VISUAL 3-D RECONSTRUCTION

Ing. Karel HORÁK, Doctoral Degree Programme (1)
Dept. of Control and Instrumentation, FEEC, BUT
E-mail: xhorak21@stud.feec.vutbr.cz

Supervised by: Dr. Jozef Honec

ABSTRACT

This paper deals about visual and non-contact reconstruction of 3-D objects. The basic idea is an active triangulation. Triangulation triangle is formed by source of light (in this work it is used a linear laser), matrix CCD camera and measured object. Mutual spatial position of camera and light source is constant and system is calibrated (exactly adjusted) for this configuration. Reconstructed items are inserted into an object space. Data which are needed for reconstruction of three-dimensional object are obtained by item rotation in object space. This data describes its morphological attributes and are used for making a computer model.

1 OPTICAL MEASURING METHODS OF 3-D OBJECTS

By measuring of 3-D objects by optical methods is acquired information characterizes its shape (morphological) attributes. During visual reconstruction of three-dimensional model always come to dimensional reduction. The object is always captured from real 3-D space to 2-D plane which is represented by CCD matrix. Due to this optical transformation the information about one spatial coordinate is lost. The problem can be solved by using optical methods of measuring. The matter in hand is a passive or an active triangulation, a time-measuring of light flight and also an optical interferometry. There is used the active triangulation in this paper.

2 ACTIVE TRIANGULATION

The active triangulation technique is based on fotogrammetrical principle of reconstruction. The measuring object is iluminated by light source – either by beam (1–D triangulation), stripe (2–D triangulation) or structured pencil and at the same time the scene is captured by camera. The camera together with light source forms a triangulation base. Furthermore, the triangulation base together with measuring object forms a triangulation triangle (fig. 1).

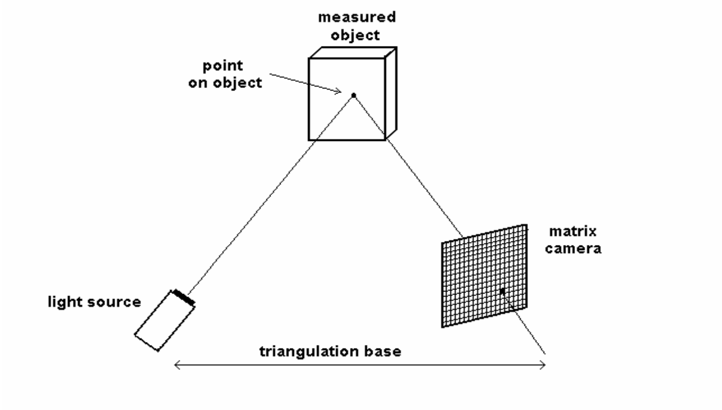

Fig. 1: *Triangulation principle*

For reconstruction it is chosen a wood hat's moulding last and the 2-D triangulation technique (laser stripe). The object is rotated on an accurate table with electronic control. For each angle it is obtained one image. In this way there are acquired constituent profiles of object as it is shown on fig. 2.

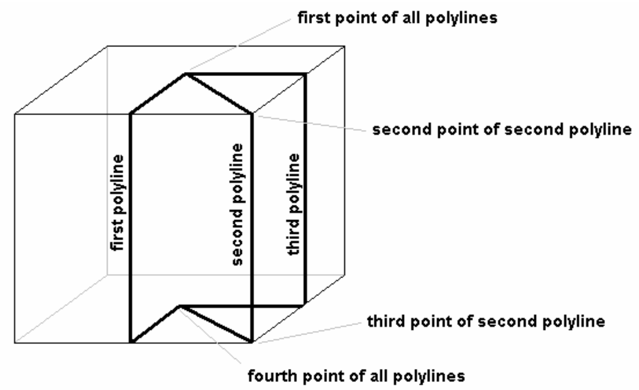

Fig. 2: *Object profiles obtains by 2-D triangulation method*

The demostration of the three-dimensional model creation in computer memory is on fig. 3. The foundation of model are line profiles (3a). Then there is wire model painted with the assistance of triangles (3b), model with solving edge-visibility (3c) and finally shaded model (3d).

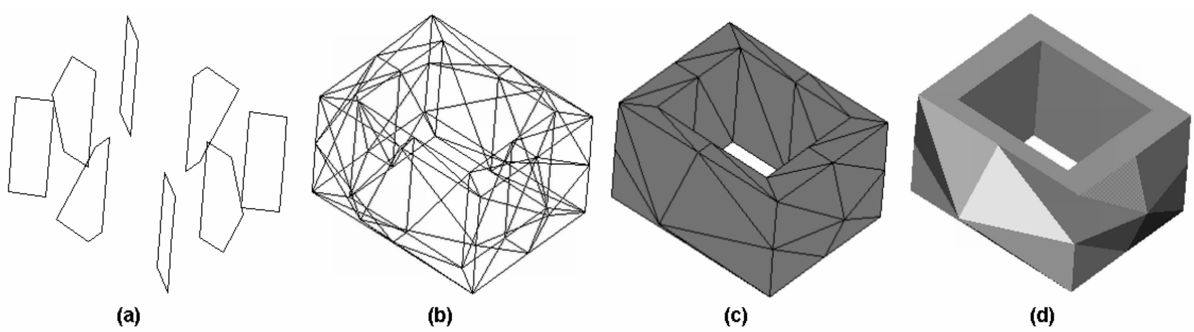

Fig. 3: *Object's model*

3 MEASURING CONFIGURATION

For the hat's model recontruction an experimental workplace is put together as it is shown on fig. 4.

