Computers and Creativity in Architecture

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Keywords: decision-making, expert systems, urban development, building types

The approach to the Project

The main purpose of this teaching and research project is to define those principles capable of determining a possible approach to computer-adied design for architecture - not seen as as a mere tool but as a way of supporting decision-making.

This project for training architects is based on two fundamental principles: **the study of urban development**, as regards historical and motivational aspects, and **the study of building types** [A] as regards architectural composition, considered as the organization of empty spaces connected by constructing enclosures hierarchically, whose inter-relations create an architectural language. These principles can be readily applied and are easily recognizable in buildings which have undergone some sort of planning and are reproducible.

Using computers as an aid to decision-making in architectural design means it is necessary to configure an expert system endowed with *Artificial Intelligence* operating through a *neural network.* By means of a set of initial input and data this system must be able to provide the most suitable responses in architectural terms to the models proposed. Another approach is to check whether it is possible to synthesize new models.

This first stage of research is particularly important from the teaching point of view and concentrates on identifying the informational input which the expert system uses to define the features needed for the appropriate classification of building type.

The historical study of urban development starts from the analysis of a city's morphology, seen as the study of the relationship between the form of the urban site and the pre-existing buildings.

The search for the general principles to create a built space starts from the analysis of the features of elements making up this space. This analysis must be conducted using spatial means, with a dynamic perception of the changes which have occurred and their influence on the built space. The study of architecture is now recognized as a **fourth dimension** [B], built up over time, revealing spatial features in gradual development in efficiently illuminated architectural spaces.

The first stage consists of drawing up an urban plan relating to an area on the margins of the consolidated urban environment and modern constructions - a plan able to provide a comparison between the two different types. Having identified the proposed plot [C] for construction an analysis is conducted of its morphological features and its relations with the proposed construction.

The next step consist of three stages: the first is to analyse the context and define an approach; the second, to produce a volumetric definition of the proposed construction seen in relation to the context; the third is the choice of building type and its spatial and tectonic [D] development. In each of these stages the computer is particularly useful and important, as we shall see further on.

The approach to the Context

Obviously identifying an urban system using empirical analysis means risking over-simplification of the phenomena observed. This occurs when the type of approach chosen requires assumptions, selecting and measuring indicators, also choosing methods and types of analysis which have to be simplified so the state of the phenomenon observed can be identified and its direction (*i.e.* its development) can eventually be manipulated.

A building is effectively and continually redefined by social interaction and therefore subject to changes caused by the various users of the building, whether these changes are individual or communal (institutional or private). An empirical approach, despite the fact it means a reduction of social complexity, is the only one which we feel enables a vision of observed reality to be achieved, which can then be checked, after defining the parameters of analysis and the methods for measuring them.

The quality of an urban environment depends on the ability of its constituent parts – built up over time by different people for various reasons – to interrelate and connect until a harmonious environment is created. If it not possible to clearly perceive them as separate entities, effectively usable and connected within the city as a whole, then the urban quality can be considered poor. If the elements composing the fabric are discrete units capable of establishing balanced coherent relationships with the other components of the urban scene, then an urban fabric is created.

Clearly, these introductory observations lead to a systemic view of the city and its different parts, which can be applied in the appropriate degrees to different scales of analysis and planning.

The finite nature of a component of the system – here of an urban unit – is achieved by combining the following features:

- **complexity**: (co-existence of different co-ordinated functions (contaminations), safeguarding against the risk of a monofunctional identification of products and areas;
- **identity**: (existence of harmonious relations between architectural products (buildings) and the urban fabric (morphological development);
- **structure**: (hierarchy created in urban spaces seen as dynamic units engendered by the merging of streets and buildings).

There are other features which help to define the quality of an urban system/part which are more easily visible when the city is considered as a *consolidated* entity, meaning the fabric where the urban role is recognized as finite and used by the community as a reference point, with the notion of city, comparable to more recent urban development.

Urban form is determined in content and meaning by the development of building types and their relations but also by their adaptation to different kinds of use, which change over time, influenced by density, traffic, etc..

Within the system flexibility can be identified, because as the various uses of buildings change over time so do the relations; in turn this affects the system so the structure is transformed, but not its identity.

By introducing this variable, the quality of urban features can be linked to their capacity for transformation and adaptation in a process of continual development. If this transformation occurs in a well-defined harmonious relationship between building type and urban morphology then the buildings, which are representative architecturally, form a **whole** (the Centre), and assume a role coherent with the evolutionary requirements of the entire city.

