Realization of Outdoor autonomous navigation based on RTAB-MAP

基於 RTAB-MAP 的室外自動導航系統的實現

組別：A90 指導教授：邱偉育 教授

組員姓名：許晏誠、何立平、張瀚

Abstract

Self-driving has been a prevailing topic of research for years. Recently with the introduction of Tesla, the realization of this technology has been shown promising. Autonomous driving requires knowledge of several fields, such as computer vision, localization, mapping and navigation. With the previous research and implementations, the indoor autonomous applications have shown some good results due to the simplicity of the environment. While indoor implementations have achieved a relatively complete framework, outdoor application has faced some hindrances, for instance, the stability of the sensors for outdoor uses and the complex environment which induce a large amount of environmental information and noises and the high cost of high precision sensors. Thus, in this paper, we'll present a simple framework of autonomous driving in an unknown place for further research on real-world on-road implementation.

SLAM and Navigation are two fundamental problems in self-driving, the former defines where the robot is in the real world while the latter tells the robot how it should do with a given goal. With the SLAM algorithm, the robot can have access to the environmental information of the surroundings, which then can allow the robot to have interaction with the real-world. The Navigation which consists of path planning and motion planning can make decisions for the robot to achieve a certain goal based on the information from SLAM. Among all the existing algorithms, RTABMAP has become our choice for mapping the real-world and localization in it. RTABMAP is capable of integrating multiple sensors' data and also supports mapping mode and localization only mode together. TEB_local_planner works as our path planner for navigation with the ROS built-in navigation stack. Hardware setup is constructed by adding Realsense D435i depth camera and RPLIDAR A2 scanner as the sensors on a RC four-wheeled

Ackermann car model. Camera is used as the main input for odometry and mapping while low cost lidar allow us to do ICP refinement and obstacle detection 360∘.

The proposed framework of system integration of various existing algorithms and hardware yields an outdoor self-driving platform for Ackermann vehicles which can perform mapping and localization with an acceptable precision and capability of navigation from point to point with obstacle avoidance. This platform can further be enhanced with other features like lane/sign detection and other behaviors for preference usage or sensor integration like high precision GNSS systems.

Our result showed that high precision localization and navigation with low cost sensors is not easy to achieve by single method. However, by integrating various algorithms and fine-tuning, it can be promising that the autonomous platform can be used to perform carrying purposes in a large-scale environment like campus.

Introduction

Autonomous navigation has been a field of various technologies being researched. Including the study of SLAM, path planning and robot controller. Navigation within an unknown place is a crucial task in autonomous study. The robot learns information about the surroundings by processing the sensor's data via SLAM approaches which allow it to map the environment and localize itself within the map. In the past, most SLAM approaches were based on the data from laser range finder or Lidar for the High-Definition map of the real world. However, the high cost of 3D lidar is stalling further application of autonomous vehicles.

Recently, with the increasing computing power of the chip, processing complex images to obtain rich information has become practical. Thus, researches and applications of implementing low cost camera sensors on SLAM have emerged. For the past few years, implementation of visual SLAM has been conducted in this project. However, only the indoor environment has been tested and the navigation system was also not integrated. Most of the SLAM solutions on the market are for indoor environments, thus, our work of a self-built car-like robot suitable for outdoor usage should provide new probabilities to utilize the autonomous technique in a campus environment. Several barriers exist for the outdoor environment, like unclear edges of roads, shifting brightness with shadow and moving objects in the real world situation. In this paper, we proposed an implementation method of current open source Visual SLAM and integrate it with the navigation system for outdoor purposes. We aim to follow predecessors' work for indoor purpose, then finish with a functional system capable of both SLAM and navigation.

Our hardware model is based on a RC remote car equipped with a stereo camera with a built in IMU sensor and a low cost 2D lidar. Stereo camera is used to estimate the pose and capture the data for building the map. The lidar is used to provide a steady source of obstacle detection while autonomous navigating. The RC car is controlled by sending signals to the remote controller. The software model is a combination of RTAB-MAP and ROS Navigation stack with certain modifications of plugins. The final architecture plays as a pioneer that successfully combined several systems with navigation.

Our current result shows that the implementation is successful to a certain extent. The robot can navigate from point to point within a mapped space with the ability of obstacle avoidance. Still, however, parts of the system can be improved, such as the reaction time of avoidance, oscillations, etc. This paper can be organized into three main parts. In Section II, the underlying methods we used in the proposal will be briefly introduced including their theorem and architecture, the reason we chose them, etc. Section III talks about the architecture of our implementation and how we set the parameters or modify the system. Section VI shows how our experiment environments are chosen and what's the performance of our robot in different aspects under different conditions.

