24th International Symposium on Automation & Robotics in Construction (ISARC 2007)
Construction Automation Group, I.I.T. Madras

DETECTION OF DUMP TRUCK FOR LOADING OPERATION BY WHEEL LOADER

Shigeru Sarata, Noriho Koyachi
AIST, Namiki 1-2-1
Tsukuba, Ibaraki, Japan

Hiroyasu Kuniyoshi, Takashi Tsubouchi
University of Tsukuba
Tenno-dai 1-1-1, Tsukuba, Ibaraki, Japan

Kazuhiro Sugawara
Hitachi Construction Machinery Co.
Kandatsu 650, Tsuchiura, Ibaraki, Japan

ABSTRACT

The authors have been conducting development of an autonomous loading system by wheel loader. As a part of the development, a detection method of location of the dump truck will be described in this paper. In the process of loading to the truck in the operation, the loader approaches to the dump truck in very close distance. The function for collision avoidance between the loader and the truck is an essential function for the autonomous system. The detection of location of the truck is based on GPS data and Laser Range Finders (LRF). The detection based on LRF is more precise and robust. The developed detecting method is installed and tested on the Experimental loader in test field. The system shows very good results.

KEYWORDS

Wheel Loader, Autonomous System, Loading Operation, Laser Range Finder

1. INTRODUCTION

Earth moving operation is a basic task in fields of construction, mining and so on. Wheel Loader (loader hereinafter) is one of the major loading machines using in those fields. The authors have been conducting a development of an autonomous system for loading operation by wheel loader [1][2]. The developing system is completely self-contained and required no assist of human operator. Localization and detection of other object such as the pile and the truck are essential function for an autonomous system.

Loading operation consists of cycle of phases: (1) scooping from the pile, (2) traveling to the dump truck, (3) loading to the truck and (4) traveling to the pile. In the phase of loading to the truck, the loader approaches to the dump truck in very close distance and the bucket overlaps on the vessel of the truck. The function for collision avoidance between the loader and the truck is important in this phase. A precise and robust detection system is required.

2. DEVELOPING WHOLE SYSTEM

The most common loading method by wheel loader is V-shape method as in Fig.1. The loading operation is carried out by repetition of the cycle with four phases described in previous section.

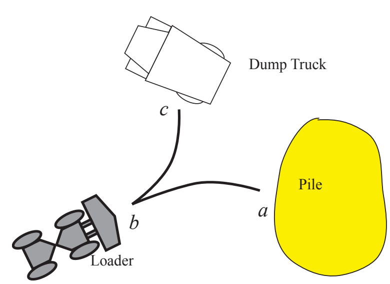


Figure 1 V-Shape Loading Method

The developing system is installed on the experimental loader: Yamazumi No.4 (YZ4) as shown in Fig.2. YZ4 is about 7m in length and about 7ton in weight. Hydraulic system is arranged for computer control with pilot valves. PCs and sensors are mounted for following functions. The autonomous system consists of the planning sub-system, the motion control sub-system and sensor system. The planning sub-system makes decision for scooping point, V-shape path and loading point to the dump truck. The planning sub-system for scooping point issues the scooping position and direction on the edge of the pile based on the position and shape of the pile. The planning sub-system for loading point issues the loading position and direction on the vessel of the truck. The path planning sub-system generates a path between the scooping point and the loading point. Because the Scooping points and the loading point are changed with advancing of the operation cycle by cycle, the planning procedure is executed for each cycle of the operation.

Figure 2 YZ4 and Experimental Dump Truck

The sensor system is classified in two categories: the inner sensors and the outer sensors. The inner sensors detect a mechanical state of the loader including angles of steering, arm, bucket and wheel. The outer sensors detect the environment including the position and direction of the loader by GPS system, the position and shape of the pile by stereo-vision system and the distance between the loader and the truck by Laser Range Finder (LRF).

3. TRACK DETECTING SYSTEM

In the experiment, GPS positioning system is installed on the experimental dump truck. YM4 and the experimental truck can communicate with each other through LAN. Therefore YZ4 knows the position and direction of the truck with accuracy of GPS positioning. GPS antennas of YZ4 are attached on the roof of cockpit and the height from the ground is about 4m. Tyres are deformed by weight of scooped material in the bucket. The position of antennas is affected by this tyre deformation up to about 0.2m in horizontal direction. In the process of loading, distance between the tip of bucket and the vessel of the truck is less than 0.5m. The position error of GPS antenna is not negligible and other sensing system with high accuracy is required.

Figure 3 LRF on YZ4

For this propose, two scan type LRF are attached on the front part of YZ4 as shown in Fig.3. As LRF emits laser beam and scan in a plane, a cross sectional shape of objects in the scanning plane is detected. Usually LRF is set in direction making the scanning plane horizontal however LRF are attached in direction which gives vertical scanning plane for the truck detection. Two LRF are attached with a bar at both side of the front part of YZ4. Attached positions are out side of the bucket slightly. The position of the bucket does not affect sensing of LRF. The maximum measuring range is set at 80 m with 10mm resolution. The scanning range is 180 degrees and the emittion interval is 0.5 degree. One set of scan data includes 361 data. The interval time of the scan is about 30Hz. In Fig.4, an example of a set of data is shown.

4. ALGORITHM FOR DETECTION

One set of data includes cross sectional shape of the truck including the vessel, the ground and other thing such as tyre of the truck. For detection of the vessel, corresponding part in the whole data should be identified. The algorithm for identify or elimination is describe below.

