#201

DEPTHSPACE3D

A Digital Tool for 3D Space Syntax Analysis

FRANKLIM MORAIS
Escola Superior Artística do Porto, Porto, Portugal
franklim@cyberoikos.com

DAVID LEITE VIANA
Nottingham Trent University, Nottingham, United Kingdom
dlvarq@gmail.com

JORGE VIEIRA VAZ
Escola Superior Artística do Porto, Porto, Portugal
iorge@hotmail.com

ISABEL CRISTINA CARVALHO
Concinnitas CRL, Porto, Portugal
isabel.cristina.carvalho04@gmail.com

CATARINA RUIVO
Faculdade de Arquitetura da Universidade de Lisboa, Lisboa, Portugal
catarinaruivopereira@gmail.com

CRISTINA PAIXÃO
Concinnitas CRL, Porto, Portugal
cmartinspx@gmail.com

1. INTRODUCTION

This poster is integrated into a set of actions presented to this 11SSS, presenting DepthSpace3D, a new digital tool for 3D space syntax analysis, free for academic use, including a workshop and a paper with a case study. Some questions as 'why SS3D?' or the demonstration of its potential appear in (Morais 2017).

2. OBJECTIVES

The research team began to work on a 3D SS software application, with some objectives in mind:

- operational features: ease of use, i.e. a rich user interface and good performance;
- but specially semantic features, more or less the same set of quantities / SS concepts to characterize the space, such as (with no hierarchy or structure at all) distance, visibility, isovist, depth, visual connectivity and integration, skewness, control, segregation and hundreds of others, that the SS research community had already produced. Those SS concepts constitute a remarkable connotational semantics that is widely used by the community, have already a strong denotational semantics in theoretical studies of architecture and urban planning. This means that the heuristic of this vision of SS is well established, if not yet in the mass of the architectural practitioners, at least in the extensive community of SS practitioners.

