Communication System of Realtime Two-dimensional Position Data with Scanning Laser Beam

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ABSTRACT

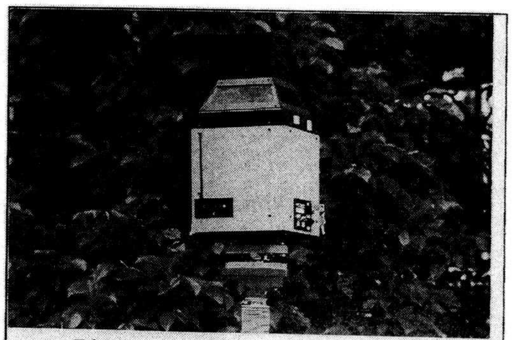
Most construction work, indoors and outdoors, involves movements. In the development of robots to be used at the construction site, one of their intended functions is movement control, positioning in particular. In the field of industrial robots as well, recent developments incorporate movement functions represented by AGV (Automatically guided vehicle), in addition to such fundamental functions as arms and manipulators. However, these movement functions usually employ optical or electromagnetic navigation and the area of movement is extremely limited. Whereas in the case of robots performing construction jobs, the required area of movement is expanded two- or even three-dimensionally to fifty meters or so. It is therefore considerably difficult to control the movement of such robots that travel along the predetermined traveling route. The use of positioning systems utilizing GPS was proposed in many case histories of robot development, some of which report their practical use. However, fluctuations in the systems' positioning accuracy are still heavy, making their application to fast-travelling robots difficult. Moreover, the systems' mechanical instability may cause run-away of robots. Another problem is that such systems are usually bulky and expensive, restricting their application and widespread use. A few other problems still remain unsolved.

In view of the situation, the authors developed a surveying system that allows real-time positioning of a moving target with high accuracy by scanning laser beams at a high velocity from two known coordinate points. Positioning data is transmitted and displayed to the target. This paper presents an overview of the "Real-time two-dimensional positioning data transmission system" developed by the authors along with case histories of its application.

1. Overview of the system

(1)Positioning system

As is shown in Figure 1, the coordinates of any unknown point (planar position) can be determined, using the triangulation theory, by taking the angle formed between two known coordinate points. In this system, two sets of optical units set up at known coordinate points scan high-velocity laser beams at 360° toward the target . The coordinates of the target, or an unknown point, can be determined instantaneously by computing the scanning angles of returning beams (α and β). As surveying is instantaneous, the target is not lost, and positioning is not discontinued by transitory laser-beam interceptions.The system specifications are given below.



