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Mobile device app for small open-channel flow measurement

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Abstract: For effective water management, particularly in irrigated agriculture, it is essential to have reliable open-channel flow data. With present methods, such data is not readily obtained as they require measurement stations, what often results in sparse data. We present a mobile device app to measure runoff in open channels. With this tool flow data can be collected reliably and cheaply.

The technology, on which the app is based, is derived from an already implemented and tested similar webcam application. The smartphone app calculates the runoff by analyzing a few seconds of a movie sequence that is recorded by the same device. The runoff is calculated from measured water level, surface velocity and from measured or a priori knowledge on the channel geometry. The water level is determined by the separation line of image segments with and without optical flow. Via calibration of the camera position this separation line is mapped to a water level. Then, the surface velocity is calculated using a modified method of the standard Particle Image Velocimetry method. Among the key characteristics of the method is the fact that no tracer particles are needed.

The methodology has been tested for the webcam application in a pilot project in Switzerland. The results show that it is capable to produce continuous and reliable data for water level, surface velocity and runoff. The accuracy is within 5% of data obtained from a commercial radar sensor. The existing preliminary results for the smartphone application indicate similar accuracy. The tool has the potential to become the state of the art method for mobile runoff measurements, as it is truly high-tech and low-cost.

Keywords*:* runoff; measurement; smartphone; high-tech; low-cost

1 INTRODUCTION

There is a need for more efficient water management, improve its allocation and use. For this, it is essential to have data in sufficient amount and quality. Based on measurements water systems can be design and operated more efficiently and respond better under different type of pressures. In the context of agriculture that relies on irrigation, its effective management is central. Among the essential inputs to such management is reliable furrow runoff data.

However, with presently used methods such data is not readily obtained, as they require measurement stations, which are costly. The situation often results in sparse and low quality data, leaving the door open for arbitrary management strategies.

In the last years Smartphones and mobile devices have become powerful and have extended their capacities including different types of sensors. These capabilities make them very interesting for its applications in water management. Even more, making use of its connection to internet, data can be readily available. Using smartphones, measurements can be made at much lower cost, since there is no need of permanent installations, which also makes it possible to take measurements in any place.

The objective of this paper is to present the new mobile device application for open-channel flow measurements. The app can be used to determine the flow in open-channel (e.g. rivers, artificial channels, irrigation ditches, furrows, etc.). The app is a stand-alone application, all the measurements are taken using the available sensors in the mobile device, and all the calculations are made make only use of the mobile device. No in-situ installations are needed. The measurements can be sent via SMS or saved in the mobile device database.

With the presented tool, flow data can be collected reliably by a crowd of smartphone holders for very low initial costs and even smaller running costs. This information can help in having a better knowledge into the water distribution, which will help in improving water management.

2 METHODOLOGY

The underlying principles to obtain the flow in open-channels are first to measure the water-level and the surface velocity field; combining this information with a priori knowledge on the channel geometry the discharge is calculated.

For the estimation of the water level we have developed an approach (patent pending) to separate in a robust fashion the moving water from the rest of the image using a sequence of images. This can be done since pixels located in the 'dry' parts of the scene will experience little change, whereas pixels located on the water are subject to constant change. Then, via standard camera calibration the detected line is mapped from image space to metric space (i.e. the line parameterization in pixel units is mapped to meters above sea level). The calibration involves reference points with known positions relative to the channel geometry and a classical pin-hole camera model. The accuracy of the procedure was found to be <1cm.

The velocity measurements are based on the well-established Particle Image Velocimetry (PIV) technique (Adrian, 1991), which since the work of Fujita et al. (1998) is also known of being successfully applied to large scale free surface flows of flumes or open channels, also known as Large Scale PIV (LSPIV). LSPIV has been applied to measure flow in rivers (e.g. Kim et al. (2008), Dramais et al. (2011) or Tsubaki et al. (2011), Muste et al. (2009, 2011)). All these mentioned PIV methods have in common that they require quasi frozen patterns on the surface which can be tracked through time. Non-moving image parts, such as transition from shade to sunlight, standing waves or transparent ground features have posed performance problems. Often, these issues can be overcome by adding well detectable artificial flow tracers of some kind. Since the method used in the mobile app is capable of separating the moving image content from the stationary image content, there is no need of artificial flow tracers, which makes it easier to implement.

