Automation and Robotics in Construction XI
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A Method of Control of Plural Autonomous Dump Trucks in Heavy Construction Sites

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Abstract

It is anticipated that autonomous dump trucks system could reduce approximate 30 % of the workers required at a heavy construction site (i.e., dam constructions, road constructions, etc.) in the future. The technologies required for an autonomous dump truck are developed by using the test vehicle. On paved roads, the continuous driving distance that the unmanned driving control could achieve is 2 km at the maximum speed of 30 km/h. The difference between the planned path and the trajectory is within ±100 cm.

This paper describes the communication function to control plural autonomous dump trucks in heavy construction sites. This system can control five autonomous dump trucks automatically in wide area by utilizing some radio station and cable communication.

1. INTRODUCTION

Faced by a need to improve productivity and safety in earthwork, an autonomous dump trucks system in heavy construction sites is developed as shown in Figure 1

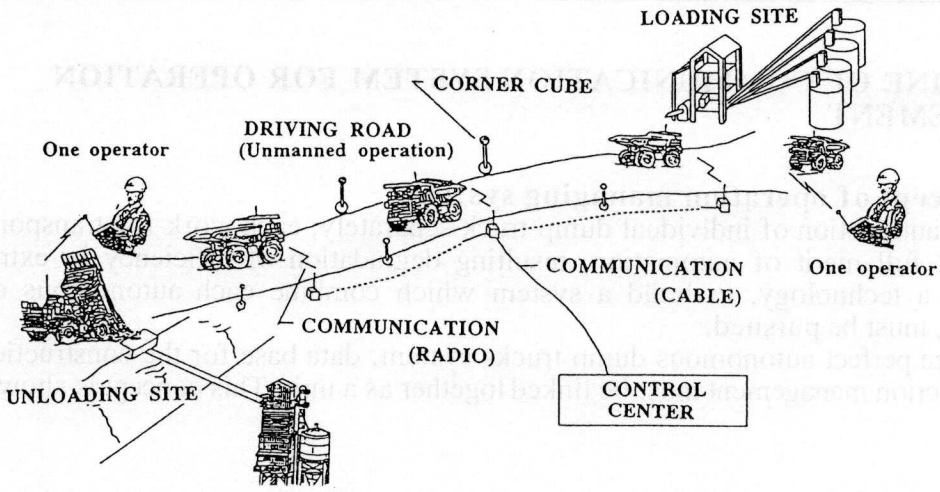

Figure 1. Image of an autonomous dump trucks system.

Photo 1. Test vehicle for development of element technologies.

The field driving experiments of the test vehicle as shown in Photo 1 were conducted in a dam construction site in 1991 and at the test course of Public Works Research Institute, Ministry of Construction in 1993. Table 1 shows the current performance of the test vehicle on paved roads.

Table 1
Performance of the test vehicle

Function	Item	Target performance	Current performance
Unmanned operation	Distance of continuous driving Width of meandering	2km ±90cm (Max. 40km/h)	2km ±100cm (Max. 30km/h)
Measurement of position & direction	Position accuracy Directional accuracy	±50cm ±0.5degree	±60cm ±1.0degree
Recognition of obstacle	Worker(fine) Worker(Cloudy,Slightly rainy) Other vehicle	100% 100% 100%	88% 83% Under development

2. OUTLINE OF COMMUNICATION SYSTEM FOR OPERATION MANAGEMENT

2.1. Concept of operation managing system

By the automation of individual dump truck separately, each work for transportation does not exhibit full merit of automation, resulting degradation of efficiency in extreme cases. Therefore, a technology, to build a system which combine each autonomous dump truck effectively, must be pursued.

To realize perfect autonomous dump trucks system, data base for the construction plan and the construction management must be linked together as a unit. This concept is shown in Figure 2.

