to be inserted are BUBBLES (function spaces),
LINKS and BARRIERS. Bubbles are given attributes (at this point
merely an abbreviated function name) by picking a label from the
menu (lines 1068 to 1078). The selection of link types is: weak,
medium and strong. Barrier types are: noise, vision, fire and
security (NVFS, Fig.9) The links and barriers are included at this
time only for the designer’s mental analysis process, but will be
incorporated into future computer analyzes as development of the
system continues.

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Fig. 9 BUBBLE DIAGRAM

We begin drawing the diagram by picking inserts from the screen menu, bubbles first, with links and barriers added as their need is perceived. The attributes are next extracted (Fig.10) and transferred to a Lotus spreadsheet (Fig.11).
Fig. 10 EXTRACTED FILE

Included as a part of the spreadsheet template is a database consisting of a set of recommendations (more about their source later), and a matrix linking each space to its pertinent recommendations (Fig. 12). Now we invoke a set of macros (Fig. 13).

Fig. 11 IMPORTED FILE

Fig. 12 DATA BASE

Fig. 13 LOTUS MACROS
which use the Lotus Data/Query commands to sort thru the matrix, transferring recommendations for each space to an output area of the spreadsheet (Fig. 14). The macros then send the list to a printer, producing a checklist for reference during design (Fig. 15).

<table>
<thead>
<tr>
<th>CRIT1 OUT1</th>
<th>CRIT2 OUT2</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIM DIM</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Fig. 14 LOTUS CRITERIA AND OUTPUT CELLS DURING MACRO OPERATION

- DIM
  - No thru traffic
  - Create conversation groupings of furniture
  - Fireplace
  - Clear wall space for larger art work
  - View if possible
  - Easy access to deck or patio
  - East or south orientation preferable

- KIT
  - No thru traffic
  - Easy access to deck or patio

- DIN
  - Clear wall space for larger art work
  - Easy access to deck or patio
  - East or south orientation preferable

- MBR
  - No thru traffic
  - Fireplace
  - Clear wall space for larger art work
  - Easy access to deck or patio
  - East or south orientation preferable

- OUT
  - Sorry, no recommendations available for this function.

Fig. 15 PRINTOUT OF CHECKLIST

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The checklist is not meant to supplant the usual design research, but to serve as a reminder of points which often are forgotten as a student concentrates on the major focus of a project. The recommendations should be carefully worded so that the "musts" can be separated from the "shoulds". Healthy scepticism needs to be fostered, and the students should be encouraged to develop their own set of mental checklists as they gain design experience.

Several methods for developing sets of recommendations are possible. General design recommendations might be gathered by surveying design instructors, tailoring each set to suit a particular design-class level. Specific sets could be developed by the technical faculty in areas such as lighting, acoustics, structures and energy, again adjusted to design level, as a way of prodding the students not to forget these factors when the focus of a project is in other areas. It would be a useful class project for students to undertake the development of such a set, researching buildings and the literature, and debating the wording and inclusion or exclusion of particular recommendations. And perhaps a class could develop a set, based upon the "style" of a particular architect, to see how following them might influence their own designs.

Why involve CAD? Why not just enter a list of spaces into a data base and extract the checklist directly? I want to keep drawing as the major activity in the process, with the computer responding as a consequence of human action, rather than taking over the action. I also intend the system to include further operations on the bubble diagram, such as automatic production of an interaction matrix. Processing the diagram's attribute information with a BASIC program rather than a spreadsheet could also produce numeric or graphic output to guide design decision-making.

Although the above two projects are in early stages, and need much further work and evaluation in class, I feel the results to date demonstrate one way that CAD can become a useful design tool as well as a useful production tool.

REFERENCES

1. The AutoCAD 2 (tm) Drafting Package User Guide
   Autodesk, Inc., 1984

   Lotus Development Corp., 1984

3. 1-2-3 Tips, Tricks and Traps
   Dick Anderson and Douglas Ford Cobb
   Que Corp., 1984