Intelligent Tacheometry with Integrated Image Processing Instead of 3D Laser Scanning?

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SUMMARY

Intelligent tacheometry 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 reflectorless measuring totalstation. .The great variety of automated and partly-automated surveying technology is widely enlarged when the use of photogrammetric tools is integrated. This enables to create new ways of surveying and to a certain amount, it also provides an alternative as well as a completion to the method of laserscanning. Additionally further uses by means of constructional modifications of the robot-totalstation are shown.

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1. WHAT IS INTELLIGENT TACHEOMETRY?

As intelligent tacheometry is the process of recording three-dimensional polar coordinates of typically the object describing points mostly based on control circuit mechanisms and iteration processes. This requires servodrives and a distance measurement without reflector. Special techniques to determine single points, points on spacial curves and points on surfaces are used. 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 such devices with varying specifications. The ability to traverse feedbacks distinguishes the active, object-oriented robot-totalstation fundamentally from the passive, not object-oriented laser scanner.

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

2. CHARACTERISTICS OF THE INTELLIGENT TACHEOMETER CONTROL

The software encloses not only special tools for architectural surveying but also all general functions needed for surveying (e.g. transformations between coordinate systems) including special tools to establish precise 3-D networks, and graphic functions, e.g. to present the measured points as well as functions working with images.

Figure 1 contains a summary of various surveying technologies which are mostly not able to be done with a laser scanner: Some of these tools will be explained below.

2.1 Measurement of Horizontal and Vertical Profiles

The profile-measuring function is proved a very powerful tool, making location-independent horizontal and vertical profiling possible. Profiles are automatically continued everywhere in the monument e.g. on both sides of a wall.

	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	expensive	simple
	supplementary network	in most cases necessary	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: Laser scanning versus intelligent scanning

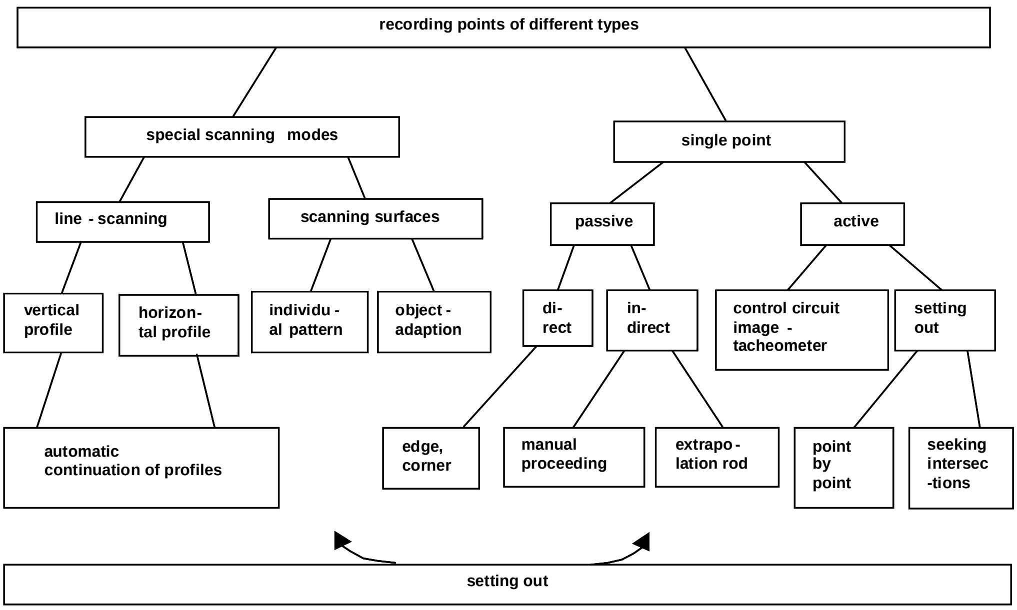

Fig 1: What laser scanners are not able to do

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 centimeter, edges cannot be otherwise determined with high precision (figure 2).

