Fuzzy Algorithm For 3d Bathymetry Simulation From Topsar Polarised Data

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Abstract
The main objective of this research is to utilize the parallel Fuzzy arithmetic for constructing ocean bathymetry from polarized remote sensing data such as TOPSAR image. In doing so, the parallel library for Fuzzy arithmetic has been developed. Three- dimensional surface modeling consisted of Volettra model, non-linear model which construct a global topological structure between the data points, used to support an approximation of real surface. The output of the parallel library was a digital terrain model for bathymetry along the coastal waters of Kuala Terengganu Malaysia. This paper describes the principles behind the Fuzzy algorithm, indicates for what type of application it might be useful, notes on the accuracy and gives an example of an application.

Introduction

The coastal waters bathymetries contemplate as key parameters for coastal engineering and coastal navigation. The bathymetry information is precious for economic activities, for security and for marine environmental protection. Ship borne echo sounder, single-or multi-beam were the classical methods, which utilized to map the sea bottom topography (Hesselmans, 2000). Although these classical techniques provide high precision results, they are very costly and time overwhelming especially when large areas are mapped. Remote sensing methods in real time could be a major tool for bathymetry mapping which they produce a synoptic impression over large areas at comparatively low cost.

The airborne Topographic Synthetic Aperture Radar (TOPSAR) contains a wealth information which can be sued to obtain information of the coastal bathymetry. The Jet Propulsion Laboratory (JPL) airborne Topographic Synthetic Aperture Radar (TOPSAR) data were acquired on December 6, 1996 over the coastline of Kuala Terengganu, Malaysia between 103° 5'E to 103° 9'E and 5° 20'N to 5° 27'N. TOPSAR is a NASA/JPL multi-frequency instrument package aboard a DC-8 aircraft and operated by NASA's Ames research Center at Moffett Field. The TOPSAR system is designed to be flown on small and large aircraft. The system requires a scanner port (18x36 cm) on aircraft underside. TOPSAR is achieved by alternately transmission the signals using horizontal and vertical polarizations. TOPSAR data are operated with fully polarimetric data were acquired at HH-, VV-, HV- and VH-polarized signals from 5x5 m pixels were recorded for three wavelengths: C band (5 cm), L band (24 cm) and P band (68 cm) (Zebker, 1992).

The main objective of this study is to develop a geomatic system tool for 3-D bathymetry reconstruction.

Model

It is generally accepted that the imaging mechanisms of the under water bottom topography is function of the current gradient over the bottom topography. It may be can be explained as (1) interaction between tidal flow and bottom topography leads to modulations in the surface current velocity, (2) modulations in the surface current velocity induce rise to local variations in the wave spectrum and (3) variations in the wave spectrum cause modulations in the radar backscatter (Alpers and Hennings, 1984). A Volterra model was used as nonlinear model to estimate the current gradient from TOPSAR data as follows

$$I(u_x, u_y) = U_x(u_x, u_y).F(k, \frac{R}{V}, S, v_x)$$ (1) Inglada and Garello (1999)

A nonlinear system of equations *U*(*x*) = 0, with $U: \Re^n \rightarrow \Re^n$, is called a *block bordered system* if it can be written as

$$\nabla U_{y_i}(y_i, y_{q+1}) = 0; i = 1, \ldots\ldots, q$$
$$\nabla U_{q+1}(y_1, \ldots\ldots\ldots, y_q, y_{q=1}) = 0$$ (2) Anile (1997)

The Fuzzy B-splines Method

The fuzzy B-splines (FBS) are introduced allowing fuzzy numbers instead of intervals in the definition of the B-splines. A fuzzy number is defined using interval analysis. There are two basic notions that we combine together: confidence interval and presumption level. A confidence interval is a real values interval which provides the sharpest enclosing range for current gradient values. A assumption level μ -level is an estimated truth value in the [0,1] interval on our knowledge level of gradient current Anile (1997). The 0 value corresponds to minimum knowledge of gradient current, and 1 to the maximum gradient current. A fuzzy number is then prearranged in confidence interval set, each one related to a assumption level $\mu \in$ [0,1]. Moreover, the following must hold for each pair of confidence interval which define a number: $\mu \succ \mu' \Rightarrow U \succ U'$

Let us consider a function $f : U \rightarrow U$, of N fuzzy variables $u_1, u_2, \ldots, u_n$. Where u_n are the global minimum and maximum values gradient current of the function on the space. Based on the spatial variation of gradient current, algorithms are used to compute the function *f.*

The construction begins with the same pre-processing aimed at the reduction of measured current values into a uniformly spaced grid of cells. As in Volettra model data are derived from the L_{HH} TOPSAR backscatter image due to the application of 2-DFFT. First of all, each estimated current data along fix window size of 512x 512 pixels and lines, is considered as a triangular fuzzy number defined by a minimum, maximum and measured value. Among all the fuzzy numbers falling within a window size, a fuzzy number is defined whose range is given by the minimum and maximum values of gradient current along each window size. Among all the intervals extremes, and whose central value is chosen as the "best choice" proficient considering the density of data within window size. Then, a membership function is defined for each pixel element which incorporates the degrees of certainty of radar cross backscatter .

