Drone Photogrammetry for Flood Preparedness

Krista Montgomery¹, Jorge Fernandez¹, Gabriele Ruggiero¹, Stefan Gordon²
¹Pix4D SA, Lausanne, Switzerland
²Microsoft, Washington, United States of America

Presenting author’s email address: jorge@pix4d.com, krista@pix4d.com

Biography of Presenting Author
Jorge Fernandez works at Pix4D in Switzerland as a business developer and marketing manager. With a background in Geo-Information Science and Earth Observation, his first contact with the drone-photogrammetry industry did not come from drones, but from advanced image processing instead. Drones, like small satellites, have tremendous potential to be unlocked, especially when combined with the right state-of-the-art photogrammetric software platforms.

Krista Montgomery is a writer at Pix4D, where she shares accounts of how professionals around the world are using the company’s drone-photogrammetry products. With a background of science in journalism, she is based at Pix4D headquarters in Lausanne, where the company was founded as a spin-off of EPFL in 2011.

Abstract:
The use of drones and drone-imagery in disaster response has become increasingly popular in recent years. However, very few organizations are currently using them to understand and reduce disaster risk in their community. Drone imagery, maps from photogrammetric software and flood simulation models present themselves as very valuable tools to survey and identify disaster-prone areas for a better understanding of flood risk.

Ideally, the combination of high resolution orthomosaics and digital elevation models (DEMs) as GIS software inputs can allow visualization of areas that would be under water at different flood intensities. DEMs and orthomosaics produced by photogrammetric software like Pix4Dmapper from drone-imagery are easily updatable, cm-grade resolution, and can be used as inputs for open source flood simulation models like Microsoft’s TerrainFlow. 3D visualization of water interaction on terrain provides better understanding and location of flood-prone areas.

The workflow’s affordability, ease-of-use and quick data acquisition time makes it accessible to those whose situation prevents them access to high-resolution topographical information or flow models. Such information has the potential to increase flood preparedness and management strategy, reduce hazard and evaluate water behavior through the consistent gathering of high-quality data. Civil engineers, government and non-government organizations, urban planners, agriculturalists, insurance companies and more have direct use impact potential.

Keywords: Drones, Flood, Photogrammetry, DEM, Disaster

Full Paper

Among natural disasters, flooding presents a substantial threat, with an average of over 100 events occurring every year (Guha-Sapir et al. 2015). According to the CRED/OFDA International Disaster Database, nearly 7,000 human beings are killed and around 100 million affected annually by flood events, with economic costs estimated at 14 billion US dollars (Guha-Sapir et al. 2015). Exact damage to infrastructure, water potability, public services, agriculture and the economy are difficult to quantify, not to mention the negative effect flooding has on society due to loss of human live and hardship inflicted on survivors.

The factors of flooding and flood-risk involve a unique combination of environmental and man-made forces. Some of the most obvious are related to the amount of rainfall, the elevation and shape of terrain, and type and location of existing water bodies in the region. Other contributing factors to flood risk are soil type and permeability; the location and quantity of buildings, infrastructure and man-made tunnels; as well as the type and location of vegetation. Physically at-risk areas notwithstanding, populations are not equally vulnerable to the effects of water disasters. Those...
living in flood-prone areas with limited access to weather services, flood management structures or warning systems live in higher danger of being caught defenseless or unprepared by a flood (Begum et al. 2007). Populations exposed to poverty and conflict situations, especially, live in augmented risk due in large part to lack of services or information. High population dense areas also have increased vulnerability to flooding, as well as those who earn a living dependent on favorable environmental conditions, like farmers and agriculturalists.

Apart from efficient disaster response management, the public and private bodies responsible for flood risk management have the complex task of assessing and mapping flood risk areas in order to implement both preparedness planning and efficient warning systems. Reducing flood damage requires this identification and estimation of potential flood severity and timing, knowledge which is driven and supported by detailed flood models on a global and local scale (Morita 2014). Constructing flood defenses, controlling development in danger zones, planning disaster response action and issuing timely warnings depends on such information.

Flood prediction is currently based on a variety of complex behavioral prediction models, which are used by hydrologists and emergency management administration to estimate flood scale, timing and risk for specific areas. Specialized, tailored models are needed due to variability in topography and interaction of contributing flood factors. In addition to a calibrated model, quality hydrological, meteorological and geological data is essential (Sulebak 2000). Meteorology stations collect data from ground equipment to satellite, adding it to recorded information and creating weather forecasts: the large amount of climate information provided by satellite and remote sensing as well as ground observations is vital to support long and short-term flood prediction models.

A basic requirement for these prediction models is a Digital Elevation Model (DEM): a 3D topographic map that shows the elevation data, contour lines and slope of an area in digital format. These are traditionally obtained via airborne surveys, satellite imagery and LiDAR sensing. Accurate DEMs facilitate reliable flood inundation modeling, as flood model predictions are affected by both DEM scale and resolution (Sulebak 2000). Figure 1 shows a photogrammetric digital surface model (DSM), a type of elevation model, as an example.