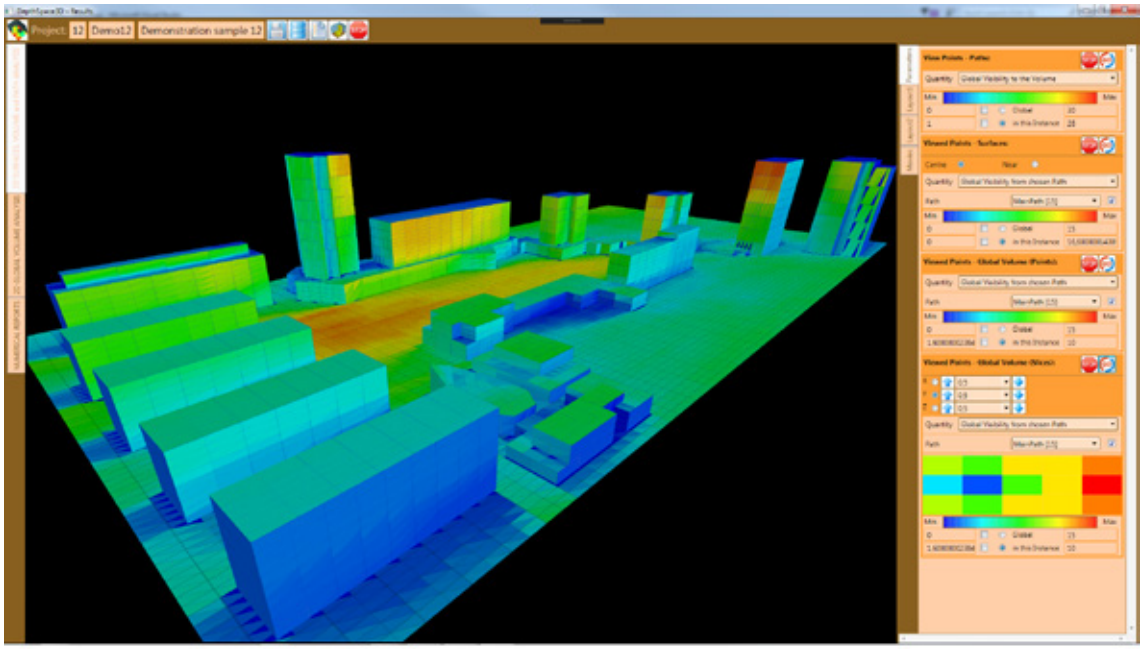

Figure 1 - the user interface

3. MODELS

(Duncan 2015) has the merit to bring to us a compilation of solutions for the problem of representation of 3D isovists. This effort was both weak and excessive for DepthSpace3D concerns. First, because the problem of the isovist flat representation is not only solved in the current 3D CAD software, but because it's the kind of thing they can not avoid to do - showing isovists is their current graphical interface. And second, because some of what was intended to be 'ego-centered, phenomenological mode' (Thiel 1997) heuristic interpretations of the isovists are, in fact, non computational models and/or models that loose (and do not gain) information relative to the original - see (Thiel 1961, 1997), (Penn 1996) (Teller 2003) and the 3 proposals of (Duncan 2015).

However (Derix 2007), Ratti and Morello's 2009 and (Varoudis 2014) have very important contributions, picked up by DepthSpace3D.

Nevertheless, the main model for DepthSpace3D development comes from 2D software. The team's intention was to create a 3D SS software that was able to do in 3D models of the built environmental world the same type of analysis DepthMap/X (Varoudis 2012) do in 2D models.

There was no intention to discuss Space Syntax paradigms. However, it soon became evident that some fundamental concepts needed not a global rethinking, but some amount of critique.

4. THE TRANSITIVE PROPERTY ISSUE

DepthSpace3D addressed the big problem of the possible transformation of SS analysis in an abelian group algebraic structure that would solve the transitive property issue. Please see *1 THE MISSING LINK.

5. VIEWING SPACE AND VIEWED SPACE

In 3D SS, following (Varoudis 2014), the active space has to be split in two conceptually different spaces, unlike SS2D, that mystifies their conceptual difference.

To view is an human activity, the objects in space are viewed by humans. Thus, DepthSpace3D considers two different spaces - the Viewing Space (space that humans can occupy), and the

Viewed Space that is offered to be seen by humans. Of course we can enlarge that concept to other possibilities, like video cameras.

Unlike (Varoudis 2014) and Ratti 2009, two kinds of Viewed Spaces are considered: besides the global Volume, the Surfaces of the objects that inhabit the global volume and are exposed to be viewed are also considered.

6. THE OBSTACLE SPACE

The Obstacle Space is composed by the set of opacifiers in the given space. There are two types of opacifiers:

- a set of surfaces, with a certain degree of transparency / opacity of the media. DepthSpace3D considers 2 opacities for each surface, one for each side of the surface. DepthMapX only consideres this type of opacifier, but only with one value - total opacity.
- the linear loss of visibility over distance (in %/m) of the volume media, for example: fog limits visibility to a certain amount of meters.

7. THE VISIBILITY FUNCTION

As in DepthMapX, the primitive mathematical concept is the visibility function, not the isovista. But in DepthMapX, it is established between any two points of the active space. In DepthSpace3D this function is always directed from the Viewing Space to the Viewed Space (concepts not existing in 2D). The domain of the Visibility Function is the set of the cartesian product of all the View Points by all the Viewed Points. The codomain is a real between 0 and 1.

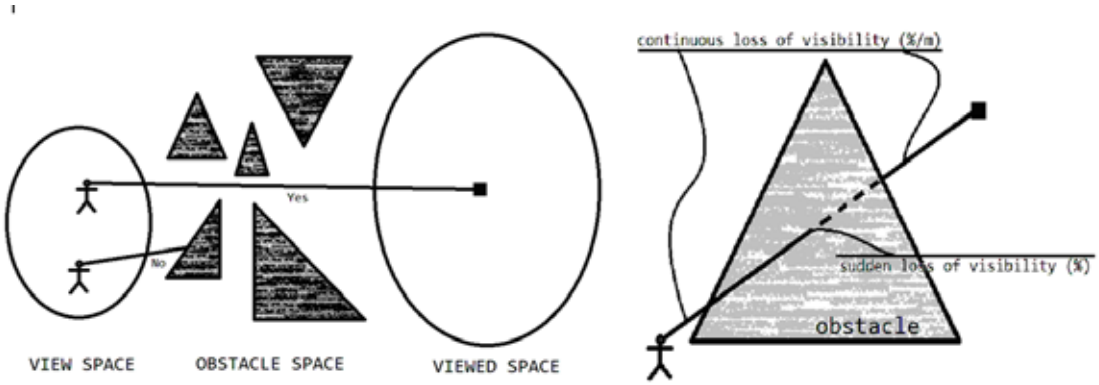

Figure 2 - the visibility function

Besides this continuous visibility function, there is another similar function - the boolean accessibility function. This one is also the representation of a graph. Thus, DepthSpace3D deals with the 'isovist model' of SS as well as the 'graph model'. Only the 'axial line model' is not supported, but 2.5D software for this model is already available.

