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MEASURING SYSTEM FOR RIVER BED AND WATER SURFACE MAPPING

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Abstract: This contribution presents a measuring system model (up to 5m crossing distance) for river bed and water surface mapping. The basic parameters of the system are given together with principles of driving/controlling and measuring data processing.

Keywords: river bed mapping, controlling system, measuring system;

1. INTRODUCTION

River bed mapping is required for:

- Scour development (bridge piers, dams),
- Sedimentation (reservoirs and rivers),
- Morphological studies (meandering channels)…

Different techniques are being applied for these purposes, such as:

- Contour mapping with wool threads,
- Sequential point-based methods,
- Projection Moiré,
- Digital close-range photogrammetry.

The benefits (+) and weaknesses (-) of named methods are:

- Contour mapping with wool threads is simple and reliable (+), but time-consuming (-) and labor-intensive (-).
- Sequential point-based methods are very precise (+), enabling automated measurements (+), makes it possible to use combinations of transducers (velocity, cross section,) (+), but are still time-consuming (-).
- Projection Moiré has the benefits at easy setup (+) and being a time and cost effective method (+), but weakness by the ambiguity of its fringe lines (-).
- Digital close-range photogrammetry works on the principle of stereovision (the human eye). The benefits of this method are the realistic representation of river beds, as well as its fully automated data processing. This method requires the installation and survey of photo control targets (at least 8 targets must be visible on every image). Moreover, the camera must be calibrated. This method fully depends on sensitivity to internal camera geometry. For data analysis special software is required.

2. MEASUREMENT PRINCIPLES

2.1 Sequential point-based methods

As already mentioned, apart from distance measurement, these methods use large spectrums of possible transducers. In addition to contact distance measurements, non–contact laser distance measurement has proved to be the best solution.

The following methods are suitable for the following purposes:

- Time of flight measurement,
- Phase shift measurement,
- Triangulation,
- Absolute interferometry.

The most frequently used methods are phase shift measurement and triangulation.

2.2 Phase shift measurement

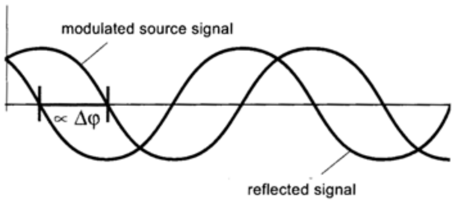


Fig. 1: Principle of phase shift measurement

Δφ is defined by the distance to the target. An unequivocal result is only possible where Δφ is less than 360°. (An amplitude modulated signal is shown for clarity).

2.3 Triangulation process

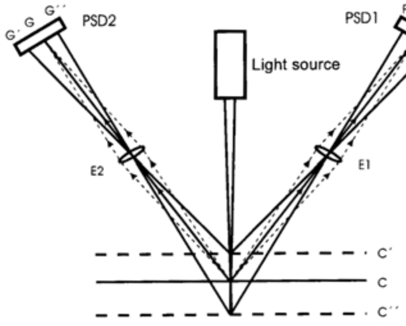


Fig. 2: Principle of triangulation

Light is reflected from level C and focused by optic E into the detector at point F. If the object is e.g. at C' or C'', the light impinges on the detector at F' or F'', respectively.

2.4 Comparison of the methods

Table 1: Comparison of the methods (measurement range, accuracy, components of emitter and detector)

	Time of flight	Triangulation	Interferometry
Measurement range	Relatively low cost 10m to 10 s of km	Few mm to 10m Usually 5-200 mm	Standard laser 1m With external cavity laser 40m
Accuracy	< 1 mm	0,01% of measurement range	Comparable with the laser wavelength
Compon. Emitter	Pulsed laser diode (850-1650nm)	Collimated laser diode (VIS or NIR) or LED	Tunable laser diode (no mode hops)
Detector	Si or InGaAs PIN – photodiode Si or GaAs APD for longer distances	PSD CCD array diode array	Photodiode

3 EXPERIMENTAL MODEL OF SEQUENTIAL-POINT BASED MEASUREMENT INSTRUMENT

3.1 First measuring equipment

Figure 3 presents the first experimental model of a laser based distance measurement instrument designed at TU Graz.