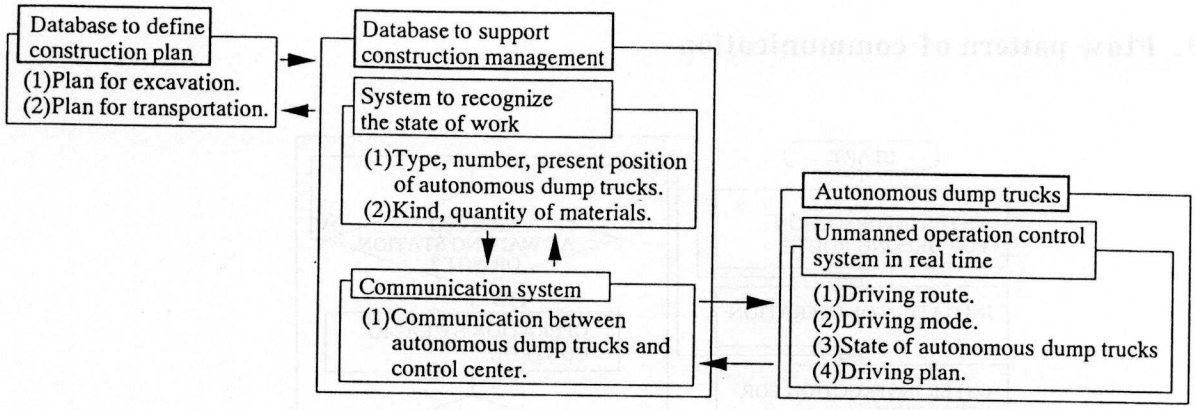

Figure 2. Concept of operation managing system.

2.2. Building of model for construction sites

A model for construction sites as shown in Figure 3 was developed to build the communication system. A representative example of this model is the transportation work of aggregate for the construction of dam. Condition of operation for the model is as follows:

(1)Driving routes of autonomous dump trucks are set up daily.
(2)Five autonomous dump trucks make up a group.
(3)Autonomous dump trucks do not pass each other.
(4)Loading and unloading are executed by radio controlled operation.
(5)We assume that only autonomous dump trucks, liaison car and specified workers are located in construction sites. Safety of operation is secured by the obstacle avoidance facility on the autonomous dump trucks and equipments at construction sites like monitoring cameras, etc.

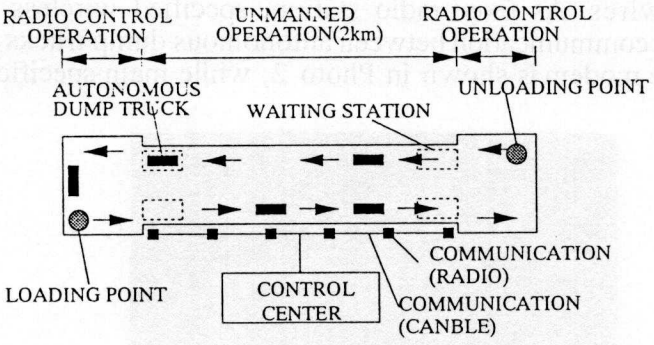

Figure 3. Model for construction sites.

2.3. Flow pattern of communication

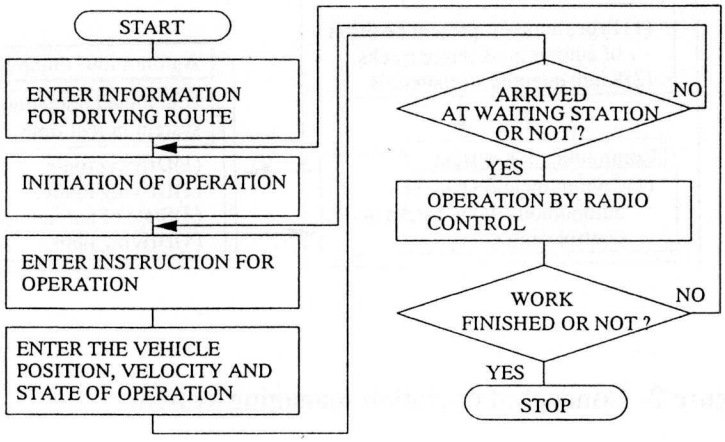

Figure 4. Flow chart for communication.

Outline of flow pattern of communication for a unmanned dump truck is shown in Figure 4. Operation by radio control in this chart can be replaced by teaching-in system in the future. In this teaching-in system, computer memorizes the operation pattern once, and this pattern is used repeatedly afterwards.

3. EQUIPMENT MAKING UP THE COMMUNICATION SYSTEM AND INFORMATION OF COMMUNICATION

3.1. Hardware

As auxiliary equipment for communication, several number of fixed radio stations are connected by RS-232C wires. As fixed radio station, specified wireless modems of small power are adopted for the communication between autonomous dump trucks and control center. External appearance of the modem is shown in Photo 2, while main specification of modem is shown in Table 2.

