TIDAL CREEK EXTRACTION FROM AIRBORNE LIDAR DATA USING GROUND FILTERING TECHNIQUE

Hyejin Kim (1), Jaebin Lee (2), Gwangjae Wie (3), and Yongil Kim (1)

[1] Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul, 08826, Korea
[2] Mokpo National University, 1666 Yeongsan-ro, Cheonggye-myeon, Muan-gun, Jeollanam-do, 58554, Korea
[3] Geostory Inc., 82, Hwagok-ro 68-gil, Gangseo-gu, Seoul, 07566, Korea
Email: vicky2@snu.ac.kr; lee2009@mokpo.ac.kr; wkj777@naver.com; yik@snu.ac.kr

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ABSTRACT: Tidal creek is any elongated indentation or valley in a wetland originated by tidal processes, through which water flows primarily driven by tidal influence. The tidal creeks act as drainage pathways and promoting tidal flat evolution and the retreat or expansion of adjacent salt marshes. Determining the location and shape of the tidal creeks is an important issue in the topographical researches of the intertidal zone. Airborne LiDAR data is most actively being used to extract the tidal topography because it can acquire precise terrain information for a wide area. Despite many studies to extract the tidal creeks from the Lidar data, there are still many limitations due to their complex and irregular shape, and the varying sizes. The purpose of this study is to evaluate the possibility that ground filtering can be used to extract the tidal creeks. Ground filtering is a technique for classification of ground surface and upper non-ground objects (e.g. building, tree et al.) from airborne LiDAR data. We applied the ground filtering algorithm to extract the tidal creeks after inverting the point cloud upside down. Representative ground filtering techniques were applied to the tidal creek extraction and analyzed. From the results, it was possible to extract the tidal creeks efficiently with various shapes, sizes and depths.

1. INTRODUCTION

The tidal flats, which are flat coastal wetlands with sediments piled up by the tidal current, filter pollutants, protect coastlines against storm surges, provide habitats of various marine life, absorb carbon, and offer sites for recreational activities (Gedan et al. 2011; Luisetti et al., 2014). As the importance of management and restoration of the tidal flats has emerged, monitoring of the tidal flat environment, especially obtaining accurate topographic information, is becoming more important. Extracting the geometric information (location, shape, and depth) of tidal creeks is an essential task for monitoring the characteristics, formation and evolution of tidal flats (Chirol et al., 2018), and also for safety such as prevention of drowning accident. Airborne light detection and ranging (LiDAR) data is most actively being used to extract the tidal creek because it can acquire precise terrain information for a wide area. Many tidal creek extraction methods use elevation and slope thresholds (Fagherazzi et al., 1999; Lohani and Mason, 2001; Anderson et al., 2017). These techniques are less adaptive to the complexity of tidal creeks because they use predefined or empirical thresholds (Liu et al., 2015; Chirol et al., 2018). Mason et al. (2006) presented a semi-automatic multi-level approach which adopted multi-scale edge detection, an association of adjacent anti-parallel edges, and a channel repair mechanism using domain knowledge. This method uses a local average height as a local adaptive height threshold to facilitate automation, and it can reduce the adaptability by generating an incorrect height threshold on complicated areas and erroneously recognizing a lower area than around, such as a puddle. Liu et al. (2015) developed an automated method for extracting tidal creeks (AMETC) by using multi-window median neighborhood analysis (MNA), multi-scale and multi-direction Gaussian matched filtering (GMF), and two-stage adaptive thresholding (TAT) with local statistical thresholds. Though the method is close to full automation, it cannot extract creeks wider than a given window size, and non-Gaussian shaped creeks such as artificially excavated creeks or bilateral asymmetry creeks. Moreover, because all of the related techniques have been carried out using digital terrain model (DTM) grid by converting LiDAR point data to a raster format, their results are affected by the DTM resolution and resampling methods. This study aims to evaluate a method of efficiently extracting the tidal creeks of various shapes and sizes using the ground filtering technique based on original LiDAR point cloud data. We carried out tests that extract the tidal creeks from the tidal flat of the west coast in Korea by applying two recognized ground filtering techniques.

