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SYSTEM PROPOSAL OF AN AUTOMATED VEHICLE CONSIDERING ITS USE IN CONSTRUCTION SITES

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ABSTRACT

By the result of system analysis of works being done in the constru-ction sites, we propose an automated vehicle system, which has color TV cameras as vision sensors. Guidance mark is a color tape placed temporarily on the floor. Thus, we can make frequent and easy changes of its possible paths.

There are many opportunities where men work on a flat surface, such as floors, cat walks etc., in a construction site. A wheel driven vehicle is supposed to be advantageous in those circumstances. But safety or stability of the system should be confirmed before any practical application starts. Concerning this reliability of the system we have made two different researches: the mark selection problem and the feedback control problem.

The mark selection problem is, for example, a question which is the best tape (color, width etc.) if it is placed on a concrete floor. We proposed a criterion function by which we can choose the best guidance mark.

1. Introduction

There are many different situations in construction sites. To name a few, building a personal house, erecting a sky scraper, or constructing a bridge in a deep mountain, all have their own peculiar circumstances. Therefore, to apply robotic technology in a construction site, we have to focus our interest into a more narrow area in which a very simple and repetitive work is being done.

A very natural understanding of the term 'robot' is meant to build a machine like human beings. But with a present status of the robotic technology we have no right to say that we can design such a humanoid. We have to be contented with at least making a special purpose machine to every possible construction labor. This is based on a so called 'divide and conquer' principle.

Fig. 1 is a fictional picture in which a robot is doing a constructive labor instead of a human worker.

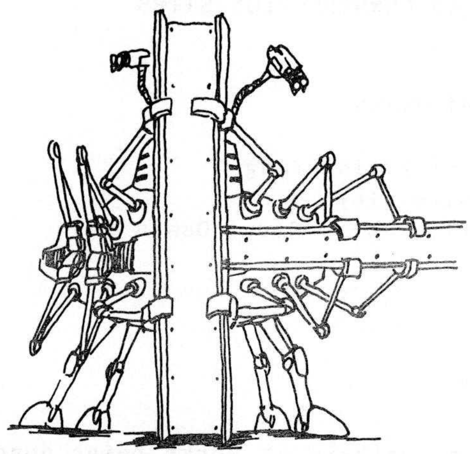

Fig. 1 Fictional robots doing constructive works.

But we all know that this situation is only an imaginary one and never comes into existence. Science and technology could never reach such a level to date.

There are at least three unconquerable problems that we can not solve with the present technology;

1. Source which can accommodate a sufficiently large quantity of energy with a reasonably light weight, and an effector to convert that energy into motion with a very high conversion rate.
2. A function which can recognize its circumferential condition through picture and voice processing.
3. An intelligent control facility with a learning and decision making mechanism.

I believe that if the robotic technology now available could contribute to the construction process, it is the specialized machine which can be operable in a specified scene of the construction activities like, for example, a bull dozer, and nothing more.

Then,there is a simple question why we use the term 'robot',since we are not accustomed to call a bull dozer as a robot. In a sense we have to clarify the difference between an ordinary machine and a robot.

The reason why this type of a question arises comes from the immaturity of the robot technology. The present robotics can not provide us with a robot having a common sense. There is a serious gap between the impression the term 'robot' gives us and the reality of the robotic technology.

We have to understand this philosophical background, in order to consider application of the robotic technology in an architectural or a constructive scene. Without the philosophy the marriage of constructive engineering with robotics comes to a divorce sooner or later.

In this paper I will analyze a construction process in a more detailed fashion, by the result of which I propose a standard architecture of robots which can be used in a construction site. My students have built a prototype of this kind of robots, and carried out many experiments, some of which I will discuss in this paper.

2. System Analysis and Proposal

As discussed in the earlier section, robots stand between human workers and construction machines. But since the today's technical level is low, they have to be placed, apart from human beings, at almost the other end of construction machine, as shown in Fig. 2.

