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TOWARDS ENERGY-EFFICIENT SOCIETY: AN EXAMPLE OF "SMART CITY SERVICE"

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Summary: *There is a clear need for "Urban Information Models". They are essential to create new smarter services capable to promote higher quality services and to improve decision-making processes in cities. The "Smart city services" that address and support energy-efficiency and sustainable urban development are of a special importance and interest. A "smart city service" project aimed to provide the information on energy-efficiency of buildings and assessment of solar energy production capabilities is being developed with support of Serbian ministry of science. The basis of the service is 3D urban model. The 3D environment needs to be created from real-world geospatial information in order to guarantee relevance and accuracy in the simulation. A Method of creating a 3D model of roofs from Digital Surface Model (DSM) is presented.*

Keywords: *3D "Urban Information Models", "smart city service", Digital Surface Model*

1. INTRODUCTION

The need for 3D "Urban Information Models" is clear. They are the base that "smart city services" are built on. And "smart city services" is a new way to address the complex issues like intelligent transportation systems, public safety, energy, water and environmental management, urban planning etc.

It is of particular public interest to develop "smart city services" that support sustainable energy policy, namely energy efficiency and renewable energy policy. Within the scope of the project "Spatial, environmental, energy and social aspects of developing settlements and climate changes – mutual aspects" funded by the Serbian Ministry of science as well as the iSCOPE project, a "smart city service" is being developed aiming to provide the information on energy-efficiency of buildings and assessment of solar energy production capabilities.

Currently, 3D urban models are produced by conventional aerial photogrammetry or from high density points from airborne laser scanners (i.e. [3], [4]). The both techniques offer solutions that are expensive or time consuming. The essential input data used to build 3D "Urban Information Model" for the service is Digital Surface Model (DSM) generated from digital photogrammetry techniques. The service requires detailed 3D model of roofs in particular to calculate slope and aspect. The DSM was generated automatically in software Socet Set but due to its low vertical accuracy, it was necessary to filter the data.

The paper describes the concept of the "smart city service" and algorithm used to produce high quality 3D model of roofs.

2. "SMART CITY SERVICE" FOR ASSESSMENT OF SOLAR ENERGY PRODUCTION CAPABILITIES

The concept of the "smart city service" can be described thorough the typical scenario. An engineer from the local energy planning department accesses, through the 3D web client, the 3D urban model to create an solar radiation map. To do so he/she selects the relevant processing services available as "smart services", from the city administration servers. The 3D dataset is connected graphically to the icon representing the process and the different services are automatically orchestrated. The result of the processing is a dataset, containing solar irradiance and irradiation in the different components (i.e. beam, diffuse and reflected) in both clear-sky conditions as well as overcast weather. Since this has been calculated for each day of the year the user can, through a slider, select the day of the year and the automatically renders the proper map over the 3D scene. As in the previous case, the engineer (who is logged in as administrator) selects the icon representing the dataset and sets the parameter that makes the dataset public. The "smart services" are automatically orchestrated and as a result the new dataset is publicly available from the 3D web client to the public. As a result citizens can access the 3D model of the city, select the day of the year, the weather condition and get a 3D representation containing the solar radiation information at urban scale. This information can be used by engineers to design solar panel systems.

3. CREATION OF 3D URBAN MODEL

3.1. DSM available

As derived from aerial photos stereoscopic coverage, DSM usually represents the canopy of landscape in which heights information is all above-ground details, including top of the buildings and trees [1]. To achieve accurate DSM through photogrammetric techniques, the data redundancy, namely multiple measurements for one point on the ground, is required. It means that there is the need for a number of stereoscopic pairs from which single point on the ground is seen. [1] report vertical accuracy achieved with this method of 35-60cm for DSM with spatial resolution of 2m from source imagery at 60cm. Contrary to this [2] generated DSM of accuracy close to 2 m from single IKONOS (0.8 m pixel) stereopair with the use of commercial software packets.
The DSM that we used in this research is generated in SOCET Set software from single stereopairs of digital airborne photo sensors. However, the result tends to be very noisy (Figure 1), providing low vertical accuracy and precision to create 3D model of roofs.

