POSSIBILITIES OF A VIDEO-TACHEOMETER

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Abstract: In this paper a surveying system based on a motorized reflectorless total station is presented. The system consists of three video cameras with different focal lengths: a wide angle camera provides an overview, a telephoto camera identifies details, and an eyepiece camera serves for the actual sighting. An advantage of this combination is the direct, pictorial documentation of tacheometrically measured points. By creating a connection between the image coordinates of the various cameras and the axial system of the tacheometer, the device can be adjusted per mouse click via the screen of the controlling computer. Furthermore always oriented images of the current position of the telescope are available, which can be used for photogrammetric purposes. The integration of tacheometric and photogrammetric methods enables us to develop a procedure which assigns a photorealistic texture to a three dimensional model. This model is generated online immediately during the tacheometric survey, without a separate referencing of image and object coordinates being necessary.

1. Introduction

Many users of surveying results require not only data and plans but also illustrated results like photo-realistically textured models. For that, it's obvious to combine surveying instruments with digital cameras.

Already in the 80's high-quality theodolites were equipped with cameras. These theodolites were mainly used in multi-instrument systems. The cameras served primarily for the detection of the laser point, which was projected by the second theodolite of the system to the object's surface [4]. Later, at the Vienna University of Technology, multi-instrument systems were developed, that use the texture of the surface of the object to find “interesting points” which can replace the artificial targets or the projected laser point [6].

The combination of a total station and cameras was not aimed at by the manufacturers of surveying instruments. Thus the commercial goal of the existing theodolite-systems remained limited to few special applications, in particular in the industrial range. The required combination of a total station and digital cameras was developed in the last years at the Ruhr-University Bochum [2],[3],[7],[8].

2. Design of the video-tacheometer

2.1. Built-in cameras

The surveying system is based on a reflectorless total station Leica TCRM1102 provided with servo motors. It is equipped with three cameras [3]. The eyepiece camera (1500 mm)[1] can be exchanged against the eyepiece of the telescope. The telephoto camera (164 mm) as well as the wide-angle camera (38 mm) are firmly inserted into the telescope casing. The cameras contain very inexpensive CMOS modules. These supply a somewhat smaller image quality compared with CCD cameras. But they are however so compact, that they can be built without large problems into the casing of a commercial total station.

Figure 1. Installing the eyepiece camera

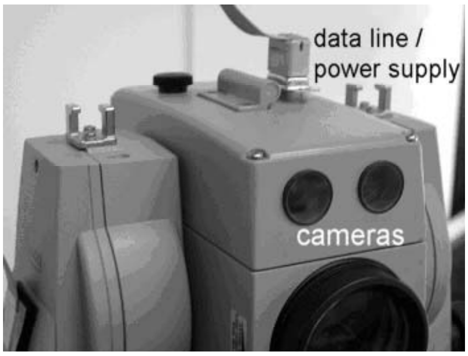

Figure 2. Wide-angle and telephoto camera

The autofocus of the eyepiece camera is directed by a step motor. In order to focus the eyepiece camera, the distance to the point of object is measured reflectorless. The focus position is adjusted by an empirically determined function.

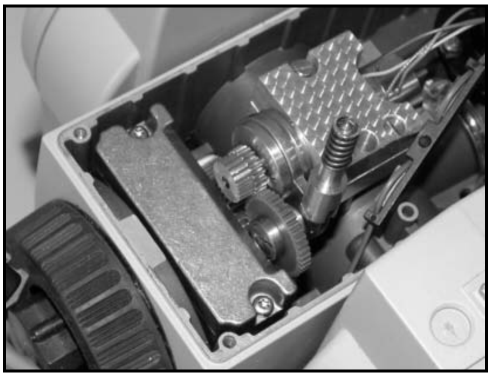

Figure 3. Step motor

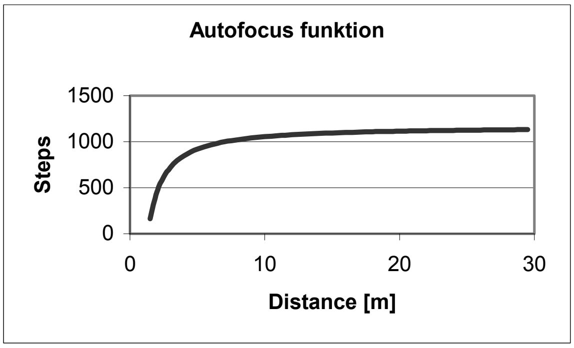

Figure 4. Autofocus function

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[1] The given value for each focal length is adjusted to 24 x 36 mm due to the smaller image sizes of the cameras

The video images of the cameras are indicated on the monitor of an attached notebook and fulfil different tasks:

- Aiming and control from the screen
- Documentation of the recorded points
- Superposition of the image with points of the model
- Creation of photo-realistic textures

Figure 5. Images of eyepiece, telephoto and wide-angle camera

2.2. The variable virtual crosshair

The telephoto camera and the wide-angle camera are inserted eccentrically to the total station’s line of sight. Due to this, the line of sight of the telescope occurs on the CMOS module (and on the screen) not as a dot but as a line; object points along the line of sight are mapped in dependence of the distance. So it is necessary to provide the images of the eccentric cameras with a variable virtual crosshair.

