THE 3DSKYVIEW EXTENSION: AN URBAN GEOMETRY ACCESS TOOL IN A GEOGRAPHICAL INFORMATION SYSTEM

Léa C.L. Souza[*], Daniel S. Rodrigues[**], José F.G. Mendes[**]
[*] Department of Architecture, Urbanism and Landscape, State University of São Paulo
[**] Department of Civil Engineering, University of Minho

Abstract

Implemented as a tool in a 3D Geographical Information System (GIS), the 3DSKYVIEW Extension introduced here calculates sky view factors values, while generating its graphical representation on both 2D and 3D scenes. The main issue here is the determination of sky view factors from a 2D representation, delineating the areas corresponding to visible sky and buildings. Using an algorithm developed to be applied in *ArcView*, the 3DSKYVIEW extension uses the tri-dimensional information of urban canyons to automatically visualize and calculate sky view factors from vector GIS files.

Key words: sky view factors, stereographic projection, 3D GIS

1. INTRODUCTION

The approach of this paper suggests the use of a GIS environment for simulating a spatial representation of urban canyons obstructions to the sky vault. A tool named 3DSkyView was developed by the authors for enhancing functions of a three-dimensional GIS, in order to calculate and visualize sky view factors. The 3DSkyView was conceived in *Avenue* scripting language in an *ArcView GIS 3.2* software environment with its 3D Analyst extension switched on (all ESRI - Environmental Systems Research Institute products).

The SVF represents an estimation of the visible area of the sky from an earth viewpoint, being defined as the ratio between the total amount of radiation received from a plane surface and that received from the whole radiant environment. It is thus a dimensionless parameterisation of the quantity of visible sky at a location. In this way the sky area results from the limits of urban canyons generated by the tri-dimensional characteristics of urban elements and their mutual relationships. As once studied by Steyn (1980), Oke (1981), Johnson and Watson (1984), Bärring, Mattsson and Lindqvist (1985), Souza (1996), Ratti and Richens (1999), Chapman (2000), and Chapman *et al.* (2001) the SVF is one of the main causes of the urban heat island phenomena, therefore required as a parameter on its modelling.

2. THE PRINCIPLES OF THE 3DSKYVIEW EXTENSION

In practical terms, the aim of the 3DSkyView is to identify a new coordinate system for the tri-dimensional urban elements, so that they could be represented in a stereographic projection on a bi-dimensional plane, in this way allowing the calculation of the SVF parameter. In the 3DSkyView extension the viewing point position is movable for all three dimensions and it can be fixed inside the urban canyon level with its focus point centred on the urban canyon level. This new coordinate system of a stereographic projection refers to the tri-dimensional relationships in the canyon. There are three important angles in the canyon determining the scene, as it is shown in Figure 1.

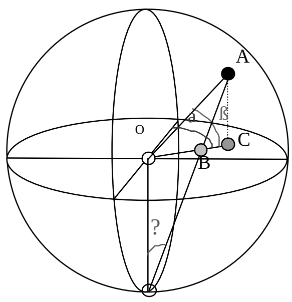

Figure 1 Stereographic Projection and Angles

[*] *Corresponding author address*: Léa C. L. Souza, Department of Architecture, Urbanism and Landscape, State University of São Paulo, Av. Engº Luiz Edmundo Carrijo Coube s/nº –, 17.033-360, Bauru/SP, Brazil, e-mail: leacrist@faac.unesp.br

First is the horizontal angle a created between the viewer North-South axes, on viewer horizontal plane, and the point of interest. Second is the vertical angle ß between the viewer plane and the point of interest. And third, is the Nadir vanishing point angle ? between the vertical plane that contains the Nadir point and the projected line from the point of interest to the vanishing point. Considering that the viewer is in a movable position and regarding the particularities that a should always be related to the vertical plane that contains the viewer (point O in Figure 1) and that ß should always be related to the viewer horizontal plane, those angles are comparable to the azimuth and altitude angles that can be easily determined. The angle ? can be calculated by Equation 1, as it belongs to an isosceles triangle.

