A Study on 3D Road Extraction From Three Linear Scanner

SHI Yun, Ryosuke SHIBASAKI
Center for Spatial Information Science and
Institute of Industrial Science,
University of Tokyo
Komaba 4-6-1, Meguro-ku, Tokyo 153-8505, JAPAN
Lab. Phone: +81 3 5452 6417 (FAX) 6414
Email: shiyun@iis.u-tokyo.ac.jp

Abstract: The extraction of 3D road network from high-resolution aerial images is still one of the current challenges in digital photogrammetry and computer vision. For many years, there are many researcher groups working for this task, but until now, there are no papers for doing this with TLS (Three linear scanner), which has been developed for the past several years, and has very high-resolution (about 3 cm in ground resolution).

In this paper, we present a methodology of road extraction from high-resolution digital imagery taken over urban areas using this modern photogrammetry's scanner (TLS). The key features of the approach are: (1) Because of high resolution of TLS image, our extraction method is especially designed for constructing 3D road map for next-generation digital navigation map; (2) for extracting road, we use the global context of the intensity variations associated with different features of road (i.e. zebra line and center line), prior to any local edge. So extraction can become comparatively easy, because we can use different special edge detector according different features.

The results achieved with our approach show that it is possible and economic to extract 3D road data from Three Linear Scanner to construct next-generation digital navigation road map.

Keywords: Road extraction, 3D road map, Image matching, TLS (Three Linear Scanner)

1. Introduction

1.1 Background

Nowadays, new demands emerge that cannot be fulfilled by traditional maps, especially in many fields like ITS, pedestrian support system and so on. For example, in pedestrian support system it need more detailed position information and more efficient guiding information which can make pedestrian avoid traffic accident especially for visually-impaired and wheelchair users. 3D road map for the next-generation navigation (we call it next-generation digital navigation map) is need.

But what is next-generation digital navigation map? We think that it must contain the following features: high accuracy (1:500), road surface (not only road network), position and shape of obstacle, and supporting information for positioning, In this paper, we present a solution of constructing the map using very high-resolution TLS images.

As a background of this research, it is necessary to review the related researches. The existing approaches of extracting road from image cover a wide variety of strategies, and different resolution aerial or satellite images. Knowledge based on image analysis for road constructing has been developed by [1]; Automatic methods usually extract reliable hypotheses for road segments through edge and line detection and then establish connections between road segments to form road networks [3]; Automatic method based on actual and complex contextual road model [2].

All of existing approaches focus on data acquisition or data update for GIS, but none of them can meet the next-generation digital navigation map mentioned above, because of limit in image resolution they used. In this paper, we present the approach based on TLS images, very high-resolution images.

1.2 Objective

The objective of this research is to develop conceptual model for constructing next-generation digital navigation map and to develop an approach to construct this kind of map based on the conceptual model. We extract the features for the map from TLS images with guidance of initial topological road network, which can be gotten from existing 2D map.

The proposed conceptual model for the next-generation digital map is divided two part models: Road intersection model and Road segment model. The extraction is done based on different part model and then to connect the two parts to construct the whole 3D road data.

1.3 TLS

TLS (Three Line Scanner) is an optical sensor for aerial survey. TLS is composed of three linear CCD arranged in parallel, and it can acquire three images of each direction (forward, nadir and backward) at the same time. Orienting it on an aircraft perpendicularly to flight direction, and scanning a ground plane, a triple stereo image of a ground object can be acquired (See Figure 1). As a result, occlusion area can be extremely reduced. Using two images of the three, it is also possible to get 3D coordinates by stereo matching.

Because of its principle of data acquisition, it have the following advantages: (1) high resolution digital image can be collected with longer CCD linear sensor by push-broom mode; (2) seamless image strips for linear ground objects without mosaic processing; (3) the same ground area is covered three times by push broom mode with 100% coverage; (4) precise geometric positioning by modern GPS technology and simple aerial triangulation with few GCPs; (5) last but not least it have low cost of data acquisition.

But because its push-broom mode is different with area CCD, the existing traditional photogrammetry methods cannot work well about TLS.