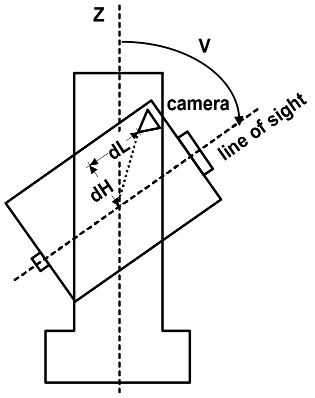


Fig. 6. Eccentric camera

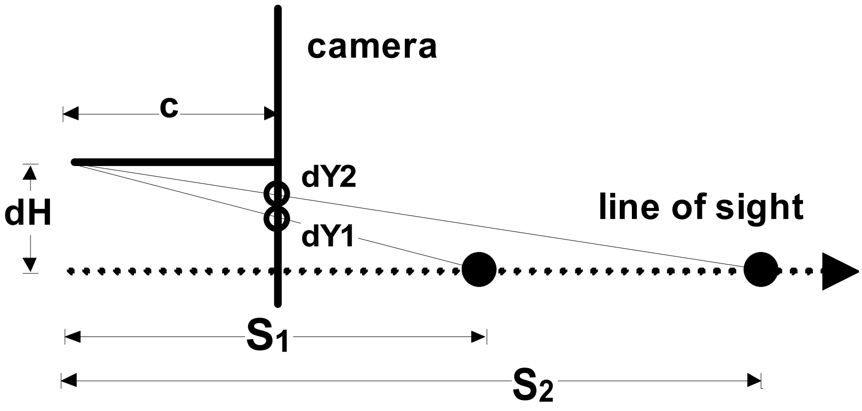


Figure 7. Distance dependance

The position of the variable virtual crosshair in the camera image can be computed quite simply by way of the theorem on intersecting lines when the eccentricities of the axis of the camera and the line of sight of the total station are known. The following illustrations show the position of the variable virtual crosshair for two different distances.

Figure 8. Distance: 3,26 m

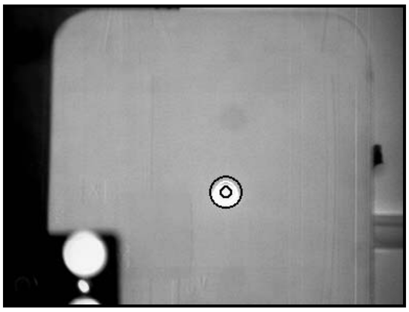


Figure 9. Distance 1,27 m

2.3. Aiming at an object point

The camera images should allow to align the line of sight of the servo-motorized total station to a certain image position. Therefore, the relationship between image coordinates and geodetic directions has to be established. This corresponds to the oblique gnomonic map projection. The gnomonic projection is projected from the centre of a sphere [1]. Transferred to the video-tacheometer the image plane touches a sphere with the radius of the camera constant and the touch point on the sphere is specified by the vertical and the horizontal angle [3] (Fig. 10).

The illustrations (Fig. 11 and 12) show the oblique gnomonic projection of the meridians and parallels in the distance of 10 gon. The shown gridlines corresponds to the motion, which is necessary in order to align the line of sight of its momentary position to a certain image position. For small vertical angles the large rotation motion around the vertical axis is clearly recognizable in Fig. 12.

