Research on UAV Positioning and Control Based on SLAM Approach

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Abstract. Drones have gradually become an essential aerial vehicle in contemporary human life, so finding a suitable control method has become a research direction for scientists. Simultaneous Localisation and Map Building (SLAM) technology is considered to be a big hit technology in the future drone control field, which is characterised by high accuracy, high robustness and high stability. In this paper, for the key technology of drone control, obstacle avoidance and navigation system, SLAM is combined with PX4 to achieve obstacle avoidance and the Robot Operating System (ROS) system is used for navigation. Obstacle avoidance and navigation systems are the two most critical technologies in drone control methods, and researchers have set up two sets of specialised systems to realise autonomous control of the drone. SLAM technology can enable drone to achieve highly efficient and intelligent navigation and obstacle avoidance, but whether the technology can maintain its own stability under long-time working conditions and whether the cost of LIDAR is too high are still issues that need to be continuously researched and solved. However, whether the technology can maintain its stability under long-time working condition and the cost of LIDAR still need to be studied and solved.

Keywords: SLAM Technology, ROS Architecture, PX4 Technology, HIGH Stability and Precision

1 Introduction

In the context of the rapid development of artificial intelligence, drones have gradually become the hottest type of aircraft, which plays an important role in military and civilian fields [1]. The advantages of drones are very obvious when they are widely used, and they have a very simple mechanical structure, which is easy to manufacture and maintain and plays an important role in the fields of aerial photography, logistics and distribution [2]. However, how to make the drone in a working state to ensure good robustness, and stability needs the majority of scholars to continue to explore the research to improve and upgrade [3].

Currently, there are two mainstream control schemes for drones, one of which is to manipulate the drone through external devices. However, this method is greatly limited

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by the application scenarios [2]. The second method is to control the drone through the SLAM method, through which the drone is able to collect data through the multi-sensors it carries, and after analysing it, formulate a route for the drone itself so as to achieve autonomous control of the drone [2].

Simultaneous Localisation and Mapping (SLAM) technology was first proposed in the 1980s, and after decades of development has now become a major research technology in computing and vision and unmanned fields such as drones and autonomous driving, etc [4]. SLAM technology can be used to collect and analyse data through the use of multiple sensors, and then realise accurate positioning [5]. The advantage of SLAM technology is that it can construct a map of the current environment in real time and perform navigation and obstacle avoidance operations in unknown environments, which has led to the large-scale application of this technology in the field of unmanned aerial vehicles, downhole operations, and pipeline repair [4].

Although SLAM technology has gained great development in these nearly 20 years, however, the technology still has some problems that need to be solved by researchers, such as real-time and accuracy, better robustness and stability [6]. The aim of this paper is to discuss the application of SLAM technology in UAV manipulation: firstly, how SLAM technology can be used for path planning; secondly, how SLAM technology can be used for obstacle avoidance; thirdly, how SLAM technology can be used for navigation and localisation; then, the advantages and disadvantages of SLAM technology are discussed; and lastly, the opportunities and challenges facing the development of SLAM technology are analysed.

2 Methodology

This paper will list and analyse the flowchart of the overall operation of the navigation system and obstacle avoidance system in the main text, in order to make the research results more graphic, this paper will add the relevant flowchart and table for detailed discussion, at the end of the paper will discuss and summarise the results listed in the paper and give the challenges faced by the technology.

3 Introduction to SLAM Technology

3.1 SLAM Technology Definition Applications and Advantages and Disadvantages

SLAM is a technique for estimating the drone's own position and building a map of the environment in real time from sensor data. SLAM can be divided into two parts, which are localisation and map building. The first part of localisation is to estimate the position information of the drone, which includes position information and pose information. By estimating the drone position information frame by frame, the motion trajectory of the drone can be reproduced [7]. The principle of SLAM technology is to predict the position and attitude of the drone through sensor data (e.g., camera, LIDAR, etc.), and then construct the environment map. SLAM technology can be mainly divided into visual SLAM and laser SLAM. Visual SLAM technology extracts feature points from the image and matches different frames to construct the motion trajectory of the feature points. construct the motion trajectory of feature points [8]. The laser SLAM technique measures the vision reflected back from the LiDAR to calculate the specific distance [9].

