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An Engineering Approach to Carriage Automation System at Construction Site(the First Report)

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ABSTRACT

We proposed a concept of carriage automation system with unmanned dump trucks at construction site four years ago. In this concept, the system is divided into three phases. Further, we have studied to realize the first phase by a prototype car. In this paper, we introduce about the concept and the development for unmanned driving system. Then we tested by the prototype car at a dum site where is under construction. We report about the result, too.

1. INTRODUCTION

In recent Japanese construction industry, there are some serious problems -for example, a decline in productivity, worker shortages and an accident on the job. In many construction works, a carriage work of materials is generally the most important. Therefore, we paid attention to a carriage work with dump trucks among some carriage ways.(Photo.1) A merit of using the vehicles is flexibility of route planning.

So we proposed a concept of carriage automation system with unmanned dump trucks. If we can realize this concept, it will be a good solution for some problems. This system is possible to drive a lot of unmanned dump trucks in the 40 ton class. But now, it is still at the stage by a prototype car.(Photo.2) This car is that we rebuilt an ordinary car. We tested by this car at a dum site where is under construction last year.

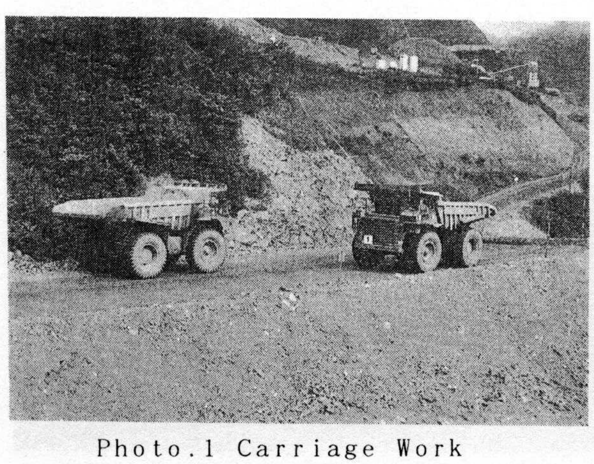

Photo.1 Carriage Work

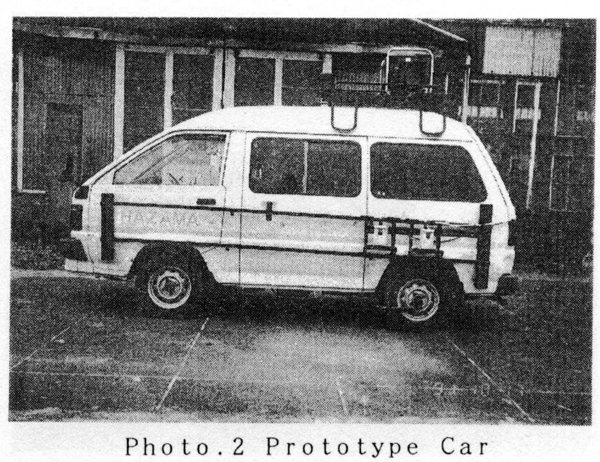

Photo.2 Prototype Car

2. CONCEPT OF CARRIAGE AUTOMATION SYSTEM AT CONSTRUCTION SITE

We proposed a concept, as shown in Table.1. And we have developed the carriage automation system with unmanned dump trucks by a practical approach, because it is very difficult to change completely the construction way that was already established.

Each phase has some characteristic routes, such as a fixed route, a changeable route and plural changeable routes. And they are able to apply to three kinds of actual carriage works, aggregate carriage, concrete carriage and rock carriage, in a dam with roller-compacted concrete (RCD).

In the zone of gathering and laying, a dump truck has to work in cooperation with other heavy construction machines -for example, a wheel loader, a power shovel. (Photo.3,4)

Table.1 the Concept of Carriage Automation System with Unmanned Dump Trucks

phase	number of staff	characteristic route	model
1	gathering : 1 transporting: 0 laying : 1	a fixed point A FIXED ROUTE a fixed point	carriage of aggregate
2	gathering : 1 transporting: 0 laying : 0	a fixed point a fixed route A CHANGEABLE ROUTE	carriage of concrete
3	gathering : 0 transporting: 0 laying : 0	PLURAL CHANGEABLE ROUTES a fixed route a fixed point	carriage of rock

