Current state overview of methodologies and tools for wind flow modelling over complex terrains

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Current state overview of methodologies and tools for wind flow modelling over complex terrains: *The current work discusses some the existing methods for modelling terrains for the purposes of 3D air flow simulations. Some of the most developed methods are discussed as well as their advantages and disadvantages.*

Key words: *computer modelling, 3d terrain modelling, air flow modeling, modeling scales, non-contact measuring methods*

INTRODUCTION

Air flow modelling

Currently in Bulgaria a great number of wind turbines, which are currently in operation, have been operating for more than 20 years. This means that they are close to their life cycle and they should be replaced. The new wind turbines have greater installed capacity, respectively wind turbine diameter and tower. The configuration of the turbines in wind farm is in a relation with prevailing wind direction and rotor diameter. Because of this the wind turbine replacement is not just a physical process of dismantling of old wind turbine and installation of a new one at the same location. Hence a further detailed analysis of the topography and the distribution of the wind speed on the surface of the ground are needed.

Current paper discusses the modern tools and methods for modeling the topography of the terrain and further wind flow modeling. This is a prerequisite for the proper configuration of wind turbines in the park and accurate assessment of energy production.

OROGRAPHY MODELING

Modeling scales

The performed study shows that there are different scales of terrain modelling. Depending on their scales the terrains can be divided into three major groups:

Micro scale: it is often used for modelling terrains for localized flows. Typical example for micro scaled simulation is model of a house with its immediate surroundings. Typical grid size for micro scaled simulation is about 10m.

Meso scale: it is used to describe bigger areas of land, including its inner particularities. The meso scale could be best described as model of a city, including all the buildings of the city, hills if any, parks etc.

Global (Synoptic) scale: it is used for modelling air currents over entire continents, weather phenomena, etc.

There are different modelling methods based on the tools. They are presented below:

Contact methods

The contact methods include the use of measuring equipment such as rulers, tape measures, clamps and other tools. They are good for really small scale object measuring, but they are not appropriate for the purposes of this paper, so they will not be discussed.

Non-contact methods

This includes the use of X-Rays, Lasers, Light measuring tools, Electronic Theodolites, etc. This paper will look into some of the most well-known tools and methods for modelling real terrains into computer software, rather than creating virtual terrains.

Those methods in turn are divided into:

Image-based Rendering (IBR)

IBR creates 3D environments directly from input images. It is vital for the technique to accurately know the camera positions or to performing automatic stereo matching for which a large number of closely spaced images is needed. Object occlusions and discontinuities, inevitably will affect the output. Therefore, the IBR method is generally only used for applications requiring limited visualisation Remondino and El-Hakim [1].

Image-based Modelling (IBM)

This is the widely used method for geometric surfaces of architectural objects or for precise terrain and city modelling (Grün [5], 2000). IBM methods use 2D image measurements to recover 3D object information through a mathematical model or they obtain 3D data using methods such as shape from shading, shape from texture, shape from specularity, shape from contour (medical applications) and shape from 2D edge gradients. Passive image-based methods acquire 3D measurements from multiple views, although techniques to acquire three dimensions from single images (Remondino and Roditakis, 2003) are also necessary. IBM methods use projective geometry (Nister [9], 2004; Pollefeys et al. [11], 2004). Those methods are good for recreating geometric shapes of buildings and monuments or other small scale models, but they are not appropriate for large scale models of terrains, since they require a great deal of additional work.

Range-based Modelling (RBM)

This method is used for capturing the geometric shape of the object directly. It relies on active sensors and can provide reliable and accurate representation of the shape that is being measured. The sensors rely on artificial lights or pattern projection. Over many years, structured light, coded light or laser light has been used for the measurement of objects. Most of the systems focus only on the acquisition of the 3D geometry, providing only a monochrome intensity value for each range value (Remondino and El-Hakim [1], 2006).

Combination of Image- and Range-based Modelling

It is always possible to combine any of the fore mentioned methods in order to achieve the desired results. Since each of the methods has its own strengths and weaknesses different combinations are necessary for each individual task

3D MODELLING OF TERRAIN

The overall image-based 3D modelling process consists of several well-known steps: design (sensor and network geometry); 3D measurements (point clouds, lines, etc.); structuring and modelling (segmentation, network/mesh generation, etc.); texturing and visualisation (Remondino and El-Hakim [1], 2006).