SLAM technology can be used in a number of different fields, such as robot autonomous navigation, path planning and environment awareness for domestic services and industry [9]. Secondly, SLAM technology can be used in the automotive industry for autonomous driving, navigation and localisation in order to improve the safety and reliability of autonomous driving systems [10]. SLAM can also be used in conjunction with Augmented Reality and Virtual Reality to provide users with a visual and sensory experience [11]. SLAM technology can also be applied to drone navigation, autonomous flight, obstacle avoidance and map construction, greatly improving the level of drone intelligence [12].

Based on the wide application of laser SLAM, it has many advantages and disadvantages. Based on different environments, laser SLAM algorithms can provide more accurate positioning and map construction functions to meet the navigation requirements in complex environments. Because lasers are not easily affected by light and other influences, laser SLAM technology has strong stability and does not change significantly in different environments. Some SLAM algorithms (e.g., ORB-SLAM2) reduce resource consumption while maintaining high accuracy and robustness, which is important for platforms with very limited computational power [6]. At the same time, feature extraction is weaker in sites lacking texture (e.g., solid-coloured walls) or in highly dynamic scenes, leading to a decrease in localisation accuracy. In addition, the overall deployment cost of SLAM systems is high due to the high price of LiDAR.

4 SLAM-controlled Drones

4.1 Overall Design of Drone Obstacle Avoidance System

To achieve more efficient obstacle avoidance using the combination of SLAM and PX4, the basic structure of the UAV obstacle avoidance system can be divided into three parts, which are the detection module, the communication module and the decision module [5]. The first part is to use sensors to detect the obstacles around; the second part is to communicate between the two motherboards for vice control and flight control; the third part is to control the flight through the data coming from the sensors, and the flight control motherboard sends out the correct instructions to control the flight, the total flow of the UAV obstacle avoidance system is shown in Figure1 below [13]:

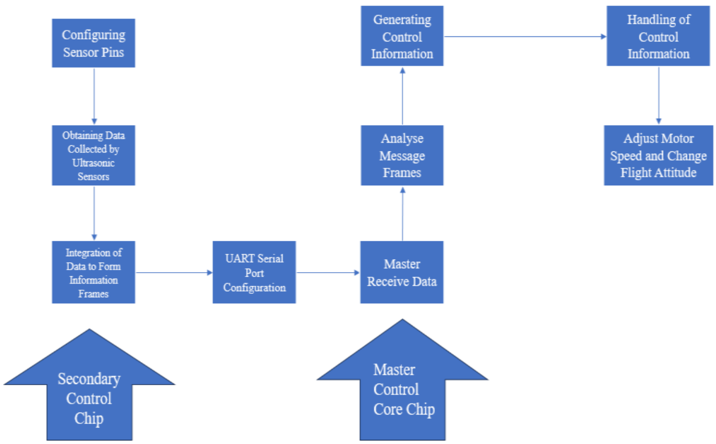

Fig. 1. Drone Obstacle Avoidance System General Flowchart [13]

As can be seen in Figure 1, when the master control chip receives the data, it generates control information by analysing the information frames, and finally adjusts the flight attitude by calculating the key frames to achieve obstacle avoidance. When the information frames are analysed, the ranging information sonarDatas can be obtained. When the distance in either direction is found to be less than a predefined value distance, the drone changes the acceleration of the drone through the pitch axis angle or the row axis angle. When the horizontal acceleration is too large, the drone may overturn accidentally. However, when moving at high speed, the drone wants a certain amount of acceleration to ensure that it will not touch the obstacles. When the Drone meets the acceleration constraints, control frames control data are generated and converted to Pulse Width Modulation Signal (PWM) signals, and the difference in rotational speeds generated by the different rotational speeds of the wings controls the Drone to perform programmed obstacle avoidance [13].

Bits 0-3 are the Frame Number, which identifies the serial number of the control frame for sequencing and identification; bits 4-7 are the YAW Offset, which indicates the offset in the yaw direction. Yaw refers to rotation around the vertical axis and is usually used to describe the steering of the vehicle; bits 8-11 are the ROLL Offset, which is the offset in the direction of rollover. Roll refers to rotation around the vertical axis, and is usually used to describe the side tilt of the vehicle; the last 11-15 bits are the PITCH Offset, which is the offset indicating the pitch direction. Pitch refers to the rotation around the horizontal axis of the hook, usually used to describe the up and down tilt of the vehicle. Table 1 below shows the control frame format [13]:

Table 1. Control Frame Format [13]

0-3	4-7	8-11	11-15
Frame Number	YAW Offset	ROLL Offset	PITCH Offset

4.2 SLAM Technology Enables Autonomous Navigation for Dron

In order to design autonomous navigation systems in a more efficient and convenient way, it is necessary to choose a more efficient development framework. In the field of autonomous navigation, Robot Operating System (ROS) has become the first choice of development framework because of its large community support, distributed architecture with high fault tolerance, convenient modular design, and flexible loose coupling mechanism. The core principle of ROS is to make its basic components into independent nodes, which can run on different computers and communicate with each other using the network. The structure of ROS is shown in Figure 2[14].

