Intelligent Scanning with Robot-Tacheometer and Image Processing
A Low Cost Alternative to 3D Laser Scanning?

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SUMMARY

The intention of this essay is to lay down the great variety of automated and partly-automated surveying technology offered by a reflectorless, notebook-controlled tacheometer - especially when the use of certain photogrammetric tools is integrated. Integration of tacheometry and image processing enables to create new ways of surveying and to a certain amount, it also provides an alternative as well as an addition to the third method of architectural surveying (besides tacheometrie and photogrammetry): The method of laserscanning.

First the characteristics between intelligent tacheometers and laserscanners are compared. In the second section certain "intelligent" functions will be explained. The third section deals with extending the instrument's possibilities of application in connection with the addition of digital images. Further uses by means of constructional modifications of the robot-totalstation are shown in the final section.

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1. WHAT IS INTELLIGENT SCANNING WITH TACHEOMETERS?

First of all a definition of the term “intelligent scanning”:

- Intelligent scanning with tacheometers is the process of recording three-dimensional polar coordinates of typically the object describing points by a largely automated control of the measurement process with a notebook-directed totalstation. This requires servodrives and a distance measurement without reflectors. Special techniques to determine single points, points on spacial curves and points on surfaces are used.
- Intelligent scanning is opposite to undifferentiated scanning with a laser scanner; undifferentiated, because laser scannning does not immediately take the object into account.

Table 1 shows a variety of differences between both methods of measurement; the origine for all differences is shown in the first row: different measuring frequency and differences in the importance of a single point.

The “intelligent” tacheometer is characterized by the possibility to locate object points computer-controlled via servo-assisted motors. The first reflectorless measuring instrument of this kind was developed at the Ruhr- University Bochum, Germany, in 1994; now the companies Leica and Trimble sell a whole range of such devices with varying specifications.

For this type of instrument, various surveying technologies were developed which are all based on control circuit mechanisms: The ability to traverse feedbacks distinguishes the active, object-oriented robot-totalstation fundamentally from the passive, not object-oriented laser scanner.

2. FUNCTIONALITIES OF THE INTELLIGENT TACHEOMETER CONTROL

The software contains three different great blocks, partially described below:

a) all general functions needed for surveying (e.g. transformations between coordinate systems) including special tools to establish precise 3-D networks,
b) graphic functions, e.g. to present the measured points and functions working with images,
c) special tools for architectural surveying.

	topic	laserscanner	intelligent tacheometer / robot - totalstation
general	measuring frequency	high (+)	low (-)
	Importance of a single point	low, point cloud random distribution (-)	high conscious accordance (+)
recording	time of selection	a posteriori single point not measurable	a priori measurement of single points
	connection of different locations supplementary network	expensive in most cases necessary	simple not applicable
	hidden points	not measurable	partly automatic recording with extrapolation rod
	manual measurement	hardly to be inserted	often avoidable, simple to insert
	remote control	not possible in general	+
	working mode	automatic	half automatic / manual
processing	finishing work	expensive when extracting corners and edges, simple describing complex surfaces	not necessary concerning simply formed surfaces
	stitching	automatic	recording of complex structures possible, it is a question of time
virtual reality	visualization	high degree of automation possible, often much manual work for complex structures	fully automatic directing of the instrument with external images
	rendering	differential rectification nearly automatic automatic rendering	parametric, differential rectification possible, also automatic rendering on site
expenses	investment	100%	20% - 10%
	universal application	special equipment	equipment to use universally
	handling	comparatively expensive	simple
	proportion work on site / domestic	1 / 10	1 / 1

Tab 1: Comparison between laser scanning and intelligent scanning

Figure 1 contains a summary of various surveying technologies for the "intelligent" controlled individual point recording. Some of these tools will be introduced or exemplified.