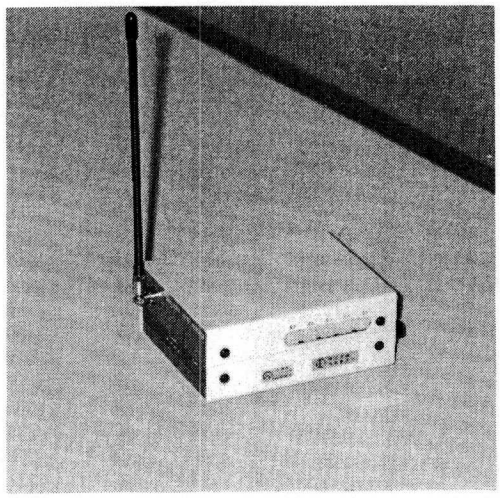

Photo 2. Specified wireless modem with small power.

Table 2
Main specification of specified wireless modem with small power

Type	NDT-10-20
Transmission system of information by wireless	Semi-duplex operation
Speed of transmission	4800bps
Frequency used	400MHz band. Specific wireless station with small power
Power of transmission	10mW+20/-50%
Restriction for transmitting time	No limitation. (Continuous)
Interface with data terminal equipment	Serial : RS-232C Parallel : Centronix
Dimensions and weight	Width×Height×Depth=90mm×50mm×110mm Weight=470g

In this communication system, an autonomous dump truck communicates with alternative fixed station successively. As dump trucks are driven at high speed of 30km/h, area of coverage for fixed station must be overlapped each other as shown in Figure 5.

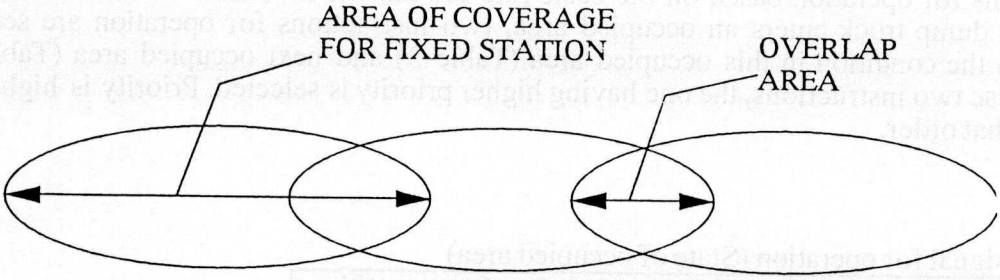

Figure 5. Area of coverage for fixed station.

The control center calls out dump trucks No.1 to No.5 by turns, while dump trucks are always waiting for calls from the center. When called from the center, dump trucks perform prefixed communication.

3.2. Information to be communicated

3.2.1. Information from the control center to the autonomous dump trucks

(1)Driving route information

Change of information for driving route is performed daily. This information is sent to the computer of each autonomous dump trucks before the operation.

(2)Institution for operation

Simple instructions for operation, shown in A to C in the following, are sent out, to prevent the delay in communication.

A:Normal speed driving.
B:Deceleration.
C:Stop.

These instructions for operation are defined by the following basic rule:

Basic rule:Equal to or more than two moving body (unmanned dump truck, liaison car or specified worker) can not exist in the same occupied area.

The occupied area means one segment in the driving route as shown in Figure 6.

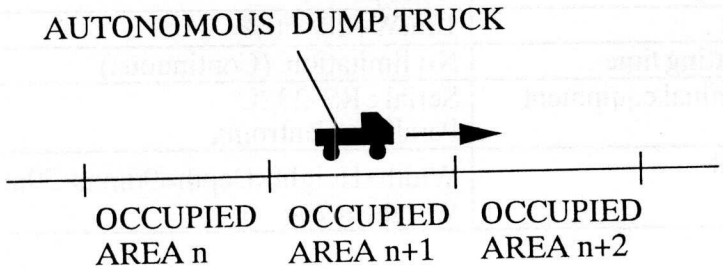

Figure 6. Occupied area.

Instructions for operation based on the basic rule are shown in Tables 3 and 4. When an autonomous dump truck enters an occupied area, two instructions for operation are selected according to the condition in this occupied area (Table 3) and next occupied area (Table 4). Between these two instructions, the one having higher priority is selected. Priority is higher for C, B, A in that order.

