Optimisation of a bathymetry module within a rip current prediction system

Or

Staring at waves – knowing what's below

During summer season, the dynamic appearance of offshore directed currents, mainly rip currents, led to several fatal incidents at the beach of Egmond aan Zee (The Netherlands) in the past. A rip current prediction system is set up in order to avoid such incidents in the future. The occurrence and characteristic of rip currents depend strongly on subtidal bathymetries, hence detailed survey data is required for accurate predictions. The video monitoring system ARGUS was considered to provide the prediction system with precise, regularly updated bathymetry data. On this background, the applicability and reliability of the ARGUS system has been investigated in more detail, including the testing of additional image processing methods and error analysis tools.

Motivation

Egmond aan Zee hosts one of the most popular beach sites in the Netherlands. Thus, guaranteeing safe recreation for every visitor is one of the mayor concerns in this area. In the swimming season of 2016, the Dutch lifeguards in Egmond, the Egmondse Reddingsbrigade, had to deal with a number of fatal incidents caused by strong rip currents. With the intention to gather reliable bathymetry, wave and tidal data for the nearshore area, the video monitoring system ARGUS was installed along the beach (Figure 1). ARGUS is a video program initially developed and distributed in the United States by the Coastal Imaging Laboratory of the Oregon State University (OSU). In Europe and further regions, the distribution of ARGUS is within the responsibility of Deltares. The system embeds functionalities that allow the location of rip currents and their velocities, which could be dangerous for swimmers. One of the applications of this system is the provision of this information to life guards on site, who can then take action before a threat is imminent to swimmers (#1). To this day, the forecast relies on bathymetry data derived from watercraft surveys by means of echo sounding measurements. This cost intensive method creates accurate data for the time being in calm sea conditions, but cannot maintain its accuracy after a storm reshaped the coastal structures. A stationary optical system like ARGUS delivers in combination with an appropriate analysing method live updated bathymetry at lower cost. Therefore, the cBathy algorithm is tested to derive bathymetries from the optical signals caught by ARGUS.

Process workflow

The basic principle behind cBathy is the relation of wave celerity to radial frequency (including the radial wave number), which can be described mathematically by the wave dispersion relation for airy waves. Thus, the basis for the cBathy algorithm is the correlation of wave frequency (number of waves per time unit at a certain point) to the water depth. The information about the frequency and the wavenumber at defined areas of the sea surface can be detected by the ARGUS system. Thus, by observing the sea surface information regarding the local water depth and the sea bed elevation can be derived.
After the raw data is gathered, the first step of the algorithm is the transformation the signal within the raw input from the time domain to a frequency domain. In the second step maps with estimated depths for chosen site-specific frequencies are merged. In the final step the results gained in step II are filtered and validated by the application of the Kalman filtering method. Several parameters can be adjusted to give the algorithm the best possible input. Besides others, parameters can be found to define the frequency band monitored factors to determine incoming wave directions as well as indicators for the dynamic behaviour of the shore.

Cutting overestimation near shore

Figure 2 compares exemplarily a bathymetry derived by cBathy (left) with results of an in-situ watercraft survey (middle). Two significant errors are obtained and countered following. The application of cBathy on the site of Egmond in 2013 pointed out that depths close to the shoreline are estimated wrong due to shallow depths and swash motions at the shore. [Figure 2]An additional function was implemented in the process workflow with the objective to prevent the overestimation of depths near shore and replace this data with intertidal bathymetries(Sembiring, 2016). In the forefront of this work a contour line was inserted which excludes the input data from shallow depths. The implementation lead to the exclusion of inaccurate estimates and improved the quality of the bathymetries at the junction between intertidal and subtidal area. The improvement can be obtained when comparing the difference plot (right) in Figure 2 and 3.

Smoothing disturbances at boundaries

The cBathy algorithm separates inaccurate input from reasonable input. Therefore bad depth estimates are rejected by the application of the Kalman Filter. Ongoing tests at the site of the "Zandmotor" near The Hague are conducted at the Technical University in Delft. Within these experiments it was highlighted, that optical wave signals are disturbed by ships, falsifying the results of cBathy in a scale around 2 m for bathymetry heights (Radermacher). Due to that, a limit for a maximum change within one timestep was introduced. Differences higher than 1,5m results were declared as unfeasible and not implemented in the final estimate. Besides that a relatively high temporal smoothing parameter was introduced. This parameter additionally slows down the algorithm changing the estimated bathymetry. Changes of significant bathymetry height conducted within hours due to faulty wave signals are excluded. This approach was tested after a storm rearranging the bathymetrical structure. It was proven that within days the estimates were insignificantly different to a measurement shortly after the storm event.

For the application at Egmond aan Zee Figure 3 shows an overestimation at the northern boundaries (x=800-1000m). The assessment of the estimated bathymetries and its input resolved certain issues within the depth estimates due to faulty optical input signals (e.g. Kite flights). After the application of the previously elaborated technique the overestimation at the boundaries is minimal and the coherence with the ground truth significantly increased.