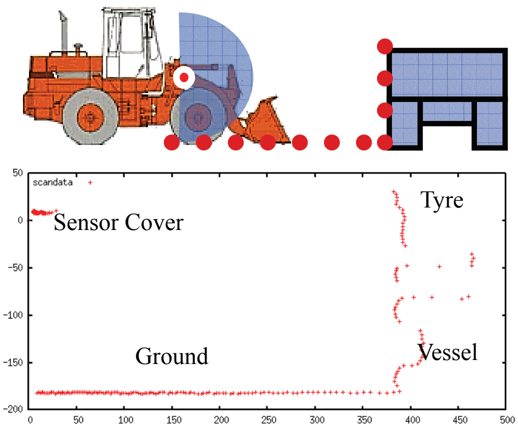


Figure 4 An Example of Set of Data

The first step is an identification of the ground. A part of the data which locates beneath the sensor can be assumed the ground with very high probability. A fitting line to a part of the data beneath LRF is drawn by the method of least square. Neighboring points of the fitting line are supposed as the ground. The rest of the points represent the truck including the vessel, the tyre and other structure.

The second step is identification of the upper end point of the vessel. During loading phase, the bucket should clear the upper end of the vessel for collision avoidance. As the side wall of the vessel is vertical, the corresponding data to the vessel make a series of point on vertical straight line. To find out the series of data, Ransac (Random Sample Consensus) method is applied. The procedure of the identification of the upper end point is as follows:

(1) Choose a certain amount of the data at random from the data representing the truck. Draw a line fitting to the chosen points by method of least square.

(2) Points whose distance to the line obtained in (1) is less than a threshold are selected as neighboring points to the line. Count the number of the neighboring points N. Then draw a line fitting to these points by the least square method again. Calculate a mean and variance of distance between each point and the line.

(3) Repeat the procedure (1)-(2) several times. Then select a set of data with the largest N and the least variance as the set representing the vessel of the truck. The highest point in the set is selected as the upper end point if the vessel.

5. EXPERIMENTAL RESULTS

Fig.5 and Fig.6 show an example of the results and the procedure. Fig.5 is the result of the identification of the ground. The data with range of 1m to 1.2m from LRF is used for the fitting. The fitting line is drawn in Fig.6. Points within 0.2m range from the line in upper and lower side are supposed to be the ground and the rest is supposed to be the data corresponding to the truck. The ground part is identified very clearly by this method.

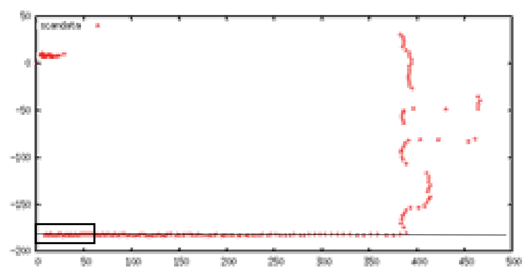
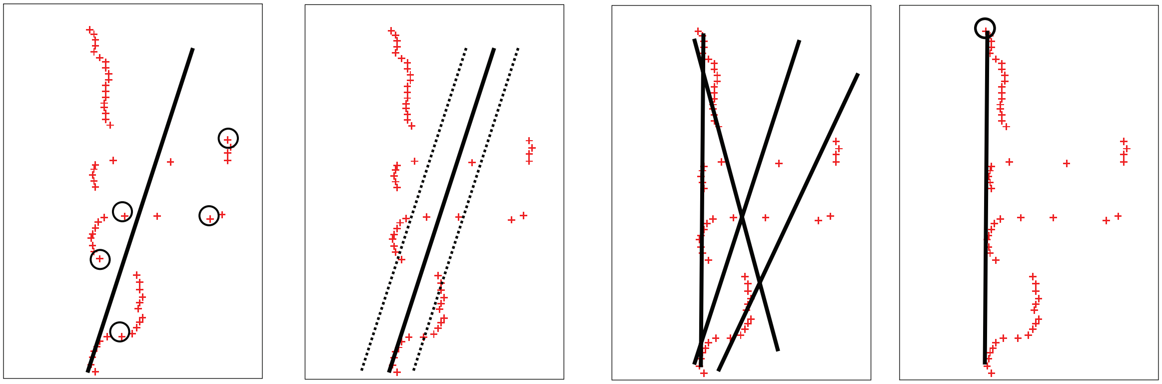


Figure 5 Identification of Ground

Fig.6 illustrates the result of the procedure (1)-(3). Fig.(a) shows the fitting line to chosen points. The amount of chosen points is 20% of the points without eliminate as the ground. Usually the total number of the point is approximately 25 to 100 and it changes by the distance between LRF and the truck. In Fig(b), the threshold lines of distance from the fitting line are drawn. The threshold distance is 0.12m. Fig(c) shows repetition of procedure (1)-(2). The number of the repetition is 50. Finally, a line with the largest number of the including points and the least variance is selected as the set represents the vessel of the truck. The highest point in the set is supposed to be the upper end point of the vessel (Fig(d)). It is clear that the most suitable point is selected as the upper end point.



Fig(a) Random Points and Fiting Line

Fig(b) Threshold Lines

Fig(c) Repetition 50 cycles

Fig(d) Final Result

Figure 6 Example of Results

6. CONCLUSIONS

As a part of development of an autonomous system for loading operation by wheel loader, detecting method of the truck by LRF is developed. The developed detecting system is installed and tested on experimental loader TZ4.The results show that the developed system can detect the truck very precisely. It works very well even in heavy rain condition.

7. REFERENCES

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