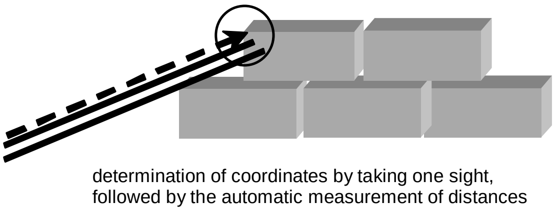

Fig 2: Precise determination of edges

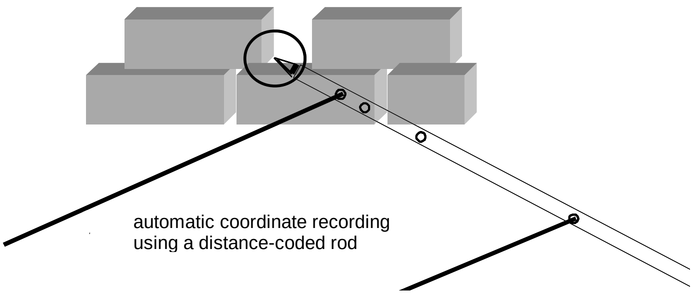

Fig 3: Measuring hidden points

2.2.1 Hidden Points

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

2.2.2 Recording of surfaces

When recording surfaces 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:

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 so significant. Also the accuracy may exceed a laser scanner. It should be examined, if and how sufficiently exact results may be achieved. Making benefit of the “intelligence” a variable point density can be set according to the quality of the surface.

With the instrument Leica TCRM the distance and angle accuracy yield to an expected accuracy of the coordinates of about ± 1mm. 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 6 mm – 12 mm limits the resolution to 3 mm – 5 mm at the most. Therefore before use could be made of the real accuracy of measurement, steps to increase the resolution were necessary. For this a diaphragm was inserted into the ray path. The benefit of resolution was detected when scanning a stair with a low point density (fig. 4, upper parts).