Analysis of the context

The first step towards an urban analysis of this kind with these objectives starts with sampling a small area in the city of Aversa. This test is ongoing as regards the construction of an expert system to support decision-making in the field of computer-aided design.

The elements used for the preliminary classification are as follows:

1. Morphological identification based on features of the boundary of the urban and building plots

The definition of the urban site is inevitably conditioned by the configuration of the streets which surround it. These can be functionally catalogued according to the quality of the points it connects and the intrinsic quality of the facilities available in the same street (landscape, dwellings, shops, communal activities, gardens, etc.). Such information and directly obtainable data are then linked to the building types to enable an analysis of the urban character of the site to be made.

2. Existing relationship between the two facing street frontages considering the heights of the architecture in relation to the distance between buildings, and the distance of the buildings from the street.

This is the first problem that needs to be addressed so that analysis by an expert system can be hypothesized. For the building type analysis, aggregation criteria are studied, then single components of the urban cell and finally the relationship between cells. A distinction is made between the urbanized areas: those consisting of constructions based on a fabric of load-bearing walls and those built using a grid of pillars and floors. This differentiation enables us to determine the value of the intrinsic approach to the context, where the building (tectonic) features are an integral part of its expression. However, in this particular approach any construction which mystifies the nature of building choices through the expression of the language of architecture appears a useless exercise. The identification of the shape of urban plots is far more simple but their morphological quality is infinitely more complex in terms of space. This quality needs to be identified from the relationship between the height of the buildings and the width of the street, the outline of the roofs, and the relationships between the the building facades.

3. Orientation of building type generators on the street axis

Given the need to match the analysis to a research principle of the computer, we used the morphing method applied to plans for the ground-floors of the buildings to reduce the inevitably irregular layouts of the old city to rectilinear representations which can be interpreted geometrically.

4. Determination of the type of 3D aggregation of minimum building units classified according to intended use and users

The interpretation of the aggregation of the individual components of the urban cell is achieved by studying the spatial zones connected by means of gaps or steps, which can be cross-referenced with the 3D version of the model. The determination of each building appears more complex, but this is possible by grouping together the semi-public communal spaces and steps and creating a hierarchy.

Volumetric definition of intervention in relation to the context

The spatial reading of the context is carried out directly on 3D models of the architecture, which is collected and input into a synthetic 3D model containing modular spatial grids – one for each of the frontages, based on a dimensional relation created at plan level on the median inter-axis of the structural elements and at elevation level on the median height of the floors.

1. Morphogenetic parameters

Using spatial grids composed of autonomous positions means that in irregular shaped lots some overlapping of the modules which have generated them will occur. So it is necessary to find points of origin, rotations and shifts in the grids to produce relations between them that are appropriate and can be verified.

The purpose of the exercise is to search for dimensional suitability of the grids obtained using two processes:

- Shifts and search for alignment axes and important landmarks;
- Rotations and search for centres and angles of rotation.

The transformation parameters of the grids were identified in the building site, the urban plot and/or externally, in other lots.

The 3D model with related grids also makes it possible by means of synthesizing the elements which constitute the built environment to check the relations of the empty urban site with other parts of the city, identifying those morphological invariants which typify the context, for application to the design.

The application of the spatial grids to the model make it possible to read the volumetric aspects of the morphologies of the buildings present on site, which have created a variety of relations between themslves and the urban site. The buildings are classified according to the kind of urban area they belong to, either in traditional building materials or structural mesh, and by morphological parameters which can be summed up as follows:

- height of buildings
- alignment along frontages of urban and/or building lots
- relationship of form between dimensions of plan and height of each building
- full/empty relationship (volumetric density)
- type of roofing

2. Legislative and planning requirements

The following planning requirements are additional parameters used for reading and comparing the urban context:

- planning consent indicators (mc/mq)
- roof features
- maximum number of floors
- maximum height of building
- distance from lot boundaries
- distance from related areas.

These values, when combined, offer various design and as many spatial choices.

The planning requirements are used either as morphing data or basic information for input into the expert system.

3. Volume produced by synthesis

Having acquired the basic data on site, the students are asked to define and design an elementary volume in 3D representative of the design in terms of the planning requirements and morphological features of the site.

The method suggested and adopted was to use a kind of “morphing” of the volume. To make their choices with the tools at their disposal the students had to build various volumes in 3D, putting aggregations of minimum volumetric units into the spatial grid. Among the various combinations of elementary volumes the students chose the one which:

- corresponded to the particular spatial features of the urban context
- met the planning requirements
- was representative of their design.

