A novel sensor platform for the rapid hydraulic characterisation of freshwater ecosystems

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1. Problem – traditional river surveying

Hydraulic assessments of in-stream habitats rely on measurements of water velocities and depths. Traditional measurement approaches (e.g. with hand-held current meters) are time-consuming, costly and require good site accessibility. A tool to enable rapid hydraulic measurements is needed.

Fig.1. Flow measurement on the River Thames at Windsor, mid 1980s

2. Project aims

A) To develop a radio-control sensor platform for rapid eco-hydraulic river assessments. The platform should - allow single-person deployment - enable data collection from multiple on-board sensors - ensure minimal data bias from pitch and roll motion

B) To develop a platform positioning system that enables precise spatial data referencing and future platform autonomy

This is achieved by transferring recent advances in open-source electronics and robotics to river sciences.

Fig.2. Platform on its transportation truck

3. Sensor platform features

Multiple-sensor data logging

Time-synchronised and spatially referenced data from multiple on-board sensors are logged on one or more computers on board and on the river bank. Currently integrated sensors include:

- Acoustic Doppler Current Profiler (ADCP)
- Bumblebee stereo-camera
- U-blox 6P GPS receiver
- X-IMU inertial measurement unit

3D water velocity & depths to quantify spatial velocity distributions & bathymetry
Stereo-frames to estimate platform position and 3D maps of the river environment
Platform positions and data synchronisation
Platform yaw, pitch & roll

Fig.3. Platform carrying a RiverSurveyor M9 ADCP on the River Thames at Eynsham, 06/02/2014

Minimal data bias from platform pitch and roll

Platform pitch and roll cause position errors in the ADCP-measured water velocities and depths. This error is quantified based on the measurements of the on-board IMU (e.g. Fig.4 & 5).

Fig.4 & 5. Pitch & roll quantification for a track

Future platform autonomy?

Platform autonomy can facilitate the implementation of pre-defined survey strategies. Real-time communication between a position logging on-board Raspberry Pi computer and the embedded propulsion control (Arduino Uno) builds the hardware basis for platform autonomy.

Fig.7. Raspberry Pi and Arduino Uno for data logging and propulsion control

4. Platform positioning system

Platform positioning is required (a) to spatially reference the hydraulic data and (b) to enable platform autonomy. Global (GPS) and local (visual SLAM) positioning techniques will be integrated.

GPS failure in densely vegetated river sections
In small rivers, vegetation can limit sky view to navigation satellites for a considerable proportion of the water surface. A low number of navigation satellites “in view” and unfavourable satellite geometry leads to degraded GPS position accuracy.

This was shown with a Hemisphere Eclipse II GPS receiver during a survey on the River Avon at Pershore. In areas with a low number of satellites and relatively high horizontal dilution of precision (HDOP) alternative, local positioning technologies are required.

Visual SLAM – positioning beyond GPS
In visual Simultaneous Localisation and Mapping (SLAM), the platform position is estimated based on stereo-images from on-board cameras. Simultaneously a 3D map of the river environment is created. This offers novel opportunities for the characterisation of river ecosystems based on image analysis.

Fig.8. GPS performance assessment on the River Avon at Pershore, 12/12/2012

Fig.9. Major steps in visual SLAM a) capturing stereo-images; b) estimation of scanline depth based on the binocular disparity of the stereo images; c) detection of salient features in the left-right intensity image; d) tracking of these features through consecutive image frames; e) pose estimate based on the 3D position change of the features relative to the platform

Platform pose estimate

Fig.6. Position error in ADCP measured water velocities and depths due to deployment platform pitch & roll

Platform track

3D water velocity & depths to quantify spatial velocity distributions & bathymetry