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# AUTONOMOUS LAND VEHICLE USING MILLIMETER WAVE SENSING SYSTEMS

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## ABSTRACT

In order to achieve higher productivity in outdoor works such as construction, mining, agriculture, forestry, etc.,, it will be necessary to develop highly-advanced machines.

We have just established a new organization for research and development activity of sensing and control systems for autonomous land vehicles for outdoor work using millimeter wave sensing system.

Compared with the current optical sensing systems, millimeter wave has greater ability of atmospheric propagation to those conditions such as dust, rain, snow, and mist.

Although it is expected that it takes five (5) years and two billion one hundred million Japanese yen investment to complete our project, we would like to clarify major technological problems of our project together with its summary.

Furthermore, the project is to be funded by Japan Key Technology Center founded by Japanese Government.

This paper briefly reports the background of the project.

## 1. BACKGROUND

It is becoming more and more popular to use mobile robots in factories and warehouses.

On the other hand, robot development for outdoor works such as building construction and civil engineering works has just started.

In spite of various development of robots in the area of

building construction and civil engineering works, it is a little bit difficult for us to declare that they are technologically matured.

Especially, in the area of civil engineering works, most of construction robots have not succeeded to contribute to the achievement of higher productivity except for several cases, which are mainly robots employed for relatively simple and repetitive works such as shield or tunnelling work.

In the civil engineering works, the automation of construction machines has been hindered by the following reasons;

1) there are so many various type of materials to be treated,
2) working process is complicated,
3) many different combination of machines are employed,
4) due to the location of changes for mobilization of machines,
5) long distance and higher speed mobile robots are required for efficient outdoor works,

and so on.

Fig.-1. shows the conceptual schema for future civil engineering works.

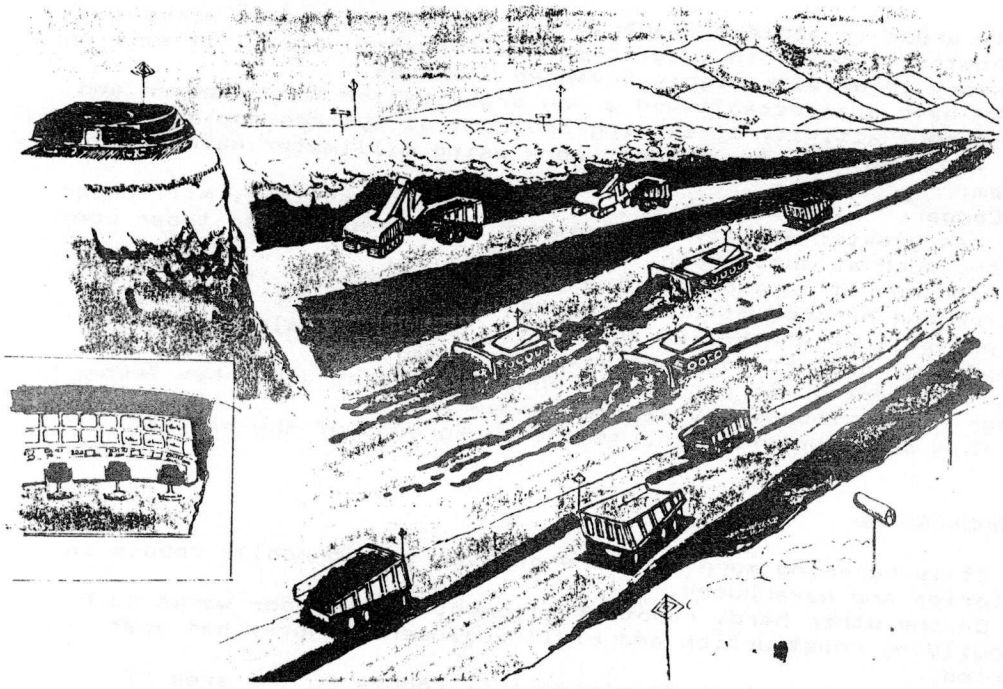

Fig-1.

## 2. INTRODUCTION

In order to develop the highly-advanced machines under these difficult situation in addition to the existing technology, it is necessary that development of machines and systems which are based on different concepts from existing machines be developed.

For the past several years, we have joined research activities for the construction industry in the future and discussed the potential of how highly-advanced civil engineering works will become.

Development of mobile robot for outdoor work will be one of the most important study for future construction industry. We have extracted the key technology for the development of a mobile robot in the civil engineering works and suggested about how these key technologies can be applied for the development of a highly-advanced construction robot.

We believe that millimeter wave sensing system can be one of the key technology for mobile robots used for outdoor works. Because, millimeter wave has many advantages over other sensing mediums such as optical, ultrasonic, and etc.,.

