Analyzing Daylight Conditions for Outdoor Vegetation in Urban Areas using Sky Factor

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ABSTRACT

Daylight is one of the most critical conditions for vegetation growth. However, densely developed urban areas may provide not enough daylight for photosynthesis of vegetation due to artificially built structures. In Korea, the most general housing type is high-rise apartment complexes which were built to maximize the use of high-price urban lands. Many of these apartment complexes have problems related to maintaining healthy vegetation landscape due to not enough daylight. The purpose of this study is to develop techniques to evaluate critical outdoor conditions for vegetation in urban landscapes to help landscape designers select proper vegetation species. This paper presents a technique to combine a photographic method to measure Sky Factors and a computer simulation method to determine sun paths in order to evaluate direct sunlight and diffuse skylight availability at the evaluated spots for vegetation

KEYWORDS

Daylight, SVF(Sky Factor), Insolation, Hemisfer, Autodesk Ecotect2011

INTRODUCTION

The design of outdoor spaces, particularly the shading provided by buildings, trees, and the landscape, substantially influence the outdoor environment. In general, complex methods of computer simulations for daylight condition analysis have been applied. The Sky Factor (SF) has been commonly used to indicate the impact of urban geometry on air temperature differences in cities. This study will apply SF methods to analyze daylight condition of space easier and faster than other daylight simulation programs. Thus, 3D modeling simulation program process will be not required if an image analysis of daylight condition is applied. Considering this approach, SF applies Fisheye lens and DSRL camera to evaluate survey image through Hemisfer program, by Swiss Federal Institute for Forest, Snow and Landscape Research WSL. The evaluation results will be compared with outcomes of Autodesk ECOTECT 2011 3D modeling simulation program to test the difference of both applications.

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Sky Factor Calculation From Orthographic Photographs

Photographs analyzing method is useful for analyzing daylight conditions of existing buildings because there is no need of 3D modeling. A digital camera (Canon 5d mark2) with a fisheye lens (Canon 8-15mm fisheye) was used to take the in situ observation. During shooting upper part of camera is adjust magnetic north. The Canon lens used has a field of View (FOV) of 180°. The lens makes Equidistant Projections to convert equidistant projection image into orthographic projection images (Fig. 1). For this conversion a polynom up to the 5th grade is used to calculate the zenith angle Θ as a function of the relative radius R (Eq. 1). The images were converted from color to white (sky) and black (ground, buildings, and vegetation) by altering the brightness and contrast of each image using Hemisfer Software (Fig. 2). This software can calculate the optimal threshold according to an algorithm which recognizes edges on the picture (Nobis & Hunziker, 2005).

$$R = a1\Theta + a2\,\Theta^2 + a3\,\Theta^3 + a4\,\Theta^4 + a5\,\Theta^5 \quad (1)$$

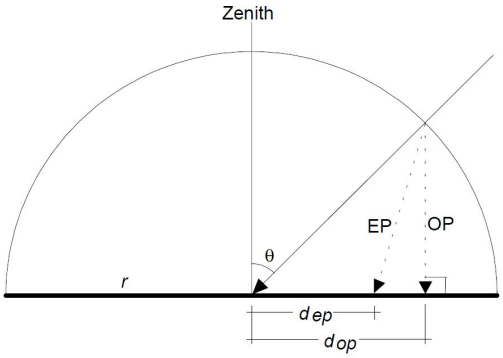

Figure 1. *Equidistant and Orthographic Projections*

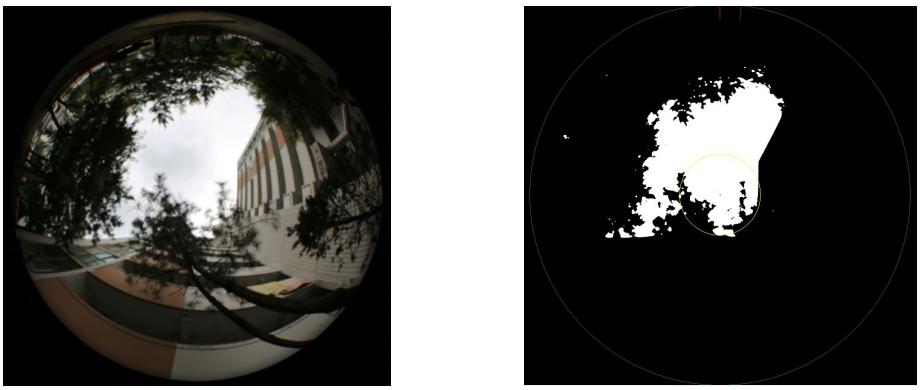

Figure 2. *Fisheye photograph before, after being processed*

Note that this function has 2 fixed points (0,0) and (Θmax,1). For this reason, the last parameter is always fixed by the previous ones.