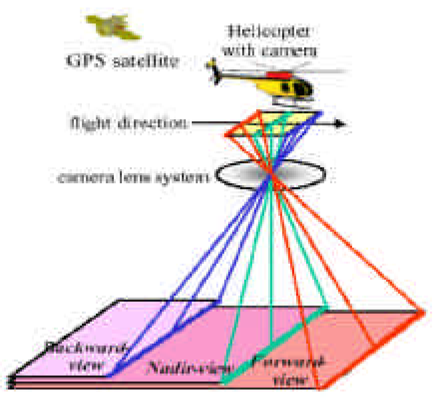


Figure 1. TLS data acquisition

2. Extraction Strategy and Methodology

2.1 The outline of our methodology

The main principle or strategy is to guide the road extraction by all *already available information* and therefore to extract firstly the *most salient parts* and the attributes of roads that are *easy* to be detected, and then to presume the road in occlusion area by prior information, and to extract from rough features to fine features of road.

In this research we use the 1:2500 2D digital map as our guiding information to give us the initial road network, which contain rough ideas about position, orientation, and topology of potential roads as well as to remove regions where no road is expected.

In road hypotheses area, we dividually extract road intersection and road segment based on our models, and then reconstruct the whole digital navigation map. (See figure 2)

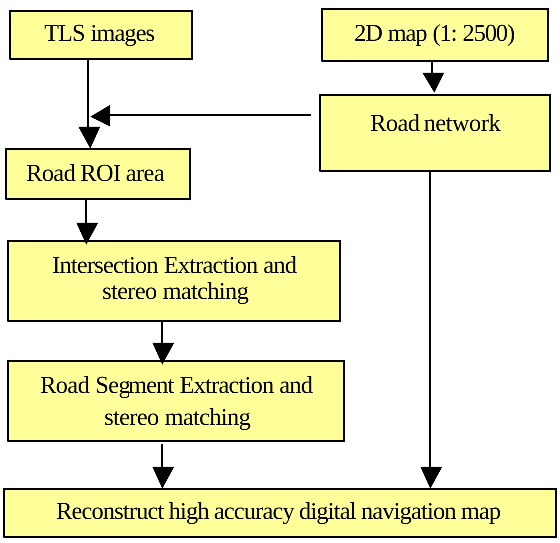


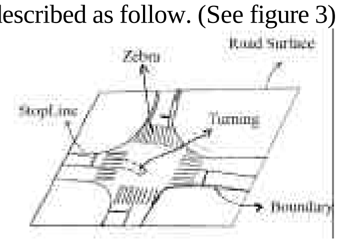
Figure 2. Flowchart of our method

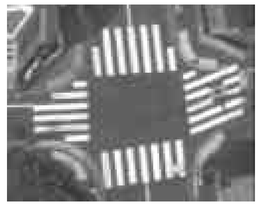
2.2 Road Intersection Model and Extraction

Why we need to extract road intersection firstly and dividually. There are the following reasons: (1) it is important features in the new road conceptual model; (2) it is comparatively easy to be extracted because of its high information and salient feature; (3) extracted intersection will be beneficial to extraction of road segment.

2.2.1 Road Intersection Model

In next-generation digital navigation map, not only road network but also road surface is necessary features. So we want to extract road surface from TLS image along existing initial road hypotheses. The model is basically described as follow. (See figure 3)





.

Figure 3.
Intersection Model

Figure 4
TLS image in intersect area

In the conceptual model, road intersection is considered as surface with special shape, boundary, and road markings. From the TLS image (See Figure 4), it is possible to extract the necessary position information and features for constructing road intersection based on the model with high accuracy.

2.2.2 Features Extraction in Intersection Hypotheses

Based on the intersection model, we mainly need extract two kinds of features (markings and boundaries). The following is outline of extraction. (Figure 5)

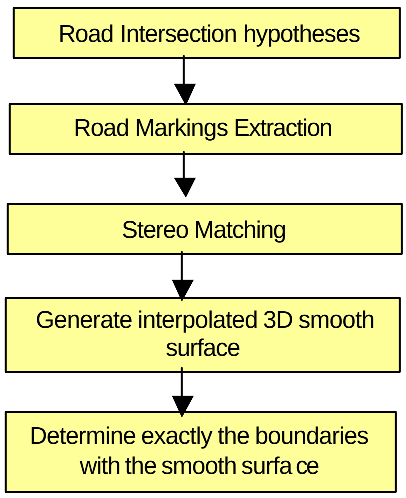


Figure 5. Flowchart of intersection extraction

Road markings such as zebra crossing, turning arrows are good indications of the existence of roads. They are generally found on main roads and roads in urban areas. Both of them have distinct color (usually white or yellow). In TLS images used in our project, road markings are white thin lines with a certain width. As far as construction of the next-generation navigation map is concerned, road markings are not only important features in the model themselves but also give the road direction and even the road centerline, the zebra crossings define the local road width. Thus, they should be extracted and then be used to guide the road extraction process or verify the extraction results. So in the approach, road markings are prioritized in the extraction not only in road intersection area, but also in whole road hypotheses.

