Small Scale Mobile Robot Auto-Parking Using Deep Learning, Image Processing, and Kinematics-Based Target Prediction

Authors : Mingxin Li, Liya Ni

Abstract : Autonomous parking is a valuable feature applicable to many robotics applications such as tour guide robots, UV sanitizing robots, food delivery robots, and warehouse robots. With auto-parking, the robot will be able to park at the charging zone and charge itself without human intervention. As compared to self-driving vehicles, auto-parking is more challenging for a small-scale mobile robot only equipped with a front camera due to the camera view limited by the robot’s height and the narrow Field of View (FOV) of the inexpensive camera. In this research, auto-parking of a small-scale mobile robot with a front camera only was achieved in a four-step process: Firstly, transfer learning was performed on the AlexNet, a popular pre-trained convolutional neural network (CNN). It was trained with 150 pictures of empty parking slots and 150 pictures of occupied parking slots from the view angle of a small-scale robot. The dataset of images was divided into a group of 70% images for training and the remaining 30% images for validation. An average success rate of 95% was achieved. Secondly, the image of detected empty parking space was processed with edge detection followed by the computation of parametric representations of the boundary lines using the Hough Transform algorithm. Thirdly, the positions of the entrance point and center of available parking space were predicted based on the robot kinematic model as the robot was driving closer to the parking space because the boundary lines disappeared partially or completely from its camera view due to the height and FOV limitations. The robot used its wheel speeds to compute the positions of the parking space with respect to its changing local frame as it moved along, based on its kinematic model. Lastly, the predicted entrance point of the parking space was used as the reference for the motion control of the robot until it was replaced by the actual center when it became visible again by the robot. The linear and angular velocities of the robot chassis center were computed based on the error between the current chassis center and the reference point. Then the left and right wheel speeds were obtained using inverse kinematics and sent to the motor driver. The above-mentioned four subtasks were all successfully accomplished, with the transformed learning, image processing, and target prediction performed in MATLAB, while the motion control and image capture conducted on a self-built small scale differential drive mobile robot. The small-scale robot employs a Raspberry Pi board, a Pi camera, an L298N dual H-bridge motor driver, a USB power module, a power bank, four wheels, and a chassis. Future research includes three areas: the integration of all four subsystems into one hardware/software platform with the upgrade to an Nvidia Jetson Nano board that provides superior performance for deep learning and image processing; more testing and validation on the identification of available parking space and its boundary lines; improvement of performance after the hardware/software integration is completed.

Keywords : autonomous parking, convolutional neural network, image processing, kinematics-based prediction, transfer learning
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