CAD AND THE BAROQUE

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ABSTRACT

After a review of various methods of teaching computer aided design in schools of architecture, including "the conventional wisdom of CAD", an approach is presented whereby the application of this "wisdom" is taught by creating very complex drawings of Baroque elevations. A description is given of how such drawings may be structured and of how a group of students may work on such drawings simultaneously to complete them expeditiously. An extension of this method of teaching architectural CAD is discussed wherein students would not only draw but would also design detailed elevations and plans of villas in the Palladian manner using recently developed computer aids to assist in the design.

INTRODUCTION

Much has been written concerning the teaching of computer aided design (CAD) in schools of architecture: How can CAD be used in the design studio and what has been the experience of those who have used CAD in studio teaching (Brown, 1987; Various, 1989)? How can one teach CAD to prepare students for the use of CAD in studio and also reap side-benefits concerning the geometrical structure and grammar of architecture (Seebohm, 1988)? Should one teach graphics programming in order to understand the nature of computer aided design in architecture (Mitchell, 1987)? Should computer aided design systems be top down or bottom up; that is, should they be based on a design method developing successively greater levels of detail or should they combine elements containing all levels of detail (Mitchell, 1989, Wojowitz, 1986)? Should CAD be used as a new medium which facilitates new vocabularies and grammars (Yessios, 1988)? Should two-dimensional CAD be studied at all because all two-dimensional images can, in theory at least, be created as projections from three-dimensional models (Schmitt, 1988)?

In all probability, there are merits in all approaches. It is helpful to recognize, however, that computer aided design is an aid which does not in itself possess any design capability. CAD skills and theory can therefore be taught separately from the studio. The importance of a "theoretical supplement to the studio" was emphasized at the recent CAD Futures 89 Conference (Van Wyk, 1989).

In view of the wide range of options, or perhaps in spite of them, I would like to introduce yet another option for the "theoretical supplement". This is the teaching of what has been called, somewhat derogatively, "the conventional wisdom of CAD" and it refers to the functionality of commercial, two-dimensional CAD systems. Although such commercial CAD systems still have not achieved the promise inherent in the first computer aided design program, namely, Ivan Sutherland's Sketchpad program of 1963 (Sutherland, 1963) and, although there will be an increasing use of three-dimensional CAD, the basic two-dimensional CAD functionality will always be needed in any architect's office. This basic functionality will also be the basis of more "intelligent" capabilities much as AutoLISP programs build on the basic capability of AutoCAD.
MERITS AND NATURE OF THE CONVENTIONAL WISDOM OF CAD

In spite of frequent references to the "conventional wisdom of CAD," this "wisdom" has not been explicitly defined. I propose that this "wisdom" can be defined and classified as follows, according to a generic, two-dimensional functionality:

1. Creation of entities-
   These entities include points, lines, circles, arcs, ellipses, text, dimension lines and cross hatching, among others.

2. Structuring of entities-
   This includes the capability to aggregate entities into objects (or blocks) which may have hierarchical structures (such as objects within objects), into layers and into drawings.

3. Editing or manipulation-
   These capabilities allow entities, objects, layers and drawings to be transformed by such operations as moving, rotating, copying, mirroring, scaling and replication.

4. Dimensional referencing-
   For accurate drawing of graphic entities to specific dimensions and in specific locations, an x-y reference coordinate system is provided. To facilitate in sizing and positioning graphic entities, functionality is provided such as snapping grids, construction lines, and snapping functions (These allow referencing to existing graphics by snapping to points on these graphics such as the end points, mid points, and intersections of lines and by allowing entities to be created parallel or perpendicular to existing graphics).

5. Viewing-
   Viewing provides a means for displaying more or less of the graphics on the two-dimensional x-y reference plane, for zooming into details, for panning (moving the view without change of magnification) and for creating specific views of graphic entities for recall at a later time with or without the simultaneous display of other views.

6. Non-graphic attributes-
   This refers to the ability to extract non-graphic text and numeric information stored with graphic objects for the purpose of tabulating, sorting and counting, for example (The tabulating, sorting and counting may be done with software external to the CAD system).

