SOMAR-3

Yet another pixel-by-pixel Depth Inversion Algorithm

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The earliest depth inversion algorithms (Hoogeboom 1986, Hessner & Bell, 1999, Dugan 2000, and many others) were based on fitting the shallow water wave dispersion equation to a 3D power spectrum. The spatial resolution was the dimension of the power spectrum Fourier transforms, which is typically ~250m. Later pixel-level depth solutions were suggested (Hessner et al. 1999, Senet et al. DiSC 2000-2008, and Stockdon-Holman cBathy 2000-2013) which have potential for much higher spatial resolution (but how much is still an open question).

My method is yet another of pixel-level approach. The depth (and current) are solved through minimization of the objective function J at each pixel location $\boldsymbol{x}$,

$$min_{\vec{u},z} J(\vec{x}) \ = \sum_{n=1}^{N-1} \left| S_n(\vec{x}) - \Psi^{\vec{u}(\vec{x}),z(\vec{x}),-\tau} * S_{n+1}(\vec{x}) \right|.$$

$\boldsymbol{S_n}$ is the ***n'***th image in a time series of $\boldsymbol{N}$ images; $\boldsymbol{\Psi^{\vec{u}(\vec{x}),z(\vec{x}),-\tau}}$ is a spatial kernel and a function of current $\boldsymbol{u}$, depth $\boldsymbol{z}$, and the time interval between image pairs $\boldsymbol{\tau}$. The convolution of the kernel with an image at time step $\boldsymbol{n+1}$ propagates the waves to match the earlier time step $\boldsymbol{n}$. The difference is a minimum when the kernel is tuned to the current and depth appropriate at location $\boldsymbol{x}$. In the absence of noise and other image distortions $\boldsymbol{N=2}$ is sufficient. But more images are useful for noise averaging.

A simulation on a Duck NC will be shown. The depth solution precisely reproduces a sand bar.

Further mathematical details are in Ref 1 and Ref 2. Ref 1 also shows results with time series of WorldView2 optical images. Ref 2 describes the implementation using fft convolutions and other tricks for efficient computation.

My goal at SOMaR3 is to discuss the practical considerations for implementation of this method with low grazing angle marine radars.

My research with marine radars used data sets provided to me by several past and current SOMaR participants. They include: Trizna (with his Duck Pier radars), Flampouris (WAMOS radar on Island of Sylt), Mortimer (CSIRO radar at Watermans Bay near Perth, AU), and Takewak (HORS radar, Hasaki, Japan). Time allowing I will include data examples in the presentation. I'll have more data analysis available for sidebar discussions afterwards.

Several issues will be discussed. First and foremost, dealing with wave shadowing. My algorithm appears to be remarkably robust in the presence of shadowing. Shadows amount to zero terms in the convolution. The missing wave terms increase depth estimation errors. But these errors are asymptotically driven to zero as $\boldsymbol{N}$ increases.

As the illuminated wave surface moves a depth solution is ‘painted’ over the entire area. So when collection of a large number of images is feasible shadows are manageable.

A further issue is azimuthal jitter due to varying wind toque. Small azimuthal offsets lead to large depths errors (especially at deeper depths). Those errors also average out with large ***N.*** There are also ways of recording and compensating for variable antenna rotation (Trizna, private communications). However, than there are time (τ) jitters.

A prerequisite for depth inversion is that the radar signal is linear with wave height or slope. I will present a test of linearity for the various data sets and discuss the consequences of non-linearity.

I look forward to discussions at SOMaR-3 providing direction and opportunities for further research.

References

[1] Abileah, R., Mapping Near Shore Bathymetry Using Wave Kinematics in a Time Series of Worldview-2 Satellite Images, IGARSS 2013, Melbourne, AU, July, 2013.

[2] Abileah, R, Methods for Mapping Depth and Surface Current US Patent 8903134, 2014