MEASURING THE PATHS OF FARM MACHINERY USING AN OPTICAL WAVE RANGE FINDER

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ABSTRACT

To straighten the path that farm machinery follows in paddy fields, it is necessary to measure and evaluate the tracks that these machines leave behind. However, there are no known methods for making such measurements and evaluations since it is difficult to accurately trace the paths that the machine make in paddy fields. Therefore, a measuring system has been developed which can accurately record the path of a farm machinery in a field by measuring the horizontal straight-line distance from the side of the field to the machine.

This system consists of a track subsystem on the machine and a range finder system. A measuring apparatus is installed on a flatcar which runs on rails over 50m long at the side of the field. The track subsystem uses a CCD camera to track the movement of the machine in the field which is following a lengthwise path. The range finder subsystem measures the distance that the measuring apparatus has traveled on the rails and the distance from the apparatus to the machine in the field. This system makes it possible to record the path that the machine travels.

Even though differences in traveling distance arise between the measuring apparatus and the farm machine, these differences are detected by image processing, which allows the machine in the field to be located accurately. The short (0.05 second) time required for image processing is enough to follow an object. In the present study, this system was able to measure the path that a moving tractor makes. Even though a lag of up to 0.4 meters occurred, this system did not miss its target during operation of the track subsystem. Thus the path measuring system developed here is able to record vehicle paths

automatically by following the movement of vehicles in the field and measuring the distance to them. It is expected to come into use in such applications as unmanned moving vehicle tests.

Key Word: Path Measuring, Image Processing

INTRODUCTION

To straighten the path that farm machinery follows in fields, various techniques using laser beam, magnetic azimuth sensors, gyro sensors, etc., or combinations thereof, were studied. In order to evaluate those techniques, it is necessary to measure and evaluate the tracks that these machines leave behind. The purpose of this study is to develop a measuring system which can accurately record the path of a farm machinery in a field by measuring the horizontal straight-line distance from the side of the field to the machine. For this purpose, efforts were made to develop an efficient technique for detecting markers by image processing which is not based on brightness conditions, a travel speed control technique using the difference in traveling distance between an apparatus and a marker, and a technique to synchronize the data of traveling velocity with the data of traveling distance which is necessary to accurately measure a traveling path. A measuring system which combines these techniques was developed and its practicality was evaluated.

TESTING EQUIPMENT

As shown in Figures 1 and 2, this system consists of a track subsystem on a machine and a range finder system. A measuring apparatus is installed on a flatcar which follows a lengthwise path on rails over 50m long at the side of the field. It measures the distance that the measuring apparatus has traveled on the rails and the distance from the apparatus to the machine in the field. This system makes it possible to record the path that the machine travels. Various specifications of the test equipment are shown in Table 1. By this method, traveling speed of the system is feedback-controlled by means of the difference between the location of the marker which was obtained by image processing and the center of gravity in the pixel. It was hard to make it travel in perfect synchrony with the target machine, since it was difficult to avoid discrepancies in traveling distance between the target machine and the measuring system. However, by compensating the traveling distance of the measuring apparatus by the difference between the center of gravity in a pixel and the center of gravity of a marker, the traveling distance of the target car was able to be obtained.

Track subsystem

The detection of the target car was made possible by image processing. A marker was loaded in the traveling car. The marker image was input in a computer by a CCD camera. By detecting the difference between the center of gravity of a pixel and the place of the image of the marker, the follow-up velocity was controlled. In order to reduce the time required for image processing, a white colored 90 cm square plate painted with a black vertical line of 20 cm in width was used as a marker. (see Figure 3)

By using the difference in brightness information within R, G, B or one of these information, a still image of the marker was photographed outdoors in order to study brightness discrimination under various lighting conditions. Since there were 640 × 512 pixels in the image input apparatus, it became possible to store each bit of brightness information of each R, G and B in the frame memory as an 8bit integer value of, 0 to 255. By acquiring images, characteristics of the brightness of the marker and the background were analyzed. The results are shown in Figure 4. By converting the threshold value to about 100 for only R brightness values irrespective of lighting conditions, the discrimination of black color line became possible. Since only 640 pixels on horizontal line were analyzed, it was possible to drastically reduce the time required for image processing. In addition, even though it caused a fluctuation in the vertical angle of the camera, it could prevent to change the place of the marker. The difference between traveling distance of the apparatus and the object was computed from the horizontal distance to the target and the traveling distance of the apparatus was compensated based on this difference and converted into the traveling distance of the object. The short (0.05 second) time required for image processing was enough to follow an object.

