CLOSE RANGE PHOTOGRAMMETRY SYSTEM FOR MEDICINE AND RAILWAYS

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ABSTRACT

A specialised digital system of close range photogrammetry has been developed in the Department of Photogrammetry and Remote Sensing Informatics of University of Mining and Metallurgy in Cracow, Poland.

The system has been implemented in two applications.

The first one is related to medicine and used for overload monitoring for the purpose of medical rehabilitation, and the second one is designated for railways, to locate points on cross-sections.

Calibrated images are required as input data for the system.

The calibration can be performed in a laboratory, using a test field, by means of cameras with constant interior orientation parameters.

For medical purposes, several points are marked on the patient's body in selected locations.

Convergent photographs composed of direct photos and images reflected from a mirror located behind the patient are used to record points at the patient's front and back.

The mirror allows to reduce to the minimum the numbers of stands for image recording. In this case, free-focus cameras, such as Kodak DC 200, were used.

The system of reference is defined by reference points located on the mirror surface. Results of measurements are shown in a graphic form.

The second application concerns locating points on railways cross-sections. Digital cameras with nearly parallel axes are placed on a special railway platform. The co-ordinates of reference points marked on the stiff frame structure are determined in relation to the rail head level and track axis. These cameras have a high-precision shutter synchronisation.

1 INTRODUCTION

Not so long ago, the negative processing has been a very serious limitation for the use of photogrammetric methods to conduct measurements in the real time or for those applications in which the measurement result was expected to be obtained already on site. This was due, first of all, to the fact that in this instance laboratory processing was necessary, and, in addition, the measurement of a photo picture had to be performed using a specialised, photogrammetric equipment.

These limitations have been overcome by the use of digital cameras to obtain pictures. Digital photogrammetry, which is based on such pictures and utilises computers to process them, has been growing dynamically, especially in the non-topographical applications.

A wide range of digital cameras is available on the market, from the simple, relatively cheap, photo cameras to digital, photogrammetric cameras, with excellent lenses and high picture resolution. Unfortunately, high picture resolution is usually followed by high price.

Cheap digital cameras are of a compact type, therefore, it is not possible to use interchangeable lenses. The majority of these cameras operate in the auto-focus mode, so it is not possible to calibrate them in any other way than during the measurement. Since there are very many types of such cameras available on the market, one can select such models which will fulfil at least part of the conditions required.

These conditions may be various. They may concern, first of all, the picture resolution, possibility of calibration, speed of picture transfer to the computer memory, possibilities of synchronising shutters of several cameras etc.

In the Department of Photogrammetry and Remote Sensing Informatics of Faculty of Mining Geodesy and Environmental Engineering at the Academy of Mining and Metallurgy in Cracow, Poland, a simple measurement system, based on pictures taken by means of digital cameras, has been developed. Under this system, the picture measurements and calculations are done by computer. This facilitates quick obtaining of the results and interpreting them on the spot, already at the measurement place.

Presently, two versions of the system exist, created for two, quite different applications: in medicine, for examinations in medical rehabilitation, and in railway transportation.

2 SYSTEM DESCRIPTION

The photogrammetric assumptions of the system are as follows:

- knowing calibration parameters of two digital cameras used to obtain images,
- measuring point co-ordinates on digital pictures by means of computer,
- relative orientating of pictures and constructing three-dimensional models of the measured objects,
- absolute orientating of the model on the basis of control points,
- own software.

The basis of processing is a pair of photos (in the application in question, these are photos with slightly convergent axes.) After transferring them to the computer and displaying them simultaneously on the screen, one measures points which enable relative orientating of two photographs, the defining of control points and traced points. Stereoscope observation is not necessary to conduct the measurement. Obviously, both the control points and the traced points may serve the purpose of relative orientation. This orientation is performed using the Schut method (Schut, 1966), and the three-dimensional model is constructed in the left camera system. Since the interior orientation elements of both cameras must be identical here, one assumes for calculation purposes the left camera constant and the location of principal point $x_0 = y_0 = 0$, while the photo co-ordinates for both photographs are calculated individually, with additional changing of the right photograph scale by means of a coefficient $s = c_{k2}/c_{k1}$.

The absolute orientation is performed by means of a non-iterative method, with the application of Rodriques-Olind matrix (Schut, 1967.) The measurement results – three-dimensional co-ordinates of the measured points may be recorded in files or displayed in graphic forms on the screen which facilitates interpreting them.