Automated obtaining of 3D model of the scene from uncalibrated images

The fully automated procedure (Nister, 2004; Pollefeys et al [11]., 2004), starts with a sequence of closely separated images taken with an uncalibrated camera. The system automatically extracts points of interest (such as corners), sequentially matches them across views and then computes camera parameters and 3D coordinates of the matched value (Remondino and El-Hakim, 2006). The images must be taken at short intervals. The first two images are generally used to initialise the sequence. The 3D surface model is then automatically generated. Some approaches have also been presented for the automated extraction of image correspondences between wide baseline images (Matas et al., 2002; Ferrari et al.,2003; Xiao and Shah [14], 2003; Lowe, 2004).

Semi-automated 3D reconstruction of the scene from oriented images

These approaches interactively or automatically orient and calibrate the images and afterwards perform the semi-automated modelling relying on the human operator (El-

Hakim, 2002; Gibson et al. [4], 2003; Guarnieri et al. [6], 2004). Semi-automated approaches are widely used when modelling complex geometric shapes. The degree of automation of modelling increases when certain assumptions about the object, such as perpendicularity or parallel surfaces, can be introduced. Debevec et al. (1996) developed a hybrid easy-to-use system to create 3D models of architectural features from a small number of photographs. The basic geometric shape of a structure is first recovered using models of polyhedral elements.

Automated 3D reconstruction of the scene from oriented images

The orientation and calibration are performed separately, interactively or automatically, while the 3D object reconstruction, based on object constraints, is fully automated. Most of the approaches explicitly make use of strong geometric constraints such as perpendicularity and verticality, which are likely to be found in architecture. Dick et al. (2001) employ the model-based recognition technique to extract high-level models in a single image and then use their projection onto other images for verification. The method requires parameterised building blocks with a priori distribution defined by the building style. The scene is modelled as a set of base planes corresponding to walls or roofs, each of which may contain offset 3D shapes that model common architectural elements such as windows and columns.

DESIGN AND RECOVERY OF NETWORK GEOMETRY

Different studies in close range photogrammetry show that:

(a) The accuracy of a network increases with the increase of the base to depth (B:D) ratio and using convergent images rather than images with parallel optical axes;

(b) The accuracy improves significantly with the number of images in which a point appears. But measuring the point in more than four images gives less significant improvement;

(c) The accuracy increases with the number of measured points per image;

(d) The image resolution (number of pixels) influences the accuracy of the computed object coordinates.

EXTRACTING SURFACES FROM POINT CLOUDS

Pre-processing: In this step the existing gaps are filled or if there are unnecessary points or points with invalid data, they are removed. Determination of global topology: Determination of the global topology of the object's surface, deriving the neighbourhood relations between adjacent parts of the surface (Remondino and El-Hakim, 2006). Generation of the polygonal surface: Triangular (or tetrahedral) networks are created satisfying certain quality requirements, for example, a limit on the network element size or no intersection of breaklines (Remondino and El-Hakim, 2006).

Surface Triangulation or Network (Mesh) Generation

- 2D triangulation

The input domain is a polygonal region of the plane and, as a result, triangles that intersect only at shared edges and vertices are generated (Remondino and El-Hakim, 2006).

- 2 ½ D triangulation

The input data is a set of points P in a plane, along with a real and unique elevation function at each point (Remondino and El-Hakim, 2006). The generated surface could be also called elevation grid.

- Surfaces for 3D models

The input data is always a set of points, no longer restricted to a plane; therefore, the elevation function is no longer unique. This could pose a problem for the generation process, since the input data is the most complex.

- *3D triangulation*

The triangulation in 3D is called tetrahedralisation or tetrahedrisation (Remondino and El-Hakim, 2006).

Post-processing

After generating the surface often refining actions are performed. They may include edge smoothing or strengthening, slight shape corrections etc.

The following things below should be consider in order to obtain better results.

Radiometric image distortion

This effect comes from the use of different images acquired from different positions or with different cameras or under different lighting conditions (Remondino and El-Hakim [1], 2006), different exposure or different lenses with the same focal length, since each lens has its own level of chromatic aberations. To avoid this, several techniques, such as blending methods based on weighted functions, can be used (Beauchesne and Roy [2], 2003; Kim and Pollefeys [7], 2004; Remondino and Niederoest, 2004).

Geometric scene distortion

This kind of error is generated from an incorrect camera calibration and orientation (Remondino and El-Hakim [1], 2006). Weinhaus and Devich (1999) give a detailed account of the geometric corrections that could be applied in order to prevent or remove distortions.

