Journal of the Korean Association of Geographic Information Studies, 21(1) 2018, pp. 1-11 ISSN 1226-9719(Print)On
https://doi.org/10.11108/kagis.2018.21.1.001 ISSN 2287-6952(Online)

Accurate Spatial Information Mapping System Using MMS LiDAR Data*

Yun-Jae CHOUNG[1] · Hyeoung-Wook CHOI[1] · Hyeon-Cheol PARK[1]※

MMS LiDAR 자료 기반 정밀 공간 정보 매핑 시스템*

정윤재[1] · 최형욱[1] · 박현철[1]※

ABSTRACT

Mapping accurate spatial information is important for constructing three-dimensional (3D) spatial models and managing artificial facilities, and, especially, mapping road centerlines is necessary for constructing accurate road maps. This research developed a semi-automatic methodology for mapping road centerlines using the MMS(Mobile Mapping System) LiDAR(Light Detection And Ranging) point cloud as follows. First, the intensity image was generated from the given MMS LiDAR data through the interpolation method. Next, the line segments were extracted from the intensity image through the edge detection technique. Finally, the road centerline segments were manually selected among the extracted line segments. The statistical results showed that the generated road centerlines had 0.065 m overall accuracy but had some errors in the areas near road signs.

KEYWORDS : Accurate Spatial Information, Road Centerlines, MMS LiDAR, Intensity, IDW interpolation, Canny Edge Detector

요 약

MMS(Mobile Mapping System) 자료를 이용한 정밀 공간 정보 매핑은 고정밀 3차원 지형 모델 구축, 시설물 관리를 위해 중요하며, 특히 도로 중앙선 매핑 작업은 정밀 도로 지도 구축을 위해 필요하다. 본 연구에서는 MMS LiDAR(Light Detection And Ranging) 자료를 이용하여 정밀 공간 정보인 도로 중앙선을 매핑 하는 반자동화 방법을 개발하였다. 우선 주어진 MMS LiDAR 자

2017년 12월 18일 접수 Received on December 18, 2017 / 2018년 1월 10일 수정 Revised on January 10, 2018 / 2018년 1월 15일 심사완료 Accepted on January 15, 2018

* This research was supported by a grant(17AWMP-B079625-04) from Water Management Research Program funded by Ministry of Land, Infrastructure and Transport of Korean government.

1 (주) 지오씨엔아이 공간정보기술연구소 Research Institute for Spatial Information Technology, GEO C&I Co., Ltd..

※ Corresponding Author E-mail : phc1209@naver.com

료를 기반으로 보간법을 이용하여 반사강도 영상을 제작하고, 에지 검출기를 이용하여 반사강도 영상으로부터 선형 세그먼트들을 추출하였다. 최종적으로 추출된 선형 세그먼트들 중에서 도로 중앙선 세그먼트를 수동으로 선택하였다. 추출된 도로 중앙선의 정확도 검증 결과, 0.065m의 정확도를 보여주었으며, 도로 중앙선이 도로 신호와 인접한 일부 지역에서 에러가 발견되었다.

주요어 : 정밀 공간 정보, 도로 중앙선, 모바일 매핑 시스템 LiDAR, 반사강도, 역거리가중 보간법, Canny 에지 검출기

Introduction

A road centerline is "a line representing the physical center of a roadway between road shoulders," (USLegal, 2017). In general, road centerlines can be used for encoding the various road characteristics(road name/width, pavement type/conditions, speed limit, travel directions, bridge weight limits, etc.), and they are generally of the single or multi lane types with yellow color (Article Extension, 2017). An example of the multi-lane-type road centerline is shown in Figure 1.

Mapping road centerlines is important for constructing detail road networks and the accurate road maps, preventing the serious traffic accidents, etc. Hu and Tao(2007), Miao *et al.*(2014), Shi *et al.*(2014) and Cao and Sun(2014) extracted road centerlines from high-resolution satellite imagery. Hu *et al.*(2014) and Hui *et al.*(2016) utilized the airborne topographic LiDAR(Light Detection And Ranging) data for extracting road centerlines.

As mentioned in the previous paragraph, research on mapping the road centerlines has been carried out using various remote sensing data. Due to the short widths, long lengths and complicated locations of the road centerlines, however, the use of the traditional remote sensing data such as satellite imagery, aerial imagery or airborne topographic LiDAR is limited for mapping accurate and precise road centerlines.

