A New Tool for Studio Teaching
Object Based Modeling

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Abstract
The scope of this paper is to present Computer Aided Architectural Design (and more particularly the dynamic and incremental modeling characteristics of Object Based Modeling) as a tool to reinforce the teaching of architectural design. Utilized within a method based on a cyclical application of “Concept and Testing”, OBM has the possibility to work as an amplifier of design ideas and as a meaningful tool for the advancement of architectural design.

Three related experiences support this hypothesis. The role played in concrete designs by an Object Based Modeling environment. Teaching with CAAD and OBM in the realm of documentation and analysis of architecture. Previous applications of the Concept-Testing methodology in design studios. The central sections of the paper focus on the analysis of these experiences, while the last section provides a 15 week, semester based, studio structure that incorporates OBM in the overall calendar and in key assignments.

While the scope of this work coincides with the thesis presented at the Acadia ’92 conference in Charleston (South Carolina), to focus the argument more clearly content, text and illustrations differ in several parts.

1. Practice, Teaching and CAAD

In the 1989 ECAADE conference this author presented an experiment to show the potential of computers in documentation and analysis of architecture. The Hypercard based stack provided, for the first time, an example of interactivity in architectural teaching and criticism. It was focussed on the Workshop for gas production by Giuseppe Terragni and it provided: access to database sections with pictures and texts, direct tridimensional exploration of the building, animation insertions in addition to electronic sketching and notes taking. But the most important aspect did not concern the isolated materials present in this and in other examples but their level of integration and of interaction with the user. [note 1]

Figure 1: Three houses in Rome. a. Object Based Modeling environment. b. Section and elevation. Luigi Franciosini, Antonino Saggio architects
This research was in the area of architectural theory and criticism. The computer's value as a creative tool in the design process (and not only in the peripheral area of documentation and analysis) has become evident during the last three years of practice [note 2]. The interest towards the use of computers at the center of the discipline is due mainly to this author's increasing understanding of the design implication of softwares based on an Object Based Modeling (OBM) environment (Figure 1). The characteristic of this approach for architectural design is the basic content of this discussion. Its ultimate goal is to define "how" OBM can he incorporated into a design studio to reinforce and enhance the Concept-Testing teaching approach.

2. Object Based Modeling. Basic characteristics

An Object Based Modeling environment, as it is described by Eastmann [ref. 3], requires representation of a design in terms of the parts that it is composed of. These parts are separate objects, which are organized in a hierarchical structure. When a primitive object is inserted at a higher level of the hierarchy it is referred to as an instance.

In an OBM structure there is a fundamental difference between what is called an "object" and what is called an "instance".

Figure 2: Objects and instances in OBM. a. & b. hierarchical model construction. c. Duplication. d. Instantiation
The object can be a fully operating three dimensional volume, created with operations of extrusion and revolving applied to two dimensional polygons. Objects may be combined one within the other in a hierarchical structure (Figure 2). For example, a roof-object is created and then inserted in a typical unit-object, which may be inserted and duplicated in a site plan-object. When the original object is inserted in another object at a higher level of the model hierarchy (for example the roof in the typical unit) it is referred to as an "instance". Although each instance can be duplicated, proportionally scaled or distorted as a whole, real changes of its geometric properties (e.g. from a rectangle to a circle) can take place only at the level of its original "object" creation. The various parts of the overall structure of a model can be accessed and seen singularly or at their various level of combination.

Based on a recent course at ETH Zürich (in which OBM was used in the realm of architectural analysis [note 3]), it is useful to summarize the most evident advantages of this environment:

-- it allows the construction of a large and complex model even on a personal computer. Because of the separation between real object and instance, the file size is minimized (every time the program finds an instance it goes to the original object to read its properties which are therefore stored only once);
- since design and manipulation of the different parts of the hierarchy are controlled through "hide" and "show" commands rendering speed is increased and many thematic views may be produced;
- interactive architectural analysis is possible in this environment directly in the final model by activating or deactivating element. The critical concepts about how the project is interpreted are contained in the way the model is built. Therefore, critical understanding of the project and hierarchical construction coincide;
- when applied in design, the hierarchical articulation of an OBM model allows interactive design decisions (or "dynamic modeling"). This is achieved through a typical OBM capability known as an "instantiation": the transformation of the original object is automatically updated (instantiated) to all its occurrences (instances) at a higher level (Figure 2d);
- instantiation is key not only for interactive design decisions but also because it facilitates (when the model is exported to a dedicated rendering program a realistic simulation and a detailed study of materials. The transformation of color, maps and material properties (gloss, transparency, refraction, etc.) of the original objects automatically updated to all its occurrences at a higher level.