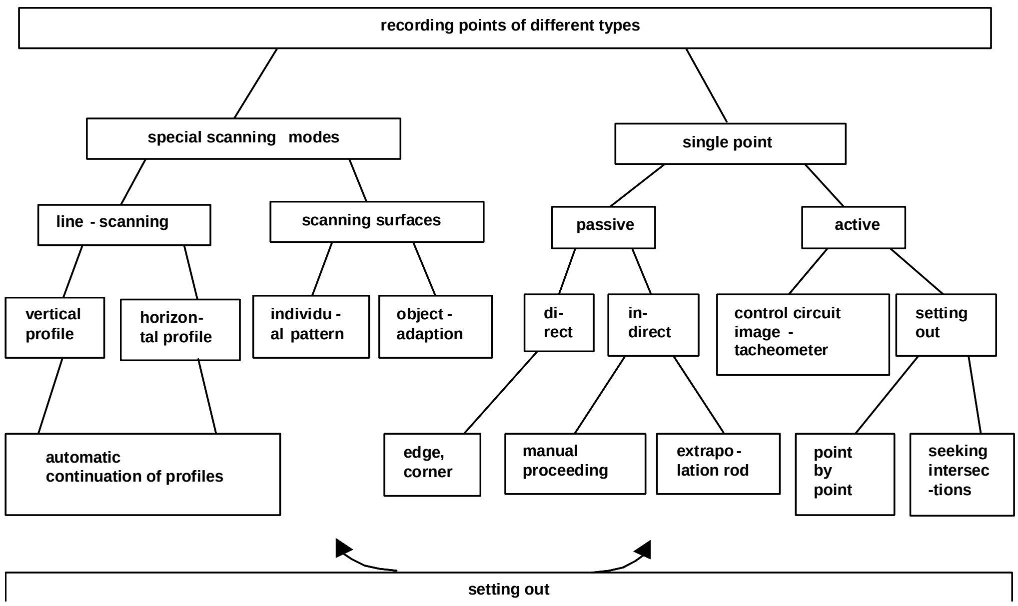


Figure 1: What laser scanners are not able to do

2.1 Measurement of Horizontal and Vertical Profiles

When documenting monuments the profile-measuring function proved a very powerful tool, making location-independent horizontal and vertical profiling possible (figure 2).

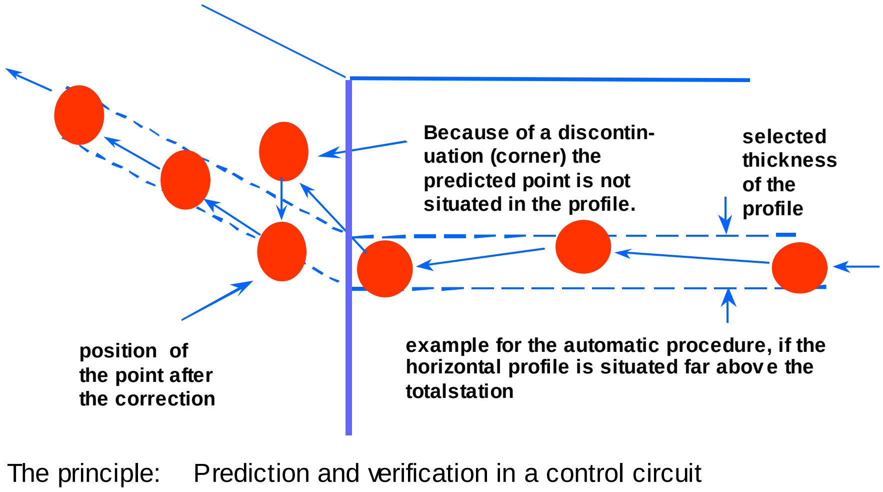
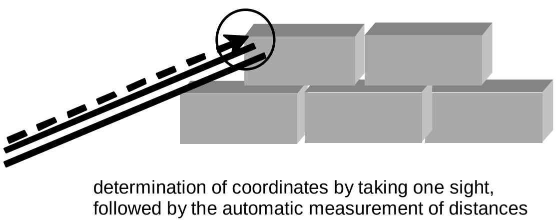


Figure 2: Scanning an horizontal profile

Profiles are taken absolutely independent from the position where the totalstation is stationed. They are automatically continued everywhere in the monument e.g. on both sides of a wall. Further useful tools, like initiating measurements out of the graph shown on the screen of the notebook enable fast, effective work.

2.2 Precise Determination of Edges and Corners

Due to the fact that the diameter of the footprint of the laser beam measures nearly one centimetre, edges cannot be otherwise determined with high precision (figure 3a)



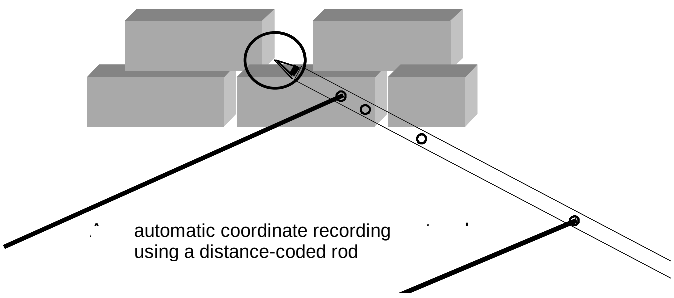


Fig 3a: Precise determination of edges **Fig. 3b:** Measuring hidden points

Hidden Points

Another tool is a specially coded extrapolation-rod which is used to measure hidden points quickly, precisely and widely automatic (figure 3b).

