

# Simulator Rules for Architecture and Civil Engineering

Gustavo Goedert<sup>1</sup>, Márcio Serolli Pinho<sup>1</sup>,  
Benamy Turkienicz<sup>2</sup>, Roni Anzolch<sup>2</sup>

<sup>1</sup>Pontifícia Universidade Católica do Rio Grande do Sul - PUCRS  
School of Computer Science  
Av. Ipiranga, 6681-Porto Alegre-RS-91.360-080-Brasil  
[pinho@inf.pucrs.br](mailto:pinho@inf.pucrs.br)

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## Abstract

This document presents a study on the application of Computer Graphics and Virtual Reality techniques for the analysis of Master Plans and for helping solve some of their problems. The concepts of Master Plans and Virtual Reality are presented. Next is presented an application that was implemented aiming both at the creation and testing of the block build according to the building codes contained in Master Plan as well as the experience of the obtained results in a Virtual World.

**Keywords: Virtual reality**

## INTRODUCTION

The master plans of a city govern the architectural form of the civil constructions of the modern cities, as well as they establish the rules for physical, social and economical occupation of the available spaces. The rules that compose these master plans define the way the buildings and their adjacent spaces are configured. Such rules are denominated *construction codes* or *edification codes*.

An important information to be considered concerning the construction codes is the possible accumulation of rules, definitions and meticulous details, that may, frequently, impeding the architects' work in the conception of the constructions. Many times, these professionals are compelled to do very generic suppositions, or they are induced to mistakes, that compromise the natural proposal of maximum use of available spaces built, proposed by the construction codes themselves.

Frequently, such rules also inhibit the architects' creative work, who in turn are worried with the rules of occupation and fail to get the best use of space they could.

The inconsistencies are evident and they result in building-dwarfs, profile segmentation, excessive

subdivision of the interior space of the blocks, chaotic alignment and big variability of building heights. However, these problems are more a consequence of a wrong use of the evaluation methodologies of the construction models than an individual problem [ANZ 95].

With the aim of solving this problem, a three-dimensional graphic simulation system was developed by the Virtual Reality Group at PUCRS, jointly with the SIMMLAB Group of School of Architecture at UFRGS. This program has as its main interface a Construction Code Editor.

Actually, these construction codes, are summarized by a group of recoil rules, indexes of land use and allowed heights. Providing the system with data about the blocks and appropriate lots, the program generates as a solution, the configuration of the spaces that can be built. This solution is presented in the form of the maximum possible construction in each lot, denominated here by *constructable bounding box*. This bounding box is probably not very different from the final construction that will occupy the lot, mainly because the dynamics of the occupation is to use the maximum of the available space allowed by the construction code.

To widen even more the analysis range and to test interactivity the results of changes in construction code variables, the simulator also creates an image output into a Virtual Reality immersion equipment [CRU 98, WOOD 98], such as virtual reality glasses (Head-Mounted Display - HMD). To facilitate the navigation it is possible to use a joystick, that will allow a fast and easy way to accomplish movements inside the environment to be built.

## 2. THEORETICAL FOUNDATIONS

### 2.1 Master plans

The master plan of a city is a basic instrument of

planning and implementing the development politics and control of the urban expansion.

Social Politics of urban development are sets of objectives and guidelines to guide the government action concerning the population distribution and the urban activities in the territory, defining the respective priorities, with the aim of ordering the full development of the social functions in a city and promoting the well-being of the population.

### 2.1.1 Construction Codes

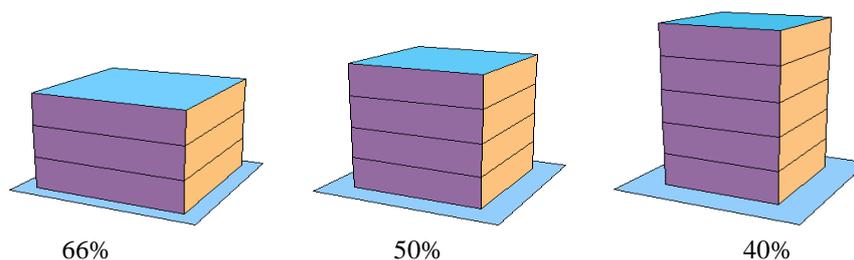
In the case of Porto Alegre city, the construction codes are inside a group of rules called RU (Urban Rules). In RUs there are parameters classified as: Use index; Occupation rate (expressed in percentage); Heights; etc.

RUs are, in turn, governed by UTP (Territorial Unit of Planning). UTPs are codes that try to adapt rules to the context of a delimited zone. A certain UTP can have as context a commercial zone, while another one can have as context a residential zone. Usually, there isn't only one construction code for a city, but several construction codes, appropriated to the context to which they are applied.

