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A Study on Avoidance Technique for Autonomous Avoidance of Unmanned Vehicle

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Abstract: In the past, an unmanned vehicle had been recognized in the category of national defense industry so that there had been many limits to its application. With the rising public attention to unmanned vehicles, domestic and foreign firms have more invested in unmanned vehicles. With the development of technology and the increased private demands, the unmanned vehicle market is on the sharp rise. Since, an autonomous car of the IT company Google in the private sector was released, Complete Build Up (CBU) firms in Germany and other countries have been launching their autonomous car. Although, some countries allow test-driving of unmanned vehicles, no country institutionalizes unmanned vehicle driving. Existing unmanned vehicles frequently have malfunction of rear sensor and face safety accidents often in unexpected situations like a blind spot of rear camera. When the trivial defects are solved, it is possible to make deregulation for commercializing unmanned vehicles. The domestic industry failed to predict the growth possibility of the unmanned vehicle market so that the development was delayed. Therefore, this study proposes the development method of the unmanned vehicle technology for autonomous avoidance in order to secure competitiveness and enter in the global market in a short period of time. The study subjects are three technologies which include the technology of measuring a frontal distance from an unmanned vehicle camera and recognizing an object in camera image and unmanned vehicle navigation technologies like the autonomous driving technology to enable an unmanned vehicle to arrive at a destination. For research, ‘Kobuki’, the ROS official reference mobile robot, various distance sensors and depth camera are used. The research purpose is to compare the accuracy of the measurement of the distance between various distance sensors and depth camera SLAM (Simultaneous Localization and Mapping) emerged in order for an unmanned vehicle to drive in an unknown space, sense surroundings and create a current position and map for its autonomous avoidance. There are a variety of SLAM algorithms which are used to create a map. The map and a path-finding algorithm are applied for navigation. For a variety of SLAM algorithms, their performance is compared in terms of mapping time and map accuracy. Through performance comparison, an unmanned vehicle uses a map and a path-finding algorithm to avoid obstacles and drive. This study also suggests the performance comparison of path-finding algorithms in terms of the shortest path, driving time and the number of operations.

Key words: Unmanned vehicle, obstacle avoidance, autonomous car, ROS, SLAM, RPLIDAR

INTRODUCTION

In the past, an unmanned vehicle had been recognized in the category of national defense industry so that there had been many limits to its application. With the increased interest of consumers in unmanned vehicles such as unmanned aerial vehicles, drones and unmanned cars, global logistics service firms began to create new business models using unmanned aerial vehicles and drones. To develop unmanned car technologies, automobile companies and main IT firms have fierce competition with each other. As such with the sharply rising public attention to unmanned vehicles, domestic and foreign companies have much more invested in unmanned vehicles. As the public interest in unmanned vehicles has been on the sharp rise these days, unmanned vehicles have increasingly been searched for in Google trends as shown in Fig.1. In addition, the technology development and the increased private demands have led to rapid growth of the new market of unmanned vehicles. The unmanned vehicle market scale is expected to grow by 20% on annual average from USD 25.1 billion 2015 to USD 153.7 billion in the 2025 (Fig. 2).

The $25.1 billion (2015) unmanned agricultural machines, military drones, private drones (photographing, farming, Transport, etc.), small drones, underwater

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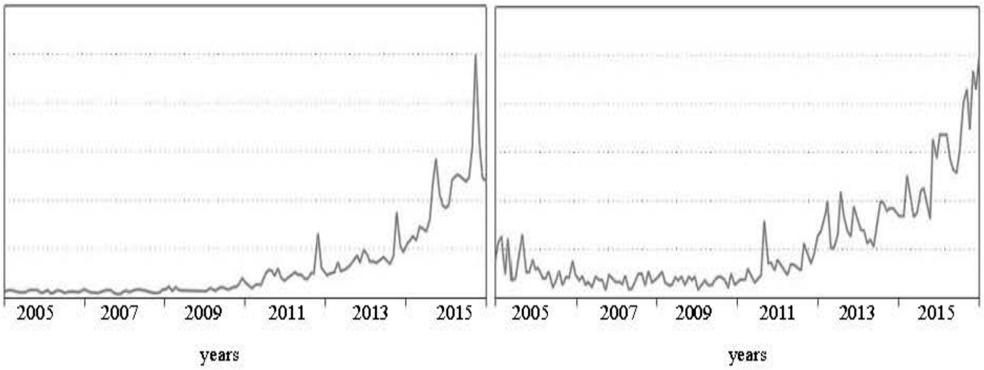

