



International Conference on Sustainable Design, Engineering and Construction

Developing a Three-Dimensional Geometric Framework for Greening Buildings' Façade

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Abstract

It is considerably challenging to alter the design of existing large and tall buildings to make them rely on natural energy due to many reasons. Among them is the large amount of parameters and geometric measurements required, such as height, width, plot ratio, aspect ratio, windows dimensions, etc. In this research, a new automatic algorithm is developed to model the existing buildings façade and extract several important parameters for building greening. The main contributions of this research are the automatic analysis of the digital building model and the detailed microclimatic analysis for each feature within the building façade. The developed algorithm starts with an automatic digital three-dimensional modeling of the building façade, followed by an automated extraction of the required parameters to alter the façade design such as orientation, height, and width. Results show that the proposed method offers very high accuracy and time/cost effective way for parametric modeling of the existing buildings' façade.

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Peer-review under responsibility of organizing committee of the International Conference on Sustainable Design, Engineering and Construction 2015

Keywords: Green Buildings, LiDAR, Façade Analysis, Parametric Design

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1. Introduction

In order to design green or sustainable architecture, architects should meet present needs without compromising the ability of future generations to freely encounter their own requirements. To achieve this fundamental concept, architects should consider their design as a research process and look for the sensitive aspects that define the green architecture. Such aspects include, but not limited to: 1) Solar radiation as a source of lighting, natural heating and energy [1]. 2) The building proportions such as aspect ratio, and mass to void ratio [2]. 3) The orientation of a building with respect to prevailing wind and sun [3]. Refurbishing and greening existing buildings is usually more challenging than designing new buildings. Not only because of site and existing structure constraints, but also because of the numerous measurements required which are not easy to collect especially when dealing with large and complex buildings. The proposed method in this paper aims to address this issue by providing an automatic algorithm to model existing buildings and extract the required measurement.

The paper is organized in five parts: starting with an introduction in the first part, followed by a summarized analysis for the main related work in the second part. The third part deals with research methods, then results and discussion are in the fourth part and finally the concluded message is in the fifth part.

2. Related work

Most of the relevant work to this research could be classified into two categories: the first deals with the environmental and micro-climatic analysis of buildings and urban spaces, and the second deals with analysis of the building design itself. Most of the research in the first category analyzes the relationships between the built environment and the surrounding micro-climate through simulation tools. Dorer et al. analyzed the impact of the urban micro-climate on the energy demand of buildings [4]. Shishegar studied the effects of street geometry namely the width/height ratio and orientation on the airflow and solar access in urban canyons [5]. De la Flor et al. investigated the performance of different building envelop elements with response to changing the outdoor environmental conditions [6]. In common among most of the work in the first category is that simulation is being used instead of real data which in the authors' opinion was because of the difficulties associated with field measurements. This opinion is more supported when the second group of literature was reviewed. Very few researches were found to deal with analysis of the building design itself after being modeled. Ripperda and Brenner studied the application of shape grammar concepts to help in façade reconstruction [7]. Shape grammar provides information about the structure of the façade design that is useful to predict the missing parts of the building façade during the surveying process due to occlusions. A study by Li et al. investigated the possibility of generating building information model (BIM) from laser scanning point cloud [8]. Attya and Habib investigated different options for building façade mapping based on the accuracy of the photogrammetric reconstruction process without any geometric analysis of the building façade design [9]. As a conclusion from the aforementioned discussion is the up to the best knowledge of the authors, there is no research that deals with the extraction of the building parameters that could be essential for building environmental design.

3. Methodology

Laser scanning point cloud data is used in this research to obtain the building measurements. The point cloud is a set of millions of 3D points on the building façade that measured by a static terrestrial laser scanner, a surveying instrument that measure the range between its setup location and millions of points on the targeted object based on the difference in time between the fired and reflected laser beam. It is assumed in this research that a digital building model (DBM) is available and the collected laser point cloud is registered to its coordinate system. There is, usually, a very limited control on the extent of the area scanned with the laser scanner, i.e., many objects that are not of interest could be recorded. Therefore a geometric analysis is required to recognize the features of interest and to extract the required parameters. **The first** step is to filter out the ground points. In this research, the histogram of the Z-coordinate of the laser-scanned points is computed then the biggest class in the histogram will represent all the ground points assuming that the ground points should not have great change in the Z-coordinate. **The second** step is to recognize the building of interest in the raw point cloud by determining the building façade plane using the

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