

AN AUTOMATIC PROCESS FOR THE EXTRACTION OF THE 3D MODEL OF THE HUMAN BACK SURFACE FOR SCOLIOSIS TREATMENT

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ABSTRACT

Back disease is a very common illness among the young people, nowadays. Scoliosis, especially, is appearing during the growth of the human skeleton and it is usually accompanied with other deformations like kyphosis and lordosis. The deformation is changing rapidly while the patient is growing and a continuous monitoring of its progress is essential in order to achieve the best possible treatment. So far the most reliable method for the diagnosis and monitoring of the illness is the radiograph examination. However the radiograph is a dangerous and destructive examination and it should not be repeated frequently.

An attempt has been made for the automatic extraction of the 3D surface model from digital images of the human back with the use of video cameras connected to a typical PC-based computer. The configuration of the automated system consists of three video cameras, (for blunder detection and consistency check purposes) capturing the image of the human back from three different positions, having a distance of about 1.5-2.5m from the object. The cameras' resolution is rather low (768x576) using 6mm c-mount type lenses. The method is using epipolar image matching techniques in order to find conjugate points and reconstruct the back surface.

The cost of the system is rather low. The hardware cost does not exceed the amount of 3.500\$. The system has been designed for use of non-expert personnel and most of the procedures are fully automated.

1. INTRODUCTION

Medical photogrammetry has become of great importance in recent years, due to many reasons. There are many advantages for medical photogrammetry procedures especially in the case of examining the deformation of the human skeleton and the diagnosis of scoliosis. So far the main laboratorial examination of the scoliosis is the radiogram. Below, the most important advantages of digital photogrammetry against the radiogram examinations, are presented:

- Digital photogrammetry uses optical images, which are remotely taken and have no effect to the human organism in order to produce photogrammetric products of great importance for medical applications such as the 3D model of the human back. On the contrary the radiograms are destructive examinations for the human organism and they cannot be repeated very frequently. Digital optical images do not need special and expensive instrumentation and due to the downfall of the prices of digital equipment a very cheap system consisting of a computer, video cameras and a frame grabber can replace the typical x-ray equipment. Not only the x-ray equipment is expensive. The used materials are expensive too. Digital photogrammetry uses no hardcopy material in order to produce the digital model of a human back.
- The radiograms provide a rather qualitative but not a quantitative mean for medical diagnosis. There can be no precise measurement for the deformation of the human skeleton when using radiograms. On the other hand optical images in digital photogrammetry can provide in numbers (quantitative) the percentage of the human back deformation after the calculation of the 3D coordinates of the points that lie on the human back. Besides, they can provide other diagnostic and monitoring means, like symmetries, angles and distances.
- Radiograms are two-dimensional (2D) images and they cannot provide the information of a possible deformation of the human skeleton in the three-dimensional (3D) real world. The use of at least one stereo pair of digital optical images can provide 3D information.
- A complete digital archive of the acquired images and the generated 3D models can be easily created for each patient. In addition to the photogrammetric by-products other tabular data can be managed in a generalized database file. A full supporting system can be created and important statistics results can be acquired from the 3D model's data. This, besides being an effective diagnostic tool, it also provides all the potential of tele-medicine, taking the advantage of the Internet for the dissemination of the patients' records among doctors and laboratories remotely positioned. Another important issue that can be of great help to the attendant doctors is a global and continuous monitoring of the disease status. More specifically the models of the human back generated in different

stages of a treatment can be referenced in a global system (Karras and Petsa.,1993) and can be compared to each other or to the model of a so-called healthy human back. Important conclusion can be inferred from those comparisons that could help the fast and effective treatment of the disease.