3 CAMERA CALIBRATION

As indicated in the system assumptions, the previously calibrated cameras are used to obtain images. The calibration process is carried out at the laboratory test field. The field consists of 160 (almost) coplanar points, distributed on wall, on the surface area of 2.3 x 2.3 m, and points located on vertical wires outside the wall plane (Fig. 1.) Therefore, this is a three-dimensional test field.

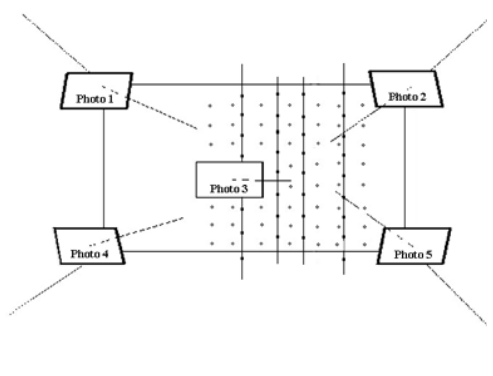

Figure 1. Laboratory test field

The wall point co-ordinates have been determined by means of geodetic method, while the wire point co-ordinates are established in the process of self-calibration which constitutes the basis for calculating the photographs' interior orientation and parameters of picture distortion functions (Boroń, Tokarczyk, 1999)

Several convergent photographs, focused at the same distance, are made for the purpose of calibration. Of course, before that, one must check to what extent the camera's interior orientation is stable.

This concerns, first of all, cameras with manually-, or computer-controlled focusing modes, or cameras in which focusing control is selected from the camera's menu. Most suitable for the calibration purpose are free-focus cameras since they have fixed lenses and permanently-set focus distances. The object to be photographed must be set in a distance within the camera's depth of field.

Calibration procedure of Kodak DC200 digital camera is described here as an example. This is a relatively cheap, free-focus camera, with picture resolution of 1152 (h) x 864 (v) pixels, and the lens focal distance of 39 mm. Pictures are recorded in the JPEG or FPX formats, on a 4MB card, then transferred to computer through RS-232 connected to one of the ports (http://www.kodak.com, 2000). For the purpose of calibration, 7 convergent pictures, from the distance of 3 m, have been taken. The field test picture points have been measured with the application of VSD-AGH digital screen autograph. The interior orientation elements x_0, y_0, c_k, the distortion polynomial parameters: K_1, K_2 (radial symmetric distortion) and P_1, P_2 (tangential distortion) have been calculated, by solving the self-calibration network with the use of the ORIENT system (TU Vienna.) The following calibration parameters, with their determining errors, have been obtained:

Kodak DC200

x_0 = 45,27±0,44 pixels
y_0= 14,44±0,45 pixels
c_k= 1305,36±0,37 pixels
K_1 = -7,783521±4,3E-02
K_2 = 0,8778863±2,0E-02
P_1 = -0,01889872±1,9E-02
P_2 = 0,0611877±1,9E-02

4 HUMAN BODY MEASUREMENT FOR THE PURPOSE OF MEDICAL REHABILITATION

The photogrammetry methods, being non-contact methods are, apart from their numerous applications, very convenient and precise tools for measuring biological forms and functions, as well as shapes, locations and three-dimensional dimensions of anatomic structures and their movements and changes in time. Measurements can be applied to the body surface, sub-surface elements (infrared and thermal ranges) and body interior (X-raying, ultrasound examinations, magnetic resonance). Due to the several years' co-operation between the Department of Photogrammetry and Remote Sensing Informatics and the Rehabilitation Clinic of the Military Hospital in Cracow, a method of measurement with the use of 35 mm cameras has been devised. The objective of the method is to determine locations of selected body points and their changes in time. This helps to learn the mechanism of overloads being essential causes of pain origin. While being easy and cheap, the method of using photo cameras required, however, negative processing and photograph measuring by means of specialised, photogrammetry equipment which considerably delayed obtaining of the measurement results. This problem may be defeated by digital picture recording, and the results can be obtained almost immediately what allows for proper rehabilitation intervention activities to be performed .

Measurement system for the above-referenced application should enable the following:

- determination of body point locations and relations between them in a three-dimensional space,
- non-contact nature of measurement, since this method only does not affect the measurement results,
- minimum level of patient troubling which means conducting measurements in the clinic and as quickly as possible,
- picture recording with the use of minimum number of cameras, and, at the same time, allowing to measure points at each side of the patient's body,
- possibility of direct computer control of the system which allows for the running observations and various analyses,
- analytical and graphical result interpretation,
- possibility of co-operating with other devices (e.g. podometer),
- system cost minimalization.

