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Surround View based Parking Lot Detection and Tracking

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Abstract— **Parking Assistance System (PAS) provides useful help to beginners or less experienced drivers in complicated urban parking scenarios. In recent years, ultrasonic sensor based PAS and rear-view camera based PAS have been proposed from different car manufacturers. However, ultrasonic sensors detection distance is less than 3 meters and results cannot be used to extract further information like obstacle recognition. Rear-view camera based systems cannot provide assistance to the circumstances like parallel parking which need a wider view. In this paper, we proposed a surround view based parking lot detection algorithm. An efficient tracking algorithm was proposed to solve the tracking problem when detected parking slots were falling out of the surround view. Experimental results on simulation and real outdoor environment showed the effectiveness of the proposed algorithm.**

I. Introduction

Various Advanced Driver Assistance Systems (ADAS) have been developed to alleviate the increasing social problems like traffic jam or traffic accident. As one of the ADAS applications, Parking Assistance System (PAS) increases safety and makes driver feel more comfortable during parking process.

Currently ultrasonic sensor and rear camera are widely used in PAS, and many commercial systems have been introduced to the market. However, for ultrasonic sensor, the detection range is short and the accuracy is low. For rear camera, it is difficult to detect parallel parking lots because the visible field is limited to the rear side of self vehicle.

Surround view system is a good solution to these problems (Fig.1). Surround view system compensates fisheye distortion of original images captured by four cameras on four sides of vehicle, transforms the undistorted images into bird's-eye view image respectively and then constructs surround view by matching four bird's-eye view images. Surround view system provides a virtual image to intuitively show the circumstance all around the vehicle, by which blind spots are able to be eliminated.

In this paper, we proposed a new surround view based PAS and its implementation on Renesas SH7766 embedded system. A tracking algorithm was also proposed to solve the problem that detected parking slots in the previous frame shift beyond view field of the current frame. Mobile robot tests and field experiments were also implemented to validate the proposed system. In this paper, related research is reviewed in Chapter II. Our proposed parking lot detection and tracking algorithm will be introduced in Chapter III, with experimental results on real outdoor environment in Chapter IV and summary in Chapter V.

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Fig.1. Surround view system

II. Related work

Ultrasonic sensor has been used in the conventional automatic parking system. Park4U®, which was put to practical use by Valeo in 2007, is one of the ultrasonic sensor based parking assistance application[1]. Park4U® is available to detect parking areas automatically by ultrasonic sensor and supports both parallel and back parking by auto steering operation.

In the case of automatic parking, there has been a trial displaying rear-view camera picture to reduce burden on driver. In its Prius model, TOYOTA first introduced Intelligent Parking Assist System (IPAS) with the rear view camera to the world in 2003[2]. IPAS lets driver decide parking target position by operating a cursor while watching the monitor, and it supports both parallel and back parking by auto steering operation as well.

Jung et al. proposed a similar parking detection method which let driver choose two entrance points of parking lot line[3][8]. The accuracy of detection was improved and computation cost was reduced by this method. Although the method achieved high precision over 90%, it failed in the situation of white line detection noise, sunlight condition and the effect of touch panel operation on driver.

In recent years, surround view system has been introduced to the market in order to help driver have a 360-degree surround view, without blind spots. Surround view system provides a kind of virtual image taken from the sky showing the circumstance around the vehicle within certain distance. It compensates the fisheye distortion of input images captured by four cameras, transforms the undistorted images into bird's-eye view image respectively and then constructs the around view of the self vehicle by matching four bird's-eye view images. A surround view example is shown in Fig.1.

Surround view image eliminates the perspective distortion of objects attached to the ground surface, so the geometrical features of parking lot lines could be used, which contributes to recognition of parking slots painted on the ground surface[4]. In addition, the surrounding of self vehicle is provided by surround view, which enables driver to easily monitor the ongoing parking process.

In this paper, a new surround view based PAS and its implementation on Renesas SH7766 embedded system[6] is proposed.

Fig.2. Valeo "Park4U®"

Fig.3. TOYOTA "Intelligent Parking Assist System"

III. SURROUNDING VIEW BASED PARKING LOT DETECTION AND TRACKING

The processing flowchart of the proposed surround view based parking lot detection and tracking algorithm is shown in Fig.4. Construction of surround view by four cameras video input will be explained in Section 3.1. In our preprocessing part, a line filter and probabilistic Hough transform will extract all the candidate line segments as potential parking lot line marker. This part will be explained in Section 3.2. Parking lot detection part includes line grouping, detection and tracking, which will be described in Section 3.3 and 3.4.