7. Obtaining hard copy output

Intentionally not included in the "conventional wisdom of CAD" is the functionality to customize the user interface, that is, to arrange screen menus, tablet menus and function keys to one's personal liking. Also not included is the ability to create "macros", that is, to be able to string a series of functions from the basic CAD functionality together to create more complex functions; nor is the ability to write software which will build onto the basic CAD functionality to provide entirely new capabilities as one can with the AutoLISP extension of AutoCAD. All of these latter capabilities build on the basic functionality in categories 1 to 7 and are therefore not included.

Note that the replication functionality (in 3 above) includes replication of objects and entities along circles, and lines, and in grids. Thus shifted and rotated grids of objects can be created. Additionally, all types of rotational, dihedral and bilateral symmetry as well as freeze and wall
paper symmetry can be studied. The various types of replication and symmetry, discussed theoretically by March and Steadman (March, 1971) and taught through programming by Mitchell (Mitchell, 1987), can therefore be introduced as part of a course on "the conventional wisdom of CAD".

Another merit of acquiring a good general knowledge of "the conventional wisdom of CAD" is the benefit of this knowledge when learning to use an unfamiliar, commercial CAD System. This is because the student of this "wisdom", when confronted with an unknown function in an unfamiliar CAD system, will at once try to classify this unknown functionality into one of the categories he already knows, and being also aware of the range of possible ways in which this functionality can be achieved, will quickly find that the unknown functionality is already familiar to him and can help him where the manuals cannot. For example, according to the above generic wisdom, all CAD systems use an x-y coordinate system as a reference to assist in positioning graphic entities. Minor variations between systems in the choice of defaults for the position of the origin of the coordinate system on the screen or for how much of the coordinate system is visible on the screen or for the manner in which these defaults may be changed, will not deter him. Moreover, he will realize that if his CAD system is such that it allows him to draw in real units such as feet or meters, without having to worry about scale, then when he wishes to plot the drawing he must decide on a scale which will allow his drawing to fit onto the drawing sheet he has provided. While he is drawing he will not be able to set the height of any text in terms of the height he would like it to have on paper when it is plotted (because that depends on the scale of the drawing to be chosen at plot time), but must choose its height in terms of the units in which the architecture is dimensioned. Alternatively, if our student is confronted with a system which creates all graphic entities as if they were being drawn on a drawing sheet whose size he can select, he will realize that he must immediately commit himself to a scale (which is not unreasonable because, as is shown below, the amount of detail which can be shown on a drawing depends on its scale). This latter system is likely to permit him to choose the height of the text in terms of the height which it will have when it is plotted and he will be able to draw in more than one scale on the same sheet (in the first system, multiple scales on a single sheet can only be achieved by applying a scaling factor to graphic entities to expand or shrink them but the user must now keep track of the scale of these entities).

This knowledge of the "conventional wisdom of CAD" also allows one to appreciate the possibilities and limitations of translators between different CAD systems and the implications of using different file formats be they DXF, IGES or something else. Again consider our student now confronted with the task of translating a drawing from one CAD system for use by another with commercially available translator software. Suppose that the system from which the drawing is to be translated structures graphic entities, as is most often the case, into layers and objects (also referred to as blocks) but does not require all entities to be structured into objects, although they must reside on layers. Suppose that the other CAD system, is like the GDS system to be discussed below, which requires all entities to be structured into objects (which in turn can be grouped into clusters) but does not use layering as it is commonly used (the system can overlay drawings). Our student will not be surprised to learn that the unstructured entities, such as lines and circles, in the first CAD system become graphic objects in the second system with each object carrying the name of the layer on which the graphic entities resided in the first system, but that otherwise all evidence of the layers in the first system is ignored in translation to the second.