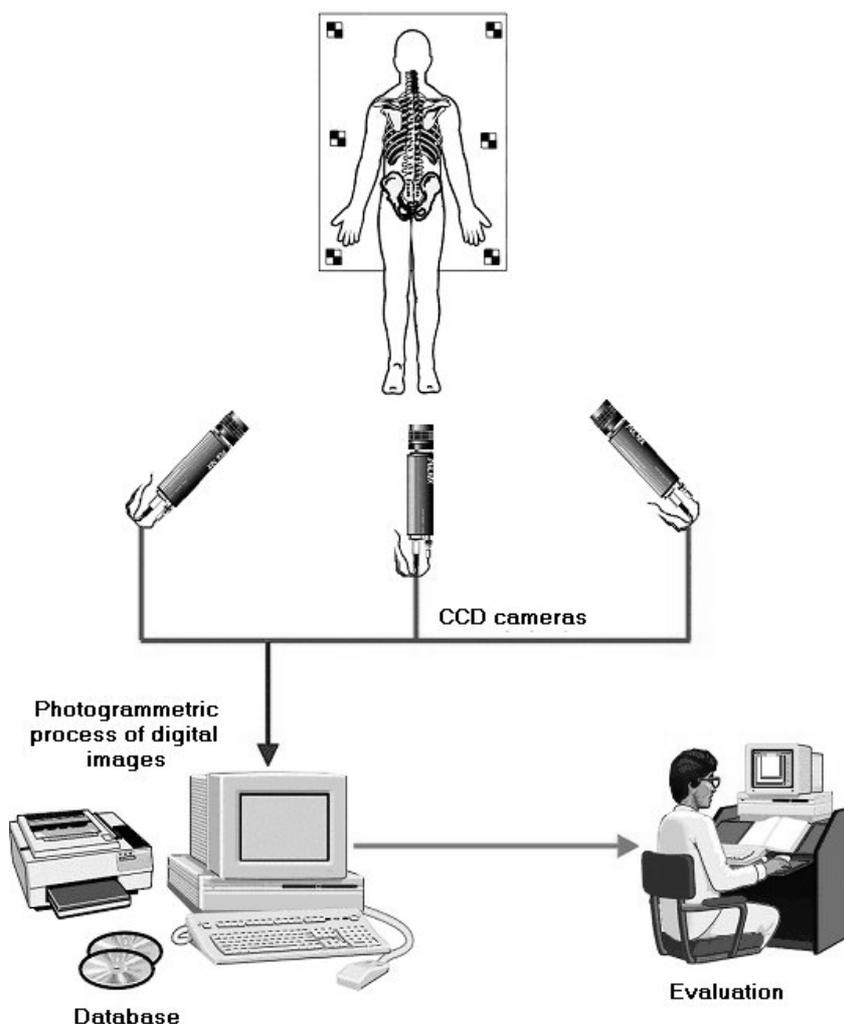


Fig. 1: The proposed system

2. FACED PROBLEMS AND IMPLEMENTED SOLUTIONS

The problems we were faced with were the following:

- More than two digital optical images of the examined human back should be acquired at nearly the same time using just one computer and one frame grabber.
- Matching techniques in images succeed only in cases where rich texture exists. The image of the human back lacks of that necessary texture.
- Video cameras normally suffer from big lens distortions, which should be removed if better accuracy in the surface reconstruction is sought.

The implemented following solutions were:

- Three monochrome cameras SONY SPT-M308CE/2 are connected to the frame grabber of the computer through an electronic circuit (figure 2) that is controlled asynchronously by the computer via RS232 serial communication port. The circuit allows the connection of each camera with the frame grabber when appropriate commands are sent through the serial communication port. The sensor dimension is 3.3x4.4 (mm), giving a B/W low resolution (768x576) pixels image after the grabbing. The focal lenses that were used are c-mount type and their nominal focal distance is 6mm