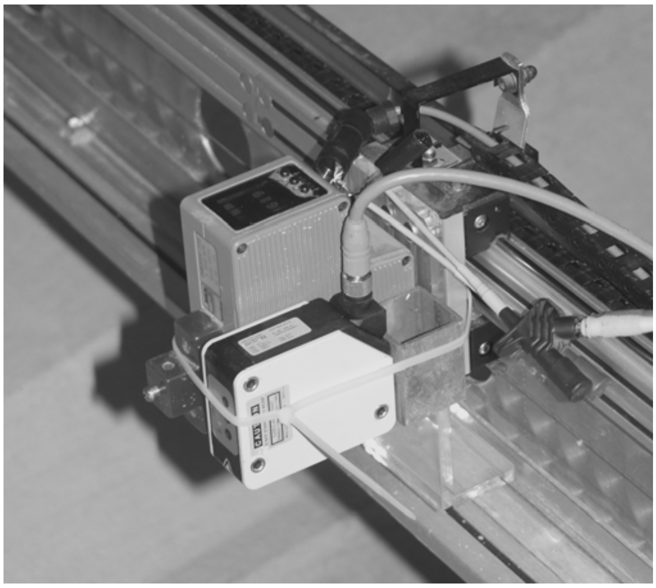


Fig. 3: Laser-based distance measurement instrument

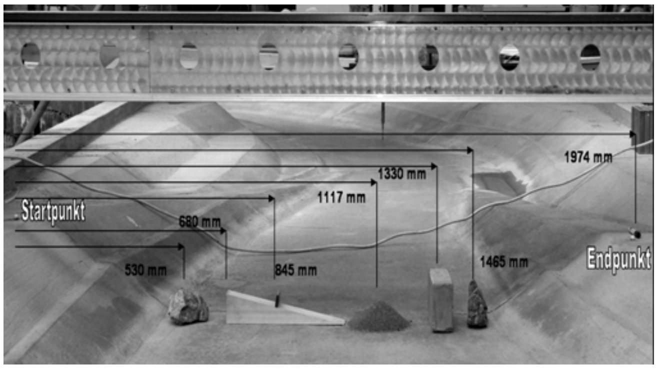


Fig. 4: Disposition of measured objects

For further testing purposes, the object was placed in a river bed, as shown in Figure 4. Figure 5 presents a comparison between the measured data yielded by two laser-distance sensors.

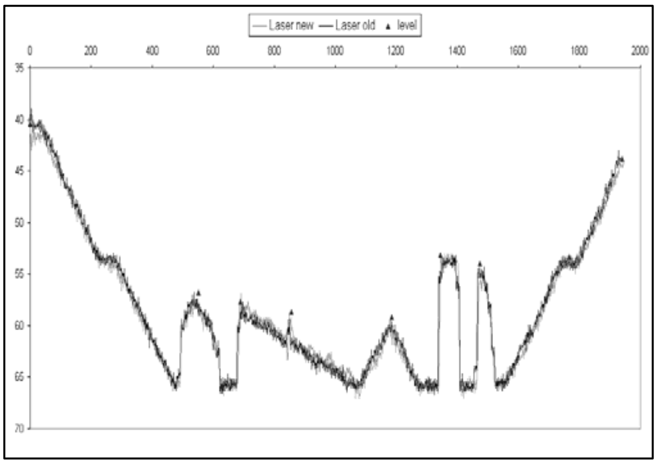


Fig. 5: Measured values of two laser-distance sensors compared with classically leveled values

3.2 New concept of measuring equipment

The measuring device was projected in order to fulfill the following demands:

- distance between river banks (Y-direction; crosswise model) 3m expandable to 5m
- length of measuring line (X-direction; lengthwise model) 2m with possibilities of expanding as far as 15m
- additionall movement in vertical direction (Z-direction) max 500mm
- reduced weight when moving the measuring device (complete device app. 200kg)

It consists of:

- mechanical part (all mechanical parts supports have gearwheel (pinion), bridge and rails with a rack)
- electrical part (POSMO drives with end switches and power supplies)
- control part (SIEMENS S7-300 with appendages)
- software (Labview)

3.2.1 *Mechanical part*

The main parts of the construction are made from aluminium profile and are standard products from Bosch Rexroth AG.

Figure 6 shows measuring device for an over 2m wide model.