Table-1. shows the merits for the sensing mediums.

Table-1 Comparative Data Among Different Obstacle Recognition Systems

| | ITEM | Millimeter Wave 49.5 GHz | Micro Wave 24 GHz | Micro Wave 17.45 GHz | Laser | Ultrasonic Wave |
|---|---|---|---|---|---|---|
| Specification | Directivity | Horizontal 2° Vertical 2° | 4° - | 5° 10° | Beam width | approx. 10° |
| | Measurement Precision | - | - | - | +- 2 m | 2 % FS |
| | Searching Range | 30 - 60 m | 5 - 100 m | 6 - 30 m | 100 m | Unsensitive distance 1.5 m 2 - 30 m |
| | Radiator | FM-CW, V-type cylinder Parabolic Antenna | Pulse Doppler 300 mm Parabolic Antenna | FM-CW Printed Antenna | | |
| Influential Factors | Objects | | | | - | Yes |
| | Surface Color of Objects | — | — | — | Yes | No |
| | Weather | There are effects according to the wave length. | | | Mist, Snow & etc., | Yes |
| | Dust | — | — | — | Yes | - |

## 3. MOBILE ROBOT AND CONTROL SYSTEMS

For research of mobile robots for outdoor works, we determined its specification based on the actual performance of conventional transport vehicles which have been employed in the construction job site.

Table-2. shows its summary.

| | ITEM | Description | Specification Required |
|---|---|---|---|
| 1 | Speed | - | 30 km/h |
| 2 | Location Recognition | Precision | +- 10 cm |
| | | Range | Radius of 2 - 4 km |
| 3 | Obstacle Detection | Recognizable Distance | 80 m |
| 4 | Mobile Actuator Control | Range of Error | +- 50 cm |
| 5 | Fleet Control | Total number of mobile robots | 100 units |
| 6 | Communication | Transmitting Distance for data | 2 - 4 km |

Table-2

Fig.-2. shows the typical constitution of mobile robots and its support system for outdoor works.

The system consists of four sub systems.

1. Location Recognition System
2. Mobile Actuator Control System
3. Obstacle Detection System
4. Telecommunication and Fleet Control System

We are planning to use millimeter wave to support location recognition, obstacle sensing and data transmission between mobile robots or robot to control center.

