MAPPING OF BED MORPHOLOGY FOR LATERAL OVERFLOW USING DIGITAL PHOTOGRAMMETRY

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Measurement of river bed morphology plays a key role for determining sedimentary processes in experimental hydraulics. Digital photogrammetry is an appropriate method for high resolution monitoring of the surface morphology of water-worked sediments. A technique to increase the quality of elevation data using an interactive editing feature is presented. A precise digital elevation model (DEM) is developed with encouraging results. An example is presented that involves a laboratory flume study consisting of a straight prismatic channel subject to a lateral overflow.

1 Introduction

The content of the present paper results from the multidisciplinary flood protection research project *DIFUSE* (**Di**gues **Fu**sibles et **S**ubmersibl**e**s, Fuse plugs and overflow dams at rivers) involving governmental offices, private companies and four research institutes. The task of the *Laboratory of Hydraulic Constructions* (*LCH*) is to study the effects of a side overflow on sediment transport in a natural channel.

A typical appearance of lateral overflow in terms of side weirs can be found in irrigation engineering and flood regulation. They are installed at the wall along the side of the main-channel to spill water over them when the water level in the channel rises above their crest. The lateral loss of water is responsible for the reduction of bed-load transport capacity in the main-channel by decreasing the bottom shear stress. This might yield to the formation of sediment deposits which raise the bed level locally. The design discharge to be diverted over the side weir is therefore increased and consequently bed-load transport capacity is further decreased. This interaction between lateral overflow and sediment transport has to be known in order to avoid uncontrolled behaviour of the diverting weir.

With the help of an experimental setup the physical processes in the main-channel and on the side weir were analyzed systematically (Rosier et al. 2004). The collected data is used to conduct a non-dimensional parameter analysis to predict the hydraulic behaviour of the diverting weir. Combined with a photogrammetrical approach, the purpose is to determine river bed changes and to find empirical relationships. Furthermore, the collected data will serve as main-input to generate a 3D numerical model.

In the present paper the photogrammetrical technique for mapping river bed morphology executed at the LCH is described and illustrated. A method to correct and improve the quality of elevation data using an interactive editing feature is presented and applied to a laboratory flume study. A precise digital elevation model (DEM) showing encouraging results is obtained.

2 Existing Surface Monitoring Techniques for Laboratory Flume Studies

For mapping river bed surface within a laboratory flume study, a number of techniques are currently available (Geisler et al. 2003).

A rather old technique is contour mapping using wool threads. The water level is slowly lowered by a certain distance, e.g. 10 mm, below the initial surface after the test run. A wool thread is then laid along the contour of the water table. Then, the water level is further decreased another 10 mm etc.. Finally, a photograph of the contour lines is taken. Quantitative measurements are possible using a CAD method. Placing the threads is a time-consuming job.

Scanning the river bed by means of mechanical profiling using manually or automatically operated depth pointer gauges is simple but a lengthy job. Thus, its application is limited to a rather small set of cross sections at wide intervals.

A more sophisticated method is the use of laser-scanning technology. A laser sensor is mounted upon a motorized positioning system which locates the laser within an assumed horizontal plane. The distance to the bed surface is measured at a point, the sensor is displaced and the cycle repeated until full coverage of the desired area is obtained.

Photogrammetry is commonly used as a three-dimensional surface measuring tool in a wide variety of disciplines. Until recently, the potential of photogrammetry has been restricted by hardware limitations and high costs for subsequent image processing. Digital photogrammetry is based upon automated analysis of digital imagery using the basic principle of the perspective projection (Slama 1980). Two images of an object are acquired from two separate locations with known coordinates. If at least five points (photocontrol points) at known object locations are clearly visible on both images, a spatial resection can be conducted to derive the positions and orientations of the images. By means of automated stereo matching, conjugate points can be identified and elevation coordinates are extracted (Lane et al. 2001, Geisler et al. 2003). As an advantageous matter of fact the speed of data acquisition and spatial density of surface information can be stated whereas the correction of matches of poor quality can be time-consuming.

3 Application of Digital Photogrammetry to a Laboratory Flume Study

1.1. *Experimental Setup and Measurement Procedure*

Apart from measuring water level, diverted discharge and velocity profiles, a central aspect of the study is the need to measure surface morphology in order to identify bed changes and to calculate eroded and deposited sediment volumes.