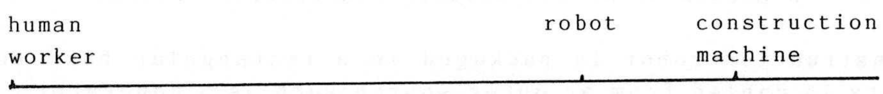

Fig. 2 Today's robots are very near to a simple machine.

More efforts have to be done for us to be able to design an intelligent and flexible robot, which can be usable in a construction site.

In fact, a vital progress could not be expected in a near future. Our robotic technology is so poor that we have to start a discussion what is an essential difference between a today's robot and a simple construction machine.

In general, a machine (e.g., NC tooling machine) is operated at a fixed location, to which works is transferred and specified jobs are executed. We can see the same pattern in, say an oil refinery, a steel plant, or any other kind of production systems. A common sense tells us that a machine operates in a house, or a man-made environment.

But construction sites differ essentially from usual machines at this point of circumstances. The construction sites are originated in the natural environment. This is a start point of my argument. Usual machines are located in an artificial environment whose conditions can be controlled, while construction robots have to do works in an at least partly uncontrolled circumstances.

Although many welding robots are installed in an assembly line for automobiles, those robots can not be converted to weld the steel frames in a construction site. They are useless in such an open air of a building site.

At this stage I will discuss some of the basic characteristics of construction robots. In the first place a construction robot must have a movable or in a sense removable characteristics. Since, as I pointed out in the earlier part, the work is fixed, a machine must be changeable in its positions. This reverse relationship of a work and a machine is the essential change in the design of robots. What I am thinking is illustrated in Fig. 3.

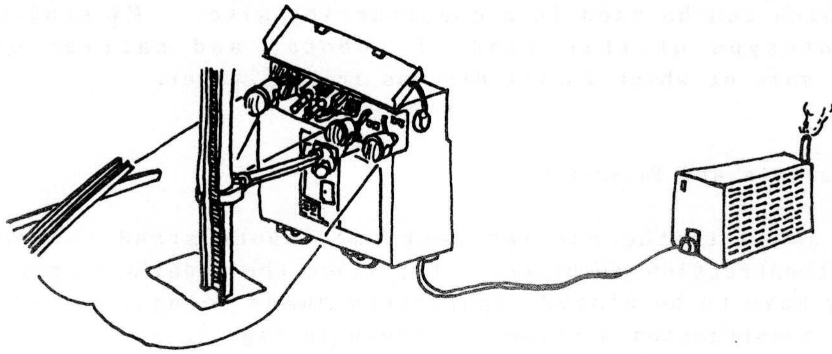

Fig. 3 A sketch of my conceivable construction robot.

A construction robot is packaged in a rectangular box, to which electricity is cabled from an outer source such as a generator. If we consider the present status of available batteries, use of generators for a power source becomes a reasonable choice. A generator might be a usual diesel engine or any of similar commercial machines.

Since construction labor needs power, compacted electrical power sources such as batteries can not be adopted as the first energy source. If we insist to combine a robot and a power source, then my construction robot becomes a type of "a robot on a car," which I also sketched in Fig. 4. You can not see a significant difference between the robots shown in

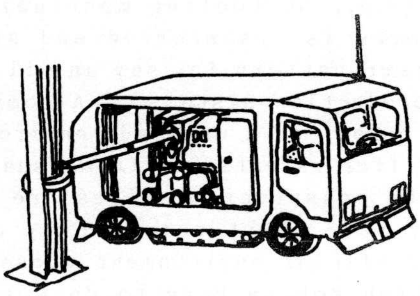

Fig. 4 "A robot on a car" type construction robot.

Fig. 3 and Fig. 4 at least from the technology concerned stand point.

I already proposed this type of robot as a "box robot" elsewhere [OKAWA, 1986]. I believe that this box robot is the only possible solution to the automation problem in a construction site. It is not the main sales point of this robot to change its places, but it is changeable, which means the robot must do a labor at a fixed point but it can be moved to another place.