Photograph 1 Optical unit

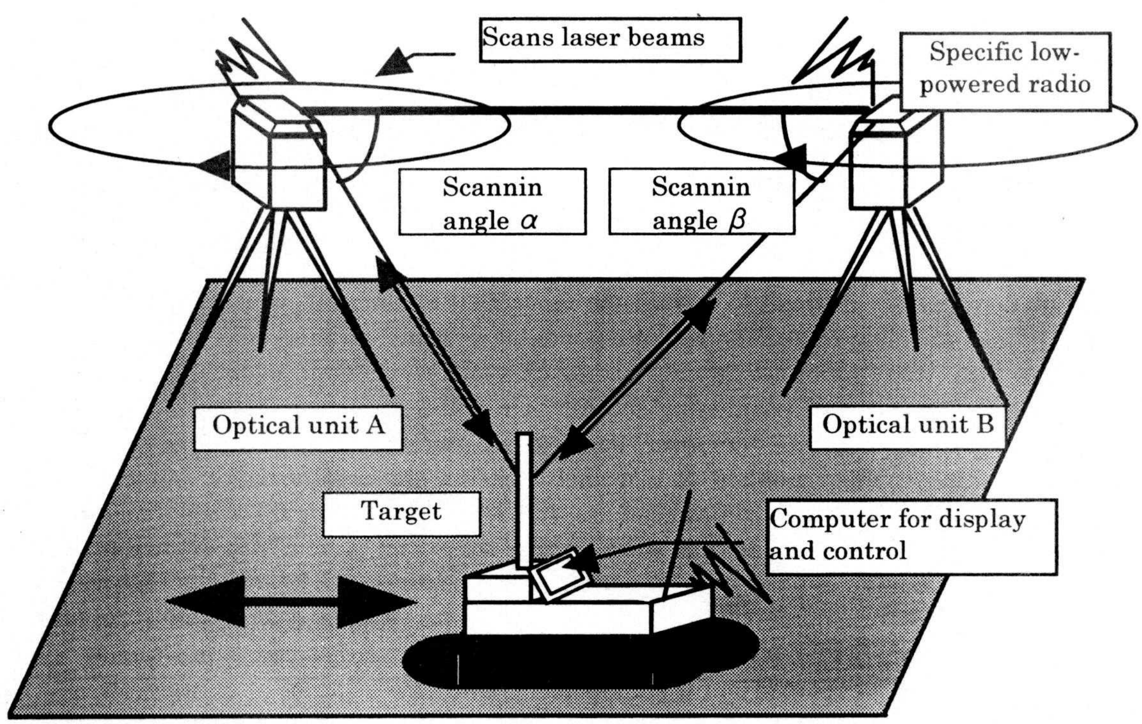


Figure 1 System configuration

- Optical unit : Two sets Output:10 mW, 810 nm
- Target : On-board for robot, retrorefletor sheet
- Communication : Between units; between units and computer for display and control; specific low powered radio modem
- Measurement range : 100 m ±100 m
- Accuracy : ±5 mm
- Output data : X coordinate, Y coordinate (20 times per second); Velocity and acceleration of a moving body (once every second)

(2) Data transmission system

The intercommunication system provided to connect the computer for display and control and other units via a specific low-powered radio modem enables the system to have such additional functions as navigation as well as plotting and a linear presentation of known coordinate points on a job site map. By utilizing two-dimensional (X and Y directions) coordinate point data obtained from the positioning system comprising simple devices mentioned above, and by relating them to data acquisition intervals, a robot's travelling velocity, acceleration and travelling direction can be grasped and controlled in real-time.