Table 3.
Instruction signal for operation (State of occupied area)

State of occupied area	Instruction signal for operation
No moving body exists	A
Preceding vehicle exists	B
On coming car passing	B
Parking car exists	C
Worker exists	C

Table 4.
Instruction signal for operation (State of next occupied area)

State of next occupied area	Instruction signal for operation
No moving body exists	A
Preceding vehicle at normal speed exists	A
Preceding vehicle at decelerating exists	B
On coming car passing	B
Parking car exists	C
Worker exists	C

3.2.2. Information from the autonomous dump trucks to the control center

Monitoring of operating condition is necessary to secure safety of each autonomous dump truck. Information for monitoring is limited to the necessary minimum to prevent delay in communication.

(1)Position of dump trucks

Data on present position of the dump trucks is sent as X-Y coordinate in multiple of meters.

(2)Speed of dump trucks

Data on present speed of the dump trucks is sent in km/h.

(3)Condition of operation

State of operation performed according to the instructions from the control center and judgment of the dump trucks are expressed as follows:

a:Normal speed driving.
b:Deceleration.
c:Stop.
d:Manned operation.
e:Autonomous stop.
f:Emergency stop.

The control center receives these information from autonomous dump trucks and exhibit on the monitoring screen as shown in Figure 7.

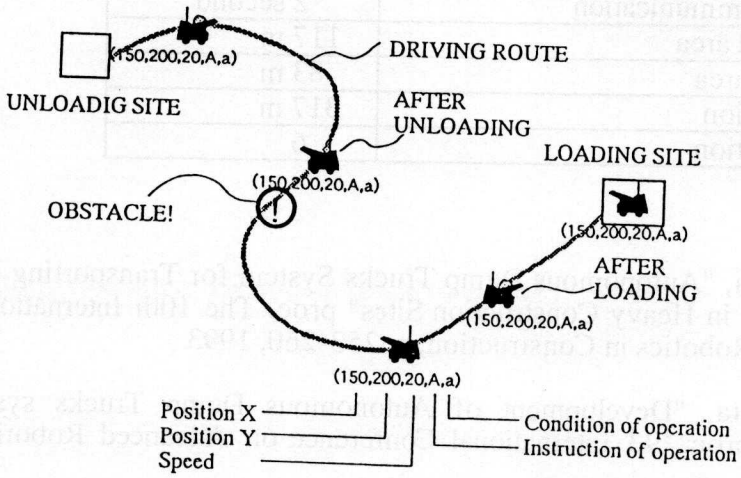

Figure 7. Image of the monitoring screen

CONCLUSION

This paper presents the communication system to control plural autonomous dump trucks in heavy construction sites. In order to realize this communication system, demonstration experiment is executed by using prototype system as shown in Figure 8.This system consists of two fixed radio stations and one moving station. This experiment proved specifications for communication system as shown in Table 5. Evaluation of this specifications will be performed by using extended prototype system.

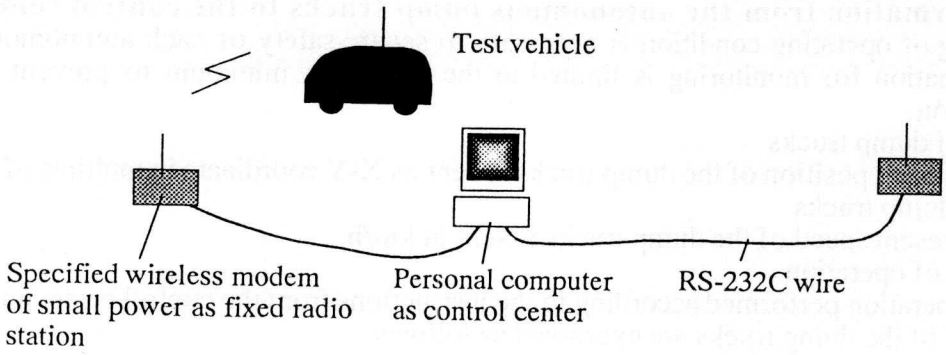

Figure 8. Prototype system.

Table 5.
Specification for communication system

Number of autonomous dump trucks	5
Maximum speed of autonomous dump trucks	30 km/h
Time required for communication	2 second
Distance of occupied area	117 m
Distance of overlap area	83 m
Interval of fixed station	317 m
Number of fixed station	6

REFERENCES

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