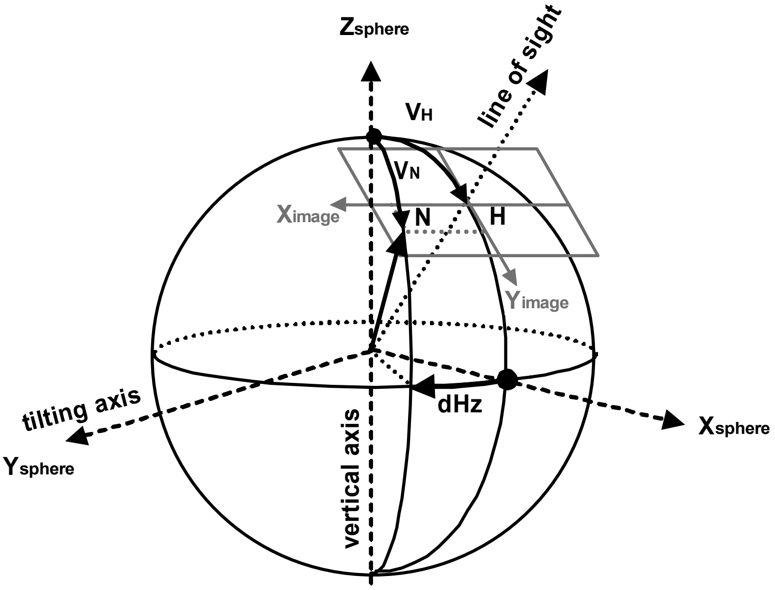


Figure 10. Oblique gnomonic projection

Figure 11. V=100 gon

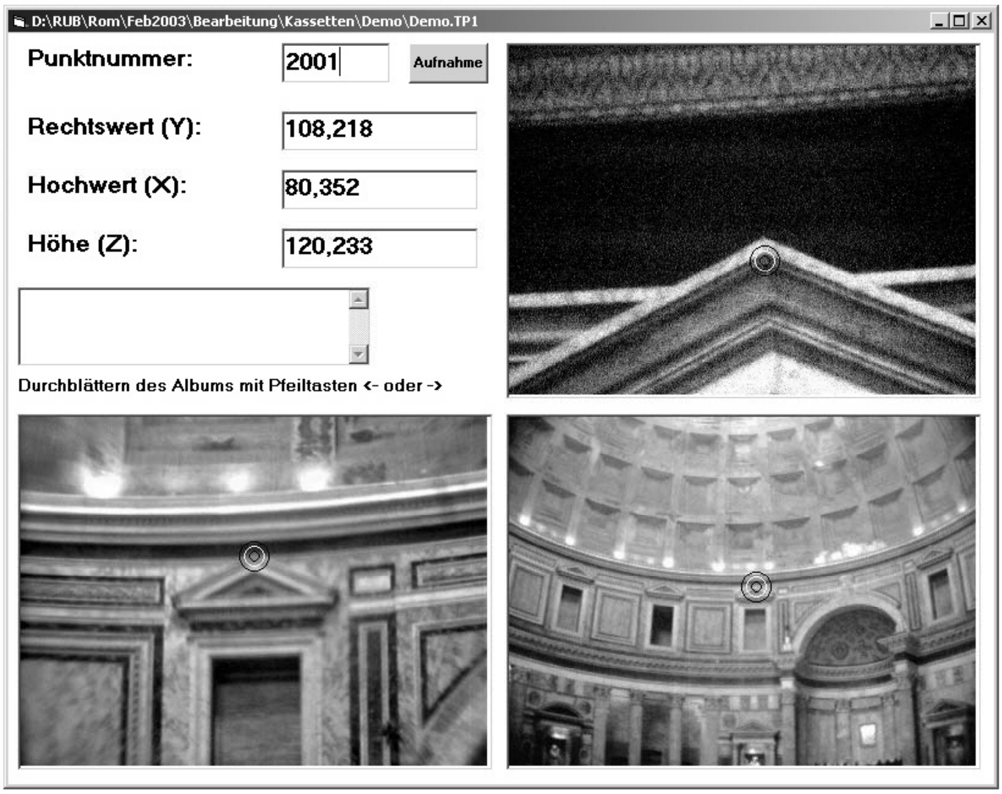
Figure 12. V=10 gon

3. Using the images

3.1. Photo documentation

The simplest way to use the image information is storing the different images of one point during its recording. In this way image archives can be developed very fast, containing points of object, geodetic reference points and in particular photogrammetric reference points.

The three different images (eyepiece, telephoto and wide-angle camera) permit a proper identification of the points.



D:\RUB\Rom\Feb2003\Bearbeitung\Kassetten\Demo\Demo.TP1

Punktnummer: 2001

Rechtswert (Y): 108,218

Hochwert (X): 80,352

Höhe (Z): 120,233

Durchblättern des Albums mit Pfeiltasten <- oder ->

Figure 13. Data set of a recorded point

3.2. Superposition

Due to the rigid coupling of the internal cameras to the total station, the exterior und interior orientation parameters - necessary for the mapping of a 3D point - are available at any time. By using collinearity equations [5] the images can be superposed immediately with geometrical elements already recorded.

