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CONNECTING BRAINS SHAPING THE WORLD
⇒ *COLLABORATIVE DESIGN SPACES*

G. Carrara
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Published by europia Productions
15, avenue de Ségur
75007 Paris, France
Tel +31 1 45 51 26 07
Fax +31 1 45 51 26 32
Email: info@europia.fr
http://www.europia.fr
http://www.europiaproductions.com

ISBN 979-1-090094-05-5

Cover designed by: Armando Trento, Gianluigi Loffreda, Antonio Fioravanti.

col·lab·o·rate *verb* \kə-ˈla-bə-ˌrāt\

intransitive verb

Definition of COLLABORATE

1: to work jointly with others or together especially in an intellectual endeavour;

2: to cooperate with or willingly assist an enemy of one's country and especially an occupying force;

3: to cooperate with an agency or instrumentality with which one is not immediately connected.

— col·lab·o·ra·tion *noun*
— col·lab·o·ra·tive *adjective or noun*
— col·lab·o·ra·tive·ly *adverb*
— col·lab·o·ra·tor *noun*

Examples of COLLABORATE

The two companies agreed to collaborate.

He was suspected of collaborating with the occupying army.

Origin of COLLABORATE

Late Latin *collaboratus*, past participle of *collaborare* to labor together, from Latin *com-* + *laborare* to labor

First Known Use: 1871

[*http://www.merriam-webster.com/*]

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Contributors

Afiq, Aliff	Multimedia University, MMU Creativista Sdn Bhd, Cyberjaya, Malaysia (p. 261).
Bazzocchi, Frida	Department of Civil and Environmental Engineering, Faculty of Engineering, University of Florence, Italy (p. 203).
Beheshti, Reza	Faculty of Civil Engineering and Geosciences, Delft University of Technology, The Netherlands (p. 41).
Beirão, José Nuno	Faculty of Architecture, Technical University of Lisbon, Portugal / Faculty of Architecture, TUDelft, The Netherlands (p. 233).
Briffaut, Jean Pierre	Institut Charles Delaunay-TechCICO-UMR6279 CNRS, Université de Technologie de Troyes, France (p. 17).
Campanelli, Lucio	University of Wisconsin-Milwaukee, United States of America (p.285).
Carrara, Gianfranco	Department of Civil, Building and Environmental Engineering, Sapienza, University of Rome, Italy (p. V).
Ciblac, Thierry	Ecole Nationale Supérieure d'Architecture de Paris La Villette. ARIAM-LAREA. France (p. 125).
Dado, Edwin	Faculty of Military Science, Netherlands Defence Academy, The Netherlands (p. 41).
Di Naso, Vincenzo	Department of Civil and Environmental Engineering, Faculty of Engineering, University of Florence, Italy (p. 203).
Dorta, Tomás	Université de Montréal, Canada (p. 83).

Duarte, José Pinto	Faculty of Architecture, Technical University of Lisbon, Portugal (p. 233).
Esposito, Maria Antonietta	TxP_Workgroup - University of Florence, Italy (p. 189).
Filson, Anne	University of Kentucky College of Design, United States of America (p. 111).
Fioravanti, Antonio	Department of Civil, Building and Environmental Engineering, Sapienza, University of Rome, Italy (p. V; 3).
Gomes, Ana Rita	TU Lisbon, Department of Civil Engineering and Architecture, Lisbon, Portugal (p. 67).
Gomes, Augusto M.	TU Lisbon, Department of Civil Engineering and Architecture, Lisbon, Portugal (p. 67).
Grazzini, Giuseppe	Department of Energetic “Sergio Stecco” Faculty of Engineering University of Florence, Italy (p. 203).
Halin, Gilles	FRE MAP-CRAI, Research Center in Architecture and Engineering, Nancy, France (p. 53).
Hassan, Hamid	Department of Civil and Environmental Engineering, Chalmers University of Technology, Sweden (p. 247).
Hemmerling, Marco	Detmolder Schule für Architektur und Innenarchitektur, Hochschule Ostwestfalen-Lippe, University of Applied Sciences, Germany (p. 159).
Hubers, J.C. Hans	Delft University of Technology, Netherlands (p. 177).
Irlwek, Manuela	University of Stuttgart, ICD Institute for Computational Design, Faculty of Architecture and Urban Planning, Germany (p.139).
Kalay, Yehuda	The Technion – Israel Institute of Technology, Haifa, Israel (p.83).
Kubicki, Sylvain	Public Research Center Henri Tudor, Luxembourg-Kirchberg, Luxembourg (p.53).