Since the simultaneous recording of points located both at the front and in the back parts of the patient's body would require at least four cameras, with the resulting cost increase, a decision has been made to use only two cameras in the first option of the system, and make use of the picture reflected in a mirror which is to be found in majority of rehabilitation rooms. In order to simplify to the maximum the measurement of control points, they have been placed on the mirror surface. The measurement is limited to simple measuring distance between the points, and co-ordinates are obtained after solving and adjustment of a simple line network. Therefore, these operations can be performed by a properly-trained medical personnel.

It has been decided that picture recording would be done with the use of popular digital cameras. When selecting them, the main criteria were the picture resolution and interior orientation elements' stability. Precise shutter synchronisation is not required, a 1-second accuracy is enough, and shutters may be released manually as well.

For example, Kodak DC200 camera fulfils such conditions and was selected to record pictures in the system prototype. The examination of point co-ordinates determining accuracy in a pair of photos made in the test field with the use of two calibrated cameras of this type, proved that for pictures shot from the distance of ca. 3 m, being slightly convergent, the measurement based on four control points located within single plane yielded a 2 mm accuracy which, in this application, is an absolutely satisfactory value.

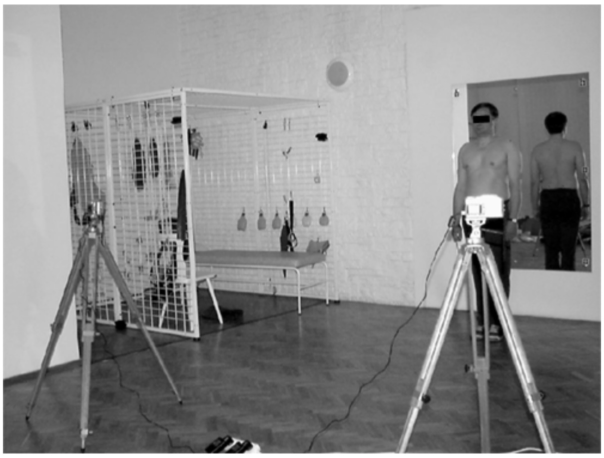

Figure 2. General view of the system elements in operation

The truth is that accuracy of points reflected in a mirror will be different, and will depend, first of all, on the mirror being non-flat and the distance between the reflected image and the cameras.

Measurement preparatory works in the rehabilitation office consist in marking photo points and their subsequent measuring. In order to simplify these procedures to the maximum, the photo points in the form of paper marks should be glued to the mirror edges. Two of them should be placed along vertical or horizontal lines. It is assumed that the mirror is in a vertical plane. Measuring the distance between the photo points allows to obtain their mirror surface co-ordinates. The third co-ordinate is assumed to be known and freely selected. The choice of stands for the photo-making results mainly from the possibility of seeing on both pictures the points on the patient's body reflected in the mirror, both the front and back ones.

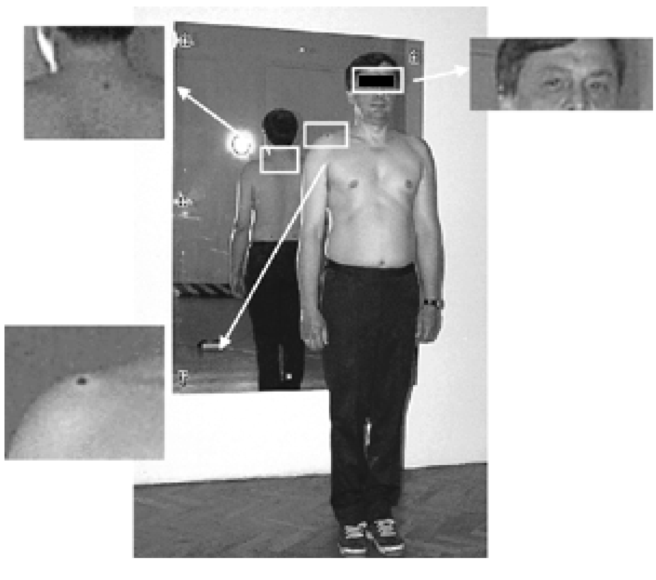

Figure 3. Targets on the patient's body

Fig. 2 presents the general view of the system elements in operation.

