UNMANNED SYSTEM FOR HEAVY CONSTRUCTION EQUIPMENT

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ABSTRACT

Major portion of current civil engineering work depends on heavy construction equipment. However, there are many points which must be improved from standpoint of construction efficiency and safety. The task of making improvements was undertaken by introducing automation technique with the object of meeting a decrease in heavy equipment operators and securing safety in construction work. This paper deals with automated control system for a heavy compacting machine used for compaction of fills in highway and fill dam construction. The machine is provided with various types of sensors in order to grasp every condition. The proposed system is composed of self-locating drive control and safety devices. Self-locating device is composed of direction measuring device based on earth magnetism and speed distance meter. The proposed system can be applied to various types of heavy construction equipment in use today and makes unmanned heavy construction equipment realizable.

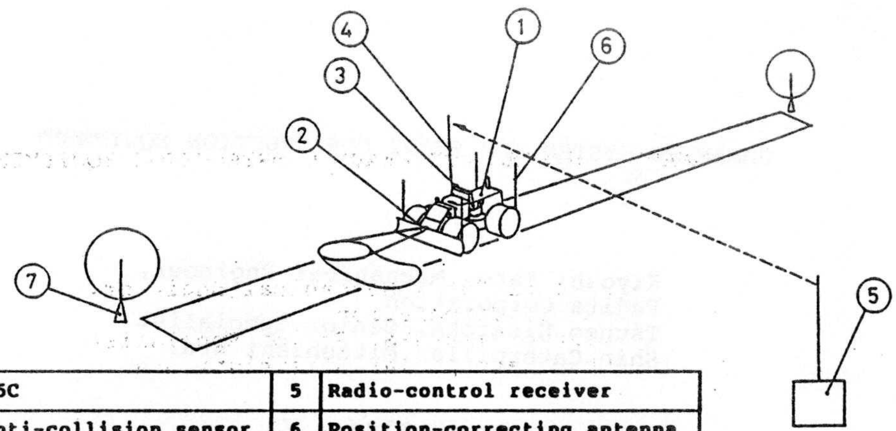
1. General Outline of System

As a part of the development of unmanned systems for construction equipment, this case study describes the unmanned system developed for Mitsubishi Caterpillar Compactor Model 825C.

Utilizing its deadweight, the compactor is used for compacting dam foundations, and expressway embankments. The operation of the compactor is comparatively simple; the equipment plies back and forth for a prescribed number of times over the embankment that has been filled to a certain thickness (15 to 30cm).

The system is composed of a self-position recognition device, vehicle controlling device, and safety devices. A general view of the unmanned system is shown in Fig. 1.

The position recognition of compactor is basically carried out by geomagnetic direction finding, and simple measurements. Furthermore, the vehicle can be manually controlled, radio-controlled, or microcomputer controlled.



1	**Compacter 825C**	5	**Radio-control receiver**
2	**Ultrasonic anti-collision sensor**	6	**Position-correcting antenna**
3	**Microcomputer**	7	**Ground radio wave marker for position correction**
4	**Radio-control receiver**		

Fig. 1 General view of unmanned bulldozer system

The command for the selection of radio-control or microcomputer control mode is given by the transmitter on the ground. Consequently, the control by microcomputer mode is only possible when shift signals are emitted by the transmitter on the ground to the microcomputer. When power to the transmitter fails, or when the vehicle travels beyond the effective range of radio waves, and runs out of control, the system turns the engine off automatically, and actuates the emergency brakes.

As to safety devices, ultrasonic and beam sensors are provided in the system to detect obstacles. Furthermore, in order to prevent the vehicle from running out of the controlled area, infrared barriers are provided as a backup.

2. System Configuration

The configuration of the system is such that most of the functions are integrated in the vehicle. Fig. 2 illustrates the outside view of equipment, and Fig. 3 shows the configuration of the system with emphasis on the microcomputers used for controlling the vehicle.

