MODELLING OF NATURAL SLOPES AND EARTHEN CONSTRUCTIONS MONITORED BY SCANNING TECHNOLOGY

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ABSTRACT

Scanning performance effect depends both on technical parameters of scanner and advancement of data processing procedures. Accuracy and reliability of model depends on grid density and edge identification efficiency. As visualisation purposes and architectonic designing need models different from ones used in structural analysis a working out the 3D model needs consideration of construction characteristics and exploitation as well as model application. The authors prove this thesis by presentation and analysis of two earthen objects viz. natural slope and geotechnical construction monitored by scanning tacheometry technology.

1. INTRODUCTION

Laser scanning technology allows to invent and monitor any complicated geometry of object. Although accuracy of monitoring of structure deformations and displacements depends first of all on accuracy of distance measurements, the final effect depends on a method of generalization of survey data. Let's notice that scanning is focused on analysis of sets of points. The final results of scanning analysis are displacements of surface or cube but in no case displacements of single points (Table 1).

Table 1

Comparison of scaning and geodoetic methods of deformation and displacements measurements

Method of measurement	Observed elements	Subject of analysis
Geodetic methods	All points observed are fixed in structure and strictly defined in XYH system	Displacements of control points
Laser scannig	Boundaries of analysed surfaces are weakly defined	Displacements of surface or cube

Topographical constrains and lack of points that can be strictly identified on the object surface cause that optimization of scanning technology used for the measurement of displacements and deformations purposes should be focused on preparing of complete technology. In the presented paper the authors discuss detailed problems of modelling which is the last stage of postprocessing analysis.

2. SCANNING TACHEOMETRY

The technology of scanning is carried out either by laser scanning or scanning tacheometry. Using of laser scanners of great efficiency gives exceptional effects but using the latter one presents some advantages too. Scanning tacheometers are considered as handicaped due to relatively long time measurement (2-4s). From the other hand a cost of tacheometer and essential software is much less than laser scanner. The authors investigations show that usebility both scanning technologies cannot be evaluated only in aspects of costs and time consuming. At realization of monitoring tasks other arguments matter a lot too. Scanning tacheometry has some advantageous features. First of all both orientation and structure details measurements as well as scanning is carried out by the same instrument. Laser scanners and scanning tacheometry take distance measures with the same accuracy, but the range of latter one is much longer. Walls of structure can be rendered by natural surface from digital photographs. But first of all it should be emphasized that relatively small number of meshes does not handicup the scanning tacheometry as a technology of monitoring of deformation. Relatively rare grid density can be controled and optimized by operator both during field measurement session and at the stage of data processing. It is the best way to increase reliability of survey.

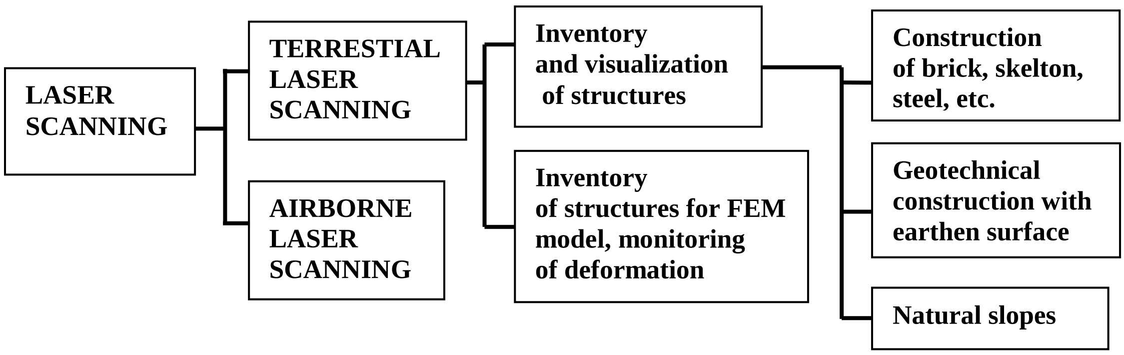

Fig. 1. Technics and applications of laser scanning

Applications of scanning tacheometry have been presented in the paper at two kinds of geotechnical objects with earthen surface.

