Paper 7505: Converting Digital Number Into Bathymetric Depth: A Case Study Over Coastal And Shallow Water Of Langkawi Island, Malaysia

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Hydrographic Surveying

Hydrographic Surveying is defined as

“That branch of applied sciences which deals with the measurement and description of the features of the sea and coastal areas for the primary purpose of navigation and all other marine purposes and activities, including –inter alia- offshore activities, research, protection of the environment, and prediction services.”

(IHO Pub. S32, 1994)

- In strict sense, it is defined as the surveying of a water area.
- However, in modern usage it may include a wide variety of other objective such as measurements of tides, current, gravity, earth magnetism and determination of the physical and chemical properties of water.
- Nevertheless, the principle objective of most Hydrographic Surveying is to obtain basic data for bathymetric surveying projects and compilation of nautical charts with emphasis on the features that may affect safe navigation.
Revolution in Hydrographic Surveying

Single Beam Echo Sounder

Multi-beam Echo Sounder

Airborne LiDAR

Satellite Derived Bathymetry
Problem statements
The vessel-based echo sounding methods applied nowadays constrained by limited ground coverage, difficulties to access shallow coastal water, labour intensive and high operating cost which significantly limits the frequent repetitions.

Due to the complicatedness in acquired the accurate and well-distributed spatial sounding data, a robust method of deriving the bathymetric data directly from the passive optically sensed satellite imagery would enhance the capability to map the seabed topography.

Objectives
- To study the usability of satellite-derived bathymetric mapping and identify the appropriate channel of Landsat 8 multispectral satellite data to be used in extracting bathymetric information.
- To product bathymetry map of the study area from multispectral Landsat 8 multispectral satellite image.
- To analyse remotely sensed data to provide an accurate and cost-effective alternative to the classical techniques for bathymetric mapping.

To map the coastal and shallow water areas in remote sensing and GIS environment.
The fundamental principle of deriving sea bed information for bathymetric mapping using optical remote sensing is that light (visible wavelengths) which can penetrate the water column in various degrees.

The measured radiance is closely related to the incoming solar radiation, attenuation of radiation in and out of the atmosphere and water column, reflectance properties of the sea bed as well as the water depth.

Satellite-Derived Bathymetry
The methods of extracting the sea bed information over clear shallow water from the satellite imagery was first addressed by Lyzenga (1978), and later on was expended and further explore by Benny and Dawson (1983), Spitzer and Driks (1987), Jupp (1988), Philpot (1989), Bierwirth (1993), Maritorena et al. (1994) and Stumpf et al. (2003).

Though remarkable efforts, a wide fusion of bathymetry retrieval algorithms have been developed as well as empirical models have been established to form the statistical relationship between image pixels values and water depth values.
**Methodology**

1. **LANDSAT DATA**
   - Atmospheric & Geometric Correction
2. **LANDSAT 8 ORI**
   - Image Processing
   - Satellite-derived Bathymetry Map
3. **Tidal Data**
4. **Nautical Chart**

**Pre-processing**

**Processing**

**Post-Verification**

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**Data and Materials**

- **Landsat 8’s Satellite Image**
  - (27 Feb 2014)
- **Malaysian Nautical Chart**
  - (MAL 5622 & 565)
- **Tidal Observation Records**
  - (Pulau Langkawi)
Procedure and Data Generation

- Radiometric and Atmospheric Correction.
- Geometric Correction.
- Spatial Sub-setting.
- Deriving Satellite Bathymetry.
- Bathymetry Accuracy Assessment

Radiometric and Atmospheric Correction

- Radiometric correction allows us to convert the raw image digital value (DNs) to spectral radiance \( L_\lambda \) using the Spectral Radiance Scaling Method’s equation:

\[
L_\lambda = \frac{L_{\max} - L_{\min}}{Q\text{CAL}_{\max} - Q\text{CAL}_{\min}} (Q\text{CAL} - Q\text{CAL}_{\min}) + L_{\min}
\]

- In order to generate the reflectance data, the spectral radiance values need to be converted into Top-of-Atmosphere (ToA) reflectance value \( P_\lambda \).

\[
P_\lambda = \frac{P_\lambda^c}{\cos\theta_{SE}} = \frac{P_\lambda^c}{\sin\theta_{SE}}
\]

(http://landsat.usgs.gov/Landsat8_Using_Product.php)
In this case, the selected Landsat 8 multispectral images of the study area was geo-referenced to the MAL Chart by selecting a sufficient number of Ground Control Points (GCPs) which were widely scattered throughout the area of study.

A numbers of GCPs which were easily identifiable had been selected to conduct the 1st order polynomial wrapping function using the Nearest Neighbour re-sampling method.
Dry Land Areas extracted from the Landsat 8 (Band 5)

Extracted of Water Surface area
Deriving Satellite Bathymetry

- An optically-derived bathymetry algorithm based on ratio of two bands was employed to produce bathymetric map.
- Stumpf et al. (2003) model to map the shallow water bathymetry of study area:

$$Z = m_1 \times \left( \frac{\ln(nR_w(\lambda_1))}{\ln(nR_w(\lambda_2))} \right) - m_0$$

- The water depth was extracted using a the corrected reflectance dataset from Band 2 (blue) and Band 3 (green).

Bathymetry Accuracy Assessment

- In this case, the geo-referenced MALs were being used to conduct the accuracy assessment of the satellite-derived bathymetric data. 50 depths ranged from -0.5 to 20.8m were adopted from the MALs.
- The extracted water depth points were used for further modal calibration and data verification. Root Mean Square Error (RMSE) Test was used to evaluate the satellite-derived bathymetry accuracy.
- The correlation coefficient ($r^2$) based on the regression model between the satellite-derived bathymetric data and bathymetric data extracted from MALs were examined.
Results & Discussions

- Based on the data quality assessment done across the checking area, the uncertainties were ranged from \(-3.18\) m to \(3.76\) m.

- Apparently, the highest RMSE recorded was of \(3.758\) m, while the lowest RMSE was of \(0.024\) m.

- Total RMSE calculated based on the endorsed 50 reference points was \(1.521\) m.
Results & Discussions

Correlation Coefficient (r²) between Satellite-Derived Depth and Endorsed Depth

Checking Depth from Nautical Chart (m)

Conclusions and Major Findings

The study was carried out to evaluate the use of satellite-derived bathymetry to map the coastal and shallow water areas in remote sensing and GIS environment. In the completion of this study, the following research objectives were successfully achieved:

1. To check the usability of satellite-derived bathymetric mapping and to identify the appropriate channels of Landsat 8 multispectral satellite data to be used in extracting bathymetry information.

2. To produce bathymetry map of the study area from Landsat 8 multispectral satellite image.

3. To analysis of remotely sensed data to provide an accurate and cost-effective alternative to the classical techniques for bathymetric mapping.
Conclusions and Major Findings

Although this study had indicated that the satellite-derived bathymetry method is able to map the shallow water, nonetheless, it is still not recommended to be the replacement for conventional vessel-based sonar sounding surveys.

Perhaps, the satellite-derived bathymetry can be an alternative method and reconnaissance tool in facilitating the increasingly demand of hydrographic surveying activities around the coastal region as well as the remote shallow water areas.

References


References


Thank you for your attentions......