$$q = \frac{90 - b}{2} \tag{1}$$

The new coordinates can then be expressed by Equations 2 and 3, composing the new coordinate system on a stereographic projection, where r is the radius adopted for the projection. Here a angle was submitted to an adjustment in order to have the same origin of the trigonometric relationships. This is done because a was calculated based on the north side corresponding to 0º, while the same angle for trigonometric calculation corresponds to east side. This rotation is the reason for the subtraction of a value from 90º in Equations 2 and 3.

$$x = \cos(90 - a).r.\tan q \tag{2}$$

$$y = \sin(90 - a).r.\tan q \tag{3}$$

With the new coordinates of the points of interest it is possible to have the stereographic projection by plotting them on the horizontal plane in *ArcView* GIS. The determination of SVF is then just a question of spatial manipulation of layers by overlaying a stereonet of equal radius on the stereographic projection of the scene and comparing the area occupied by buildings and the sky area (see also Souza et al, 2003).

3. AN APPLICATION

The user interface was developed to be easy-to-use by architects, climatologists and engineers, as can be seen in Figure 2. Once the user is familiar with the *ArcView GIS 3.2'* environment, the extension can be downloaded and an icon is automatically created to run the algorithm from the main software interface screen. The whole process is run through this unique interface window. The resulting windows of this process are: a projection of the urban canyon in a 2D stereographic representation, a projection of the urban canyon in a 2D orthographic representation, a table of contents indicating the SVF value for that urban canyon and a 3D scene representing the reflection of the urban canyon on a hemispherical surface, as a 'fish eye surface'.

For the file representing an urban canyon in the city of Braga - Portugal in Figure 3, an application of 3DSkyView extension results in the projections shown from Figure 4 to Figure 6, where the limits of the visible sky area and buildings area are automatically delineated, consequently, the sky view factor can be calculated. In the resulting Table 1 it is possible to identify the total sky area, which would be available without the obstruction of the buildings. As the canyon obstructing area and the visible sky area are also available, the SVF value is directly determined.

