study of underwater topography change with measurement and analysis

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abstract. techniques developed in previous studies were applied to positional data and depth data concerning underwater topography of a reservoir. the gauss-kröger projection was applied to horizontal coordinates of positional data. the horizontal coordinates and the vertical coordinate yielded a curve in an underwater topography. a surface containing the curve was obtained by a fixed point iteration. numerical results for two time periods were compared.

1. introduction

recent disastrous heavy rain events brought a number of casualties and tremendous damages to infrastructures and houses. damages due to the 2018 japan floods included 119 people killed, 29 people wounded, 213 houses completely destroyed, 340 houses half destroyed, and 290 houses partially destroyed [1]. damages due to the 2019 typhoon 19 and related heavy rain falls caused damages included 95 people killed, 5 people missing, 40 people severely wounded, 435 people slightly wounded, 1981 houses completely destroyed, 10168 houses half destroyed, and 12510 houses partially destroyed [2]. as the climate change progresses, those disastrous events may increase, and the preventive maintenance of rivers, reservoirs, and coastal areas as well as measurement and analytical systems for underwater topography are important.

in this study, measurement and analysis were carried out. technics developed in previous studies were applied to positional data and depth data obtained on december 25th, 2019 and january 6, 2020 from measurement conducted in a lake called kojima lake. the gauss-kröger projection was applied to horizontal coordinates of positional data output from a rtk-gps (real time kinematic-global positioning system) in vrs (virtual reference station) mode. the horizontal coordinates were combined with depth data output from an echo sounder unit, and a curve in an underwater topography was obtained. an rtk-gps antenna was set at the upper end of a pole. an oscillator of an echo sounder was attached to the lower end of the pole submerged under water. the equipment was set on board a boat (figure 1). a surface containing a curve was obtained by a fixed point iteration proposed in a previous study. results obtained in this study and a previous study were compared.
2. Output from measurement

Seto Inland Sea lies between the main island and the Shikoku Island of Japan. Kojima Bay is situated in the coast of the Seto Inland Sea along the main island. The deepest part of the Kojima Bay was embanked to be a reservoir named Kojima Lake whose width is approximately 10 km². Primary water sources of the Kojima Lake are inflows from two rivers, Sasagase River and Kurashiki River. The water level of the Kojima Lake is maintained by the discharge into the Kojima Bay through gates located at a bank between the Kojima Lake and the Kojima Bay. The topography of such a reservoir is subject to erosion and sedimentation, and updated topographic data should be provided on a regular basis.

Topographic measurement of the Kojima Lake was conducted on December 25th, 2019 and January 6th, 2020. Output data from an RTK-GPS in the VRS mode and an Echo sounder were recorded. The Gauss-Krüger Projection was applied to positional data on the reference ellipsoid expressed in terms of longitude and latitude for transformation to rectangular coordinates (Figure 2).

![Figure 1. RTK-GPS antenna and boat ‘Okayama 1’](image)

![Figure 2. The Gauss-Krüger Projection was applied to the Horizontal components of RTK-GPS outputs](image)
Figure 3. Positional data and depth data were combined to set topographic data.

Those data plus altitude data were combined with the depth data to be three dimensional topographic data (Figure 3). The vertical component of the topographic data \((x_j, y_j, z_j)\) was defined by

\[ z_j = h_j - d_j - z_0 - l, \]

where \(h_j\) [m] is the antenna height, \(d_j\) [m] is the output from the echo sounder, \(z_0\) [m] \((z_0 = 36.652)\) is the geodetic height of the mean sea level, and \(l\) [m] \((l = 2.3356)\) is the distance between the antenna and the oscillator.

3. **Surface containing topographic data**

A triangular mesh that contains all the significant GPS tracks was set (Figure 4). A technique developed in previous studies [3] was applied to the topographic data. The topographic surface was defined as a fixed point of a map defined for depth data at nodal points. It took 2497 fixed point iterations till the residual error reduced to 0.001 (Figure 5, Figure 6).

Figure 4. Triangular mesh and GPS tracks.
Figure 5. Initial topography and topography after 2497 iterations with topographic data.

Figure 6. Topography after 2497 iterations.

4. Discussion
Techniques to update the underwater topography with RTK-GPS data and echo sounder data were previously developed [3, 4]. In particular, a fixed point of depth data at nodes of a triangular mesh led to the updated underwater topography [3]. The system length was reset (2.3356 [m]) for the result obtained in the previous study [3], and the topography was recomputed. Figure 7 shows the difference between the nodal data for December 25th, 2019-January 6th, 2020 measurement and September 28th-October 4th, 2019 measurement over the part of the region (200 ≤ x ≤ 1200, 3000 ≤ y ≤ 4000). Note overall erosion over the area.
Figure 7. Difference between the nodal data for December 25\textsuperscript{th}, 2019-January 6\textsuperscript{th}, 2020 measurement and September 28\textsuperscript{th}-October 4\textsuperscript{th}, 2019 measurement.

References

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