This is one possible translation scenario which our student may find acceptable for his purposes. He may, however, wish to have an equivalent of the layering in the first system after translation so that those parts of objects residing on certain layers in the first system may result in separate objects in the second. These parts of objects could then be suppressed as if layers were suppressed in the first system (This assumes that objects can be suppressed by name in the second system. As will be seen in the discussion below, the GDS system allows whole collections of objects to be addressed conveniently because of the naming structure it employs for its objects.). A flexible translator where the user has a choice as to how graphic structures from one system are translated
to another would permit such a translation. With a flexible translator it should also be possible to translate layers from the first system into discrete drawings in the second. The second system could then overlay these drawings using its windowing capability (to be discussed below) to provide a drawing image identical to that on the first system together with an equivalent layer structure. The student of the “conventional wisdom of CAD” will therefore look for translators with the maximum possible flexibility regarding how a particular translation is to be affected (although this does not preclude some convenient default settings) and will be able to make intelligent choices from among those offered so that the translated drawings provide both the appearance and the structure he seeks. He will also be concerned as to whether or not a particular file format for storing a CAD drawing, such as DXF or IGES, will be able to represent the drawing structure and image he is seeking.

Much of the conventional wisdom of CAD, as defined above, can be learned by students on their own using computerized tutorials (for example, CadPLUS Tutorials for AutoCAD). There is, however, a paucity of learning material in how to apply this “wisdom”. For example, how does one organize objects, layers and drawings in architectural practice (one approach is suggested by Schilling–Schilling, 1987)? What organizational principles are involved where groups of people work together on large, complex drawings using multi-user or networked systems?

THE BAROQUE IN CAD

In what follows, a course is described which covers both the “conventional wisdom of CAD” and its application. In this course students learn to use two CAD systems, one running on stand-alone desk top computers (AutoCAD on DOS machines) and the other on a multi-user minicomputer (McDonnell Douglas GDS software on a VAX 11/785). Computer tutorials, special seminars on the more difficult aspects of these two CAD systems, and the application of the systems to the creation of specific floor plans and elevations provide a reasonably general knowledge of CAD “wisdom” which transcends any particular system.

The true “wisdom” to be gained from this course comes from the creation of extremely complex Baroque elevations with the GDS software. So far, three elevations have been tried. One is Carlo Maderno’s facade for St. Peter’s in Rome dating from 1626 (Figures 1 and 2). Another is the facade of the Villa Giulia in Rome by Vignola and Ammannati dating from 1530 (Figure 3). A third is a section-elevation of the Palazzo Farnese in Rome by Antonio Sangallo the Younger dating from 1530-89 (Figure 7). The drawings are too complex for individual students to complete in the available time. Groups of ten to twelve students have, therefore, worked simultaneously on the same drawing necessitating a careful structuring of the drawings and the use of multi-user system features. Most essential of these features is the ability of each student to be able to overlay his or her drawings, by means of a windowing capability, onto the drawings of all the other students for a systematic coordination of the work of all of the students.

The procedure for creating the elevations can be divided into eight steps as follows:

1. Dimensional information for the elevations is obtained, where possible, directly from the dimensions on the drawings in Letarouilly’s large and rare folio volumes (Letarouilly, 1872 and 1884). What cannot be read off directly is obtained by proportional subdivision using large photographic prints (16” x 20”) photographed directly from the large folio volumes. Proportional subdivision is the process whereby distances are obtained by proportionally subdividing a known distance (as read from Letarouilly’s dimensions) to obtain additional dimensions such as the distance between successive moldings in the jambs of a window.

2. The elevation is analyzed to determine the graphical objects of which it is composed and to determine the underlying grid on which these objects are placed. It appears that a classical elevation can always be analyzed in this way. Figure 4 shows a sketch recording
Figure 2  Detail of facade of St. Peter's Rome.
Drawn with GDS.
Figure 3  The Principal facade of the Villa Giulia, Rome 1555. Drawn with GDS Software.
Figure 4 Sketch analysis of the facade of St. Peter's, Rome showing objects and naming conventions for use with GDS Software.
Figure 5  Ordering grid superimposed on the facade of the Villa Giulia
Figure 6  The ordering grid for the Villa Giulia after some of the window and central door objects have been inserted on the grid.
the analysis of the graphical objects for the facade of St. Peters. Figures 5 and 6 show the
grid underlying the facade of the Villa Giulia. A master grid drawing is therefore prepared
by one of the pairs of students into which the class is divided so that the other pairs can use
this grid as a reference when placing their objects.