Fig. 1: The change in the public attention to unmanned vehicles

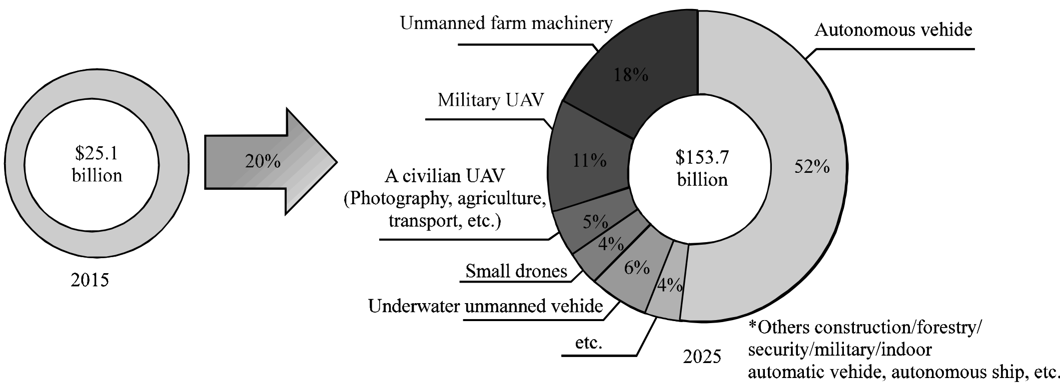

Fig. 2: Outlook of the unmanned vehicle market; material the minsity of science, unmnned moblie vehide engineening industry development strategy repoart 2015

unmanned vehicles. Others, autonomous cars others: construction, forestry, guard, military, indoor autonomous cars, autonomous ships, etc.

Since, an autonomous car of the IT company Google in the private sector was released, Complete Build Up (CBU) firms in Germany and other countries have been launching their autonomous car. Although, some countries allow test-driving of unmanned vehicles, no country institutionalizes unmanned vehicle driving. The domestic industry failed to predict the growth possibility of the unmanned vehicle market so that the development was delayed. As a result, the domestic core technology of unmanned vehicles is evaluated to fall behind the technology of foreign companies and countries and the appearance and growth of small and medium venture businesses with innovative technology have been delayed. As shown in the regulations of small drones, the commercial application of unmanned vehicles is still limited. To commercialize unmanned vehicles, it is necessary to complete relevant laws, systems and infrastructure and secure competitiveness and enter in the global market in a short period of time. Therefore, his study proposes the development method of unmanned vehicle technology of autonomous avoidance. The study subjects are three technologies which include the technology of measuring a frontal distance with the use of a depth value obtained from an unmanned vehicle camera and recognizing an object in camera image and unmanned vehicle navigation technologies like the autonomous driving technology to enable an unmanned vehicle to arrive at a destination (Kim, 2011).

Literature review: In order for an unmanned vehicle to avoid obstacles and arrive at a destination, the vehicle is required to measure and estimate a position on its own. Such existing vehicles as cars are able to estimate their position through GPS only outside. Because of a large error, they are unable to use GPS indoor. For the reason, Dead Reckoning is applied. It is a process of estimating a vehicle's position with the use of the rotation values of its two wheel axes. On the basis of the rotation values of wheels, a travelled distance and a rotation value are

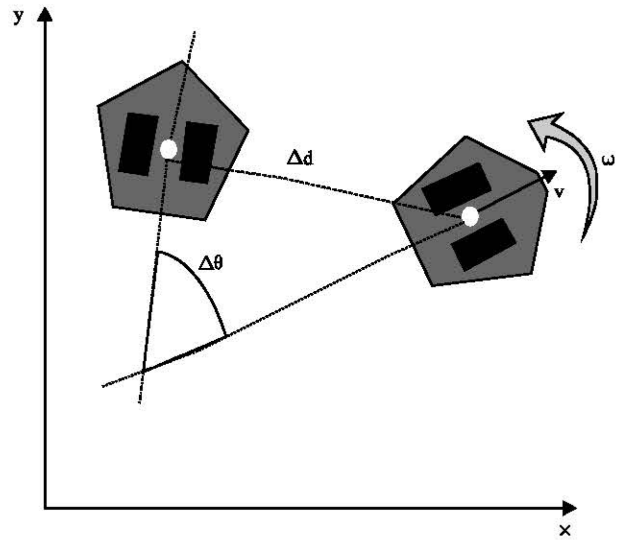

Fig. 3: Dead reckoning calculation; Ek E1p; The encoder value of left motor (current and previous values); E_{rc} E_{rp} the encoder value of right motor te; Elapsed time; v1 vr angular velocity of left and right wheels; r radius of wheel; V1 Vr ; Linear velocity of robot; ω angular velocity of robot