MMS(Mobile Mapping System) is a moving

FIGURE 1. Example of a multi-lane-type road centerline (captured from a figure in iamtraffic (2017))

platform operated to determine the position and orientation of the platform and the 3D positions of the objects captured by various remote sensors(optical camera, LiDAR)(Madeira *et al.*, 2012). Research on extracting the various features using the MMS sensor has been carried out of late. Jwa *et al.*(2015) and Pastucha(2016) extracted the linear features using the MMS LiDAR data while Tsai and Han (2013) and Choung(2017) extracted the road surface features using the MMS LiDAR data. Sairam *et al.*(2016) and Soilán *et al.*(2016) generated the road sign inventory using the MMS. Hence, it was assumed that the MMS LiDAR sensor is also useful for extracting the road centerlines because it provides the geometric and surface reflectivity information of the road surfaces with high precision and accuracy. Hence, this research proposes a semi-automatic method for extracting the road centerlines from the MMS LiDAR point cloud.

Study Areas and Data

In this research, one section(length: 500m) of the roads, located around Indeokwon IT valley in Uiwang City, was selected as the study area due to the data availability(see Figure 2). Figure 2 shows the multi-lane type road lines(the red circle in the right figure in Figure 2) in

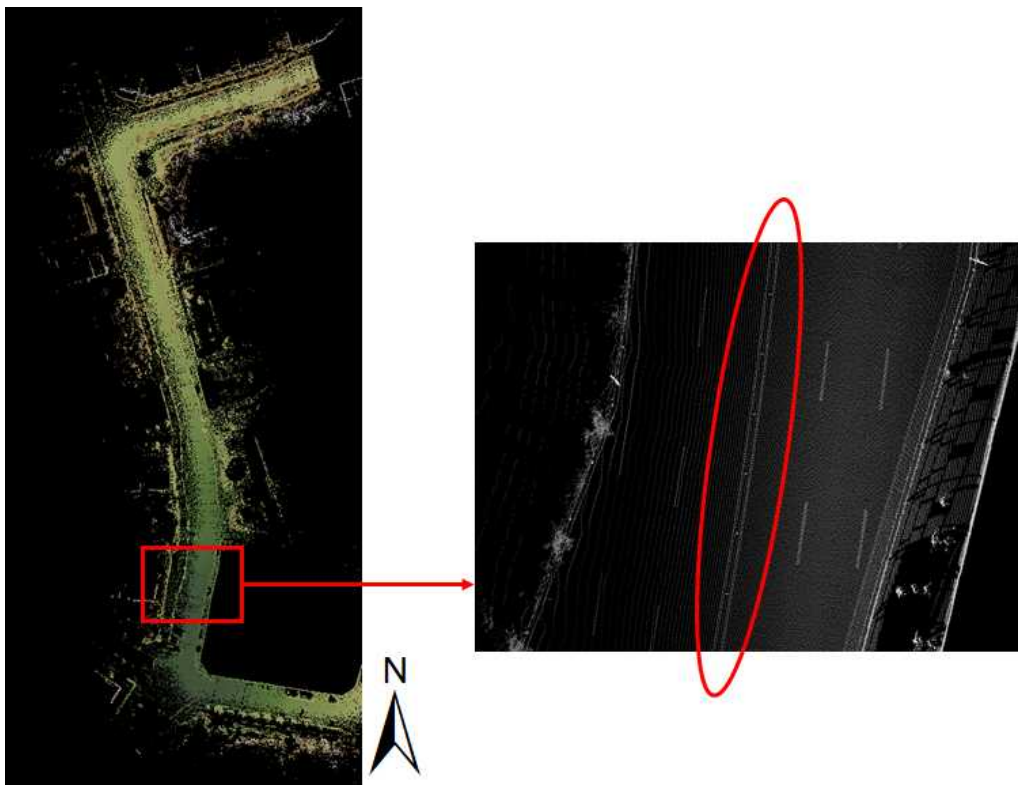


FIGURE 2. MMS LiDAR data used in this research

TABLE 1. Specification of the given MMS LiDAR data

MMS model	Number of acquisition points	Accuracy
MMS-K 320 (made by Mitsubishi Electric Co. Ltd.)	27100 points/sec	6 cm (RMSE: Root mean square error)
Average point density	Acquisition date	Geodetic reference
7cm	2016.09.06	WGS(World Geodetic System) 84 UTM(Universal Traverse Mercator) 52N

the entire study area.