3. The graphical objects are named so as to apportion a certain number of them to each pair
of students. Furthermore, the objects are structured hierarchically by naming a number of
sub-objects which make up each complete object (This allows for flexibility in the reuse of
subobjects as well as the complete object). This structuring is possible because every object
can be designated with a faceted name such as TG5:WIN:A:MAIN where the facets are the
characters between colons. Consider as an example a window on the facade of the Villa
Giulia which might be described by an object name with three facets as shown in below:

   TG5:WIN:A:PANA
   TG5:WIN:A:CEN
   TG5:WIN:A:PANB

Figure 8  Faceted Object Naming for a Window

All the objects comprising the above window can then be referred to with the wild card
notation TG5:WIN:A:**. With this notation the entire window can be copied and moved as
one object. The same window without the panel beneath the sill can then be referred to as
TG5:WIN:A**: less TG5:WIN:A:PANA (which is one way to identify a collection of
objects in GD3). A more hierarchical naming convention is also possible, however, as
shown below in Figure 9:

With this convention, the entire window “A” can be referred to by TG5:WIN:A:***. The
window without the lower panel could then be referred to as TG5:WIN:A:CEN:***, while
the window without a panel below or above could be referred to as
TG5:WIN:A:CEN: MID.

It is clear then that the hierarchical structure is determined by the way the components have
certain facets in common in much the same way that directories and subdirectories are
structured in the DOS, VMS, and UNIX worlds.
Figure 9  Faceted Object Naming for a Window

4. All the graphic objects consisting of straight lines and arcs are drawn, and each grouping of objects, such as a window, is placed in its own drawing (Note that GDS does not allow one to draw anything without having named a graphic object first to contain the graphic entities such as lines and arcs). All sculptural details, such as capitals, are digitized from enlarged photocopies using a digitizing tablet. The details are traced at the scale of the enlarged photocopies. As in the case of drawn objects, each detail is traced into its own drawing to avoid clutter (although more than one detail can be traced into a single drawing). Digitizing details brings into focus another lesson of the course: namely the question of the appropriate level of detail necessary for a drawing at a particular scale. For example, the capitals in the St. Peter's drawing in Figure 1 are too detailed whereas the same level of detail is quite appropriate for the large detail in Figure 2 (The elevations were plotted, before reduction, at 1:130 in the case of St. Peter's, at 1:50 in the case of the Villa Giulia and at 1:100 in the case of the Palazzo Farnese).

5. Each pair of students transfers all of the objects they have created on their small drawings to their master drawing, which represents their contribution to the overall elevation (Consolidating the objects into one drawing per group is only one approach. Sometimes, for reasons of display time, it is convenient to retain several drawings which when overlaid together represent a pair's contribution to the elevation).

6. Each pair of students then overlays their master drawing with the master grid drawing and the master drawings of all the other students. The students accomplish this by creating a named window (from their computer account) which looks onto the master grid drawing overlaid with all of the students' master drawings. Each drawing is stored in a "phase" of the window. A phase is analogous to a layer in a layered CAD drawing with the difference that each phase is a separate drawing rather than part of one drawing and can be interchanged with another drawing at any time. In each phase a drawing can be made "hitgable", that is, the drawing will be one in which the graphics can be snapped to but not changed, or it can be made "editable", meaning that the graphics can be changed, or it can
be made "visible" so that the graphics are neither "hitable" or "editable" but only visible. All drawings in all phases are made hitable except a particular student pair's own master drawing. What appears then in each group's window looks like a layered drawing, each phase being like a layer and appearing in a different colour. By using windows as described here, each pair of students is able to place their objects, such as the windows and columns of the elevation, on a master grid and to coordinate all their work with that of the other students so that railings and moldings may be aligned, for example. At any moment in time the drawings visible in all the phases are the latest versions of the other students' drawings because they correspond to the most recently filled versions. There can never be confusion as to what is the latest version and one does not have to chase down the other students to ask for the latest version of their drawing (it is noted that windowing onto drawings in another account is only possible if the owner of the other account provides permission to read by setting an attribute to this effect for the drawing file to be windowed).