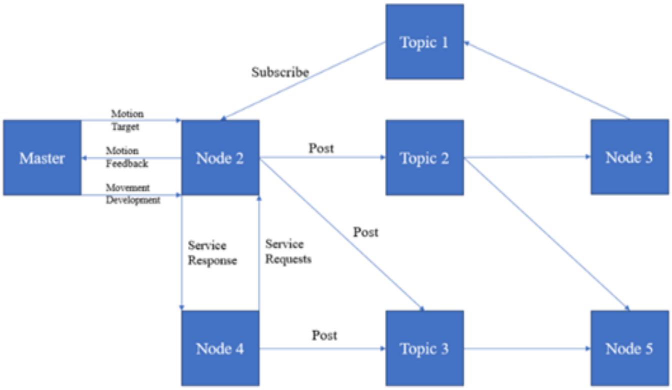

Fig. 2. ROS Structure [14]

A complete navigation system has three main parts in terms of software: navigation electronic map, positioning algorithm and motion control. In this paper, a set of autonomous navigation framework is designed on the basis of ROS framework. As shown in Figure 3:

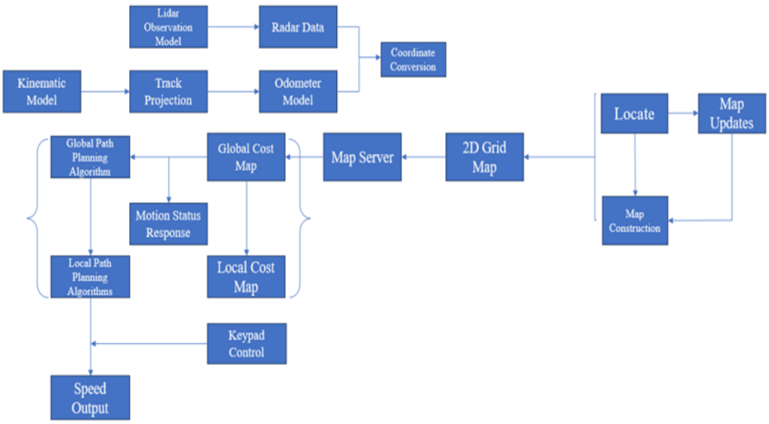

Fig. 3. Overall Framework Structure [14]

As can be seen in Figure 3, the navigation e-map section: in order to provide a comprehensive collection of sensor data, the researchers integrated the LIDAR with the wheeled odometer data of the drone as the core input to the navigation system. The LiDAR is responsible for scanning the surrounding environment and accurately capturing obstacle information, and these scanning points are positioned based on the radar coordinate system (LASER). At the same time, the wheel odometer monitors the wheel speed through encoder sensors and calculates its linear and angular speed variations in conjunction with a kinematic model. Using the trajectory projection method, this paper in order to obtain the odometer data, i.e., the coordinates and heading of the chassis, and establish the odometer coordinate system (ODOM) at the current positional attitude of the chassis. Since the sensor coordinate system is relative, in order to ensure the uniformity and consistency of the data, this paper uses the TF coordinate transformation technique to transform the sensor data under the global coordinate system (ODOM). Next, the Cartographer algorithm uses the odometer data to initially estimate the position of the drone and matches these initial values with the lidar data to continuously update the position estimator. As frames of radar data are processed through motion filtering and overlaid, a 2D raster map is eventually formed. This process not only completes the construction of the map but also achieves the precise positioning of the drone. At this point, this paper to a new coordinate system (map), as the global coordinate system of the reference. Finally, the map server (Map Server Node) is designed to save and read the map information, which provides strong support for the development, design and simulation modeling of the autonomous navigation system. Through this series of processes, this paper presents the whole process from sensor data acquisition to map construction and positioning, which lays a solid foundation for autonomous navigation of drones. Sensor data acquisition is required, and the data from the LiDAR combined with the wheel odometer of the cart chassis is used as the input of the whole navigation system. The laser radar scans the surrounding environment and obtains the obstacle information of the surrounding environment, at this time, the radar scanning point is in the radar coordinate system (laser); the wheel odometer is measured by the encoder sensor to obtain the rotational speed of the wheel combined with the kinematic model to obtain the speed of movement (Linear and Angular Velocity) changes, and through the trajectory projection method to obtain the odometer data (Chassis Coordinates and Heading), and to establish an odometer coordinate system in the chassis' position. The odometer coordinate system (ODOM) is established at the position of the chassis. Since the sensor coordinate system is a relative coordinate system at this moment, it is necessary to transform the sensor data to the global coordinate system, and use the TF coordinate transformation to ensure the uniformity and consistency of the data. The Cartographer uses the odometer data to obtain the position estimation values of the vehicle, and at the same time, takes these position estimation values as the initial values, and matches them with the radar data to update the values of the position estimator, and one frame of radar data is filtered by the motion filter. A frame of radar data after motion filtering, and continuously superimposed to form a two-dimensional raster map, this process completes the construction of the map and positioning, at this time to get the new coordinate system (map) as the global coordinate system, and then the map server (Map Server Node) can be autonomous navigation system development, design and simulation modelling 15 to save and read the map information [15].