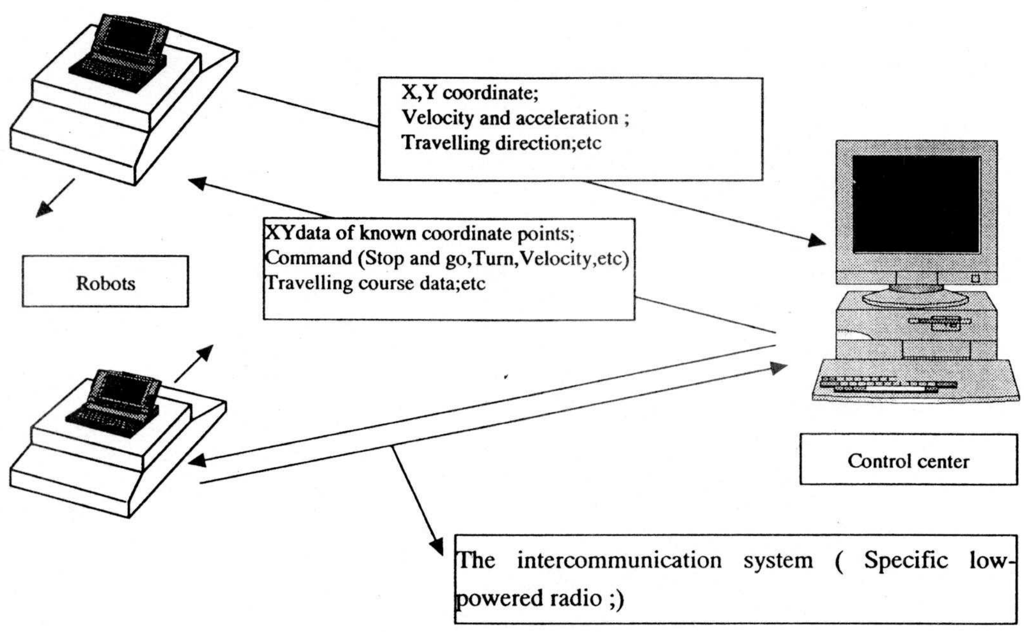
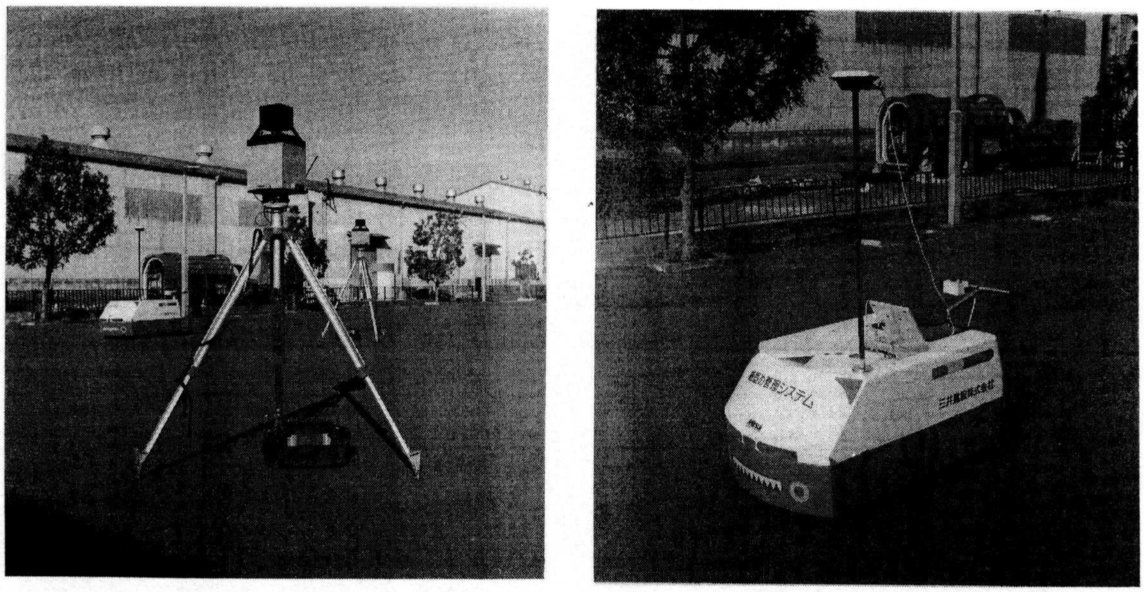


Figure 2 Data transmission system configuration

2. Accuracy verification testing

In order to verify the positioning accuracy of the newly developed system, a comparative experiment was carried out using a robot mounted with the same target used for the system and

GPS receiver. For comparison purposes, positioning was carried out concurrently with RTK (Real-time kinematic) - GPS. A pole wrappedaround with a reflecting sheet and with an antenna attached on the tip was set up on the robot to serve as the system's target. The Position of the robot that traveled along a straight line at a uniform velocity was determined with both the newly developed system and the GPS to compare the positioning accuracy



Photograph 2 The experiment in progress

(Photo.2). A transit was used to control the linear movement of the robot as well as to maintain perpendicularity (Fig. 3). The graph shown in Figure 4 is plots of two-dimensional positioning data, with the robot's travelling direction taken on the transversal axis, output at one second intervals from the two different systems. The positioning errors that appear in the direction that crosses the robot's travelling direction at right angles are attributable to the developed system.

