Rear-view Camera System for Improving Safety using Particle Filtering

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Abstract. This research presents a rear-view camera system that utilizes the rear view camera to implement obstacle detection while driving in reverse. The results derived from the initial experiments confirmed that the simple recursive estimation for the background modeling and an efficient detecting algorithm are available for proper procedure. It exhibited that only a single digital video camera with an embedded image processing system can monitor and detect obstacles simultaneously. Additionally, experiments showed that the proposed simple technique can produce outstanding equivalent results with substantially reduced computational complexity and memory requirements.

Keywords: Rear-view camera, Particle filtering, Geometric transform, Obstacle detection, Parking assistance

1 Introduction

Since driving assistance systems are an increasingly important part of modern vehicles, various sensors are now fitted as standard to improve safety and aid in navigation. This camera, a standard feature of many current models, views the road surface directly behind the vehicle during normal driving. Studies show that drivers responded better to a camera image than audio alerts and market research indicates that a subset of rear-view cameras will incorporate embedded vision to automatically detect objects, estimating their distance to the vehicle’s bumper, and warn the drivers visually and audibly of an impending collision. Compared to the conventional systems for parking assistance using the radar or the ultrasonic range-finders, the advantage of a vision-based obstacle detector is a combination of a camera and a range sensor that can be mounted in a single, low-cost piece of hardware [1]. Our objective is to design a single camera-based system that can achieve similar camera-based system that can deliver analogous results compared to those of other costly sensors. We present an embedded vision system using particle filtering for smart rear-view camera with object detection and tracking. The requirements, challenges and outcome of creating a smart rear-view camera system designed to reduce back-overs, fatalities and injuries are presented.

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2 Detection System

Fig. 1 shows the flowchart of the proposed system for a rear-view camera system for monitoring the rear view of a car for safety purposes. The proposed system detects objects through rear image of the scene using a single rear view parking camera by first deforming the incoming raw video frames and then performing the necessary transformations on the image scene.

![Flowchart of the rear-view camera system](image)

For a single rear camera module, the use of a wide-angle lens ensures that a sufficient side-to-side viewing region behind the vehicle is visible. However, a tradeoff of using a wide-angle lens is that the wider the field of view of the lens, the lower the resolution of the image the further away from the lens’ optical center. The object in the image always has perspective distortion. Therefore, we must perform perspective correction to the object before trying to detect obstacle [2]. The region of interest is associated with the ground region and any feature located in the collision volume is determined to be an obstacle. As the first step before detecting obstacle, we perform automatic perspective correction for Region-of-Interest (ROI) to make a rectangular window. The algorithm for recovering the distorted rectangle object is as follows:

1. Get the image from camera.
2. Select trapezium area.
3. Get the corners by finding intersections between lines.
4. Determine top-left, bottom-left, top-right, and bottom-right corner.
5. Apply the perspective transformation.

We extract the ROI from the incoming video and perform automatic perspective correction to obtain the normal view. Note that we simplified the problem by taking trapezium area on the scene. The perspective function accepts an image source, a destination image, and a transformation matrix. The transformation matrix is the relation between the two images as shown in Fig. 2. We obtain the transformation matrix from the corner points of the object above and the corner points of the destination image. The quadrilateral object now transformed to normal view similar to Fig. 2.
Tracking objects in video involves the modeling of non-linear and non-Gaussian systems. In order to model accurately the underlying dynamics of a physical system, it is important to include elements of non-linearity and non-Gaussian in many application areas, which can be achieved by using Particle Filters. They are sequential Monte Carlo methods based on point mass representations of probability densities, which are applied to any state model [3]. Particle Filter is concerned with the problem of tracking single and multiple objects [4,5]. It is a hypothesis tracker, which approximates the filtered posterior distribution by a set of weighted particles. It weights particles based on a likelihood score and then propagates these particles according to a motion model [6].

Using the optimized version of block matching algorithms, the image features across multiple frames are able to be detected and tracked. The algorithm operates by continuously tracking objects in the region of interest (ROI) at the rear-view and then transformed into a normalized rectangular image. The system can provide alerts from three different zones (left, right, and center) when approaching obstacles in any or multiple directions. Fig. 3 shows some examples of obstacles detection: obstacles are detected on the left, at the front, or combination of those.

![Fig. 2. An original video image, Region of Interest (ROI) at rear-view, and transformed ROI](image)

### 3 Conclusions

We proposed a system using particle filtering, which analyzes image sequence from a rear-view camera to detect and track obstacles at the rear side of the vehicle. From the preliminary experiments, the results indicated that the proposed method is applicable for detecting obstacles, especially for the embedded rear view monitoring system. While complicated techniques may often be able to produce a superior and enhanced performance, our experiments showed that the proposed simple technique can produce excellent comparable results with significantly lower computational complexity and memory requirements. The process for detecting objects and minimizing error is still ongoing. Further research is needed to enhance robustness against environmental noises, sudden changes of illumination, and to provide a balance between a fast adaptation and robust modeling. One way of increasing the reliability of the proposed system is to enhance the solution with distance information from another sensor such as ultrasonic sensing technology. Adding distance data from
a single ultrasonic sensor integrated inside the camera module with the image sensor combines the strengths of vision-based system and ultrasonic technology to reduce the chances of not properly detecting objects with insufficient features.

Fig. 3. Examples of obstacle detection: original image (top-left), detected on the left (top-right), detected at the front (bottom-left), and detected on the left and front (bottom-right)

References