3. Incremental Modeling

When applied in design the OBM environment has an other key ingredient. Its capability to support "incremental modeling" consists of two interrelated aspects: (i.) the concurrent maintenance of diverse alternatives within the same model and (ii.) the support for further refinements of design elements already placed within a scheme.

Figure 3: Three houses in Rome. DueEmme Constructions. Luigi Franciosini, Antonino Saggio architects
A real project (Figure 3) clarifies the relevance of these characteristics for the design process [note 4] The working environment on this problem consisted of paper and pencil for sketching, a personal computer (8 megabytes of ram), a laptop computer (2 megabytes of ram), a dot matrix A3 and a laser A4 printers. The software programs were a two dimensional vector drawing package (VDP), a high rendering package (HRP) and an OBM [note 5]. To make a comparison with a traditional setting, the reader has to imagine that the design was carried out in parallel in a drafting table (for exact orthogonal drawings) and in a cardboard model for development of volumetric ideas (Figure 1). Although software improvements will provide a live link between the two programs, the information from one to the other flew “manually”, with electronic cutting and pasting.

In a site of 41 by 25.10 meters, with usable construction surface of 430.35 square meters, a single detached house existed. The only access was from the street located on the shorter side of the rectangular area of construction.

The developer asked for the substitution of the single house with three attached units while maximizing floor area, providing garages and family room below the ground level and a bedroom and bath underneath the sloped roof. The legal floor area was 75 square meters net per units, but with attic and family room, it doubled.

The project started by designing what the developer had preconceived. Three cubes (aggregated to create a simple row and covered by a pitched roof) were generated in minutes in the OBM and a plan was drafted in the VDP (Figure 4a). While this scheme would satisfy the

![Figure 4: Three houses in Rome. a. Block scheme. b. Rowhouse schemes and plan. c. Cluster scheme and plan. DueErme Constructions. Luigi Franciosini, Antonino Saggio architects](image-url)
Figure 5: Three houses in Rome. Roof alternatives of the cluster scheme. Luigi Franciosini, Antonino Saggio architects

developer, it did not accomplish the goals that the author of this paper and architect Luigi Franciosini, co-responsible of the project, had. A search for articulation of spaces and for a more efficient plan started and a new scheme (based on the reciprocal sliding of the night and day zone of the unit) was laid out. Keeping the first block alternative, the model was enriched by the new rowhouse scheme. Several alternatives were studied to find out the best organization of the new scheme on the site and the interplay of elements from key view points (Figure 4b). Each of these sub-alternatives, was treated as a separate object in the overall model.

After these experiments, it was clear that a simple row house organization was not the best solution. (A purely linear organization would have provided very large yards for the two end units - which take advantage of die set back area - and a very compressed outdoor space for the middle one. In addition, a row house organization perpendicular to the access street would be a very illogical response to the context.) A third site plan scheme (Figure 4c) was based on an "L" unit, which could receive natural light by two extra sides. (This possibility allowed a 90 degree's rotation of the middle house providing a yard size comparable to the two end units and a cluster organization that is more appropriate to the site's suburban context). A typical unit plan was studied in details and drafted in the VDP and a new volume created in OBM. Elements such as windows, already prepared for the previous alternatives, were inserted in the new shape.

The design was ready to be submitted to the developer for evaluation. Each hypothesis was presented with unit plan and three dimensional views. With the help of the hide and show command, the developer judged directly on the computer the impact of the block, rowhouse and cluster alternatives. The cluster alternative, based on the "L" unit, clearly was the best one and was approved for further development. (From the developer's point of view, this scheme provided larger exploitation of the underground area in the project. The backyard of the central unit was big enough to make it almost as marketable as the others. Other pluses were concerned.)

Figure 6: Three houses in Rome. Object Based Modeling environment, Overall model, one house object, object list. Luigi Franciosini, Antonino Saggio architects
Figure 7: Three houses in Rome. Site plan at 0.00 and North facade, DueEmme Constructions. Luigi Franciosini, Antonino Saggio architects
with direct ventilation of bathrooms, compact and efficient unit layout and correct solar orientation. From the designers' point of view, this scheme also provided a more logical response to the context than a row house one and a richer environment for volumetric and formal manipulations.