calculated so as to measure a position. However, this process causes a floor slip or a mechanical cumulative error so that inertial sensors like IMU or a filter are used for position error compensation. Kalman filter and particle filter are typical ones (Fig. 3).

$$v_t = \frac{E_{lc} - E_{lp}}{T_e} \frac{\pi}{180} \left(\text{rad/sec}\right) \quad (1)$$

$$v_r = \frac{E_{rc} - E_{rp}}{T_e} \frac{\pi}{180} \left(\text{rad/sec}\right) \quad (2)$$

$$v_t = v_t r \left(\text{m/sec}\right) \quad (3)$$

$$v_r = v_r r \left(\text{m/sec}\right) \quad (4)$$

$$v = \frac{v_r + v_t}{2} \left(\text{m/sec}\right) \quad (5)$$

$$\omega = \frac{v_r - v_t}{D} \left(\text{rad/sec}\right) \quad (6)$$

$$x_{k+1} = x_k + T_e V_k \, \text{Cos}\left(\theta_k + \frac{T_e \omega_k}{2}\right) \quad (7)$$

$$y_{k+1} = y_k + T_e V_k \, \text{Sin}\left(\theta_k + \frac{T_e \omega_k}{2}\right) \quad (8)$$

$$\theta_{k+1} = \theta_k + \omega_k T_e \quad (9)$$

In Dead Reckoning Method, on the assumption that a distance of wheels is D and a radius of a wheel is r, the encoder values of left and right motors are used so as to process Eq. 1-4 conversions and calculate a robot's linear velocity (v) and angular velocity w as shown in the Eq. 5 and 6. Finally, with the use of Runge-Kutta formula, it is possible to calculate travelled distance values and an approximate value of an angle as presented in Eq. 7-9.

There are various sensors to measure obstacles such as distance sensors, vision sensors and depth cameras. Distance sensors typically include LRF, ultrasonic sensor and UV sensor. Vision sensors include stereo camera, mono camera and omnidirectional camera. These days, depth cameras such as Kinect and Xtion are frequently used. A distance is measured with the sensors. In this study, the depth data obtained by the depth camera 'Kinect V2' is used for distance measurement. Kinect V2 uses the depth sensor (IR Projector+IR camera) that obtains depth information from the reflex and return time of flood infrared. When the depth data for one pixel value of an image was obtained with the use of the camera, fine errors occurred at the time of measurement in the unit of 0.01 mm. There might be a small problem at the time of measurement in the unit of 1 cm. However, when a measurement is made in the unit of 0.1 cm, a large error occurs. Therefore, it is planned to compare other distance measurement sensors in the future research.

What an unmanned vehicle needs to find a path is a map which includes information on walls and obstacles. SLAM (Simultaneous Localization and Mapping) is developed in order for an unmanned vehicle to create a map on its own or with a little of human help. SLAM enables an unmanned vehicle to drive in an unknown space, sense surroundings and create a current position and map for its autonomous avoidance. It is the core technology for autonomous driving like navigation. There are a variety of positioning methodologies such as Kalman filter and particle filter which are very significant research areas. If an unmanned vehicle performs positioning properly, it is possible to easily address the issue of SLAM for creating a map. However, there are many problems including uncertainty of sensor observation information and difficulty of the real-time performance for operating in an actual environment. Therefore, a variety of positioning methods are researched. A navigation technology is applied to