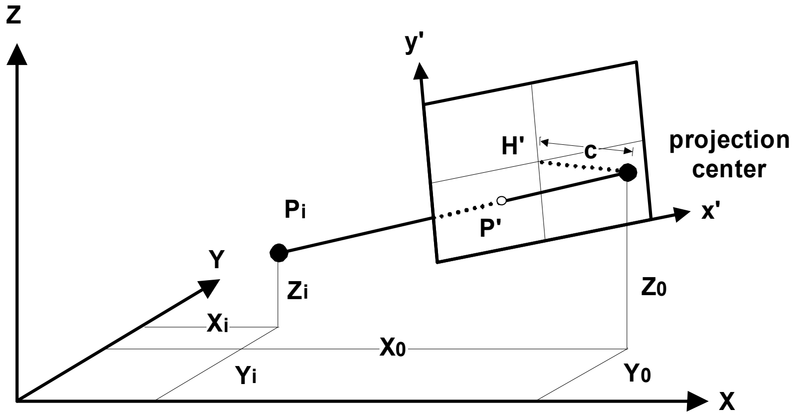


Figure 14. Mapping of a point

In this way very simply plausibility and completeness controls of surveyed geometry can be accomplished (Fig 15). Likewise it is possible to superpose the image with geometrical elements from a project, for example to illustrate a planning.

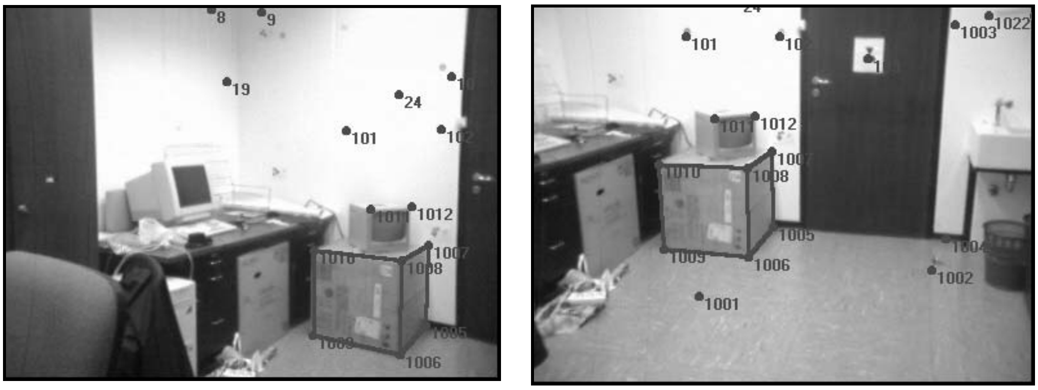


Figure 15. Example for superposition (different lines of sight)

4. Direct modelling

4.1. Procedure

To create a photo-realistic rendered model, the surfaces of the model are to be provided with images mapped to the plane. The images are to be mapped to the plane in such a way, as if they had been taken perpendicularly to the respective surface. Usually the photo-realistic rendering is taken separately in two logical steps:

In the first step the geometrical model is created. In the second step the allocation from certain model surfaces to certain image sub-areas is performed. The rectification of image sub-areas can be accomplished in different ways:

On the one hand, projective transformation can be used, which, in general, maps planes to planes. For this the 2D-coordinates of four points of object lying in one plane and the appropriate image coordinates are needed. With this method the knowledge of the orientation parameters of the camera is not necessary.

On the other hand, the method of the parametric rectification requires oriented images. The procedure for the allocation of a model divided into space triangles is represented in the following.