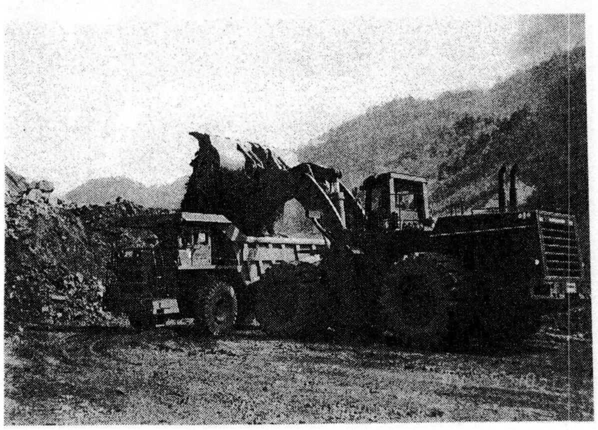

Photo.3 State of Gathering

Photo.4 State of Laying

2.1 Unmanned Driving System for a Fixed Route(Phase-1)

This system is divided into two zones and one route, as shown in Fig.1. The dump truck is operated by a driver or a remote control apparatus in the zone of gathering and laying. If this system is realized, many dump trucks will be drived by only two operators. In the fixed route, unmanned dump trucks run about 2 km by a laser navigation system. The fixed route means a road where doesn't change about once a month or more. In RCD, this system is able to apply to an aggregate carriage.

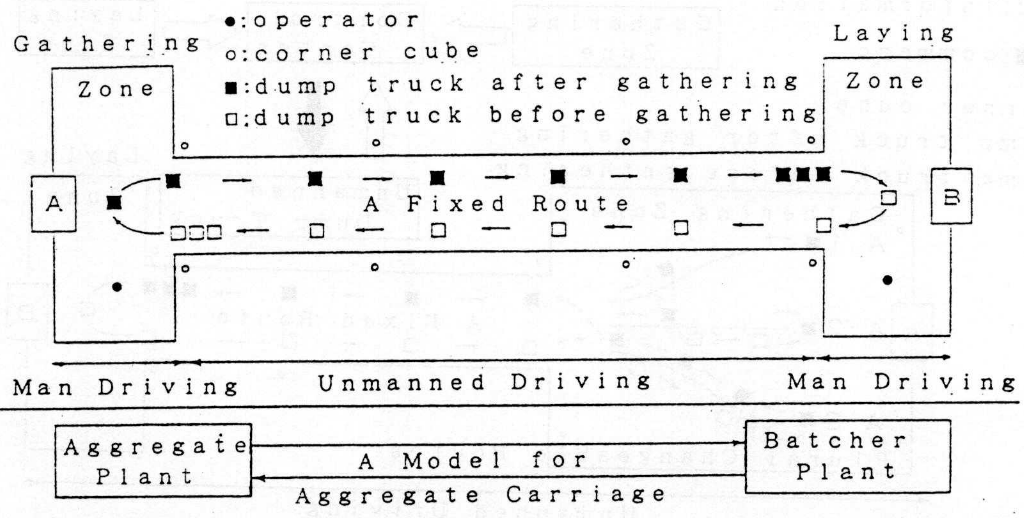

Fig.1 Unmanned Driving System for a Fixed Route

2.2 Unmanned Driving System for a Changeable Route(Phase-2)

This system is divided into two zones and one route, as shown in Fig.2. The system of gathering zone and a fixed route is similar to Phase-1. There is the changeable route in laying zone. The changeable route means that where changes about once a day. In this route, dump trucks is operated by unmanned driving. The measurement of a position and heading for vehicles is done by the application of Phase-1. If this system is realized, many dump trucks will be drived by only one operator. In RCD, this is a model for concrete carriage.