ITEMS OF SUB THEME

(1) Research and development of transmitter for millimeter wave

(2) Research and development of sensing technology for millimeter wave

A) Location recognition technology

B) Obstacle detection technology

C) Sensing and control technology

(3) Research and development of telecommunication and fleet control system

A) Fleet control system

B) Telecommunication system

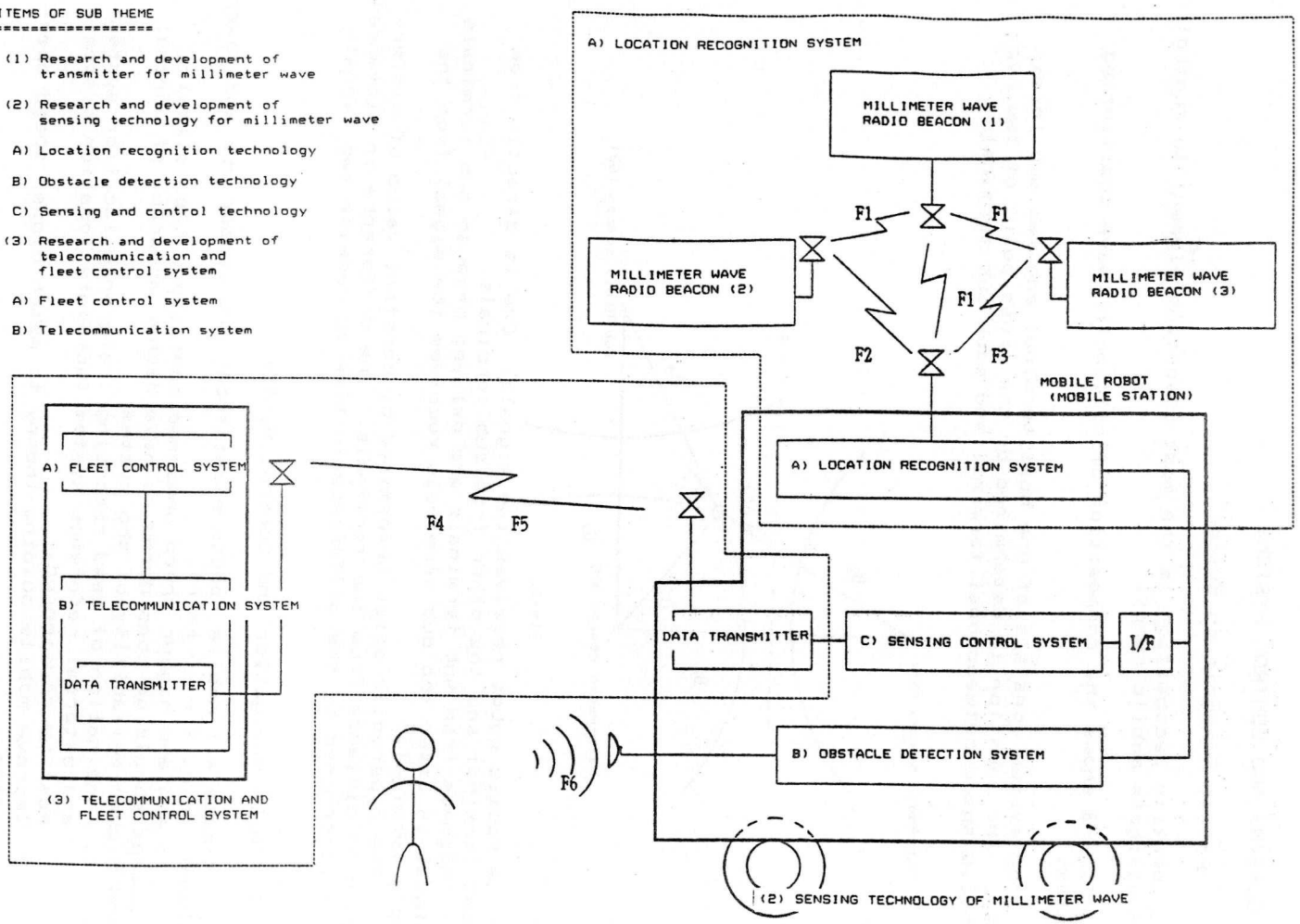


Fig-2. Mobile Robot and Support System

## 4. SENSING AND CONTROL SYSTEMS

### 4.1 Location Recognition System

Location recognition is the most important element to control and navigate mobile robot.

Fig.-3 shows the composition of millimeter wave positioning system.

The system consists of one host terminal and two sub terminals. The location is determined by the cross point of two hyperbolic space between host terminal and each sub terminals.

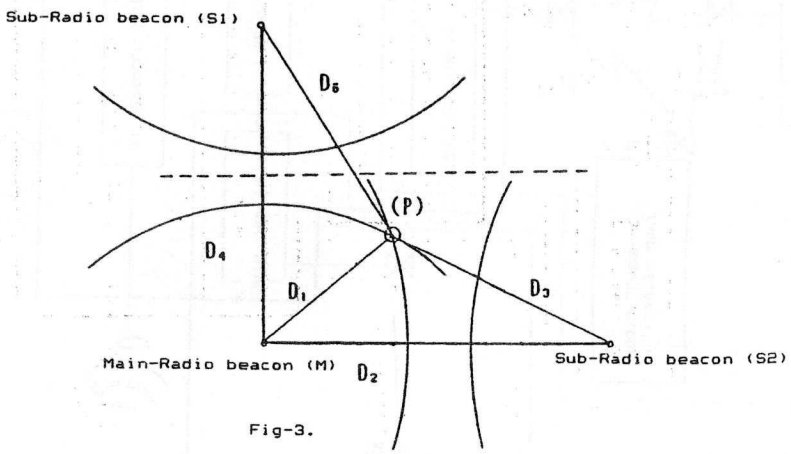


Fig-3.

A mobile robot receives two signals. One is directly from host terminal and the other from sub terminals.

Signals from sub terminals are delayed because sub terminals signal is after the sub terminals receives the signal from the host terminal.

The hyperbolic space determined by constant value of difference in distance from two terminals. The difference in distances are determined by the difference in time to receive two signals.

### 4.2 Mobile Navigation and Control System

Almost all mobile robots exist today are indoor use and lower speed (e.g. 1 - 10 km/h).

To achieve higher speed unmanned operation, the following concept should be considered to have higher accuracy of control and higher reliability of the system.

1. Combination of dead recording (reference location system) and external reference system (absolute location system) must be considered.
2. Improve mobile guiding theory to match higher speed operation.

3. Higher speed and parallel signal processing, and newer conceptual operating system should be examined.

Fig-4. shows the total system of navigation and control for mobile robots.

