Vehicle Detection from Ultra-high Resolution Aerial Image, Three Line Scanner

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Abstract: Year by year, traffic congestion is severe on street in big cities such as Tokyo because vehicles increase rapidly compared to constant street surface. Furthermore, this problem causes economic and environmental waste. Therefore the attempt to monitor vehicles and their behaviors becomes challenging demanding unavoidably on vehicle statistical analysis for efficient and effective traffic planning and management. One potential method of several vehicle-monitoring ways is on aerial images with digital photogrammetry algorithms due to observation of wide-area coverage at the time. Recently, new aerial sensor, Three Line Scanner (TLS), has been realized with a capability of centimeter-ordering resolution and seamless imaging digitally as well as linear object trackability. TLS images are well fitted to fulfill Vehicle Monitoring on streets in Mega City. Therefore, unique and original algorithm of Vehicle Detection from TLS image has been researched and realized. The framework of this study is divided into three steps: Preparation Step, the Automatic Vehicle Detection and the Semi-Automatic Vehicle Detection in difficult area. In preparation step, at first stage, the raw TLS image is segmented by region growing At later, noise removal and over-segmented region correction are by morphological techniques and geometric constrains as well as nearest interpolation. Also, a nearest-region network is generated by dilation techniques. Building Shadow, detection occlusion, is detected and corrected by sunny-shadow object relation and overlay techniques. Moreover, the road, regions of interest for vehicle detect, is extracted as linear-feature objects by radon transformation and buffering methods. At a final proceed of preparation step, regions on street is detected. Non-vehicle regions as road surface, lane line, road mask are filtered and only rest of vehicle region candidates are still existed. In automatic vehicle detection stage, the vehicle model hypothesis has been crated from generic vehicle component and vehicle size catalog. At time, Vehicle Shadow/ Dark Vehicle is detected and applied as vehicle cue. At a cue position, “cluster” neighbored regions along sun side is detected by frame detector. “Cluster” is merged as a region by expansion process. Finally a “cluster” as vehicle, satisfied with a vehicle model hypothesis, is detected. Some vehicles especially under occlusion such as a building shadow, however, are not detected. Therefore, at the semi-automatic vehicle detection, some region is given as the starting point to generate “cluster” by the expansion process. A “cluster” as vehicle is validated and matched with the vehicle model as same processing in a automatic vehicle detection. Finally, the robust method has been developed and promising results are performed in this paper.

1. Introduction
At the present, mega cities around the world are facing severe traffic congestion on street and the problem is turning down rapidly every year. This problem causes varied direct and indirect negative impact on human and environment. Especially, during rush hour in mega cities, traffic congestion causes economic losing extremely. Therefore, a variety of on-street vehicle monitoring techniques for Vehicle Information & Communication Systems of
Intelligent Transportation Systems (ITS) have been developed for the sustainable traffic planning in the short and long terms. One potentially practical application is a vehicle monitoring by using images of High Altitude Remote Sensor such as aerial camera or spaceborne sensor etc due to wide-area covered observation. Some countries enact the national transportation planning using Remote Sensing Methods such as USA etc in [4]. Nowadays, modern airborne sensor has been begun in aerial imaging operation. It is called “Three line Scanner” or TLS. TLS contributes a several merit points with Ultra-high resolution images in three directions simultaneously: forward, nadir and backward directions (see figure 1). One potential advantage of TLS is Seamless imaging and effective trackability of linear feature such road or river etc. Moreover with ultra-high and centimeter-order resolution, vehicle is well-recognized with its component such as rear minor etc. Therefore, in this study the challenging and practical method of Vehicle Detection has been researched and realized with high performance.

A structure of this paper is arranged as follows: Chapter 2 reviews the existing researches of vehicle detection. The overall structure of Vehicle Detection is depicted in chapter 3. Charter 4 proposes the novel and unique automatic algorithm of Vehicle Detection by using modern aerial image of TLS. Chapter 5 presents semi-automatic vehicle detection, compensated algorithm of omission from the method in chapter 4. Finally, Chapter 6 summarizes our experiment and proposes further tasks.

2 Existing Researches of the Vehicle Detection by using Aerial image.

In remote sensing, computer vision has also been applied especially in terms of the object detections. It, however, is challenging but there are existed few researches of vehicle detection using aerial image in the world. Approach of Vehicle Detection is categorized into two approaches in terms of mathematical theory: Structure Base and Neural Network Base. T. Zhao and his group proposed Neural Network Based to detect Vehicle from Low Resolution Aerial Image with promising results [5]. With Structure Based Approach, R. Chellappa and his group presented an algorithm of the Vehicle Detection based on Generic Property of Vehicle with a high rate of detection [1] and again Vehicle Detection from high resolution aerial image by Structure Based Approach is developed and performs promising results by S. Hinz and A. Baumgartner [2]. However, all of existed researches are applied by using frame aerial image. There is no application of vehicle detection by utilizing line image with ultra-high resolution such as TLS images and all of their works have not mention on analysis algorithms of Vehicle Behavior as parking or moving etc. Therefore, this study is to focus on the development of new approach for Vehicle Detection and vehicle behavior analysis by using modern ultra-high resolution aerial image. A detail of the algorithm is mentioned in a next charter.

3. Framework

Based on potential and practical advantages of TLS images, the novel algorithm of vehicle detection by using new kind of image from TLS has been developed. (See Figure 2)
Behavior Analysis respectively. A detail of each stage is described in a next charter.