Table 1 shows the specifications of the given MMS LiDAR data. The MMS LiDAR data used in this research was acquired in September 6th, 2016 by using the MMS-K 320 model made by Mitsubishi Electric Co. Ltd. In addition, the horizontal datum, the average point density and the accuracy of the given data were the WGS 84 UTM 52N, 7cm and 6cm, respectively.

Methodology

The developed semi-automatic methodology includes the multiple steps for extracting the road centerlines from the MMS LiDAR point cloud as follows(see Figure 3). First, an intensity image was generated through the interpolation method. Then numerous line segments were extracted from the intensity image through the edge detection technique. Finally, the road centerline segments were manually selected by considering their lengths.

1. Generation of an intensity image

In general, the LiDAR point cloud consists of the multiple attribute information including the X, Y, Z coordinates, the intensity, the return numbers, etc.(ArcGIS for Desktop, 2017a). The LiDAR intensity represents the reflectivity of the surfaces

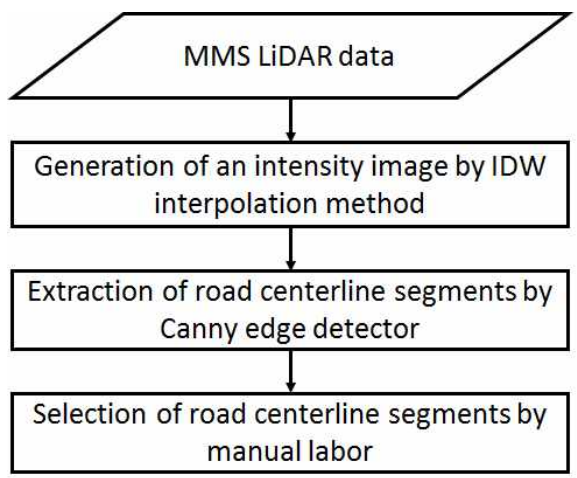


FIGURE 3. Operation of the semi-automatic method for extracting the road centerlines from the given MMS LiDAR data

struck by the laser pulse, for which reason the intensity values are used for detecting features(ArcGIS for Desktop, 2017b).

In this step, an intensity image was generated from the MMS LiDAR point cloud through the interpolation method to detect the seamless line segments. There are various interpolation methods, such as linear interpolation, IDW(Inverse Distance Weight) interpolation, Kriging interpolation, spline interpolation, etc.(Choi, 2005; Lee, 2010). In this research, IDW interpolation was utilized to generate the intensity image because it reflects the intensity values of the nearest LiDAR points for generating grids, and causes the features with a different surface reflectivity to be well visualized in the intensity image generated by it (Cho *et al.*, 2006; Minh and Hien, 2011). The resolution of the intensity image was set as 10cm because the 10×10cm pixel can include at least one LiDAR point in the generated intensity image if the average point density of the given MMS LiDAR data was considered. Figure 4 shows one section of the original MMS LiDAR data(Figure 4(a)) and the intensity image generated by IDW interpolation(Figure 4(b)).

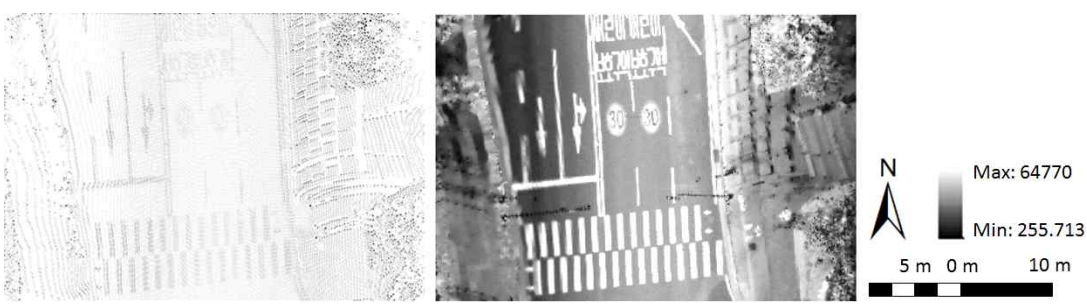
As can be seen in Figure 4, the various features, including the road centerlines and road signs faintly shown in the original MMS LiDAR data are well visualized in the intensity image generated by IDW interpolation.