The study is concerned with determining the interaction between lateral overflow and sediment transport, erosion and deposition processes in the main-channel. A 30 m long and 2.0 m wide flume was subdivided longitudinally into two separate channels by a vertical 0.9 m high smooth wall. The first channel, being 1.5 m wide, represents the actual testing facility including the mobile bed and the side weir on the right river bank. The second one, 0.47 m wide, constitutes a lateral channel permitting to evacuate the laterally diverted discharge. The slope of the originally horizontal channel is created by adjusting the mobile bed to the requested slope. The mean thickness of the sand layer is 0.24 m. The bed material used in all tests consists of sand having a mean diameter of d_m = 0.75 mm. Table 1 summarizes the characteristic parameters involved.

Table 1. Characteristic parameters of test series B02.

N^o of weirs [-]	Length of weir crest [m]	Sill height [m]	Flume slope [%]	Discharge [l/s]	Test duration [h:min]
1	3.0	0.10	0.2	210	03:21

For the present study imagery was acquired with a Zeiss Jena UMK 10/ 1318 calibrated camera having a focal length c of 64.32 mm. Five photographs with an overlap of 60 % have been taken to cover the whole channel. This has been done for the initial flat bed situation and after each experiment for the final bed situation after controlled drainage of the channel. 18 photocontrol points were distributed along the sidewalls of the channel and in the laboratory not to create unacceptable disturbances while inserted in the active bed. The resulting flying height of the camera (mounted at the gantry crane) to cover all photocontrol points was 6.5 m above the flume.

1.2. *Creation of a Digital Elevation Model (DEM)*

After image scanning (DSN 200 Helava-Leica, each pixel has a dimension of 10 µm), the triangulation and orientation (position and aiming angles) process as well as the creation of the DEM have been performed on the photogrammetric workstation DPW 770 by Helava-Leica running on Unix. The program system used for the analysing process is called SocetSet. For the creation of the DTM a grid resolution of 2,5 x 2,5 cm has been chosen. A summary of the stages of a photogrammetrical analysis is shown in Fig. 1.

Stereo matching (Fig. 1) may significantly decrease data acquisition time, but may also result in incorrect matches which need careful checking and perhaps manual editing of any derived DEM. This problem has come across in the present study. A particular difficulty in this stage of photogrammetric analysis is the high relative relief of the bed surface due to the formation of bed forms with respect to the flying height of the camera. Especially the crest of dunes result in erroneous matches and poor height estimates. To cope with this problem the following technique has been adopted to obtain a correct DEM of high precision.

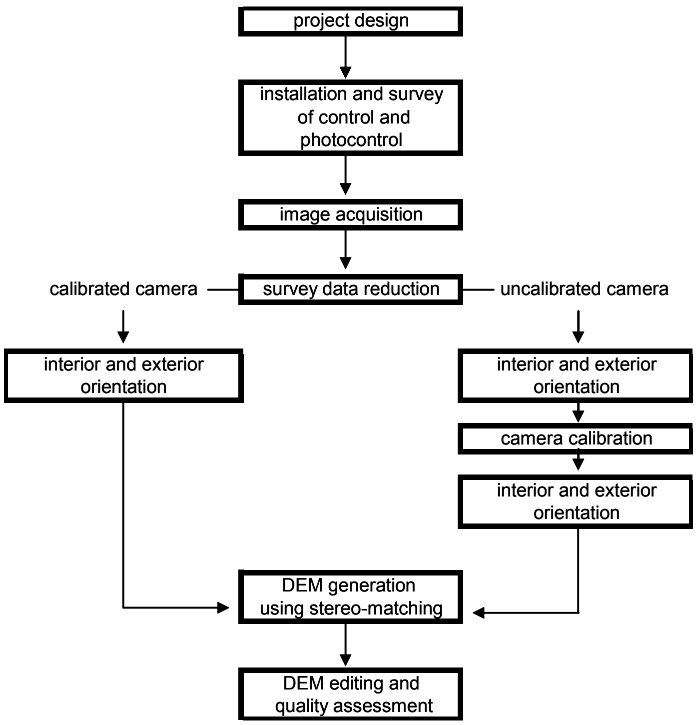

Figure 1. Basic stages in data collection using digital photogrammetry (Lane et al. 2001).