2.3 Recording of Surfaces

In this particular functionality the totalstation and the laser scanner have the most similarities: there is no differentiated selection of the measured points, but merely a polygonal separation of the measurement area with subsequent automated measuring of the matrix points (see figure 10).

2.4 Setting Out of Single Points and Spacial Curves on Surfaces

This is a domain of the totalstation. The intelligent tacheometer is the only device with the option of setting out on complex surfaces by consequential use of control circuit techniques. Neither photogrammetry nor laser scanning have this ability. The example in figure 4 shows the recording of a facade with subsequent setting out automatically corrected in the control circuit.

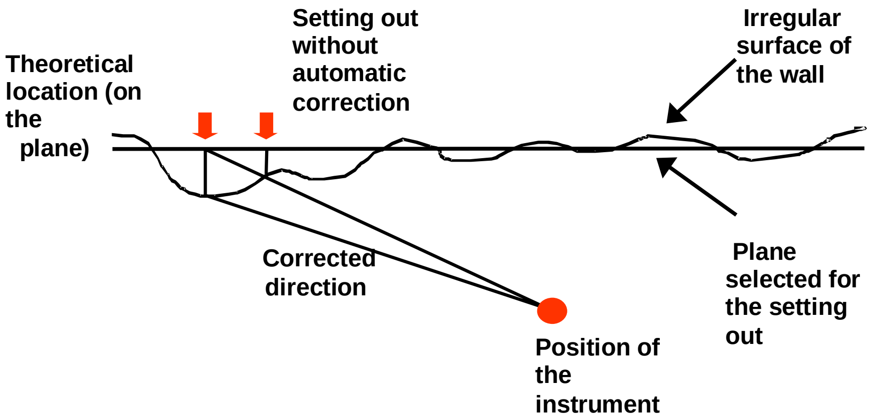


Figure 4: Automatically setting out on a facade

Some further functions concerning setting out are: marking a reference height, arbitrary intersections, detection and display of the exact local position of the point of intersection for profiles with edges and for different profiles among themselves.

The above mentioned functionalities can be used even more efficiently by taking digital images into account.

3. INTEGRATION OF GEOMETRICAL AND VISUAL FUNCTIONALITIES

Taking the image into account is an advantage in three different areas: for documentation and archiving for targeting and calibration and for visualization and modelling, e.g. to generate ortho-images (figure 5).