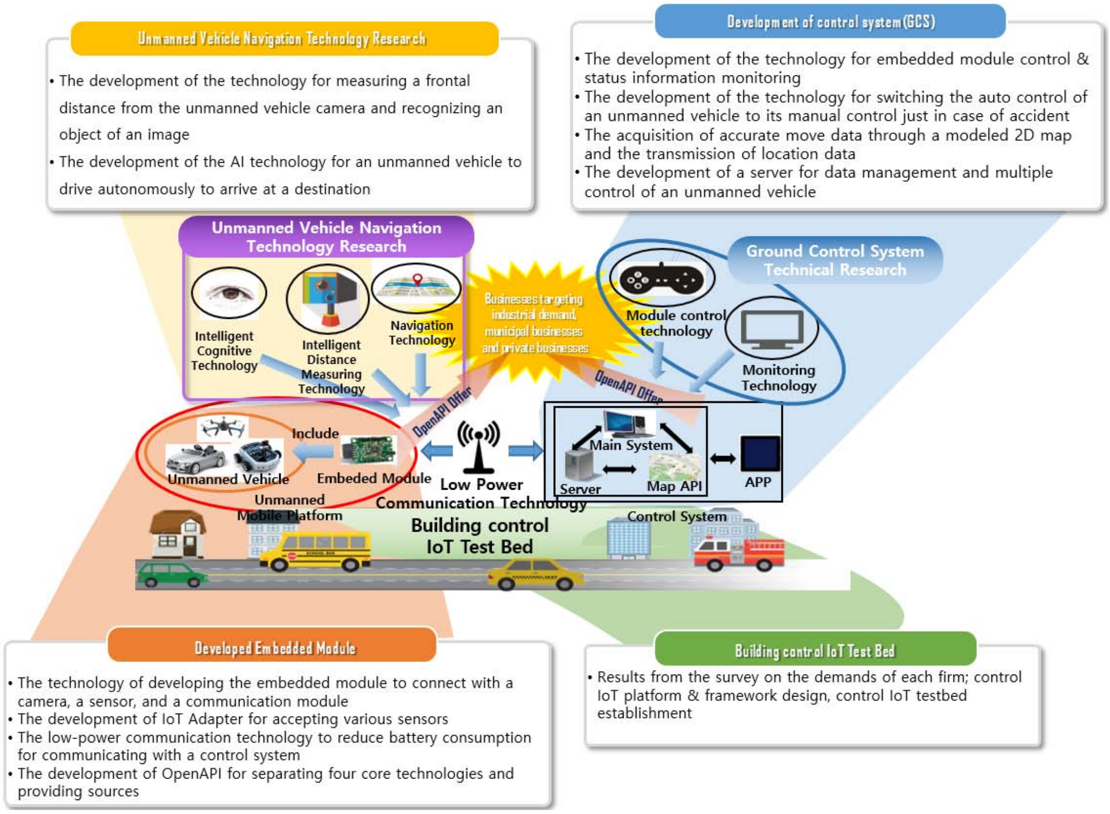

Fig. 4: Model of the proposed system

calculate and drive the optimal path to a destination on the basis of a map. It is called path search and planning which includes various algorithms such as Electromagnetic Field algorithm, particle and graph.

MATERIALS AND METHODS

System model

Overview: The final purpose of this study is to develop the wireless IoT platform for unmanned vehicles and the original technology of autonomous avoidance. There are four relevant studies. The first one is about unmanned vehicle navigation and driving technology. The second one is about functional recognition technology and distance measurement technology. The third one is about the development of integrated control system. The fourth one is about the establishment of control IoT testbed.

As an embedded module that plays a core role in the unmanned vehicle platform of the model proposed by this research for autonomous avoidance technology of unmanned vehicles, Lattepanda is used. Raspberry Pi 3 Model B that had been used for research had the problem of large memory use in the imaging process of web-cam based recognition technology research and showed poor performance. Therefore, it was changed to Lattepanda. As a body of unmanned vehicle platform, the TurtleBot 'Kobuki' was used with RPLIDAR and Kinect V2 sensors (Fig. 4).

