Chapter 1

Introduction

With recent developments, mobile robots are becoming integral parts of society and these robots are envisioned to coexist with humans to fulfill various kinds of tasks and bringing great benefits for mankind. Considering technological developments, the future for mobile robotics is very bright and navigation will play a key role in the future. These robots are being employed in growing numbers not only in industries but also in service centric applications (which include domestic and entertainment applications) as well.

1.1 Motivation of Research

The robot system, the sensor types and the environment all determine the navigation process for mobile robot. The navigation of mobile robot cannot be seen in a meaningful way without knowing three fundamental competences (i.e. Sense, Plan and Act), those are interrelated. In this context, the navigational competence of a mobile robot is one of the key problems in the development of an autonomous mobile robot. The navigation of mobile robots is a broad area which is under investigation by many researchers. The rising interest in learning and development emerges from the fact that all major mobile robot navigation tasks including mapping, target tracking, path planning or manipulation in general can be performed more accurately and more efficiently while formulating and addressing the above issues. The navigation of mobile robot system tries to find an optimal path based on the data acquired by the sensors, which represents a map. Till date, there is still no ideal navigation system and is difficult to compare the results of researches, since there is a huge gap between the robots and the environment of each research.

As many mobile robots are autonomous to certain degree that allow the robot to interact with its environment whether on land, underwater, in the air or in space.

Autonomous mobile robot navigation carries out tasks without continuous guidance in different environments. This thesis explores the use and implementation of vision sensor in the autonomous navigation of the mobile robot. This research work focuses on real-time mobile robots navigation in various known/unknown and static/dynamic indoor environment. The mobile robot needs to operate under static or dynamic environment conditions and to be able to respond to situations that are unpredictable and alter quickly. In addition to this research, author addresses the three key issues such as performance, safety and accuracy concerning mobile robot navigation problems.

Challenges in setting up a system that works for dynamic real-time environments include choosing the best sensor for the job. Vision sensors are typically the best option for highly difficult conditions, although multiple sensor configurations for complex operations in dynamic environments are best. Compared to the other types of sensors on the mobile robotics field, vision sensors greatly improve the performance and provide information whether the environment is static or dynamic. As computing technology advances, vision sensor has been widely utilized in many industrial applications. One of the applications for vision system is to navigate mobile robot safely.

1.2 Thesis Aims

This thesis is focused on the development and investigations with experimental validation of different navigational techniques for mobile robot capable of planning and carrying out a variety of tasks undertaken in structured/unstructured real-time environments. Mobile robot navigation is a challenging field. Robot navigation includes different interrelated activities such as perception and interpreting sensory information; exploration of the strategy that guides the robot to select the desired direction of movement; localization to estimate the robot position within the spatial map; path planning to find a path towards a goal location being optimal and path execution, where motor actions are determined. Path planning is one of the most common and basic parts of mobile robot navigation. Path planning involves determining the collision-free path that can be divided into static and dynamic environments, depending on the nature of environment. The static path planning represents a mobile robot navigating through static obstacle. The dynamic path planning represents mobile robot navigating through dynamic obstacle that changes its position and orientation with respect to time. However, there are many difficult phases in real world situation that need to be resolved the navigational problem, such as obstacle avoidance, current or goal position identification, tracking the path trajectory and so on. A navigational algorithm must be capable of (i) Identifying the current position of the mobile robot, (ii) Determine a path to the target, and (iii) Avoid obstacle(s). Therefore, mobile robot navigation problems are a challenging task and several studies have been attempted with various number of solutions have been identified.

Nowadays, mobile robots are equipped with several sensors and other accessories which add to the sophistication and flexibility and help in developing overall capability and intelligence of the system. While dealing with robot navigation, sensors are usually used for positioning and obstacle avoidance. The sensors that are used for navigation include infrared sensors, sonar sensors, laser range finders, inertial sensors and vision sensors.

Infrared (IR) sensors have been used as proximity detectors and range finders lies in their limited range and having susceptibility to ambient light interference. IR sensors are also known for their non-linear behavior and their reflectance dependency on the surface of a target [Gorostiza et al. (2011)]. Sonar sensors are computationally affordable and their data are simple to read, but the reliability of their data is low due to the environmental disturbances [Dinh & Inanc (2009)].