2. Extraction of line segments

The next step was to extract the line segments from the intensity image through the edge detection technique. The edge detection technique is "an image-processing technique for finding the boundaries of objects within images," (MathWorks, 2017). As the Canny edge detector generally has the superior performance compared to other detectors in detecting the significant edges(Geozalez and Woods, 2007; Choung *et al.*, 2012; Choung, 2015), in this research, the Canny edge detector was employed to extract the line segments, including the road centerline segments, from the intensity image(see Figure 5).

3. Selection of road centerline segments

As can be seen in Figure 5, it is difficult to select the road centerline segments among the numerous line



(a) (b)

FIGURE 4. One section of the original MMS LiDAR data and the intensity image generated by IDW interpolation

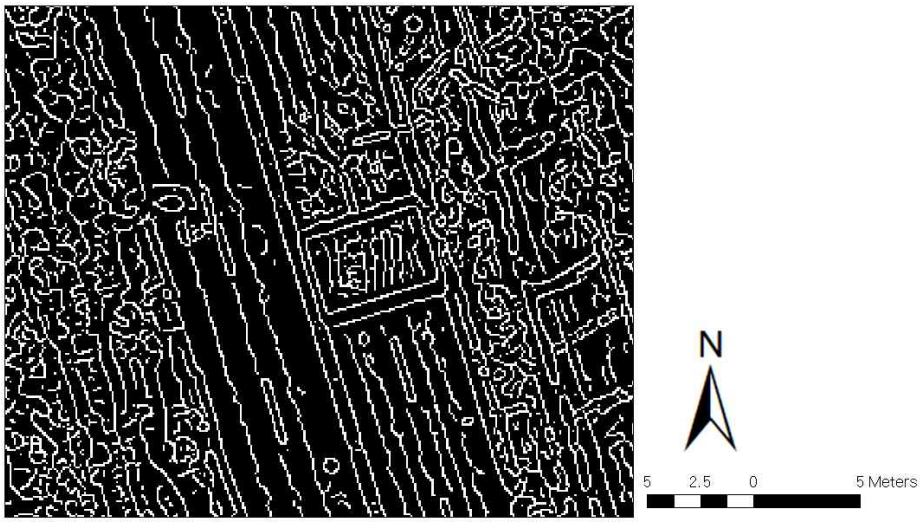


FIGURE 5. Example of the line segments extracted from the intensity image by the Canny edge detector

segments extracted from the intensity image. As the dotted road lines on the local roads are set to have at least 3m length (MOLIT(Ministry of Land Infrastructure and Transport), 2010), the line segments longer than 3m were extracted(see Figure 6).

As can be seen in Figure 6, there were still many line segments that are not related to the road centerlines. In this

