MEASURING SURFACE WATER FLOW VELOCITIES BY A DRONE AND LARGE-SCALE PARTICLE IMAGE VELOCIMETRY (LSPIV)

Traditionally, flow velocities in water systems are measured using advanced and expensive velocity measuring equipment. Examples of such equipment are Acoustic Doppler Velocimeters (ADVs) and Acoustic Doppler Current Profilers (ADCPs). They can be characterised as intrusive instruments and are ill-suited for measurements in shallow water channels, large-scale flow phenomena (e.g., flood flows), or inaccessible locations (e.g., densely vegetated systems). Velocity measurement methods employing remote sensing technologies have been recently explored and may offer a solution to this challenge. This research work assessed whether it is possible to use video recordings obtained by a drone to reliably estimate surface water flow velocities in large-scale fluvial applications.

The so-called ‘large-scale particle image velocimetry’ (LSPIV) method was used. The LSPIV method aims to generate a two-dimensional velocity field based on the recorded motion of visible particles (e.g., plastic beads, foam, air bubbles) on the water surface. High-speed spatial cross-correlation is employed in this method to relate the particle displacements in the video recording to the surface velocities in the flow.

The LSPIV workflow can be characterised by four main stages, including (1) data acquisition; (2) image pre-processing; (3) image evaluation; and (4) post-processing. First, video recordings were collected downstream of a hydraulic structure in the Dinkel River (Figures 1 and 2) and Meuse River study areas using a commercial drone. Next, the recordings were pre-processed to eliminate image distortions and deformations. Afterwards, a time series of velocity fields was generated, representing the instantaneous surface flow velocities. Finally, the velocity fields were time-averaged, spurious velocity vectors were removed, and an accuracy assessment was performed.

Figure 1: Weir in the Dinkel River. Note the natural flow seeding (foam) due to the interaction between the water and weir.

The findings of this research reveal that, under the right conditions, drone-based LSPIV can derive velocity fields (e.g., Figure 3) that accurately describe the bulk flow behaviour and capture horizontal flow structures at different spatial scales. Whether adequate LSPIV performance can be achieved highly depends on the seeding conditions, that is the seeding density and spatial distribution of particles across the water surface. Low seeding densities (<10%) and seeding inhomogeneity were detrimental to the measurement accuracy. Based on a sensitivity analysis, the key parameters are the frame rate of the video recording, interrogation area size, and video recording duration; these parameters must be specified with extreme care prior to the LSPIV analysis. All in all, drone-based LSPIV may allow for quick, safe and comprehensive quantification of surface flow velocities. However, flow seeding remains a critical limitation.

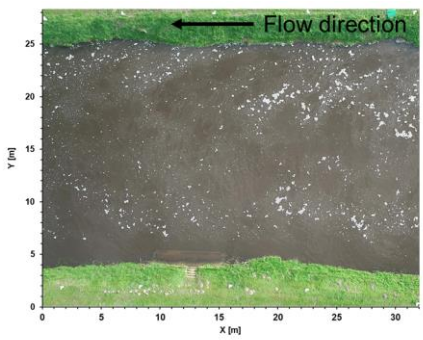

Figure 2: Snapshot of a reach of the Dinkel River located 75 m downstream of the weir as shown in Fig. 1. Recording was obtained by a drone at a height of 40 m.

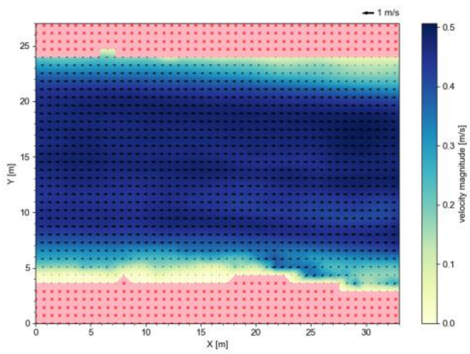

Figure 3: Surface water flow velocity field corresponding to the video recording in Fig.2 time-averaged over 60 s.

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