Robot Farming System Using Multiple Robot Tractors in Japan Agriculture

Noboru Noguchi *, Oscar C. Barawid Jr. **

** Professor, Laboratory of Vehicle Robotics, Graduate School of Agriculture, Hokkaido University, Kita 9 Nishi 9, Sapporo, Japan 065-8589*
email:noguchi@bpe.agr.hokudai.ac.jp
***Post-doctoral Fellow, Laboratory of Vehicle Robotics, Graduate School of Agriculture, Hokkaido University, Kita 9 Nishi 9, Sapporo, Japan 065-8589,*
email:oscar@bpe.agr.hokudai.ac.jp
***Affiliation: Assistant Professor, Department of Engineering, Aurora State College of Technology, Baler, Aurora, Philippines 3100*

Abstract: The objective of the research is to develop a robot farming system using multiple robots. The research will discuss the application of multiple robots in Japan agriculture for rice, wheat and soybean. The robot farming system includes a rice planting robot, a seeding robot, a robot tractor, a combine robot harvester and various implements attached on the robot tractor. One of the key elements of the robot farming system is that it should be more economical to the farmers. The important parts of the farming system are the robot management system, low-cost system, robot farming safety, and real-time monitoring/documentation.

Keywords: multiple robots, robotics, robot farming system, robot tractors, robot management system, low-cost system

1. INTRODUCTION

With the ever-growing population comes the problem of food shortage. Researchers are finding ways to increase food production without compromising our planet's natural resources and ecosystem. One viable way to increase food production is to integrate the new technologies such as GPS (Global positioning system), spatial information, robotics technology, laser scanners, CCD (Charge coupled camera), gyroscopes, etc. to agriculture.

This research will discuss the application of robot tractors in agriculture by developing a robot farming system in Japan using new technologies. Research institutions around the globe are conducting researches about autonomous vehicle for agricultural use and usually they rely on RTK-GPS (real-time kinematic global positioning system), GIS (geographical information system), navigation sensors, image sensors, total stations, VRS (virtual reference station), etc. depending on the application.

Recently, there are many research institutions already developed robot tractors and robot vehicles for agricultural purposes. Khot *et al.*, (2005) developed an autonomous tractor for intra-row mechanical weed control in row crops and a prototype robot vehicle for posture estimation of autonomous weeding robots navigation in nursery tree plantations greenhouse application. Nagasaki *et al.*, (2004) developed automated rice transplanter. Barawid and Noguchi (2010) developed low-cost and small scale electronic robot vehicle for orchard application.

Also, many researches have desire to modernize agriculture (Linker and Blass, 2008). This desire led researches to numerous studies related to the development of agricultural robot and semi-robot vehicles (e.g. Debain et al., 2000; Han et al., 2004; Pilarski et al., 2002; Morimoto et al., 2005).

The problem with the recent researches is that it is only concentrated on a specific application such weed control, crop detection, etc. Robot farming system is necessary that can be applied from seeding/planting to harvesting. This can be done by the recent advances in science and technologies using spatial and temporal information.

In Japan, the number of farmers is decreasing and aside from the fact the problem in aging farmers. In the near future, Japan farmers will decrease rapidly that will result to shortage in food production. That is why researchers in Japan are doing a research about robot farming system which is one of the possible solutions to solve the food shortage production. The objective of the research is to develop a robot farming system using multiple robots for rice, wheat, and soybean. The research will discuss the recent on-going projects and future projects on how to develop a robot farming system. It includes management system, low-cost navigation system, safety of robot farming, and real-time monitoring of the crops/plants.

2. RESEARCH MATERIALS

2.1 Robot platforms

Our laboratory, Laboratory of Vehicle Robotics successfully developed one electronic robot vehicle and two robot tractors. The electronic robot vehicle could control basic functions such as movement (forward, backward, and neutral), steering, speed, and emergency stop (manual or remote control switch). This robot vehicle will be used for real-time autonomous data acquisition and crops monitoring in the robot farming system. Figure 1 shows the electronic robot vehicle.