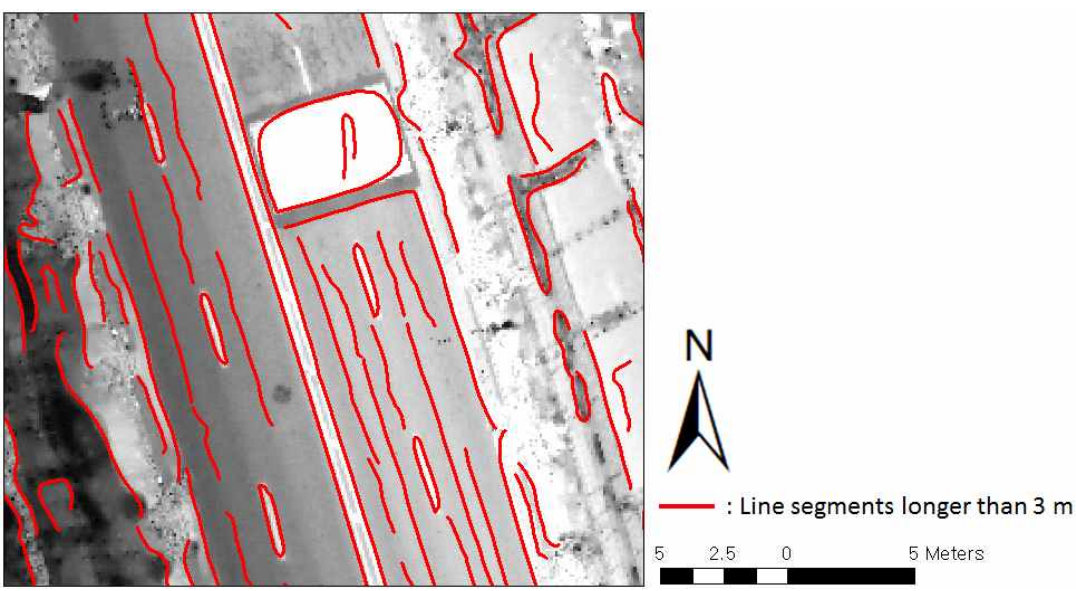


FIGURE 6. Example of line segments longer than 3m

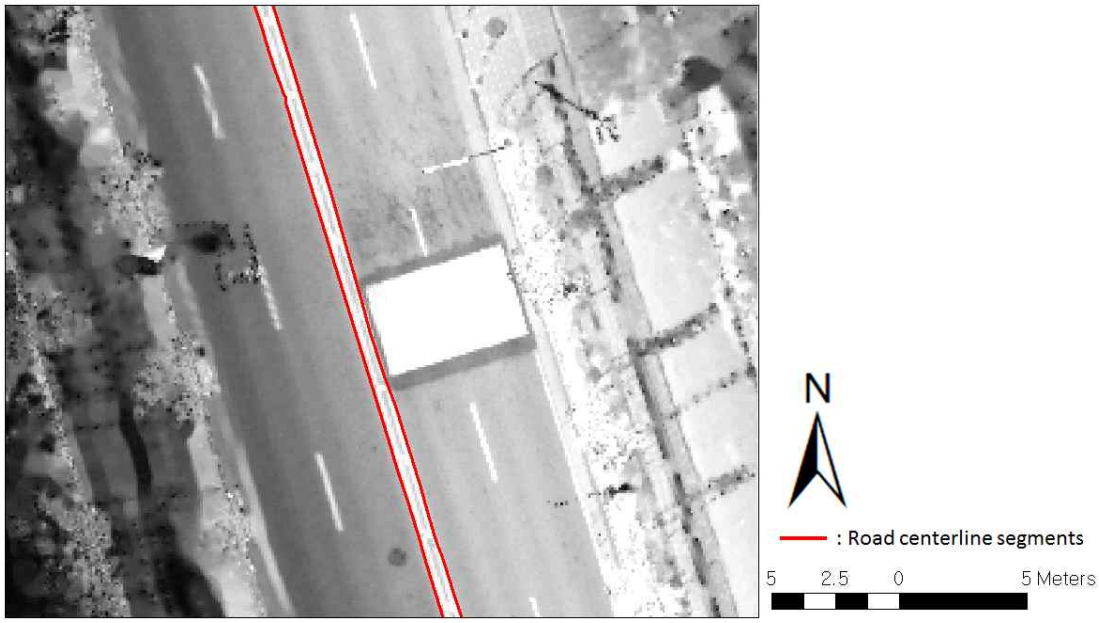


FIGURE 7. Example of the road centerline segments finally selected

research, the road centerline segments were manually selected among the extracted line segments. In the future research, the automatic method for extracting the road centerline segments from the intensity image will be developed. Figure 7 shows an example of the road centerline segments finally selected.

Results and Discussions

The accuracy of the road centerlines generated by the proposed methodology was measured as follows. First, the 20 checkpoints were manually generated based on the intensity map, and the average distance between these checkpoints was 50m(see Figure 8).

Then the shortest distance from each checkpoint to the generated road centerlines was separately measured to calculate the accuracy of the generated road centerlines. Table 2 shows the statistical results of the accuracy of the road centerlines generated by the proposed methodology.

Table 2 shows that the generated road centerlines had 0.065m overall accuracy due to the high average point density(7cm) of the given MMS LiDAR data, but had few errors in the areas near the road signs (see Figure 9).

As the boundaries of the road signs were extracted by the Canny edge detector as well as the road centerline segments, as can be seen in Figure 9, the road centerlines generated by the proposed methodology had errors in the areas near the road signs.