The algorithms used in the app were first tested on images taken with a fixed webcam at the station Galgenwäldli in Switzerland. The results were compared with the ones taken using a fixed radar system (Sommer Ltd). It measures both, water level and water surface velocity, roughly at the center of the river width and data is logged at 10 minutes intervals. Using the webcams images were taken at intervals of 2 seconds; then, the velocity profile was estimated at discrete span-wise river positions via a roughness dependent mixing length model (Absi, 2006, cfd-online.com). The integral over these velocity profiles across the river width finally yields the discharge. For comparing the 'radar data' with the 'webcam data', the later has also been averaged using a gliding average with 10 minute width. Figure 1 left, shows the data for the height h above channel bottom and the figure 1 right shows the mean surface velocity. Generally there is good agreement for the two methods with a standard deviation of <1cm. However, there are two major features that are different. Firstly, the current implementation of the webcam system works only at daylight. However, recently an infra-red beamer with 70Watt power has been tested to 'illuminate' the scene, and preliminary results show that this will be enough to obtain data also during the night. Secondly, especially around the days 20-25, corresponding to the final days of the very hot period around mid-September 2013, there are significant discrepancies between the two methods, both for height and velocity; the radar values are much lower. On-sight inspection that was performed regularly in weekly intervals, revealed the reason. The warm period favored a significant growth of organic material mainly around the center plates of the river channel, which in turn increased the surface roughness locally. As a consequence, the flow ‘avoided’ this rougher section in the middle, resulting in too low radar estimates, as it measures only in the middle of the channel.

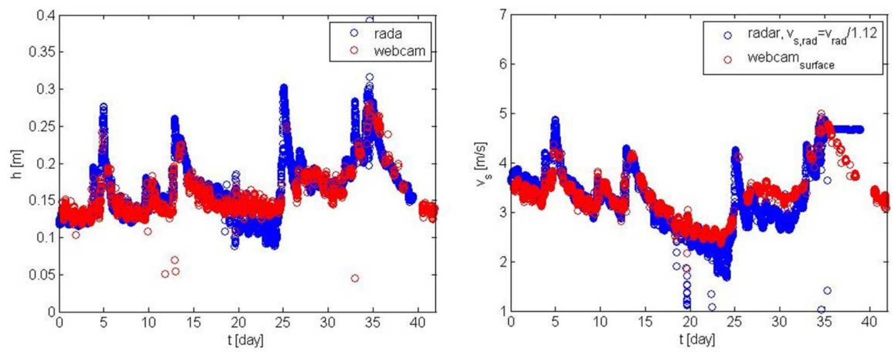

Figure 1 Direct comparison of webcam and radar measurements for water-line (h) and surface velocity (v)

3 SMARTPHONE APPLICATION

In order to implement the method described above in a mobile device some adaptations had to be done since there are some important differences. The mobile device is hand-held, image sequences need to be stabilized and its position and orientation needs to be calibrated for each use. Even though the impressive computational power of even the cheapest smartphone, it still very modest compared to a ‘normal’ PC, which makes necessary to optimize the code. But on the other hand, mobile devices have also some advantages, as the accelerometer which can simplify the calibration process, GPS sensor which has been used to save the coordinates of the measurement location and the GWM network which is used to transmit the results.

The app is currently on an alpha stage and it has been developed in an Android environment. The app has been tested using a Huawei Android smartphone Ascend Y300, which is among the cheapest smartphone models on the market.

The main differences with the fix webcam implementation are mainly because the hand-held device is not fixed. Therefore the calibration procedure was modified and images had to be stabilized. The calibration routine requires only two reference points and it takes additional information related to the inclination from the phone’s accelerometer sensor. For this it is necessary to place two fixed markers of ~5cm scale. The markers positions relative to each other and relative to the channel geometry need to be measured once. Also the channel geometry needs to be measured once. The app is designed to guide the user towards an approximate position relative to the channel and the calibration marks for calibration and recording of a O(1sec) image sequence. This will be enough to determine water level and water surface velocity, from which the discharge will be determined.