Results and Discussions

Figure 1 shows the regions of interest that used to simulate the bathymetry information from L-Band with HH polarization. The bathymetry information have extracted from of the 4 sub-images, each sub-image was 512 by 512 pixel. Figure 2 shows the signature of underwater topography. Underwater topography is obvious as a frontal lines parallel the shoreline.

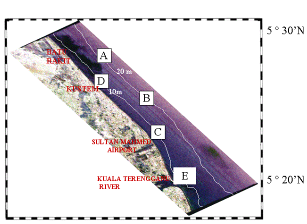

Figure 1. Selected Window Size

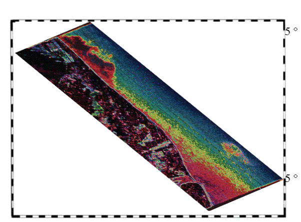

Figure 2. Signature of Bathymetry

Figure 3. Shows the current spectra density, which varied along the distance. The current intensities varied along the range direction. The maximum current speed is 1.3 m/s. This is because of the fact that Volterra series expansion considers as linear transform. This result confirms the finding of Maged (1994).

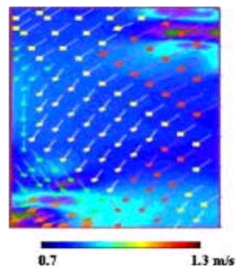

Figure 3. Simulation of current flow from TOPSAR data

Figure 4 shows the 3 D bathymetry simulations over different locations. It is obvious that the coastal water bathymetry along the locations A, B, C, D have a gentle slopes and moving parallel to the shoreline. The bathymetry at location E shows a sharp slope. This could be due to strong current flow from the mouth river of Kuala Terengganu. This study confirms the study of Maged et al., (2002).

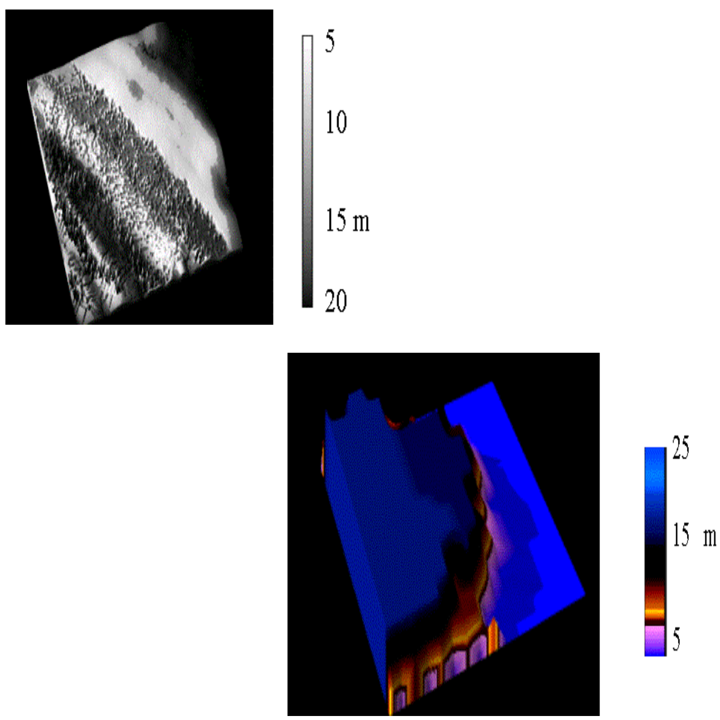

Figure 4. 3-D Bathymetry Fuzzy Reconstruction at (a) Locations A , B,C, and D and (b) E

Conclusion

This study has introduced a new approach in 3-D reconstruction of coastal waters bathymetry. The integration between Volterra model and the Fuzzy B-Splines method can provide a 3-D construction for coastal waters bathymetry. This approach can provide characteristics of coastal waters bathymetry. In 3-D reconstruction of coastal bathymetry will be easy to detect the gentle and sharp slope. Utilization of composite TOPSAR L-band polarized data (HH) assists in 3 D bathymetry reconstructions.

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