8. OTHER CONCEPTUAL MODELS

DepthSpace3D can be considered a convergence of the development of the paths of (Varoudis 2014) and Ratti 2009, as well of DepthMapX. Both (Derix 2007, 2008) and (Shroder ?) present different conceptual solutions for the 3D SS problem.

Shroder solution seems comparatively weak, although much easier to implement. Nevertheless, his 'slope' SS concept seems to introduce new very promising semantic paths not yet developed by current visibility straight line primitive.

In the other end, Derix solution seems to have a very strong primitive semantic, with very high potential to develop new connotational concepts. Why not this path for DepthSpace3D? Well, DepthSpace3D privileged the safe path of using the established and disseminated VGA semantics.

9. NUMERICAL OR ANALYTICAL? DISCRETE OR CONTINUOUS?

DepthSpace3D had to deal with many issues relating to the operational paradigm that would have to process the conceptual paradigm just exposed. Decisions on 'discrete versus continuous' or 'numerical versus analytic' have been made by reasons this paper will not bring to the collation.

DepthMapX discretizes all the space in a regular grid. As seen, there are three conceptual spaces in DepthSpace3D, with two more two sub-spaces. Following Ratti and Morello's 2009 and (Varoudis 2014), both the Global Volume and the Viewing Spaces are discretized in significant points. Not regular grids are allowed, in order to allow versatile solutions for case studies. This comes with a cost: two kind of weight functions had to be appended to each voxel, to normalize the model.

Unlike DepthMapX, obstacle surface space is discretized in analytic triangles and not discrete points in a grid. (Varoudis 2014) don't have the problem, because there is no such space in this model. It's more accurate then DepthMapX that pixelizes the obstacle line, although the solution brings some 'friction' in graphic representation.

10. SPACE VISIBILITY OF SPACE CONFIGURATION?

DepthSpace3D addressed the problem of the main objective of SS - space visibility or space configuration. Please see *1 THE MISSING LINK.

11. AUMENTED VISIBILITY GRAPH ANALYSIS

(Varoudis 2015) presented some new features for new generation VGA. Most of those features are already developed in DepthSpace3D:

- introduction of 3D immediately solve most of the issues due to the reported difference between visibility and physical accessibility;
- the concept of path as aggregation of viewpoints and the conceptual differentiation between viewing and viewed spaces address directly to the proposal of directed land mixed links;
- transparencies (in the obstacles and in the global volume) are a standard feature of DepthSpace3D;
- proposed layered information of the model of the reality under study is partially solved by the concept of hierarchical Properties (developed in DepthSpace3D) that can be assigned to any subset of the viewed space. However some of the proposed new information (like temporal logic) can not be solved only with the expressivity of the SQL queries language, provided by DepthSpace3D. Some more expressive generative grammars had to be embedded in the calculations.

12. GRAPHICAL REPRESENTATIONS

DepthSpace3D has graphical representations of the SS concepts: one for the surfaces, one for the viewpoints of the Paths and three for the volume points.

These volume representations are either a generalized version of Ratti and Morello's 2009 'isovistmatrix' model (2D slices/sections through the isovistmatrix and, using a colour scale, indicate how visible individual voxels from street-level (Dalton 2015) or (Varoudis 2014) 3D arrays of coloured balls or collapse data to two-dimensional floor-level maps.

For a special purpose (Czyńska 2015) developed the *Visual Protection Surface (VPS) model. Similar results can be produced by DepthSpace3D.* But *VPS uses two special graphical representations - 3D mesh* and a map with height levels marked above ground level that have add heuristic value and will be reproduced in DepthSpace3D in future releases.