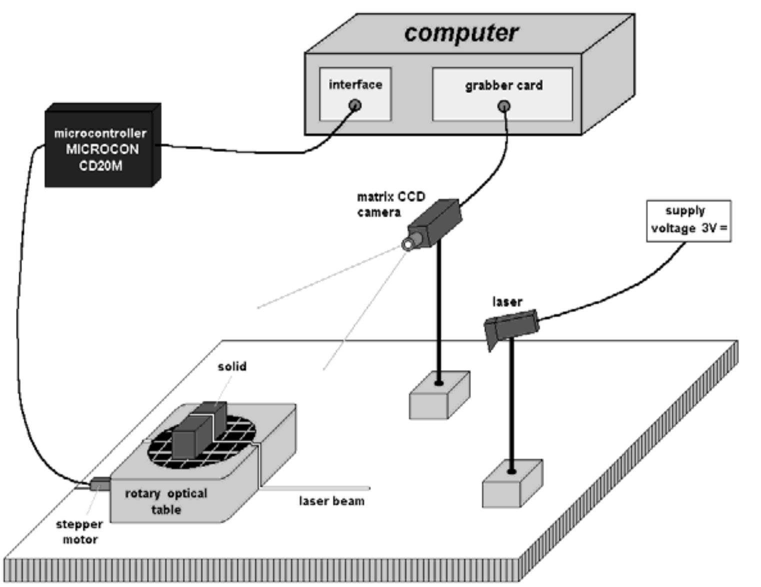

Fig. 4: *Workplace configuration*

The measured object is rotated by rotary table which is drived by a stepper motor. The motor is controlled by its own microcontroller due to data from computer. The step of table rotation between individual images is 1 º thus in this way is acquired 360 images around the whole model's circumference. Contrast laser stripe, determines the hat's profile, is algorhitmically found on each image. Every point of this profile is transformed from image coordinates *(u, v)* to spatial coordinates *(x, y, z)*. Then the acquired model can be drawn point by point, points connect, emerge surfaces colour in, shade and so on. Coordinates transformation is executed by transform matrix that is computed during object space calibration.

4 CALIBRATION

For transform from image coordinates *(u, v)* to spatial coordinates *(x, y, z)* is necessary to know transform matrix. The matrix dimension is 3x3 and each constituent member represents mutual relation between image and object space:

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} t_1 & t_2 & t_3 \\ t_4 & t_5 & t_6 \\ t_7 & t_8 & t_9 \end{pmatrix} \cdot \begin{pmatrix} u \\ v \\ 1 \end{pmatrix}$$

For matrix members (from t_1 to t_9) determination is needful to make calibration by known object as it is diagrammatically shown on fig. 5 and at real calibration on fig. 6.

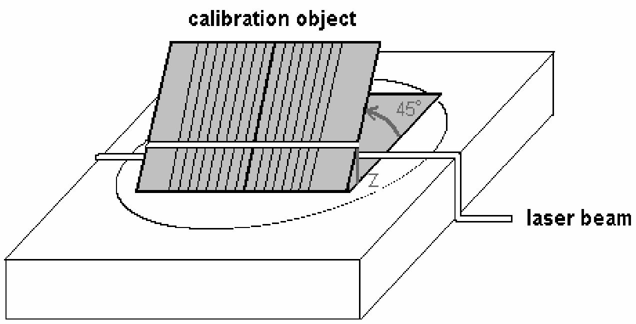

Fig. 5: *Calibration principle*

At the calibration object there are vertical equidistant lines which are intersected by laser stripe in specific level (at exactly defined shift of calibration object on rotary table). Thus is obtained trio spatial coordinates *(x, y, z)* and relevant image coordinates *(u, v)* for each point. The members of transformation matrix are iteratively computed (by the least mean square method) from these two data sets.

