Testing Computer Vision techniques for bedload sediment transport evaluation in sewers

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Summary

The potential of Computer Vision techniques to support estimation of bedload transport in sewers is investigated. A specific methodology combining the use of algorithms for sediment detection and tracking with advanced image filtering procedures was setup in order to identify the sediment particles contributing to the bedload transport. The methodology was preliminary applied to a large combined sewer channel of Paris City for which videos capturing sediment transport processes during a flush experiment are available.

Keywords

sewer sediment transport, computer vision, image processing, field experiments, sewer flushing

Introduction

Sediment transport in sewer systems has been the subject of several studies in the past two decades (see for instance Ashley et al., 2004). Although large efforts have been devoted to understand the behaviour of in-sewer sediments, many aspects concerning the dynamics of sediment transport processes in sewer channels still remain unclear. One of the reasons of the existing gap of knowledge is associated to the difficulty to run field experiments for monitoring the transport of sediments in real sewers.

Recently, the use of Computer Vision (CV) techniques has gained the attention of researchers as a non-intrusive method to evaluate sediment transport in open channels. Algorithms to detect spherical particles and track their trajectories in the flow have been successfully developed by various researchers (e.g. Böhm et al, 2006; Radice et al., 2006). However, the available results have been obtained under laboratory-controlled experimental conditions only, i.e. steady flow conditions, uniform sediments, optimal light conditions, etc. Conversely, applicability of CV methods for sediment transport evaluation in real sewers has not been tested, yet.

The objective of this paper is to investigate the potential of CV techniques to support bedload transport estimation in sewer channels. A specific methodology combining particle detection and tracking techniques with advanced image filtering algorithms was developed to identify bed particles contributing to bedload transport.

The methodology was developed based on the video data recorded during field experiments in a large combined sewer channel of Paris City. The experiments were carried out within the framework of a larger research project aiming at analysing the performance of flushing in sewers (Shasavari et al., 2016).

Methods and Materials

Videos were recorded by a GoPro camera placed in a plexiglass box and encased in the sewer channel side wall. The videos (1920x1080 pixels, 24fps) show the hydraulic and sediment-related processes including sediment transport during a 3.5 hour long flush experiment. Videos were firstly pre-processed to improve the quality of the images, and eliminate distortions. A control window (ROI – Region Of Interest) (350×80 pixels) was selected for each frame in proximity of the water-bed interface with the aim to focus on bedload transport (see Fig. 1), thus including particles that may move only by rolling, sliding, and by saltation.

Two sets of 24 frames (one second video each) were selected in which each particle was manually labelled in order to be used as training samples for a CV-based supervised machine learning algorithm.

Firstly, algorithms for particle detection were developed. Two classes of sediment particles were identified based on their appearance in each frame. In particular, sediments moving faster than the exposure time of the camera appear as "stripes", while others showed a "core" shape. A single-layered Convolutional Neural Network was trained to find the optimal image filters needed to achieve the best classification results with a shape-based detection algorithm for the detection of particle geometry on the plan on the image (Battiato et al., 2016). Overall, 24 frames were used for the calibration of the algorithms, while the remaining 24 frames were used for the validation. Secondly, particle tracking analysis was carried out to evaluate velocities of the detected particles. Dense Optical Flow (DOF)-based tracking algorithms (Tao et al., 2012) following the particles on time through subsequent frames were used for core particles. Instead, velocities of "stripes" particles were calculated based on the analysis of the path left by the particle in each frame. Finally, area and velocity of particles subject to motion were automatically evaluated by the algorithm for comparison with the values obtained manually for the 24 frames of the validation sample. Sediment transport in the ROI control window was finally evaluated based on the sum of the products of area and horizontal velocity for each detected sediment particle.

