Publications of the Institute of Geophysics, Polish Academy of Sciences
Geophysical Data Bases, Processing and Instrumentation
vol. 439 (E-12), 2022, pp. 5-8
DOI: 10.25171/InstGeoph_PAS_Publs-2022-003
Webinar on Methods for Ecohydraulics: Remote Sensing, 17–20 May 2022

Experiences with LiDAR and Aerial Imagery for the Assessment of Winter Habitat, Hydraulic Modelling and Riverscape Classification

Knut ALFREDSEN

Norwegian University of Science and Technology,
Department of Civil and Environmental Engineering, Trondheim, Norway

✉ Knut.Alfredsen@ntnu.no

Abstract

The growing availability of remote sensed data provides new opportunities for analysis of conditions in lakes and rivers. Scanned terrain and bathymetry from LiDAR, various kind of satellite and aerial imagery and climatic data from satellite and combined products provide both a spatial and temporal resolution that is unavailable in traditional measurement approaches. Examples of use is drones and structure from motion to map ice formation and remnants in rivers. Effects of river ice is important for instream habitat in cold climate rivers and notoriously difficult to measure. Topographic and bathymetric LiDAR is used to build terrain models as a foundation for hydraulic modelling, providing highly detailed and accurate models. Finally, machine learning is used to classify historical aerial imagery providing a basis for the evaluation of the development of rivers.

Keywords: LiDAR, aerial imagery, hydraulic modelling, winter habitat, environmental assessment.

1. INTRODUCTION

Many analyses in eco-hydraulics require accurate spatial and temporal data. Recent developments in remote sensing techniques have opened new possibilities for a multitude of analysis, and data with better spatial and temporal resolution are becoming readily available. Data are both available from satellite and other larger aerial platforms, but the increasing availability of relatively low-cost drones with cameras and other instruments also opens possibilities for collecting remote sensed data on our own. This abstract briefly summarizes some applications.

2. EXAMPLES OF REMOTE SENSING APPLICATIONS

2.1 Using drones and structure from motion for winter habitat assessment

Instream habitat in winter in cold climate regions is strongly controlled by the formation of different forms of river ice, and the break-up of river ice can create sudden alterations to flow conditions and scouring of the riverbed from drifting ice. Mapping river ice can be a difficult undertaking since access to the ice in rivers can be difficult and at times even dangerous. For larger rivers, satellite imagery is commonly used to describe river ice on large scales, but for smaller rivers or cases where detail is needed the resolution of satellite images might not be adequate. Combining drone imagery and structure from motion allows for the creation of digital terrain models of various types of ice forming on the rivers (Alfredsen et al. 2018). This DEM could be used to evaluate ice forms and ice masses in rivers (Rødtang et al. 2021), provide input to hydraulic modelling and used to evaluate the ice impacts on flow and available habitats. The drone-based approach provides a fast and safe sampling method and through successive measurements the formation and decay of river ice can be quantified. Figure 1 shows and orthophotomosaic of anchor ice formation in the river Sokna in Norway. The damming effect of the ice significantly transform the depth and velocity distribution in the river section and alters the available habitat in a period with dropping or near constant discharge.