7. All that remains at this stage is to complete the master drawings by copying the objects, which had been transferred to them in step 5, to the correct locations over the master grid by snapping the origin point of the objects into the appropriate horizontal and vertical grid intersections (it is assumed that when the objects were drawn an appropriate origin was selected keeping in mind placement on the grid).

At the conclusion of this step the drawings in all of the phases of the window created in step 6 are complete. For the Villa Giulia, Figure 10 shows an exploded view of the phases which were used to create the complete drawing in Figure 3 (Construction line and grid line objects have been suppressed in Figure 3). Nine phases were used to complete this drawing (three of which are shown coalesced into one phase for the purpose of this illustration). Given that five pairs of students worked on the project it is clear that most of the students used more than one master drawing. Note that each of the elements of the elevation, such as windows and columns, were created on separate, small drawings in step 4 and then transferred to a particular drawing in a particular phase as shown for a second floor window in the upper left of Figure 10.

8. A plot of the final elevation is obtained by plotting the window with the view of all the overlaid drawings. For this purpose, the window created by any one of the pairs of students, could be used because it contains all drawings.

Classical architecture, of which the Baroque is a phase, lends itself to the teaching and application of much conventional CAD functionality including various repetitions and symmetries. For example, at the cornice of the Villa Giulia (Figure 3) there is a continuous row of brackets which represents a simple frieze group (to use March and Stedman's terminology, March, 1971) consisting of one shape, the bracket, translated and repeated along a linear axis. Linear repetition is basic to conventional CAD functionality. The same functionality could be applied to the triglyphs and metopes at the first floor's frieze of the Palazzo Farnese (Figure 7) and similarly it could be applied to the friezes at the second and third floors. Mirroring belongs as well to the basic tools of CAD functionality. This capability can be effectively applied to the many occurrences of bilateral symmetry in the Baroque elevations presented here: every door and window is symmetrical and every part of the elevation has a symmetrical counterpart. In fact, only half of most elements on the elevations needed to be drawn. There are, however, many other examples of repetition: many elements in the elevation from columns and windows to roof tiles can be replicated directly while others may be copied by interchanging, adding or deleting subcomponents like the panels which appear above certain windows but not others. On account of these various forms of repetition and symmetry, a CAD system will show significant gains in productivity over manual drawing when used to create Baroque elevations. In addition there is the benefit of being able to draw fine details at a larger scale than shown in the final drawing and of drawing with great dimensional precision.
Figure 10  Exploded View of the Phases Used to Create the Elevation of the Villa Giulia in Figure 3
Dimensioning is therefore another important lesson where much insight can be gained in creating Baroque elevations. Perhaps the most important step in creating the elevations is the laying out of the dimensioning grid (Figure 6) and the relation of all dimensions to the grid both when determining the size of the graphic objects to be placed on the drawing and when choosing appropriate insertion points on the grid for placing the graphic objects on the elevation. If objects are not dimensioned in relation to the grid by proportional subdivision, when no explicit dimensions are available, experience indicates that, as a result of cumulative dimensioning errors, the objects will not quite fit into the space available on the elevation. Thus a window may slightly overlap its jambs, bounding columns or pilasters (Scaling to correct for this would only introduce other errors). If insertion points are not chosen to lie on the dimensioning grid, much time will be lost in zooming to place objects on the basis of other visual cues. The lessons from laying out Baroque drawings apply equally well to modern working drawing practices. A well chosen reference grid for dimensioning (often coinciding with column lines) makes it easier to comprehend the dimensions and makes it easier to lay out dimensions in the field.

