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ARCHITECTURE 'in computro'
Integrating methods and techniques

A CD-ROM containing the digital version of the proceedings is enclosed with this book

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I know that it is a repeat but it must be said again that during the whole preparation eCAADe president Henri Achten and, the ever-so-helpful conference liaison officer, Bob Martens were always available when needed!

Nobody can organise a conference like eCAADe 2008 alone, whatever his resources might be. Without a team no conference is possible. By this I would like to thank, for all their efforts, Leslie Luypaert (international affairs), Nadine Tulfer (finances), Wim Maes (graphics), Toni Van Remortel (website en db), Christophe Gabriëls, Jean Claessens en Steven Wittevrouw (IT-Team), the student helpers and everyone from the technical team of the University College Artesis Antwerp (formerly known as Hogeschool Antwerpen).

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Marc Muylle
September 2008

Section 23: City Modelling 2

Digital Architectures Generated Using Forces in Urban Environment

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Abstract. *A paper, a description of a software application is given, which allows to generate tridimensional models of buildings, directly inside a geo referential context, following a parametric approach, in which the volume of the building is put in direct relation with forces/law bonds emerging from the urban context. The user is, therefore, able to interactively operate within a project process, in which, by changing the parameters values and by verifying in real time, the results of the changes, he/she is able to evaluate all possible infinite scenarios. The system, thought for Trento's (Italy) urban context, may also be applied on other cities.*
Keywords: *Generative design; performative architecture.*

Introduction

The final configuration of a new architectural space is deeply conditioned by all due environmental context constraints, as pre-existing buildings, road infrastructures, urban development, vehicles fluxes, people and information, monumental emergencies, climatic features.

The most innovative instruments, allowing to relate the architectural shape with its urban context, are based on parametric techniques, 'Shape Grammars' or 'Evolution Algorithms' (predominantly 'Genetic Algorithms'). These instruments allow, throughout implementation of specific generative procedures, to manage the architectural shape in an interactive way, by changing its features, in order to optimize specific environmental aims, or to adequately give birth to its shape, according to the urban and architectural elements that characterize the context.

Interesting are the works based on 'Shape Grammars' origin, formalized process ideated to describe architectural language (Stiny and Gips 1972); as the methodologies developed by P. Wonka (Wonka P. et alii, 2006), who uses 'Split Grammars', to generate building and city models, based on the architectural characteristics of the context, as the façade or the covering (Figure 1).

Significant is the work carried out by K. Shea (Shea K. et alii, 2004), who uses a parametric technique denominated 'STSA' (Structural Topology and Shape Annealing). It is a methodology that associates programming with tridimensional modeling;

the used instruments are 'Generative Components' for modeling and 'Eiform' for structural verification. The generative design allows to obtain a stadium covering by fixing some geometric properties (girder dimensions, number of rods of the reticular girders, minimum and maximum height in relation to the soil). When changing the parameters, the user modifies the configuration of the covering, results and structural behavior of different covering elements, are visualized, in real time, thanks to 'Eiform' (Figure 2).
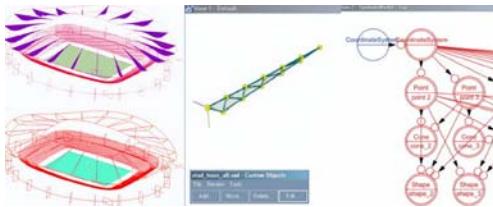
'Declarative Programming' and 'Genetic Algorithms', are used, instead, by D. Plemenos (Plemenos D. et alii, 2005), for implementing an application which allows to generate building models, according to an optimization shape process, in respect of formal criteria, declared by the user (Figure 3).

Development of the application

Hereafter, an application is suggested that gives the user the possibility to develop 3D Models of buildings on an urban scale, directly inside a 3D Geobrowser, by taking charge of the 'forces/constraints'

emerging from the context, as actions that model the architectural space, causing particular inflexions on the shape of the buildings.