5. Conclusions

Mapping road centerlines is important for constructing accurate road maps,

FIGURE 8. Example of the checkpoints for measuring the accuracy of the extracted road centerlines

TABLE 2. Statistical results of the accuracy of the road centerlines generated by the proposed methodology

Average (m)	Standard deviation (m)	Max (m)
0.065	0.051	0.257

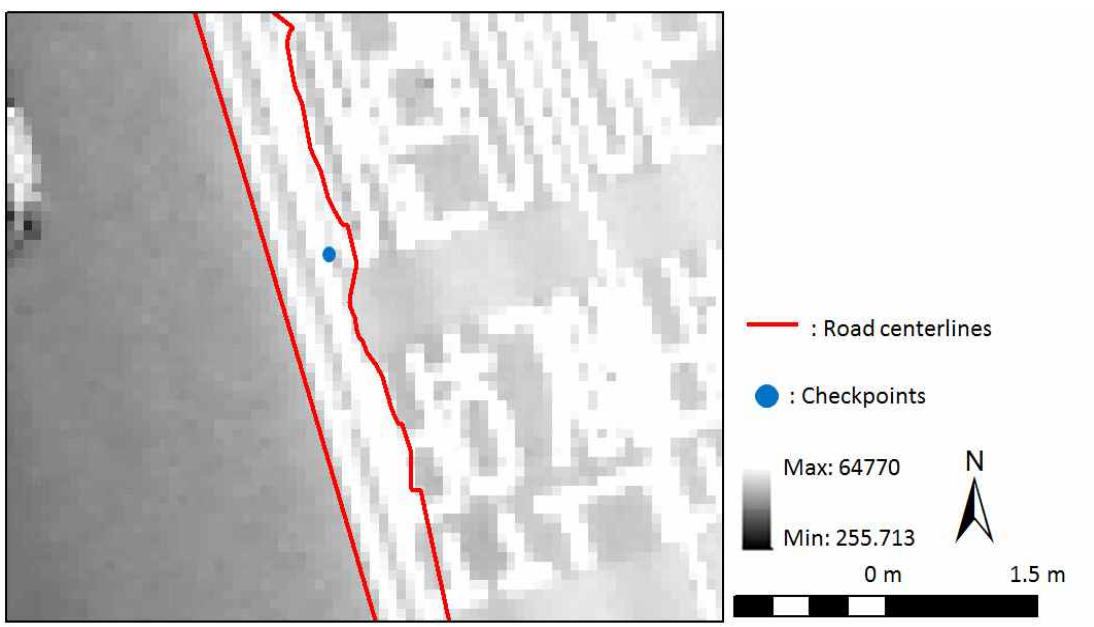


FIGURE 9. Error that occurred in the areas where the generated road centerlines were near the road signs

preventing traffic accidents, making precise road maps, etc. MMS LiDAR is useful for mapping road centerlines because it provides the three-dimensional(3D) information of the road surfaces with high accuracy and precision. This paper propose a semi-automatic methodology for mapping road centerlines using the MMS LiDAR data. The road centerlines extracted through the proposed methodology had 0.065m accuracy.

Further research is required, however, for the following reasons. First, a robust technique is required for removing the numerous noise edges in the step of selecting road centerline segments. Second, an additional technique is required for improving the accuracy of the road centerlines that are near the other features. Third, the different interpolation methods such as Kriging interpolation method and the linear interpolation method should be tested for detecting the various features from the MMS LiDAR data. Fourth, the proposed methodology should be applied into the various types of the road centerlines such as the curved centerlines and the dotted centerlines. KAGIS

REFERENCES

ArcGIS for Desktop. 2017a. What is lidar data? http://desktop.arcgis.com/en/arcmap/10.3/manage-data/las-dataset/what-is-lidar-data-.htm (Accessed March 21, 2017).

ArcGIS for Desktop. 2017b. What is lidar intensity data? Available at : http://desktop.arcgis.com/en/arcmap/10.3/manage-data/las-dataset/what-is-intensity-data-.htm (Accessed March 21, 2017).

Article Extension. 2017. What is a road centerline? http://articles.extension.org/pages/37952/what-is-a-road-centerline (Accessed March 21, 2017).

Cao, C. and Y. Sun. 2014. Automatic road centerline extraction from imagery using road GPS data. Remote Sensing 6:9014-9033.