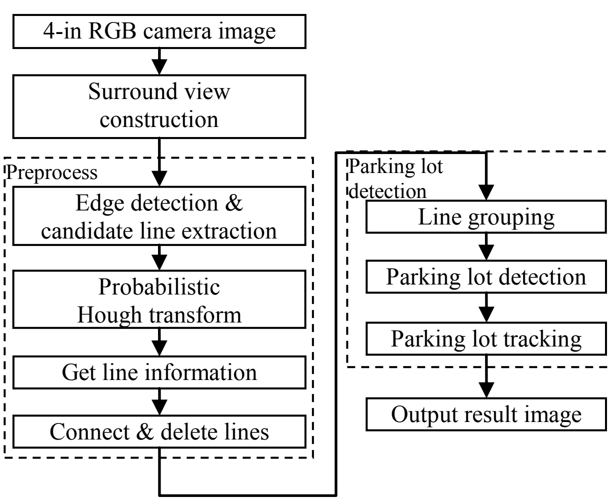


Fig.4. System block diagram

3.1. Construction of surround view

Our test vehicle, as shown in Fig. 5, has been equipped with four fisheye cameras in front, rear, left and right side respectively. The fisheye cameras provide wide-angle FOV images which have more than 180 degrees of FOV in horizontal and 145 degrees of FOV in vertical. It is common that the surrounding view system be composed of four fisheye cameras because it is necessary to get the picture around the vehicle and to avoid any blind points. Calibration is necessary because image acquisition of the fisheye cameras is usually accompanied with a big distortion. In addition, viewpoint conversion to top-view is necessary before composing an image.

Fig.5. Test vehicle

3.2. Detection of candidates of the parking lot line

The surround view image constructed in section 3.1 is gray-scaled and filtered by a differential filter. Because the domain of the parking lot line has higher luminosity than the neighborhood, the luminosity greatly changes from low to high and from high to low. So a positive edge will be detected from low to high luminosity and a negative edge will be detected from high to low luminosity. An adaptive threshold is used to detect the pair of edges. The middle point will then become the candidate point of the parking lot line.

In our previous study[5], line filter (Fig.6) was used as a differential filter. It utilized a special 1* (2n+1) line filter to extract the edge candidates. However, this filter suffered from big memory consumption and computational complexity. In this paper, we proposed Sobel filter as the differential filter which consumed less memory.

An example of parking lot surround view image is shown in Fig.7. The result of Sobel filter of the x direction on the scanning line (y=100) and the y direction on the scanning line (x=115) are shown in Fig.8 (a) and (b) respectively which are similar to our previous line filter and are able to extract a pair of positive and negative edges.

The extracted candidate points will be fed into the probabilistic Hough transform[7] to extract all line segments as candidates of parking lot markings (Fig.9). Please refer to [5] for detail description.

-1	…	-1	-1	0	1	…	1	1

|← n →| |← n →|

Fig.6. Line filter

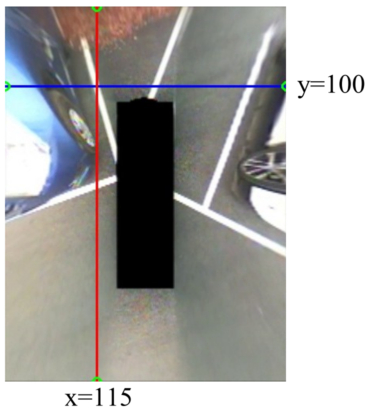


Fig.7. Surround view sample image.

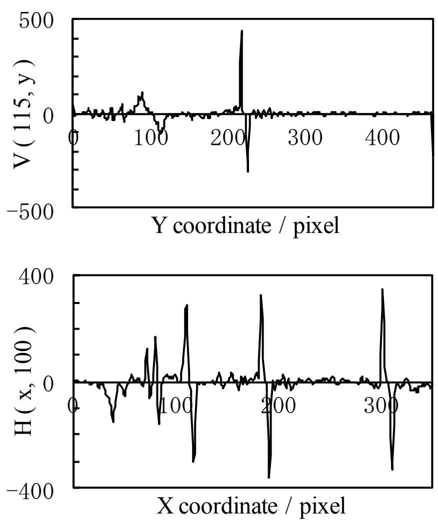


Fig.8. (a) the result of sobel filter(dy) in Fig.7 on x=115
(b) the result of sobel filter(dx) in Fig.7 on y=100

3.3. Parking lot detection

Three kinds of most popular parking lot markings in Japan are shown in Fig.10. We assume that the target parking lot markings belongs to one of these three types.