2. METHODS

In order to minimize user intervention and extract the tidal creek efficiently with the original LiDAR point data, we design an approach applying ground filtering technique. The ground filtering is a technique for removing non-ground objects, such as building or tree, from airborne LiDAR data. It is a technique of classifying irregularly protruding objects upward from the datum surface. Conversely, the tidal creek extraction is a technique of separating the regions protruding downward from the datum surface. Figure 1 describes the process of our approach. The point clouds of the tidal flat are inverted upside down in order that the tidal creeks convert to upper direction of the surface. Then the ground filtering algorithm is applied to classify the tidal creek and the flat ground surface. After removal of the flat ground surface and inverting upside down again, we can obtain the tidal creeks. Two representative ground filtering techniques which were evaluated as excellent performance in classifying non-ground objects of varying sizes, heights and shapes (Polat and Uysal, 2015; Yilmaz and Gungor, 2018), were adopted to derive a technique suitable for the creek extraction. The first method is a ground classification of Terrasolid TerraScan (TSCAN) based on adaptive triangulated irregular network (ATIN, Axelsson, 2000). The second one is cloth simulation filtering (CSF) proposed by Zhang et al. (2016).

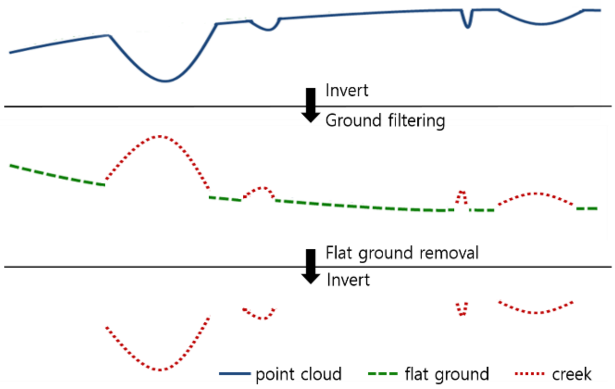


Figure 1. Process of the tidal creek extraction using ground filtering

2.1 TSCAN

TerraSolid TSCAN is one of the most powerful software available for the manipulation, processing and analysis of LiDAR data (Polat and Uysal, 2015). The ground filtering of TSCAN classifies ground point by creating a triangulated irregular network (TIN) surface model iteratively (TerraSolid, 2016). After selecting local low points as the initial ground point, a surface model (TIN) is built. The iteration routine molds the model upwards by adding more and more points in order that the TIN can be more closely with the true ground surface. There are six parameters including maximum building size (MBS), terrain angle (TA), iteration angle (IA), iteration distance (ID), edge length for reducing iteration angle (ELR), and edge length for stopping triangulation (ELS). MBS defines the search area for initial ground points and the edge length of the largest building, and could be the width of the widest tidal creek in our case. TA is the steepest allowed slope in the ground surface, recommended the maximum terrain slope plus 10 ~ 15 degrees in natural terrain. IA defines the maximum angle between a point and the closest triangle vertex, and ID is the maximum distance from a point to the triangle plane. ELR and ELS are optional parameters to avoid the addition of unnecessary point density to the ground model when every edge of the triangle is shorter than a given edge length.