Lattuca, Raimondo	Dipartimento di Architettura, Università degli Studi di Palermo, Italy (p.167).
Lecourtois, Caroline	ARIAM-LAREA, Ecole Nationale Supérieure d'Architecture de Paris-la-Villette–Paris, France (p.25).
Lesage, Annemarie	Université de Montréal, Canada (p.83).
Loffreda, Gianluigi	Department of Civil, Building and Environmental Engineering, Sapienza, University of Rome, Italy (p. V; 3).
Macchi, Irene	Aeroporto di Firenze S.p.A., Italy (p. 189).
Macii, Enrico	Dipartimento di Automatica e Informatica, Politecnico di Torino, Italy (p. 217).
Menges, Achim	University of Stuttgart, ICD Institute for Computational Design, Faculty of Architecture and Urban Planning, Germany (p. 139).
Montenegro, Nuno	Faculty of Architecture, Technical University of Lisbon, Portugal (p. 233).
Nanni, Umberto	Sapienza, University of Rome, Dipartimento Informatica e Sistemistica (p. 297)
Octavia, Dita	Multimedia University, MMU Creativista Sdn Bhd, Cyberjaya, Malaysia (p. 261).
Osello, Anna	Dipartimento di Ingegneria dei Sistemi Edilizi e Territoriali, Politecnico di Torino, Italy (p. 217).
Pellitteri, Giuseppe	Dipartimento di Architettura, Università degli Studi di Palermo, Italy (p. 167).
Pérez, Edgar	Université de Montréal, Canada (p. 83).
Rafi, Ahmad	National Academy of Arts, Culture and Heritage, Ministry of Information, Communication and Culture, Kuala Lumpur, Malaysia (p. 261).
Rempling, Rasmus	Department of Civil and Environmental Engineering, Chalmers University of Technology, Sweden (p. 247).

Rohrbacher, Gary	University of Kentucky College of Design, United States of America (p. 111).
Rosário, Daniel P.	TU Lisbon, Department of Civil Engineering and Architecture, Lisbon, Portugal (p. 67).
Roupe, Mattias	Department of Civil and Environmental Engineering, Chalmers University of Technology, Sweden (p. 247).
Salleh, Azhar	Multimedia University, Malaysia (p. 261).
Sampaio, Alcinia Zita	TU Lisbon, Department of Civil Engineering and Architecture, Lisbon, Portugal (p. 67)
Santos, Joana P.	TU Lisbon, Department of Civil Engineering and Architecture, Lisbon, Portugal (p. 67).
Temperini, Marco	Department of Computer and Systems Sciences, University "La Sapienza" of Rome, Italy (p. 297).
Tuffanelli, Chiara	Arup, London, United Kingdom.
Trento, Armando	Department of Civil, Building and Environmental Engineering, Sapienza, University of Rome, Italy (p. V; 3).
Valori, Aurora	Department of Civil and Environmental Engineering Faculty of Engineering University of Florence, Italy (p. 202).
Wondimu, Paulos	Department of Civil and Environmental Engineering, Chalmers University of Technology, Sweden (p.247).
Wurzer, Gabriel	Vienna UT Architectural Sciences | Digital Architecture and Planning, Austria (p. 273).
Yi, Yun	Multimedia University, MMU Creativista Sdn Bhd, Cyberjaya, Malaysia (p. 261).
Zignale, Daniel	FRE MAP-CRAI, Research Center in Architecture and Engineering, Nancy, France. Public Research Center Henri Tudor, Luxembourg-Kirchberg, Luxembourg (p. 53).