Based on this assumption, we look for parallel lines of the long side firstly from the candidates of parking lot line segments. And then we search for the segments which are perpendicular to these parallel lines. We consider it as a parking lot marking of (a) if perpendicular lines exist at both ends of parallel lines. A parking lot marking of (b) will be recognized if it only occurs on one end of parallel lines. In addition, it will be a parking lot marking of (c) if perpendicular lines of the parallel ones do not exist.

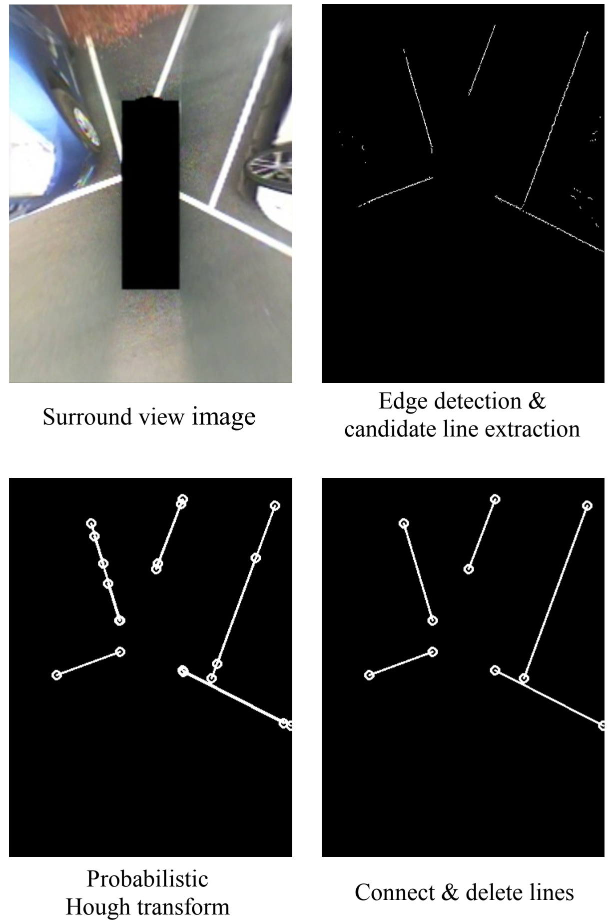


Fig.9. Result of preprocess

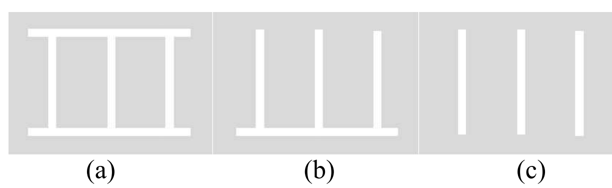


Fig.10. Parking lot markings for detection

3.4. Parking lot tracking

Tracking is very important for parking assistance. The movement of the surround view image can be considered as a two-dimensional rotation and translation because the surround view will be constant if the ground is considered as plane. Therefore the tracking process of surround view image can be realized if the two-dimensional rotation and translation of the object in the present and previous frames can be always provided.

In our previous study[5], the detection process would fail when the parking slot was falling outside of surround view. It was very common since the field of surround view is relatively small. Especially when the vehicle needed to move back and forth to park, the target parking slot was always losing of track. In this paper, we proposed a method of tracking for all the slots to solve the problem.