The process began through the analysis of the relationship between architectural shape and environmental context; it then continued with the definition of the 'Field of Forces', of the existing relations between the architectural envelope and elements of the field of forces, in order to reach drafting and implementation of a relative code, carried out by using the OOP (Object Oriented Programming) technique and the 'Drools' (Jboss) instrument (http://www.jboss.org/drools), an Open Source project (Figure 4) that implements the so called 'Rule Engine' system, based on the 'Algorithm network' elaborated by C. Fergy (Fergy C. L., 1982).

The application was afterwards applied on a real case. The chosen 'forces' correspond to the constraints forced on the shape of the architectural envelope; they were individuated and enclosed within due classes, denominated 'Urban Constraints', 'Parameters' and 'Architectural Constraints'.

The 'Urban Constraints' class defines the dimensional limits of the building and comprehends the most important dimensions linked to the urban law: building index (Ie), ratio of covering (Rc), maximum building height (Hmax), maximum number of stories (SNmax), minimum distance of land borders (DBmin), minimum distance from the generic urban elements (Dmin), as roads and close by buildings; within this class, typical architectural elements are also found, which characterize the typology of façade and windows inside the local context of reference. The 'Architectural Constraints' class is made up
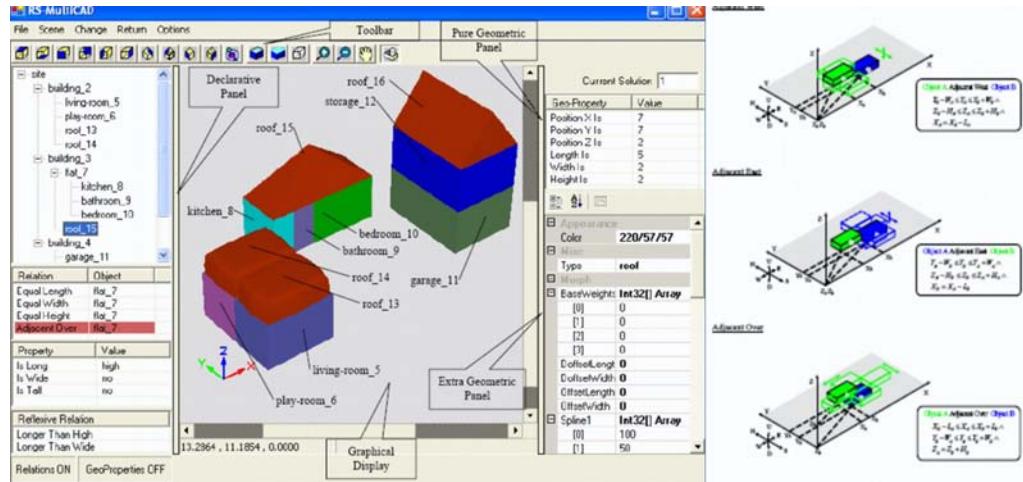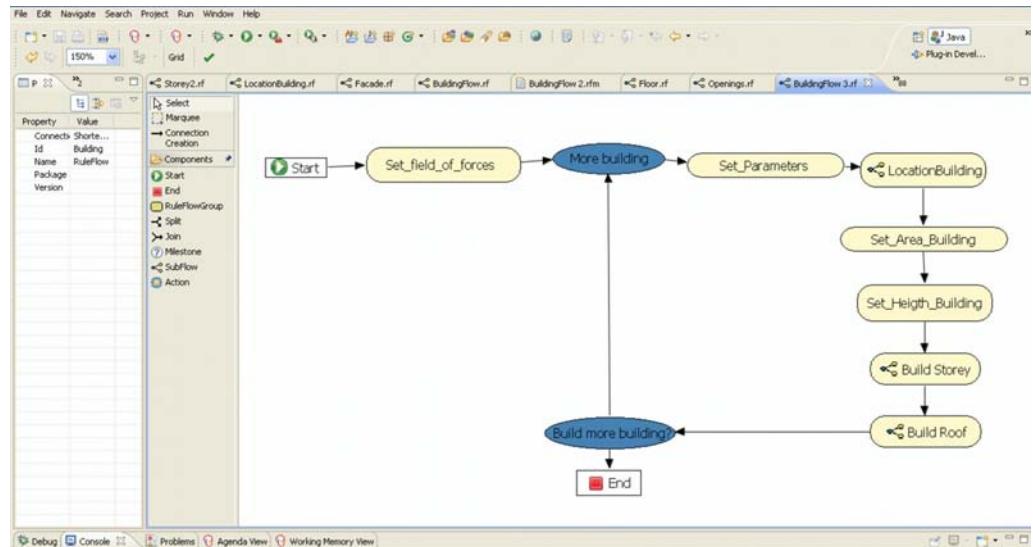
by the geometric parameters, necessary to generate the building and to locate it in the context, as perimeter, height of the building, number of stories, height and height of each building storey, number of windows on the façade.