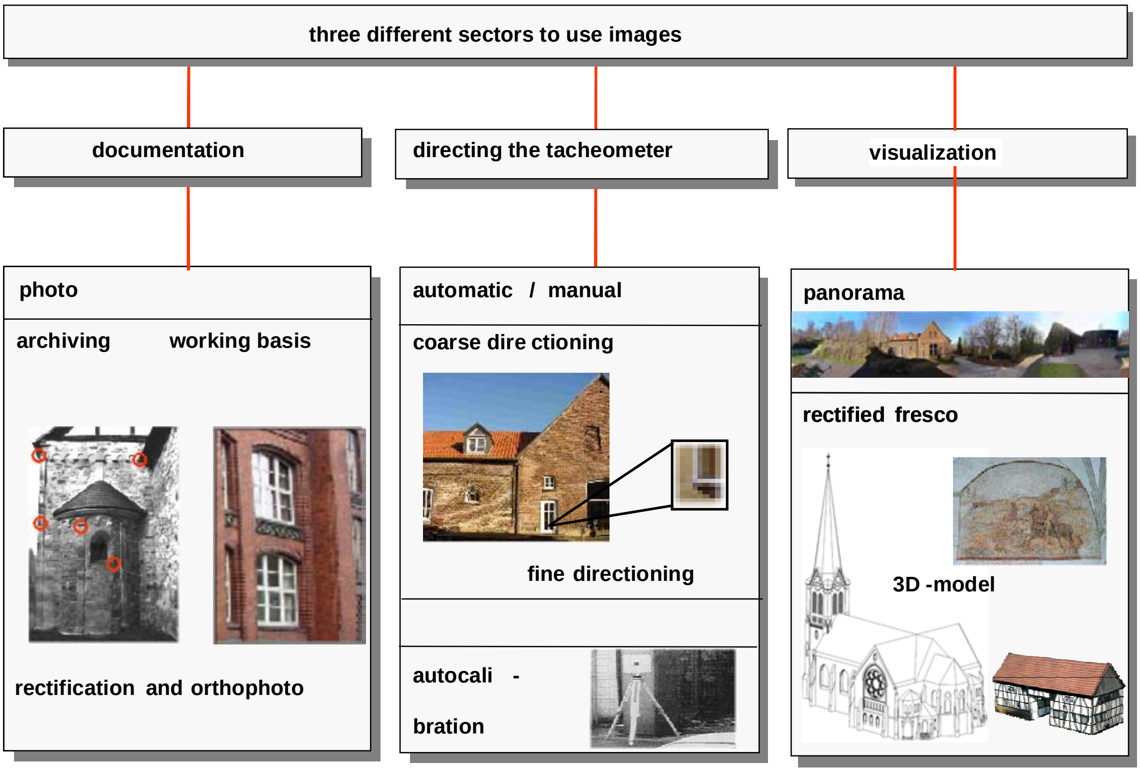


Figure 5: The role of the image

Below some of the numerous applications are explained in more detail.

3.1 Rectification and Orthophoto for Restauration Purposes

So called 4-point-rectification is possible either through distances measured in the images or through coordinates. When determining the coordinates on site with the total-station

- the steps of identification and referencing are omitted,
- known geometric properties may be taken into account (parallelism, rectangular angles)

3.2 Parametic Rectification with Automatic Direction of the Instrument

This procedure allows a particulary fast on-site generation of ortho-images and 3D visualization with the following steps (see figure 6):

- Make the photo, save it to a laptop and orient the image using control points to be measured in the course of the process. This delivers the position of the camera at the time of recording.
- Click on a point of a surface in the image; automatic steering of the distance measuring laser dot to the corresponding point on the object takes place. The real coordinates of the clicked point are automatically measured. Thus the area (plane) may be defined by three points.
- Click the corners of the surface in the image, connect them, cut out image planes resp. triangles for visualization software.

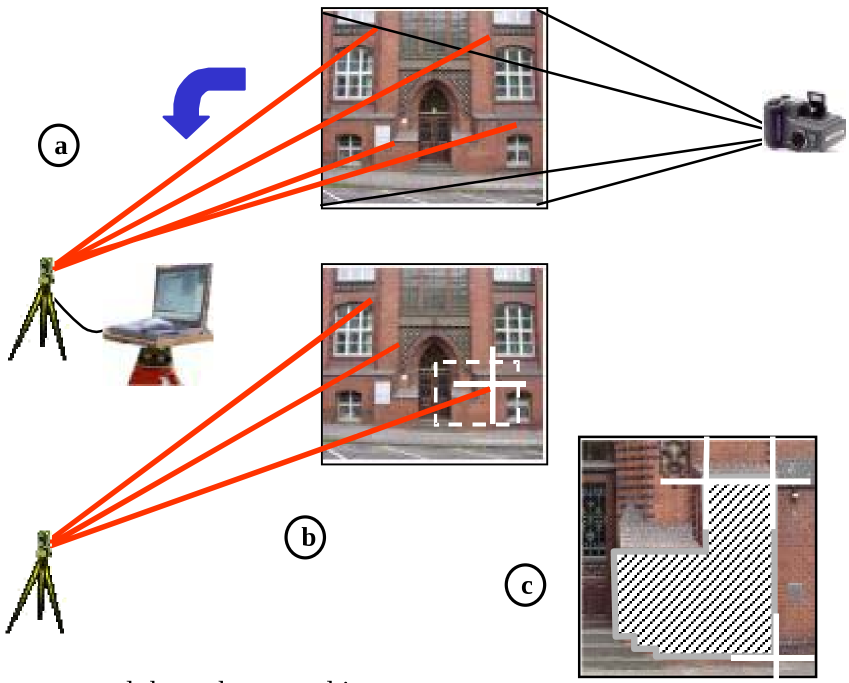


Figure 6: Intelligent control through external images

3.3 Dynamic Measurement Protocol

A continuously growing graphical measurement protocol is generated through the parametric link between the coordinate system and the image. In an oriented image, single points and connecting lines are faded in automatically (figure 7).