PART III

GENERATIVE AND PARAMETRIC DESIGN

A Generative System to support architectural and urban design

Giuseppe Pellitteri [1], Raimondo Lattuca[2]

[1,2]*Dipartimento di Architettura, Università di Palermo, Italy*

[1,2]*http://unipa.it/~dpce*

[1]*pellitt@unipa.it,* [2]*lattuca@unipa.it*

Abstract. The work presents a system able to generate three-dimensional models of buildings, directly within a 3D geobrowser as Google Earth™. For this purpose we have developed the prototype of a parametric application that allows the designer to handle the architectural shape by using the main constraints belong to urban regulations.

The system integrates two different research topics: modelling in geo-referenced environment and modelling constraints. Compared to the related works (Building Modeling within georeferenced environment), our application is the first Generative Design System based on the urban regulation. It is a Decision Support System (DDS), useful at the early stage of city planning as well as at the stage of architectural design.

Some case studies are presented in order to test the Generative Design System: the design of residential buildings in an Italian city.

***Keywords**. Generative design; architectural design; urban design; georeferenced environment.*

1. Introduction

The software implementing complex algorithms based on parametric techniques, evolutionary systems, and shape grammars to model architecture, has been the focus of interest in the past years. Several digital design tools enable designers to manage an interactive architectural design process generating one building or a very large urban place (City Modelling). Some generative systems allow to bridge the gap between architectural shape and various forces or constraints emerging from the context. Among these, the systems implementing some constraints derived from the urban regulation are particularly interesting.

One of the most remarkable examples is CityZoom (Turkienicz et al., 2008). It is a Decision Support System (DDS) to urban planning: the buildings are generated by applying urban on plot geometry, according to input parameters. The system determines the geometrical features of the building which have to be assessed or optimised, such as number of floors, front or size width, and plot occupation. It is a powerful tool to evaluate the impact of urban regulations.

Urban Generator is a hybrid system integrating the generator of a large number of design solutions and the browser to search and structure the high-dimensional space of the design solutions, according to variable and customisable factors defined by the designer. It allows user to simulate different urban scenarios considering as input, total building volume, front and depth dimensions, floor number and height, number of buildings, minimal distance between buildings, minimal distance from the edge (Caneparo et al., 2007).

City Generator (Tang, 2008) is a tool for urban simulation. The central feature of the tool is a Genetic Evolution (GE) engine, which can quickly generate various urban forms by the combination of L-System controlled procedural model and the GIS map controlled SO (Spatial Occupancy) model.

CityCAD develops the automatic generation of buildings. This system allows analysis of urban masterplans at the early design stages. It calculates floor areas, densities, costs, car parking spaces and a wide range of other planning, environmental and financial data.

Prototype for Urban Code Constraints is a Decision Support Systems that simulates several options for the building shape, according to the parameters required by the city zoning planning, such as ‘Buildable coefficient’, ‘Site coverage coefficient’, ‘Setback requirements’ and ‘Sky exposure plane’ (Donath and Lobos, 2008).

Another example is the Parametric Envelope (Mellantoni, 2006), which allows designers to create prototypes in Revit©: the urban code is turned into computable data and theoretical volume is shown in real time.

ArchiGen is a generative application that enables designers to generate architectural shape, within a Building Information Modeling (BIM) environment like ArchiCAD©; it is based on GDL (Geometrical Description Language). The designer is able to explore architectural schape, by changing parameters such as ‘floors count’ and ‘floor height’ (Mallasi, 2007).

High FAR allows designer to generate a high-level residential district planning, with the focus of a layout of high ‘Floor Area Ratio’ (FAR). The tool is based on the principle of Multi-Agent System (MAS) and simple genetic algorithms (Biao et al., 2008).

Besides, formal local planning codes, patterns of movement, social codes, and other interventions, which affect the architectural shape, can be included in the process to obtain a new modelling technique (Erickson and Lloyd-Jones, 1997). These patterns may be used to explore the emergent properties of different types of the urban settlement. Moreover, they can suggest ways in which the planners could beneficially influence the development processes that are otherwise beyond their control.

In the architectural design process, the designers are able to handle other constraints such as architectural features of the envelope, types of façade as well as types of windows and roofs. An interesting example is Split Grammars (Müller et al., 2006). It is a technique derived from shape grammar, which generates many configuration alternatives of the building façade.