A new file was created, objects of the previous alternatives were destroyed, and a more accurate and hierarchically efficient construction took place. The new model allowed a design search concerned with the impact of sloped roofs. It was the most difficult component of the design and different alternatives were studied and simultaneously present in OBM for several weeks (Figure 5). None of them was satisfactory from the designers' compositional point of view and from the developer's concerns about attic usable floor area. The final solution was developed on a diagonally symmetrical roof placed upon the square geometry created by the interconnection between the two arms of each "L" unit. Final legal drawing in VDP, and views of the model were ready to be produced (Figures 7, 8).

OBM environment in this case became a stimulating basis for an incremental development in design, which in the past was conducted by this author only with traditional tools [ref. 6]. At the beginning, its hierarchical organization permitted the concurrent maintenance of different schemes (block, row house, cluster), later it supported the study of different roof configuration within the accepted "L" unit scheme and finally it allowed the development of the final project with a progressive refinements of elements (Figure 6).

From a design process standpoint, the concurrent maintenance of different hypothesis in various moments of design development was crucial not only for the communication with the client, but also to support further design explorations. The labyrinthian way of the design search was supported by the firm basis of the previous scheme, which could always be tested and confronted with the next hypothetical advancement. The OBM environment not only allowed this approach to problem solving, it stimulated it to anew, unexpected, level of sophistication. OBM in this context, became an intellectual engine for the development of the design.

Figure 8: Three houses in Rome. View of the final solution. Central unit's plans. Luigi Franciosini, Antonino Saggio architects

Concept-Testing cycle

From the practical side, the application of this framework begins by asking students to respond to a site with generic goals in mind and practically no constraints. The first step starts the cycle by producing a first design hypothesis. New information in the form of guidelines, lectures by the instructor, comparable studies, client interviews, spatial, functional and compositional characteristics of the problem are incrementally added in each new cycle. In response to each input, students have to develop a new design hypothesis or elaborate on a previous one. The project therefore moves incrementally towards definition in a continuous process of adding information, conjecturing about new design ideas and the testing of those ideas.

Each cycle consists of three fundamental components: input, processing, output. A design scheme, coming from the previous completed cycle, together with new and discrete piece of information, represents the input of each cycle. The processing component corresponds to: i) the translation of the new information into design goals and quantitative criteria (e.g., urban requirements are incorporated into goal "flexibility of space" and then into criteria "each room can be furnished in three different ways"); ii) the development of several design alternatives. The output, which is the result of the testing activity, is the selection of the most appropriate design alternatives in the light of the specified criteria. The chosen design scheme goes to the next cycle and contributes, together with new information, to create the subsequent input and to reiterate the cycle.

![Concept-Testing cycle diagram]

Figure 9: a. The feasible area is defined before design explorations start. b. Concept-Testing. The feasible area becomes more defined as design exploration progress and new information are collected.

Studio Prerequisites

- the course must be at an intermediate level of architectural design education (second-fourth year);
- the ratio of students per instructor (or students per assistant in a European system) should be no more than fifteen to one;
- a cluster of personal computers with printing facilities and OBM software must be available; The cluster has not to be located necessarily in the proximity of the studio room.
- students have to give up about ten hours of the total instructor’s design feedback time in order to compensate for the explanation of the new tool; This figure can rise to thirteen hours if students have not previous knowledge of the personal computer operating system. On the other hand, it can decrease to seven hours if they are familiar with computers. The overall reduction of design feedback will be, in the most pessimistic case, no larger than 10%.
- a 15 week semester course that demands about 270 hours of studio presence. Students will spend about nine hours with instructor in lectures, seminars, desk critics and class reviews and an average of eight ten hours of individual design development per week.
- the design program of the first eight weeks, and the related mid term presentation, must be dimensionally quite small. For example, six housing units and a small community service on an urban site is an example of an appropriate program. Based on previous experiences, the level of complexity of the housing theme and the intermediate expertise of students cannot bring to positive results if students are expected to respond in detail to too large a range of themes. The fact that ten percent of instructor time will be devoted to OBM’s related matter, will be another factor for the choice of a small project in the first half of the course, and for the assumption that only a comprehensive contextual response or construction details can be provided in the second part.
4. Concept-Testing Approach to Studio Teaching

The use of OBM as a dynamic and incremental technique to develop and test design, shares one fundamental characteristic with the approach, which the author adopts, for teaching architectural design in a traditional studio setting. [note 6]

This technique is fundamentally different from the methodology commonly used in Italy, which we may call Analysis-Synthesis. In A-S two phases create the studio structure. The first collects all relevant information to a given problem - Analysis. The second - Synthesis - is concerned with design development within the "area of feasibility" established in the first phase (Figure 9a). [note 7]

On the contrary the Concept-Testing approach bonds design decisions to analysis throughout the entire studio development. The need for new information comes at the moment that a design hypothesis is defined. The search for new information tests the hypothesis. Refinements of a scheme, or new search direction, are responses to various aspects and constraints presented by new pieces of information.