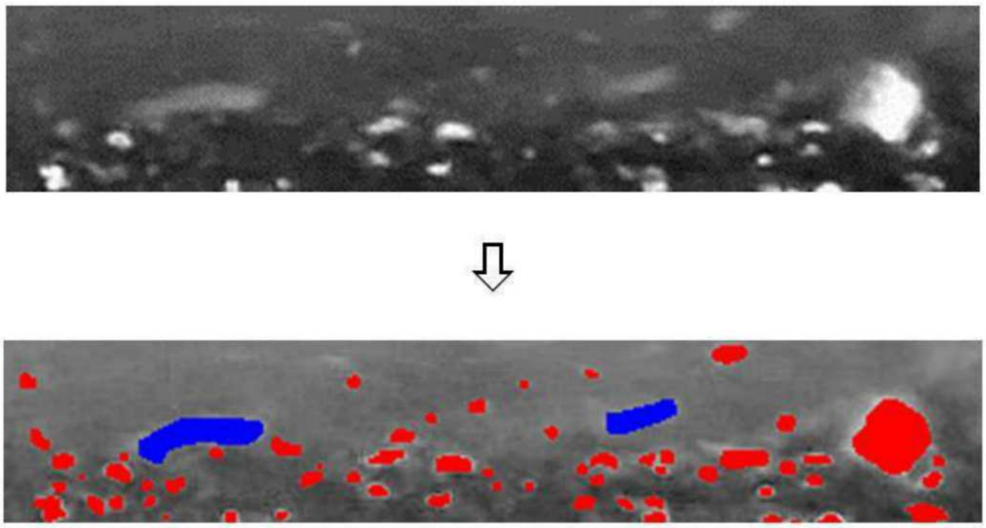

Fig.1. *Example of application of the particle detection procedure within the ROI of the frame.*

Results and Discussion

The results of the application of the used CV techniques for particle detection are summarized in Fig. 2. The figure shows the number of particles labelled manually and detected by the used machine learning algorithm. Globally, average 95% of the sediment particles were correctly detected by the algorithm for each frame.

The particle tracking algorithm was able to automatically attribute a velocity vector to about 80% of the detected particles. Conversely, the remaining 20% particles were not identified by the tracking procedure. Reasons of this relatively low performance were: i) some particles went out of the ROI without the possibility to identify them in the subsequent frames; ii) some particles were "covered" by other sediments; and iii) turbidity locally impeded particle vision.

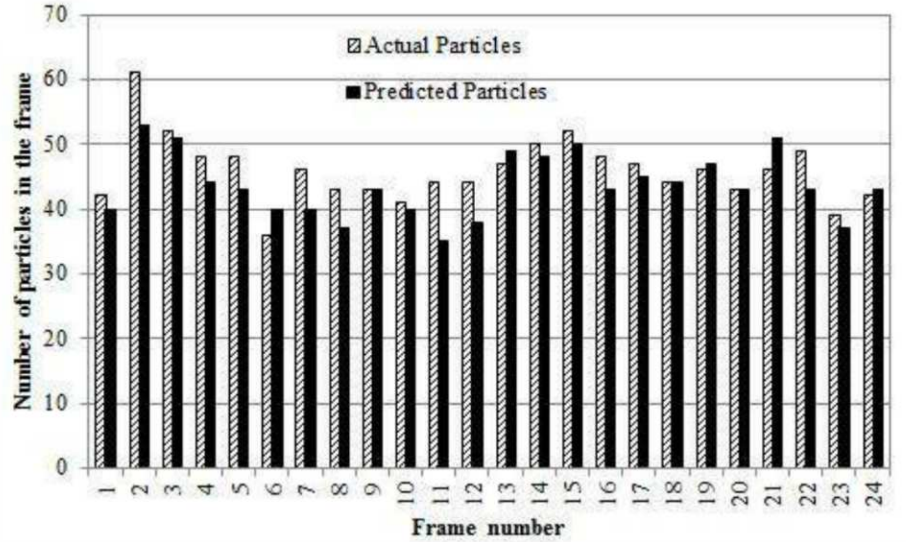

Fig. 2. *Comparison between number of particles detected manually and by CV algorithms. Calibration procedure.*

Conclusions

Globally, the obtained results are to be considered as preliminary. However, the used CV techniques showed promising results with relatively high accuracy also under non-optimal experimental conditions in sewer systems.

References

Ashley, R., Bertrand-Krajewski, JL., Hvitved-Jacobsen, T., & Verbank, M. 2004 Solids in sewers. Characteristics, effects and control of sewer solids and associated pollutants. 14, IWA Publishing.

Battiato, S., Farinella, G. M., Giudice, O., & Puglisi, G. 2016 Aligning shapes for symbol classification and retrieval. Multimedia Tools and Applications, 75(10), 5513-5531.

Böhm, T., Frey, P., Ducottet, C., Ancey, C., Jodeau, M., & Reboud, JL. 2006 2D motion of a set of particles in a free surface flow with image processing. Expe in fluids, 41(1), 1-11.

Radice, A., Malavasi, S., Ballio, F. 2006 Solid transport measurements through image processing. J Expe fluids.

Shahsavari, G., Arnaud-Fassetta, G., Bertilotti, R., Campisano, A. & Riou, F. 2015 Bed evolution under one-episode flushing in a trunk sewer in Paris, France. Journal of Civil and Environmental Engineering, 9 (7), 759-768.