The app contains the following menus (Figure 2):

1. Measure: Activates the camera and records a movie. 5 seconds are enough. It also records the geographical location of the measurement via GPS.

2. Process: It calculates the water level, surface velocity and the discharge. The methodology used is based on the one described in section 2.

3. Transmit: It has the option to send the results via SMS.

4. View history: It creates a database of the measurements taken, as well as for the different locations.

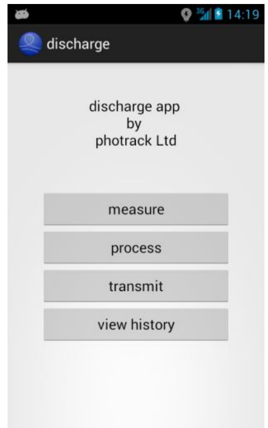

Figure 2 App main page.

The menu guides to user to take a short video, having in the frame the fixed points needed for calibration. Then the process menu, from the recorded images, it calculates the water level, surface velocity and the discharge using the information introduced before related to the channel geometry. Finally the information collected can be send via SMS to a central where all data is collected (Figure 3).

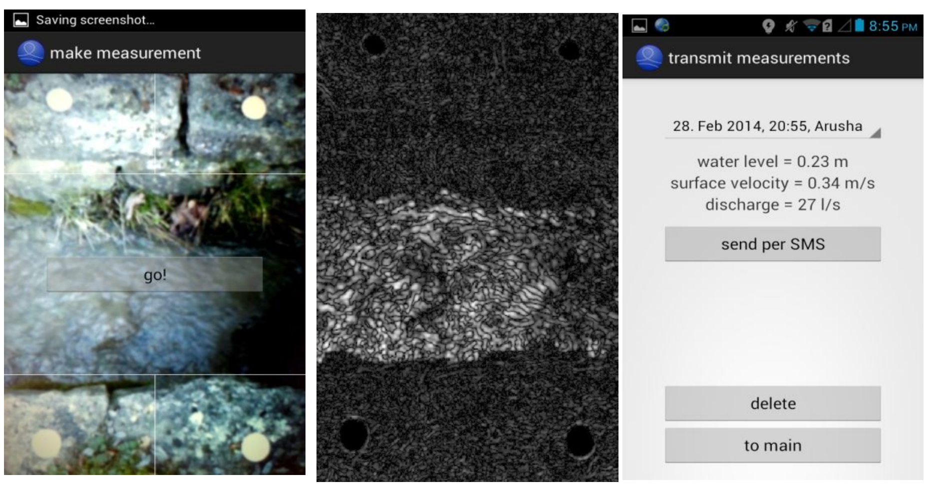

Figure 3 Actual flow measurement using the mobile device app.

The app must be capable of working for different open-channel conditions (e.g. light conditions, turbidity of water, materials of the channel, etc.). During the development of the app different tests have been performed under different conditions showing good results.

4 CONCLUSIONS AND RECOMMENDATIONS

We have developed and tested an app for Android smartphones and mobile devices for measuring open-channel flow. In order to calculate the discharge it is only necessary to place two control points with a known distance between them and take a short video. With this information the app estimates the flow. The app is based on two principal calculations: the water level and the surface velocity. The water level is determined by separation line of image segments with and without optical flow. Via calibration of the camera position this separation line is mapped to a metric water level. The surface velocity a modified method of the standard Particle Image Velocimetry method (PIV) is implemented. Among the key characteristics of the method is the fact that no tracer particles are necessary.

The algorithms in the app are derived from an already implemented and tested similar webcam application. From the webcam test an accuracy of <1cm for water level and <10% for surface velocities were obtained.

The app allows obtaining the flow for very low initial costs and almost no maintenance costs, since no installations are required. It also has several advantages, like the simplicity in its use, the time required to take measurements and the easiness in the data collection via SMS. All this can help considerably in the design of water management strategies and daily operation of irrigation channels.

The tool has the potential to become the state of the art method for mobile open-channel flow measurements, as it is truly high-tech and low-cost.

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