Design decisions result from two basic intellectual operations: "conjecturing and testing". [note 8] The process of testing an hypothesis about information is illustrated in Figure 9b; the «*» represents a possible design decision and the dark line, the information that defines the feasible region. If the «*» is inside the feasible area, the test procedure produces a positive result and the student can go on to define the idea in another iteration. If it is not, the student has to discard it and find another solution. This process takes place many times during the course of a design studio. The feasibility area of a project becomes smaller and smaller as new analyses and information are added and new design decisions are made (see Concept-Testing cycle)

This method presents some disadvantages [note 9], but it helps most students to find a creative and innovative solution to a problem. During the beginning phases of design, too much information is not hindering students from exploring a large area of possible directions and solutions.

The fact that new information is incrementally added, helps students to focus on its design implication. Since information has operative importance on a project's advancement, "information and constraints" tends to become "design opportunities".

Finally, this method is more in line with the normal sequence of documents that architects produce in practice. In the sequence schematic design, design development and construction documents, new information and constraints are added at each stage and ideas become more defined.

5. A Studio Structure

It should be clear at this point, why OBM and C-T can be merged and mutually supportive. The usefulness of an OBM environment within a C-T studio structure, relies on the fact that both share a similar hierarchical and cyclical nature and on the fact that an incremental design process, which is typical of the C-T approach, can be supported and stimulated by OBM.

The potentials of an OBM environment in a C-T studio can be subdivided in three categories. The first is a common characteristic of every 3D model. That is the "simulation" component that is crucial for the testing cycle in C-T. Simulation applies to two different areas: spatial tests and, within a CAAD environment, quantitative evaluations (not only of generic aspects, concerning surface and volumetric requirements, but also features such as cost, energy efficiency and structural feasibility- if appropriate modules become available).

The second characteristic has to do with "interactive design" (or dynamic modeling as has been defined) as it is supported by the hierarchical structure of OBM. In this environment, the designer works with a tool that does not exist in a traditional setting. It is a model able to react

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*Figure 10: Studio structure based on a Concept-Testing model. Object-Based Modeling is inserted in weeks two, three, four and ten.*
to a designer’s input not only by performing spatial operations but also by facilitating and testing complex changes, even in advanced design phases, thanks to automatic instantiation.

The last, and most relevant, aspect is the incremental nature that OBM shares with C-T: both follow a process that goes from less to more informed design decisions. One of the most interesting features of OBM is its capability to support incremental definitions of parts and the concurrent coexistence of different hypothesis during the design development (Figure 4-6).

The next section describes the fundamental structure of a studio course that would incorporate OBM in the teaching of architectural design.

The project development follows a C-T framework, which has been described in details in other publications [note 10] and must be based on a series of preconditions (see Studio Prerequisites).

Figure 10 illustrates how such a studio might be structured. The teaching of this tool can be divided into four fundamental parts. The first three, should be presented to students in weeks two through four. Assignments are based on the first scheme that is generated and on the critical analysis of a comparable project. The first three concepts to address are:

(i). the basic functioning of the three dimensional environment. (Creating of volumes: extrusion, revolving sweeping; scaling; duplicating; three dimensional modifications; view controls; animation). The assignment consists of the creation of a 3D model of the first scheme;

(ii). the hierarchical structure of the OBM. (Object characteristics, how to create a hierarchical organization, legal and illegal structures). Since this topic will be introduced before the students have a developed scheme, the reconstruction of an existing project is the theme of its application;

(iii.). the concurrent maintenance of design alternatives in OBM. (The capability to have more than one design hypothesis available at the same time in the same model as well as the possibility to use some objects - for example the context or specific design elements - in alternative schemes.) With this level of knowledge about OBM, the assignment can refer again to design development. Students are asked to develop three site plan alternatives within the same three dimensional file.