The objective at this stage was to check that the formal aspects of the volumetric solutions were compatible with the context using a sort of morphing of the volume in real time, controlled automatically by an expert system. According to the input data (planning requirements, morphological, spatial and architectural features of the site) and combinations of these, it was then possible to produce 3D representations of the whole and of details, guaranteeing the continual representation of the results proposed and a range of various possibilities.

This way the urban void is redesigned with constant checking in real time of some of the possible configurations and relations connecting the design and the site, also determined by the application of planning restrictions to its morphological features.

The multiple solutions which satisfy the combinations imposed by the systems used represent the domain in which the choice of building type and the tectonic and distribution solutions will be checked in the next stage.

Choice of Building type; spatial and tectonic structure

The students who conducted this experimental analysis were confronted by a site morphology of two different building types: traditional terraced housing in masonry along one frontage, and separate modern buildings, unaligned with the boundary of the site, along the other side.

The design and subsequent realization of an architectural product create a precise building type within a morphology, defined at a previous stage, and modify it dynamically by reciprocal influence. In this approach the morphology does not merely play the part of a container but is intrinsically linked to the building type by a relationship which connects the "type" of building to the *genius loci* of the street, the square and entire quarter. A building is assigned a certain type using a classification of its constituent parts and specific analogies.

The criteria used to define the type are as follows:

Aggregation of the cell

The organization of the cell occurs by aggregation of individual modules which are functionally interconnected minimum structural units.

1) Depth of cell (measured in modules)
   a) Simple depth
   b) Multiple depth
2) Width of cell (measured in modules)
   a) Simple frontage
   b) Multiple frontage

Vertical connections

The classification of the vertical elements is based on:

1) Connection features
   a) Serving a single building
   b) Serving more than one building
2) Position
   a) Internal
   b) External
   c) Central
3) Dimension
   a) Ramps
   b) Elevation/tread
   c) Landings

A. Related spaces

Part of the undeveloped building site may be related to one or more cells and be positioned:

1) Externally (on the boundary of the site)
2) Internally (not on the boundary of the site)

B. Elevations

These are created using modules seen as the minimum analysis element contained between two vertical and horizontal structural elements which may be assembled in ***n*** orders and show the widths and heights of the buildings.

The modules are:

1) Full
2) Empty
3) Entrance
4) Portico
5) Loggia
6) Balcony/-ies
7) Window/s
8) Round windows (portholes)
9) Slit/s
10) Terrace

C. Aggregations of dwellings

The aggregation is the result of the organization of dwellings inside the urban plot using a 3D grid. The aggregations according to their distributive and tectonic function are as follows:

1) Terrace
2) Row
3) Courtyard
4) Gallery
5) Tower

The tectonics are structured on elementary components which are compatible in their constructional aggregation:

A. Vertical load-bearing elements

1) Continuous masonry
2) Masonry pillars
3) Concrete pillars
4) Iron pillars
5) Wooden pillars

B. Horizontal load-bearing elements

1) Wooden floors
2) Stone vaults
3) Concrete beams and floors
4) Iron and brick beams and floors
5) Steel beams and floors