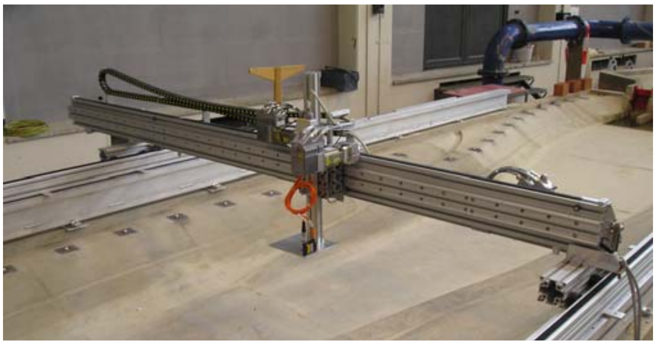
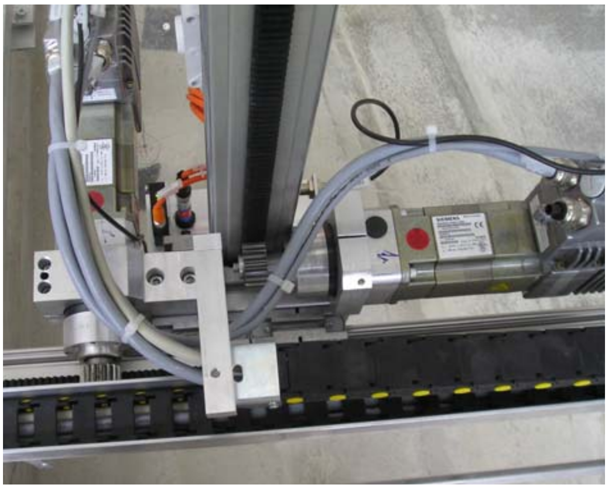


Fig. 6: Measurement device over model

a



b

Fig. 7: Toothed belt drive for X-axis (a) and gear drives for Y and Z-axis (b).

Whilst the Y- and Z-axes (Fig 7b) are driven directly, the X-axis is driven by toothed belt drive (Fig.7a), as can be seen in Figure 7.

3.2.2 *Electrical part*

The electrical equipment comprises a POSMO A electromotor drives, inductive end switches, power-supplies, cables, electric case with main switch and emergency stop switch and supplemental emergency-stop switch.

POSMO A drives are connected to a control loop by using PLC (Siemens S7-300) and PROFIBUS DP interface connections (Fig 8).

Fig. 8: Connection of POSMO A drive in control loop

Fig. 9: Position of S7-300 and SM-331 in the electrical case

A Siemens S7-300 was chosen for the control of motor movement. Moreover, an A/D module SM331 was applied with 8 analog inputs. The control algorithm enables point-to point movement, and continuous mode movement.

3.2.3 Software for control and presentation of measured data

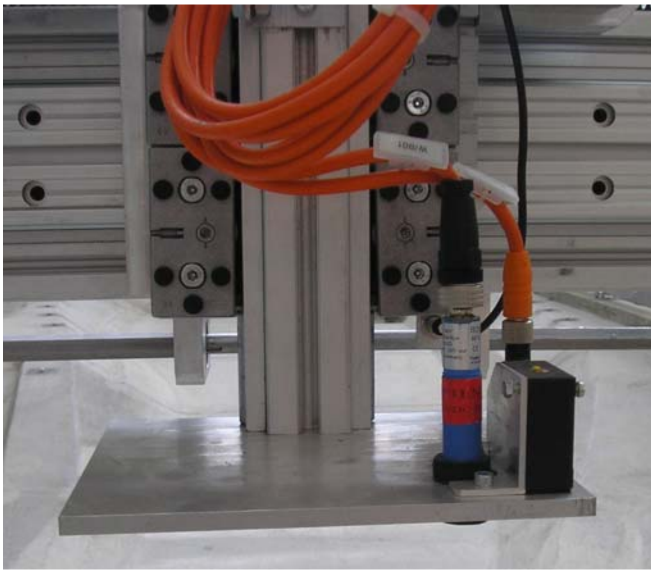


Fig. 10: User interface – front panel

Figure 10 provides the positions of the applied sensors left: placed ultrasonic transducer; right: distance measuring transducer laser.

3.2.4 Software for control and presentation of measured data

Software comprising the controll, acquisition and storage of measured data for surface measuring consists of:

- a program for measuring point-to-point methods as well as
- a program for measuring in continuous mode.

Both programs apply similar user interface for input of the required data, and representation of the measured data.

Labview 7.1 was chosen for environment, with the possibilities of upgrading the source program.

The program facilitates

- controll of measurement,
- communication using PLC (with OPLC Server),
- Storage measured data in ASCI format.