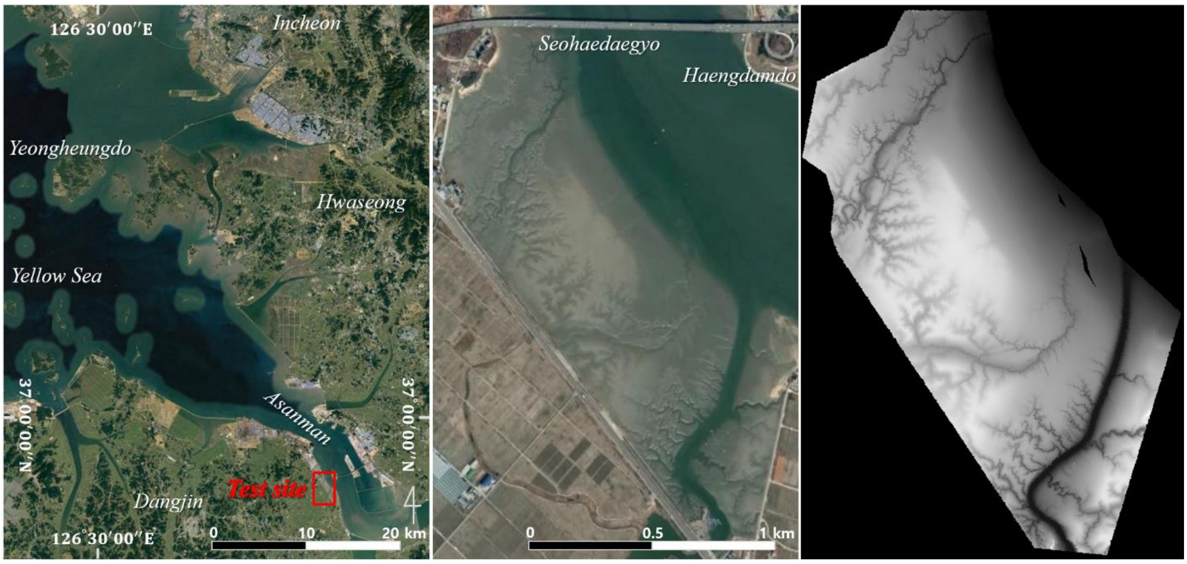
2.2 CSF

Zhang et al. (2016) developed CSF algorithm to classify ground point from LiDAR points. They assumed that if the terrain were turned upside down and covered with a rigid cloth on it, then the shape of the cloth would be an inverted DTM. To simulate the process, they employed a cloth simulation technique (Wail, 1986), which is used for simulating cloth within a 3D computer graphic. During cloth simulation, the cloth can be modelled as a grid that consists of particles with mass and interconnections, called a Mass-Spring Model (Provot, 1995), which is based on gravity, collision force, and internal force. The authors modified the cloth simulation technique to be appropriate for ground filtering. After inverting the point cloud, user-defined grid resolution is applied to determine the number of particles. The initial grid particles are defined as the horizontal plane with the highest height of the LiDAR data. Each particle repeats the descent by gravity and the rise by internal force between adjacent particles until the height variation becomes sufficiently small. Then, a point is classified as non-ground if its vertical distance to the grid particles is greater than the specified threshold. When applied to relatively flat terrain, the CSF requires only three parameters of rigidness (RI), grid resolutions (GR), and distance threshold (h_{cc}). RI describes the rigidness of the simulated cloth to represent the terrain type (flat terrain or gentle slopes: 3, steep or terraced slopes: 2, and high and steep slopes: 1). GR represents the horizontal distance between two neighboring particles, h_{cc} is the distance threshold between the cloth and LiDAR point to classify ground and non-ground.

3. IMPLEMENTATION

3.1 Test Data

Airborne LiDAR data at the west coast of Korea was used in our test (Figure 2). The test site locates in Asanman Bay, Dangjin City, Choongnam Province, South Korea (Figure 2a and b). The tidal sediments consisted mainly of clay and silt. The test data was acquired Teledyne Optech coastal zone mapping and imaging LiDAR (CZIMIL) Nova (Teledyne Opthech, 2015) at the low tide on May 8, 2017. The raw LiDAR data obtained through low-altitude flight was converted to point cloud after calibration and preprocessing using Teledyne Optech HydroFusion software. The tidal flat area was cropped from the point cloud and used for the experiments (Figure 2c). The number of points is 427,520, and the point density is 0.85 per square meter. There are a wide variety of size, depths and shapes of the tidal creeks at gradual slope tidal flat of less than one degree. The width of the tidal creek ranges from a few tens of centimeters to a maximum of 60 meters, and the depth ranges from a few tens of centimeters to four meters.



(a) (b) (c)

Figure 2. Test areas; (a) Location of the study area, (b) aerial photo of the test site, and (c) LiDAR point cloud of the test site