The morphogenesis of architectural shape could be performed by using climatic or physical features, such as solar radiation (Caldas, 2005) and solar passive evaluation (Marin et al., 2008), based on the Unified Day Degree (UDD) method. They lead to the optimisation of architectural envelopes through a Genetic Algorithm to minimise HVAC and lighting energy, in the first case, and solar passive qualities in the second case.

CityEngine (Parish and Müller, 2001) is a tool based on 'Procedural Modeling of Cities'; it was developed to enable designers to generate many digital models of buildings and cities, changing a set of specific rules that can be managed by designers.

Wall Grammar is used to automatically generate building façade (Larive and Gaildrat, 2006). The tool imports GIS data such as '.dxf', '.vmap', containing the building footprints. The building outlines and heights can be either obtained automatically or defined in a GIS environment. Then the system uses such data to create 3D building models.

The most recent development of Geo-Visual Analytics offers to designers and city planners new opportunities. Some systems, such as World Wind© (NASA), Google Earth™ (Google), Virtual Earth® (Microsoft), provide three-dimensional models of earth surface. The information available through geographical services can be employed to create 3D representations at territorial scale that are useful to land planning and urban design.

2. Overview on implementd rules

We present a System able to generate three-dimensional models of buildings, directly within a 3D geobrowser such as Google Earth™. We have developed a prototype of parametric application that allows designer to generate digital models of buildings by using the main constraints based on urban regulation. The System integrates two different research topics: modelling in geo-referenced environment and modelling constraints. Compared to existing works about the building modelling within georefenenced environment, our application is the first Generative System based on the use of urban regulation.

The urban planning regulation establishes some parameters and constraints to control urban structure, shape of the buildings and their geometrical features, such as height (H), number of storeys (SN), storey height (hi), area of the floor (A_{floor}), area of the building footprint ($A_{footprint}$), distance from boundaries plot (d_i), with i = 1, 2… SN, We take into account the following set of parameters:

- Building Index (BI): multiplied by the area of the plot, determines the maximum volume of the building.
- Coverage Ratio (CR): multiplied by the area plot, determines the maximum area footprints.
- Maximum building height (H_{max}): the maximum vertical distance between the ground level and the highest point of the building.
- Maximum storeys number (SN_{max}).

- Setback requirements: the minimum distance between the sides of building footprint and the plot boundaries (DB_{min}).
- Minimum storey height ($h_{s\text{-}min}$): the minimum vertical distance between the floor and the ceiling of an inhabitable room.

Each of these parameters affects the volume and all the geometrical features of the buildings, through the following relations (Figure 1):

$$BI \geq \Sigma(h_i A_{floor}) / A_{plot} \quad (1)$$

$$CR \geq A_{footprint} / A_{plot} \quad (2)$$

$$H_{max} \geq \Sigma(h_i) \quad (3)$$

$$SN_{max} \geq SN \quad (4)$$

$$DB_{min} \geq di \quad (5)$$

$$h_{s\text{-}max} \geq h_i \geq h_{s\text{-}min} \quad (6)$$

Term A_{plot} represents the area of building plot. The maximum storey height ($h_{s\text{-}max}$) is an important parameter for the generative process and it. is not indicated in urban planning regulation, being set by the designer according to specific architectural requirements. The relations 1, 2, 3, 4, 5, 6, duly codified through an object-oriented method, become generative rules that enable designer to create 3D models of the buildings.