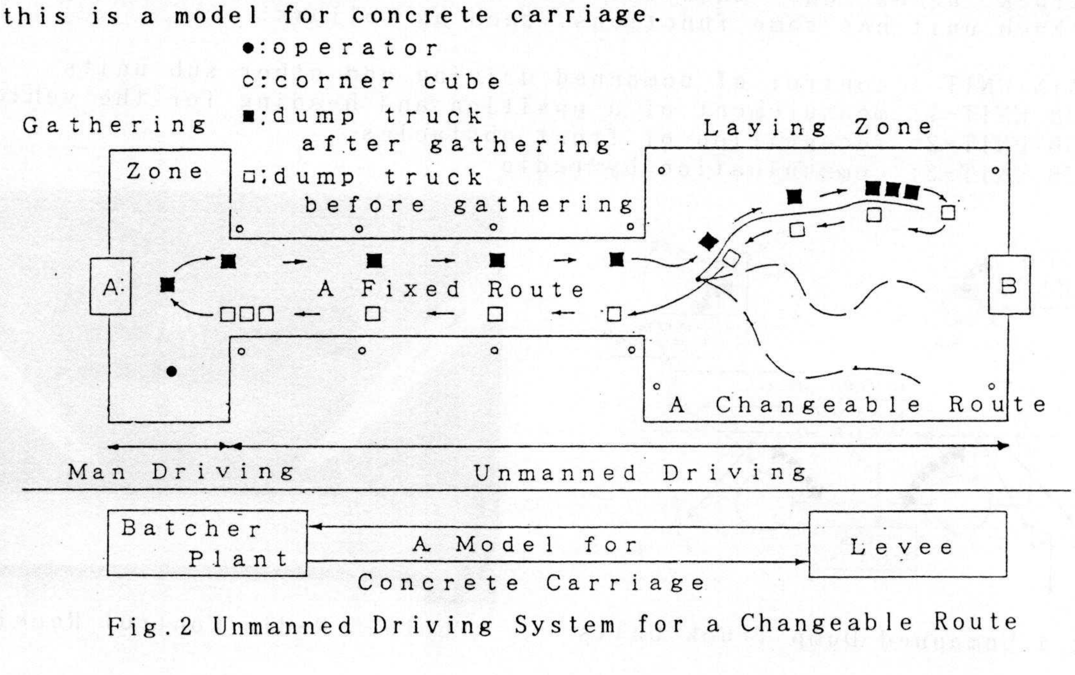

Fig.2 Unmanned Driving System for a Changeable Route

2.3 Unmanned Driving System for Plural Changeable Routes(Phase-3)

This system is divided into two zones and one route, as shown in Fig.3. The system of a fixed route is similar to Phase-1. In laying zone, dump trucks are drived without a driver or a remote control apparatus. There are many changeable routes in gathering zone. At each gathering point, the number of dump trucks and the order of work is flexible. In RCD, this is a model for rock carriage.