3.2 Parameter Optimization

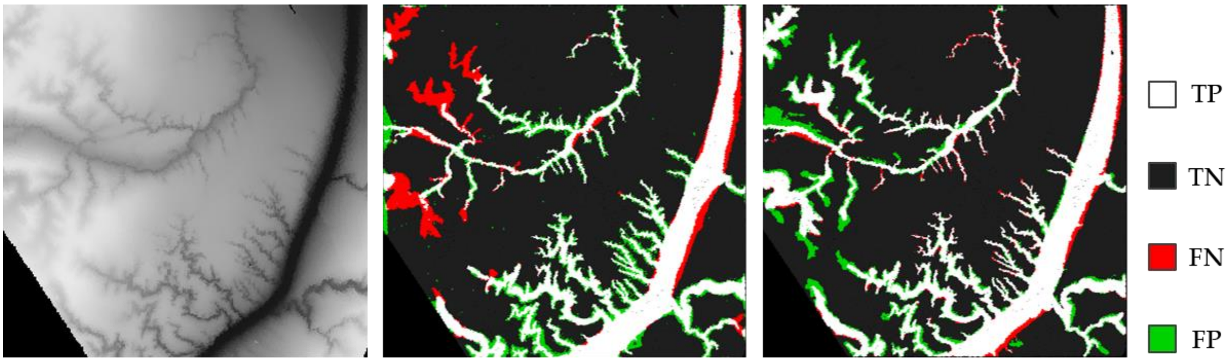
Appropriate parameter optimization is required to apply the ground filtering used to remove the objects on the ground to the tidal creek extraction. Liu et al. (2015) reported that the tidal creeks less than 50 m wide were broadly and densely distributed but difficult to extract whereas extensive tidal creeks were not common and were easy to correct manually. Therefore, we regard a transitional waterway with a width of less than 50 m as a tidal creek in this study, and aim to extract them. Since we aim to extract the tidal creeks less than 50 m wide, the maximum size parameter (MBS) of the object was set to 50 m for TSCAN. The remaining parameters of the TSCAN were empirically determined as TA = 15°, IA = 3°, ID = 0.10 m, and ELAR = 1. The CSF is not a window-based technique and does not require the parameter related to the maximum object size. The CSF classifies ground-points based on the difference in height from the approximate surface. The height difference threshold h_{cc} was determined as 0.2 m. Too small threshold can cause many noise errors on the uneven surface, and too large threshold can omit shallow tidal creeks. Given that Korea's tidal flats were very gentle slopes, the parameter RI, which reflected the slope and undulation of the terrain, was set to 3 in CSF. The grid size GR was set as 2 m empirically.

3.3 Reference Acquisition

The tidal creeks in the test site are manually traced to generate reference data. Manually defining of the tidal creek area is not easy, because of irregular banks and complex shape of creeks (Mason et al., 2006; Liu et al., 2015). In particular, it is difficult to determine the tidal creek region where the tidal creek has asymmetrical sides or very gradual side slope. The reference points were obtained by considering criteria as follows: (1) the elevation discrepancy of the tidal creeks and their surround, (2) slope alteration of the cross-section, (3) continuity of a tidal creek, and (4) submerged area of the cross-section at high tide. The cross-sections of each tidal creek were checked continuously to select corresponding points.

4. RESULTS

Each result of the two ground filtering techniques was compared with the reference data to evaluate the applicability. The performance of a binary classification can be represented in terms of these four possible cases: true positive (TP), true negative (TN), false negative (FN), and false positive (FP). In this study, positive (P) represents as the point of the tidal creek point, and negative (N) is the point of the non-tidal creek point. Figure 3 shows the results for the partial area of the test site. Both methods properly extract deep and narrow V-shape tidal creeks. For more irregular shaped or very wide tidal creeks, the results were different depending on the method. The TSCAN did not extract bilateral asymmetry or very wide shallow tidal creeks with a gentle slope. The CSF performed relatively well on these various types of the tidal creeks. The TSCAN also caused noise errors (FP) at the uneven tidal flat surface. The CSF was comparatively robust to the roughness of the surface.



(a) (b) (c)

Figure 3. Tidal creek extraction results: (a) LiDAR point data the test site; (b) TSCAN results; (c) CSF results.

5. CONCLUSIONS

LiDAR data is most actively being used to extract the tidal creek. The tidal creeks have a wide variety of irregular shapes, sizes, and depths, which are very difficult to trace manually and have shown limitations in extracting by existing techniques using the threshold of height or slope, or edge detection. Besides, all existing tidal creek extraction methods based on the DTM grid can generate different results depending on the grid resolution and the resampling technique. Our approach aims to overcome these limitations by applying the ground filtering technique developed to classify non-ground objects of various sizes, heights and shapes. We carried out tests that extract the tidal creeks applying two recognized ground filtering techniques and evaluated the applicability. From the results, CSF algorithm is robust at the noise of the uneven surface, and the parameter optimizations for tidal creek are relatively intuitive and simpler than the TSCAN. The CSF also extracts the tidal creeks of various widths and shapes. This study verified that the ground filtering technique could be used for tidal creek extraction. In order to validate the effectiveness of our approach, it is necessary to implement experimental and quantitative evaluation of more test sites.

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