As obvious from the graph, these errors are smaller compared to those inherent in the GPS and reduced further to one third when averaged. Major deficiencies in the GPS positioning are that the geometrical arrangement of satellites were inappropriate, system functions were disabled when buildings were approached and robot operations had to be suspended for several minutes until the system regained its functions. On the contrary, with the newly developed system, positioning could be carried out trouble-free under any conditions, although with some exceptional cases where data acquisition was disabled only for a fraction

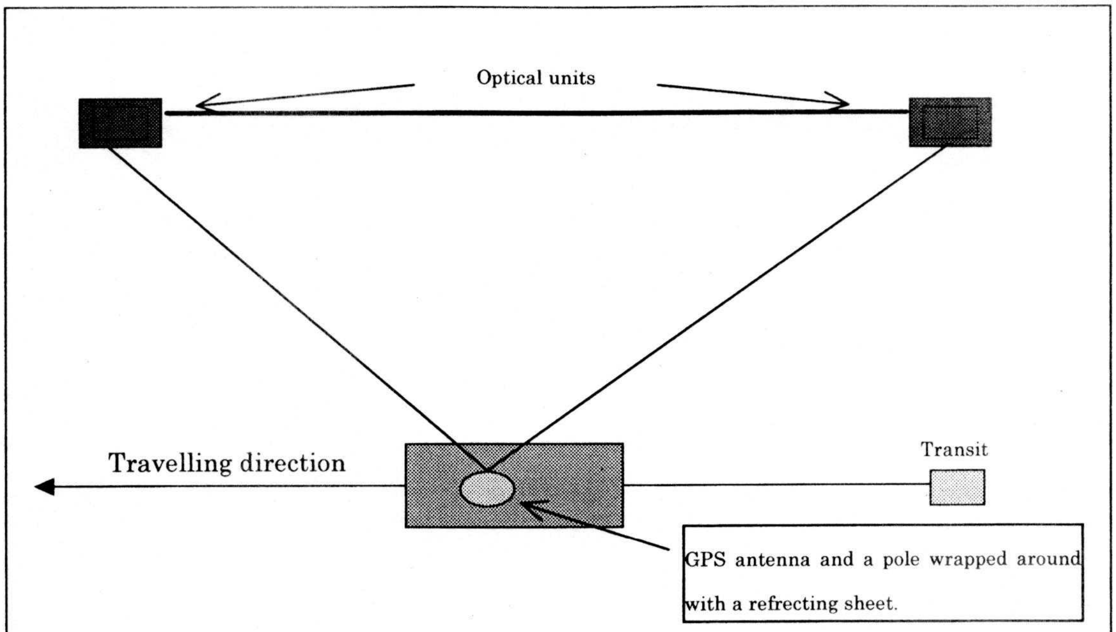


Figure 3 Overview of the experiment

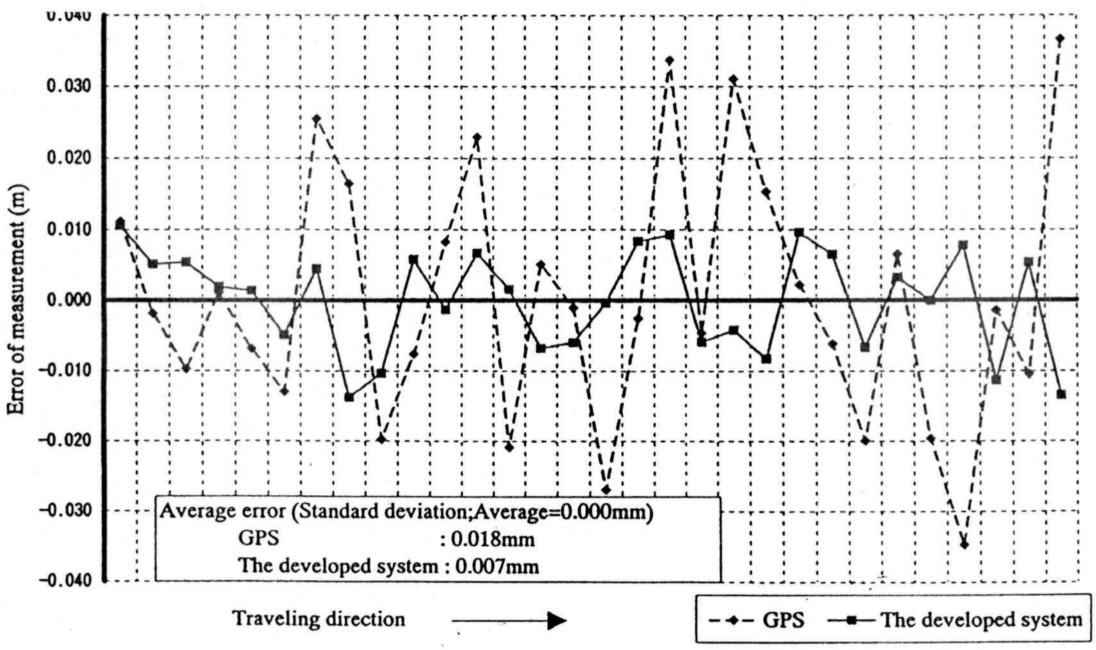


Figure 4 Results obtained from the experiment

of a second due to interception by an unknown object. From this it can be concluded that the system is applicable to the job site under the following operating conditions:

1. Where enhanced accuracy is required, such as plotting of positioning data on a job-site map.
2. Where overhead clearance is not adequate.
