USING OF LASER AND DIGITAL CAMERA BASED SYSTEMS FOR 3D OBJECT DOCUMENTATION

K.Pavelka

Czech Technical University in Prague, Faculty of Civil Engineering, Dept. Mapping and Cartography,
Laboratory of Photogrammetry, Thákurova 7, 166 09, Prague 6, Czech Republic
Tel.:+42024354951, Fax:+42024310774, E-mail: pavelka@fsv.cvut.cz

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ABSTRACT:

Examples of systems based on simple digital camera and laser are discussed in the paper. At the Czech Technical University in Prague, photogrammetric measurement is performed in the Laboratory of Photogrammetry (Faculty of Civil Engineering). Based on a grant of the Czech Grant Agency, a large project on historical monument documentation and presentation by using a new digital technology has been started. In the framework of co-operation between the Laboratory of Photogrammetry and the Laboratory of Quantitative Methods of Monuments Research (Faculty of Nuclear Physics and Physical Engineering), new methods of 3D objects documentation as a part of project are tested. Two devices for 3D object co-ordinates capturing are being developed at present. The first device uses a rotating platform developed for small objects, a laser for point or profile marking (on the object) and a digital camera (for image sequence saving) on theodolite. Such a 3D scanner can be used for small compact objects, such as small sculptures, vessels, models and so on. The second device uses rotating stabile base equipped with a digital camera and a laser for point marking. This type is suitable for profiling of tunnels for example. The expected outputs are not only the 3D co-ordinates of the object, but also the experience with a new technology based on using laser and automatic image processing.

1. NEW DEVICES FOR 3D OBJECT MEASURING

In the framework of co-operation between the Laboratory of Photogrammetry and the Laboratory of Quantitative Methods of Monuments Research (Faculty of Nuclear Physics and Physical Engineering), new methods of 3D objects documentation as a part of project are tested. Two devices for 3D object co-ordinates capturing are being developed at present. The aim of the project is to develop a small inexpensive device for special purposes of 3D documentation. By combining several electronic parts such as CCD camera, laser marker, computer and distance measuring device a new laser sensor has been developed. There are only few possibilities how to construct laser based 3D sensors. The principle of these devices is the same: the laser beam is used as an object point marker (single point or line on object) and the laser track is recorded by using of a small CCD camera. The camera and laser position are convergent to the object, 3D co-ordinates can be computed from laser-camera basis.

2. LASER SYSTEM WITH ROTATING PLATFORM

For small objects such as small sculptures, vessels or models a system with rotating platform has been constructed. A laser beam optically modified to a thin line on the object is recorded from a basis with CCD camera. A maximum of 25 frames per second can be used. The measured object is situated on a rotating platform with a possibility to change the rotating velocity. All the images are stored on a PC and processed by using of special software. From the image coordinates of marked object points the real 3D coordinates are computed. The scanning process is demonstrated on Fig.1.