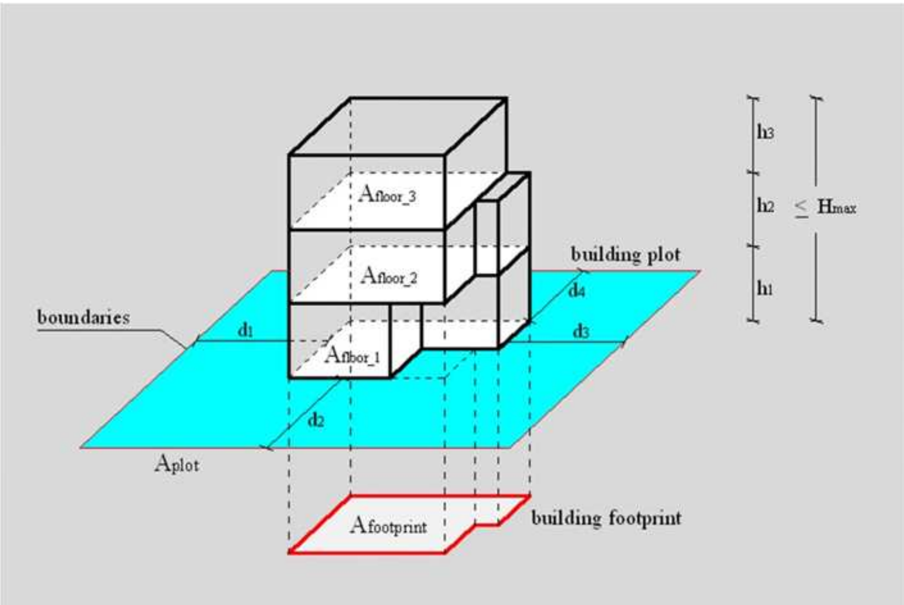

Figure 1
The geometrical features of a building generated according to urban planning regulation, duly codified through an object-oriented method.

3. The System

The System is a Decision Support System (DSS), useful at the early stage of city planning and architectural design. During the city planning process, the system allows the planners to evaluate the impact of the urban regulations and therefore to choose the best set of rules and parameters in order to achieve the desired environmental goals. It also enables the designer to interactively operate in the early stage of the architectural design process. It allows the designers to optimize specific formal requirements, and generate 3D model of buildings according to the most significant urban parameters. The designer can explore quickly many urban scenarios and various possible alternatives of the architectural shape. He can change the value of selected parameters and visualize in real time the results of the changes.

The architecture of the developed System is based on Java Enterprise Edition Environment and XML mark-up language. The System consists of three components: Data Processor, 3D Model Generator and Visualizator.

Data Processor implements the generative rules describing the urban regulations, the geometrical and topological relations, and it carries out computational tasks including conversion of coordinates vertices (from latitude and longitude units to meters), determination of geometrical attributes of the building models, such as building height, storeys number, storeys height. The outcome consists of a list containing the vertices (x, y, z) to triangulate.

3D Model Generator is based on 'COLLADA' (COLLAborative Design Activity) and '.kml' (Keyhole Markup Language) technology. It generates two format files representing the building model: 'model.dae' and 'model.kmz'. The 'model.dae' is exportable into many commercial CAD software; the 'model.kmz' consists of a compressed file, which contains much information about the 3D models, not only the geometrical attributes but also the texture of façades and his location on the earth surface. The 'Texture Library' contains many data images (.jpg, .bmp, .gif), consisting in textures to apply on the 'model.dae'. The designer can always access inside the 'Texture Library', in order to update and enrich it.

Visualizator enables designer to use the powerful 3D viewer and the other features provided by Google Earth™. It is based on a Java class that launches Google Earth™ and places the 'model.kmz' on the earth surface.

The parametric Graphical User Interface (Figure 2, left) allows to control specific data:

Geometric input file, '.dxf', '.shp' and the 'kml' formats, which contains polygons (building plots or building footprint). The designer defines different polygons ('polyline' command), such as convex, concave, regular or irregular ones, by using the commercial CAD software or GIS systems. The input file must be georeferenzed, in order to achieve a correct visualization of the building models within the 3D Geobrowser. The system supports georeferenced files, not only in latitude/longitute units, but also in UTM (Universal Transverse Mercator) units. UTM coordinates are more preferred than latitude-longitude, because the system run very quickly and efficiently.

Parameters input are defined by urban planning regulation, such as building index, coverage ratio, maximum building height, maximum storeys number, setback requirements, minimum storey height; other required parameters are maximum storey height and texture of façade.

The designer manages the interactive generative process (Figure 2, right): he sets the parameters, loads the geometric input file and runs the application; the System calculates geometrical attributes of the building, generates 3D models and displays them in Google Earth™. Parametric and geometrical modifications involve the automatic regeneration of the 3D models with all architectural features.