Result: New optimized Version of cBathy

The application of ARGUS in combination with cBathy delivers accurate results. The main issues which occurred during tests could be resolved. Nevertheless a confirmation for a generic application cannot be made. Coastal structures need to be relatively uniform. In order to gain precise results for other sites specific calibrations of setting parameters need to be done. At the OSU the importance for an aware setting of physical parameters within cBathy is made on a frequent basis. At the OSU and within Deltares a lot of experience is present in setting these parameters. Additionally it is pointed out that the documentation as well as the community of applicants is open, extensive and easy to enter.

cBathy: Past, present and future

For 20 years ARGUS has been used by Deltares to reliably map intertidal bathymetries on several sites using the Automated Shoreline Mapper (ASM). The application of cBathy and the junction of cBathy-bathymetries with ASM-bathymetries deliver an approach to live monitor a shore area with enormous importance. The certainty of ARGUS as well as its resulting precision constantly increases with the number of applicants. A final status will not be reached since the horizon of applicable sites is wide. The application of cBathy concludes a logical step in the chronic of ARGUS. The step towards a combination of subtidal and intertidal bathymetries is relying on further tests. In this matter the sensibility of the settings parameters for cBathy is most valuable.

In January 2017 the Coastal Imaging Research Network, consisting of an international group of researches exploiting optical signals in coastal, estuarine and riverine environments published an open source version of cBathy. This version was developed parallel to the cBathy version being applied in the present work (#3).
It sparks chances to widen an active community of applicants and thus the chance for cBathy to reach the status for generic application.

Multimedia

(#1) http://zandmotorapp.deltares.nl/ (@Roderik: A few intersections were taken offline. Do you nevertheless want this app to be linked in the article as an example?)

Mobile phone application Swimmer Safety: a multi-source information platform to control swimmer safety at the Sandmotor; R. Hoekstra, C.M. Swinkels, B. Stengs, Deltares, Delft, the Netherlands;

(#2) http://cosmos.deltares.nl/RipCurrentsNL/index.html

(#3) https://github.com/Coastal-Imaging-Research-Network/cBathy-Toolbox

Authors

Roman Schotten conducted the work on the cBathy algorithm in the curriculum of a Civil Engineering degree at the Technical University in Dresden. The work was executed at the Dutch Research institute Deltares. The team of experts guiding, consisted of Roderik Hoekstra, Giorgio Santinelli, Bas Stengs and Rinus Schroevers. Additionally Leo Sembiring, UNESCO-IHE and Max Radermacher TU Delft supported the outcome of the present article.

Images

Figure 1, Opener: View from Argus station in Kijkduin with Camera in the front and shoreline in the background.

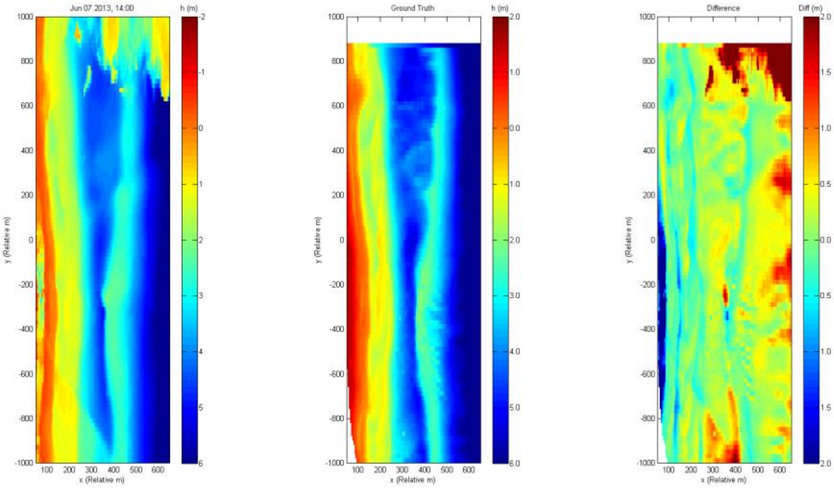

Figure 2: Site Egmond aan Zee Jan van Speijk; Left: Prior cBathy estimate for 7 June 2013 14:00 GMT ; Middle: surveyed bathymetry 8 June 2013; Right: Difference plot cBathy Estimate minus survey;
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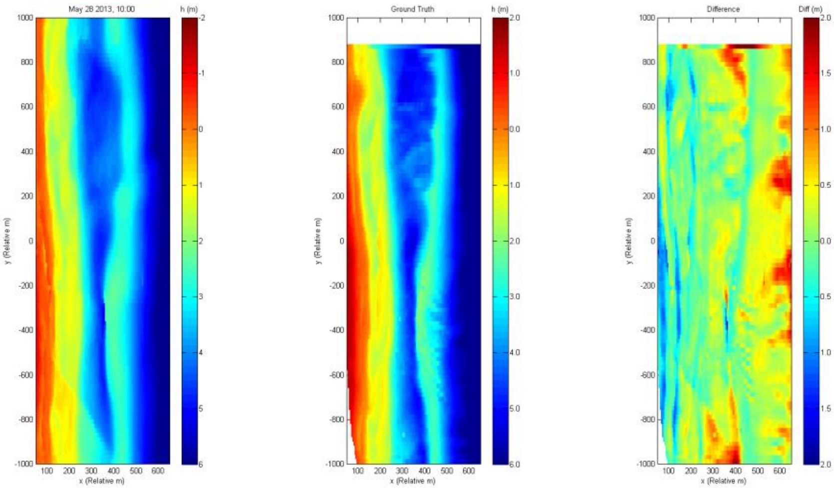

Figure 3: Site Egmond aan Zee Jan van Speijk; Left: Improved cBathy estimate for 7 June 2013 14:00 GMT ; Middle: surveyed bathymetry 8 June 2013; Right: Difference plot cBathy Estimate minus survey;