Sky Factor Calculation From Analysis of Computer simulations

Computer simulation analyzing method is useful for analyzing daylight conditions of construction design stage. This method is applied by using Autodesk Ecotect 2011 program. Through a blueprint of applied location (G buildings, Ansan-si, korea) is drawn in 3D modeling (fig. 3). and information on geographical features (fig. 4) are added. This program demonstrates Orthographic Projection that displays 200 points within the diagram, spaced such that they represent 0.5% of the daylight illuminance based on the CIE Uniform Sky, in which all areas are equally weighted. This can calculate time of direct daylight through displaying Horizontal sun path diagram.

***Figure 3**. Applied location(G buildings, Ansan-si, korea), 3D modelling image*

Tabulated Daily Solar Data

Latitude: 37.5? Date: 10th September
Longitude: 126.9? Julian Date: 253
TimeZone: +8.0hrs Sunrise: 06:13
OBJECT No.: None Sunset: 18:45

Local	(Solar)	Azimuth	Altitude	
06:30	(06:00)	85.9?	3.3?	--
07:00	(06:30)	90.5?	9.2?	--
07:30	(07:00)	95.1?	15.2?	--
08:00	(07:30)	100.0?	21.1?	--
08:30	(08:00)	105.1?	26.9?	--
09:00	(08:30)	110.7?	32.6?	--
09:30	(09:00)	117.0?	38.0?	--
10:00	(09:30)	124.2?	43.1?	--
10:30	(10:00)	132.5?	47.8?	--
11:00	(10:30)	142.2?	51.8?	--
11:30	(11:00)	153.6?	55.0?	--

***Figure 4**. Information on geographical features*

RESULTS

Orthographic Photographs shows the area of a region that can be determined by counting the number of pixels in the region. The circle contains a total of 8,317,853 pixels. To count the number of pixels in the projected images of white 1,582,987 pixels, black 6,734,866 pixels. Results of applied formula (Eq. 2) is Sky Factor 19.1%. The analysis of only building and building surrounded by trees resulted in 41.5% and 39.2% by applying Sky Factor Calculation from Analysis of Computer simulations (fig. 5). In the case of existing buildings using the first method, without applying a complex computer simulation program, daylighting condition can be determined. Second method can predict daylight condition in construction design stage. This methods developed techniques to evaluate critical outdoor conditions for vegetation in urban landscapes to help landscape designers' select proper vegetation species.

$$SF = n / N \tag{2}$$

Where 'n' means total No. of pixels in the Circle, 'N' means total No. of Pixels in the Sky.

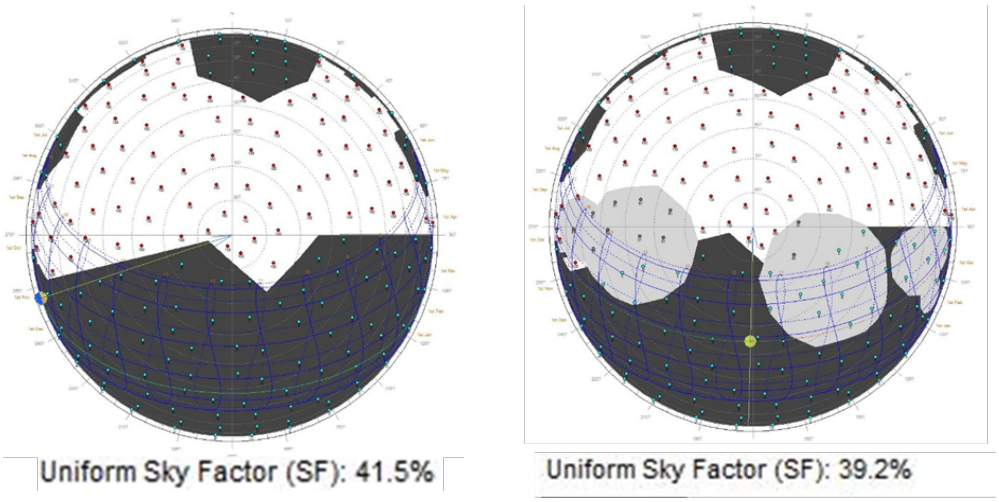

***Figure 5**. Result of sky factor calculation from computer simulation*

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