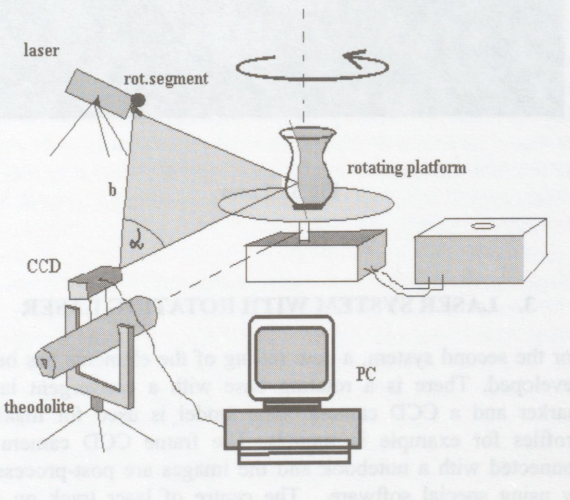

Fig.1: Rotating platform system

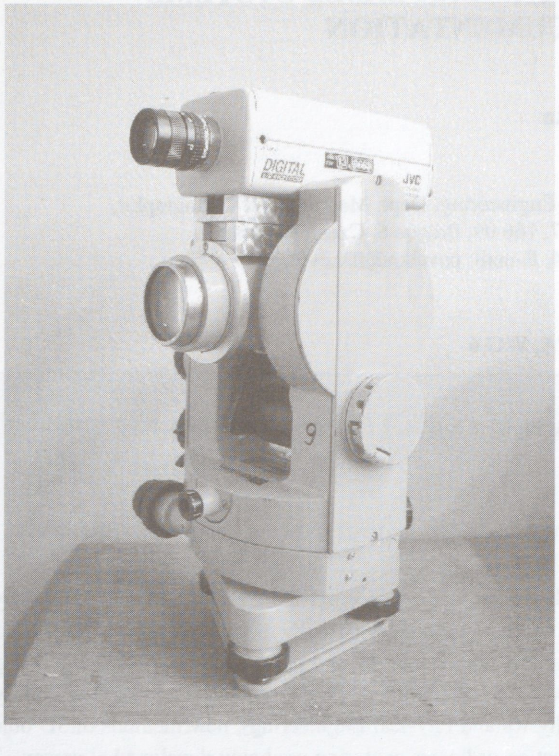

Fig.2 : Theodolite with CCD camera

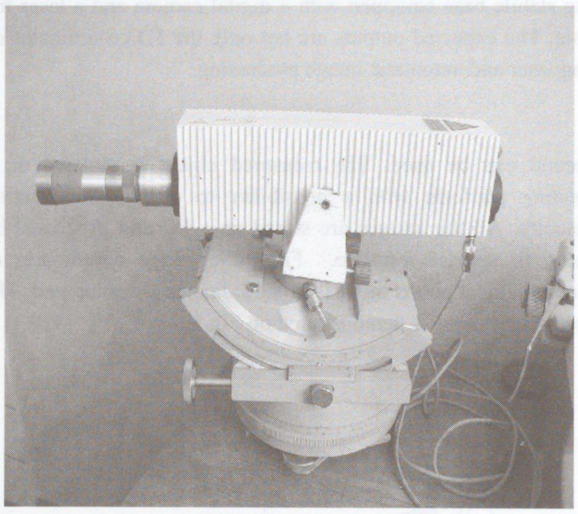

Fig.3 : Laser

3. LASER SYSTEM WITH ROTATING LASER

For the second system, a new setting of the elements has been developed. There is a rotating base with a convergent laser marker and a CCD camera. This model is used for making profiles for example in tunnels. The frame CCD camera is connected with a notebook and the images are post-processed by using special software. The centre of laser track on the images is detected with a sub-pixel resolution and the centre of laser trace (in image co-ordinates) represents a horizontal paralax. The first image with a laser trace is used as a base measurement and, however, the distance y_0 between the base and the object is known by using self-reflecting distance meter. For each image the rotating angle is recorded. Further, the distances to the object point are computed from paralax and the final 3D co-ordinates are determinated from rotating angle. The system is fixed on a platform and the platform position must be observed by using a total station. For this reason three reflecting prisms are added to the platform. The scheme is illustrated on fig.2. From a technical reasons it is better, when the camera is stationary and the rotating device is equipped by a prism.

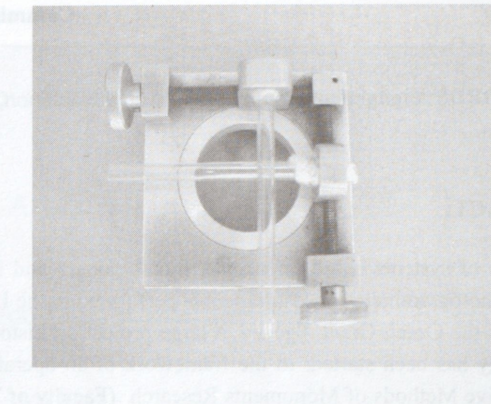

Fig.4: : Optical device (for line track)

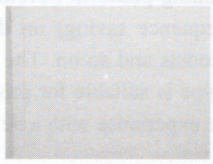

Fig.5: : Laser point track on the wall

Mathematically, the method is based on measurement of horizontal paralax of laser track centre. The first image is used as a base measurement. The difference between a laser track centre on the first image and the next images gives the paralax. The b is the known base distance and it is know, y_0 must be measured at the beginning of the experiment. The camera axis is perpendicular to the base. In this case we can use an equation for normal case of terrestrial photogrammetry. For this method the relation to terrestrial photogrammetry is evident.

$$\frac{y_0}{b}=\frac{dy}{p}, \qquad dy=\frac{y_0}{b}p \tag{1}$$

From equation (1) it is clear, that it is not necessary to know the camera constant. Nevertheless, for output precision reason it is recommended to use an objective with maximum focus distance. The precision of this can be obtained by derivation of (1):

$$dy=\frac{y_0}{b}dp+\frac{p}{b}dy_0-\frac{y_0 p}{b^2}db \tag{2}$$

The precision is given by the element y_0 / b. For example by using a CCD with the resolution 640x480pixels, the object distance about 4m and basis 40cm, the precision in dy is better than 10mm.

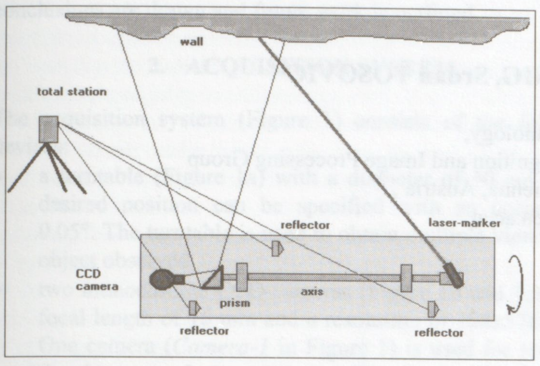

Fig.6: Profile measuring - the principle

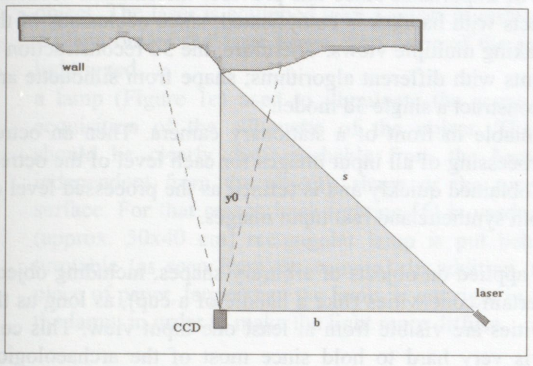

Fig.7 : First object point

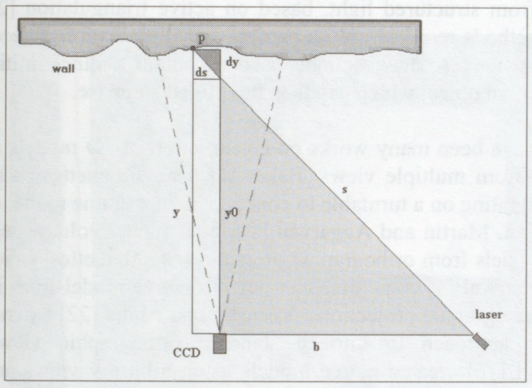

Fig.8 : Next object point

4. CONCLUSION

Examples of inexpensive systems based on simple digital camera and laser are discussed in the paper. Both systems are under construction on Czech Technical University in Prague and they are used for the technology testing

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