Working with a CAAD’s spreadsheet

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This paper shows the content of a subject imparted at the ETSAB (UPC). It describes the use of CAD systems in tasks that could not even be thought before new technology arrival and traditional methods had to be used. CAD systems potential to simultaneously work with constitutive objects and relations between them is taken into advantage. The definite design is not only the juxtaposition of some but the tight relation linking them. This work proposes CAD systems to be used in architectural design projects as spreadsheets to perform arithmetic calculations. The process to obtain an architectural model has ended in a logic sequence of formal operations, which uses completely defined objects as data. Any element of the project, data or operation, can be changed and model updating is automatically performed obtaining the new result. Finally a concrete exercise developed along the course is shown like a practical example.

Keywords: teaching, CAD, architectural design, planning.

Introduction

The aim of this paper is presenting the content of a subject imparted at the ETSAB. The subject’s objective is the analysis of CAD’s potential to improve the design process, by means of the new working methods supplied by the most recent technologies.

When a design has to be created, the architect devises a system of relations between their constitutive elements. It can be seen like an articulated organism including from the most general point of view, that is the global project, to the most specific detail. So appears the importance that each element has in what global result concerns. The main goal of the subject is to transfer this logic structure, inherent in an architecture project, to a CAD system.

Along the academic period three aspects are specially discussed:

- Advanced management of graphic information
- Workgroup experience
- Computer model of the design’s logic structure

Background

Either in educational environment or in the professional one, CAD systems are usually included into the architect’s work to make easy the most usual tasks. Performing projects with computer help is easier and more operational than with the traditional instruments. Nevertheless only the instrumental qualities of the computer are taken into account precluding any meaningful changes in the established steps of the working process. The tasks are still developed according to similar criteria and in the same order that were done before, considering the security and effectiveness provided by the tradition.

CAD systems were introduced in Architect Schools presenting the new technologies as described. Except for some cases, no deeper analysis
of the new possibilities offered to the architects was done. This work shows the use of CAD systems in tasks that cannot be even thought with traditional methods. Fully new operative concepts, which cannot be imagined till the computers emergence in the drawing table of the architect, are shown.

CAD systems ability to simultaneously work with constitutive objects and relations between them is taken into advantage. The definite design is not only the juxtaposition of some but the tight relation linking them. The design, at any time, is the result of combining objects and their relations. Any operation, either on the data or on the relations, rightly affects the final design. Being the later the reflection of the latest modifications.

Why a spreadsheet?

When an arithmetic calculation has to be done, a group of data is used. It is introduced in a predetermined sequence, developing operations in a specific order, to reach the desirable result. The classic process is done, either by hand or with an electronic calculator, and the final result is obtained correctly. Even so, if some of the data has to be changed or part of the sequence is modified, it is necessary to repeat the whole process to obtain the new result. Computer advances give us a tool – the spreadsheet – which, among other things, allows building a scheme of the operation’s sequence that has to be performed. The obtained result obviously matches with the one from the traditional method. But the elements and the existing relations between them have been fixed. It is possible to carry out any modification, the data itself, the operations or the operation’s order at the proper place and then the final result is shown, including intermediate values of the process performed automatically by the computer. Therefore, the goal is not to perform an amount of operations but to define the arithmetic structure of the calculation process. This structure can be easily and repeatedly used with any needed variant.

An architectural proposal can be seen as the result of a process as the one exposed. The data is composed by geometric elements and the operations are manipulations of this data (instantiations, transformations and combinations). A parallelism between configuring a complex geometric form and performing an arithmetic calculation can be established. Consequently, the emergence of CAD systems involved the substitution of manual working methods by electronic calculator. This work proposes to use CAD systems to design architectural projects as spreadsheets are used to perform arithmetic calculations.

This proposal has some similarities with the logic structure that allows representing an object by a CSG model. In this model the object is the result of a boolean operations sequence with the instantiation of parametric primitives. If it is possible to change any constitutive element of a CSG model (primitives, operations or the sequence order), it is possible to control the final result in a fast, easy and effective way, similar to the one explained in the foregoing paragraphs.

Use in architectural design

Architectural conception can be hierarchically structured. The global model is subdivided in smaller meaningful parts. These parts could be subdivided again with the same criteria. Thus a hierarchic logic structure is obtained, which defines the final object. The notion of building from general concept to particular elements (top-down), can be made otherwise (bottom-up) noticing the existence of basic elements that, as constructive pieces, are gathered to build more complex objects. These more complex objects can be put together again producing even more complex ones. Where more complex objects are used, several levels can be defined till the final result is obtained in the highest hierarchic level.

Two kinds of elements appear on this process. The specific piece’s shape and the composition rules to ensemble them have to be specified. Both questions have to be answered together due to their strong
interdependence. The basic design elements cannot be a specific set of predetermined constructive elements. Their type depends on the kind of project that has to be performed. For instance, when an urban residential unit is projected, the pieces are whole buildings and their clusters, but when a building itself is being projected the pieces are constructive elements like walls, doors, windows, structural elements, etc.

To create a computer model representing the creative process, a tree structure is used. The root node is the whole model and a subdivision process generates each level. The elements that correspond to the terminal nodes (leaves) have the geometric definition of the architectural elements, basic constitutive elements of the general model. They are called ‘data nodes’. The other nodes, that have ‘children-nodes’, performing geometric operations with them, are called ‘operation nodes’. Hierarchic relation is found at each level of the model. The ‘operation nodes’ can be seen as ‘root nodes’ of a sub-tree defined with the same rules used on the general model.