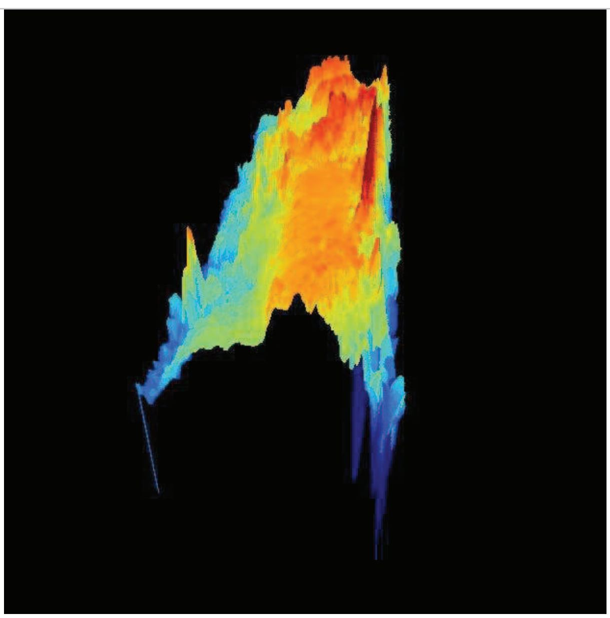

Figure 1. An example of raw DSM of the 2-plane roof used in the experiment

3.2. Algorithm for roof surface generation

The aim was to produce 3D model of roofs in raster format with defined roof planes. There are two algorithms created: a) for the case of a single plane roof, and b) for the case of 2-planes roof.
In case of single plane roof, the DSM was filtered by defining first order polynom trend surface [5] using Least Square Method and calculating residuals for each pixel. The process is iterative: each time points with residuals

greater then calculated Cook's distance [7] were deleted from the model and new trend surface was calculated (Figure 2). The process stops when residuals are below 0.5.

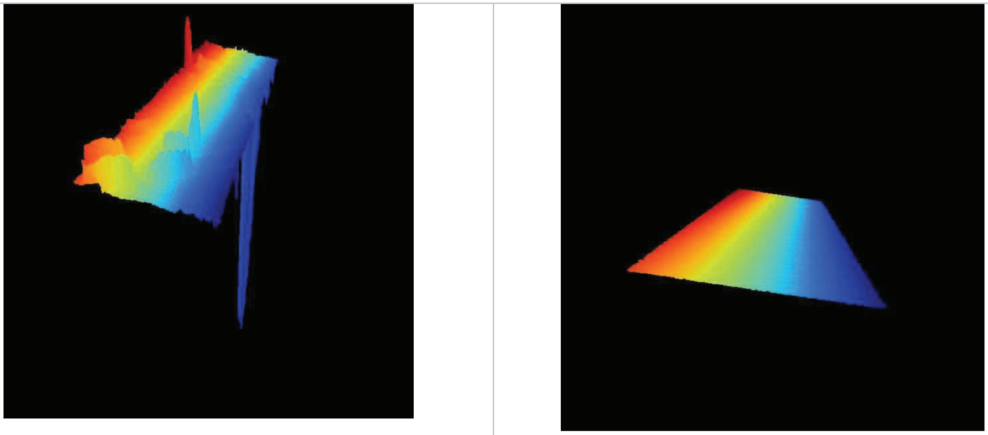

Figure 2. Raw DSM for the single plane roof (left) and filtered DSM (right)

The 2-planes roof represents a more complex case if there is no data on lines where roof planes intersect. Since the DSM was too noisy, it was necessary first to remove the most significant artifacts. The second order polynom trend surface [5] using Least Square Method was calculated (Figure 3.) and the pixels with residuals greater then Cook's distance were removed afterwards. The process is also iterative and stops when residuals are lower than 0.5.

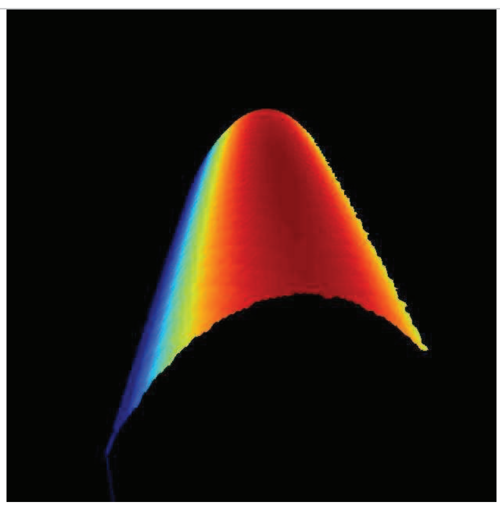

Figure 3. Second order polynomial trend surface for the raw DSM of 2-planes roof presented in Figure 1.