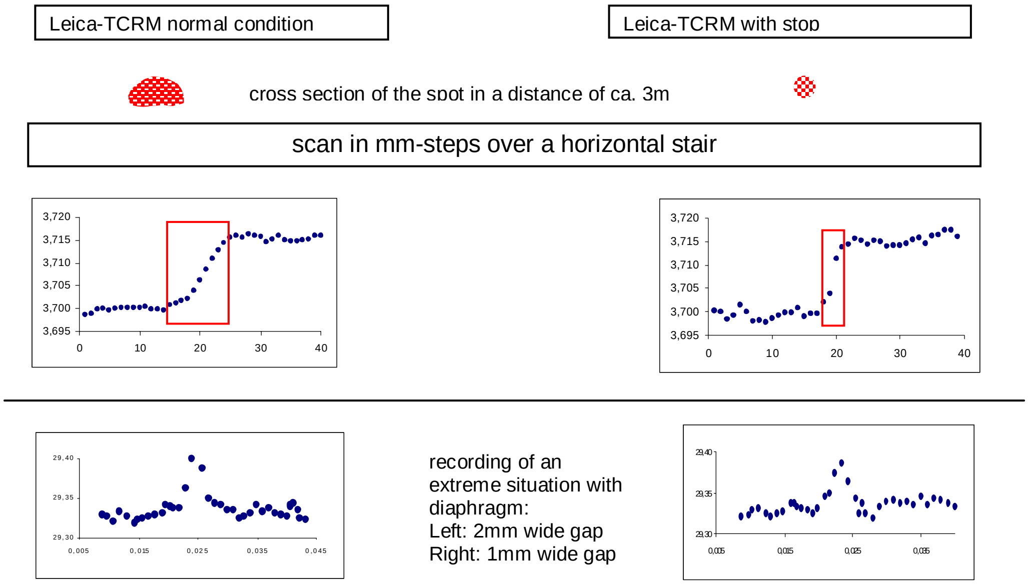

Fig 4: Improvement of the resolution

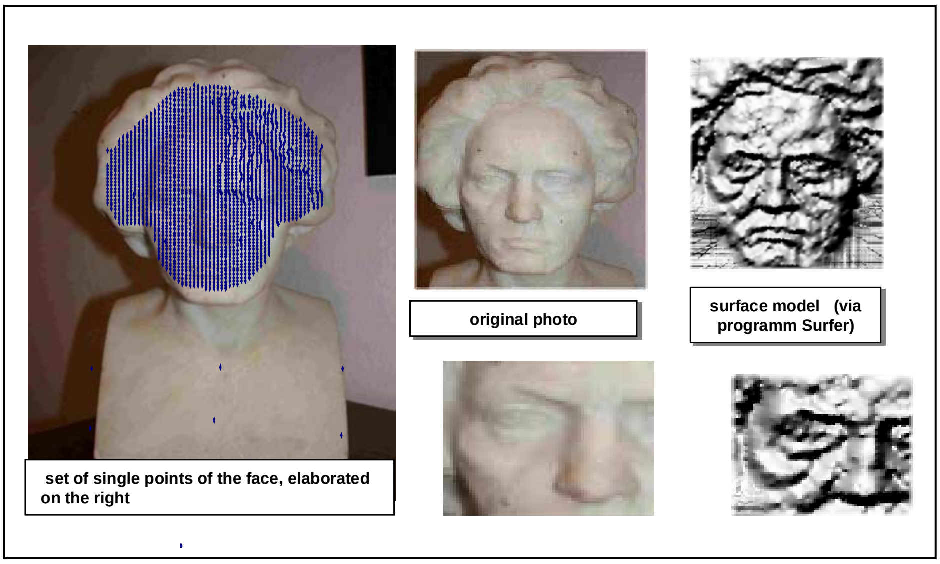

Fig 5: Steps towards a 3D model

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 .Figure5 shows a bust scanned with a small ray diameter.

2.2.3 <u>Setting out of single points and spatial curves on surfaces</u>

This is a domain of the totalstation. Neither photogrammetry nor laser scanning has the ability of setting out on complex surfaces. The example in figure 6 shows the recording of a facade with subsequent setting out automatically corrected in the control circuit.

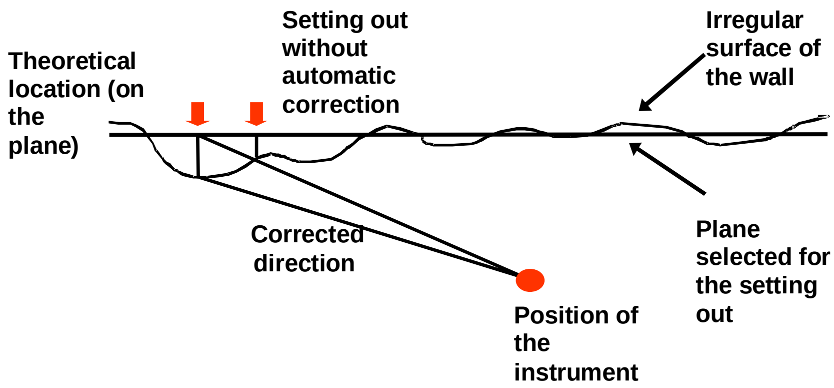

Fig 6: Automatically setting out on a facade

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. All these tools are possible due to consequential use of control circuit techniques.

3. INTEGRATION OF TACHEOMETIRIC AND PHOTOGRAMMETRIC 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: Below some of the numerous applications are explained in more detail.

3.1 Rectification and Orthophoto for Restauration Purposes

When determining the coordinates on site with the total-station
- the steps of identification and referencing are omitted,
- well known geometric properties may be taken into account (parallelism, rectangular
- angles)

3.2 Parametric Rectification with Automatic Direction of the Instrument

This procedure allows a particularly fast on-site generation of ortho-images and 3D visualization. It may consist of the following steps (see figure 7), however various other procedures are possible:

- 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 and the direction of the camera at the time of recording (parametric orientation).
- Click on a point of a surface of the edifice in the photo; 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, and cut out image planes resp. triangles for visualization software.