### 2.1.2 Involved variables

The construction codes are summarized basically to limitations and recoil and clearance rules that can be specified by variables as, for instance: number of floors; occupation rate; occupation index; and recoil related to the number of floors.

As example, a certain construction code can establish that a construction should not have an occupation index superior to 2. A construction built under this code can have an occupation rate of 66% if it has 3 floors, 50% if it has 4 floors, 40% if it has 5 floors, and so on, as shown in figure 1.



**Figure 1 - Example of use of Occupation Index Rule**

In another example, the construction code can establish that a construction should have a recoil of 0.5 meter for each floor. This construction then should have 2 meters of recoil if it has 4 floors, 3 meters if it has 6 floors, and so on, as shown in figure 2.

## 2.2 Virtual Reality

The virtual reality can be seen as a new user interface paradigm [PIN 96, PIN 97, RAW 98]. In this paradigm, the user is not more in front of the monitor, but, inside the interface. With special devices, the virtual reality tries to capture the user's body movements (in general arms and head) and, from these data, to accomplish the man-machine interaction.

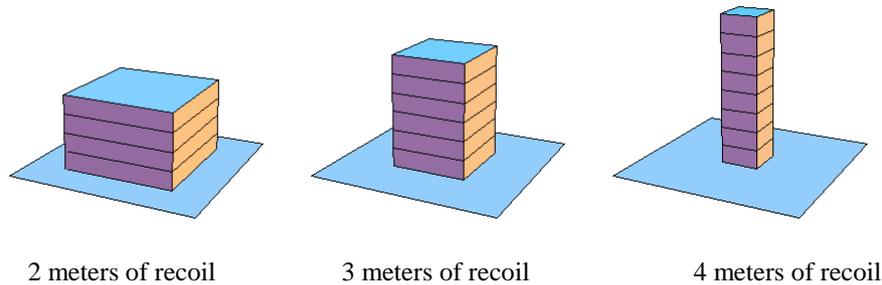
## 3. PROJECT DESCRIPTION

### 3.1 Goals

The main goal of this work was to offer to architects and civil engineers a tool that makes it possible not only to project and to test construction codes but also to apply these codes in the building projects, helping in this way, in the search of the maximum use of space. In this view, the simulator has two types of users:

- The responsible for the elaboration of construction codes;
- The users of these codes (architects and engineers).

The responsible for the elaboration of construction codes can, through the simulator, verify, in real time, the form that the code will impose to urban spaces. The program allows this user to test several configurations of a construction code and aid in the choice of the most appropriate configuration.



**Figure 2 - Example of the *Recoil Rule* relative to the number of floors**

The architects and engineers, who need to use the construction codes, can use a tool that, given a construction code, could help to extract from them a constructable bounding box suitable for his needs.

The program also allows to export the results to very common file formats used in virtual reality programs and applications, like WLD[ROE 95] and VRML [CLA 96, HAR 98, SIG 95] file formats.

### 3.2 Architecture of the Simulator

This simulator was developed under Microsoft Windows system, with the DELPHI programming tool [BOR 96].

The program “Construction Rules Simulator” is divided in two main modules: the Edition Module and the Visualization Module. In the Edition Module the user is able to create and to edit the construction codes, and to interact with the Visualization Module that shows the results of these codes applied to blocks and lots also defined by the user. The Visualization Module can also export the results to the WLD and VRML file formats.

This program was projected using multi-windows user-interface or MDI (*Multiple Document Interface*), where several blocks and construction rules can be simultaneously loaded in the corresponding modules. The user can test with this, at the same time, different construction rules, applied on several different blocks, comparing and evaluating the results.

#### 3.2.1 Edition Module

The Edition Module is composed by restrictive variables, that regulate (or model indirectly) the form of the envelope in which the building should be contained, the so called constructable bounding box. For each floor several recoil will be associated. These recoils and clearances can correspond to a master plan that the user wants to test.

This module was elaborated together with the architects from the SIMMLAB, always having in mind that it must be easy to use and must have a reasonable capacity for representing many different master plans. The figure 3 shows the screen of the Edition Module.