The 'Parameters' class foresees control factors that allow to regulate the influence of the constraints present in 'Field of Forces' and to manage the relationship between the force and the geometric characteristics of the architectural envelope.

Given the introduction of the 'Field of Forces' concept, some of the most important environmental

aspects, duly codified, become generative elements that can be managed by the user.

Functions of the system

The system offers the user many innovative suggestions, associating the modeling ability, typical of the CAD systems, to the opportunity offered by the geo-referenced systems, to evaluate in real time the impact of the work directly on its environment, within which it can be generated and manipulated.

The system brings inside a generation process, with factors that traditionally belong to different planning stages and that consequently become parameters generating the architectural shape.

The operations that the system allows to carry out concern:

- Optimization of volumetric and formal properties of the envelope; on the base of parameters given by the system, in terms of volume constraints (Ie, Rc, Hmax, Nmax, DBmin, Dmin).

- Optimization of the façade configuration; according to the constraints given by the façade configuration (window's type and dimensions, features of the covering material), it is automatically applied, on the digital model obtained, a texture that beholds the most important local architectural features, also codified within the field of forces.

- Evaluation of the visual impact on the environment; the digital model is put in relation with the elements of the urban context in which it is located. Operating directly inside a geo-referenced context, it allows the user to verify, in real time, the results of the variations and to explore the different scenarios and the various possible alternatives, directly evaluating the introduction of the building within the context and its environmental impact.

In the follow figure a synthesis of the generative process is illustrated.

The user may address the project process towards
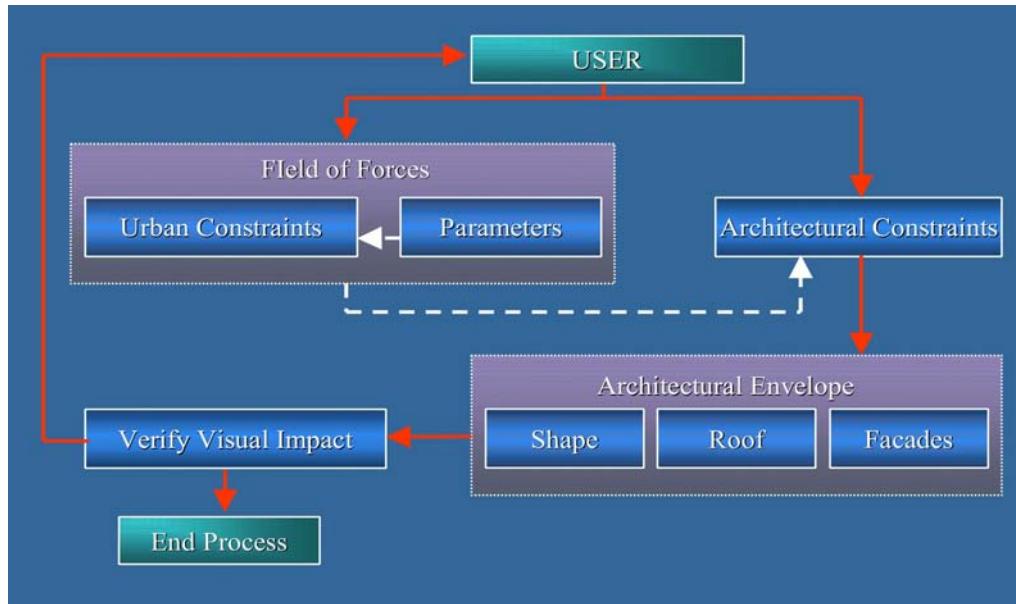
Figure 5
Scheme of the generative
process.

the optimization of the formal and volumetric properties of the building, in respect of the urban parameters and of the architectural elements given as constraints. The system, by grouping different project stages, allows an easier project planning, offering the possibility to skip those extreme stages, as the meta-project stage, in which maximum volume, height and realizable surface, as well as that of final verification, are calculated.