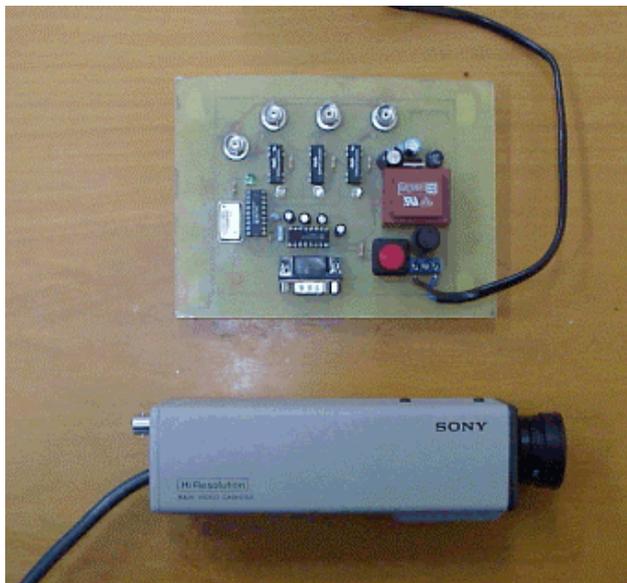


Fig. 2: Electronic circuit switch and the Sony camera

- The electronic circuit consists of three video signal inputs and one output and a processor unit fetches the commands that are sent from the computer to the port. When a specific command is sent to the port of the computer, with the press of a button in the application program, the processor decodes the binary word of the command and responds accordingly. There are two kinds of commands:

1. commands that restore the connection from a specific video camera to the frame grabber of the computer. Through that commands, the image from one of the cameras is directed to the computer.
2. commands that disconnect the specific camera from the frame grabber of the computer.

With the help of this electronic circuit it has been feasible to pass images from all the cameras to a single computer and with the use of just a single frame grabber, in only a few seconds (less than 3 seconds). No sophisticated software is used to control the whole setup (just typical serial

communication library commands).

- The low color texture of the image of a human back is enriched by the projection of a regular grid of black circular dots on white background using a typical slide projector. This technique has been widely used in most of the cases where the color texture of the examined object is rather poor (Jones, et al., 1996, Gabel & Kakoschke, 1996). Other researchers have also used a random texture grid in order to provide color texture on the surface of the human back (Apuzzo, 1998, Thomas, 1996). The shape of the circular dot has been used deliberately because it is rotation invariant and can be easily matched from the one image to the others. Those dots cover the whole interest area of the human body. Several tests have been taken place in order to determine the optimum size and spacing of these dots. A configuration of a grid consisting of dots 3-5 pixels in diameter and with a spacing of 9-15 pixels gave the best results.
- Lens distortion is removed from the original images with the use of home-made software application (Sechidis, et al., 1999). This program takes as input the original image (figure 3, left photo) and a file defining the lens distortion parameters calculated a-priori for all the recording cameras. The program produces the new corrected image (figure 3, right photo) in a few seconds (approximately 5 seconds using a Pentium 166MHz processor).

