Leveraging video data to assess urban pluvial flood hazard

J. P. Leitão[1]*, S. Peña-Haro[2]

[1]Department of Urban Water Management, Eawag, Überlandstrasse 133, 8600 Dübendorf, Switzerland
[2]Photrack AG, Ankerstrasse 16a, 8004 Zürich, Switzerland

*Corresponding author email: joaopaulo.leitao@eawag.ch

Highlights

- The Surface Structure Image Velocimetry (SSIV) method can provide relevant flood information
- Videos uploaded to social media platforms can be used to assess urban pluvial flood hazard
- The presented methodology can support real-time pluvial flood management in urban areas

Introduction: the need for urban pluvial flood management tools

During flooding caused by intense rainfall events, it is essential to assess the risk faced by people and also by rescue services. As presented by various authors (e.g. Shand et al., 2011), to estimate flood hazard to people and assets it is essential to consider both water depth and floodwaters velocity conditions. However, it is uncommon to have flood (water depth or flow velocity) sensors installed to provide such information. Therefore, real time pluvial flood hazard estimation is, in most situations, not possible. Nevertheless, more recently, a new set of information is becoming available through social media platforms, e.g. videos being a common type of data made available. These videos can provide useful information about floodwaters velocity and flood depth, which can ultimately be used to asses pluvial flood risk.

The objective of this study is to show the usefulness of videos found in social media platforms to estimate the flood depth and floodwaters surface velocity and ultimately assess pluvial flood risk. We analysed a flood event which took place on the June 16th, 2019 in Terceira island (the Azores, Portugal). Two videos were analysed and the flood hazard to people and evacuation services was calculated based on them.

Methodology: extracting flood information from video data

Santa Bárbara catchment (Terceira, the Azores, Portugal) and flood event characteristics (16 June 2019)
The case study used to demonstrate the proposed methodology (*Santa Bárbara* catchment; Figure 1) is located in the south west coast of Terceira island (the Azores, Portugal). On the evening of 16th June 2019, an intense rainfall event was recorded by the *Angra do Heroísmo* meteorological station which is located at approximately 10 km from the case study catchment. The accumulated rainfall volume amounted to 60.1 mm in 14 hours and 23 mm during two hours[1]. In comparison, the average rainfall volume for the entire month of June in the island is 48.8 mm!

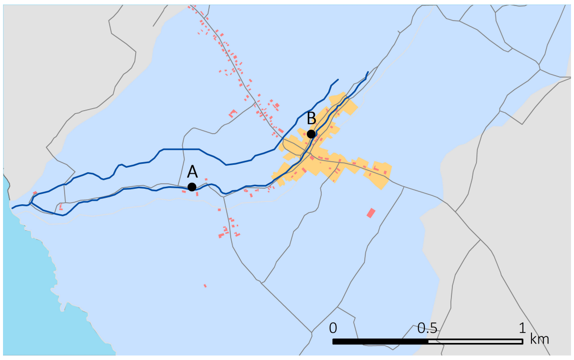


Figure 1. Location (Terceira island, the Azores, Portugal) of the videos used in this study (A: *Canada dos Vinte*; B: *Rua do Poço*). The red polygons in the figure represent buildings and the orange area represents the urban area.

[1] Data made available by Instituto Portugues do Mar e Atmosfera (IPMA): www.ipma.pt

The two videos used in this study were downloaded from social-media platforms (e.g. Facebook, YouTube) and were taken at locations A and B identified in Figure 1. One video has a duration of eight seconds while the other has a duration of 22 seconds – in any case, a short duration video (e.g. three seconds) is needed to calculate the flow surface velocity. As such, the videos were cut to where they were the most stable (i.e. with less camera movements). The videos were recorded using mobile phone cameras, and have a resolution of 224x400 pixels – although low, this resolution is sufficient to estimate the flow surface velocity according to Leitão et al. (2018).

Estimating velocity of floodwaters: the Surface Structure Image Velocimetry (SSIV) method
The surface velocity was estimated using the Surface Structure Image Velocimetry (SSIV) method developed by Photrack AG[2], which extracts the surface structures in the water surface and applies a cross-correlation technique to estimate the surface displacement.

Estimating flood depth
A few studies have presented methods to estimate flood depth from images. Most of these methods compare a known dimension of static structures in the image (e.g. bridge pillars, house doors, traffic signal posts) with the visible dimension of such structures during the flood event (e.g. Lv et al., 2018). One other method takes a slightly different approach by considering objects of standard sizes to estimate the depth of the water from images of flood scenes (Chaudary et al., 2019). In this study, we empirically estimated the water depth taking into account some estimation error associated with, which is considered during the flood risk assessment step.

Assessing flood risk for people safety and for evacuation route planning
The assessment of flood risk for people safety and for evacuation route planning followed the methodology presented in HR Wallingford et al. (2006). To estimate the flood risk level for people safety, the equation (1) and the hazard classes presented in Figure 3.2 of HR Wallingford et al. (2006) were used. Since the land uses of the case study catchment are mixed and the water depth estimation presents a significant level of uncertainty, the value of debris factor (DF) considered was 0.5.

$$HR = d \times (v + 0.5) + DF \qquad (1)$$

Where HR represents flood hazard rating (-), d is the depth of flooding (m), v is the velocity of floodwaters (m s^{-1}) and DF is a debris factor (-) varying from 0 to 1 (Udale-Clarke et al., 2005).