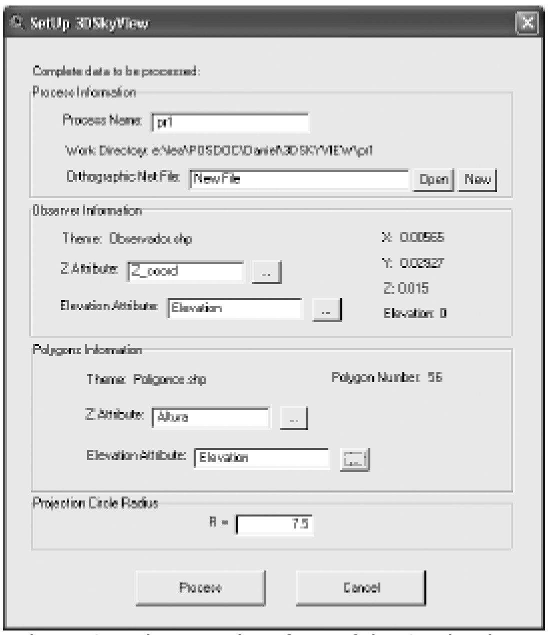

Figure 2 – The User interface of the 3DskyView

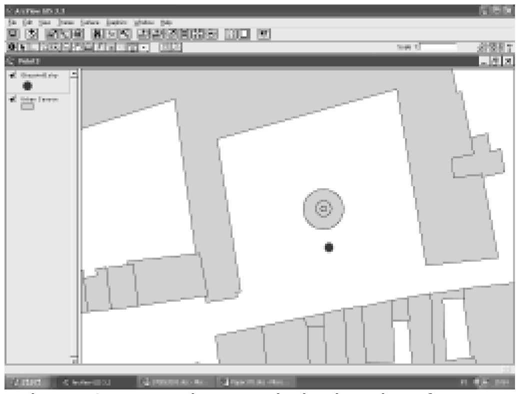

Figure 3 – A real scenario in the city of Braga

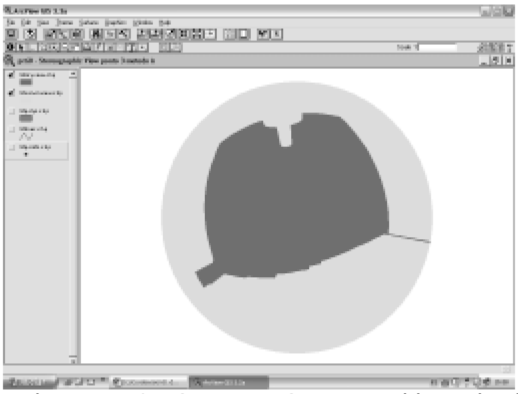

Figure 4 – 2D Scene on Stereographic Projection

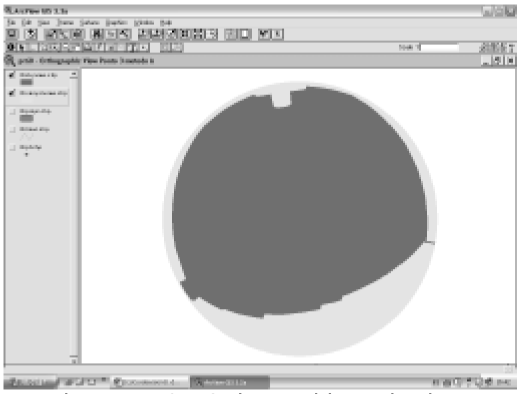

Figure 5 – 2D Orthographic Projection

Table 1 – Resulting table with SVF values

SkyArea	CanyonArea	VisiSky	SVF
353.2500	120.8644	232.3856	0.65785

The 3D Scene of Figure 6 allows a visualization and understanding of the whole geometric relationship between the observer and the buildings. Changes on the view point of the 3DScene are possible, so the user can interact to get the best angle to verify the tri-dimensionality of the canyon.

Based on the widespread solar equations available in Szokolay (1996) and in ABNT (1999), it is possible to identify the solar declination, altitude and azimute angles at any place of known latitude and longitude, and at any time. These parameters allow then the determination of stereographic and orthographic solar coordinates in ArcView by applying the same equations described before, considering though that a is now the value of the solar azimute. All these stereographic and orthographic coordinates can be then available in an attribute table. So the views resulting from the 3DSkyView Extension can be overlayed with sun-path diagrams for specific latitude, allowing the analysis of the solar access into the urban canyon. That is the subject of Figure 7, which allows the visualization of the solar access of the urban canyon studied. In Figure 7, the points plotted within the urban canyon are the monthly sun position in 1 hour time intervals. Based on that overlaying, it is possible to verify that, in that urban canyon for most part of the winter season the sun penetration is blocked by buildings.