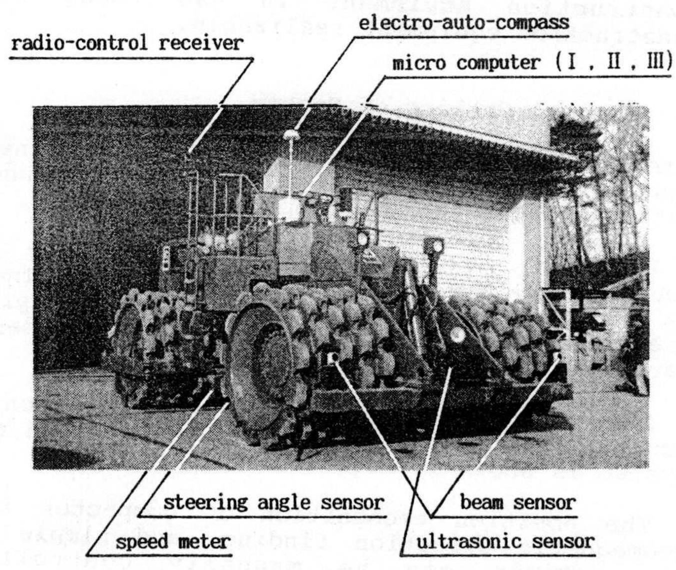


Fig. 2 Outside view of an unmanned bulldozer

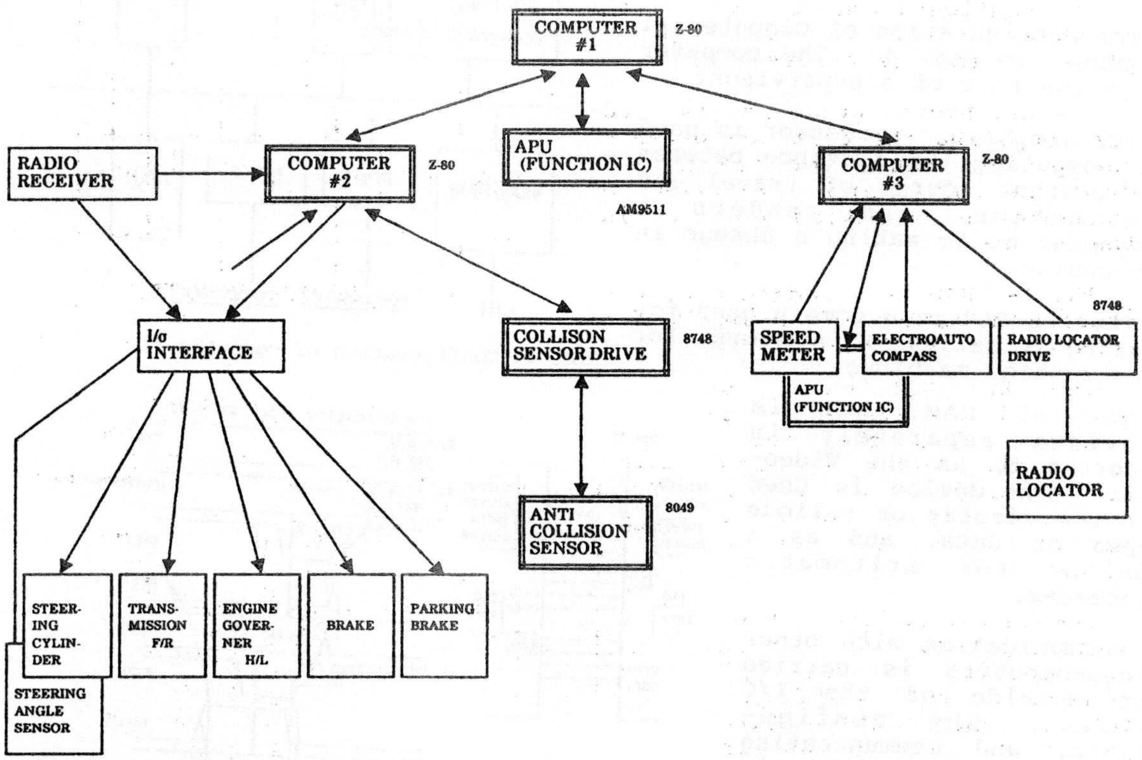


Fig. 3 System configuration

As illustrated in the figures, the system is basically of hierarchical structure. The system on the whole is made up of six general-purpose processors, and two arithmetic processors.

Z-80 is used as the high-order CPU, or Computer #1 that is equipped with arithmetic processor AM9511. The computer plays the overall role of supervising the system. The primary assignment of the computer is to decode the operation instructions beforehand, and provide the macro operation instructions (such as "Swivel 25° to the left, and Proceed" or "Stop Temporarily".

Computers #2 and #3 are directly dependent upon Computer #1. The respective computers are linked to Computer #1 by an 8 bit parallel communication line. Computer #2 is equipped with a Z-80 CPU, and performs the line control of actuators.