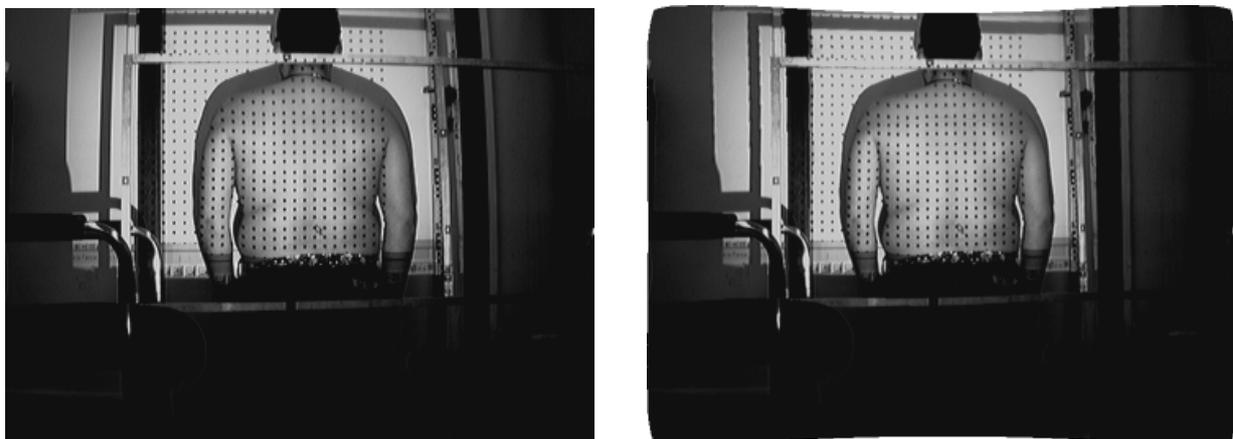


Fig. 3: Original and corrected (from lens distortion) images

3. IMPLEMENTATION OF IMAGE MATCHING

The three corrected images of the human back are inserted to the image matching program (Patias and Tsioukas, 1999). The previous calculated inner orientation along with the corrections (lens distortion and focal length determination) for the video camera systems are applied automatically to the images. The position of the cameras is fixed. The exterior orientation of the images, that has been previously calculated, is applied and there is no need to be calculated every time new images are acquired.

The user interacts with the system only by defining the 4 edge dots. Automatically, the template of the dot is defined on the first image and the approximate positions of the conjugate points in the other images are computed through cross correlation. These are the interest points that will be used in the image matching procedure. Least squares epipolar image matching is then applied for more precise matching. Possible blunders during matching are identified and eliminated through statistical analysis and consistency checks. The ground (body) coordinates of the surface points are calculated with the use of a multiple intersection adjustment. The produced DTM is converted to a regular grid of height points, using a third party interpolation program on the background, and its shape can be examined in a special 3D-preview window. The model is created using OPENGL commands. Orthoimage production is also possible.

Several calculations can be applied to the generated DTM such as the non-symmetry factor, points of greater depth or greater altitude etc. Those data can automatically be inserted in a record of a patients' database file along with other data such as age, height, weight, sex, date of examination etc.

4. RESULTS

The area that has been tested for automatic DTM generation has an extension of approximately 0.3 m². A total number of 212 points were projected on a human's back and 184 of them were recognized error free conjugate points. The rest points were automatically identified as mismatches or matches of low quality. The DTM was generated with the use of a multiple intersection process. The calculated points had then been used to produce a regular grid of DEM points (figure 4).

