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Mini Review

State of Mapping and Path Planning Research for Multi-Wheeled a Literature Review

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Abstract

With the continuous advancement of autonomous navigation in the automotive industry, a wide range of research is being conducted with the ultimate goal of improving or applying the autonomous navigation of passenger vehicles. However, the volume of research analyzing autonomous principles for multi-wheeled military and heavy vehicles that utilize steerable wheels is greatly lacking in comparison. These vehicles traditionally have three or more axles and are expected to carry larger loads in hazardous terrain resulting in increased complexity during modelling and analysis. As such the majority of research aimed toward steerable wheeled vehicles is performed in simulation. After a canvas of recent literature concerning the field of autonomous navigation experimentation, it was seen that the majority of studies are also performed using differential drive platforms with four or fewer wheels lacking car-like features such as actuated steering or suspension. Therefore, it is evident a gap exists in the area of physical experimentation for autonomous navigation of multi-wheeled platforms with steerable wheels. The proceeding sections of this paper will highlight recent, key studies and methods for this area concerning steerable, wheeled platforms.

Keywords: Autonomous navigation; Multi-wheeled; Mapping; Path planning; Steerable wheels

Introduction

Autonomous navigation entails the ability of a vehicle to propose or plan a path of motion and execute this motion without intervention. The advances in autonomous technology for self-driving cars are enhancing safety through the use of sensors, reducing human intervention, and effectively blurring the lines between passenger vehicles and mobile robotics. Several general subfields important to autonomous navigation include path planning and mapping. Zafar et al. define path planning as finding a collision-free path of motion, possibly in an obstacle-prone environment to navigate safely from the start point to the goal [1]. Mapping involves incrementally generating a representation of visual data for an unknown environment. The final product is a map that the robot can use to relate position to different landmarks and obstacles [2]. Various experimental platforms are seen in the literature to aid with autonomous navigation investigations. As seen in the proceeding sections, several key studies are highlighted, concerning physical platforms with multi-wheeled, multi-steered (MWMS) capabilities as well as related differential drive (skid steering) platforms used to study mapping and path planning.

Mapping Methods

For the concept of mapping, there is a wide array of techniques being used, the most popular of which is Simultaneous Localization and Mapping (SLAM) [3]. SLAM involves a robot simultaneously estimating its position relative to landmarks to incrementally build a map [4]. Bawden et al. use a SLAM-based mapping method alongside a four-wheeled robot capable of two-wheel drive and two-wheel steer [5]. In this application, a map is generated initially of a weed-infested field with the robot navigating between crops to identify and remove weeds. Wei et al propose a modified SLAM mapping method that operates by fusing visual data from a stereo camera alongside acceleration and other dynamic information from an inertial measurement unit [6]. The subsequent map created is robust and contains information on the position in a grid format as well as key visual features. Furthermore, the authors tested their framework using a three-wheeled robot with front-wheel steering. Duong et al use another method based on the rapidly exploring random tree (RRT) method that builds the subsequent map based on obstacle boundaries [7]. In addition, local data from the robot's sensors are used to make modifications to the map in real-time. The authors performed their study as a four-wheel drive, four-wheel steer numerical model without a physical platform.

Path Planning Methods

A key research topic involves successful navigation on the optimal path in an environment and various techniques are used to accomplish this. Wen et al. use a set of four, four-wheeled, car-like robots capable of two-wheel drive and steering (2WD2WS) alongside a path planner known as the multi-agent pathfinding approach [8]. This method involves building a search tree to iteratively find a set of branches along the tree that provide an obstacle-free path to the goal. Shojaei also uses a set of three, 2WD2WS robots in simulation alongside a neural network-based controller which assists in locally maintaining the formation and path of the robots during navigation [9]. Neural network-based methods for path planning have become quite popular in recent years due to increased computing power available, making these methods feasible. Another interesting study was conducted by Rosman et al. and involved testing and comparing a proposed path planning method on both a 4WD4WS platform as well as a four-wheeled, differential drive platform [10]. In this study, the timed elastic band method is used to locally generate the optimal path by connecting a series of robot poses as well as the time taken by the robot to reach each position. It was seen by the authors that the platform with steerable wheels required less time to navigate the path when compared with the differential drive platform.

Conclusions

Currently, automotive research continuously shifts towards driverless technologies. However, as seen in literature there is an area that is still relatively unexplored within this field. The application and study of autonomous navigation for military and heavy vehicles comprised of multiple axles and steerable wheels are lacking. This is particularly true for experimental investigations as it was seen that the vast majority of studies performing physical experimentation utilized differential drive robots with very few platforms composed of more than four wheels. This is possibly due to the enhanced complexity involved with systems that can assign steering angles to independent wheels. For example, further hardware is required on a vehicle such as actuating components that can physically move the wheels to achieve steering. As such, the authors of this work are currently utilizing a custom-built, eight-wheeled, 1:6 scaled, fully electric combat vehicle alongside implemented autonomous navigation algorithms to widen the research in this area. Furthermore, the vehicle is capable of complete eight-wheel drive and eight-wheel steer allowing for an independent wheel speed and steering angle to be assigned to each wheel during navigation. It is the hope that as time progresses further research will be conducted in this area using a wider array of physical, MWMS platforms.

Acknowledgement

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Conflict of Interest

No conflict of interest.

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