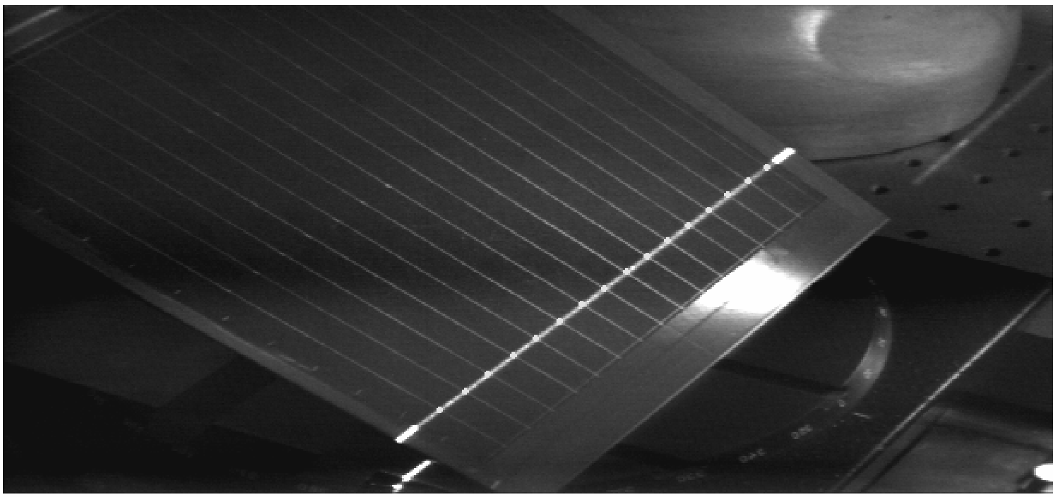

Fig. 6: *Picture from real calibration measuring*

5 SPATIAL MODEL

After workplace's setting and calibration of triangulation scanning device (in object space) there are taken hat's profiles around whole circumference. One image of the hat illminated by laser stripe is on fig. 7a and 7b shows for better view about measured object a photography of the hat's last.

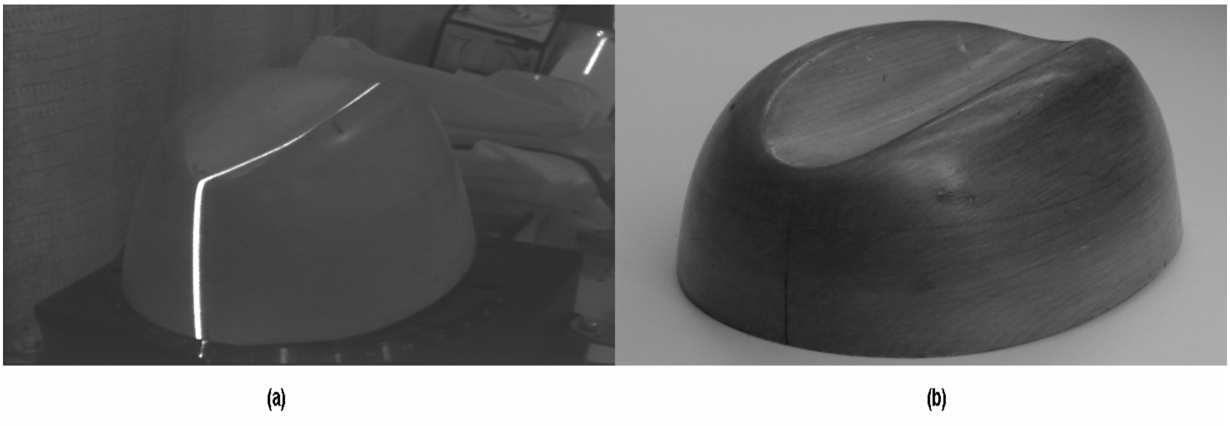

Fig. 7: *Measured hat's last*

By measuring are obtained 360 shapes of curves hat's last in total. From all profiles is put together the wire model (fig. 8).

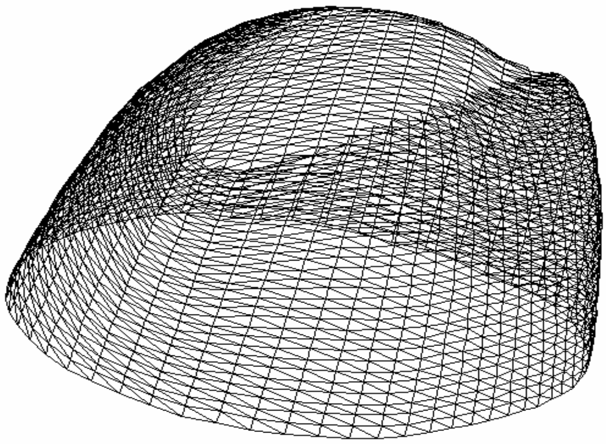

Fig. 8: *Computer model of hat`s last*

REFERENCES

[1] Horák, K.: Semestrální práce 1 – Fotogrammetrické vyhodnocení reliéfu 3D objektů, FEKT VUT Brno, 2002, 30 p.

[2] Kalová, I.: Semestrální práce 1 – Rekonstrukce povrchu prostorových objektů, FEKT VUT Brno, 2002, 32 p.

[3] Žára, J., Beneš, B., Fekel, P.:Moderní počítačová grafika, 1st edition Praha: Computer Press, 1998. 448 p., ISBN 80-7226-049-9

[4] Beneš, B., Felkel, P., Sochor, J., Žára, J.: Vizualizace, 1st edition Praha: Publisher ČVUT, 1997, 197 p., ISBN 80-01-01582-3

[5] Serba, I., Zendulka, J., Sochor, J.: Základy počítačové grafiky, 1st edition Brno: Publisher VUT Brno, 1991, 184 p., ISBN 80-214-0351-9