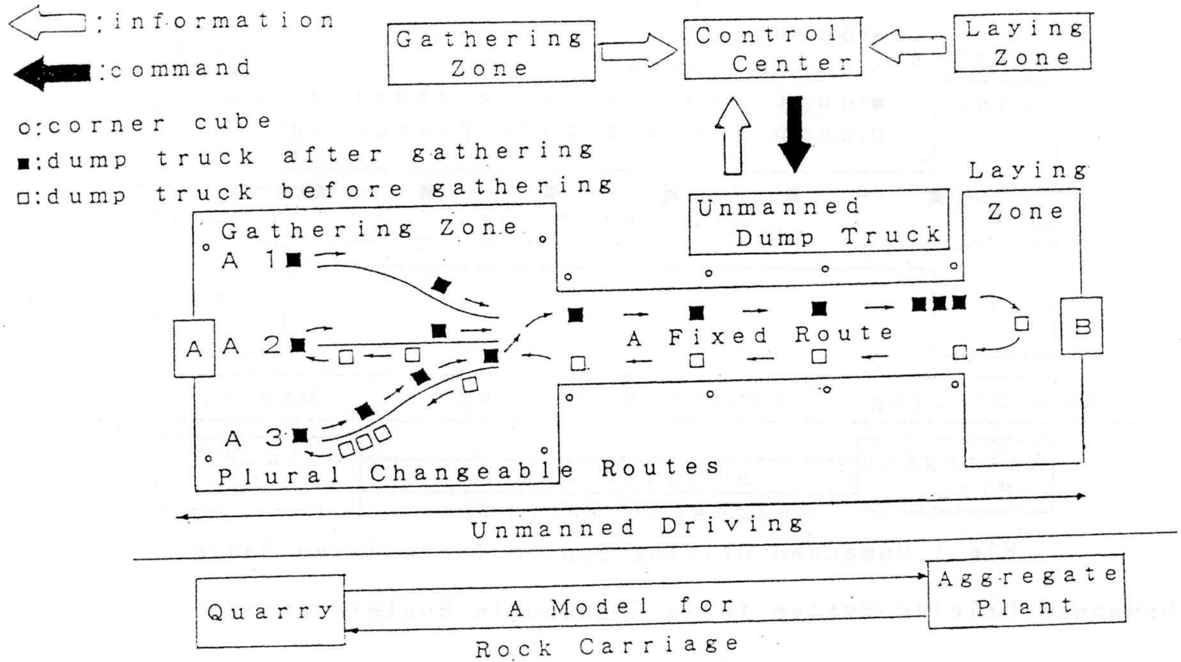

Fig.3 Unmanned Driving System for Plural Changeable Routes

3. DEVELOPMENT FOR UNMANNED DRIVING SYSTEM

Now, we are studying about Phase-1 of three phases. The unmanned dump truck needs one main unit and three subsidiary units as shown in Fig.4. Each unit has some functions, such as follows.

1. MAIN UNIT : control of unmanned driving and other sub units
2. SUB UNIT-1: measurement of a position and heading for the vehicle
3. SUB UNIT-2: recognition of front obstacles
4. SUB UNIT-3: communication by radio

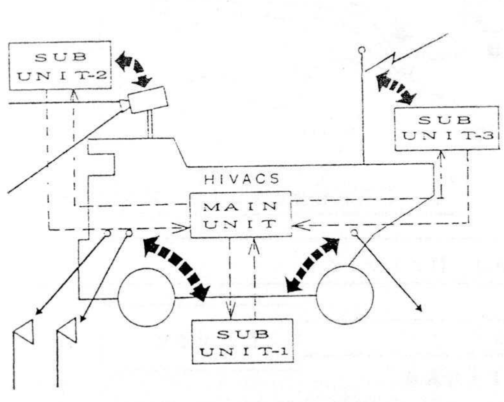

Fig.4 Unmanned Dump Truck Units

Photo.5 Radio Control Receiver

Now we are mainly studying about MAIN UNIT, SUB UNIT-1 and SUB UNIT-2 among them. But a communication system by radio is necessary to drive a lot of unmanned vehicles, too. Therefore, we have tried to operate a vehicle by a simple remote control apparatus first.(Photo.5) In next report, we will propose about a communication system by radio for many unmanned dump trucks.

3.1 Unmanned Driving (MAIN UNIT)

The vehicle runs along a route map that was inputted before driving. MAIN UNIT consists of four actuaters and one MAIN CPU. Photo.6 shows those actuaters and Fig.5 shows the composition of an automatic actuater system. There are two actuaters for braking and accelerating on the passenger's seat. And there is one actuater for shifting between the driver's seat and the passenger's seat. The actuater for steering gear is a stepping motor that was installed at the root of a steering wheel shaft.

