APPLICATION OF STRUCTURE FROM MOTION FOR LARGE WOODY DEBRIS RESEARCH

GABRIEL SPREITZER
Department of Civil & Environmental Engineering, University of Auckland, 262-390 Khyber Pass Rd., Auckland, 1010, New Zealand

JON TUNNICLIFFE
School of Environment, University of Auckland, 20 Symonds St., Auckland, 1010, New Zealand

HEIDE FRIEDRICH
Department of Civil & Environmental Engineering, University of Auckland, 23 Symonds St., Auckland, 1010, New Zealand

Large woody debris (LWD), together with overhanging bank vegetation and large rocks are generally attributed as microhabitat ecosystem units that influence riparian vegetation and sedimentation processes. Especially for hydraulic flow conditions during extreme flood events, when most in-stream material is mobile, it is important to consider interactions of biotic (LWD) and abiotic (sediments) materials. For the investigation of LWD accumulations on channel formation processes we are introducing Structure from Motion (SfM) methodology for capturing both, sediment dynamics as well as LWD jam formation. A multi-camera array, consisting of off-the shelf cameras, has been design to capture high resolution images that can provide detailed information about shape and size of a debris accumulation and volume dynamics of bedload activities. All tests and experiments are undertaken in a custom designed, fully scaled river channel. A cart, with the installed multi-camera array, running on rails at the top of the flume, ensures high quality data collection. Benefits of using SfM in the laboratory are guided by being low cost and allowing fast data collection, in contrast to a commonly used technology, such as laser scanning. Ultimately, the aim of our work is to gain a better understanding of biotic/abiotic interaction processes in stream systems, to enhance freshwater ecosystem management.

1 INTRODUCTION

Natural forest disturbance and modern forest harvesting techniques produce significant quantities of large woody debris (LWD) in steep mountain terrain that tend to develop into jams. These in-channel accumulations may affect a stream's runoff behaviour and hydraulic capacity, which can have both, positive and negative outcomes. LWD is a valuable part of a fluvial ecosystem, providing habitat and environmental complexity for numerous living organisms [1]. Wood can protect stream sections from erosion. It regulates a river's sediment budget, due to sediment storage and energy dissipation processes [2-5]. On the other hand, LWD in fluvial systems can be dangerous for infrastructure, when it is transported during flood events and accumulates at constricted cross-sections. LWD considers any species of wood in a water system, exceeding a certain dimension per definition. A common metric for 'large wood' dimensions has been described in previous studies as wood pieces with a minimum dimension of 0.1 m in diameter and at least 1 m in length [6-11].

Here, we are investigating the use of Structure for Motion (SfM) to capture LWD accumulations. Our research takes into account the effects of LWD accumulations on hydraulic flow conditions and channel morphological changes. A multi-camera array, consisting of five cameras, captures sequences of channel bed dynamics, which are processed via a commercial photogrammetry software, to generate digital elevation models (DEMs). The three-dimensional model of the channel course provides information about location and volume of aggradation and erosion fields, formed in the presence of a LWD accumulation. The gained knowledge of this work will inform New Zealand's freshwater and forestry management.

2 METHODOLOGY

2.1 Experimental Setup

Our experiments take place in a 6 m long, 1.5 m wide and 1 m deep, glass sided flume at the Water Engineering Laboratory of the University of Auckland. An inlet structure with flow straightener was installed at the upstream end of the flume, while the discharge is adjustable with a valve, ranging from 3 to 75 l/s. In the flume, a fully scaled river section has been built with a scale ratio of 1:15 (Figure 1). 4 m downstream of the inlet structure a 'one-lane-bridge' with a single pier represents the constricted cross-section. The environment in the flume was designed according to a prototype steepland New Zealand catchment, with a size of roughly 100 km2. The channel bed consists of a mobile gravel mixture in the range of 4 to 63 mm, whereas the embankments are fixed with an 8 to 16 mm gravel concrete mixture. An outlet structure with two fine material screens, sediment trap and tail gate was installed. At the top, at a height of 1 m, a cart traverses in streamwise direction, carrying the multi-camera array. A novel, custom-designed conveyor-belt feeder supplies gravel and wood to the channel, a short distance downstream of the flow straightener. This system allows very accurate control on feeding rates, even with bulky material such as coarse gravel and wood logs of various size.

Figure 1. Plan view of LWD accumulation in our laboratory setup.

Investigation of interaction processes between bedload material and a log jam formation at a single bridge pier is undertaken in line with the following procedure to ensure the same initial conditions for each experiment. Each experimental data set consists of three runs. Before each test run, the mobile channel bed is installed. Firstly, experiments without debris accumulation are undertaken, before bedload changes are observed caused by a fixed installed LWD accumulation at the bridge. Thereafter, an initial flowrate of 5 to 10 l/s lasting 4 hours establishes an armour layer, before being followed by a flood event, which is specified as a 75 l/s discharge, lasting for 30 minutes. SfM images are obtained for each of the three stages. During post-processing a DEM of difference (DoD) is obtained. This will provide information about changes in volume and location of aggradation and erosion zones.

2.2 Structure from Motion (SfM)

SfM uses a combination of multi-view stereo and bundle adjustment techniques [12, 13] to generate a three-dimensional model (Figure 2) from images taken from slightly different perspectives. Over the last few years this photogrammetric surveying tool has become more attractive for field and laboratory, as demonstrated in several recent studies [13-15]. In order to obtain relatively cheap, detailed and accurate surveys of our experimental setup, we are using a multi-camera array consisting of five off-the-shelf high resolution cameras with a 13 MP image sensor (Figure 2). The cameras are set in a fixed alignment at a height of 1 m above the channel bed. The geometry of the camera array provides an image overlap of 84% for SfM reconstruction. Altogether 250 images are obtained for each set of images. This is sufficient to generate point clouds exceeding 10 million data points, covering an area of around 7.5 m2.

Figure 2. SfM setup (left,a) and orthophoto of LWD accumulation captured with SfM (right,b).

3 RESULTS AND DISCUSSIONS

We tested the suitability of SfM for the investigation of log jam formation processes with a manually assembled LWD accumulation. An orthophoto, as captured with our SfM setup, is shown in Figure 2. This shows the suitability of SfM for future LWD research. The data allows volumetric calculation of the accumulation. Considering energy losses, accompanied with LWD accumulations and backwater effects, then allows to study the effect on bedload transport. So far, little is known about LWD dynamics, especially about the interaction processes with the channel bed and sediment transport, and our research will provide data to better understand those processes.

Since MacVicar and Piégay [16] demonstrated that most LWD material is transported at the rising limb of the hydrograph, it is likely that an already developed accumulation will block the constricted cross-section at peak discharge. LWD thus reduces the conveyance capacity of a cross-sectional flow area. A significant decrease in discharge occurs in combination with fine material [17, 18], which is often neglected in research studies. Decreases in the porosity of a large wood accumulation results in a higher accumulation density. As a result of this cross-sectional reduction, backwater effects may occur, as shown in Figure 3, leading to overtopping of stop banks and flooding of the riparian zone.

Figure 3. Side view - observed backwater effect (in red the backwater influenced water level, in blue the normal water level).

4 CONCLUSIONS

We do expect that using SfM will improve our knowledge of log jam formation mechanisms and transport processes, and in turn better understanding of the ecohydraulic influences of LWD. Our current research project investigates LWD in a laboratory flume, there is still a large gap in our knowledge of better understanding LWD movement and accumulation processes. In future, we will work on incorporating the measurement of LWD impact forces.

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