The following-up speed control part

The degree of control of a follow-up velocity was determined by the degree of displacement in a pixel of the marker image which was obtained by image processing. The rotation speed of a DC electromotor was controlled by a D/A converter. The relation between the traveling speed of the measuring apparatus and the control voltage was linear. From a preliminary test, the response characteristic of a traveling velocity of the flatcar could be written as Eq.(1).

$$y(t) = 1 - (1 + t/\tau)e^{-\frac{t}{\tau}} \qquad (1)$$

In the Eq.(1), the value of time constant τ is a characteristic of the 2nd degree time-lag differential factor and differed according to the target value; when a velocity was slow, it understood that τ was big and the response was slow. For this reason, when travel was started from a stationary state, it was necessary to increase the degree of control over the normal value in order not to miss the target.

The range finder subsystem

The range finder subsystem measures the distance that the measuring apparatus has traveled on the rails and the distance from the apparatus to the machine in the field. The measurement interval varied from 0.02 second (accuracy: 20mm) to one second (accuracy: 3mm). Measured data was transmitted to the computer through a serial cable. The rotation speed of the wheel of the flatcar was measured by a rotary encoder. The signal from the encoder was read by a counter. In order to synchronize the data of the traveling distance of the measuring apparatus with the data of the distance to the marker, the distance data from the rotary encoder was read as soon as the reading action of the data of the optical wave range finder started. Using the measuring system mentioned above, a measuring test on the path of a farm machine was conducted. Block diagram of experimental apparatus is shown in Figure 5.

RESULTS AND DISCUSSION

In the test, a four-wheel tractor was used to follow and measure the path in a field. The marker was set at the side of the tractor. The traveling speed of the tractor was adjusted to about 1 m/s and travel meandered a little. The measurement interval for distance was set at 10cm and the range finder accuracy was set at 5mm. Though a lag of up to 0.4 meters occurred, this system did not miss its target during the operation of the track subsystem. The path measuring system was able to record vehicle paths as shown in Figure 6. Thus the system could record the paths automatically by following the movement of vehicles in the field and measuring the distance to them. It is expected to come into use in such applications as unmanned moving vehicle tests.

CONCLUSIONS

A measuring system has been developed which can accurately record the path of a farm machine in a field by measuring the horizontal straight-line distance from the side of the field to the machine. This study attempted to develop an efficient technique for detecting markers by image processing which is not based on lighting or, brightness conditions, a travel speed control technique using the difference in traveling distance between an apparatus and a marker, and a technique to synchronize the data of traveling velocity with the data of traveling distance which is necessary to accurately measure a traveling path. A measuring system which combined these techniques was developed and its practicality was evaluated. The path measuring system developed here was able to record vehicle paths automatically by following the movement of vehicles in the field and measuring the distance to them.

Table 1 Specifications of the paths measuring system

Flatcar	Driven by DC motor, DC24V 300W Weight: 120kg
Controller	Personal computer, CPU:486SX 33MHz
Traveling speed controller	16 bit D/A converter w/DMA transfer
Image processor	CCD color video camera 640×512 pixels color video capture board
Distance measuring device	Optical wave range finder, Error: ±3mm～±20mm Data transmitting rate: 19,200bps
Traveling speed measuring device	1000 pulse/c Rotary encoder 24 bit Pulse counter
Programming language	C and Assembler