Geometric definition of an object that has the finest level of detail in the logic work scheme is found at the ‘data nodes’. These leaf-nodes are the more elementary pieces used in the building of a project. Only these elements contain information about the real world. And it is this information that is used in any kind of operation, graphical or arithmetic.

The operations to be performed with ‘child-nodes’ are in the ‘operation nodes’. These operations cannot modify the information contained inside the elements, they only can make a determined number of copies, deciding parameters like position, orientation or scale.

When the whole model has been built, any future modification can be easily done in any node, as if in a spreadsheet. The process to obtain an architectural model has ended in a logic sequence of formal operations, where clearly defined objects are used as data. Any element of the project, data or operation, can be changed and model updating is automatically performed obtaining the new result.

But a further step has to be done. Ability to choose between a wide range of possibilities for all the kind of nodes of the tree would make the tool truly useful. Data type or operations combinations should be generic and non-restrictive, as possible. Several pieces can be used at any level of the logic structure. Thus, each node’s content can be easily substituted by an equivalent piece, obtaining a new design solution in an automatic way (like in a spreadsheet). The richness of possibilities depends on the available pieces set at any level of the model. Its flexibility depends on the substitution mechanism.

**Implementation using AutoCAD**

The CAD system used by the author, and the one explained at the subject this paper refers, consists in PC computers with Intel processors and the AutoCAD installed. So this section explains how to develop the exposed idea in these work conditions.

The nodes of the tree have been described as information containers. Geometric description of the object is stored in the ‘data nodes’, while the references to other nodes and their inclusion conditions are saved at the ‘operation nodes’. The

![Figure 1](image-url)
behaviour of AutoCAD blocks fit these needs. Each tree-node of the general model is implemented as a block. 'Data nodes' gather the group of entities that exactly describe an element. At the 'operation nodes', the child-nodes are nested blocks. Insertion point, scale factors and turn-angle define position, proportion and 'piece's' orientation respectively. Nesting shows the dependence of a block from the one at the higher level, like a child-node is linked to its father-node.

Inserting a block means the instantiation of all the information it contains (a node is added to the tree with all its information, which can be in its turn a sub-tree). The difference with external referenced files (XREF), even not being significant in this work scheme, is important in the general work of AutoCAD. The need of having several alternatives for each tree-level (nesting levels in the AutoCAD model) is solved with a proper number of independent files containing the information needed to create a tree-node.

**Example**

The ideas exposed in this paper are presented to the student in the basis of a concrete exercise developed through the fifteen weeks the course lasts. The project’s proposal is building a logic structure in AutoCAD that defines the design of the proposed architectural subject. Several alternative solutions for each complexity level have to be also presented, so easy modifiability of the generated model can be verified. Working interactivity is a good aim in this proposes. The abstraction of the proposal allows emphasising the model-tree without a formal reference.

**Description of the working theme**

In a new peripheral urban area 180 houses should be placed. A rectangular field can be used and there have to be two streets in each direction to give access for every home. Pedestrian roads can be added crossing the city blocks.

Alternatives for each unit type should be defined. The contact relations will determine the study of proper variations. Similarly, solutions for the rows have to be studied too. The different kind of row’s organisation should be able to be changed, resulting in different urban spaces.

**Logic structure chosen**

The global model is composed by; an element that represents the urban environment and eighteen elements representing a row of ten house each one. Each row is composed by five groups of two houses each one. The table shows an overview of the scheme where each column represents a (complexity/abstraction) level and boxes represent ‘operation nodes’.

As explained before, several alternatives for each element are needed to obtain an interesting model. These alternatives mean several files containing accurate information about each level node set in the defined logic structure. An example of increasingly complexity, from particular to general, is shown.

**Components definitions**

A set of files contains different kind of houses, with different solutions that are used according to row’s
position. 2D and 3D versions of the houses should be useful to improve work operativity. Although more files are used to describe the houses with several detail levels, only the ones of lowest detail are used in this paper.

These dwellings units are gathered on groups of two units where the following points are defined (as yes/no):

- The two houses look the same (use the same block)
- They have the same wall alignment
- They are mirrored respect the party wall
- The groups placed at the end of the row need a special unit type

Gathering these five groups, rows are obtained. These rows are considered the same size, to simplify the process. Two more additional aspects have still to be determined:

- The kind of group used at each position
- The alignment of each group respect the adjacent ones

The global model is obtained placing the rows on the urban environment.

There it can be easily seen the kind of element used at each level of the chosen organisation. The result obtained by changing any ‘piece’ by another one from the available set can be easily predicted. This modification can be done by the mechanism of block’s redefinition, so simple in AutoCAD.

Conclusions

There is a tight relation between the architectural logic structure and the computer organisation of the model, allowing a strong dependence between the intellectual
process of taking design decisions and the tool used on the operation.

Abstracts elements are used along the whole design process. These elements are formally defined with the needed detail level at the last steps of the work. This allows the following advantages:

- Relations between the components and the final result are clearly shown
- Using lesser information amounts allows better system performance
- The use of basic concepts of the model’s logic structure, free of formal considerations, supports the making decisions activity.

Ability of adding alphanumeric information to ‘data-nodes’, defining no-graphic features of the object (physical, economic, social ones...), and evaluation of relations between the distinct ‘pieces’ have to be noticed. This strengthens the idea of developing functions that score conclusions from the quantifiable consequences on predefined parameters that any formal operation does. As a further step, it could be possible to program applications that propose corrections to determined decisions, comparing the obtained data and a predefined evaluation criteria.

**References**


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