Design and Implementation for a Vision-Guided Wheeled Mobile Robot System

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***Abstract*—A vision-guided wheeled mobile robot system with PID control law is designed and implemented in this paper for the purpose of autonomous following a given lane. Except for motors, the wheeled mobile robot system consists of a self-designed interface controlling this system; a camera for vision-guided purpose; a battery/power module for power supplying, as well as an Arduino board being the system platform. By Wi-Fi, images taking from the camera are transmitted to a computer to process so that enable the robot system to detect the edge of the lane. According to the experimental results shown, the control law can efficiently control this implemented system.**

I. INTRODUCTION

In most recent decades, topics related to autonomous vehicle systems got many attentions. Its applications and developments are still continuing and getting more and more popular [1-3]. One of them is about to the topics of automated guided vehicles [1, 4, 5]. For a vision-guided mobile robot/vehicle, the ability moving on a lane is essential, which means that the mobile robot/vehicle has the ability to detect the edges of lanes and to follow the lane safely. For the purpose, most early literatures convert the information extracted from images into a 3-D, vehicle-centered Cartesian coordinate system aligned with the ground plane. Steering decisions are then determined in this coordinate system [6]. References [6, 7] provide vision algorithms based on a visual field theory that involves precomputing the expected instantaneous optical flow values in the camera imagery arising from every point in 3-D space. Reference [5] proposes other vison algorithm based on Catmull-Rom spline-based lane mode, which tries accurately detect generic lane boundary based on specific set of control points. Then, a reference trajectory is generated relying on control points created in the line connecting two control points on the left and right boundary lanes. More other vision-guided algorithms developed in recent years can refer to References [2, 3].and references therein.

The main objective of this paper is to implement a vision-guided wheeled mobile robot so that it could satisfy two important requirements: automatic movement along a given lane and lane keeping that is preventing the wheeled robot to move outside the lane boundaries. In order to do so, the wheeled robot consists a forward facing camera placed in front of it for vision-guided purpose. The robot system follows a PID control law to follow a given lane and to move. An interface programmed by Visual Studio C# allows users to tune gain parameters of the control law, to set signal processing procedures, and to show the experimental results in a computer.

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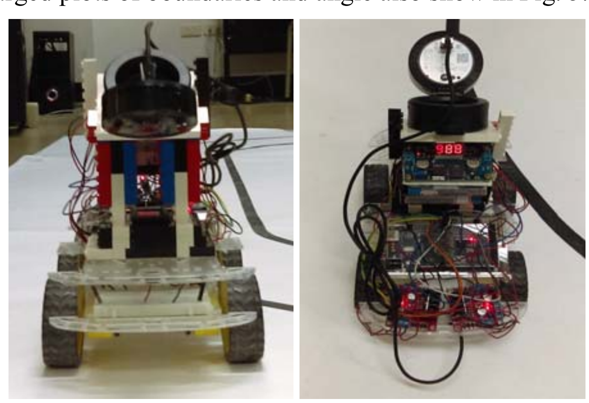
II. SYSTEM DESCRIPTION

The vision-guided wheeled mobile robot system, as shown in Fig. 1, consists of an IP network camera (DCS-936L), a mobile power module, four DC motors, two drive motors (L298N), a rechargeable battery and battery booster module, an Arduino board (MEGA 2560), one Bluetooth module (HC06), and a computer. The rechargeable battery and battery booster module is the power supply of the mobile robot system. Fig. 2 is the system block diagram, which introduces the connection of components with different kinds of signals. A mobile power supplies power to the IP network camera that set on the top of the mobile robot. Via Wi-Fi, the IP camera transmits images to a personal computer to process images. Results of these image processes provide information about lane boundaries and attitudes of the robot (angles between the centerline of lane boundaries and the trajectory trend of the robot's centroid). Suitable control instructions therefore transmit to the robot (Arduino) as well as to drive motors. Fig. 3 is the flow chart of corresponding image processes. Need to note that these processes are continuing until turning the robot off.

In addition, in computer side, the mobile robot system includes an interface programmed by Visual Studio C#, which enables to set necessary operations and record results of experiments conveniently. The interface shows in Fig. 4. The green block in Fig.4 is a dynamic region of interesting (ROI) for the system, which enables to adjust according to practical situation via the tuning of the upper second and third tuning bars. After image processing for the ROI, the interface also provides a region and table to show the lane boundary plots as well as sequential angles (θ) between the centerline of lane boundaries and the trajectory trend of the robot's centroid. The enlarged plots of boundaries and angle also show in Fig. 5.