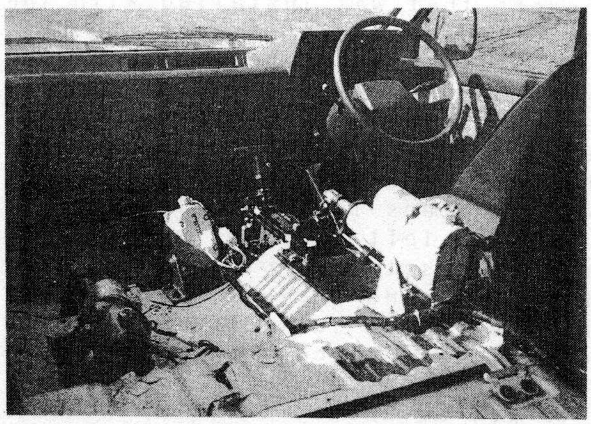

Photo.6 Actuaters to Control

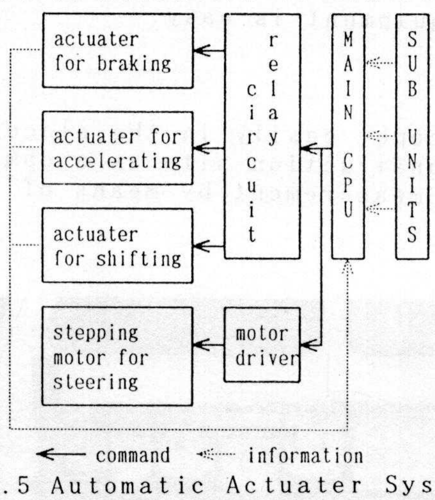

Fig.5 Automatic Actuater System

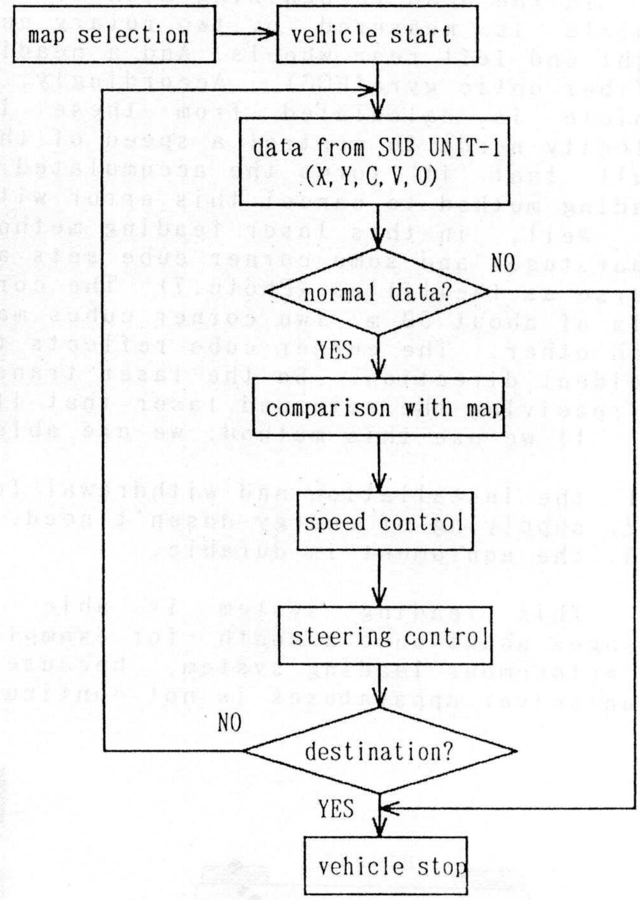

Fig.6 Unmanned Driving Control

Fig.6 is a process of the control for unmanned driving. If you use this vehicle by unmanned driving mode, first you must select a suitable route map among some maps that was inputted before driving. The map has position data, speed data and area decision data. Next you sends a start signal by a radio control apparatus. After that, this vehicle continues to drive by repetition of a process, such as follows.

1. Getting some real time data from SUB UNIT-1 -for example, position data(X, Y), Heading data(C), Velocity data(V) and Angular velocity data(O).

2. Comparing the real time data with a route map.
3. Calculating the best angle of steering wheel and the velocity of the Vehicle.
4. Controlling a speed of the vehicle by two actuaters for braking and accelerating.
5. Controlling a steering gear by the stepping motor.

Then this vehicle stops when it gets to a destination or finds wrong data. If it receives a stop signal by a radio control apparatus or recognizes front obstacles,this vehicle stops momentarily.

3.2 Measurement of the Position and Heading for a Vehicle (SUB UNIT-1)

We are adopting the leading system, as shown in Fig.7. This is a measurement system of the position and heading for a vehicle that combined a laser leading method with a dead recognizing method.

In the dead recognizing method, a distance and a velocity of the vehicle is measured by two rotary encoders that was installed with the right and left rear wheels. And a heading of the vehicle is measured by a fiber optic gyro(FOG). Accordingly, a position and heading of the vehicle is calculated from these informations. The information of a velocity needs to control a speed of the vehicle. But this method has a fault that it forms the accumulated error. Then we are using a laser leading method to cancel this error with a dead recognizing method.

Well, in this laser leading method, it needs two laser transceiver apparatuses and some corner cube sets along the left or right side of the course as facilities.(Photo.7) The corner cube sets are placed at intervals of about 5Ø m. Two corner cubes make a pair and they are placed near each other. The corner cube reflects the laser beam just contrary to the incident direction. So the laser transceiver can detect the corner cubes by receiving the returned laser that it transmitted.

If we use this method, we are able to get advances, such as follows.

1. the installation and withdrawal for equipment is easy.
2. supplying of energy dosen't need.
3. the equipment is durable.

This leading system is able to cope easily in the place where changes about once a month -for example, construction site as a dam. This is autonomous leading system, because the measurement by means of laser transceiver apparatuses is not continuous.