3. MODELLING

The point cloud no matter of its density which is produced by scanning procedure has to be replaced by a model. Three types of models can be taken into consideration. But for the purpose of structural analysis only TIN model of tiny triangles is useful. Solid cube models play the important role at architectonic designing, face models are used very rare.

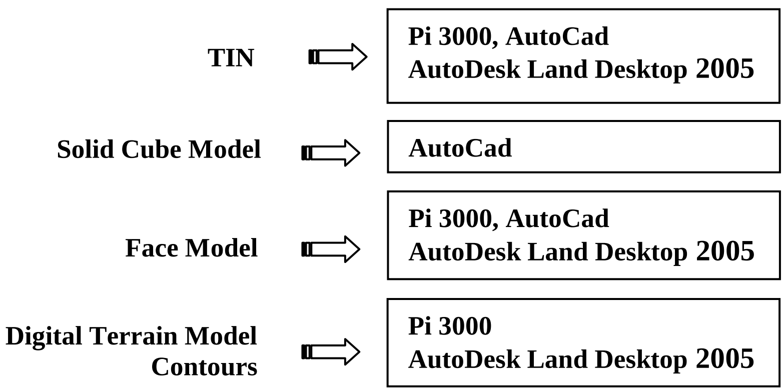

Fig. 2. Software applied in data processing

4. SCANNING OF NATURAL EARTHEN SLOPE

Differentiated morphology of earthen natural slopes is difficult for modelling. That is why on the great scale map only a slope outlines are marked. A shape of each surface may be shown by grid of points with proper density. Net density depends on a purpose of survey. At the case of natural slope the meshes of submeters in sizes meet typical technical demands.

Fig. 3. The scanned slope

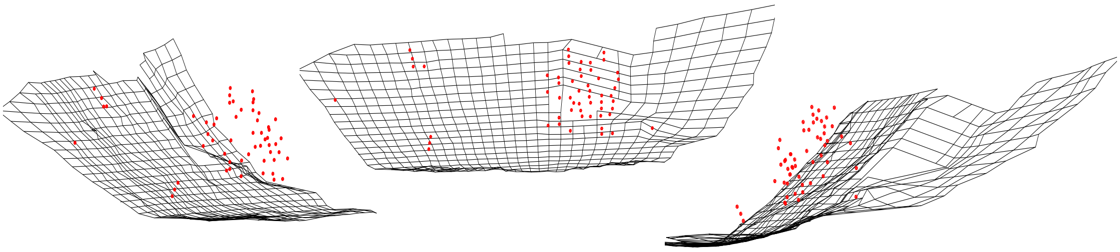

Fig. 4. Different perspective of point cloud expose data which should be removed

The presented earthen natural slope is 6 m in hight and 30 m long (Fig.3). Both scanning and classic survey was carried out from one station situated about 30 m from the bottom edge of the slope. Scanning grid covering the slope was approximately regular all over the analyzed surface. The size of each mesh side did not exceed half a meter. The measurement of 600 points took almost 1 hour.