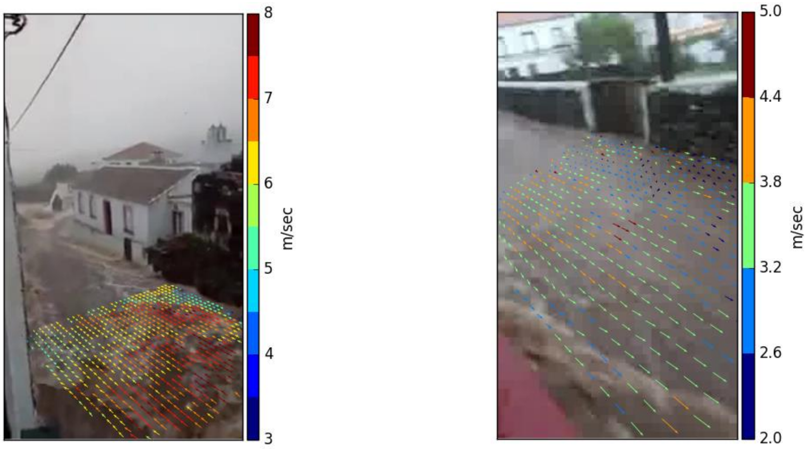
To assess the flood hazard for flood evacuation route planning, the methodology proposed in Ramsbottom et al. (2003) was implemented. Contrary to the flood risk assessment for people safety, in this case the flood risk is estimated using a simple graphic method (Figure B.1 in Ramsbottom et al., 2003) in which different levels (“Low”, “Medium”, “High” and “Extreme” hazard) of flood hazard for emergency planning are mapped.

The velocity of floodwaters and the depth of flooding are provided using the methods described in the two previous sections.

Results and discussion: enabling novel and real-time flood hazard mapping

Based on the videos of the two locations, one could estimate that the velocity of the floodwaters ranged (for the duration of the videos) between 2 and 8 m s^{-1} in the two locations. The maximum floodwaters surface velocity for location A and location B was 7.8 m s^{-1} and 4.8 m s^{-1}, respectively (Figure 2).

[2] Photrack AG: www.photrack.ch.



(a) Location A (*Canada dos Vinte*, Santa Bárbara) (b) Location B (*Rua do Poço*, Santa Bárbara)

Figure 2. Calculated velocity vectors for the two locations.

The maximum floodwaters surface velocity values were used to calculate the flood hazard (Table 1). These results reflect the fast flow conditions seen in the videos and show (i) the applicability of the SSIV method to estimate the velocity of fast flows and (ii) its usefulness to assess flood risk from observed events/ conditions (in *quasi* real-time).

Table 1. Flood hazard rating (HR) associated with people safety (yellow: "*Danger for some*"; orange: "*Danger for most*"; red: "*Danger for all*") and for flood emergency planning

	Flood hazard for people safety [-]		Flood hazard for flood evacuation route planning	
Depth [m]	Location A	Location B	Location A	Location B
0.1	*1.33*	*1.03*		
0.2	*2.16*	*1.56*	**Extreme hazard**	
0.3	*2.99*	*2.09*		

Conclusions and future work

The preliminary results obtained showed that the videos available on social media platforms can be used to determine the hazard caused by urban flooding to people, becoming an alternative and viable data source. However, the videos usually posted to social media platforms are of low-resolution and not stable, creating challenges to the use of the SSIV methodology. One way to overcome this challenge is to use surveillance cameras videos, which are in most of the cases stable. Further investigation will complement these preliminary results by evaluating additional flood videos of different flood events in different locations.

References

Chaudhary, P., D'Aronco, S., Moy de Vitry, M., Leitão, J.P., Wegner, J.D. (2019). Floodwater level estimation from social media images. In *ISPRS Annals Photogrammetry, Remote Sensing and Spatial Information Sciences*, IV-2/W5, 5-12. doi: 10.5194/isprsannals-IV-2-W5-5-2019

HR Wallingford, Flood Hazard Research Centre, Risk & Policy Analysts Ltd. (2006). *The Flood Risks to People Methodology,* Report FD2320/TR2. Defra – Flood Management Division, London, UK

Ramsbottom, D., Floyd, P., Penning-Rowsell, E. (2003). *Flood Risks to People – Phase 1*, Report FD2317/TR. Defra – Flood Management Division, London, UK

Leitão, J. P., Peña-Haro, S., Lüthi, B., Scheidegger, A., Moy de Vitry, M. (2018). Urban Overland Runoff Velocity Measurement with Consumer-Grade Surveillance Cameras and Surface Structure Image Velocimetry. *Journal of Hydrology*, 565 , 791–804. Doi: 10.1016/j.jhydrol.2018.09.001

Lv, Y., Gao, W., Yang, C., Wang, N. (2018). Inundated Areas Extraction Based on Raindrop Photometric Model (RPM) in Surveillance Video. *Water*, 10(10), 1332. Doi: 10.3390/w10101332

Shand, T., smith, G.P., Cox, R.J., Blacka, M. (2011). Development of Appropriate Criteria for the Safety and Stability of Persons and Vehicles in Floods. In Proceedings of the 34th World Congress of the International Association for Hydro- Environment Research and Engineering, June, Brisbane, Australia

Udale-Clarke, H., Ramsbottom, D., Dyer, B., Wade, S., Segura Dominguez, S., Bain, V., Davison, M., Surendran, S. (2005). *Flood Risk Assessment Guidance for New Development - Phase 2*, R&D Technical Report FD2320/TR2. Defra – Flood Management Division, London, UK