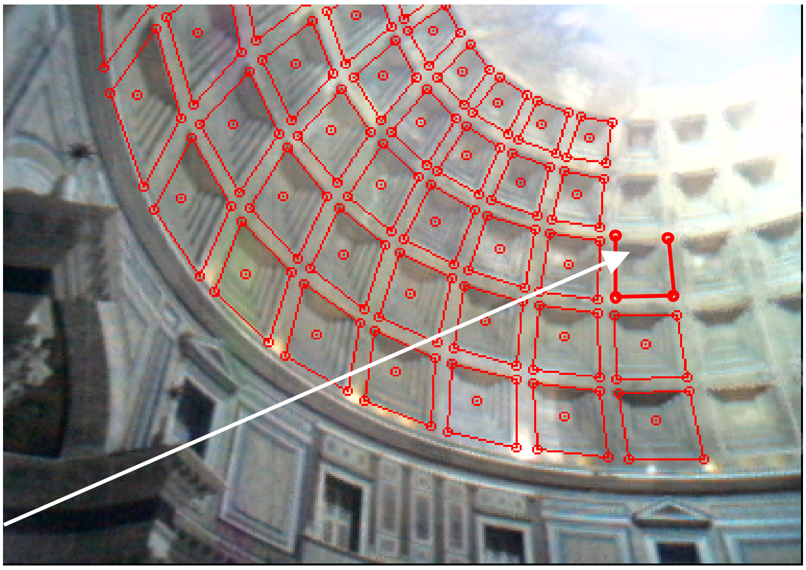


Figure 7: Dynamic measurement protocol

Point numbers can be registered for future applications, e.g. for monitoring or densification of the network or referencing for photogrammetric purposes. The link between the images and the coordinates is permanent. Therefore the totalstation can be adjusted at any time by clicking on the points in the image.

4. ENHANCEMENTS OF THE APPLICATION SPECTRUM THROUGH INSTRUMENTAL CHANGES

Two instrumental additions to the intelligent tacheometer enhance its functionality.

4.1 Integration of Cameras Into the Tube of the Telescope

Two wide-angled cameras with different focal lengths are integrated in the casing; a third camera is located in the plane of reticule (figure 8). This so called ocular camera is automatically focused by a gearing in the tube of the telescope. The appliance can be remote controlled through the images and measurements directed towards the zenith can be done without any problems. For subsequent identification, the measured points can be documented at the time of the recording for various purposes. This is particularly important for work with "natural points".

