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Author(s)	劉, 羽飛
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学 位 論 文 内 容 の 要 旨

博士の専攻分野の名称　　博　士（農学）　　　氏 名　劉　羽飛 (Liu Yufei)

学 位 論 文 題 名

Autonomous Navigation for an Agricultural Unmanned Airboat in Paddy Field

（水田用無人ボートの自律航法に関する研究）

I　Introduction

The developing smart agriculture is an agricultural revolution to change the mode of agricultural production, and then change the life-style of humans. Many farm tasks in paddy field could be carried out automatically by using robot tractors under the autonomous navigation method. However, because of the environmental particularity in paddy field, it is hard to drive a ground vehicle such as a tractor after transplanting the paddy seedlings. But, an airboat is flexible to float on the water surface, and it doesn't destroy the paddy seedlings. Based on the mentioned above, the objective of this study is to attempt and develop the different autonomous navigation systems and methods on an unmanned airboat in the paddy field.

II　Research platform and attitude estimation

An agricultural radio-controlled unmanned airboat named Hokuto Yanmar RB-26 was selected in this study. The electronic control unit (ECU) and the computer control system were developed to control the airboat through three digital servo motors which linked the engine throttle, the blade of the air propellers and the rudder, respectively. Furthermore, the emergency stop devices were developed for airboat and environment safety. In addition, a small-size, light-weight and low-cost attitude measurement unit was composed out for estimating the attitude information of the running airboat in paddy field. In the comparison between the attitude measurement unit and a highly precise fiber optic gyroscope (FOG), the root mean square (RMS) of dynamic angle errors are 0.3 degrees in the roll direction and 0.4 degrees in the pitch direction.

III　Mathematical modeling of unmanned airboat

To achieve precise automatic control, the maneuverability of the airboat was derived based on Nomoto model which describes the dynamics relationship between the rudder deflection and the airboat turning angular rate. An accurate inertial measurement unit (IMU) was used for obtaining the airboat running status. A series of zig-zag maneuvering experiments were conducted for obtaining the maneuverability indices. Then, using the obtained maneuverability indices combined with Nomoto model to simulate the circular turning motion and sinusoidal running motion. The corresponding field tests verified the feasibility of the achieved maneuverability indices. Results of the comparison showed the difference of turning radius between field test and simulation were 0.25 m, 0.44 m and 0.04 m in the rudder angle 15º, 25º and 35º, respectively. It was concluded that simulation model had satisfied accuracy.

IV Path planning of unmanned airboat

Before autonomous navigation, the path planning is necessary to be required to cover the whole paddy area. Two path planning methods were proposed in this study. The first algorithm is fitted to the rectangular paddy field. The input parameters include the beginning and end positions of the first path, the path number, turning direction and path spacing. According to this unmanned airboat platform is susceptible when the speed of the nature wind is stronger than 7 m/s. Hence, the second algorithm took wind direction into account by making a path map which is parallel to the average wind direction. In this case, the influence from the wind could be reduced when the unmanned airboat running on the straight target path. The proposed algorithm is suitable to match any shapes of the convex quadrangular paddy fields or ponds.

V Autonomous navigation of unmanned airboat

Autonomous navigation is the core research in this study. There were three solutions were proposed in this study to make the unmanned airboat run on the predefined path map and avoid the external influence like the person and the edge of paddy field. The first solution used a global positioning system (GPS) and an electric compass, which could provide the global position and heading for the airboat. Then, comparing the navigation error between the position of airboat and the path map by using line-of-sight (LOS) guidance law for autonomous navigation. The experiment result showed that the RMS of the lateral error was less than 0.24 m on the straight line. The second solution was to develop an air station which consisted of a hexrcopter unmanned aerial vehicle (UAV), a wide-angle camera, and a Bluetooth transmitter to recognize the location of the airboat refer to the paddy field. The accuracy of the navigation is the RMS of the lateral error was less than 0.17 m. The final one was a low cost solution which used a laser scanner to calculate the position relation between the airboat and the edge of the paddy field by using Otsu thresholding method. This solution applied to the small paddy field with straight edge. The experiment result indicated that the RMS of lateral error was about 0.18 m. This later scanner was also used for safety detection. If a person was detected, the airboat could stop and wait until the person moves out. If a front edge of paddy field was detected, the airboat will turn to next target path. Every field experiment showed that the navigation accuracies were satisfactory to the requirements of weeding and fertilizing in paddy field.

VI Conclusion

In order to realize automatically weeding and fertilizing by an airboat in paddy field, autonomous navigation is the core research in this dissertation. All mentioned including the attitude estimation, mathematical modeling and path planning served for autonomous navigation. Three solutions based on a GPS compass, an air station and a laser scanner respectively, were proposed to make the unmanned airboat run on the predefined path map and avoid the external influence like the person and the edge of paddy field. The results of each solution performance showed the navigation accuracies were acceptable to meet the requirement of weeding and fertilizing in paddy field.