The control framework of 'Field of Forces' consists in the parameters found in 'Urban Constraints' and 'Parameters' classes. These both allow to act on the architectural envelope, but with a huge difference; 'Urban Constraints' is a characteristic of the urban context and it is common to all buildings generated within it; furthermore, it defines the values that have to be considered as limits, given by the national and local laws.

The 'Parameters' class, on the contrary, is linked to a single building and is constituted by factors over which the user has decisional power. Through the coefficients of the 'Parameters' class, the designer decides the entity of the influence of the 'Field of Forces' on the geometric features (Architectural Constraints), and consequently the configuration of the architectural envelope.

Changing the first, equals to changing the territorial reference context, with its own laws and with the elements that characterize the architecture. To work on the second type of class, equals to changing the shape of the envelope, leaving unchanged the field of forces and therefore, the effects on the architectural envelopes previously generated.

Given this application, it is therefore possible for each project solution, to create different scenarios, each of which differs due to the value of the constraints in 'Urban Constraints' or because of the value given to the control parameters of the 'Parameters' class. This can be useful, for example, when realizing many buildings with the intent of giving each one of them different aims, without being forced to modify the 'Field of Forces', that would, otherwise, produce changes in the already generated buildings.

A real case

A test of the developed application was conducted on a portion of the territory of Trento (Italy). The area under examination, located in an inhabited centre, includes a part of the old town centre and a digital model was elaborated in GIS environment (Figure 6).

The user, gives the system the necessary data to duly define 'Field of Forces'; inside the GIS environment, the minimum number of geometric parameters,

necessary to define it, are assigned to the building. These are the coordinates of the apex of the perimeter of the total area on which it is going to be built.

The system, according to the implemented rules, determines the remaining geometric parameters, which allow to generate the digital model of the building, in a configuration that we call 'Scenario' A1 (Figure 7), visualized in real time.

The 'Scenario' A2 (Figure 7) is obtained by keeping the previous 'Urban Constraints'. The 'Parameters class, is modified so to reduce the influence of 'Rc' and to increase that of the 'DBmax'. This change determines a reduction of the base area, an increase of the number of stories and of the height of the building, but the initial value of the volume is kept. In the previous scenario, instead, even though the building could reach a higher number of stories, it was yet lower, since its volume decreased to the limit imposed by 'Ie'.

It is obviously possible, to obtain substantial variations of the building's shape by changing
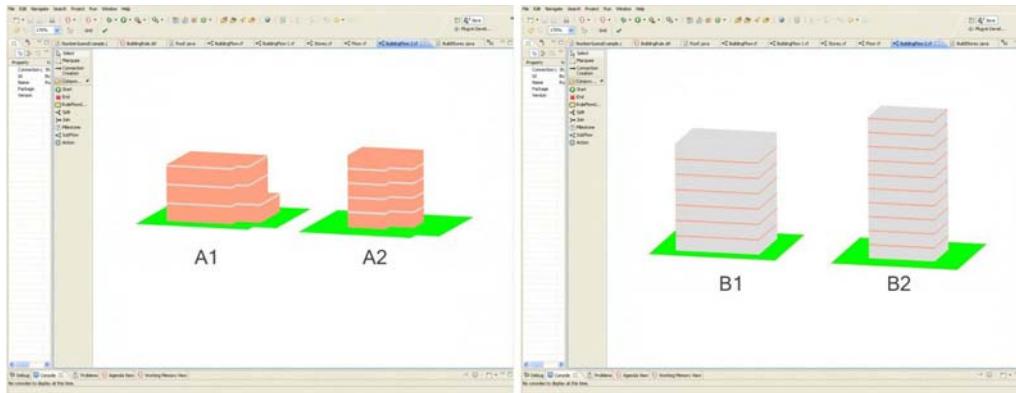
more parameters, as in the case of the following scenarios.