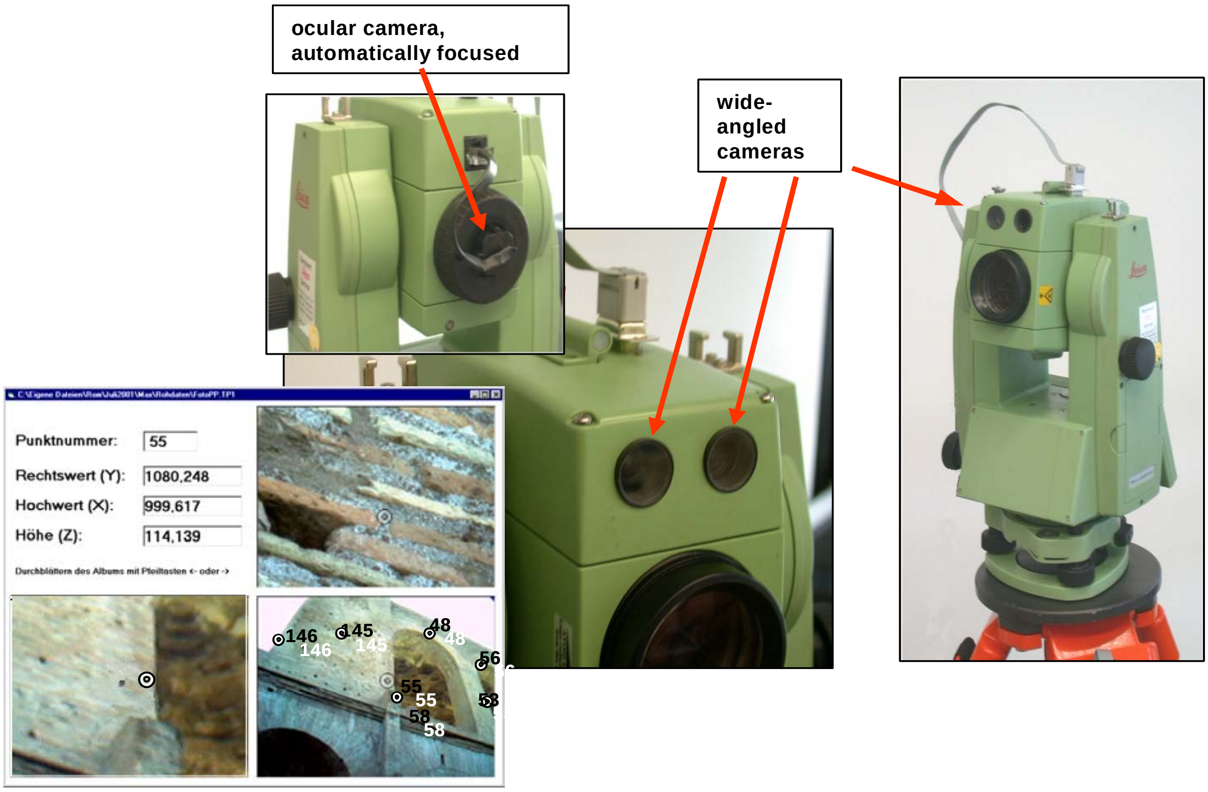


Figure 8: Integrated cameras and a set of photos of a natural point

4.2 Improvement of the recording requirements for the automated surveying of small objects

For the measurement of points, the computer-controlled tacheometer is considerably slower than the laser scanner. But since it can work automatically this disadvantage is not very significant under some circumstances. Therefore it should be determined, if and how sufficient exact results can be achieved.

With the instrument Leica TCRM the distance and angle accuracy yield to an expected accuracy of the coordinates smaller than ± 1mm. The experiences with free stationing are the same when coordinate-systems of different stations are assembled. Besides this general accuracy of measurement the diameter of the distance measuring ray is crucial for the recording of details. A standard spot diameter of 6mm – 12mm limits the resolution to 3mm – 5mm at the most. Therefore before the real accuracy of measurement could be used, steps to increase the resolution were necessary. For this a diaphragm was attached to the ray path. The benefit of resolution can be detected when a stair is scanned with a low point density (fig. 9, upper parts).

The effect of the reduction of the spot-diameter by the stop can be measured from the greatly reduced width of the transit-area – here it is marked by rectangles for the scan in horizontal direction.