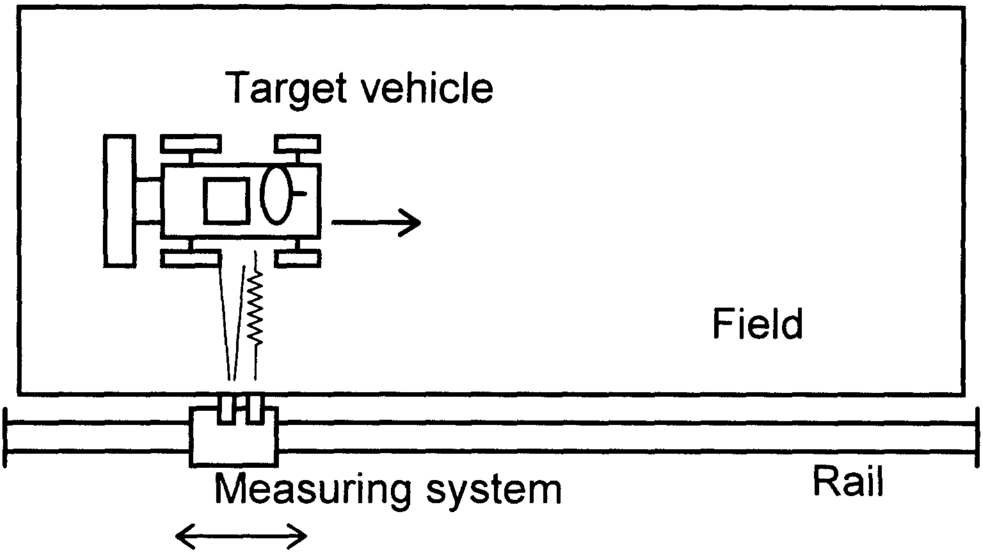

Fig. 1 Plane figure of the test field with rail

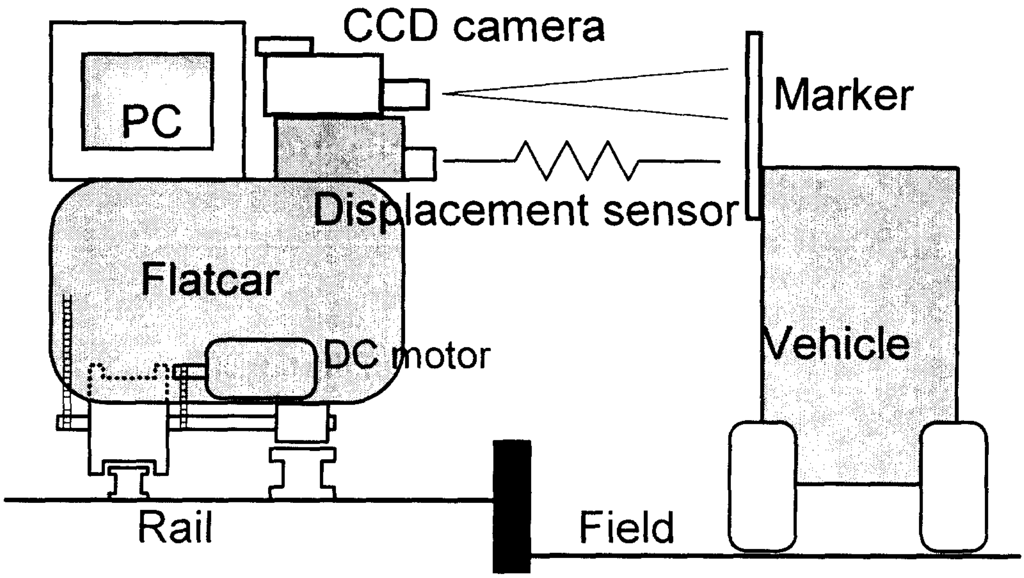

Fig. 2 Schematic diagram of the measuring system

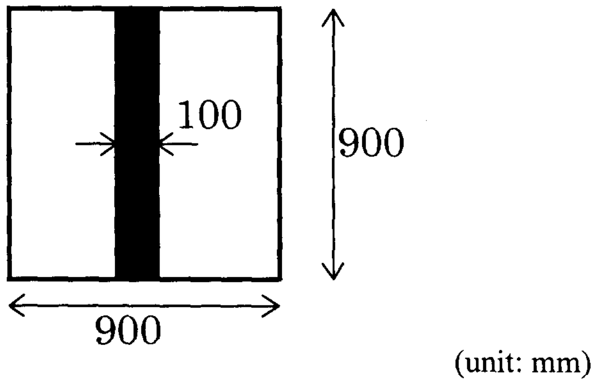

Fig. 3 Front view of the marker