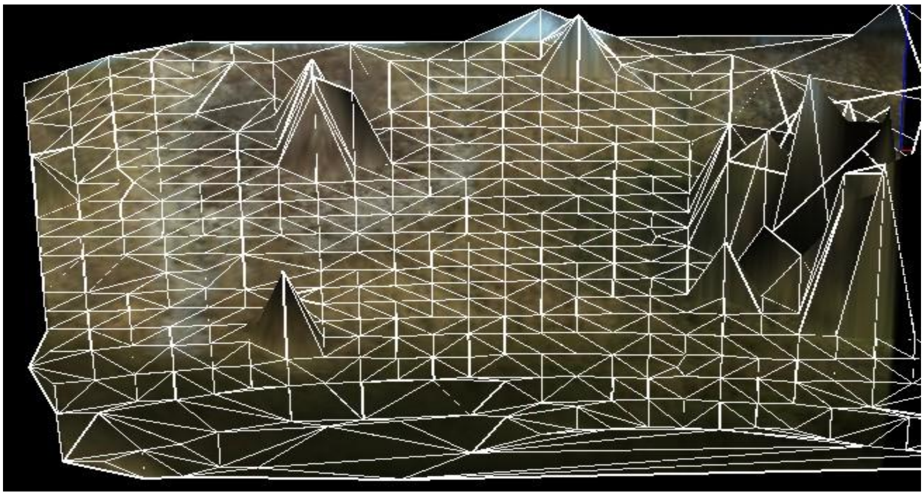

Fig. 5. The result of scanning before data filtration

As it is shown in Fig.3 and Fig.4 about 30% of the slope area needs filtration due to shrubs, trees but sometimes grass too. As automatic software procedures are not sufficiently reliable the corrections of scanning images and TIN model have to be done manually. Having in mind manual operations the grid density and number of points play an important role in optimization of time and work expenditure (Fig.5).

5. SCANNIG OF GEOTECHNICAL CONSTRUCTION – J. PIŁSUDSKI MOUND

The object of measurement has a shape of a cone of 33 m in height, 113 m in base diameter and 355 m in base circumference (Fig.6). The initial measurement in planned monitoring of the mound deformation was carried out from five stations located 16 ÷ 44 m from the mound base. So small distances of the control points were constrained by surrounding topographic conditions. Pathes going to the top of the mound which are the only details of structure have been measured by polar method using reflectors. The pathes has been assumed as break lines separating scanned parts of slopes. Additionally for the orientation purpose 30 points have been fixed in the earthen layer of the mound surface. They have been measured with great care by polar method.

Fig. 7. The mound of J. Pilsudski in Cracow

The scanning cloud was composed of 3000 points. The scanning areas were strictly determined by FC-100 software on the digital photographs. Procedure of scanning was carried out at regular interval of vertical and horizonthal angles. However despite the constant interval of angles the scan grid was not regular due to circular shape of construction (Fig.7). This harmful effect caused by oblique and tangent sight lines could be minimized only by greater number of stations. That is why the filtration of data should be completed before an integration of all points into one cloud.

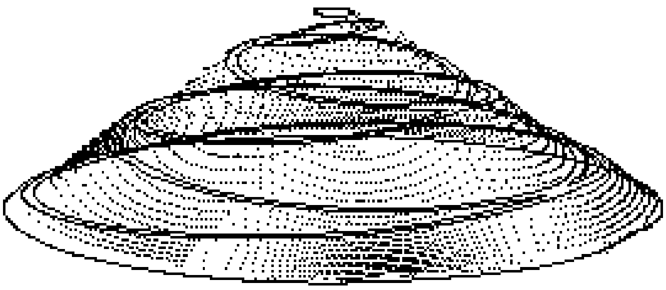

Fig. 8. Integration of scanning and polar method data; pathes edges are treated as break lines

Result of survey has been developed by software PI 3000 and AutoCad. In both cases the harmful effect of tangent sight was so evident that it had to be corrected by filtration of survey data. In both presented works it has been done basing on direct (manual) and detailed review of the whole sets. Using AutoDesk Land DeskTop software two kinds of models have been

produced contour map and TIN model (Fig.8) In both models path edges which have been measured by classic survey have been shown as spline lines. These lines separate surfaces treated as continuous ones. The grid density was sufficient although its irregularities and different shapes of meshes are not useful for further advanced analysis.