The control output of the system is basically used for the ON/OFF control of solenoid valves. In order to maneuver the vehicle precisely by fine control of selenoid valves, Computers #2 decodes the macro instructions given to #1 Computer into fine control instructions.

Computer #3 is a microcomputer assigned with the task of computing the position of the vehicle in accordance with dead reckoning. In other words, Z-80 CPU and AM9511 are the processors used for computing.

2.1 Computer #1

The configuration of Computer #1 is shown in Fig. 4. The computer plays the role of a supervisor.

The arithmetic processor is used for computing the distance between the present course of travel and destination, and renders a judgement as to making a change in the course.

The 18K RAM is a domain used for storing a series of commands for construction machines.

The 8K RAM that is provided separately is referred to as the Video-Ram. The device is used for the display of various types of data, and as a monitor for arithmetic processes.

Communication with other microcomputers is carried out outside of the I/O board. The configuration, and communicating procedures are shown in Fig. 5.

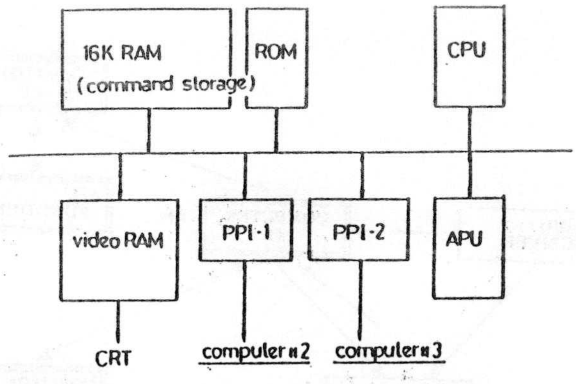


Fig. 4 Configuration of computer #1

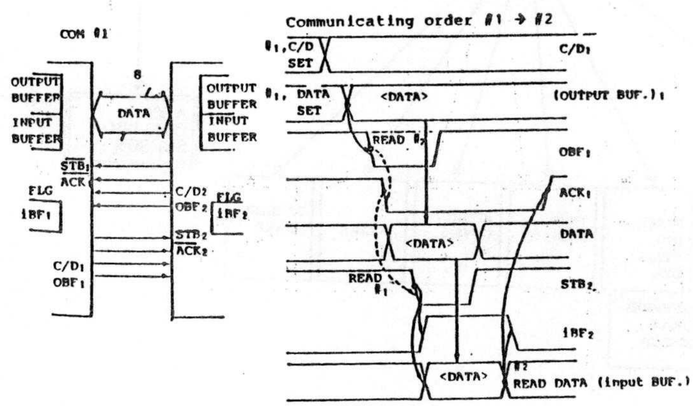


Fig. 5 General outline of parallel communications system (physical bus and communicating order)

2.2 Computer #2

The composition of Computer #2 and related peripheral units is shown in Fig. 6. The radio-control unit for backup is provided with an 16 CH ON/OFF control. CH 0 ~ 14 are used for transmitting operation instructions. CH 0 ~ 7 in particular are directly connected to actuators without going through the computer so that the vehicle can be directly operated under the radio-control mode.

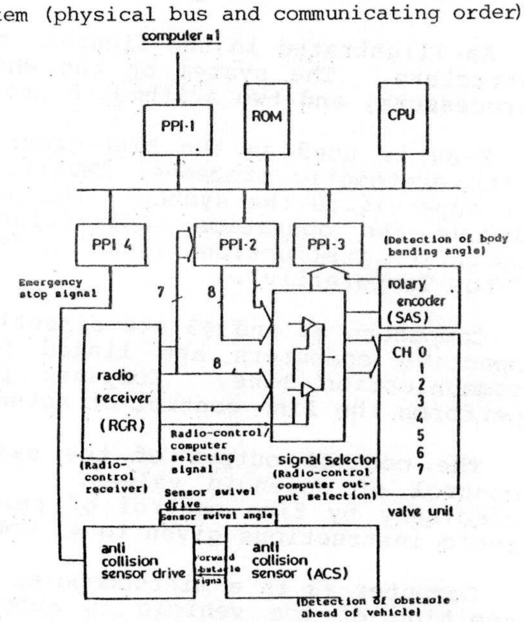
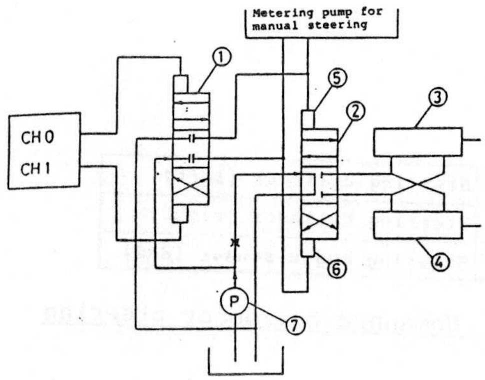