The user communicates with the equipment through a user interface-front panel (Fig.11). This front panel includes indicators, controls and diagrams for easier work.

Controls (switches, user input values,...) facilitate the input of certain required data or status. Switches are used for either enabling or disabling the inputs or representation of data, as well as for control purposes (ending of input, resetting of errors, ending of measurements, etc.). As for the process of inputting numerical data, both direct and indirect inputs are possible. On the one hand, direct input data will be inputted through a keypad.

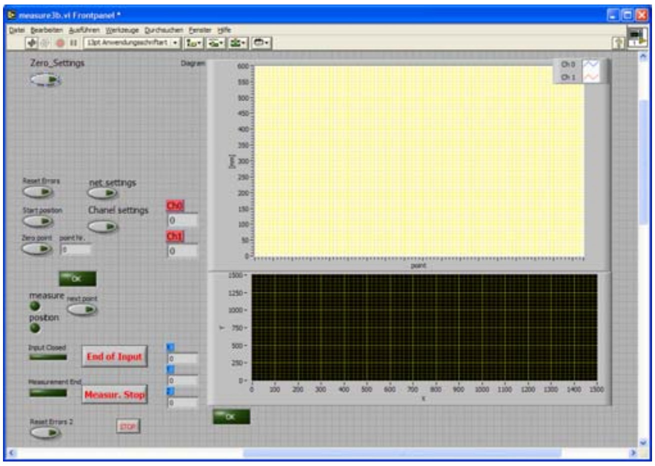
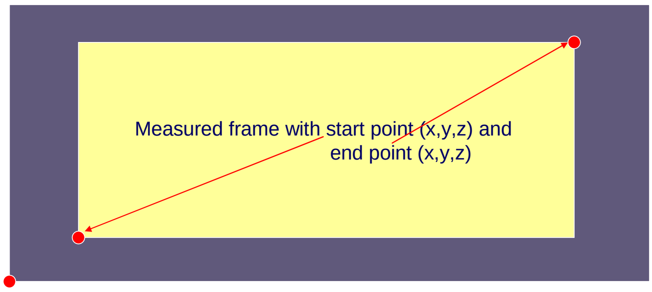


Fig. 11: User interface – front panel

The measurement field is defined by the start and end points as shown in Fig. 12



Absolute zero point

Fig. 12: Measurement field

The user can do measurements from the front panel and see the current measuring position. It is represented in a graphical field (as a red dot) and as positions in x, y and z directions.

4 EXPERIMENTAL RESULTS

Level measurement and laser distance measurement at field in a 2m x 3m (5cm Grid – surface concrete) are performed at the model river bed (Fig. 13). Number of the measuring point is 143.

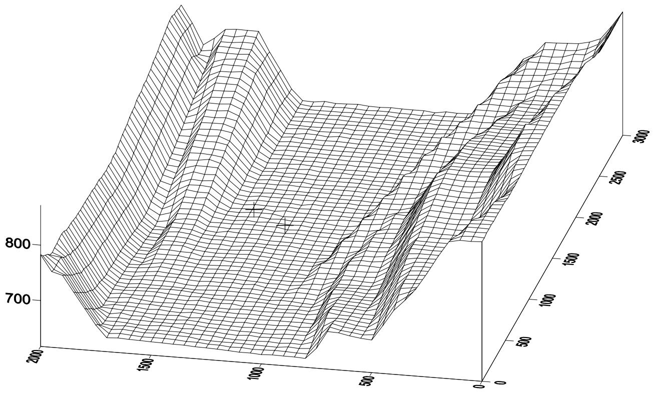


Fig. 13: Model river bed

Position of base points, top view (Fig. 14).