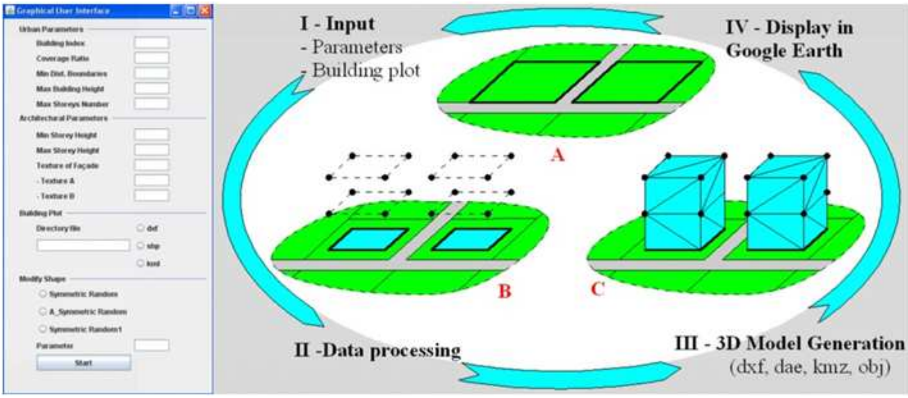

Figure 2
Left: Parametric Graphical User Interface. Right. The generative process: building plots (A); the System calculates the vertices of the floors according to the generative rules (B); 3D building shape is generated and consisting of triangular mesh (C).

The compatibility with the architectural CAD systems was one significant issue on which the work has been focused. The compatibility is especially important in order to enable the designer to interactively handle the input file, during the generative process. Referring to input stage, the System is able to interface itself with many kinds of software supporting three widely used file formats, such as:

CAD systems supporting the '.dxf' format: AutoCAD®, ArchiCAD©, Microstation®, Autodesk Map 3D®.

GIS systems, supporting the '.shp' format: ArcGis®, fGIS®, PostGis®, GrassGis®, gvGIS®, OpenStreetMap®.

3D Geobrowsers, supporting the '.kml' format: Google Earth™, Nasa WorlWind©.

The application combines the modelling ability of CAD systems with the several opportunities offered by Geovisualizations and 3D Geobrowsers; the interactive environment enables the designer to make better decisions. The System was designed to display the outcome in Google Earth™ and allow designers to navigate through a three-dimensional scenario, which represents the city modeled, with the blocks, plots, buildings and reconstructions of the 3D terrain.

The designer is able to export the three-dimensional models generated by the System, even within the most commercial software used in the field of architectural design. The '.dae' extension of the digital model enables the export within CAD, GIS and CFD systems, including AutoCAD®, Revit®, 3D Studio Max®, Blender®, Maya®, Catia®, MicroStation®, Poser®, Cinema4D®, Softimage XSI®, MeshLab®, CityEngine, SketchUpPro®, Simlab Composer v2®, Arc2Earth®.

The CFD (Computational Fluid Dynamics) systems, integrated with the architectural digital model, allow to predict temperatures, air flow direction/velocities and pollution dispersion, inside the urban space during the early design stage.

The designer are able to make architectural changes, i.e. modify architectural shape or urban configuration until to get desired results.

Two considerable CFD packages are CFX® and Fluent®. The New Fluent releases enable designer to use directly the existing native CAD geometry, without translation to '.iges' or other intermediate geometrical formats. Both CAD and CFD systems allow the designer to achieve a complete simulation, and to take in account many constraints, not only urban regulations but also climatic features.

4. Case Studies

We present three case studies concerning the design of buildings in a peripheral area of Palermo (Italy). Each of these allows to generate a range of possible formal solutions and evaluate the results of their spatial organizations. In order to facilitate the simulations and to make these more concrete, we have avoided forms totally invented, without any reference to spatial aggregations really possible.
So we have referred to projects done in three different European cities: Zandaan and Rotterdam (Netherlands) and Berlin (Germany), which however have had relationship with an environment very similar to those taken into account. We have also chosen very different configurations, referred to three different types of buildings: tower, courtyard and terraced houses.