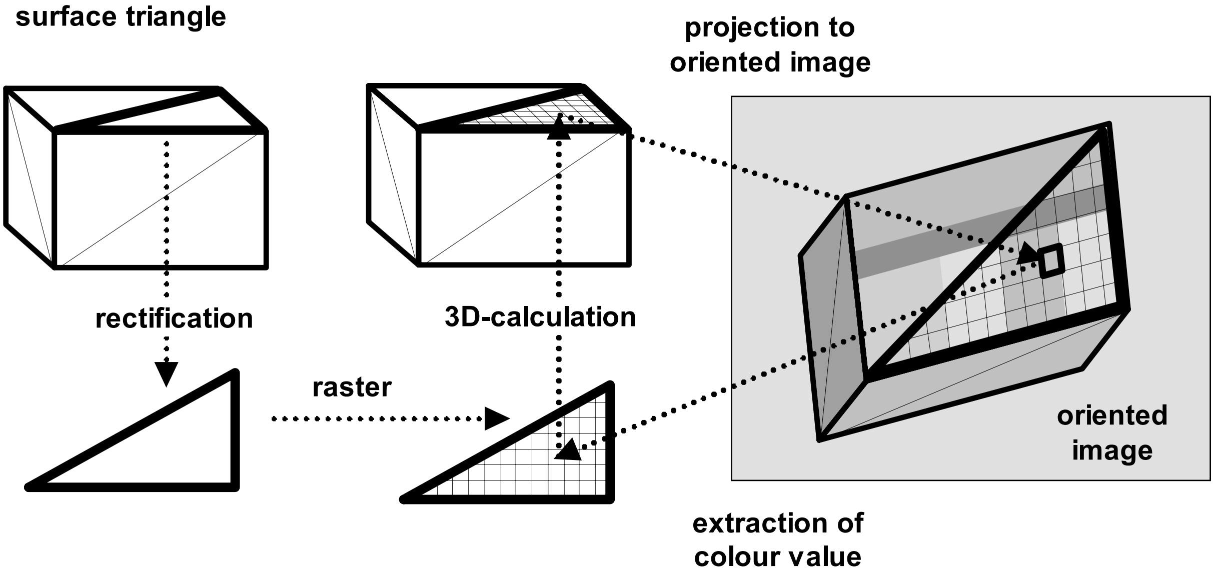


Figure 16. Direct modelling process

- The images are to be oriented by orientation procedures for external or internal cameras [5].
- Each individual spatial surface triangle has to be mapped to the plane.
- A raster is specified, which determines a pixel density (pixel per length unit) for each triangle separately.
- The image scale and the size of the resulting image, which has to be filled with colour value, result from the raster.
- For each raster point of the mapped triangle its 3D coordinates are calculated.
- Each calculated 3D point is projected with the help of the collinearity equations onto the original image.
- The colour value of this image position is transferred to the resulting image (Fig. 18).
- The colour values are interpolated bilinear.

During the direct modelling process the creation of photo-realistic textures of an object takes place at the same time with the tacheometric recording. The following illustrations show an oriented image superposed by model information. From this, a surface triangle occupied with colour information was derived.

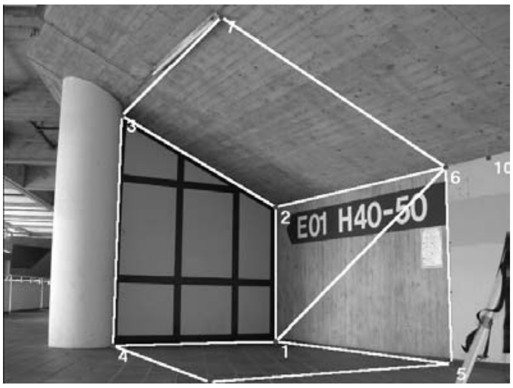


Figure 17. Original Image

Figure 18. Textured rectificated triangle

As mentioned in (3.2), the exterior and interior orientation parameters of the internal cameras are available at any time. Thus each tacheometrical recorded point can be projected immediately into a fixed video image. So, (manual) referencing image- to 3D-coordinate becomes unnecessary. The user can define triangles, which are automatically filled with image information in the fixed image solely by tacheometric recording.

4.2. Representation tool

For the realistic representation of the results an universal tool is necessary. The script language VRML (virtual reality modelling language) was selected as tool for the allocation and presentation of the data. It serves for the description of virtual 3D worlds, which can be exchanged over the World Wide Web. VRML is not a programming language in the conventional sense. VRML is a specification language, with which one defines, how three-dimensional objects have to look, as they are arranged in a virtual world and which relations they have with one another. For the representation of VRML worlds one needs a web browser and a VRML-Plug-In e.g. the "Cosmo Player" from SGI (Silicon Graphics Inc.).

Figure 19. Different perspectives

The illustrations above show the modelling of a simple room with VRML and the view of the model in freely selected perspectives.

5. Conclusions and Outlook

In this paper some outstanding possibilities of the video-tacheometry are presented. It was shown, that the movements of the total station's line of sight to a certain image position can be calculated by the oblique gnomonic projection. Thus, the user of the developed system is able to control the total station by mouse-click to a certain image position on the screen. The system may also create an image archive during the tacheometrical recording of the object points. Furthermore, the user is able to create rectified images of the object's surface during the tacheometrical recording. These images are necessary to render the model photo-realistically.

Only in the last year TOPCON equipped a total station with cameras in series. In recent years there was an enormous increase in efficiency of digital cameras accompanied by a price decline at the same time. Therefore it is to be hoped, that in the future also "standard" total stations are equipped in series with inserted cameras, possibly as option. To that may also contribute the fact, that already now efficient field version PCs are available, which are able to indicate and process video images. By the use of pattern recognition algorithms, the user could be supported to a large extent in future. So surveying could be automated still further.

6. Acknowledgements

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