An Effective Camera Based Water level recording Technology for Flood Monitoring

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ABSTRACT

Beside the technical flood protection constructions, a timely warning is a crucial factor for preven-tion or reduction of damages caused by flood disasters. The monitoring of water level at dams and dikes provides information to determine their water balance, which is one of the crucial factors for their stability. A continuous monitoring of surface water level is therefore very necessary and can be carried out by different methods. The optical water level measurement is a new method for this purpose. The aim of this work is to develop a new effective method for a continuous contactless water level measurement even under critical conditions like floods and hydraulic jumps, under which other localised gauging methods could be temporal out of operation or not sufficiently rep-resentative. In particular the access to images of the site, which are the basis of the new gauge method, will allow investigating the situation and judging on the quality of the water level meas-urement. The developed method was successfully validated at several sites and under different conditions.

KEYWORDS

water level;continuous monitoring;contactless measurement;optical method;floods

INTRODUCTION

Flood risk management has an increasing importance in many areas of the world, especially under the consideration of the potential influence of climate change and the reduction of natural river meadows caused by human activities. "Floods have the greatest damage potential of all natural dis-asters worldwide and affect the greatest number of people" (unsidr, 2002). A recent confirmation of this fact is the June flood, which was with 15.2 billion US$ the most expensive natural disaster in 2013 in Germany (Munich RE, 2014). Very large amounts of precipitation caused flooding in most river basins in Germany (BfG, 2013). Therefore, an effective and timely monitoring of surface water level is a very crucial factor of the quantitative flood risk management for the reduction of potential damages. Especially in potential flooding areas, e.g. near rivers and dams, is a continuous surface water monitoring with an effective alarm system very necessary. The monitoring of surface water level at dams and dikes provides information to determine their water balance, which is one of the crucial factors for their stability. Physical and numerical models have shown that even partially

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saturated conditions on the air side of dams and dikes could cause mechanical instabilities (Hasan et al., 2012).

Monitoring of surface water level can be carried out by different methods. Pressure sensors, floaters, radar sensors and ultrasonic techniques are some of the most applied methods providing accurate and reliable data acquisition for water level measurement. A disadvantage of these methods is the regular visual inspection of the site required due to environmental changes. The optical water level measurement is a new method for this purpose, which has been investigated more widely in the recent years. A significant example of water level detecting based on image processing is the camera system of HydroPix Monitoring, which is installed in a closed sewer system having the ad-vantage that light conditions are stable without any day and night time changes and that electrical power connection is available (Nguyen, 2009). Further optical gauge system is the GaugeCam, which is designed for open channels and tested in the laboratory and at one site and proposes the usage of infrared light for night applications (www.gaugecam.com).

Other applications like RiverBoard (www.tenevia.com) use server based image processing which al-low to connect different camera technologies but require available and stable internet connections for real-time processing.

The aim of the present work is to develop a new effective method for a continuous contact-less water level measurement even under critical conditions like floods and hydraulic jumps, under which other localized gauging methods could be temporal out of operation or not sufficiently representative. In particular, the access to images of the site, which are the basis of the new water level detection method, will allow investigating the situation and judging on the quality of the water level measurement. The image processing and, as a result, the obtaining of water level data should be occur on site.

METHODS

SEBA Hydrometrie GmbH & Co. KG has developed a new gauge for enhanced water Level detection by image processing, which is based on the edge detection principle. The new instrument for optical water level measurement is called GaugeKeeper. The detection algorithm is running in real-time on the device.

As it is shown in the Figure 1, GaugeKeeper system consists of the following components: day and night camera, infrared projector, a white board, a processor unit, a data logger and data transmission unit. All units are integrated in one system but it is also possible to apply only the GaugeKeeper-Algorithm for an existing system (e.g. an installed camera).
Using this technology it is easy to survey, measure, and verify the water level data (Hies et al., 2012). Independently, alarm limits can be defined for the case the water level reaches a critical limit or hardware warnings (i.e. battery capacity). SMS alarms can be sent to up to

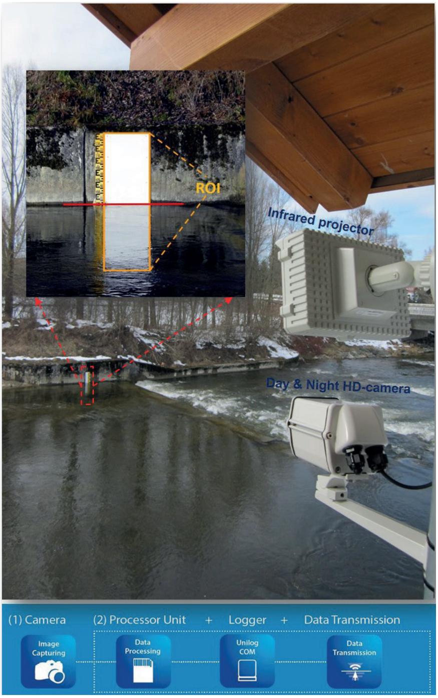

Figure 1: This figure shows the GaugeKeeper components and an on-site picture of the installed system.