As it can be seen, the system may be installed in any room (here the rehabilitation gym). Targets on the patient's body are marked by means of self-adhesive, coloured circles, dia. 5 mm, fixed in the places selected by the doctor (Fig. 3.)

Measuring is done by pointing the respective points with the cursor. In view of the specific shapes and colours of the points, the subsequent system versions assume the automatisation of measuring process. The final result is the determining of the three-dimensional location of selected points and visual displaying them in several projections. One can also obtain certain line and angular relationships between the points and line segments which link them.

An example of displacement of several points subjected to measurement and their selected screen display outlook is shown in Fig. 4.

Fig. 5 presents projection of the determined points on horizontal plane and shows distinct mutual distortions of specific line segments.

These data are to establish the mechanism of overloads which are the source of pain. By watching the distribution of particular line segments and their mutual distortions on the screen, the doctor evaluates influence of compensation movements on particular axes of human body arrangement.

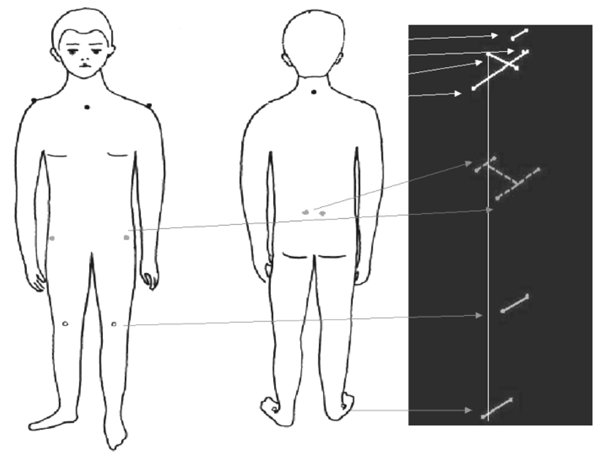

Figure 4. Points subjected to measurement and their selected screen display outlook

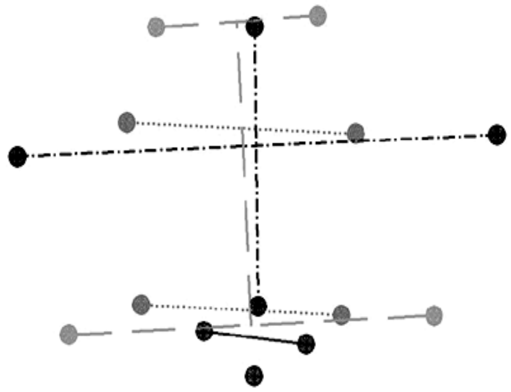

Figure 5. Projection of the determined points on horizontal plane and distinct mutual distortions of specific line segments.

5 THE USE OF THE SYSTEM IN RAILWAYS

The objective of the system in this application is determining three-dimensional co-ordinates of points located in selected planes which are perpendicular in relation to the track axis. In addition to the assumptions specified in Paragraph 2 of this paper, there are other conditions resulting from the specific nature of the application, i.e.:

- precise synchronisation of the pictures,
- immediate transfer of pictures to the computer memory,
- stability of relative orientation elements of both cameras, possibility to check and correct this condition,
- stability of control point co-ordinates in the travelling platform arrangement,
- taking into account corrections relating to the track curvature,
- recording onto the pictures the outline of the range of that part of cross-section, transverse in relation to the track, inside which the points will be measured.

The first two of these conditions affect the choice of proper digital cameras: they cannot be popular photo cameras since, in this case, precise synchronising of their shutters is not possible. The stability of calibration parameters imposes application of cameras with focal distance locks, and quick picture transfer to the computer may be achieved through the application of wire frame, with the reduction of the picture file size through the application of monochromatic cameras.

6 CONCLUSIONS

This Report presents a brief description of close range photogrammetry system prototypes which may be used in medicine and railway applications.

The undoubted advantage of both systems is the fact that they can be handled by non-professionals since the software does not have to operate in the stereoscope observation mode.

This is particularly important since the users of both systems will be people not involved in such activities (medical and railway personnel.)

The second, unquestioned advantage is that the systems are based on their own software. This allows for any modifications to be introduced (adding new procedures, correcting the existing ones) and provides for, in the later stages, the possibility of introducing automatic modes for certain operations.

It is expected, among others, that automatic measuring of points on the patient's body and check points in both applications will be used, which should considerably improve the process efficiency.

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