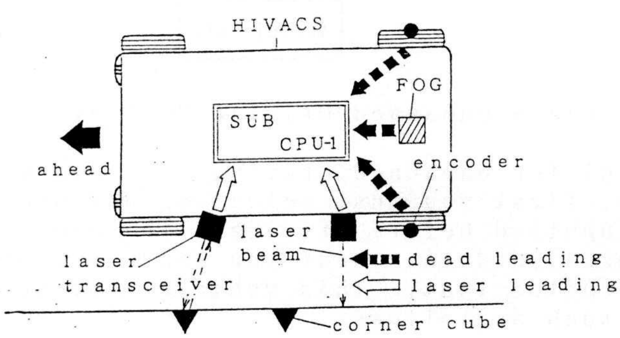

Fig.7 Leading System

Photo.7 Laser Transceiver

3.3 Recognition of Front Obstacles (SUB UNIT-2)

The recognition technique of front obstacles is necessary for unmanned driving. Because it is basic to take safety measures -for example, an autonomous avoidance and a stop for an emergency. First, we have tried to recognize a yellow helmet that the worker puts on from many obstacles on the carriage road at the construction site. The vehicle can get a front view by a CCD camera that was installed over the passenger's seat, as shown in Photo.8. The image from the CCD camera is processed by a personal computer with a transputer(INMOS Ltd.).(Photo.9, Fig.8)