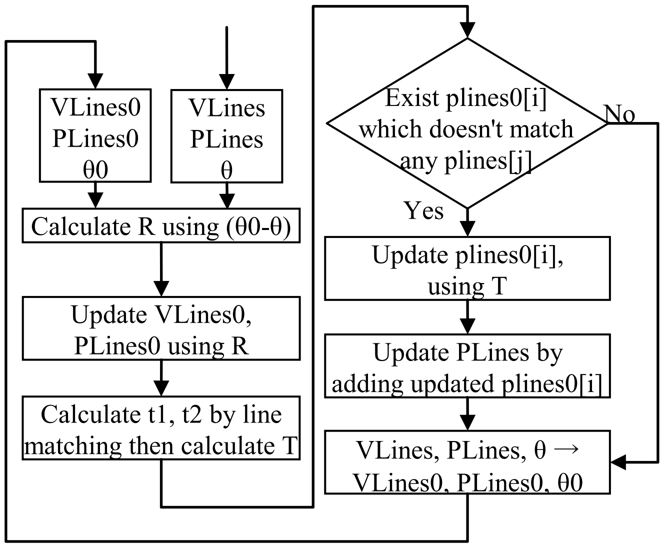


Fig.11. Summary of parking lot tracking

The summary of parking lot tracking is shown in Fig.11. The parameters in a figure are defined as follows (i, j are arbitrary, the same hereinafter). R is rotation matrix, T is translation vector, PLines are parallel line groups of the rectangular long side when parking slot in the present frame are considered to be a rectangle, and plines[i] is each element of PLines. VLines are the perpendicular line groups to PLines, and each element of VLines is vlines[i]. θ is the average angle of PLines. Similarly, we define the variables in the previous frame as PLines0, plines0[i], VLines0, vlines0[i] and θ0. The processing steps are shown as follows:

1. R is derived from the angle difference of average angles θ0 and θ.
2. VLines0 and PLines0 are updated by using R.
3. The new VLines0 and VLines are matched by distance between each segment.
4. By using a pair of corresponding segments, normal vector t1 from VLines0 to VLines can be obtained.
5. Similarly, normal vector t2 can be obtained by PLines0 and PLines.
6. t1 + t2 becomes the translation vector T from the previous frame to the present frame like Fig.12 because VLines and PLines are perpendicular to each other.
7. A plines0[i] which did not perform matching becomes a candidate of the parking lot line which disappeared from the surround view in the present frame.
8. If the result of updating this plines0[i] using vector T meets the condition of Plines, it is the parking lot line which disappeared. So the parking lot line which disappeared can be interpolated by adding the result to PLines.
9. Finally VLines, PLines and θ are substituted with VLines0, PLines0 and θ0.

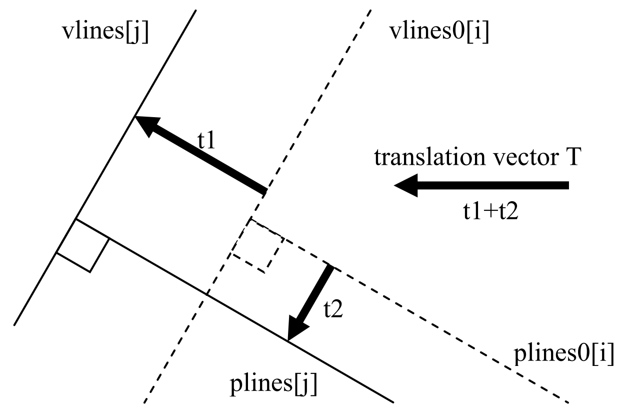


Fig.12. Translation vector

IV. Experimental Result

4.1. Test environment

As shown in Fig.5, the test vehicle is equipped with four fisheye cameras and the parking lot detection is based on the surround view. We have tested several typical parking lot types which include different conditions of lighting and color of pavement. Vehicle speed is limited to below 30 km/h as parking mode.

4.2. Evaluation method of the experiment

In this experiment, a section of 1000 frames in which parking lot lines are included by all means is used. We establish some indexes in evaluating performance. We define the number of detected parking slots in each frame under the viewing as a truth value. The frames are classified into detected frames, non-detected frames and false detected frames. Detected frames are the frames with at least one detected parking slot without false detection. Non-detected frames are the frames without detection. False detected frames are the frames with false detection. The detected frames are classified into perfect detected frames and partial detected frames. Perfect detected frames are the frames with detected parking slots over truth value. Partial detected frames are the frames with at least one detected parking slot but less than truth value. We computed some detection rates as follow:

$$\text{detection rate} = \frac{\#\text{of detected frames}}{\#\text{of all frames}} \tag{1}$$

$$\text{non-detection rate} = \frac{\#\text{of non-detected frames}}{\#\text{of all frames}} \tag{2}$$

$$\text{false detection rate} = \frac{\#\text{of false detected frames}}{\#\text{of all frames}} \tag{3}$$

$$\text{perfect detection rate} = \frac{\#\text{of perfect detected frames}}{\#\text{of all frames}} \tag{4}$$

$$\text{partial detection rate} = \frac{\#\text{of partial detected frames}}{\#\text{of all frames}} \tag{5}$$