A quality control feature for the automatic terrain extraction may indicate a successful automatic correlation or good measurement as well as the opposite. This tool is called Figure Of Merit (FOM). A FOM is a numerical value assigned by the terrain extraction process. FOMs are proportional to the average correlation coefficient, so in general the larger the number, the better the measurement. As mentioned above, especially the crest of dunes showed a low average correlation coefficient (Fig. 2). For this reason, DEM data points possessing a lower average correlation coefficient than 54 have been eliminated by the help of a macro written in Excel. The value of 54 has been chosen according to experiences made by Kölbl (Kölbl, personal communication 2003).

When the matches of poor quality are eliminated, values are interpolated from surrounding matched data. The eliminated data points mainly are located on the crest of the dunes. Therefore the resulting DEM misses the fundamental information characterizing the morphology of the river bed (Fig. 3).

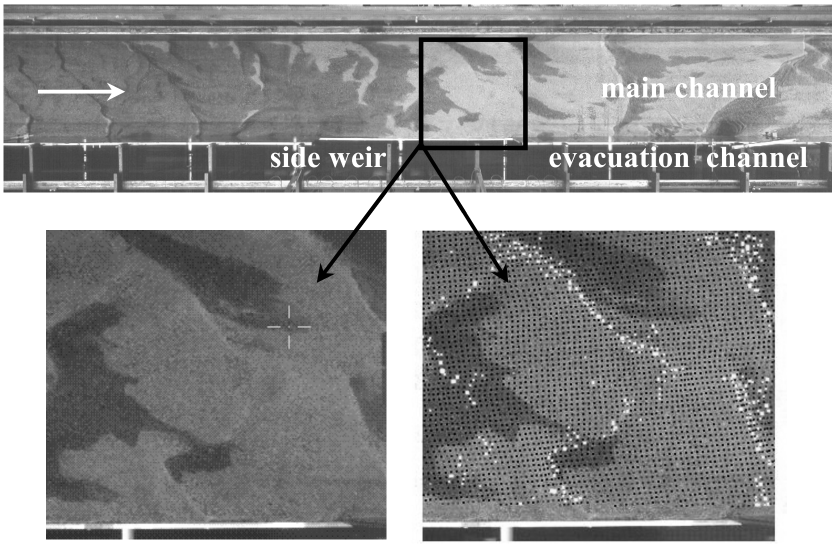

Figure 2. Top: Final bed surface. Bottom: Detailed view with FOMs ≤ 54 (white) and FOMs > 54 (black).

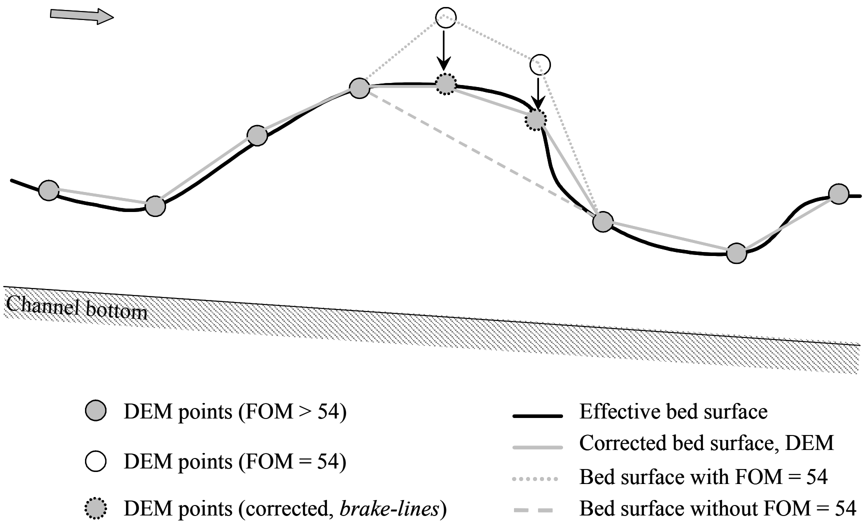

Figure 3. Influence of incorrect matches on the precision and quality of the DEM.

To replace the missing data points, the software provides an interactive editing feature using stereo vision. The tool is called Geomorphic Editor. Linear features such as ridges and drains can be drawn manually by so called brake lines (Fig. 4). This correction technique finally leads to a proper and precise DEM used for further analysis (Fig. 5).