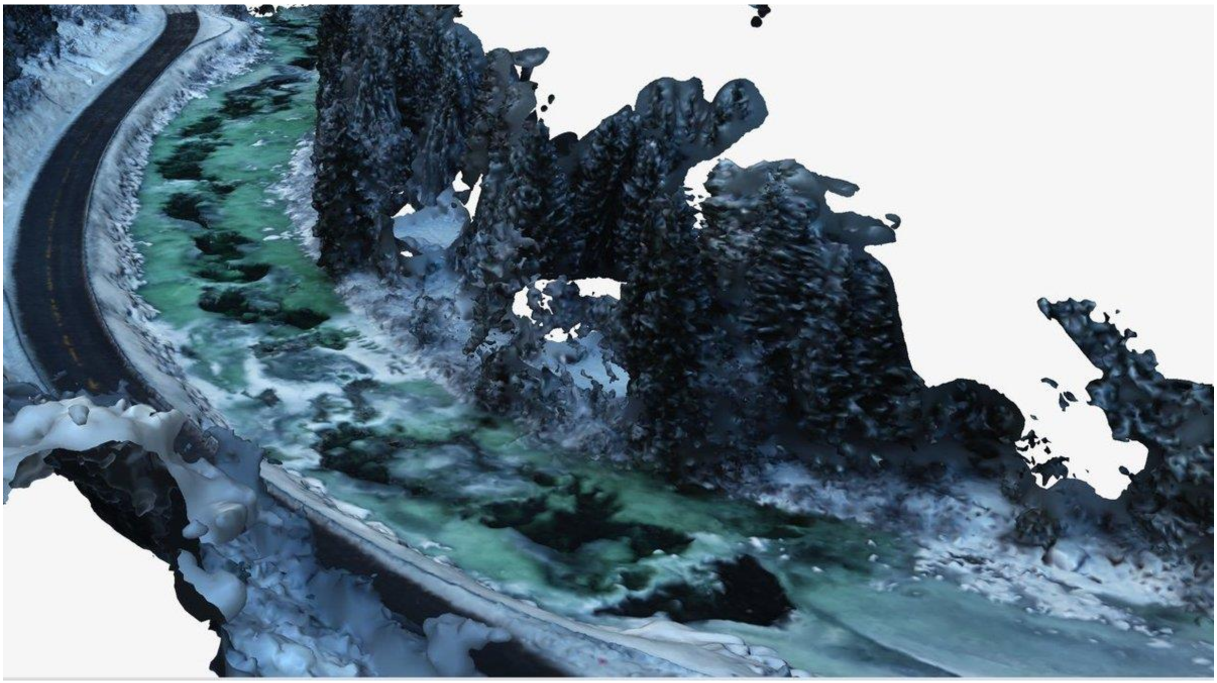

Fig. 1. Drone imagery of anchor ice damming a section of the river Sokna in Norway.

2.2 Using bathymetric LiDAR for hydraulic modelling

Hydraulic modelling has many applications in eco-hydraulics and have been used since the initial tools for the assessment of physical habitats were developed several decades ago. Providing data in adequate detail for the hydraulic simulation tools can be a challenge, and it can be time consuming and costly. The advent of bathymetric LiDAR provides a tool that can create highly detailed elevation models of rivers suitable for several different applications. Juarez et al. (2019) used a detailed LiDAR bathymetry and a hydraulic model of the Storåne river in Norway to predict ramping rates and dried out areas downstream of the Hol 1 power plant during peaking operation. The model was evaluated against measured water levels and water covered areas from aerial imagery and provided an accurate description of the wetted areas for the range of the production discharges of the power plant. The results from the modelling study was used to propose an alternative operational regime that would reduce the stranding potential for fish in the dried out areas.

Historically, weirs have been used as a compensation measure in several regulated rivers in Norway to maintain water covered areas for several different reasons including ecology, visual aesthetics, recreational fishing and to keep ground water levels in adjacent farmlands. Recently the effects of weirs have been questioned, and possible negative effects on migration of fish and quality of habitat have been raised. Removal or adjustments of weirs have been done, and the precise terrain description available from LiDAR data can be utilised in assessing the effect of weir removal projects (Brekke 2020; Junker-Köhler and Sundt 2021). Through modelling the weir and different adjustment options the effect of the changes can be assessed both up-stream and downstream the weir providing input for the planning process of the removal. The precise elevation models obtained through the bathymetric LiDAR is also promising related to sediments and the assessment of the geomorphology of rivers.

2.3 Historical development of rivers

Anthropogenic factors influence the development of rivers and is acknowledged as a major driver for impacts on biodiversity, and the UN has dedicated the coming decade to ecosystem restoration. Knowing the historical development of rivers is important for untangling the various forcing's driving change, but such data can be hard to find. Utilising the Norwegian repository of black and white aerial imagery (www.norgeibilder.no) we used a convolutional neural network (CNN) to classify the riverscape over several decades in a number of rivers in Norway (Alfredsen et al. 2021). The training data set consisted of an initial set of images from two rivers that was manually annotated. The annotated images were used to create an initial trained model was then used to segment a third river, and the result from this segmentation process was then manually corrected and added to the training data to form an expanded dataset. The expanded dataset was then used to train and validate a second model. This model was then tested on data not used in the training process and the goodness of fit was evaluated using confusion matrices, an example from river Gaula in 1963 in Table 1.

Table 1
Confusion matrix for Gaula in 1963

		Predicted [%]				
		Water	Gravel	Vegetation	Farmland	Human
True [%]	Water	91.31	0.38	1.38	2.39	0.28
	Gravel	7.84	76.73	6.72	10.07	6.05
	Vegetation	2.10	1.75	88.96	4.59	1.64
	Farmland	0.60	2.49	8.37	96.79	0.27
	Human	2.85	2.19	7.34	14.15	82.96

The trained CNN is used to generate segmented datasets for a number of rivers which are the fundament for the evaluation of the impact of human (e.g. hydropower, flood control, agriculture) and natural (e.g. floods) on the rivers. An example of river Nea from 1963 is shown in Fig. 2. We find that the CNN effectively replaces the tedious and time-consuming job of manually annotating the maps, leaving only minor manual corrections needed.