Dynamic range of the image

Digital images often have a low dynamic range. Therefore, bright areas are generally saturated while dark parts contain low signal to noise (S/N) ratio (Remondino and El-Hakim, 2006). To overcome these problems high dynamic range images should be created. This could be done by combining images of the same object or area that have correct exposure for each of the image parts. This will allow uniform lighting in the resulting picture.

Object occlusions

Static or moving objects such as pedestrians, cars, other monuments or trees, imaged in front of the objects to be modelled are obviously undesirable and should be as far as possible removed in the pre-processing step (Böhm [3], 2004; Ortin and Remondino [10], 2005).

CONCLUSION

In this work an overview of some of the current methods and technologies was made. There are a many other methods and technologies for modelling available, but they are not covered since they have limited application for terrain modelling. Based on the research done the next step is to make a detailed research in the range-based modelling methods, since they can be applied to terrain modelling.

List of References

[1] Remondino, F. and El-Hakim, S., 2006. Image-based 3D Modelling: A Review, The Photogrammetric Record 25(112), pages 269-291.

[2] Beauchesne, E, and Roy, S., 2003. Automatic relighting of overlapping textures of a 3D model. Proceedings of IEEE Computer Vision and Pattern Recognition, 18th to 20th June 2003. Vol. 2, 742 pages: 166–173.

[3] Böhm, J., 2004. Multi-image fusion for occlusion-free facade texturing. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 35(5): 867–872.

[4] Gibson, S., Hubbold, R. J., Cook, J. and Howard, T. L. J., 2003. Interactive reconstruction of virtual environments from video sequences. Computers & Graphics,

27(2): 293–301.
[5] Grün, A., Remondino, F. and Zhang, L., 2004. Photogrammetric reconstruction of the Great Buddha of Bamiyan, Afghanistan. The Photogrammetric Record, 19(107): 177–199.
[6] Guarnieri, A., Vettore, A. and Remondino, F., 2004. Photogrammetry and ground-based laser scanning: assessment of metric accuracy of the 3D model of Pozzoveggiani church. FIG Working Week 2004, The Olympic Spirit in Surveying, Athens, Greece, 22nd to 27th May 2004 (on CD-ROM).
[7] Kim, S. J. and Pollefeys, M., 2004. Radiometric alignment of image sequences. Proceedings of IEEE Computer Vision and Pattern Recognition, Washington, DC, 27th June to 2 July 2004. Vol. 1, 901 pages: 645–651.
[8] Lee, S. C. and Nevatia, R., 2003. Interactive 3D building modelling using a hierarchical representation. Proceedings of IEEE Workshop on Higher-Level Knowledge in 3D Modelling and Motion in conjunction with 9th International Conference on Computer Vision, Nice, France, 17th October 2003. 83 pages: 58–65.
[9] Nister, D., 2004. Automatic passive recovery of 3D from images and video. Proceedings of 2nd IEEE International Symposium on 3D Data Processing, Visualization and Transmission, Thessaloniki, Greece, 6th to 9th September. 1010 pages: 438–445.
[10] Ortin, D. and Remondino, F., 2005. Occlusion-free image generation for realistic texture mapping. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 36(5/W17): 7 pages (on CD-ROM).
[11] Pollefeys, M., Van Gool, L., Vergauwen, M., Verbiest, F., Cornelis, K., Tops, J. and Koch, R., 2004. Visual modelling with a hand-held camera. International Journal of Computer Vision, 59(3): 207–232.
[12] Remondino, F. and Niederoest, J., 2004. Generation of high-resolution mosaic for photo-realistic texture- mapping of cultural heritage 3D models. Proceedings of the 5th International Symposium on Virtual Reality, Archaeology and Intelligent Cultural Heritage (VAST04), Brussels, Belgium, 7th to 10th December 2004. 279 pages: 85–92.
[13] Remondino, F., Guarnieri, A. and Vettore, A., 2005. 3D modelling of close-range objects: photogrammetry or laser scanning? Proceedings of SPIE-IS&T Electronic Imaging: Videometrics VIII, San Jose, California. Vol. 5665, 374 pages: 216–225.
[14] Xiao, J. and Shah, M., 2003. Two-frame wide baseline matching. Proceedings of the 9th IEEE International Conference on Computer Vision, Nice, France, 14th to 17th October 2003. Vol. 1, 1525 pages: 603–610.

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This paper has been reviewed.