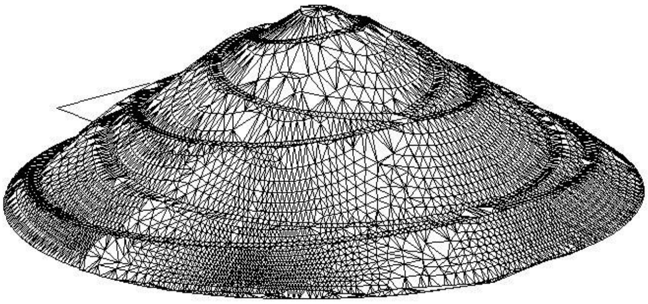

Fig. 8. Surface of the mound by TIN generated by Auto Desk

Point cloud in Fig.7 has also been worked out by a solid cube model. The cube model built by AutoCad software consists of small cubes of different shapes. Usually each surface of such cube is described by a few points of cloud. The partial modelling has been carried out by CIS module. Only this method allows to carry out the logical operations viz. addition, subtraction and multiplication. In modelling very useful are functions of cubes fitting, drawing the traces by cutting of two cubes, operation on the cube surfaces etc. Vertical surfaces (walls) of the models are produced by pulling out the regions being the bases of the cubes. The described procedures of modelling were time consuming due to curvature of the mound surface and differentiated morphology of its surface. The cube model presented in the Fig.9 has been built at the assumption that the differences between measured positions of points and their position approximated by surface of model do not exceed 5 cm.

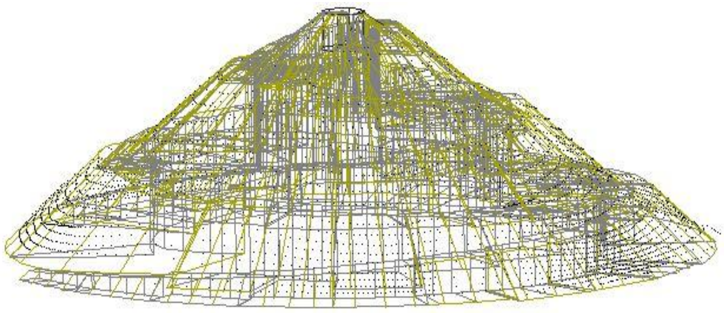

Fig. 9. The model of the mound worked out by AutoCad software with accuracy 0.05 m

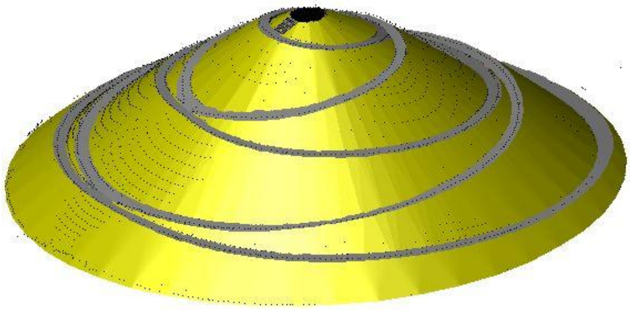

Fig. 10. The model consists of six seperate cubes, the accuracy of the model is about 0.25 m

Model 3D may be worked out at much less work, provided that considerable generalization of final geometrical shape can be assumed. In the Fig.10 the cube model presents the real shape of mound structure with accuracy of 25 cm. The most important feature of that model is that it consists only from six cubes which were put one over the other. These partial cubes are easy recognized in the Fig.10.

6. FINAL REMARKS AND CONCLUSIONS

- **Presented examples confirm the thesis of the work pointing at the necessity of optimization of scanning technics in dependence from type of a structure and scope of model application. This view seems to be particulary important in the case of earthen objects.**
- **If the measurements is carried out for the purpose of structural analysis the scanning should be designed to get model TIN consisted of tiny triangle meshes.**
- **Cloud of point can be used only for the purpose of visualization. Architectural designing needs cube solid models. Preparing of such models is time consuming especially in the case of earthen objects with different morphology. The processing of point cloud covering typical structure is usually much easier.**
- **Scanning sights should be perpendicular to wall of scanned objects. Usually to get this effect a number of stations have to be increased. Number of stations does not decrease accuracy of measurement provided that each station will be measured exactly by polar method. Number of stations should correlate with scanning area to eliminate oblique sights and doubling of scanning images.**
- **Each step of data processing should be checked by operator and corrected manually to get high reliability of measurement. Only in this way the problem of precise identification of break lines as well as filtration of scanning data can be solved successfully.**
- **Presented examples prove that combining laser scanning, precise polar measurement and digital photogrametry seems to be the optimal methods not only in the monitoring of natural slopes and earthen structure. But it should be also emphasized that despite advanced computer postprocessing software the optimization problem of survey procedure will be important permanently and opened for such details as shape of object, purpose of measurement and scope of application of model. And this context of optimization of scanning technology can be considered as actual research problem of engineering surveying.**

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