RESULTS AND DISCUSSION

Research on unmanned vehicle navigation technology: Research on unmanned vehicle navigation technology is one of detailed cores studies. The navigation technology is used to find the optimal path among various paths of a RPLIDAR based unmanned vehicle to its destination and to avoid obstacles on the way to the destination. To make the navigation technology success, a variety of functions and algorithms are needed, among which the first one is a map. What matters to autonomous avoidance of unmanned vehicles is whether a navigator has an accurate map built in. SLAM includes various methodologies, such as KF (Kalman Filter), PF (Particle Filter), grapth and BA (Bundle Adjustment) based methods. KF is based on the assumption of system linearity so that it is unable to be applied to a non-linear system. Therefore, EKF (Extended Kalman Filter) and UKF (Unscented Kalman Filter) usable for a non-linear system are mainly applied. If an initial estimation is incorrect or a system model is designed incorrectly, EKF causes easy divergence. Nevertheless, it provides good performance in non-linear status estimation areas such as driving and GPS. On the assumption that there are enough samples, PF is more accurate than EKF and UKF. But, if there are not many samples, it causes a problem. A typical method is RBPF (Rao-Blackwellized) based SLAM using PF and KF at the same time. Recently, graph based SLAM becomes a main issue. In the past, many operations led to poor real-time performance. These days, many methods to overcome the problem have been proposed. BA (Bundle Adjustment) is used for correcting the positions of cameras and features in vision-based SLAM areas and is applied in combination with Graph based SLAM. As such, there are many methods which are still being researched. Therefore, the future goal is to compare various SLAM methods in terms of map quality. There are two methods to compare map quality. One is the method of comparing absolute positions. The other is the method of comparing relative relations of positions. The comparative items of map quality include a map creation time and the accuracy of created maps (compared to actual places). The maps will be applied to navigation technology. In addition, in terms of operations, shortest distance and time and other kinds of performance, various methodologies, such as navigation, positioning, path search and planning, Dynamic Window Approach (DWA), Potential Field, Particle Filter and Graph are compared (Kim, 2015; Batra, 2015). In addition, new methods are presented to reachtargets without obstacles in the dynamic environment of moving mobile vehicles (Cho *et al*., 2007).

Research on intelligent recognition technology: Research on intelligent recognition technology uses relevant algorithms and OpenCV libraries in order to recognize persons, lanes, objects and buildings. Road detection techniques such as technologies that detect the direction indicators of the road surface and assist the driver and for intelligent distance measurement, the algorithms of measuring a distance with the depth information obtained by a depth camera will be researched and developed. After that, the algorithm of measuring a distance in real time will be implemented. A depth camera provides 3D depth information as an output, supports real-time image processing and features lower noise by lighting change than other cameras. For the reason, it is evaluated to become a technology with high expectation in order for drones, autonomous cars and recognition technology. This study implements the integrated control system that includes the SLAM algorithm, a shortest path, a navigation algorithm, a distance measurement algorithm and the algorithm of recognizing persons, lanes, cars and buildings. The integrated control system is equipped with GCS (Ground Control System) that has the function of transmitting a measurement distance and image data to the control system and the module control function for controlling an unmanned vehicle. Aside from that, the low-power communication technology to reduce battery consumption in the communication of embedded modules and the security enhancement technology for wireless communication will be researched and developed. As a result, the final goal is to establish the control IoT testbed and draw results.

CONCLUSION

What was described earlier is in the category of data survey. The future goal is to implement what is proposed and draw and examine results. A depth camera provides map-type 3D depth information as an output, supports real-time image processing and features lower noise by lighting change than other cameras. For the reason, it is evaluated to become a technology with high expectation in order for drones, autonomous cars and recognition technology. Therefore, the depth camera can be effective at SLAM methodologies or distance measurement for unmanned vehicles. The future research is to compare Kinect, LIDAR, UV sensor and ultrasonic sensor in terms of performance so as to examine whether a depth camera fits an unmanned vehicle and distance measurement. In addition, it will be necessary to apply Kalman filter, particle filter, GraphSLAM and other methods to unmanned vehicles and apply improved algorithms so as to find which algorithm is better in a certain situation. Kalman Filter applied to a robot cleaner is the only commercialized method. In such an analysis, it is possible to determine the quality of a map created by a SLAM method. There are no given SLAM algorithms so that it is expected to improve SLAM technology through the examination. The recognition technology of unmanned vehicles will be implemented. The improved recognition function will provide stability and reliability of unmanned vehicles to users. The development of unmanned vehicle technology is expected to expand the market size of unmanned vehicles and derivative manufacturing industries, create various new and high value-added businesses, increase more new jobs, improve social convenience, establish stable traffic network, reduce traffic accidents because of automation and enhance disaster and safety monitoring and response. Problems such as primitive security issues such as car theft and rogue code security issues such as ransomware have become a huge global issue. Use effective security mechanisms and coordination systems upgrade increased security. It will also be the most vulnerable and problematic for wireless communications security for communications such as V2V and V2X. Therefore, it will become the issue of these researchers (Gwon and Kim, 2016; Jaeteon and Younghyum, 2016; Song and Hwang, 2014).

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