3. Where irregular reflection of radio waves is induced by the operations of more than one heavy equipment (cranes, etc.)

3. Applications

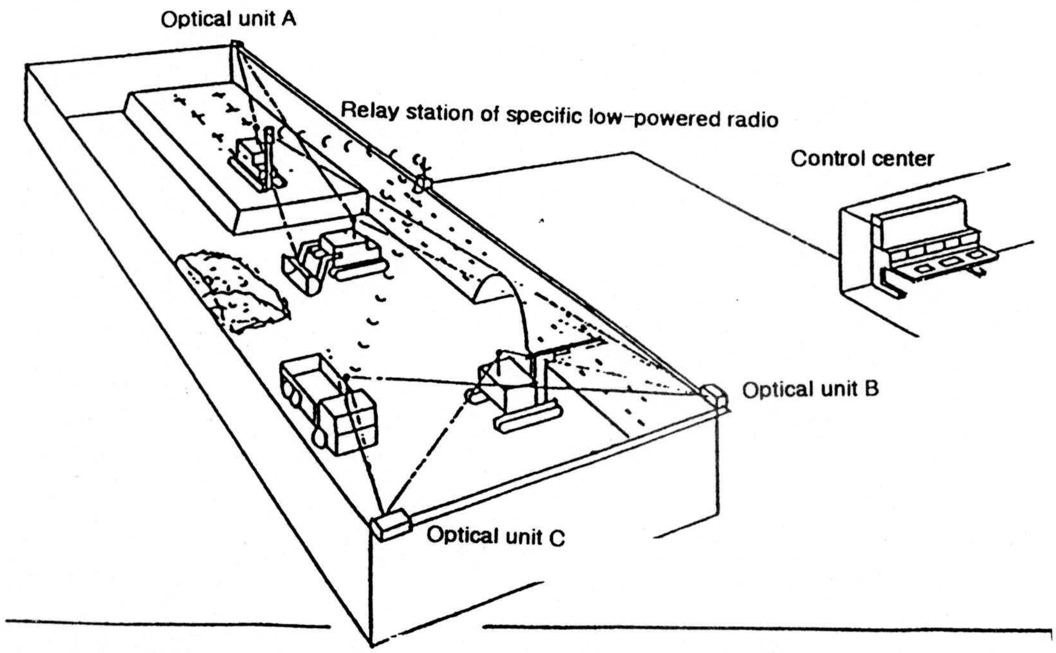


Figure 4 Future application of the system to positioning of robots performing construction jobs

One of the most noteworthy characteristics of the system is that positioning can be attained with enhanced accuracy within a range of approximately 100 m. Experimental applications of the system can be found in case histories where robots are required to perform highly accurate positioning, such as pile driving in which robots perform surveying operations, compaction management where robots are used for quality evaluation, green cutting and rolling compaction work in RCD construction, trowel finishing of floor surfaces and marking operations at the building construction site. Besides building construction, the system has also been used experimentally in mechanized agriculture for route monitoring and control of lawn mowers and large-sized agricultural machinery.It is believed that the system will find its future application at the construction site for accurate and rapid positioning of robots performing different jobs, as shown in Figure 5.