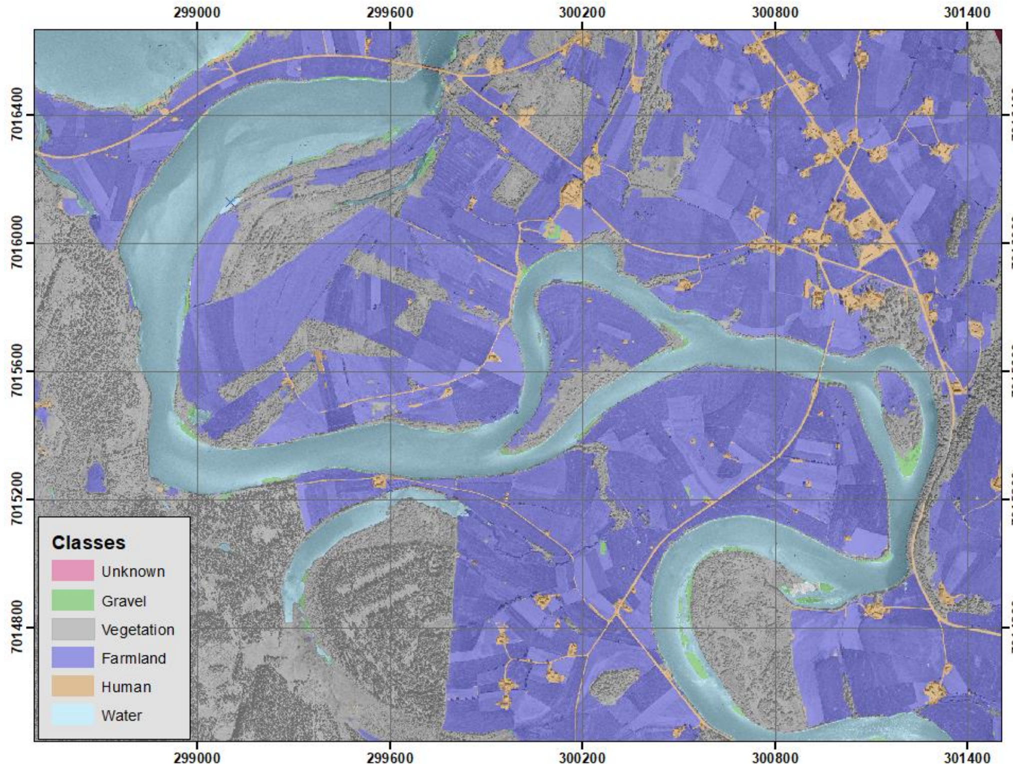

Fig. 2. Classified riverscape for river Nea overlaid aerial imagery from 1962.

A c k n o w l e d g m e n t s . I would like to thank Einar Rødtang, Ana Bustos, Ana Juaréz, Etienne Limpens, Mahmoud Awadallah, Håkon Sundt, Jo Halvard Halleraker, Saeid Shamsaliei, Arild Dalsgård and Odd Erik Gundersen. I also wish to thank Morten Stickler for funding and the initiation of many interesting projects.

R e f e r e n c e s

Alfredsen, K., C. Haas, J.A. Thuthan, and P. Zinke (2018), Brief Communication: Mapping river ice using drones and structure from motion, *The Cryosphere* **12**, 627–633, DOI: 10.5194/tc-12-627-2018.

Alfredsen, K., A. Dalsgård, S. Shamsaliei, J.H. Halleraker, and O.E. Gundersen (2021), Towards an automatic characterization of riverscape development by deep learning, *River Res. Appl*. **38**, 4, 810–816, DOI: 10.1002/rra.3927.

Brekke, I. (2020), Modellering av terskelfjerning og terskelendringer i Nea [Modelling weir removal in river Nea], MSc Thesis, Norwegian University of Science and Technology (in Norwegian).

Juarez, A., A. Adeva-Bustos, K. Alfredsen, and B.O. Dønnum (2019), Performance of a two-dimensional hydraulic model for the evaluation of stranding areas and characterization of rapid fluctuations in hydropeaking rivers, *Water* **11**, 2, 201, DOI: 10.3390/w11020201.

Junker-Köhler, B., and H. Sundt (2021), Assessing visual preferences of the local public for environmental mitigation measures of hydropower impacts—does point-of-view location make a difference? *Water* **13**, 21, 2985, DOI: 10.3390/w13212985.

Rødtang, E., K. Alfredsen, and A. Juarez (2021), Drone surveying of volumetric ice growth in a steep river, *Front. Remote Sens.* **2**, 767073, DOI: 10.3389/frsen.2021.767073.

Received 9 May 2022
Accepted 16 May 2022