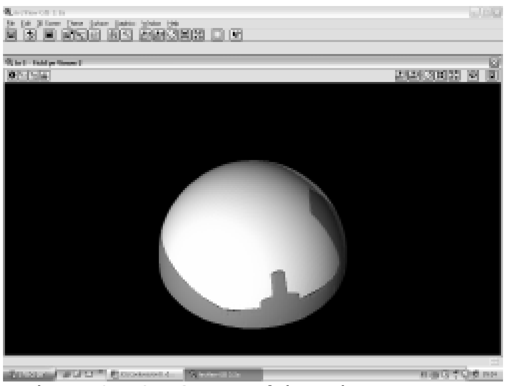

Figure 6 – 3D Scene of the urban canyon studied

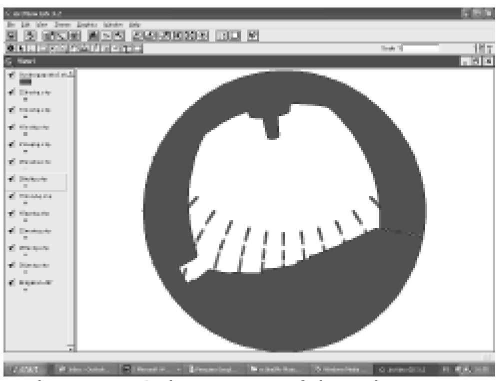

Figure 7 – Solar access of the urban canyon studied in Braga

4. Conclusions

One of the main contributions of this work is the automatic delineation of the visible sky and obstructions, not previously possible except from image processing methods. This version of 3DSkyView can be a useful tool for developing countries, while working as an alternative solution for the estimation of SVF. Once an urban basis with information about the third dimension is available, it results in optimization of time for the estimation of SVF. It has here the advantage of being a low cost tool, if compared to some photographical accessories usually applied for the same purpose. On the other hand, the representation and calculation of SVF values are strongly related to the quality of the geometrical basis of the input file.

The quality of the *ArcView GIS* environment working nearly as an open GIS gives it the possibility of its application for many environmental analyses purposes. Taking this advantage of *ArcView GIS* and the possibilities of the 3DSkyView Extension into account, one might now incorporate the SVF as a parameter in an urban thermal model, by applying the model in an *ArcView GIS* environment.

Acknowledgments

The authors would like to express their gratitude to the Brazilian agencies CAPES, FAPESP and CNPq, and to the Portuguese agency ICCTI, which have supported our efforts for the development of this work in different ways and periods.

References

ABNT - Associação Brasileira de Normas Técnicas (1999). **Iluminação natural – Parte 2: Procedimentos de cálculo para a estimativa da disponibilidade de luz natura**l. Projeto 02:135.02-002. São Paulo. Available in: //www.labeee.ufsc.br/conforto/normas/index.htm.

Bärring, l.; Mattsson, J.O.; Lindqvist, S. , 1985, Canyon geometry, street temperatures and urban heat island in Malmö, Sweden. **Journal of Climatology**, **Vol. 5**, 433-444.

Chapman, L., Thornes, J.E.; Bradley, A.V. ,2001, Rapid determination of canyon geometry parameters for use in surface radiation budgets. **Theoretical and Applied Climatology**, **Vol. 69, 81-89**. (www.cert.bham.ac.uk/research/urgent/canyongeometry.pdf)

Chapman, Lee , 2000, Improved one dimensional energy balance modeling utilizing sky-view factors determined from digital imagery. **Proceedings of the 10th SIRWEC Conference**, Davos-Switzerland, March 2000. (www.sirwec.org/conferences/davos2000.html)

Johnson, G.T.; Watson, I.D., 1984. The determination of view-factors in urban canyons. **Journal of Climate and Applied Meteorology, Vol.23**, 329-335.

Oke, T.R., 1981, Canyon geometry and the nocturnal urban heat island: comparison of scale model and field observations, **Journal of Climatology**, **Vol.1, No.1-4,** 237-254.

Ratti , C.; Di Sabatino, S; Britter, R.; Brown, M.; Caton, F.; Burian, S. , 1999, **Analysis of 3-D Urban databases with respect to pollution dispersion for a number of european and american cities**. (www.dmu.dk/AtmosphericEnvironment/ trapos/abstracts/CERC_2.pdf).

Ratti, C.F.; Richens, P. , 1999, Urban texture analysis with image processing techniques. **Proceedings of the CAADFutures 99**, Atlanta, GE. 1999.

Souza, L.C.L., 1996. **Influência da geometria urbana na temperatura do ar ao nível do pedestre**, PhD Thesis in Science of Environmental Engineering, University of São Paulo, Brazil.

Souza, L.C.L.; Rodrigues, D. S; Mendes, J.F.G., 2003. A 3D-GIS extension for sky view factors assessment in urban environment, **Proc. of the 8th International Conference on Computers in Urban Planning and Urban Management, Sendai**, 27-29 May, 2003: Japan.

Steyn, D.G. , 1980, The calculation of view factors from fisheye-lens photographs. **Atmosphere-Ocean**, **Vol.18, No.3**, 254-258.

Szokolay, Steven, 1996, **Solar Geometry**. Queensland, University of Queensland.