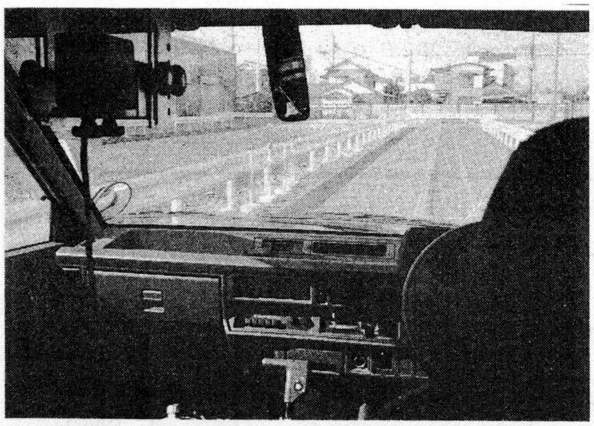

Photo.8 CCD Camera

Photo.9 Front View from Driver's Seat

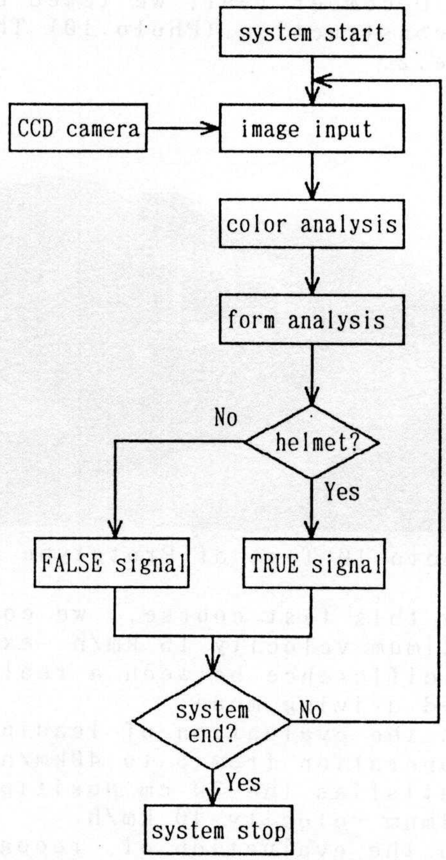

Fig.9 Helmet Recognition Process

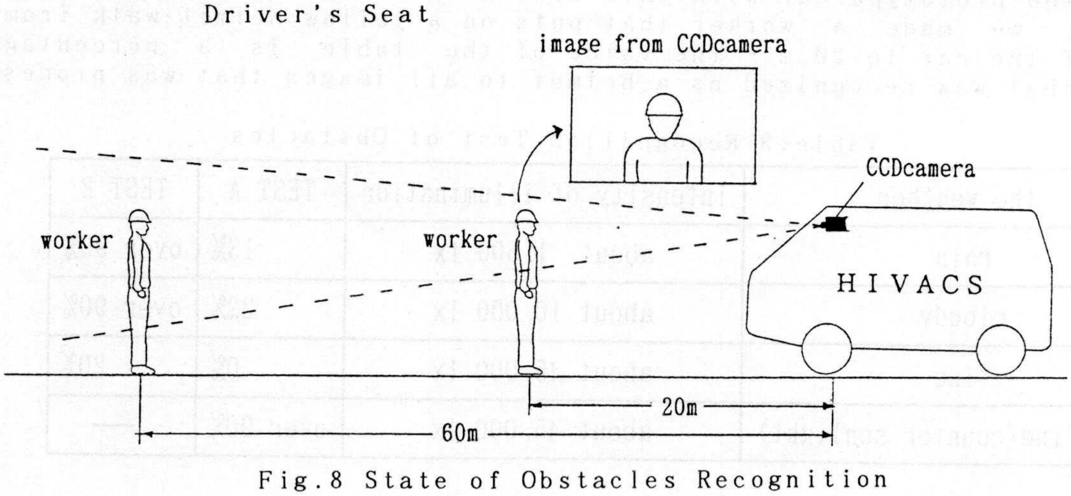

Fig.8 State of Obstacles Recognition

The process for recognizing of a helmet is shown in Fig.9. SUB UNIT-2 has SUB CPU-2 for image processing. First, An image is inputted from a CCD Camera to SUB CPU-2. Next, yellow of a helmet is selected from many color picture signals in the image by chromaticity. But if others is same yellow, SUB CPU-2 will recognize as a helmet. Then SUB CPU-2 searches a true helmet by form analysis. Because the feature of a helmet is the roundish form. Afterward if SUB CPU-2 recognizes as a helmet, it sends a TRUE signal to MAIN UNIT. If SUB CPU-2 doesn't recognize as a helmet, it sends a FALSE signal to MAIN UNIT.

4. TEST OF PROTOTYPE CAR

In December 1991, we tesed by a prototype car at a dum site where is under construction.(Photo.10) The test course is a paved road, as shown in Table.2.

Photo.10 Test of Prototype Car

Table.2 State of Test Course

total distance	500m
road width	7m
minimum radius	39m
maximum grade	1.0%

In this test course, we confirmed that this prototype car can drive at maximum velocity 15 km/h except a sharp curve and within about 90 cm in the difference between a real running route and a planned route by the unmanned driving mode.

In the evaluation of leading system, we drived the prototype car by man's operation from 5 to 40km/h. And we confirmed that this leading system satisfies the 70 cm position accuracy and 1.6 deg. heading accuracy at maximum velocity 40 km/h.

In the evaluation of recognition system of front obstacles, we tested two types, test A and test B, as shown in Table.3. In test A, we drived the prototype car with this system on road without workers. In test B, we made a worker that puts on a yellow helmet walk from 60 m ahead of the car to 20 m. The value of the table is a percentage of images that was recognized as a helmet to all images that was processed.

Table.3 Recognition Test of Obstacles

the weather	intensity of illumination	TEST A	TEST B
rain	about 1,500 lx	13%	over 90%
cloudy	about 10,000 lx	22%	over 90%
fine	about 45,000 lx	0%	20%
fine(counter sunlight)	about 45,000 lx	over 90%	—

This system is effective when it is a fine rain and cloudy, but it must improve to reduce the wrong recognition. When it is fine, the probability of a success is low in the recognition of a helmet. Then, we are going to use another system for only fine day together. Because we developed the system one year ago. In the counter sunlight, it is very difficult to recognize a helmet by this system. In the near future, we will develop a new system for the counter sunlight.

5. CONCLUSION

From these tests, we are convinced that it is possible to realize unmanned driving system for a fixed route. But this prototype car is imperfect as the system to realize. Then we set some goals, such as follows.

1. driving at maximum velocity 40 km/h by unmanned mode.
2. driving within a difference of 70 cm from a planned route.
3. making the leading system of the 50 cm position accuracy and 0.5 deg. heading accuracy at maximum velocity 40 km/h.
4. improving the ability for the recognition of obstacles.

we have to make over the steering gear and examine again about the basic algorithm of each unit to achieve these goals. We think it is effective to improve each unit that many data was gotten by this test. And we are going to realize this unmanned driving system for a fixed route by some dump trucks of 40 ton class as early as possible.

Last, we would like to express our heartfelt thanks to assistant professor Yuta who gave us many good advice.

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