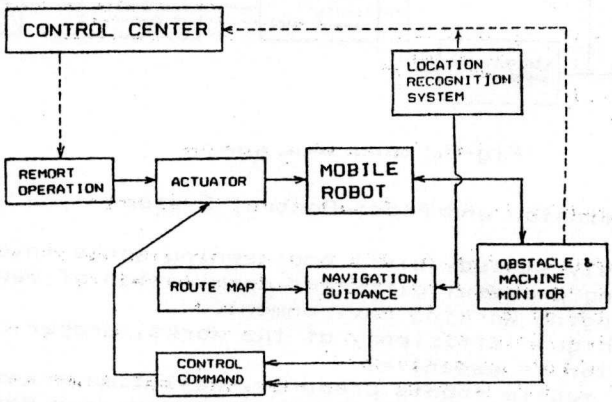


Fig-4. Navigation and Control System

## 4.3 Obstacle Detection and Avoidance System

To utilize the obstacle sensing for higher speed mobile robots, electromagnetic wave system or optical sensing system is essential.

Compared with current ultrasonic system or optical sensing system, electromagnetic wave (millimeter wave ) system has the following advantages.

1. 80 meter as the range of surveillance for obstacles is anticipated. (Existing system can provide only maximum 10 meter.)
2. Superiority in terms of sensitivity to changing natural environmental such as rain, wind, mist, and etc.,.
3. Precision for measurement of obstacles at far distance is superior to existing systems.

In spite of the above advantages, several technical problems listed below remain unsolved.

1. In some occasion, the obstacles with rader cross section for reflection cannot be recognized as the objective.
2. The development of technique for removal of dispersed signal such as multi path error will be required.
3. Highly-advanced technique of signal processing for the removal of objects located in the job site except for scheduled travelling passage, individual recognition of objects.

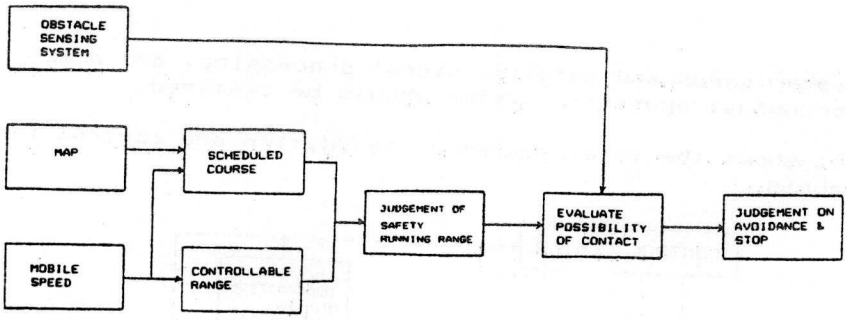


Fig-5. Obstacle Sensing System

## 4.4 Data Transmission and Fleet Control System

As previously stated, civil engineering works involve complicated working process, different combination of machines and a constantly changing working environment.

To attain higher efficiency of the works, proper control of machine operation is essential.

To control mobile robots properly, real time transfer of data from numerous robots to the controlling center and decision making for optimization of machine control have to be realized.

In order to solve these subjects, it is required to develop the algorithm based on the research that dynamic performance simulation of machines, queuing theory, linear programming, network theory, traffic control and etc., are applied for.

Fig-6. shows the development schedule for data transmission and fleet control system.

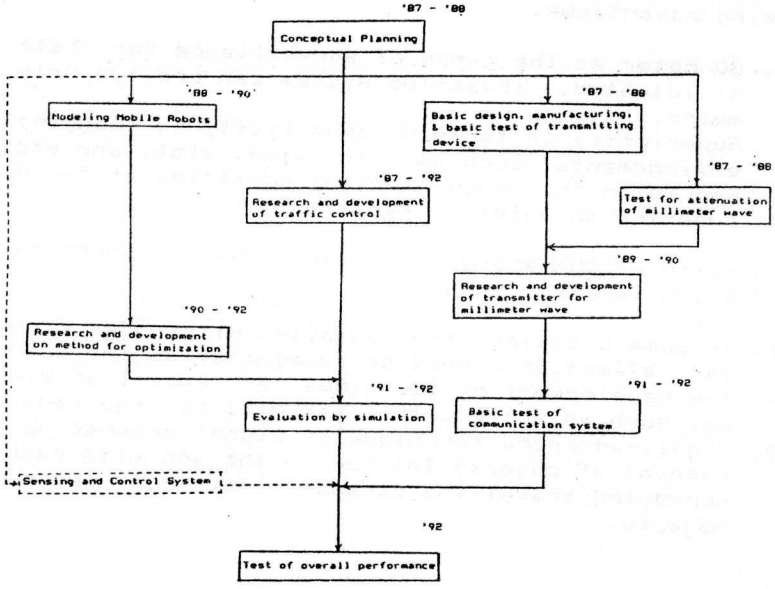


Fig-6. Procedure for research and development of communication system

## 5. CONCLUSION

Our research and development activities of sensing and communication systems using millimeter wave are one of the possible approach to develop the advanced system for construction technologies. However, we believe the results or processes of our research and development activities will be good assistance for the realization of future construction robots.