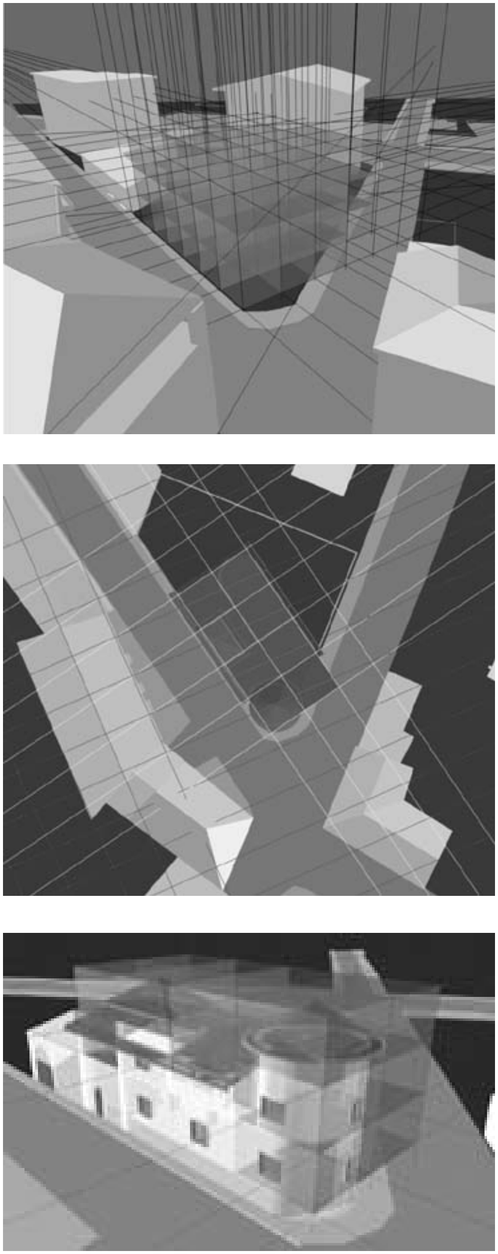

Figure 1. 'Volumetric definition of intervention in relation to the context' by arch. Alessandro Ceso (a) aggregations of minimum volumetric units (top), (b) generation of spatial grid (middle), (c) An application (bottom)

C. Roofs

1) Flat
2) Pitched

D. Load-bearing façade elements

1) Masonry
2) Concrete
3) Metal
4) Wood
5) Steel and glass

E. Façade apertures

1) Windows
2) Doors
3) Portals
4) Arcades

Tectonics and building type progress together at this stage, as the volume gradually assumes its identity. Tectonics supply information about the static functioning, and the building type identifies the features necessary for the dimensions, and together they contribute to the spatial and distribution proportions.

Significantly, functional distribution is part of the residential culture of a site, and as it does not possess uniform parameters or those which can be determined physically this aspect is defined in each case using the application criteria of the expert system. So at this stage of the student design process these parameters have been ignored.

The volume of the design is now modified and will continue to be, following informational input and relevant suggestions on modification supplied by the output, depending on the need to modify it from an ideal model to a building design. This transition starts from an initial configuration of three conditions **tectonics, building type** and **functional distribution**. This procedure triggers a continuous retrogressive cycle which stops only when a neutral configuration has been achieved. In fact, if a parameter relating to a static function of the building is changed it is necessary to discover how much the change influences the functional distribution and if it is still coherent with the type of building chosen. The final result can then be a balanced system - not a mere sum of parts.

This method does not supply predetermined, formal, distribution or tectonic solutions – only suggestions and hypotheses. However, it is possible to exercise rational and effective control in terms of efficiency and economy over the buildings, enabling the designers' individual creativity to be developed.

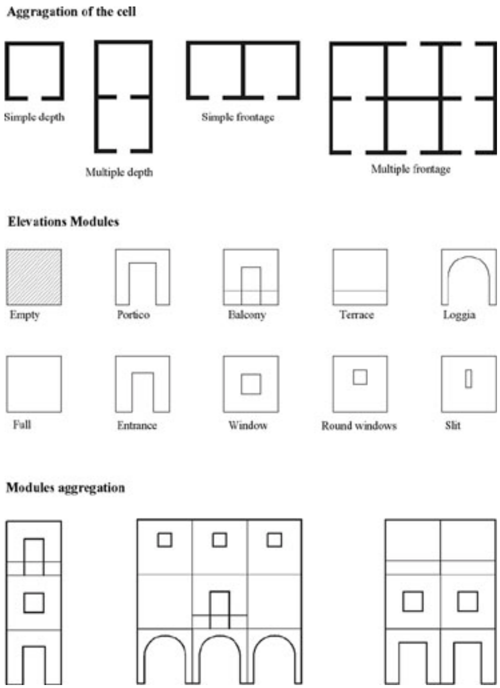

Figure 2 (right). 'Spatial and tectonic structure catalogation' by arch. Stefania Barba

Notes

[A] "building types" is used here but Italian uses the term: *tipologia*, from the Greek meaning impression or model. An *analisi tipologica* is the study of architectural types by classification according to specific analogies. Here classification is based on rules governing the distribution of spaces at all levels of aggregation, from territory to single dwellings. The type is not a stylistic or formal model but "*the total logical projection of the building, a complete organism, with its own history dependent on the various kinds of identification depending on the use at the level of critical consciousness, **responding to the choice of type deemed most appropriate***". G.Caniggia under **Tipo** in *Dizionario di Architettura Urbanistica*, Rome, 1969.

[B] Cf. Bruno Zevi, *Architettura in Nuce*, Rome, 1960.

[C] Building lot corresponding to a given construction unit.

[D] Tectonic is used here to mean consideration of general principles governing the static functioning of buildings, not specific analysis of structural behaviour or technological features.

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