Cho, W.S., Y.S., Kim and H.J. Chang. 2006. Land cover classification using lidar and optical image. Journal of the Korean Society of Survey, Geodesy, Photogrammetry, and Cartography 24(1): 139-145.

Choi, H. 2005. Evaluation of the optimum interpolation for creating hydraulic model from close range digital photogrammetry. Journal of the Korean Society of Survey, Geodesy, Photogrammetry, and Cartography 23(3):251-260.

Choung, Y.J., H.C. Park and M.H. Jo. 2012. A study on mapping 3D river boundary using the spatial information datasets. Journal of the Korean Association of Geographic Information Studies 15(1):87-98.

Choung, Y. 2015. Development of a dike line selection method using multisspectral orthoimages and topographic LiDAR data taken in the Nakdong river basins. Journal of the Korean Society of Surveying, Geodesy, Photogrammetry and Cartography 33(3):155-161.

Choung, Y.J. 2017. Extraction of 3D objects around roads using MMS LiDAR data. Journal of the Korean Association of Geographic Information Studies

20(1):152-161.

Gonzalez, R.C. and R.E. Woods. 2007. Digital image processing, 3rd Edition, Upper Saddle River, NJ, Pearson Education, p.976.

Hu, X. and V. Tao. 2007. Automatic extraction of main road centerlines from high resolution satellite imagery using hierarchical grouping. Photogrammetric Engineering & Remote Sensing 73(9): 1049-1056.

Hu, X., Y. Li, J. Shan, J. Zhang and Y. Zhang. 2014. Road centerline extraction in complex urban scenes from LiDAR data based on multiple features. IEEE Transactions on Geoscience and Remote Sensing 52(11):7448-7456.

Hui, Z., Y. Hu, S. Jin and Y. Yevenyo. 2016. Road centerline extraction from airborne LiDAR point cloud based on hierarchical fusion and optimization. ISPRS Journal of Photogrammetry and Remote Sensing 118: 22-36.

Jwa, Y., G. Sohn, J. Won, W. Lee and N. Song. 2015. Railway track extraction from mobile laser scanning data. Journal of the Korean Society of Surveying, Geodesy, Photogrammetry and Cartography 33(2):111-122.

Lee, H.S. 2010. Comparison and evaluation of root mean square for parameter settings of spatial interpolation method. Journal of the Korean Association of Geographic Information Studies 13(3): 29-41.

Madeira, S., J. Goncalves and L. Bastos. 2012. Sensor integration in a low cost land mobile mapping system. Sensors 12(3):2935-2953.

MathWorks. 2017. Edge Detection, Available at: https://kr.mathworks.com/discovery/edge-detection.html (Accessed March 23, 2017).

Miao, Z., W. Shi and H. Zhang. 2014. Road centerline extraction from high-resolution imagery based on shape features and multivariate adaptive regression splines. IEEE Geoscience and Remote Sensing Letters 10(3): 583-587.

Minh, N., and L. Hien. 2011. Land cover classification using LiDAR intensity data and neural network. Journal of the Korean Society of Survey, Geodesy, Photogrammetry, and Cartography 29(4): 429-438.

MOLIT. 2010. Documents of the regulation for road line painting.

Pastucha, E. 2016. Catenary system detection, localization and classification using mobile scanning data. Remote Sensing 8(10):1-22.

Shi, W., Z. Miao and J. Debayle. 2014. An integrated method for urban main-road centerline extraction from optical remotely sensed imagery. IEEE Transactions on Geoscience and Remote Sensing 52(6):3359-3372.

Sairam, N., S. Nagarajan and S. Ornitz. 2016. Development of mobile mapping system for 3D road asset inventory. Sensors 16(3):367-385.

Soilán, M., B. Riveiro, J. Martínez-Sánchez and P. Arias. 2016. Automatic road sign inventory using mobile mapping systems. Proceedings of the International Achieves of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Prague, Czech Republic, July 12-19, 2016.

Tsai, M.J., and J.Y. Han. 2013. A preliminary study on the road surface feature extraction using MMS collected point clouds. Proceedings of ACRS 2013 Conference, Bali, Indonesia, October 20-24, 2013.

USLegal. 2017. Centerline of a roadway law and legal definition. https://definitions.uslegal.com/c/centerline-of-a-roadway/ (Accessed March 21, 2017).