Intersection Boundary defines the shape of intersection. Based on direction of road marking, and width of zebra crossing, using SNAKE model, we can fit the boundary, and then stereo matching is conducted on extracted boundary to get 3D boundary. (This work can see in [4] and [5]).

2.3 Road Segment Model and Extraction

With help of the above extracted road intersection and with guidance of initial road network, we can extract necessary features such as road markings, boundaries, and obstacles, to reconstruct the road segment surface based on the road segment model (See figure 6).

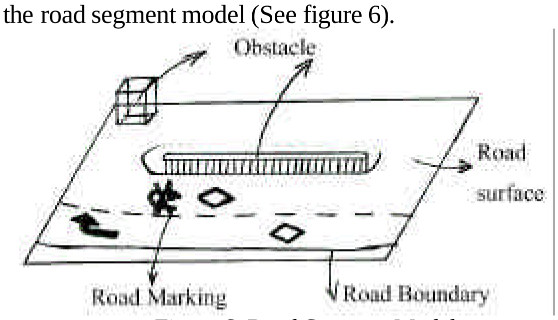


Figure 6. Road Segment Model

Since the road markings have enough information and are easy to detected, we also begin our work with extracting the road marking. In many cases the correct road centerlines can be even derived directly from present road marks and/or zebra crossings. This is especially useful when the roadsides are occluded or not well-defined, such as in cities or city centers.

After we get the 3D road markings using stereo match, in road hypotheses (Road ROI), we generate interpolated 3D smooth surface, and then determinate exactly the boundaries with the smooth surface. (The strategy of construction is the same with the above intersection extraction).

The other necessary features for constructing the road map, like obstacles, signal light, and signboard, they can be detected by manual and automatically stereo matched to get shape and height of them.

Finally with the guidance of road network, it is easy to connect intersection surface and road segment surface to complete constructing of the next-generation digital navigation map.

3. Experiments and Results

In this experiment, we just use TLS image data and existing 2D road map. From the result in this test area, the road marking extracting and stereo matching have good result, and if the road boundary isn't covered by trees or vehicles, the good result can be gotten. The following map show our extracted road smooth surface. Red line is boundary of road surface, and blue one is road marking.

4. Conclusion

In this research, based on the conceptual model of next-generation digital navigation map, with guidance of initial road network, extraction of the high accuracy and high information digital navigation map from TLS image is studied.

As a conclusion of this research, we can say that it is efficient solution with using TLS image to construct the high accuracy digital navigation map. However so far some of extraction must be supervised by manual.

In future, we will focus on perfecting our conceptual model and decreasing supervision by manual, which mean that constructing the map based on the conceptual model can be finished as automatically as possible.

Acknowledgement

The authors would like to express the appreciation to the STARLAB Co. Ltd and their staffs for TLS images distribution and necessary related knowledge about TLS system for this research, and want to thank specially to Mr. Nakagawa, Mr. Nakamura, Dr. Guotao and Mr. Sompoch for their help and suggestion and our laboratory members.

References

[1] Zhang Chunsun, Baltsavias E., Gruen A., 2001. Knowledge-based on image analysis for 3D road Reconstruction. Asian Journal of Geoinformatics, Vol. 1, No. 4 June 2001, pp, 3-14.

[2] Hinz S., Baumgartner A., 2003. Automatic Extraction of Urban Networks from Multi-view Aerial Imagery. In: International Journal of Photogrammetry and Remote sensing. 58/1-2, pp 83-98.

[3] Wang, Y., Trinder, J., 2000. Road Network Extraction by Hierarchical Grouping. In: International Archives of Photogrammetry and Remote Sensing, Vol.33, Part B3/2, pp. 943–950.

[4] Masafumi NAKAGAWA, Ryosuke SHIBASAKI, 2002. Fusing Stereo Linear CCD Image and Laser Range Data for Building 3D Urban Model, 23rd Asian Conference on Remote Sensing, 2002.

[5] K. NAKAMURA, M.. NAKAGAWA, R. SHIBASAKI, 2002, 3D Urban Mapping based on the Image Segment using TLS Data 23rd Asian Conference on Remote Sensing.