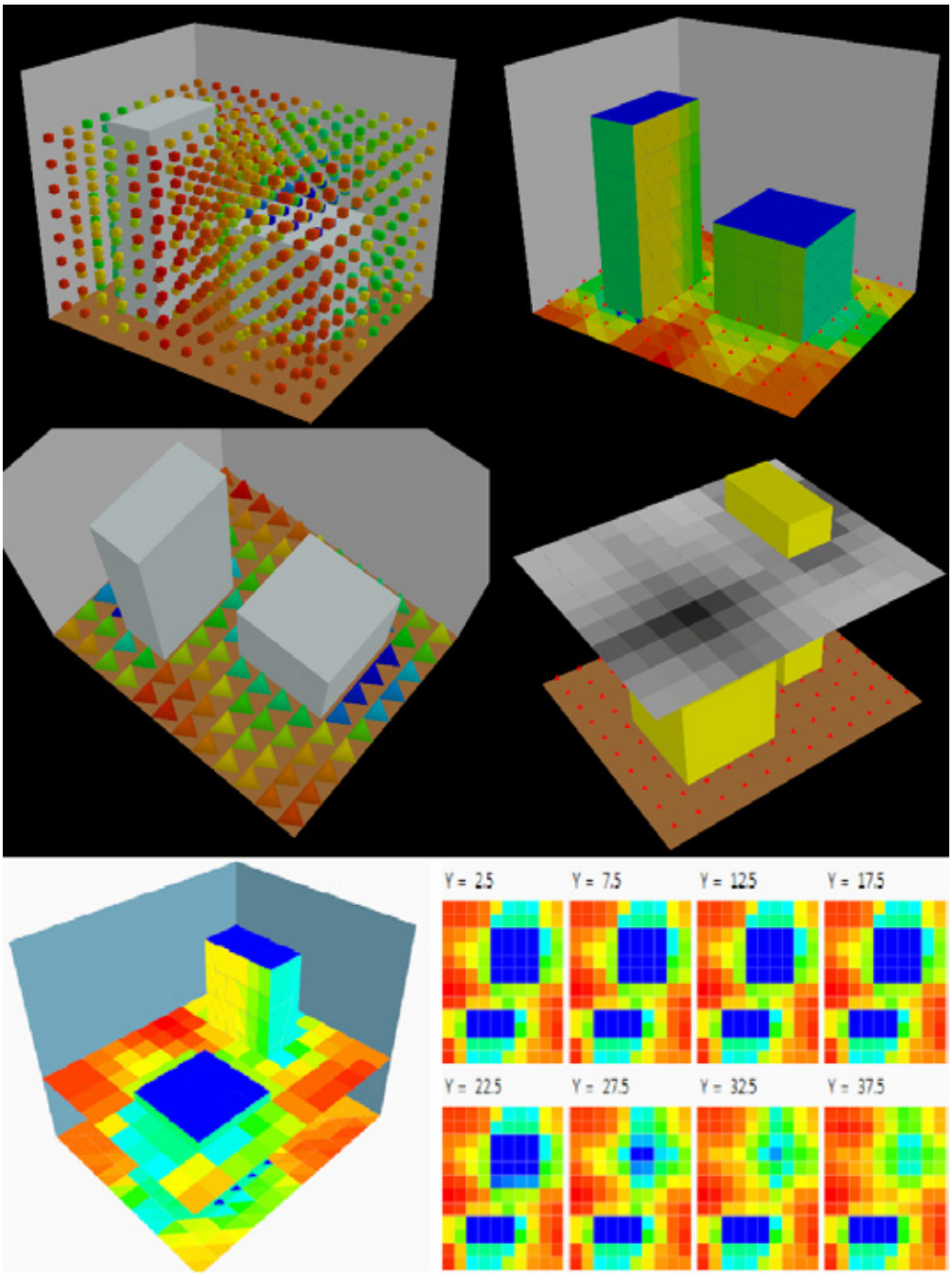

Figure 3 - graphical representations

*1 THE MISSING LINK
As it is not possible for this short paper to present simultaneously the characteristics of the software and its theoretical framework, we tried to stick to the last theme, with the certainty that 1500 words was only able to surface the subject. So, see more in the site of OPO'ArchFormalMethods, please!

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