After the first three weeks, which have been partially dedicated to the explanation of the OBM methodology, the course develops normally with specific attention to architectural issues. While learning of OBM should not take more than ten percent of the entire studio time, its use in design development should account for twenty five - thirty percent of the time devoted to design development. (These tentative figures are based on the design experience described in 3. Incremental Modeling).

Week eight focuses on the midterm presentation. Students will submit a complete and clearly drawn proposal for the given site. It is expected that some of the three dimensional experiments be included in this presentation.

In week nine the cycle that leads to the final project begins. A new project’s program for a larger site is provided and either context or construction play a relevant role in the design. A formally detailed and rich program should be provided for this final phase.

Week ten addresses the fourth topic of OBM: incremental definition of elements. (The possibility of creating objects with a low level of detail that can be studied further in successive design phases. The original location in the model of the object is kept, but its new version is automatically updated in all its occurrences in the whole model). In this last sequence devoted to OBM, students will learn how to develop in detail an acceptable overall massing scheme, how to study different variations of the elements and how to verify the implications of the design decisions at larger and smaller scales.

A combination of traditional and computerized drawings will be produced for the final presentation. [note 11] Other possibilities will involve the export of the model to high level rendering package, the creation of analytical animation and walkthroughs. It should be noted, that these options are secondary to the real goals of the studio, which primarily are concerned with architectural education and secondarily with the value of OBM to reinforce the design process.
It is crucial to ask students, at the end of the semester, to express their opinions about the inclusion of OBM in the studio structure. Identifying the tradeoffs between the OBM approach to three dimensional reasoning and traditional methods, the impact of learning and application time on the quality of the studio and evaluation of the difference between expectations and results can help determine the value of OBM in a studio setting.

The assumption that OBM can support a C-T approach to teaching design, can then be evaluated. Students' feedback will provide an important starting point for critical evaluation and adjustments and refinements for the next cycle of teaching a Concept-Testing studio with the help of Object Based Modeling.

Figure 11: Three houses in Rome. transversal section. Luigi Franciosini, Antonino Saggio architects

References


Notes


[2] The development of small and middle scale projects, particularly in the field of housing, and of larger projects submitted for Competitions in Europe and in the United States, are the focus of a practice based in Rome since 1980. From the second half of Eighties, this design work was intended primarily as an experimental activity with the view to create synergies with teaching and research.

[3] "Giuseppe Terragni Architecture. A Formal Analysis Using CAAD" was offered by this author at the Swiss Federal Institute of Technology Zürich in winter semester 1991-1992 following the invitation of Gerhard Schmitt who holds the Chair of CAAD. The fundamental difference between traditional ways of analyzing architecture and the method that was followed in the course is that the process of de-construction and re-construction was not delegated to a set of different drawings. The critical concepts about how the project is interpreted are contained in the way the electronic model is built. Critical understanding of the project and hierarchical construction coincide.

[4] The design theme was a small scale housing design on the periphery of Rome. The project was designed in summer 1991 and construction is scheduled to start in the second part of 1991. It is the fourth project that has been developed by the author with the support of OBM. While the first three have been discussed in other occasions (Cfr. Saggio, A. “Modellazione Tridimensionale per Oggetti. Verso una Progettazione architettonica Interattiva” I.CO:GRAPHICS Atti del Convegno, Mondadori, Milano 1992 pp. 592-607) this one is original because it develops the "incremental" aspect of OBM that could become a salient component for studio teaching.


[6] The Concept-Testing-approach to studio teaching was used since 1984. The first experience was conducted jointly with Prof. Louis Sauer at Carnegie-Mellon. In three studios (conducted together with other instructors), C-T was used partially, but it formed the overall framework of live subsequent studios, independently conducted.


[8] These activities are undertaken in a cyclical fashion that is powerfully described by John
Zeisel (cit.) as a spiral converging on a domain of acceptable responses progressively developed or discarded.

[9] Inexperienced students may be confused by the continuous cycle of Hypothesis - Verification. As new information and constraints are added, some students cannot keep a good solution because they are not well acquainted with new information. Other students are not able to set up a series of goals and criteria with which to test their hypothesis.


[11] The use of VDP for drafting, and of computergenerated output is not part of the studio scope. It will depend solely on the student's initiative and on the required standards for presentation.

Figure 12: Three houses in Rome. TGarden elevation. Luigi Franciosini, Antonino Saggio architects
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