8 different mobile phone numbers as well as to a facsimile. Prior to using the system for the first time, the Gauge-Keeper needs to be calibrated to the site‘s specific conditions. That is done via a graphical user interface (GUI). Thereafter the software calibrates the system and defines an individual measuring scale. The surveillance camera is ruggedized, equipped with special, non-visible infrared illumination for night-time measurement and uses an integrated powerful processor to automatically convert data to measurement values. The obtained data are available as hydrographs, images and time-lapse movies. The frequency is configurable and the images are saved to a local SD-card for preservation of evidence. The water level is measured and converted inside the processor unit and stored on the data logger. Those data and the images can be downloaded via remote access (e.g. GSM/GPRS, satellite, landline, radio transmission, DSL, Ethernet). The major steps for the robust detection of the water level are summarized below:

- Automatic, adaptive selection of the region-of-interest (ROI);
- An image processing technique, the so-called edge detection, is applied to obtain the edge image of the ROI image edge-detection assuming discontinuities of intensities of pixels of images are linked to physical changes e.g. material changes, depth changes, surface orientation changes etc. (Barrow et al., 1981), (Lindeberg, 2001), (Jaehne, 2002);
- Hough-transformation calculating the longest straight line in the edge image of the water level (the red line).

Figure 2 and 3 show the transformation of the captured images to undistorted frontal-view images with the region of interest and red line indicating the water level.
After the water level is detected through the above methods, the water depth of the channel is interpolated based on the field measurement done at the ROI (Hies et al., 2012).

Figure 2: This figure shows the water level detection for an image captured by the day-camera (left: original image, right: transformed image).

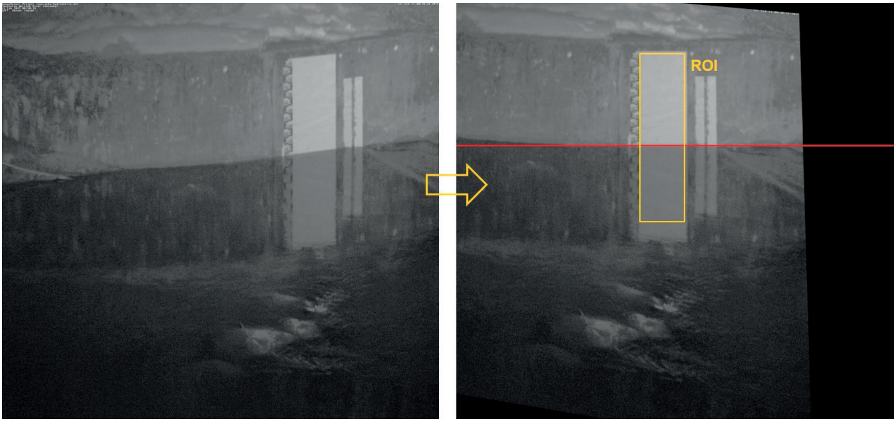

Figure 3: This figure shows the water level detection for an image captured by the night-camera (left: original image, right: transformed image).

RESULTS

The developed optical gauge was tested at several sites and under different conditions (rain and heavy tropical rain events, snow, fog, day and night) in Germany and Singapore. The validation was carried out by comparing the water levels determined by the new developed gauge against the levels measured by conventional sensors like radar and pressure sensor at the same location. The agreement between the measurements carried out by the optical gauge and by the two reference sensors was very good (Fig. 4 and 5). The accuracy of the camera system was 1.1 % for the test period between April and December 2011. A second test, with a pressure sensor as a reference gauge, was carried out in the period between December 2014 and February 2015. The relative deviation was in this case around 0.95 % and the root-mean-square error (RMSE) was about 1 cm (the average water depth of the site was around 76 cm).

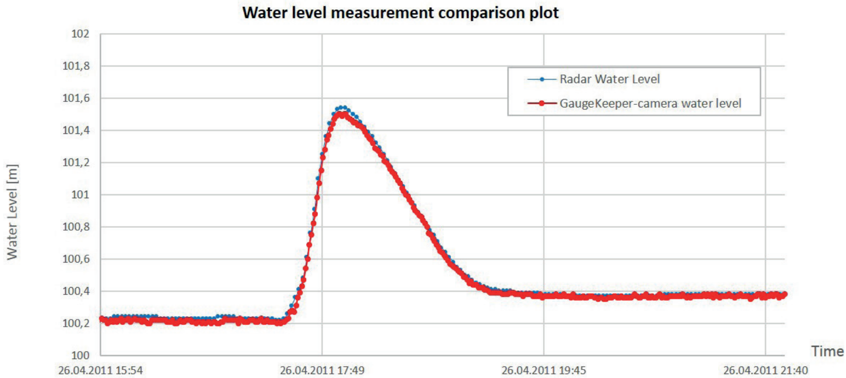

Figure 4: This figure shows a water level measurement comparison between GaugeKeeper and a radar sensor at a site in Singapore.

