

Characterizing mixing properties in large rivers based on UAV measured Lagrangian surface flow data

M. Zsugyel

MTA-BME Water Management Research Group, Budapest

G. Lükő and S. Baranya

Budapest University of Technology and Economics, Budapest

ABSTRACT

A data processing method is presented for characterizing large rivers surface mixing processes in a groyne field, using an affordable, i.e. low-cost and easy-to-learn, new field data acquiring technique: Unmanned Aerial Vehicles (UAVs).

1 INTRODUCTION

In the last decade, indirect video based velocity measurement methods are available to investigate river surface flow, e.g. large-scale particle image velocimetry (LSPIV) [1] and space-time image velocimetry (STIV) [2]. These methods deal with the Eulerian analysis of the flow, i.e. the flow is described at fixed points. However, in the last few years, the use of Unmanned Aerial Vehicles (UAVs) in engineering surveys became very popular thanks to the increasing value-for-money and the always developing, user-friendly attitude of this tools. UAVs have a huge potential also in river engineering measurements, since the airborne video recordings inherently allow us to observe the surface processes based on a Lagrangian view, i.e. to describe the flow field with moving particles in the water. In this study the Particle Tracking Velocimetry (PTV) method was applied to assess the spatially complex nature of the flow field in a large river. To the authors' knowledge no such analysis has been performed yet to describe the flow field and mixing processes in large rivers.

2 FIELD MEASUREMENTS

Airborne videos about the water surface were taken by a DJI Phantom 3 Standard UAV at a groyne field in the Danube River in Hungary. This UAV is able to fly safely about 15-20 minutes continuously and has a 2.7K resolution camera with high frequency (30 fps) sampling. In order to reveal a Lagrangian velocity flow field of the water surface, hundreds of

regular yellow tennis balls were used as floating tracers. These balls were deployed close together at the same time from a boat upstream to the tip of the groyne. The motion of the balls was recorded in such way that the UAV stayed in the same position until the balls left the field of view (107 m x 60 m from 50 m height). When it was happened the UAV was driven into a new position where it stayed for a longer time again. This process was repeated until the UAV's needed to recharge. Finally, the balls were collected by the stuff of the boat for the next release. Complementary moving boat acoustic Doppler current profiler (ADCP) measurements were also performed to capture the three-dimensional flow velocity field. The post-processed ADCP measurements provided Eulerian spatio-temporally averaged flow field, which could be directly compared with the Lagrangian approach.

3 IMAGE PROCESSING ALGORITHM

A multi-object tracking algorithm in MATLAB was improved to analyze our UAV videos. The algorithm is based on two main pillars: the *particle detection* and the *particle matching*. In the very first step the video must be segmented into images in a given frame rate. In each image a color masking is performed using the built-in Image Thresholder MATLAB App. Only the yellowish pixels remain in the image, everything else is blocked out, so the remaining calculations became much faster and the results contain less bad detections. However, the shimmering on the water surface cannot be entirely eliminated. Next, according to the size of the tracer, a Gaussian filter is determined and applied to every images. This results in a kind of 'heat map', where the structures (floating balls in our case) of the given size are recognized by appearing high values. The appropriate choose of the threshold value can separate the real floating particles from the shimmering effects. Finally, a local 2D extreme value finder function determines the center of every detected

tracer particle. In Figure 1 an example of the final result of the particle detection algorithm in a single frame is shown.

The particle matching frame by frame is then calculated using a Kálmán filter algorithm. According to the estimated position of a tracer, based on the expected surface velocity, the algorithm calculates a distance (cost) matrix to all possible detections in the next time step. The lowest distance between the estimated and real positions will be accepted as the new particle position. If the lowest distance is greater than a given value, the particle is defined as lost particle and will be not tracked in the future.

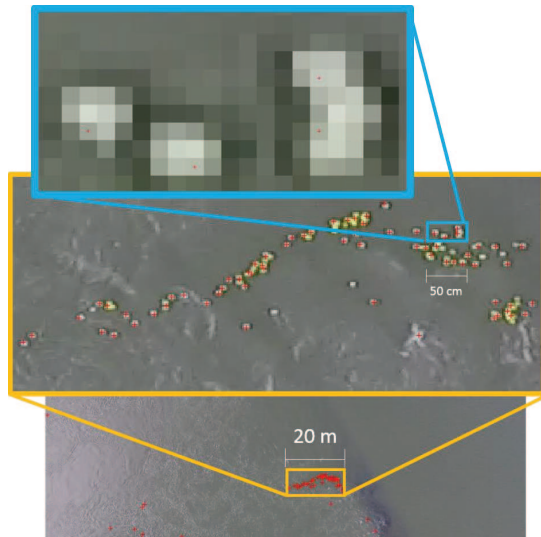


Figure 1. Result of the tracer particle detection in three different size scale: the tracer size, the size of the floating dye and the original image, from up to down, respectively.

4 RESULTS

In Figure 2 the reconstructed trajectories of the first UAV position are shown. From this position the field of view contains the closest vicinity of the groyne, including the main flow, the shear zone and the recirculation zone, from left to right, respectively. The crossing tracer trajectories clearly indicate unsteady, complex flow characteristics. The transversal motion of the tracers indicates the mixing effect of the vortices generated by the shear layer at the groynes.

A quantitative assessment on mixing parameters can be performed based on the reconstructed Lagrangian instantaneous velocity field. Moreover, the large number of long floating particle paths allows us to quantify chaotic mixing features [3] in real large river environment.

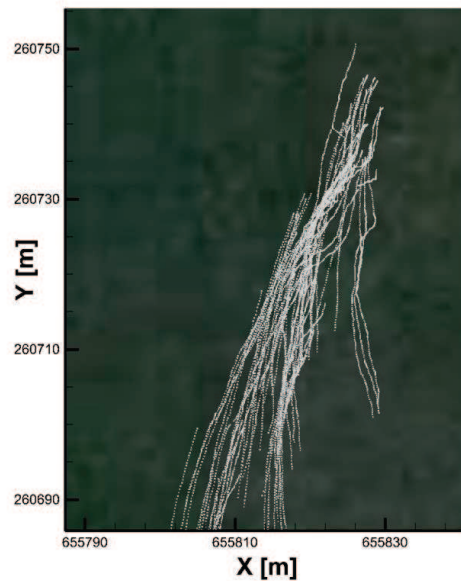


Figure 2. Tracer trajectories reconstructed from the UAV video recordings. The crossing trajectories indicate the complex mixing occurred in the shear zone of the groyne field. (A groyne tip is about the upper right corner of the image and the river flows from top to bottom, spatial coordinates are in local system.)

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