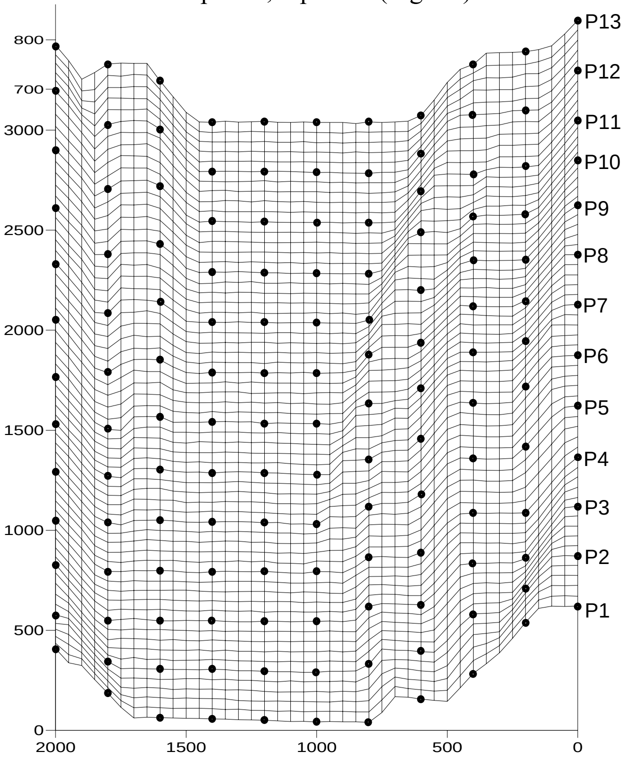


Fig. 14: Top view of model river bed

Experimental data by continuous mode with the usage of wet sand, are presented in Figs. 15 and 16.

Fig 15: Experiment with wet sand

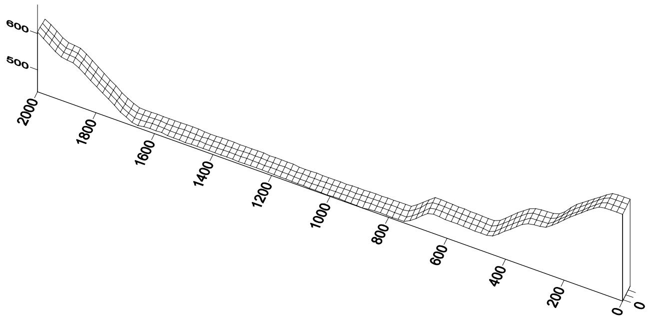


Fig 16: Measured data with wet sand

The measurement results on wet sand show correct results with minor differences, caused by the volume of sand.

Experimental data by continuous mode with the usage of charcoal dust are presented in Figs. 17 and 18.

Fig. 17: Measurement system at laser testing on black pattern.

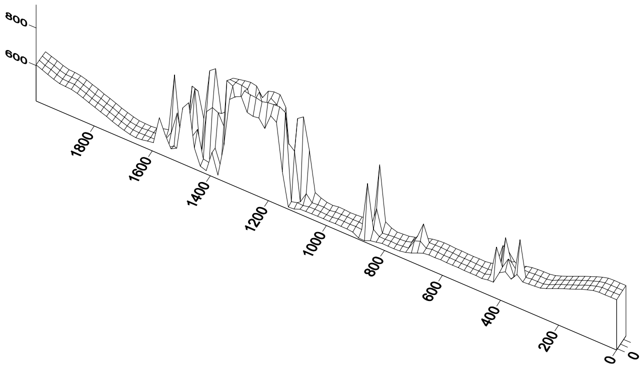


Fig. 18: Measurement results at laser testing on black pattern.

The results are incorrect, due to absorption of the laser light. The Laser-System causes a failure (out of the measured range).

5. CONCLUSION

The designed system is considered to be an effective device for hydraulic model research within the major field of its application, particularly the registration of geometrical patterns (sedimentation, as well as sediment deposition processes).

Basically, the core of the equipment is made-up of either a single sensor or several sensors, respectively, which all serve the purpose of measuring various physical parameters (distance, current velocities). The non-contact recording of distances considerably accelerates the registration patterns. On the one hand, the water levels can be recorded by means of ultra-sound sensors. On the other hand, current velocity is registered with the help of various velocity measuring sensors (wing sensors, ultra-sound sensors; one to three dimensional).

A servo system facilitates sensor control in the x-direction (lengthwise model) and y-direction (crosswise model), as well as the z-direction (vertical model). The designed scanning system's substantial benefits (accuracy, velocity) lie in the application of new laser and ultra-sound sensors. Computerized servo-engine control facilitates an excellent precision regarding the scanned targets, whereas the mechanical concept makes variations according to the model´s dimensions (width up to 7m or more; length up to 15m or more), highly feasible. Scanning surfaces still involving this particular phenomena have to be taken into account. So, laser performance on black surfaces (charcoal dust), has yet to be investigated in more detail. The recording of sedimentation and sediment deposition processes during ongoing flow would certainly prove to be highly favourable. In order to achieve such system optimization, however, further research projects will be required in the near future.

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