(a) Front view (b) Back view

Fig. 1 The vision-guided wheeled mobile robot

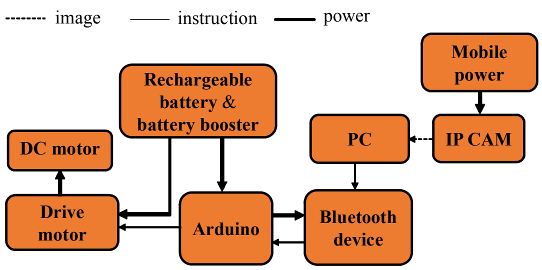


Fig. 2 System blocks diagram

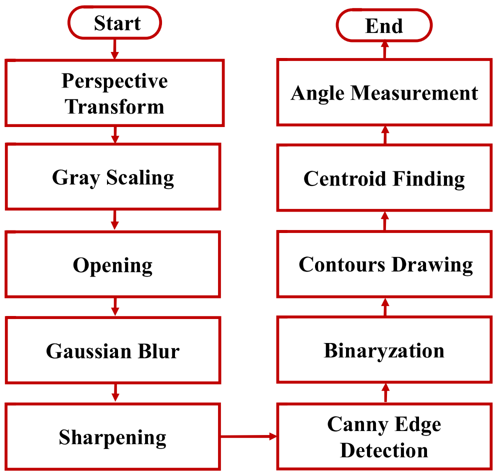


Fig.3 The flow chart for image processes

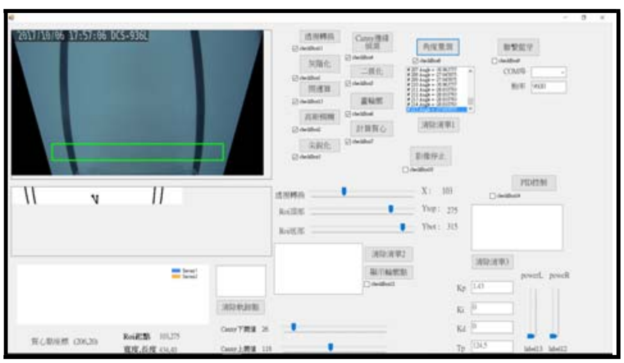


Fig. 4 The interface of the robot system

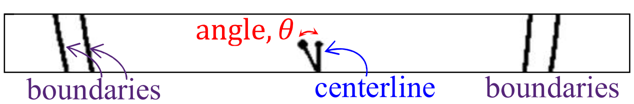


Fig. 5 Boundaries and angle in ROI after image processing

III. CONTROL LAW DESIGN AND EXPERIMENT RESULTS

In order to enable the mobile robot to move along a given lane automatically and safely, the system applies a PID control law to control the drive motor according to the angle θ shown in Fig. 5. Based on the Ziegler-Nichols method, choose a feasible (but not optimal) set of the gain parameters $\{K_p, K_i, K_d\} = \{1.18, 0.038, 3.9975\}$ where the sampling time $dT = 0.033$ *sec.*, and the period $P_c = 1.353$ *sec.*, results in the experimental results, some of them show in Fig. 6. The film of the experiment can refer to Reference [8].

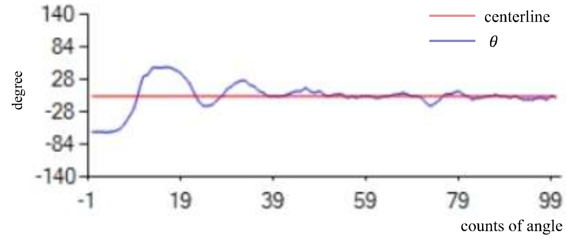


Fig. 6 (a) Segmented results: starting in a straight-lane area

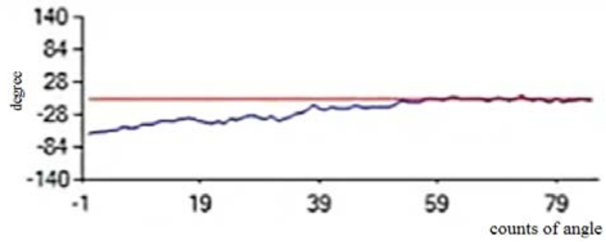


Fig. 6 (b) Segmented result that the robot goes through a curved area into a straight lane area

The unit of the horizontal axis in Fig. 6 is the counts of the angle, where each count is equivalent to 0.033 seconds. These results show that the control is efficient, especially in a straight-lane area. The robot is able to go through the curved-lane area safely, though the efficiency of the response is not perfect yet.

IV. CONCLUSION

In this paper, a vision-guided wheeled mobile robot system is implemented, which only applies a simple PID control law to control drive motors, so that the robot system is able to follow a given lane automatically and safely. Applied other auto tuning methods for the PID control law to the robot system is one near future work.

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[8] The film of an experiment: https://www.youtube.com/watch?v=8RuCN039Bug