VIDEO-BASED DEPTH INVERSION IN SHALLOW WATER: A CASE STUDY AT BYEONSAN BEACH, SOUTH KOREA

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INTRODUCTION
Beach topography information is essential to enhance understanding of coastal processes. However, surveying the nearshore bathymetry is challenging due to poor visibility and limited accessibility. Conventional in-situ bathymetry survey techniques, such as echo-sounding with GPS, provide reliable bathymetry information, but are relatively labor-intensive and time-consuming, as investigators should directly approach measuring points. As a promising alternative, video-based depth inversion algorithms (DIAs) have been introduced. These algorithms aim to retrieve the wave parameters, i.e., wave period and wavenumber, from a wave field video photographed by camera installed at high-rise buildings or drones, and estimate water depth using linear dispersion relation. However, the accuracy of DIAs still falls short comparing to the in-situ instrumentation.

One frequently mentioned source of errors in the DIAs is the discrepancy of the linear dispersion relation in shallow water due to wave nonlinearity. In shallow water, wave nonlinearity continuously increases as shoaling waves propagate toward shoreline, leading to an increase in wave celerity, which is known as amplitude dispersion effect. However, limited studies have tested the DIA in shallow water due to the challenges of obtaining in-situ ground survey. This study aims to retrieve the coastal bathymetry in shallow water using Depth from Wave (DfW) algorithm proposed by Kim et al. (2023), one of the DIAs, incorporating corrections for wave nonlinearity.

VIDEO-BASED DEPTH INVERSION
The DfW algorithm, an adaptive depth inversion algorithms based pm drone imagery, was applied to the site of this study. The DfW algorithm involves a sequence of preprocessing steps, including image resampling, masking, distortion correction, stabilization, rectification, and georeferencing in the local coordinate system. The processed video result, a three-dimensional matrix of light intensity $I(x, y, t)$, was analyzed to retrieve pairs of wave frequency and wavenumber at all pixels in the region of interest.

Representative wave frequencies $f(x, y)$ are identified using time series data of I in Fourier domain. Optimal wavenumber $\mathbf{k}(x, y)$ is estimated by detecting the surrounding wave pattern with spatial windowing. The window size is adaptively determined based on wavelength and bottom elevation variability. These determined wave parameters are then applied to the linear dispersion relation to estimate the water depth h. The correction factor for wave nonlinearity incorporated in the algorithm, the ratio of estimated wave celerity in surf zone to that with linear assumption, is determined based on wave asymmetry, a planform wave property that characterizes nonlinearity.

FIELD EXPERIMENT
The field data were collected at Byeonsan beach, located in the west coast of South Korea, during the field experiment during the spring tide in July, 2023. The experiment consists of wave field video acquisition, ground control point (GCP) measurement, and in-situ bathymetry survey. The Byeonsan beach is 0.727 km long along the coastline and 41 – 68 m of the sandy backshore width. A camera-equipped drone (Phantom 4 RTK, DJI) was used to record the wave field video at three fixed points toward the incident wave direction. To reproject the video into the local coordinate (UTM coordinate system in this study, EPSG:32652), GCPs were installed for each of video recordings and their precise locations were measured using a real-time kinematic GPS device (Sokkia GRX1). The intertidal range in water surface elevation at the site was approximately 4.5 m. The wave monitoring and in-situ bathymetry survey were conducted during high tide and ebb tide, respectively to the depth inversion result with high-resolution ground truth data in shallow water, including surf zone and swash zone.

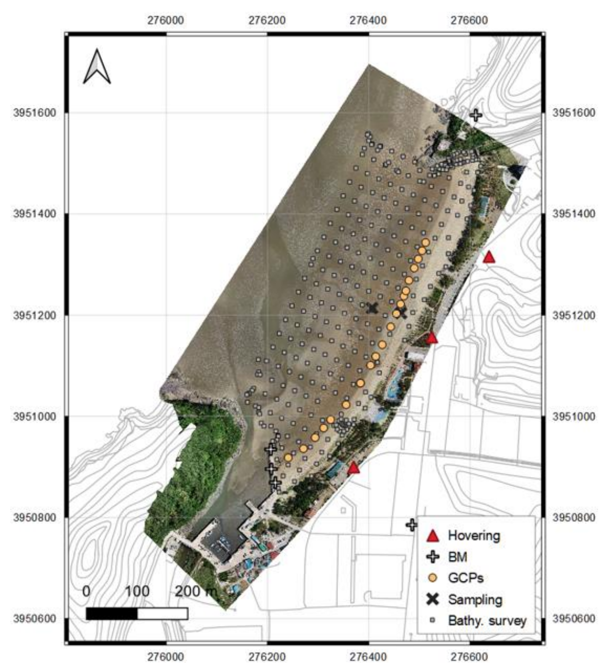

Figure 1 – Site map and data acquisition points in Byeonsan beach

RESULTS

To demonstrate the validity of DfW algorithm in shallow water, the depth inversion results were compared to the results of ground truth survey, and by and large, good agreement was achieved. Locally-high variability of bathymetry of, e.g., the river mouths were well-reconstructed as well. It was also found that the nonlinearity correction factor strongly correlated to the wave asymmetry from planform wave pattern in surf zone prior breaking. As expected, ripples on bottom that have small length scale were smoothen and not appeared.

CONCLUSION

The DfW algorithm was tested in the tidal flat of Byeonsan beach, where the high-resolution ground truth survey is available in the shallow water region, i.e., surf zone and swash zone. Overall accuracy of depth inversion result, including nonlinearity correction without knowing the wave height, showed good agreement. Yet, the depth inversion in the region of breaking and swash remains challenging.

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