The next step was to calculate aspect of all pixels and to subsequently cluster the data with respect to the aspect values using Hill-Climbing method [6]. The result was two classes within the roof, representing areas of different roof planes and thus defining the line where roof planes intersect (Figure 4). The problem is now reduced to the case of 2 single plane roofs.

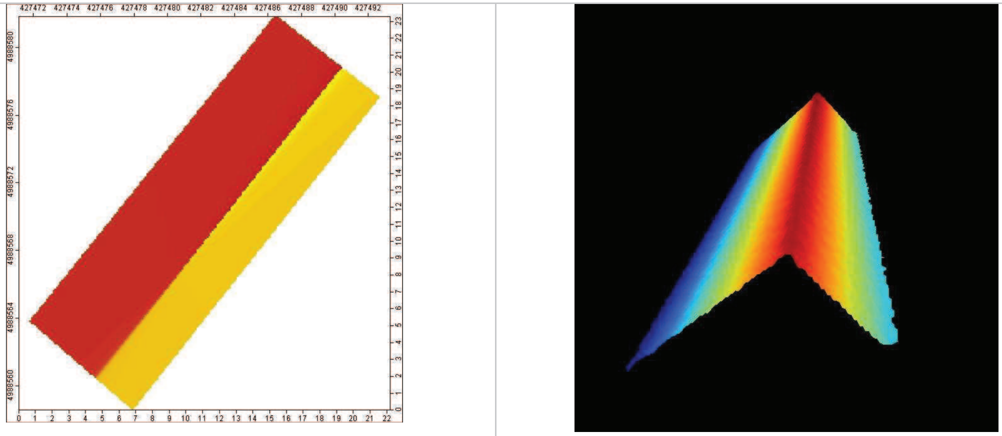

Figure 4. Clusters with respect to the aspect values-the line where roof planes intersect is clearly recognizable (left) and final 3D model of 2-planes roof (right)

3.3. Accuracy assessment of the results

To assess the accuracy of the generated 3D model of roofs, several parameters are calculated for both single plain and 2-plains roof cases. Since for the service purpose of assessment of solar energy production capabilities there is the need for data on aspect and slope [8] of the roof planes, those parameters, as well as the height values of the pixels in the generated roof models are compared with the models produced by manual methods of classical photogrammetry (that we can consider of high quality).
The results are given in Tables 1 and 2.

Table 1. Differences in heights, aspect and slope for the case of single plain roof

	Number of pixels	Minimum	Maximum	Mean	Standard deviation
Height (m)	17395	0.000314	0.379614	**0.193921**	**0.103811**
Aspect (°)	17395	0	0.922687	**0.001293**	**0.01794**
Slope (°)	17395	0.000228	0.721203	**0.248249**	**0.151658**

Table 2. Differences in heights, aspect and slope for the case of 2-plains roof

	Number of pixels	Minimum	Maximum	Mean	Standard deviation
Height (m)	1065	0.000197	0.486569	**0.120322**	**0.103383**
Aspect (°)	1065	0	12.5	**1.32686**	**3.154805**
Slope (°)	1065	1.690043	10.583567	**4.759772**	**1.928329**

The results show that achieved vertical accuracy is in both cases is around 20 cm. However, mean aspect and slope difference of respectively 0.001293 and 0.248249 decimal degrees in the case of single plane roof are lower than in the case of 2-plains roofs (1.32686 and 4.759772) which have also higher standard deviations of the differences. Nevertheless, we can consider that both 3D models are produced with the sufficient accuracy for the purpose.

4. CONCLUSION

Geometrically accurate and up-to-dated 3D "Urban Information Model" is an essential component of any "smart city service". In this case, the service is aimed to obtain information on energy-efficiency of buildings and assessment of solar energy production capabilities. For that purpose, a high quality 3D model of roofs was needed. To generate such model in an efficient and cost effective way, a rather automatic method of filtering of DSM that is automatically obtained from single streopairs is evaluated. The two cases are examined: single plain roof and 2-plains roof. The results in both cases show good accuracy of the parameters relevant for the service, namely height, aspect and slope. There is still a solution to be found for more complex roofs.

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