4.3. Experimental result

By having tracking process or not, Table 1 is the result of the detection rate, non-detection rate and false detection rate while Table 2 is a result of the perfect detection rate and partial detection rate. In addition, Fig.13-16 are some examples of the image of detection results.

According to Table 1, a detection rate, a non-detection rate and a false detection rate indicate that they are not influenced by having tracking or not, because a detection rate, a non-detection rate and a false detection rate have accrued already before tracking process, and tracking process depends on detected frames only. Therefore the tracking process does not contribute to the improvement of non-detection and false detection.

But according to Table 2, a case including tracking process improved the performance of perfect detection rate by 20%, and when you look Fig.13 you find that the performance of slot detection is better than the truth value (in Fig.13 (b), for example, the truth value includes 4 slots, while the result includes 5 slots) by tracking process. The reason is that missing detected parking slots are estimated by tracking previous detected parking slots to current ones.

Table1. Detection, non-detection and false detection rate

Tracking	Detection rate	Non-detection rate	False detection rate
Yes	0.936	0.062	0.002
No	0.936	0.062	0.002

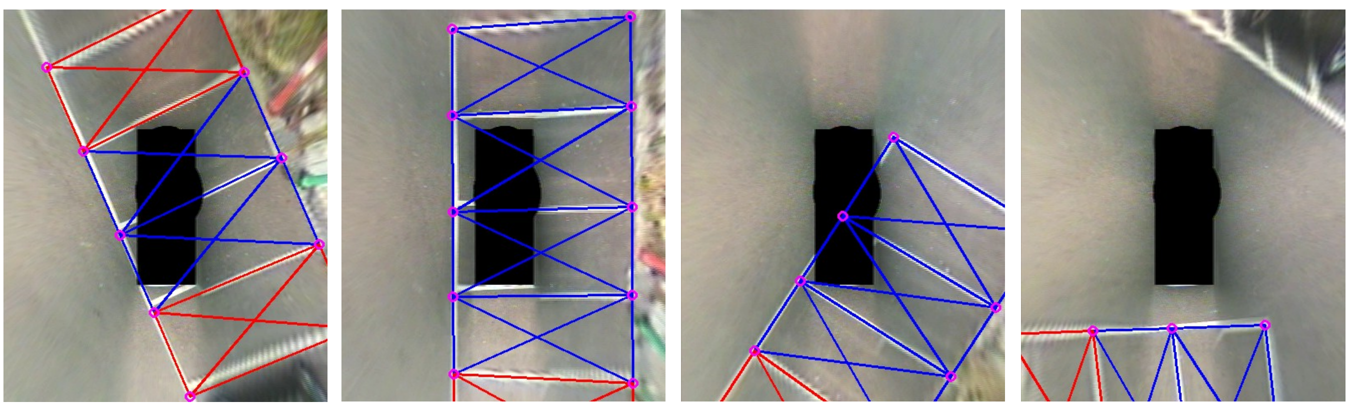
Table2. Perfect and partial detection rate

Tracking	Perfect detection rate	Partial detection rate
Yes	0.741	0.196
No	0.561	0.376

V. CONCLUSION

In this paper, detection failure of the parking slots which disappeared from the surround view was solved using tracking process. This is a problem of conventional parking lot detection systems using surround view. We have confirmed that the performance of the parking lot detection was improved by 20% with the tracking process.

As the future work, reduction of the number of non-detected frames and false detected frames is necessary. Therefore we must build a system which is robust to resisting the image distortion of surround view.