The two robot tractors could both control functions such as transmission (forward, backward, and neutral), speed, steering, three-point hitch, PTO (power take-off), and emergency stop (manual or remote control switch). These robot tractors will be used as a platform for the implementation of the tractor implements such as rotary tillage, weeder, seed broadcaster, fertilizer, and seed planter in the robot farming system. Figure 2 shows the robot tractors.

Rice transplanter and combine harvester are also included in the robot farming system shown in Fig. 3. These robot vehicles are under development and hopefully, test runs will be conducted in early summer of 2011. Actual experiments will be conducted using the multiple-robots at the same time to make the farming as autonomous as possible. Monitoring system will be also included in the system and it will be discussed in the results and discussion section of the research.

Fig. 1. Electronic robot vehicle

Fig. 2a. Wheel-type robot tractor

Fig. 2b. Crawler-type robot tractor

Fig. 3. Rice transplanter and combine harvester

2.2 Navigation sensors

To perform an autonomous navigation of the robot tractors and vehicles, navigation sensors are necessary. In the laboratory's current system, a method called sensor fusion was used to determine predetermined paths. Predetermined path also called as navigation map can be made by obtaining two-points in UTM (universal transverse Mercator) coordinates. These two-points will be used as the reference points to create navigation map using the developed software in the laboratory (Kise et al., 2001). The sensors used were RTK-GPS (real-time kinematic global positioning system) and IMU (inertial measurement unit). The RTK-GPS was used to obtain the vehicle position with respect to UTM coordinates and IMU was used to obtain the vehicle posture (roll, pitch, and yaw angles). These navigation sensors were used to follow the predetermined points in the navigation map. Figure 4 shows the RTK-GPS and IMU. The RTK-GPS has an accuracy of ±2 cm while the IMU has an accuracy of 0.5 deg/hr.

However, these sensors were expensive and it was not economically accepted to the farmers. That is why the laboratory tried to substitute the IMU with inexpensive sensor called Hemisphere GPS compass which is shown in Fig. 5.

RTK-GPS IMU

Fig. 4. RTK-GPS and IMU as navigation sensors

Fig. 5. Hemisphere GPS compass

Fig. 6. AGI-3 GPS compass

This sensor gives absolute heading angle and position of the vehicle. The heading angle accuracy is 0.3 deg and position accuracy is 60 cm in DGPS (differential GPS). An autonomous run was conducted using the GPS compass and obtained a satisfactory result by following the navigation map with minimum errors both in lateral and heading deviations.

A new inexpensive sensor was also used as the navigation sensor called AGI-3 GPS compass shown in Fig. 6. The sensor includes a satellite receiver, antenna, inertial sensors and memory storage for complex path planning and control algorithms. This sensor substituted the RTK-GPS and IMU sensors and eliminated the difficult sensor fusion algorithm. Preliminary autonomous run tests were conducted using the AGI-3 GPS compass sensor. Using the AGI-3 GPS compass as the navigation sensor, results showed that it could follow the navigation map accurately. However, more experiments are needed in order to increase the accuracy of the navigation system.

2.3 Safety system

One of the important things needed to include in the robot farming system is the safety of the farmer or operator. During the operation of the robot tractor in the field in an autonomous mode, safety measure should be included in the system. A 2-dimesional laser scanner was used as the safety sensor attached at the front of the robot tractor shown in Fig. 7. This laser scanner could obtain distance and angle of the objects in front of it with respect to its set scanning range distance. The laser scanner scanning angle can be set into 100 deg and 180 deg modes. The scanning distance can be set into 8m, 16m, 32m, and 80 m modes.

For obstacle detection sensor, an ultrasonic sensor (Bosch and Sensing Technology) was used to detect obstacle in front of the robot tractor. Figure 8 shows the ultrasonic sensor and its basic specifications. This obstacle detection system is still under development.