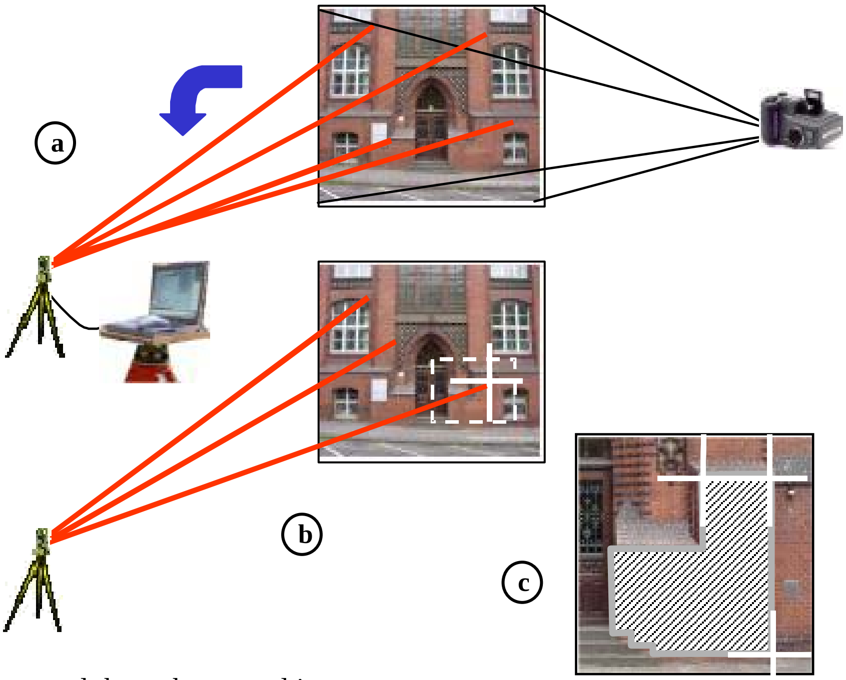

Fig 7: Intelligent control through external images

3.3 Dynamic Visual Measurement Protocol

A continuously growing graphical measurement protocol is generated through the parametric link between the coordinate system and the image. Additionally in an oriented image, single points and connecting lines are faded in automatically (figure 8).

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 directed at any time by clicking on the points in the image.

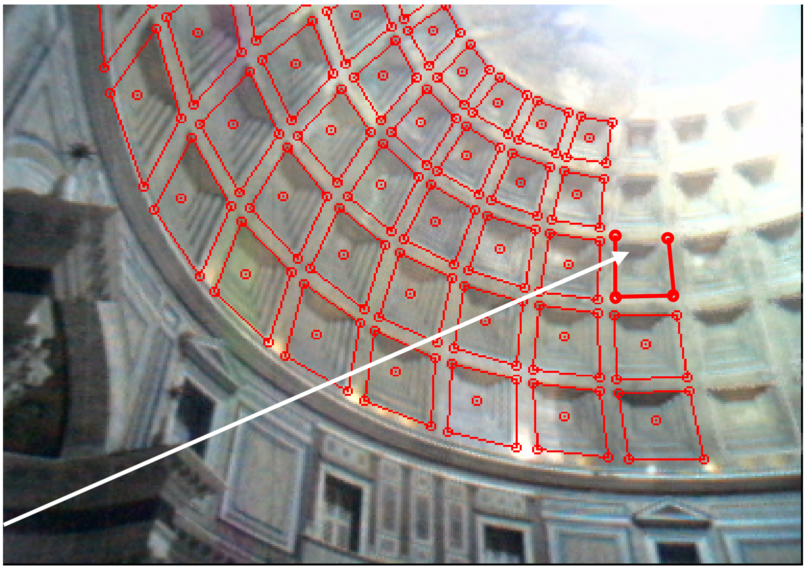

Fig 8: Dynamically visualized measurement protocol

4. CONCLUSION AND A LOOK INTO THE FUTURE

To make the instrument even more mobile and to enhance the possibilities, additional cameras were integrated into the totalstation. This innovative development might become standard one day:

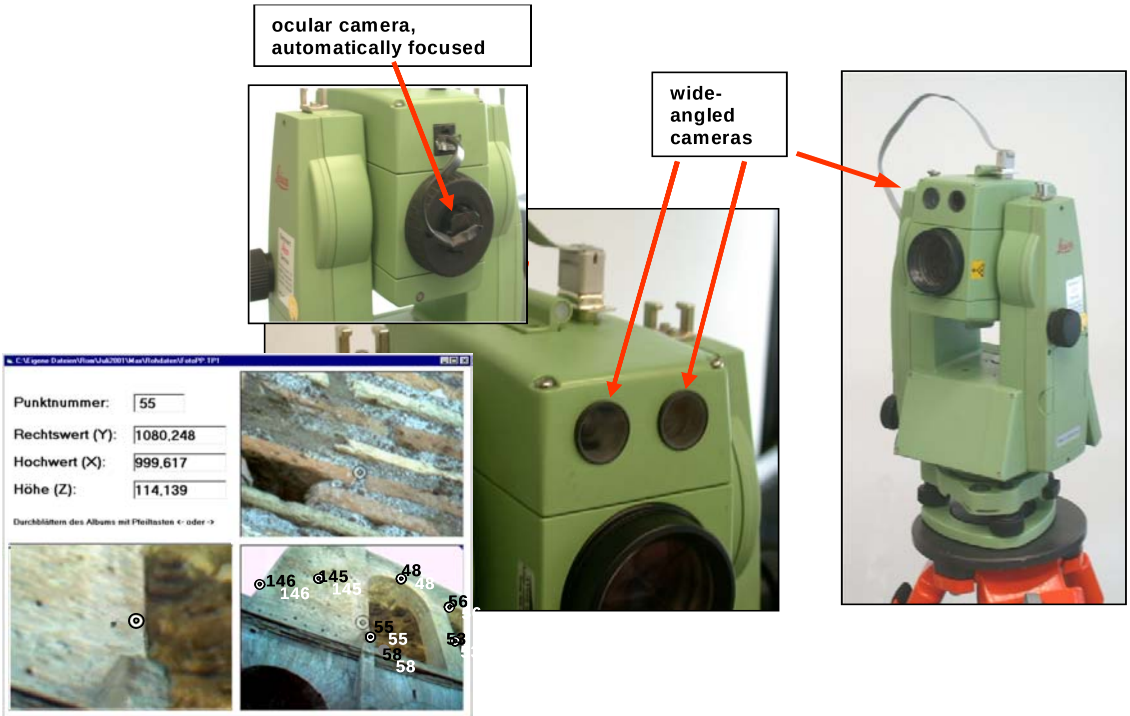

Fig 9: Integrated cameras and a set of photos of a natural point

Two wide-angled cameras with different focal lengths were inserted into the telescope casing and a third camera in the plane of reticule (figure 9). 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; measurements directed towards the zenith are done easily. For subsequent identification, the measured points may be documented at the time of the recording for various purposes, which is particularly important for work with "natural points".

As it was shown different special tools for architectural surveying enable the recording of objects fast and accurate by consequent use of the intelligent tacheometry the integration of digital images gives numerous further advantages. So 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 exist. For the recording of small irregularly formed objects scanning very analogous to the working method of the laser scanner may be reasonable.

In the long term the combination, integration and even synthesis of the point-oriented method of measuring with the tacheometer with the area-oriented method of the laser scanner should yield optimal results for any field of application. Very interesting tools concerning the integration of the software may be expected, enabling also to get more results on site.

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