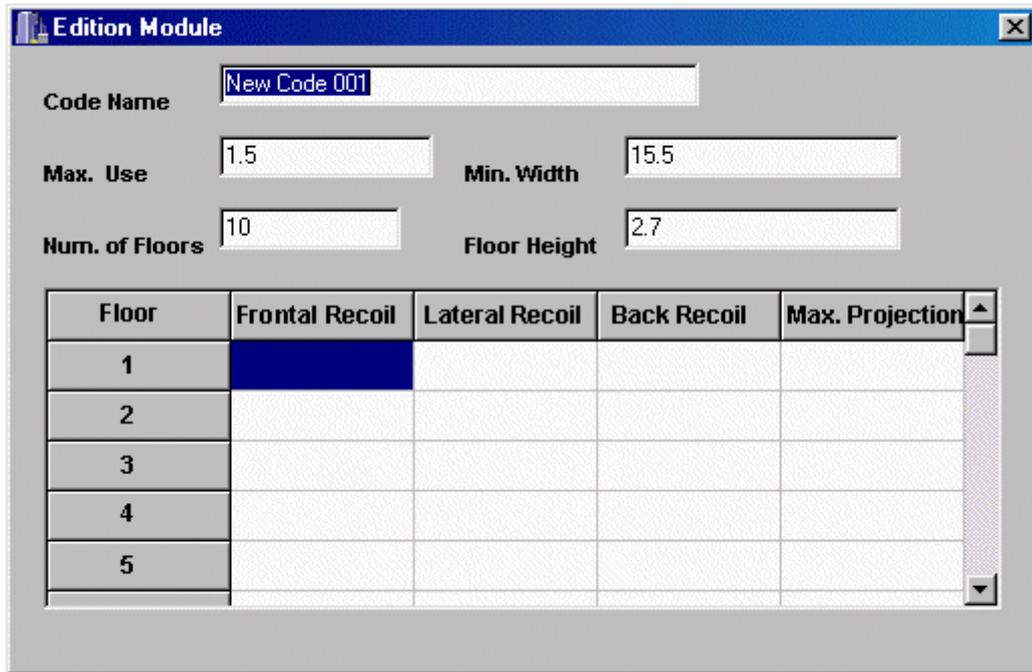
In this screen there are two groups of restrictive variables:

Variables for all the building independently of the number of floors;

Variables that are dependent of the number of floors.

The variables that are independent of the number of floors are: Code Name; Maximum Occupation; Minimum Width; Height of the floor.

The variables that are linked to the number of floors are: Frontal and sides recoils; Maximum Projection.



**Figure 3 - Edition Module**

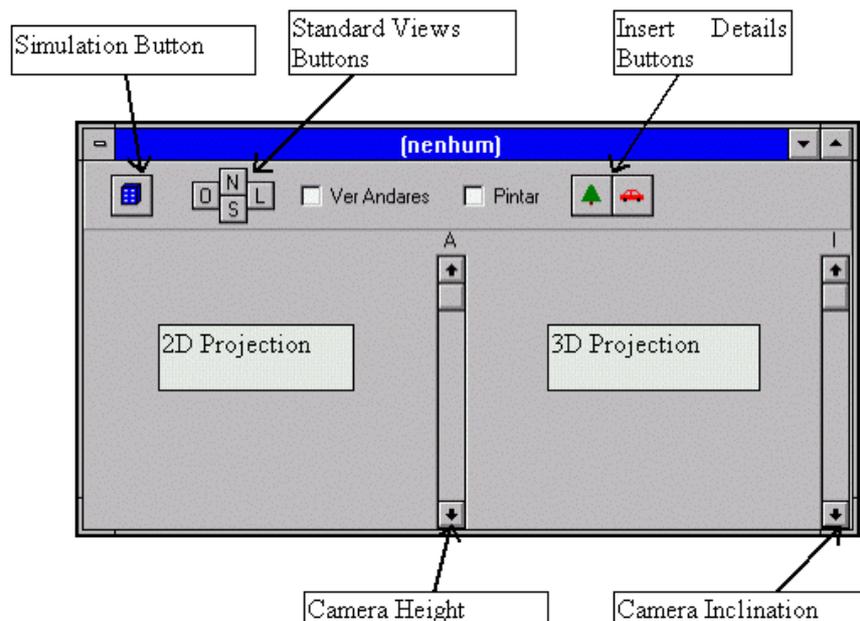
### 3.2.2 Visualization Module

The Visualization Module is composed of three parts: the toolbar, the two-dimensional projection and the three-dimensional projection, according to figure 4.

The blocks and lots are loaded from a DXF file. The file DXF can be generated by the AUTOCAD modeling program [AUT 93]. The blocks and lots should be represented by closed *Polylines* entities. As a DXF file is divided in *Layers*, the *Polylines* that

represent the blocks should be in *Layer* QUADRAS and *Polylines* that represent the lots should be in *Layer* LOTES.

In toolbar it is possible to control several aspects of the simulation. These tools are: Simulation; Standard Views; Option for Floor Visualization; Option for Painting; Buttons to Insert Details.



**Figure 4 – Visualization Module**

The 2D Projection (superior view) was created to give a general vision of the simulation, and also to position the camera and the target for the 3D Projection. The camera is represented by a small arrow and it can be positioned using the left mouse button, the camera target can be positioned using the right mouse button.

The 3D Projection supplies a three-dimensional perspective of the simulation, and it is useful to show result of the application of the construction rules on the block.

There are also two scroll bars, one located on the left of the 3D projection (representing the camera height), and the other placed on the right of the same 3D projection (representing the orientation, or inclination, for camera in its X axis).