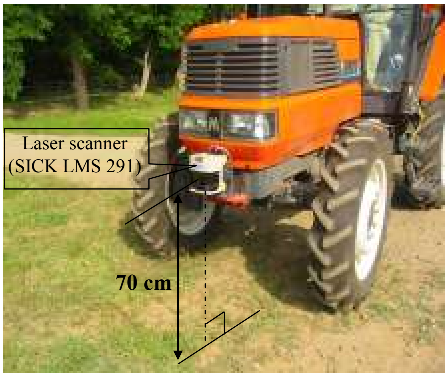
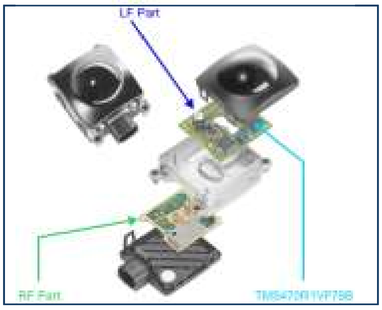


Fig.7. Two-dimensional laser scanner attached to the robot tractor



Bosch LRR2 with dimensions of 73 x 70 x 60 mm (2.9 x 2.8 x 2.4 in) can be integrated almost anywhere on the front of the vehicle

Fig. 8 Ultrasonic sensor and its specifications

3. RESEARCH METHODS

3.1 Robot farming system

The idea behind this research was to develop a robot farming system for rice, wheat, and soybean fields. The robot framing system will fully automate the farming from planting to harvesting until to the end user of the products. The robot tractors will be used to plant and seed the crops using inexpensive sensors for its navigation. A full overview of the robot farming system is shown in Fig. 9. It includes robot management system, real-time monitoring system, low-cost navigation system, and safety system. In the robot farming system, the robot tractors receive command from the control center and send information data using wireless LAN and packet communication. The robot tractors can perform its designated tasks and can work simultaneously with each other. The operator at the control center can analyze the data sent by the robot tractors in a real-time basis and can immediately send the necessary information to the farmers, retailers, producer's cooperation, etc. Also, the operator can see the real-time status of the robot tractors using a GeoMationFarm (Hitachi Soft) while their performing its task.

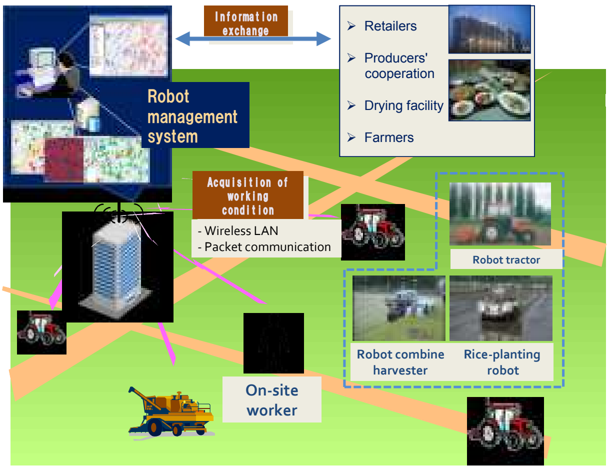


Fig. 9. Overview of the robot farming system

3.2 Low-cost navigation system

In order to be economically acceptable to the farmers the application of the robot farming system, low-cost navigation system is necessary to consider. The choice of navigation sensors will depend on the accuracy and its application. There are many companies commercializing navigation sensors but the problem is the algorithm on how to do sensor fusion and how to increase its accuracy. In our laboratory, we already successfully made a sensor fusion of RTK-GPS and IMU sensors to obtain the vehicle's absolute heading angle and position in UTM coordinates. However, these sensors were expensive. In this system, a low-cost navigation sensor based on multi-GNSS (global navigation satellite system) was used as navigation sensor called AGI-3 GPS compass made by TOPCON. This AGI-3 gives vehicle's absolute heading angle and position in UTM coordinates. The fusion of RTK-GPS and IMU sensors will be replaced by this AGI-3 sensor. Aside from the low-cost of the AGI-3, the company already did the sensor fusion of the GPS and inertial sensors.

3.3 Robot management system

One of the important parts of the robot farming system is the robot management system. Robot management system is developed based on GeoMationFarm integrated with GIS map which is commercialized by the Hitachi Soft. Different information can be generated and can be seen by the operator which is located in the control center. The robot management system will send the information necessary to control the robot tractors during their operation such as navigation map. In the navigation map, details about working information of the vehicle are included such as number of path, three-point hitch position, vehicle speed, and PTO rotation. Robot management system can also obtain crop information data from the robot tractors using the sensors attached to them. This crop information includes crop status and soil quality. From this information, a variable rate fertilizing map can be generated and the control center can send it back to the robot tractors for fertilization of the crops. Figure 10 shows the mission plan map.