Fig. 1 Robot model

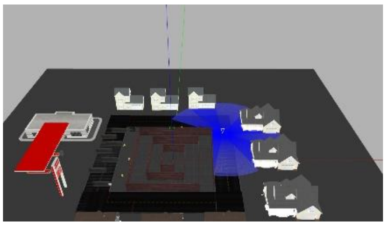

Fig. 2 Gazebo Simulation

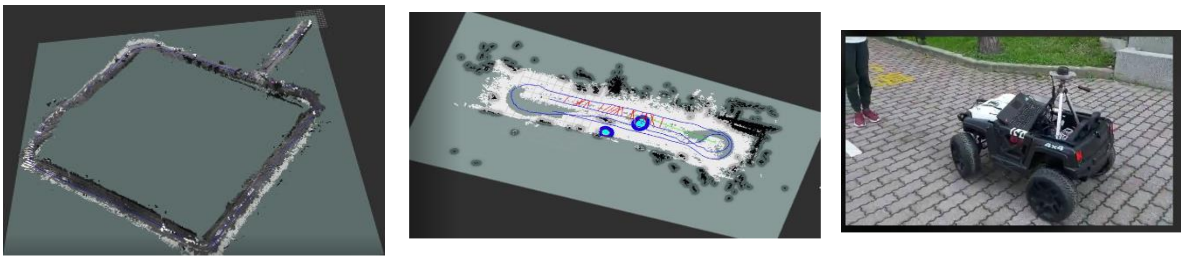

Fig. 3 Open-space Outdoor Mapping and Navigation

心得

何立平：

經過了將近一年的時間，專題也將告一段落。這段期間，我也得到許多寶貴的知識與經驗。我學會使用 Ubuntu 系統，接觸了光達、深度攝影機等硬體，並對 SLAM 有了基本的認識。另外，我認為收穫很多的是，我對於「與人合作的關鍵能力」有了更深的體悟。過去的我，在團隊合作中，是沒有效率的，而且執行力低。但在這次的專題中，我不斷地觀察我的隊友—許晏誠 的做事方法、也和另一位隊友—張瀚 討論如何讓做研究的效率提升，讓我對於「團隊合作」的效率和執行力方面，有顯著的進步。

最後，我想感謝我的組員們和感謝我的專題教授。

謝謝我的組員—許晏誠、張瀚，謝謝你們在這一年的時間裡，非常認真努力的投入在專題中，你們真的辛苦了。我會永遠記得與你們一起做專題的每個美好回憶，跟你們一起共事，真的很快樂。

謝謝我的專題教授—邱偉育老師，謝謝教授在每次 meeting 的時候，很細心的給我們很多好建議，讓我們能夠對專題更有方向。也謝謝教授給予我們很多資源，讓我們可以有效的完成專題。

張瀚：

這次的專題做的真的蠻辛苦的，因為沒有用過 ROS 系統，也沒有人可以教我們，所以花了非常多時間去熟悉，下載軟體也會會有很多問題，常常卡在一個問題無法前進，都是透過不斷的上網查才得以解決，常常解決了一個，馬上又有另一個，過程中其實感到無力很多次，但是也因為這樣，每完成一步就會有許多成就感，每一步都是值得紀念且無比艱辛的，最後車子真的上路的時候，大家都喜極而泣了。

另外還要感謝我的組員許晏誠、何立平。許晏誠對專題的付出跟熱忱，是我必需學習的，他花了很多時間，也推動我們大部分的進步。何立平對於硬體跟設備總是毫不吝嗇，在他得幫助下，我們的設備很齊全，車子也架設的很棒。最後感謝邱偉育教授一年以來的指導，總是在每個禮拜給我們給我們方向，也不吝嗇的花錢讓我們買硬體設施。

許晏誠：

This undergraduate project is very attracting at first because no other professors had given such a topic related to robotic. At the meantime, it was also challenging because most of my course are about IC design but not algorithm for robotic field. Moreover, this field requires lots of different background. That’s why I’m grateful that I have met my teammates and professor within this one-year project. I appreciate for the professor’s support of equipment and suggestions to guide us to the right track and also my teammates’ hardworking and the perseverance when facing difficulties. Within this project, not only a successful autonomous model did I earn, but also a broad overview of the robotic field, the cooperative techniques and lastly, a deeper knowledge of both my teammates and professor.