In B1 scenario (Figure 7), the same base geometric parameters were kept (perimeter of the area) that were used for scenario A1. In comparison with previous cases, even though the same shape of the area was kept, the building is located in a different part of the territory, in which it undergoes to the action of a field of forces characterized by higher values of 'Ie', 'Rc' 'SNmax' e 'Hmax', in comparison to A1 and A2 scenarios.

Given the same building area, in B1 Scenario, a bigger volume building was obtained, characterized by more stories and by a greater height.

The B2 scenario, (Figure 7) is characterized by the same values of 'Urban Constraints'. The 'Parameters' class are arranged so to increase the distance between the architectural envelope and the soils' perimeter. The system verifies the respect of other constraints, in particular the 'Rc' and determines a new configuration for the envelope, which, in comparison with scenario B1, becomes smaller within the perimeter of the area. The measure of the volume is unaltered, but the shape and the dimensions are changed, and the height and the number of stories are increased.

The shown scenarios of the studied case, are four, but there can actually be many more, duly operating on constraints and parameters. The presented examples, show how the most important urban elements, concerning the urban law system and the physical features of the context, when correctly codified inside a rule motor, can become elements, able to give birth to architectural shapes.

The most important aspect is represented by the opportunity for the project planner, of following an optimization process of the architectural features of the envelope, formal as well as volumetric, in which he becomes the protagonist; any variation to one or more parametric variables, is applied to all the components of the envelope, giving it a new configuration, which is visualized in real time and is therefore contemporarily changeable.

Future developments

Among the objectives for the near future, the introduction of other elements, inside the 'Field of Forces' class is foreseen, so that it will be possible to link the shape to more environmental factors and to increase the capacity of the system to simulate the effects on the context. Specially, in presence of already existing buildings located in the 'old city Centre', or in presence of significant environmental elements. A 'Climatic Class' for example is going to be introduced, so that the physical aspects may be taken under

consideration when generating the shape, as the insulation grade, the intensity and the direction of dominant winds. The aim is that of potentiating the application in order to manage more and more complex shapes.

Among the goals, there is also the study of the possibility of integration with other planning tools in use, as CNC (Computer Numeric Control) for the prototype simulation and CFD (Computational Fluid Dinamics) for verification of the dynamic behavior according to surrounding air fluxes, calculation of thermal fluxes through the envelope, and verification of the energetic functions of the same.

The integration between our application and other instruments is a must for a complete project planning process, which allows to ensemble all variables and parameters, so to evaluate, in real time, within a single process, the most important functional aspects required.

Conclusions

The new techniques open new fields for the development and exploration of more and more complex as well as innovative architectural shapes, where complexity is considered not only in the sense of geometric and topological properties of the shapes, but also in the relationship that links architecture to the elements of the surrounding environment.

The most complex problem is the difficulty in finding the relations between the elements that are often of different nature, defining significant variables that characterize the urban context, and to attribute them the respective values. Many of the actions which limit the shape, derive from considerations that can not be immediately translated and represented according to pre-defined codes, therefore giving origin to qualitative nature evaluations and choices non applicable in quantitative terms. These difficulties, aside from the complexity itself bound to concepts that rule a planning process, sometimes also force to a partial behavior in coping with the planning aspects, leaving out some

that may be, at times, necessary, in order to research simplifications that the complexity of the system requires.

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ARCHITECTURE 'in computro': practice, methods and techniques

For more than 25 years CAAD has been available and more and more successfully used in research and commercial architectural practice. In education, which by definition should prepare students for the future, the constantly evolving CAAD metaphor is provoking a challenge to cope with the ever expanding scope of related topics. It is not surprising that this has led to differing opinions as to how CAAD should be taught. Questions such as how advanced research results can be incorporated in teaching, or if the Internet is provoking self-education by students, are in striking contrast with the more fundamental issues such as the discussion on analogue versus digital design methods. Is CAAD a part of design teaching or is it its logical successor in a global E-topia? Although the E of education is a prominent factor in the "raison d'être" of the organisation, the eCAADe is open to all other relevant contributions in the area of computer aided architectural design.

eCAADe 'Education and Research in Computer Aided Architectural Design in Europe'

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