In the first case we have referred to the project known as 'Salamander' designed by M.A. Miguel and L.B. Mastenbroek and realized in Zaandam (1999-2006). The building consists of 79 apartments with a courtyard, with a free public space, and 14 service apartments and community facilities.

The outline of the building and its height have been deliberately opposed to the urban context, which is a neighborhood with terraced houses and multi-storey row houses. The scenario of the planning allowed the simulation to assess the inclusion of the building in the urban context of the Palermo's periphery (Figure 3).

The second case concerns the building called 'De Ruyter', one of the 13 blocks of apartments designed by F. Van Dongen and Architecten CIE for 'Müllerpier', near Maas River, between downtown and Rotterdam-West. The shape of the building has been derived combining two different types of houses, courtyard and tower. The scenario was generated aggregating several buildings properly arranged, forming a whole block in the neighborhood in accordance with the urban regulations of Palermo (Figure 4).

Figure 3
The 'Salamander' building (M. Loosand and B. Mastenbroek, Zaandam, Netherlands, 1999-2006). The 3D model was used to simulate an urban scenario in an peripheral area of Palermo, Italy (Google Earth™).

Figure 4
The building 'De Ruyter' (F. Van Dongen, Müllerpier, Rotterdam, Netherlands, 2005-2008). Its 3D model was generated aggregating several buildings within the same area.

The third case deals with terraced houses designed by architect K. Muller-Rehen (Cambi et al., 1992) and built in Berlin (Germany, 1956). The generated scenario shows that the buildings have been arranged in groups of four units following the inclination of the area chosen for simulation (Figure 5).

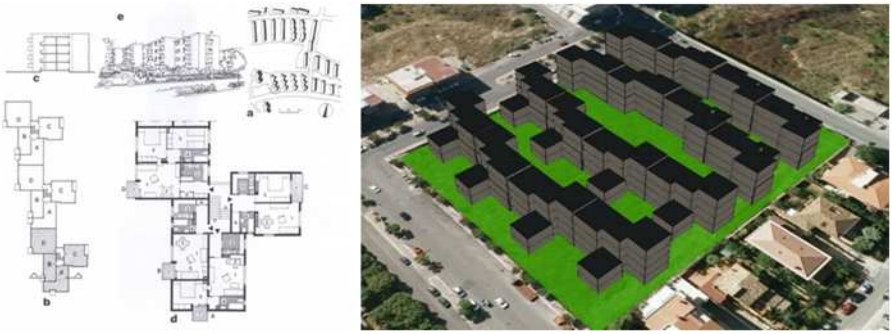

Figure 5
The 'Row houses' (K. Muller-Rehen, Berlin, Germany, 1956). The 3D building models generated and displayed in the same area.

Conclusions

The results show that using specific information and tools, in the early stages of the architectural design or the city planning, reduces the time of work, and allows to explore many alternatives in a short time. Many difficulties have arisen when collecting information. The most complex problem was the difficulty in finding relationship between elements that are often of different nature, defining significant variables characterizing the urban context. Some environmental features could be easily identified and encoded: geometric components as height, floor number, area of building footprint and other aspects derived from general regulations. However, other types of environmental factors, such as social codes, economic factors and psychological aspects, are very often difficult to translate into generative rules.
The most complex issues dealt with finding and implementing relationship between various types of features, as well as defining significant parameters characterizing the architectural shape and environmental context. Many actions limiting the shape derive from considerations that can not be immediately translated and represented according to predefined codes, therefore giving origin to qualitative natural evaluations. Aside from the complexity itself bound to concepts that rules a planning process, these difficulties sometimes also impose a partial behaviour to coping with the planning aspects. Then we have to leave out some of it that may be at times necessary, in order to research simplifications that the complexity of the system requires.We will improve the System in order to introduce other kinds of parameters, specially typological and formal, that constraint the shape to urban local conditions or to specific needs. Besides, other environmental features will be added to better simulate the effects of the context. For instance, physical and climatic factors such as solar radiation. A better system of generating architectural shape could be developed by dividing the space of a building into functional units, connected and related between them. We would include geometric rules for the generation of streets, lots, and land-use on a small scale.

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Printed in June 2011
by

Società Tipografica Italia a r.l.

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