THE BROAD APPLICATION OF A DEPTH INVERSION ALGORITHM BASED ON THE DYNAMIC MODE DECOMPOSITION

Matthijs Gawehn, Delft Technical University / Deltares, M.A.Gawehn@tudelft.nl / Matthijs.Gawehn@deltares.nl
Sierd de Vries, Delft Technical University, Sierd.deVries@tudelft.nl
Stefan Aarninkhof, Delft Technical University, S.G.J.Aarninkhof@tudelft.nl

INTRODUCTION

Mapping coastal bathymetries from remote sensing is an attractive alternative to in situ measurements due to the large spatial coverage and relatively low costs. The idea to derive bathymetries from video of a wave field stems from the 1980's and has since lead to the development of various depth inversion algorithms (DIAs). Originally developed for stationary beach cameras and/or radar, these algorithms were built for accuracy on specific locations and high computational speeds and broad applications were not a primary concern.

The technological boost of drones and satellites now offers new and more flexible platforms for video-based DIAs; it thereby signals a desire to generate depth estimates on-the-fly, requiring more flexibility and high computational speeds of the DIAs. For this purpose, a novel algorithm was developed, which is fast enough to be used for on-the-fly depth and surface current estimation at a broad range of application areas.

METHOD

To reach high computational speeds we make use of a dimensionality reduction technique called a Dynamic Mode Decomposition (DMD) (e.g. Schmid, 2010). It describes a wave field in terms of dynamic modes, which in this case resemble the significant wave components. Their wave periods are combined with wavenumber estimates from localized two-dimensional FFTs (2D-FFTs), which can then be used to estimate water depths, but also vector fields of wave propagation and surface currents (Gawehn et al. 2019). For quick convergence of the depth and current estimates, we successively analyze small time-blocks of video frames and use an on-line Kalman filter for quality control during each iteration.

In essence, the new method is a "lean and mean" approach to computationally more expensive 3D-FFT based DIAs. To study the robustness and the flexibility of the DMD-based DIA, we performed experiments to video footage from various sites around the world, amongst which the Netherlands, Australia and the US. Both fixed stations and drones are used. Moreover, we use a modern variant of the DMD (Askham & Kutz, 2018), which is superior in both accuracy and flexibility.

RESULTS

Experiments on 2 Hz video of the field-site of Duck, (North Carolina, USA) implied that time-blocks of 16 s of video were enough to produce dynamic modes that are stable between iterations (Gawehn et al. 2019), forming a solid basis for depth inversion (Figure 1). However, it was unclear whether these settings were specific to the case or generally applicable.

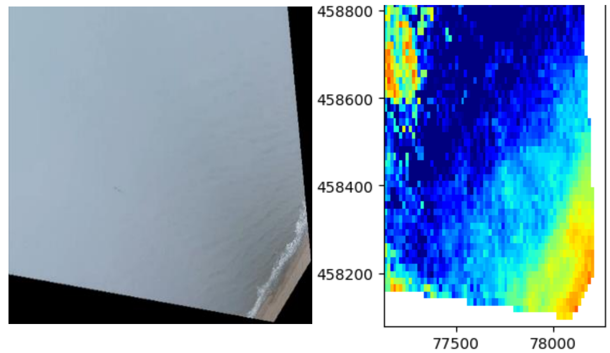

Figure 1 - Depth (right) from video of Scheveningen, NL (left). Time-blocks of 32s.

Analyses of 2 Hz video footage collected with drones at the field-sites of Scheveningen (Netherlands) and Narrabean (Australia) suggest that a universal setting for the DMD can be found in using time-blocks of 32s. After 1 min of video, root mean square errors (RMSE) of the corresponding depth estimates are 0.8 m (Scheveningen)(Figure 1), 2.6 m (Narrabean), 0.5 m (Duck). The larger errors at Narrabean are suspected to be caused by inaccuracies in the orthorectification of the video. Nevertheless, after 10-15 Kalman iterations the errors reduce to 0.6 m(Scheveningen), 1.3 m (Narrabean) and 0.4 m (Duck).

CONCLUSION

Depth inversion from video using dynamic modes has proven to be applicable to derive coastal morphology at different locations using images from drones and fixed stations. The DMD significantly reduces data complexity, leading to fast and accurate computation of depths and surface currents. The analysis of video from three different field-sites in the Netherlands, Australia and US, suggests that 32 s of video are sufficient to correctly capture the significant wave components in the wave-field. It means that DMD-based depth inversion is suited for fast coastal reconnaissance.

REFERENCES

Askham, & Kutz (2018): Variable projection methods for an optimized dynamic mode decomposition. SIAM Journal on Applied Dynamical Systems, 17(1), 380-416.

Gawehn, de Vries, Aarninkhof (2019): Depth and Surface Current Inversion On-the-fly: A new Video-based Approach using the Dynamic Mode Decomposition. Coastal Sediments 2019, pp. 2511-2520.

Schmid (2010): Dynamic mode decomposition of numerical and experimental data. Journal of Fluid Mechanics, 656, pp. 5-28.