The manner in which the elevations are composed clearly points to the applicability of a "top down" approach in which objects such as columns and windows are placed on a grid and then elaborated, by substituting more detailed designs for simpler ones. A more bottom up approach where parts of elevations, such as entire entries which are themselves assembled from completed objects, are placed on the grid, is also possible. The question of bottom up or top down suggests an idea for a more innovative course which can lead to a deeper appreciation of the Baroque as well as of the application of knowledge-based techniques. The idea would be to ask students to design detailed Baroque elevations as part of an overall building design in the manner of a certain architect. Various treaties by, say Alberti, Palladio, Vignola, Scamozzi, Serlio and Sir William Chambers, can be consulted for the elements of Classical or Baroque architecture such as columns, capitals, pedestals, cornices and arches. These elements could be copied and scaled or they could be programmed by students in AutoLISP, for example, to build up over time, a library of parameterized elements, where the parameters would allow the adjustment of actual dimensions to the design at hand with the proportions always remaining as required by the treatise in question. While prescriptions for the ordering grid do not appear in the treatises of the above architects, the grid may be based on the fact that all classical architecture is symmetrical and based on the tripartite scheme of proportioning (Tzonis, 1986), either in its simple form, ABA, or in elaborations such as the ABCBA of the Villa Giulia facade or the ABCDCB of St. Peter's. Given that Mitchell et al (Mitchell, 1988) have already programmed a number of the required elements from Scamozzi, Vignola and Palladio in the TOPDOWN System, one could use that system to produce some of the elements for the proposed course (assuming that a translator was written to move TOPDOWN files to GDS). Indeed, Mitchell et. al. have foreseen this possibility.

As described so far, the proposed extended course presupposes considerable knowledge of the Baroque which suggests that the course focus on the work of a particular architect to limit the knowledge required. Although they predate the Baroque, the villas of Palladio could provide more focused subject matter and a more precise method of determining the underlying grid of the elevation. The work of Mitchell and Stiny (Mitchell, 1978a, 1978b) on Palladian floor plans and the work of Hershey and Freedman (Hershey, 1990) on Palladian floor plans and elevations could be used to determine the underlying grid on which to dispose the classical elements on the elevation. Both approaches have advantages and disadvantages. Mitchell and Stiny's approach has the ability to systematically enumerate different plan forms on the basis of an underlying tartan grid (eg. a grid composed of five rows and three columns of rectangles) but they do not supply a working program nor do they supply explicit algorithms to proportion the grid and hence the rooms. Krishnamurti has produced such algorithms but they are not readily available (Krishnamurti, 1978).

Hershey and Freedman supply a computer program for the Macintosh which includes implicitly Palladio's proportioning schemes. The method is based on subdivision of a rectangle into rooms
Figure 11  Floor plan and elevation resembling the Palazzo Antonini as generated by the Freedman and Hershey Program (with permission)
but it produces layouts randomly thus precluding a systematic selection of a preferred layout. One simply has to accept what one obtains after a random number of trials. Once a floor plan has been decided upon, (and this could be the floor plan drawing exercise of the first part of the course) an elevation can be generated by Hershey and Freedman's program. This elevation can then be "adjusted", given that the program's judgement is sometimes questionable, and elaborated with classical elements created in Mitchell et. al's TOPDOWN approach. Any elements which cannot be created in the TOPDOWN approach could then be copied from the known work of Palladio as built or as in the Quattro Libri in a bottom up approach in which a finished grouping of elements, such as doorways, are placed directly. Figure 11 shows a floor plan and elevation, resembling the Palazzo Antonini, which was generated by the Freedman and Hershey program.

CONCLUSION

A course has been described which teaches the "conventional wisdom of CAD" through the use of two commercial CAD systems. The course also teaches the application of that "wisdom" to the creation of very complex Baroque elevations. By removing some of the teaching of the basics of the "conventional wisdom of CAD" to an introductory course, that is, by removing the AutoCAD portion to an introductory course, the present course can be extended to include top down techniques and allow students to design Baroque elevations rather than copy them. In the process, students would go far beyond the "conventional wisdom of CAD" to such current techniques as knowledge-based CAD and to a deepened understanding of the Baroque.

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