4. Preprocessing

At this stage, TLS raw image is pre-processed to create fundamental information for further stages in a next charter. Whole compulsory image processing is depicted in figure 3

<table>
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<th>Preprocessing Level</th>
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<td>- Buffering Approach</td>
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Figure 3 Systematic Diagram of preparation stage

Image Segmentation and Labeling: due to ultra resolution of TLS image in centimeter-order, one efficient method of image segment to preserve vehicle body and the component, Region Growing is applied Region Labeling is applied for Spatial Indexing in further processing.

Noise removal and Over-segmented region Correction: segmented image by region growing method, however, have noise as isolated smell region. Therefore, erosion of Morphological Mathematics has been applied and then from this operation, black pixels exist in segmented image. The nearest interpolation by calculating and searching shortest Euclidean distance between black pixel and pixel of labeled region has been utilized to label black pixels into nearest labeled region. Finally, the noise regions and black have replaced and labeled. The result is called “Cleaned image”. (See figure 4)

![Cleaned Image](https://via.placeholder.com/150)

Figure 4 Results from some of all preprocessing stage

Nearest region network: as necessary information or expansion processing, dilation of selected region and subtraction between dilated region and original image are proceeded to generate nearest region network.

Road Definition: due to linear feature trackability of TLS, road as linear feature have been detected by Radon Transformation and then the road surface is generated by buffering the area into both sides of Radon-detect line. Finally only regions existing on road are detected by line geometry property.

![Road Definition](https://via.placeholder.com/150)

Figure 4. Road definition as Vehicle position of interest

Non-Vehicle Region and Vehicle Candidate Region Extraction: Using geometric constrains related pixel-size and vehicle size from vehicle dimension database [3], no-vehicle regions, not satisfied with
Geometric Constrain, are filtered. The rest of regions on road surface still exist as candidate of vehicle region component. In figure 5, candidates of vehicle region component with their center of mass are shown.

Figure 5 the result of detection of candidates of vehicle region component

Building Shadow Correction: due to effect on directly object detection or recognition based on gray scale, building shadow lying on the road has been detected by using object brightness on Sunny and Shadow relationship. Please see figure 6

A)Raw Image of TLS with Building Shadow

B)Result of Building Shadow correction

Figure 6 building shadow corrections

5. Automatic Vehicle Detection

After fundamental information has been created, on TLS nadir image, new area image, vehicles have been detected by new algorithm. A detail of the algorithm is depicted in Figure 7

Automatic Vehicle Detection

- Cluster Satification with Vehicle Model

Vehicle Shadow detection: As important cue, vehicle shadows have been detected by simple set of image processing such as median filter and gray threshold. Later, to segment vehicle shadow object, Region Segmentation and Region Label is applied. Those Vehicle Shadow Regions only on street are extracted. Moreover, some part of vehicle, others of all important cues such as roof or front minor is detected under building shadow, enclosing with polygon in this procedure.

Figure 7 result of Vehicle Shadow Detection

Vehicle Model: due to a variety of vehicle size, a lot of fixed-size vehicle, the template of vehicle are not able to create. Therefore the fixable geometric constraints as vehicle model have been developed from a several vehicle generic characteristics such as orientation of vehicle, vehicle as rectangular shape etc.
Frame Detector and Expansion Process: On sun side of vehicle shadow, frame has created to detect regions along the vehicle shadow by creating polygon as frame and detect regions inside this frame called "Frame Detection" and thus a group of regions detected by Frame Detection is clustered to be "Vehicle Candidate Cluster". This algorithm is depicted in Figure 8.

Vehicle Detection: to validate the vehicle in the image, cluster, generating by Frame Detector and Expansion Process, is matched with "Vehicle Model". The Cluster, accepted with "Vehicle Model Constrain", is vehicle. Finally, with the rectangle-fitting model, vehicle is enclosed with the rectangular polygon. Therefore, based on this robust algorithm, the promising results of vehicle detection from TLS Nadir, Ultra High Resolution aerial image have been obtained. Please see one of example in Figure 9

6. Semi Automatic Vehicle Detection
The vehicle, however, is detected by the robust algorithm mentioned in lasted. It is well detected in sunny area and vehicle with shadow. The vehicle under Building Shadow is not detected or misdetected. Therefore, to solve this problem, the Semi-Automatic Vehicle Detection algorithm has been developed. The detail of the algorithm is depicted in Figure 10.

Seed Point Selection: from building shadow corrected image, seed region, as origin of expansion is inputted by mouse upon the GUI interference. (See Figure 11) The selected point is cue of vehicle such as vehicle roof, front windshield etc.

Cluster Generation: from selected region and excluded regions, neighbored regions surrounding are
clustered as Vehicle Candidate. The detail of algorithm is shown in figure 12.

![Figure 11 GUI of Semi Automatic Vehicle Detection](image)

Vehicle Detection: cluster matched with the Vehicle Model in a last charter is vehicle. The detail of processing is mention in charter 5. the automatic algorithm to solve this problem is being developed and will be realized soon.

![Figure 12 detail of Semi-Automatic Vehicle Detection](image)

7. Conclusion

The new and robust algorithm of vehicle detection with novel aerial image from TLS has been realized with promising results. Also, omission in occlusion area has been solved by semi automatic vehicle detection methods with friendly-user interference. At a present, some further research and improvement are being realized as below:

1. The correction algorithm of overlapped vehicle polygon to distribute only unique vehicle is being implemented.
2. A discrimination algorithm of Moving and Stopping Vehicle is being developed and will be created soon.
3. Vehicle Behavior Analysis such as Stopping or Signals Waits will be realized in near future.

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Reference


4. U.S. Department of Transportation (DOT), Commercial Technology Applications Program in Support of the Department of Transportation (DOT) Program on Remote Sensing Applications in