Fig. 6 Configuration of computer #2

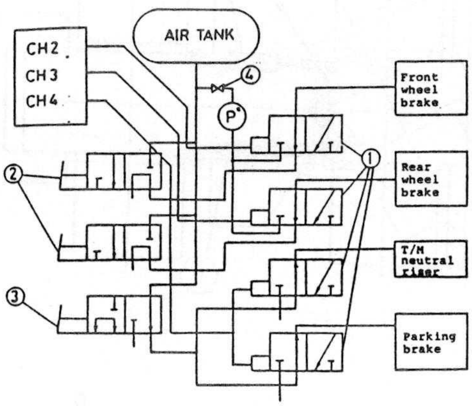
At present, the microcomputers control the operation of two hydraulic and five pneumatic valves. This combination carries out the various actions of compactor 825C (Fig. 7).

(1) Hydraulic steering system



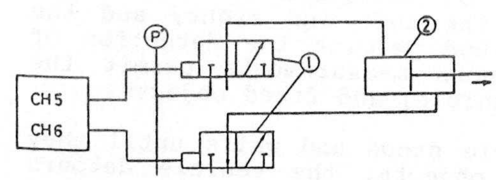
1	Solenoid valve	5	Neutral riser valve (left)
2	Steering control valve	6	Neutral riser valve (right)
3	Steering cylinder (left)	7	Steering pump
4	Steering cylinder (right)		

(3) Brake system



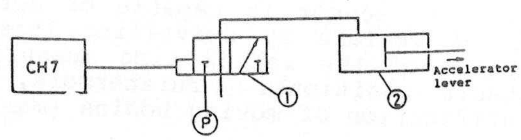
1	Air solenoid valve	3	Parking brake knob
2	Brake pedal	4	Control release valve

(2) Forward/reverse control



1	Air solenoid valve
2	T/M shift cylinder

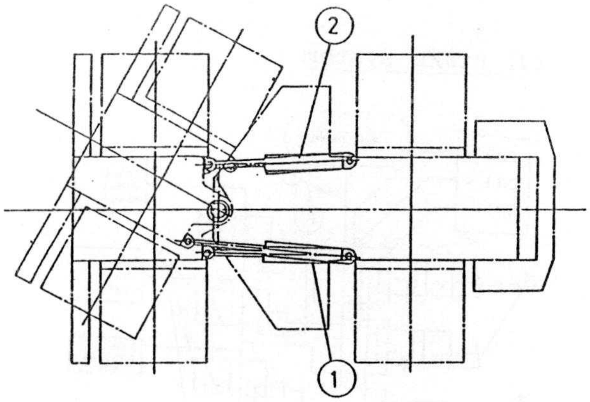
(4) Engine control



1	Air solenoid valve
2	Governor control cylinder

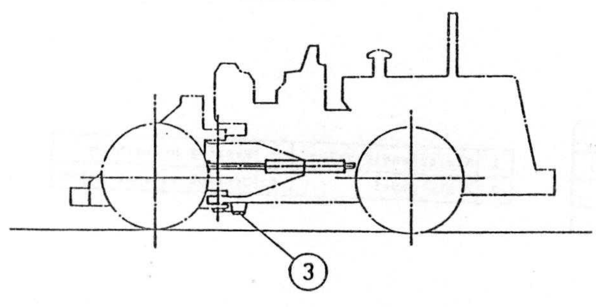
Fig. 7 Unmanned bulldozer actuator program

Steering is carried out by the extension and contraction of left/right steering cylinders. Therefore, in order to steer the bulldozer at a certain angle, it is necessary that the bending angle of body is measured by the rotary encoder for feed-back (Fig. 8).