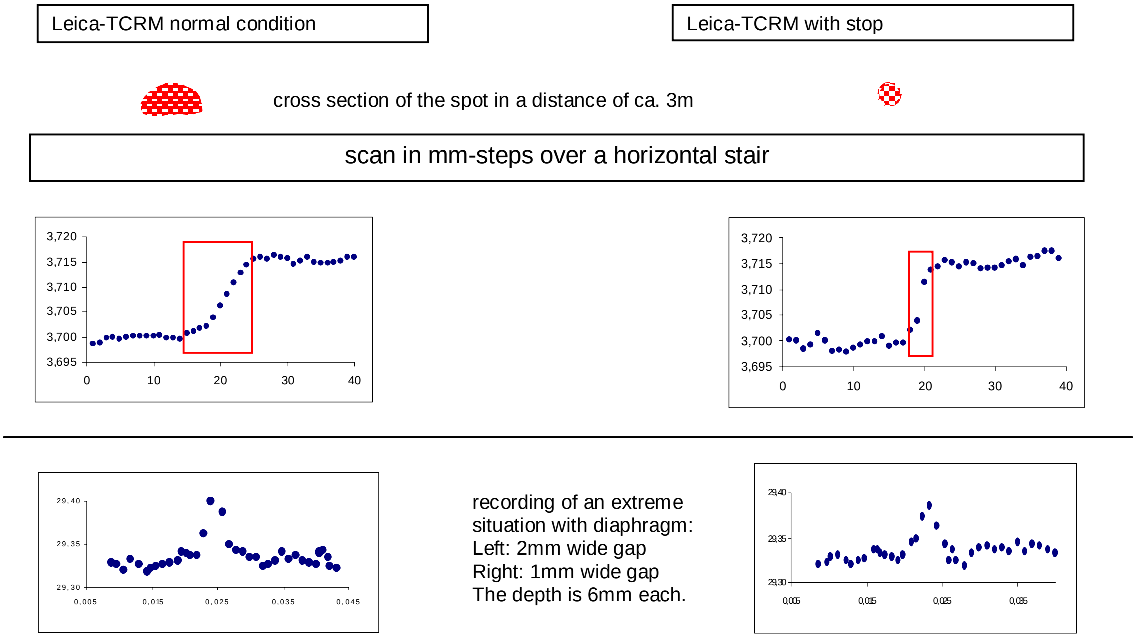


Figure 9: Improvement of the resolution

Figure 10: shows a bust scanned with a small ray diameter.

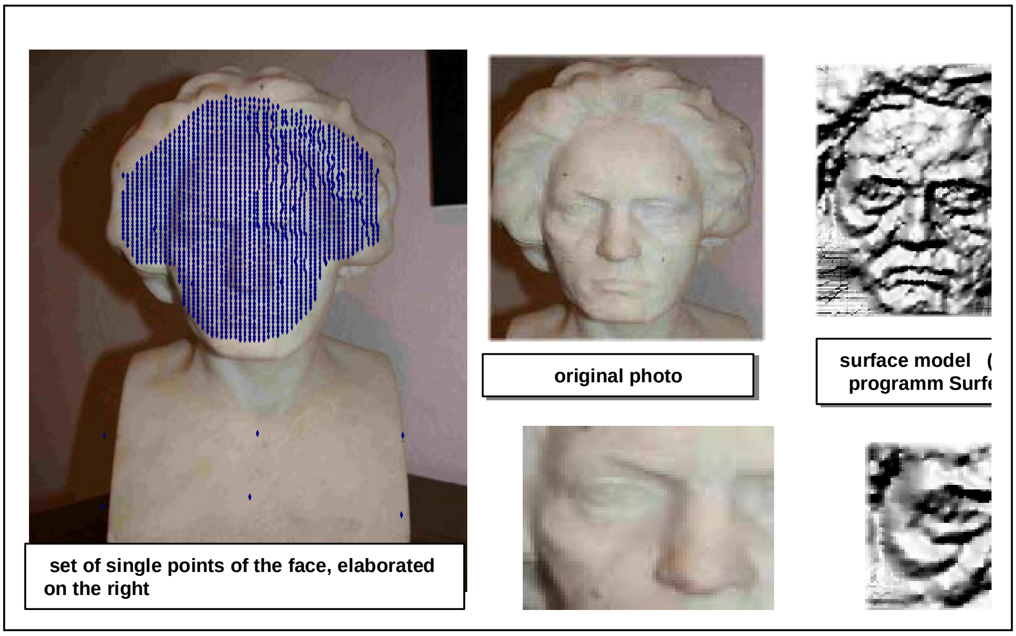


Figure 10: Steps towards a 3D model

For small objects the recording of a point cloud with the intelligent totalstation can be worthwhile. In some cases the accuracy may exceed a laser scanner. In general it does not matter that this method needs more time, because the totalstation operates automatically. It is not required to measure an unnecessary high amount of points. Making benefit of the "intelligence" a variable point density can be set according to the quality of the surface. The intelligent scanning can be further enhanced through automated recognition of the normals of surfaces to reduce the amount of points and to increase the quality of the points by considering the slope of the object. Another possible enhancement is through automated distance correction for signals of variable intensity.

5. CONCLUSION

Numerous tools make it possible to record objects fast and accurate with an "intelligent" robot-totalstation. The integration of digital images brings siginificant further advantages. A fundamentally enhanced working method for the surveying of points of special importance for the modelling of an edifice and for the visualization is achieved.

The intelligent tacheometer is predestined for many tasks: know-how, technology and software already exist. For the recording of small irregulary formed objects scanning analogous to the working method of the laser scanner can be reasonable. In the long term the combination of the point-oriented method of the tacheometer with the area-oriented method of the laser scanner should yield optimal results for any field of appliction.

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BIOGRAPHICAL NOTES

Michael Scherer is born in 1945. He carried out studies at Bonn and Berlin, degree diploma; graduate civil servant; graduation in the sector of satellite geodesy: postdoctoral lecture qualification in the field of geodetic measuring methods, professor at university of Bonn, since 1988 at Bochum University; currently working on the development of surveying methods in architecture and cultural heritage.

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