(a) (b) (c) (d)

Fig.13. Result of perfect detection

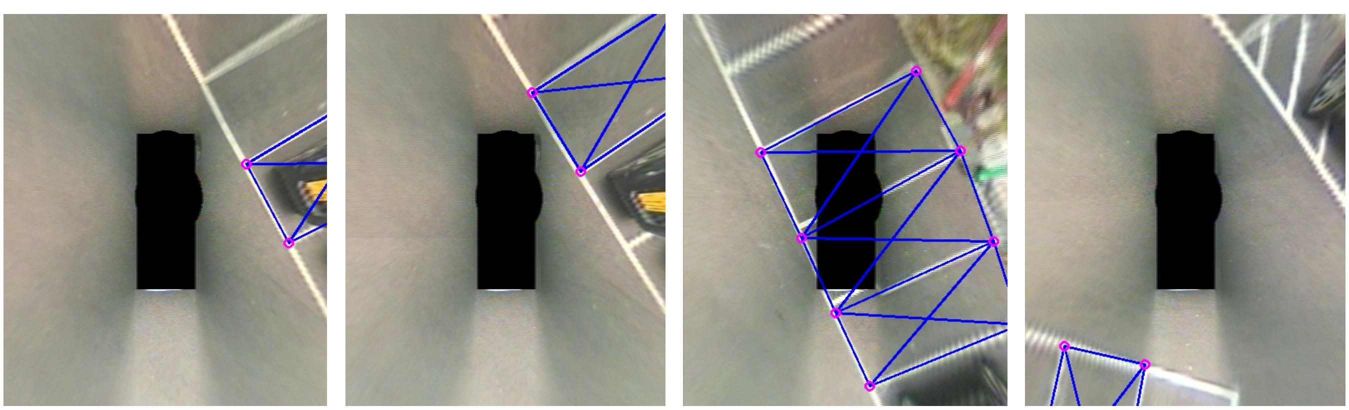


Fig.14. Result of partial detection

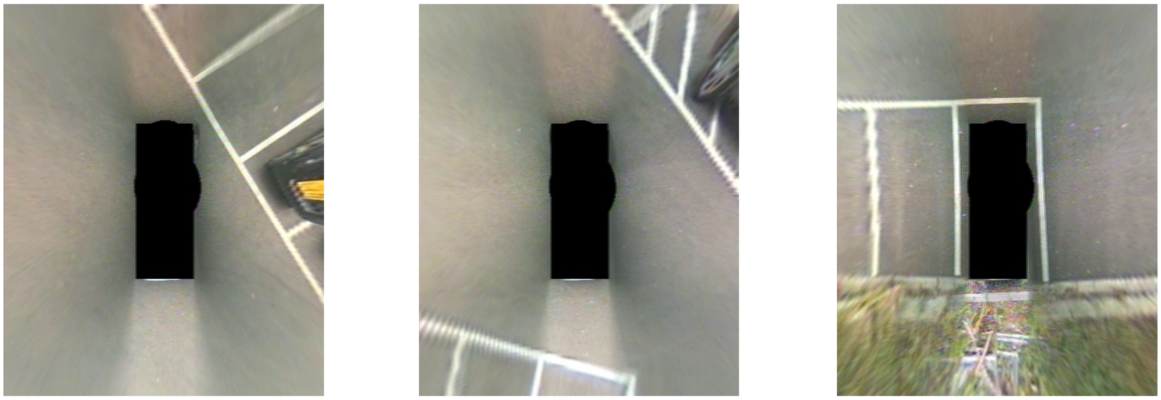


Fig.15. Result of non-detection

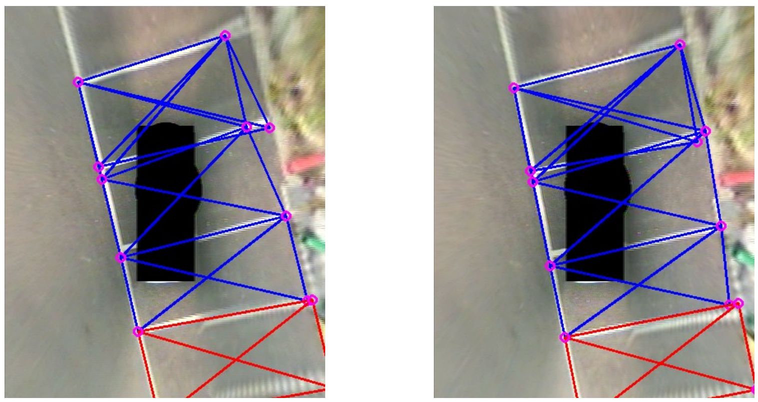


Fig.16. Result of false detection

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