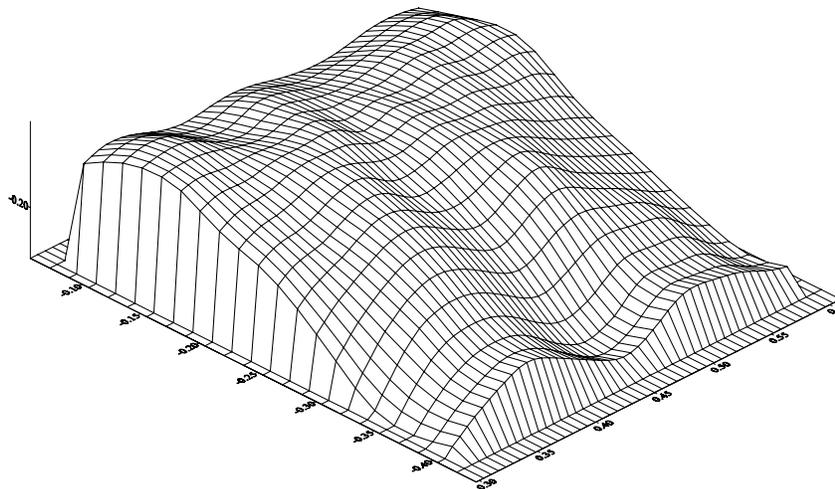


Fig. 4: 3D model of a human back surface

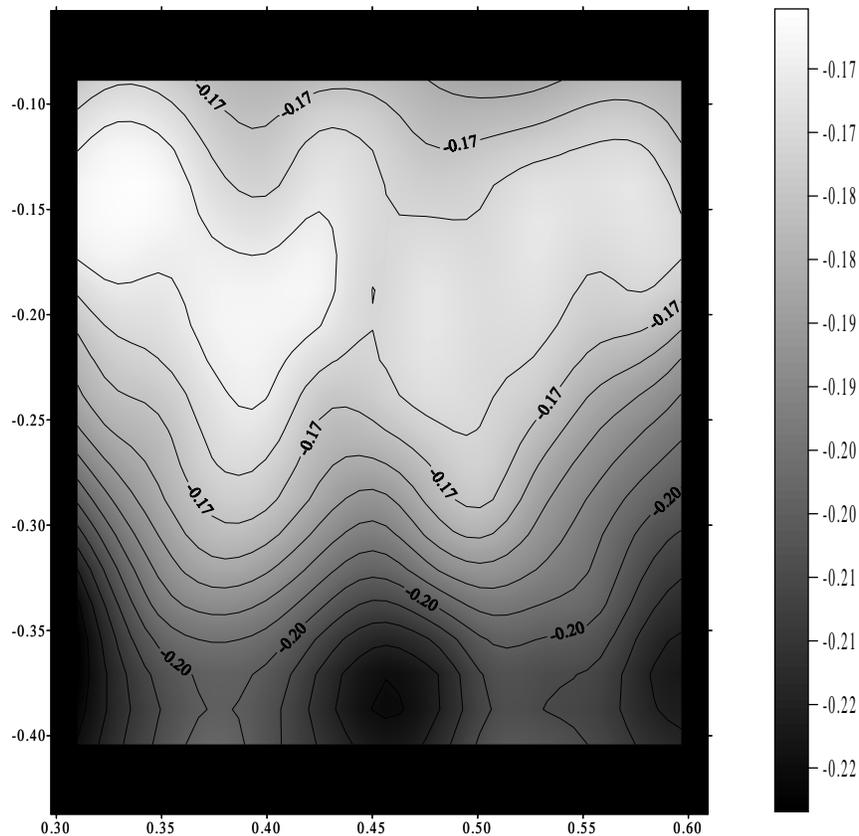


Fig.5: Height shaded map of the human back surface

5. ACCURACY

The pixel size in ground values is 1 mm. Since the accuracy of the determination of conjugate points (through the matching process) is less than one pixel the estimated accuracy of the observations is better than 1mm. The root-mean-square-error of the computed 3D body coordinates using the corrected images (lens distortion is removed) is better than 2 mm in planimetry and 3 mm in height.

6. THROUGHPUT TIME

The system responds rather fast as soon the images have been acquired. 10 minutes time is adequate for the extraction of a detailed DTM of the human back, consisting of about 150-200 points. The proposed technique is sometimes faster than the typical x-ray examination.

7. CONCLUSIONS

Although a stereo pair of images would be enough for the automatic extraction of the DTM, an additional third image is acquired so that blunders are excluded and better results for the ground coordinates of the DTM points are achieved. Additional data can easily be produced such as an orthophoto of the back or a contour map of the generated model.

The presented paper actually introduces a new trinocular (non stereoscopic) system that can be used for the determination of the 3D model of a distorted human back. The introduced examination has no effect to the human organism and there is no restriction for its repetition, as there is for x-ray examinations.

For this approach a new electronic device (fully controlled by the host computer) has been designed for the acquisition of an image triplet in near-real time.

It is anticipated that such a system provides an excellent diagnostic tool, since it can produce a highly accurately and detailed model of the human back and all the necessary geometric information for the diagnosis of scoliosis. Besides, it provides a high throughput while requiring no expertise for its use. Finally, producing all-digital records it possesses all the advantages of a tele-medicine system, which can exploit the Internet and provide diagnosis and treatment for doctors remotely situated.

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