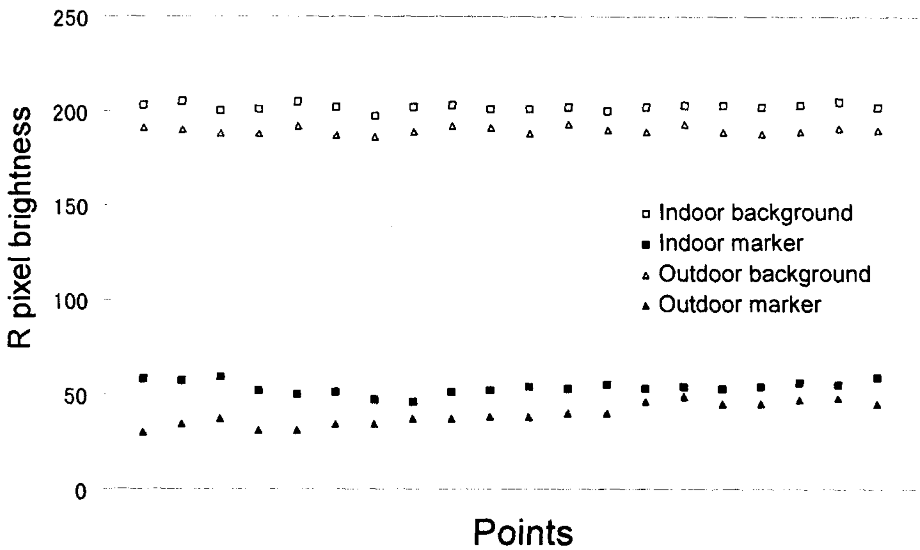

Fig. 4 Pixel brightness of the target

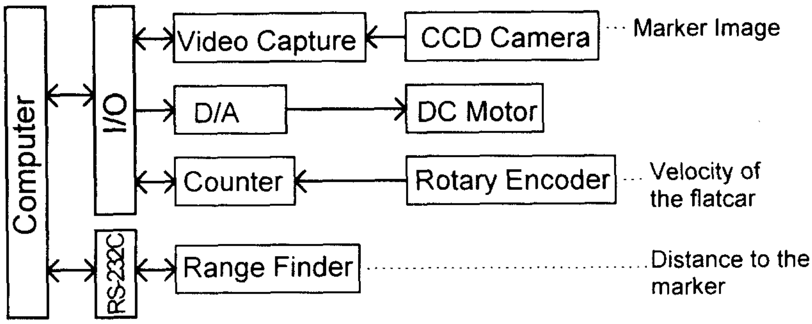

Fig. 5 Block diagram of experimental apparatus

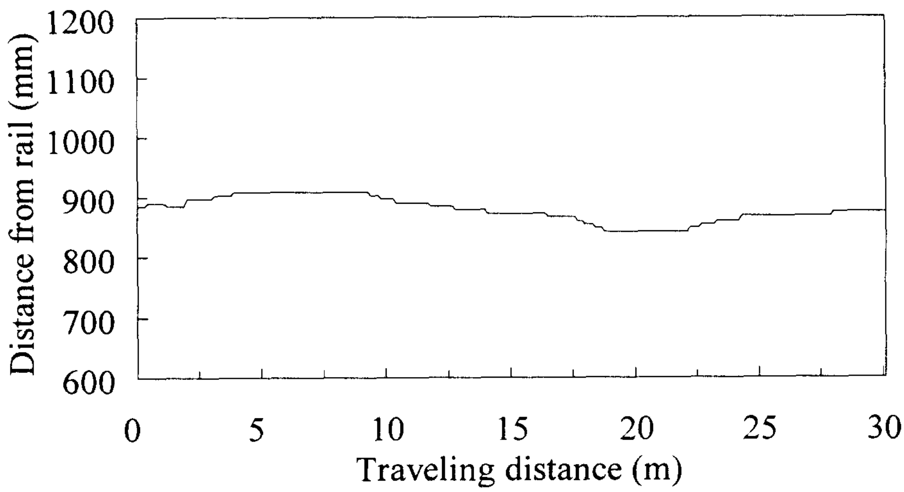

Fig. 6 Measurement Result