The topography of many floodplains in the developing world has been surveyed with high resolution sensors, providing high quality DEMs of a majority of populated areas. Access to this data is limited, however, due to the costs associated in obtaining and analyzing it, as well as the reluctance of the authorities to release it for either security reasons or the potential impact it could have on property prices and the local economy (Sampson et al. 2016). For remote areas and spaces in many developing countries, quality terrain data is often simply not available. Publicly accessible or free data sets, notably the global digital elevation models provided by the Shuttle Radar Topography Mission (SRTM) and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), have a raw
data resolution of between one arcsecond (30m) and three arcseconds (90m), which has limitations due to the resolution and present errors (Nikolakopoulos et al. 2006).

For flood assessment and prediction to be as accurate as possible, the DEM must contain a large amount of terrain information and be up-to-date. This means high-resolution, or Ground Surface Distance (GSD) and correctly-scaled data that is current with changes in vegetation, landscape and building development. Global datasets like SRTM, for example, are nearing 20 years old and risk being outdated, especially in developing countries and areas that have seen drastic change (Sampson et al. 2016). Acquiring this data along with the use of calibrated prediction models has traditionally been expensive and limited, making proper flood analysis and weather prediction limited to highly populated areas in wealthy nations (Sampson et al. 2016).

Drone technology, photogrammetry software, and the development of open-source flood simulation models create new possibilities in remote sensing and management of hazard-prone areas. Easy to operate and globally accessible, drones are now capable of acquiring high-resolution aerial imagery at low cost. Other surveying options to acquire high resolution DSMs, TLS for example, costs two or three times that of a UAV survey (Mancini et al. 2013). This imagery, taken specifically for mapping, is used in advanced photogrammetric software to produce topographic maps and models. One such software, Pix4Dmapper, uses computer vision principles to convert overlapping images into precise 3D point clouds and digital surface models (DSMs), with vertical resolution that can reach centimeter-level accuracy. This enables buildings, riverbanks, ditches and vegetation detail to be captured and accounted for in a flow model. Drone imagery is acquired beneath the cloud coverage line, avoiding the need for satellite VHR imagery for generating DEMs.

An example of this use can be found in a research project done by the Disaster Prevention Research Center of Taiwan, who used a UAPER drone, Samsung NX1000 camera and Pix4Dmapper to produce digital surface models of the Ba-Tz river creek. Modeling was done before and after the flood periods between 2012 and 2014, and DSMs were compared over time in order to monitor and further control river stability as seen in Figure 2 (Yen 2015). The drone imagery provided an affordable option for frequent data collection as vegetation coverage varied up to 36 percent. In order to check accuracy, elevation differences of the generated DSMs were compared with surveyed ground points, with an average difference value of 0.08 meters and standard deviation of 0.096 meters; this matches the ground truth data enough to be considered reliable (Yen 2015).

Another particularly useful application of drone-imagery DSMs is for coastal mapping: areas at risk for flooding where the constantly changing coastal geomorphology requires accurate and highly detailed topographic information in order to provide trustworthy flood risk evaluation. Researchers from the University of Bologna, Technical University of Bari and SAL Engineering tested UAV imagery and photogrammetric software in order to produce highly accurate DSMs of a foredune in Ravenna, Italy on the North Adriatic coast. They found the workflow promising and highly automated, giving fast data access with topographic quality and vertical accuracy comparable to GNSS survey data.
(Mancini et al. 2013). Figure 3 shows a small island, representing the type of coastal mapping mentioned above in a DSM.

![Fig. 3. DSM of a small island, produced in Pix4Dmapper using drone-acquired imagery.](image)

These high-resolution maps can then be placed into flood simulators like Terrain Flow, a free and open source modeling system currently being developed by Microsoft, that predict rainfall and water behavior in 3D. TerrainFlow will provide a visualization of water absorption, collection and path using topographic maps as inputs. For those who are unable to invest significant resources in soil testing and customized professional models, TerrainFlow is accessible and offers insight on water and land interaction without requiring specialized training. Users will be able to select variables such as soil type, rainfall intensity and duration, as well as simulate the effect of land modifications (like the building of a pond, channel or trench) and artificial water sources. Requiring only GeoTIFF elevation maps (DEMs) and available public data as inputs, the barrier to entry would be lowered significantly. The 3D simulation will be viewable in real time with adjustable speed and perspective, providing data for a quick understanding of potential flood hazards, improvements in water management, or further investment needs.

The low cost and learning curve of drone technology, Pix4Dmapper and TerrainFlow enable those with little access to high-resolution data or the resources to invest in flood prediction models to gather their own accurate topographical data for regular updates of rapidly changing and high flood-risk areas. Although not capable of replacing traditional remote sensing and flood prediction techniques, this workflow has enormous potential in both providing high quality DSMs and analyzing land and water interaction for disaster preparedness purposes and more:

- Environmental resources monitoring
- Agricultural management
- Civil engineering/city planning
- Water management
- Insurance purposes

For future research, local floodplain knowledge gained via this workflow can serve to compliment large scale topographical information from satellite data, and even be integrated together. Small and high resolution predictions could be combined with broader satellite data in databases or complex meteorological simulation models for a more holistic view of water behavior, as well as contribute to long-term information usage. In the future, topographical information, flood behavior patterns and best practices might also increasingly be available online, compatible to industry integration and open to collaboration for better disaster preparedness practices worldwide.
References