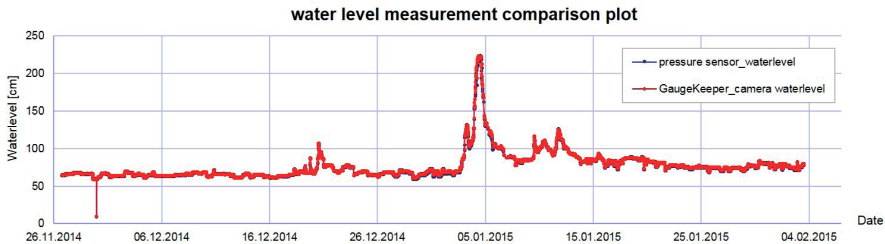

Figure 5: This figure shows a water level measurement comparison between GaugeKeeper and a pressure sensor at a site in Germany.

Due to the optical image processing method, the developed gauge system requires no contact with the measured medium. Therefore, silting or flotsam have no influence on the operation of Gauge-Keeper and it can work even in extreme events such as floods and hydraulic jumps. The distance can be up to 70 m be-tween the camera and ROI (the white board).

The special lighting of the presented gauge system enables its operation under many different weather and light conditions. The low energy consumption of the measuring allows a permanent autonomous battery or solar operation. The implemented low power components allow continuous 24 hours, 7 days operation with real-time monitoring access based on battery power supply for a minimum duration of 14 days (Hies et al., 2012).

The activation of the measuring system can alternatively be controlled by trigger pulses. This can be very useful in cases where the water doesn't flow permanently or if the water level exceeds a pre-defined value (e.g. flood events). Applying a water detection sensor, Gauge-Keeper automatically will be switched from a sleep mode (e.g. every 24 hours) to a dynamic measurement mode with higher data recording frequency (e.g. every 2 minutes). This feature provides a detailed visual representation of the observed events and saves energy significant-ly. The user of this gauge system can be immediately informed by SMS and/ or e-mail when critical system states (e.g. in case of low battery voltage or sensor drift) are reached or when definable thresholds are exceeded/ fallen be-low.

CONCLUSIONS

The presented optical gauge was successfully verified and validated under various weather and lighting conditions. The new developed gauge has proven to be a reliable method for on-site water level measurement. In addition to the measured water level value, the associated photographic evidence can be provided by the gauge system. The application of this technology within flood protection measures can give a real time overview about the observed sites to undertake timely the suitable actions especially in urban areas and where landslides and dike-breaches are potential. The GaugeKeeper is maintenance-free. The camera lenses and the glass of the illumination unit must be clean and free of dirt. The white board is coated with special coating materials, which minimizes the cleaning work.
The developed optical gauge will be tested in the future in industrial and agricultural sectors to detect the filling level of liquids and solids.

REFERENCES

- Barrow, H. G. and Tenenbaum, J. M. (1981). Interpreting line drawings as three-dimensional surfac-es, Artificial Intelligence, vol 17, issues 1-3, pages 75-116.
- Hasan, I., M. Meyer, J. Guo , P.-W. Gräber, (2012). Simulation of the hydrological regime in earth dams and dikes as a basis for stability analysis using the software PCSiWaPro®. ISBN 978-83-60455-66-1. Opole/ Polen (2012).
- Hies, T. Parasuraman, S.B., Wang, Y., Duester, R., Eikaas, H.S, Tan, K.M. (2012): Enhanced Wa-ter-level Detection by Image Processing. Proceedings 10th International Conference on Hydroin-formatics, HIC 2012, Hamburg, Germany
- Jaehne, B. (2002). Digital Image Processing, Springer, ISBN 3-540-67754-2.
- Lindeberg, T. (2001). Edge detection, in M. Hazewinkel (editor), Encyclopedia of Mathematics, Kluwer/Springer, ISBN 1402006098. (http://eom.springer.de/E/e120040.htm)
Munich Reinsurance (2014). http://www.munichre.com/de/media-relations/publications/press-releases/2014/2014-01-07-press-release/index.html
- Nguyen, L. S., Schaeli, B., Sage, D., Kayal, S., Jeanbourquin, D., Barry, D. a, & Rossi, L. (2009). Vision-based system for the control and measurement of wastewater flow rate in sewer systems. Water science and technology, 60(9), 2281-9.
- The United Nations office for disaster risk reduction (2002). http://www.unisdr.org/files/558_7639.pdf
- The Federal Institute of Hydrology (Bundesanstalt für Gewässerkunde, BfG) 2013. Annual report 2012/213. ISSN 0170–5156. http://www.bafg.de/EN/03_The_%20BfG/AnnualReport1213.pdf?__blob=publicationFile
- http://www.gaugecam.com
- http://www.hydropix.ch
- www.tenevia.com