Laser range finders provide better reliability, instantaneous measurement, superior range accuracy, and precise angular resolution than sonar, with finer directional resolution, but at much higher cost. The laser range finder has a disadvantage that the scan may be prone to missing transparent objects, such as glasses and windows [Chong et al. (2015)]. Inertial navigation sensors such as accelerometers and gyroscopes provide orientation and trajectory measurements of the mobile robots, but provide no information about the obstacles in the environment that the robot is traversing [Ahmad et al. (2013)].

Sensing capabilities are closely linked to the ability to perceive, without which sensor data will only be a collection of meaningless information. Visual sensing provides a rich source of knowledge in biological systems for individuals, who use this knowledge for their navigation and planning. The same can be said for autonomous mobile robotics systems, which have made vision a normal sensory tool on robots. A vision system is considered as a passive sensor and has the fundamental advantages over the active sensors such as infrared, laser, and sonar sensors. Passive sensors such as cameras do not alter the environment by emitting lights or waves in acquiring data, and also the obtained image contains more information than active sensors. All these sensors acquire less information about the physical environment than a camera can capture and with the continued growth of faster and cheaper computing power that is now being used for designing real-world vision based navigational systems. Cameras are cheap to purchase, with even the most expensive cameras being relatively affordable. Hence vision as a sensing mechanism for mobile robots offers a very realistic solution.

1.3 Thesis Structure

The research objectives of this thesis are to experimentally investigate navigational solutions for mobile robots and their ability to cope with real world situations. The mobile robot functionality is to be divided into individually maintainable components and functional modules by software architecture. As discussed earlier, various sources of vision based navigation of mobile robot will be discussed. The first is concerned with operating in real time environments dealing with static obstacles for path planning. The next topic examines operating in same environments with path planning, which tracked the mobile robot system. The most challenging issues, such as illumination changes in dynamic environment, are not dealt in chapter 5 and 6, apart from the feature-based approach and tracking-learning-detection (TLD) method to track the mobile robot. The following explains the contents of each chapter in detail and its importance to the topic of research.

Chapter 1, discusses the inspiration with an outline of motivation of research. A brief developmental history of mobile robot is described, and the various components used in navigation are then identified, with some context on the purpose of the thesis.

Chapter 2, provides background to the mobile robot navigation framework and an overview of the existing approaches to deal this problem. It also introduces vision based object detection and tracking problems that are the focus of later chapters. Subsequently this chapter discusses different approaches for path planning and provides an overview of Kalman filter for denoising. This filtering algorithm has been chosen to extend and augment the tracking activities discussed in later chapters.

Chapter 3, presents an integrative approach for tracking of mobile robot with vision sensor. It addresses an experimental approach which incorporates feature based object detection, KLT Algorithm based tracking method and Kalman filter based de-noising technique in a real-time environment. Results from mobile robot experiments with ground-truth comparisons are presented.

Chapter 4, introduces path planning of mobile robot for navigation using vision sensor. In this work, a mobile manipulation-based path planner was developed with a focus on multi-target object clean-up operations. This work classifies objects into handleable or non-handleable type from real-time measurements. This chapter is the extension of chapter 3 with the application of a vision-based A* algorithm path planning for mobile manipulators.

Chapter 5, presents an integrative approach for path planning and tracking of shape aware mobile robot in structured environment using vision sensor. This chapter provides a shape-aware A* path planning approach to accommodate the shape of mobile robot with a heuristic function. This chapter explores real-time shape aware based mapping and navigation algorithm developed for collision free path. The detection of obstacles has been analyzed with structured real-world environments using vision-based refinement like thresh holding, erosion and clustering. Subsequently, the mobile robot is tracked using KLT algorithm while navigating in static environment and denoising of the tracked path using Kalman filter.

Chapter 6, presents D* Lite algorithm for mobile robot navigation in unknown environment with static/dynamic obstacles with TLD tracking algorithm. This work examines the application of safe path tracking and denoising problem while mobile robot is navigating in an environment with static/dynamic obstacles to create the shortest possible path from any current location to its target position.

Chapter 7, concludes with a summary of the thesis, its contributions, limitations and the future directions of the work. To make the thesis readable some of the important steps are discussed in various appendices, which provide the detailed steps, and necessary information. These are referenced appropriately in the respective chapters.