For the internal three-dimensional projection it was used, in a first moment, the BSP-tree technique [FOL 90]. This technique is interesting for this application because when only the camera moves the scene can redraw very quickly. Now we are using the OpenGL library [WOO 97, WOO 98].

### 3.2.3 Visualization with Virtual Reality

As noticed before, the results obtained by the visualization module can be exported to WLD and VRML file formats. It can also generate some extra details, as trees and cars, that can be positioned by the user in order to give more realism to the generated scene. Two virtual reality devices can be used:

- A *Head-Mounted Display*: This equipment is used to input and to output data. As input it returns the position and the orientation of your user's head. As output it shows stereoscopic images of the simulated spaces. In the project we are using an I-Glasses HMD [I-GLA 99];
- A *Joystick*: This equipment is used for input. The user can move around in the environment, manipulating the *Joystick*.

## 4. AN EXAMPLE

Next an example of the use of the Simulator will be shown.

Figure 5 shows the Rules Editor with the data from the Edification Code number 5 of the Master Plan of Porto Alegre [ANZ 95]. The figure 6 shows the result on a neighborhood lot.

The screenshot shows a software window titled "Edition Module" with the following input fields:

- Code Name: Code 05
- Max. Use: 1.5
- Min. Width: 15.5
- Num. of Floors: 10
- Floor Height: 2.7

Below the input fields is a table with the following data:

Floor	Frontal Recoil	Lateral Recoil	Back Recoil	Max. Projection
1	4	0	0	0.6667
2	4	3	3	0.6667
3	4	4	4	0.5
4	4	4	4	0.5
5	4	4	4	0.5

Figure 5 – The input of the Code 05



**Figure 6 - Neighborhood with the Code 05**

## 5. CONCLUSION

The developed tool is useful to study the construction rules and its effects, making estimates of the constructions that can be built, given the place and the rule of construction.

The interface with the virtual reality allows a realistic idea of the generated constructions.

As a result, the simulator can contribute not only to increase in the efficiency of the industry of civil construction, but also for the improvement in the use of the urban spaces, propitiating, this way, an unquestionable improvement in the life quality for the inhabitants of the modern cities.

The program can also be used with other virtual reality applications, because it can very quickly build entirely realistic neighborhoods. These data can also be used to test new *software* and *hardware* of virtual reality.

## REFERENCES

- [ABN 92] ABNT - Associação Brasileira de Normas Técnicas Normas para elaboração de Plano Diretor - NBR 12267. 1992.
- [ANZ 95] ANZOLCH, Roni; TURKIENICZ, Benamy Urban Shape Codes. Master Thesis, UFRGS, Porto Alegre, Rio Grande do Sul, 1995.
- [AUT 93] AUTODESK Inc. Autocad Release 12 User's Guide. Autodesk, 1993.
- [CRU 98] CRUZ-NEIRA, C. "Applied Virtual Reality". Siggraph'98. Course notes, 1998.
- [CLA 98] Clark, Pete. "The Easy VRML Tutorial". Available at <http://www.mwu.edu/~pclark/intro.html>
- [BOR 96] BORLAND Inc. Borland Homepage. Available at <http://www.borland.com>, 1996.

[FOL 90] FOLEY, J. D. et alli "Computer Graphics, Principles and Praticce". Addison - Wesley, 1990 2ed.

[HAR 98] HARDENBERG, Jan C. VRML Frequently Asked Questions, 1995. Available at [http://www.oki.com/vrml/VRML\\_FAQ.html](http://www.oki.com/vrml/VRML_FAQ.html)

[I-GLA 99] I-Glasses. I-O Display Systems Inc. <http://www.i-glasses.com>

[ROE 95] ROEHL, Bernie. "Using AVRIL - A Tutorial", 1995. Available at <http://sunee.uwaterloo.ca/pub/avril/avril20.zip>,

[PAU 98] Paush, R. "Imersive Environments: research, applications and magic". Siggraph'98. Course notes., 1998.

[PIN 96] Pinho, Márcio S. "Virtual reality as a tool for education". VII SBIE. Belo Horizonte - MG, Novembro, 1996.

[PIN 97] Pinho, Márcio S e KIRNER, Cláudio. "An introduction to virtual reality". Course notes. X SIBGRAPI - Brazilian Computer Graphics and Image Processing Conference. Campos do Jordão, SP, Outubro, 1997.

[SIG 95] SIGGRAPH'95 - Course notes Available at <http://www.siggraph.org/conferences/siggraph95/siggraph95.html>

[WOO 97] Woo, Mason et al. "OpenGL Programming Guide, The Official Guide to Learning OpenGL", Release 1, 1997.

[WOO 98] Woo, M. "A visual introduction to OpenGl programming". Siggraph'98. Course notes, 1998