On the basis of the constructed global and local cost maps, once the coordinates and orientation of the target point are specified, the global path planner fuses the coordinate system transformed sensor data to carefully plan an offline globally optimal path. At the same time, the local planner precisely calculates the optimal trajectory-speed combinations for the actual movement based on the detailed information of the local cost map to ensure that the vehicle can travel efficiently and safely. If an emergency fault is encountered during the navigation process or the target point is found to be unreachable, the system will immediately activate the motion state recovery mechanism. This mechanism can quickly help the drone reassess the current environment, adjust the navigation strategy, and re-open the navigation process to ensure that it can continuously and stably complete the navigation task. After specifying the coordinates and orientation of the target point in the established global and local cost maps, the global path planner plans the globally optimal path offline by combining the transformed sensor data from the coordinate system. The local planner settles the velocity combination of the optimal trajectory in specific motion based on the local cost map information, and if an emergency failure or goal unreachable is encountered, the motion state recovery mechanism is activated to help the cart to restart navigation [16].

Motion control section: according to the speed calculated by the local planner, it is passed to the drone to control its speed so that the drone can navigate correctly to the original path. : As the last part of the autonomous navigation system, the combination of velocities calculated by the local planner is passed to the cart chassis controller to control quantities in the form of linear and angular velocities, so that the cart achieves tracking motion on the given path.

5 Conclusion

This paper mainly explores the SLAM technology in autonomous navigation, localisation and obstacle avoidance of drone. The flowchart of obstacle avoidance system and the flowchart of navigation system are listed in the paper, and the operation of these two systems is analysed in detail. Through the study, it is found that SLAM technology can construct maps, navigation and obstacle avoidance in real time in unknown environments, which is still facing problems of real-time, accuracy, robustness and stability despite the development.

Laser SLAM technology has become a big hit in the field of drone control in the future with its own advantages of high stability and high algorithmic accuracy. In the field of obstacle avoidance, the existing research in the drone mainly applies SLAM technology and PX4 technology combined together, so as to achieve the high efficiency of the drone obstacle avoidance. The algorithms of these two technologies achieve the two main characteristics of high accuracy and high stability, which enables the drone to react quickly when encountering obstacles. In the field of navigation and localisation, the drone is fitted with multiple sensors to capture and analyse the environmental data around the drone in real time, so that the drone is always able to build a map model quickly. In this system, the drone captures its own speed information through sensors used to monitor itself, and then the drone will use this data to formulate a reasonable route and locate its own position information. Taken together, these two systems make the drone smarter, more efficient and less susceptible to human influence.

Although SLAM technology has undergone decades of development and has been improved over time, it lacks the conditions to be marketed on a large scale due to the high cost of the LIDAR used in the technology. However, due to the high cost of LIDAR, the technology lacks the conditions for a large-scale market rollout. Moreover, it is still questionable whether SLAM technology can maintain its high accuracy and stability when the drone is used for a long period of time.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

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