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An evaluation of image velocimetry techniques under low flow conditions and high seeding densities using Unmanned Aerial Systems

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Image velocimetry (IV) is a remote technique which calculates surface flow velocities of rivers (or fluids) via a range of cross-correlation and tracking algorithms. IV can be implemented via a range of camera sensors which can be mounted on tri-pods, or Unmanned Aerial Systems (UAS). IV has proven a powerful technique for monitoring river flows during flood conditions, whereby traditional in-situ techniques would be unsafe to deploy. However, little research has focussed upon the application of such techniques during low flow conditions. The applicability of IV to low flow studies could aid data collection at a higher spatial and temporal resolution than is currently available. Many IV techniques are under-development, that utilise different cross-correlation and tracking algorithms, including, Large Scale Particle Image Velocimetry (LSPIV), Large Scale Particle Tracking Velocimetry (LSPTV), Optical Tracking Velocimetry (OTV), Kanade Lucas Tomasi Image Velocimetry (KLT-IV) and Surface Structure Image Velocimetry (SSIV). Nevertheless, the true applications and limitations of such algorithms have yet to be extensively tested. Therefore, this study aimed to conduct a sensitivity analysis on the commonly relatable parameters between the different algorithms, including the particle identification area parameters (such as Interrogation Area (LSPIV, LSPTV and SSIV), Block Size (KLT-IV) and Trajectory Length (OTV)) and the feature extraction rate (or sub sampled frame rate).

Fieldwork was carried out on Kolubara River near the city of Obrenovac in Central Serbia. Cross-sectional surface width was relatively constant, varying between 23.30 and 23.45m. During the

experiment, low flow conditions were present with a discharge of approx. 3.4m^3 s^{-1} (estimated using a Sontek M9 ADCP), and depths of up to 1.9m. A DJI Phantom 4 Pro UAS was used to collect video data of the surface flow. Artificial seeding material (wood-mulch) was distributed homogenously across the rivers' surface, in order to improve the conditions for IV techniques during slow flows. Two 30-second videos were utilised for surface velocity analysis.

This study highlighted that KLT, SSIV, OTV and LSPIV are the least sensitive algorithms to changing parameters when no pre- or post-processing of results are conducted. On the other hand, LSPTV must undergo post-processing procedures in order to avoid spurious results and only then, results may be reliable. Furthermore, KLT and SSIV highlighted a slight sensitivity to changing the feature extraction rate, however changing the particle identification area did not affect significantly the outputted surface velocity results. OTV and LSPTV, on the other hand, highlighted that changing the particle identification area provided a higher variability in the results, whilst changing the feature extraction rate did not affect the surface velocity outputs. LSPIV proved to be sensitive to changing both the feature extraction rate and the particle identification area.

This analysis has led to the conclusions that during the conditions of sampling with surface velocities of approximately 0.12ms^{-1}, and homogeneous seeding on the rivers surface, IV techniques can provide results comparable to traditional techniques such as ADCPs during low flow conditions. All IV algorithms provided results that were, on average, within 0.05ms^{-1} of the ADCP measurements.