1	Steering cylinder (left)
2	Steering cylinder (right)
3	Steering angle sensor (SAS)

Fig. 8 Unmanned bulldozer steering



Another role played by Computer #2 is the emergency control when obstacles are detected ahead of the travelling vehicle. Ultrasonic sensor and light sensor are used as unit-collision sensors. The ultrasonic sensor is capable of detecting all obstacles in the forward area of vehicle by swivelling itself to the left and right, and the adoption of the reflex time measuring method permits the detection of obstacle positions. Furthermore, continuous measurements permit the identification of moving bodies (man and vehicle) and fixed objects.

In the case of moving bodies, the vehicle stops and waits until they pass through, and in the case of fixed objects, the vehicle detours around them.

When objects abruptly dash in front of the vehicle, the beam sensor installed on either side detects the objects, and actuates the emergency brakes.

Accordingly, in order to generate the emergency stop signal, a considerable arithmetic processing capability is necessary. For this reason, a one chip micropocessor (C8748) is provided in the system to activate the ultrasonic sensors.

2.3 Computer #3

Computer #3 is a computer used for sequentially calculating the position of vehicle in an absolute space.

The configuration is schematically illustrated in Fig. 9. One pulse is generated by the distance sensor each time the vehicle travels for a distance of about 30cm. The present position of vehicle can be obtained by using the vecor method for cumulating the travelling distance of 30cm based on the directional information provided by the geomagnetic sensors. In other word △ = (△X, △Y), the amount of vehicle movement per pulse interval is calculated by the following equations in accordance with EAC output (x, y) per interval.

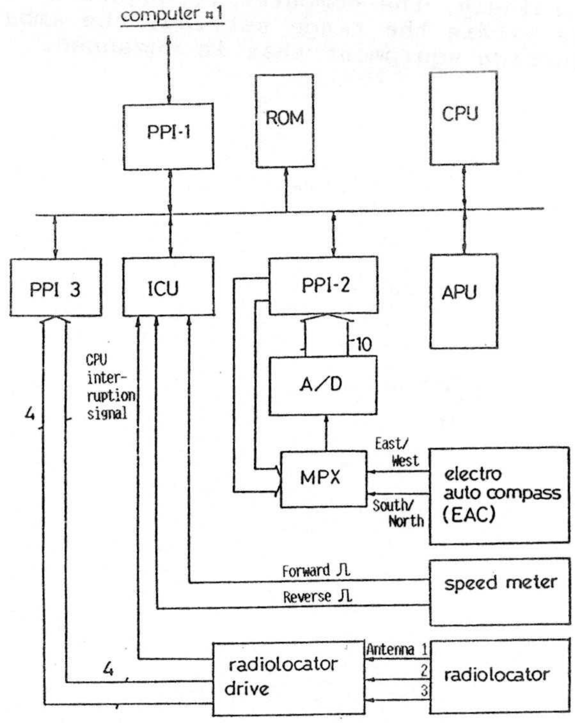


Fig. 9 Configuration of computer #3

$$\triangle X = S \cdot \left(\frac{x-bx}{ax}\right) / \sqrt{\left(\frac{x-bx}{ax}\right)^2 + \left(\frac{y-by}{ay}\right)^2} \quad \cdots\cdots\cdots\cdots \quad (1)$$

$$\triangle Y = S \cdot \left(\frac{y-by}{ay}\right) / \sqrt{\left(\frac{x-bx}{ax}\right)^2 + \left(\frac{y-by}{ay}\right)^2} \quad \cdots\cdots\cdots\cdots \quad (2)$$

Where S is the distance of vehicle travel per pulse interval. The distance of travel (x, y) from the original point is obtained by adding △ as per vector method.

$$X = \Sigma \triangle X \quad \cdots\cdots\cdots \quad (3)$$

$$Y = \Sigma \triangle Y \quad \cdots\cdots\cdots \quad (4)$$

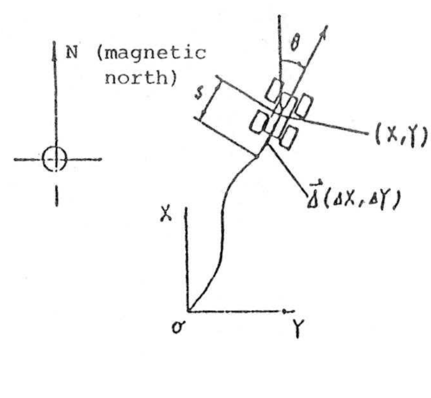


Fig. 10 Path of travel

Accordingly, the computer recongnized the position, and as the vehicle travels within the range setting, the embankment can be compacted by the construction equipment that is unmanned.