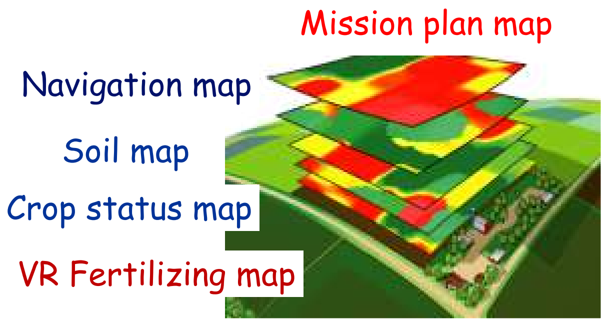


Fig. 10. Mission plan map in robot management system

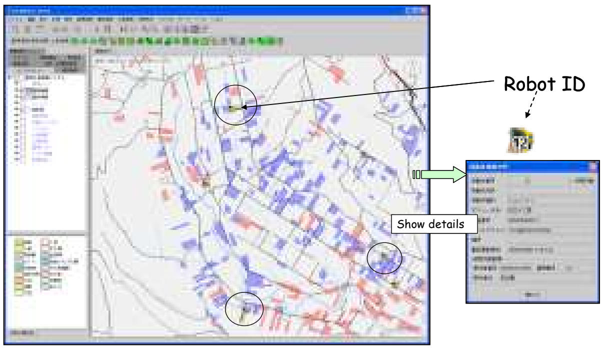


Fig. 11. Real-time monitoring system

Another function of the robot management system is the real-time monitoring of the robot tractors while in working condition. Using this management system the current location and status of the robot tractors can be seen. Also, the current information of the working condition of the robot tractors can also be observed. Figure 11 shows the real-time monitoring system of the robot tractors. In the figure, each working robot tractor has its own Robot ID. By clicking the Robot ID to the computer screen, details about the robot tractor will be seen.

3.4 Safety system

Our laboratory successfully developed an obstacle detection algorithm system using 2-dimensional laser scanner. This system was used for safety purpose. The system was included in the robot tractor navigation program. If the laser scanner detects obstacles in front of it within the set scanning range, the navigation program will command the robot tractor to stop. Even though the laser scanner has high accuracy, it is expensive and it is not economically accepted for the farmers.

That is why the research is focusing on the inexpensive sensors. Ultrasonic sensor is one of the choices to substitute the laser scanner. The obstacle detection using this ultrasonic sensor is still under development.

4. RESULTS AND DISCUSSION

4.1 Current status of the robot farming system

Three-robot vehicles (electronic robot vehicle and two-robot tractors) were already developed for the robot farming system as platforms. The electronic robot vehicle will be used to obtain crop information by attaching sensors to it and two-robot tractors will be used to perform the various implement functions. On-going developments and modifications on the rice-transplanter robot vehicle and combine harvester robot platforms are in the making.

Low-cost navigation sensor selection is also one of the top priorities in the implementation of the research. The navigation sensor that will be used will come from different companies which have the lowest cost compared to the other companies.

The current status of the robot farming research is already started and good developments are going-on according to its research plan.

4.2 Future plan and evaluation of the robot farming system

The research is under a five-year plan and it was started April 2010. The first three years will focused more on hardware developments of robot platforms (rice transplanter robot, combine harvester robot and robot tractor) and also it will include the software developments such as robot management system, obstacle detection algorithms, and real-time monitoring system.

For the remaining two-year in the plan, a feasibility test and evaluation of economics of the robot farming system will be conducted.

5. CONCLUSION

The research discussed about the development of robot farming system for rice, wheat, and soybean fields in Japan. Multiple robots were used in order for possible development of a robot farming system. Robot platforms were already developed and other robot platforms are on its way of developments. Also, the research discussed the application of inexpensive navigation sensors to be able to economically acceptable with the community. The robot farming system development will be a great help in the near future in Japan agriculture because the farming will be fully automated. Also, increase in food production will be one of the great outputs of this research.

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