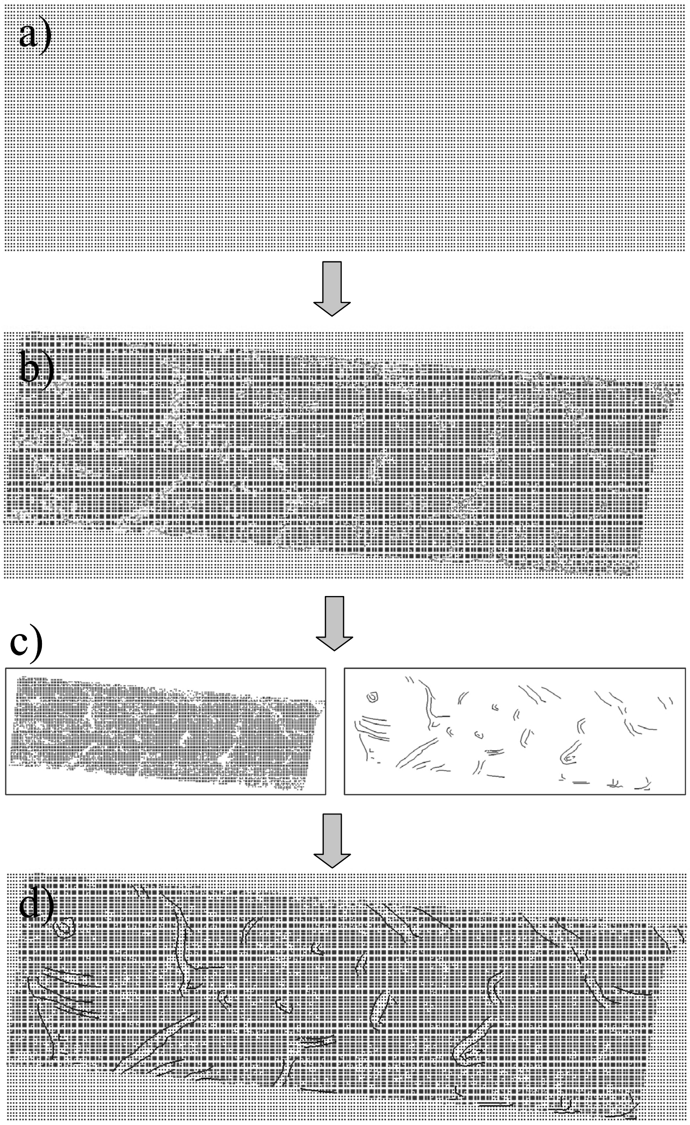

Figure 4. Correction technique to improve the DEM using an interactive stereo vision editing feature: a) basic rectangular grid comprising the flume, b) DEM with FOMs > 54 (dark) and FOMs ≤ 54 (light), c) DEM after elimination of incorrect matches (FOMs ≤ 54) and edited linear features (brake lines), d) final DEM.

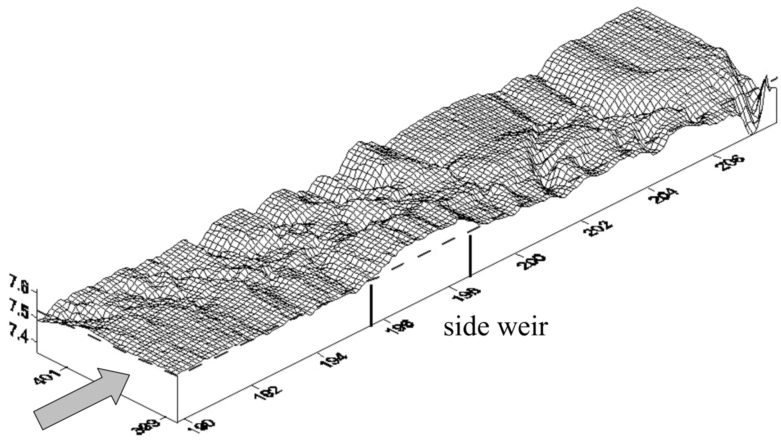

Figure 5. 3D view of the final DEM after application of the amelioration technique.

4 Conclusions

Digital photogrammetry is a powerful and commonly used three-dimensional surface measuring tool. The paper demonstrates the capability digital photogrammetry has for mapping laboratory flume surfaces.

Problems and inadequacies encountered while creating a DEM for flume surfaces having pronounced bed forms such as dunes are described. A correction technique is presented being able to obtain a proper and precise DEM. The technique has been successfully applied to a laboratory flume study.

By means of the improved and adopted procedure to create a DEM, a reduction of the cross section near the weir alignment of about 33 % has been figured out leading to an increased diverted discharge of 25 % compared to fixed bed conditions.

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