The second robotic problem in a construction site is the material transfer or handling problem. That is, I divide the works done in a construction site into two categories: fixed point jobs and material transfer. For the fixed point jobs I already proposed a box robot shown in Fig. 3 and 4. The largest remaining problem to solve is the material handling.

A belt conveyer is the most popular material transfer mechanism, which is also partly used in a construction site. A belt conveyer is the fundamental material mover, but it lacks flexibility, which, I think, is the fatal shortcoming of this system. We need a more flexible material handler, which becomes possible by the introduction of robotic carts or automated vehicles, which is already realized in the most advanced production plants.

As I mentioned in the first section, a construction site does not have the same flat floor as a production plant has. It is full of obstacles such as temporarily placed materials, tools etc. Because of this unpredictable nature of the floor condition in a construction site, the application of wheeled vehicles seems impossible.

Crawler type movers have been proposed against the wheeled vehicles [NAKANO et al., 1985], [MAEDA et al.,1985]. Their ideas are shown in Fig. 5 and 6.

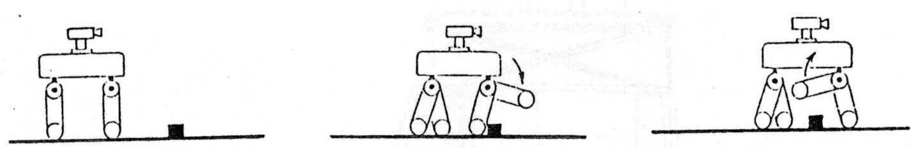

Fig. 5 Crawlers used as legs. [MAEDA et al., 1985]

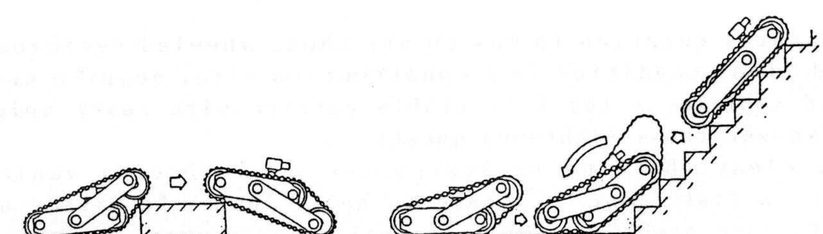

Fig. 6 Crawler to climb a stair. [NAKANO et al., 1985]

I think that legged robots remain in a purely academic stage and is not realized in such an application oriented scene of a construction site. So we can eliminate the possibility of introducing legged robots into construction site.

I have thoroughly counted the gains and losses of the two driving mechanisms of wheel and crawler in the background of construction, and come to the conclusion that a wheeled vehicle is better than a crawler.

Although the crawler shown in Fig. 5 or 6 can move through a non-flat floor like a stairway or a small gutter, but essentially it needs a flat floor. Today's crawler can not override many of the possible obstacles in a construction site.

Summarizing the above discussions, I can show you my idea of a carrier as a sketch of Fig. 7.

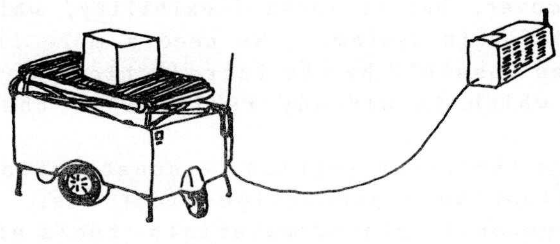

Fig. 7 The proposed robotic vehicle.

If the power source must be contained, this becomes an automobile like carrier shown in Fig. 8.

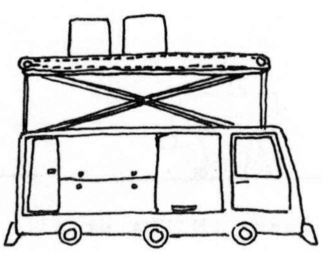

Fig. 8 Automobile is the natural answer for self contained vehicle.

The natural question is how to use those wheeled vehicles in such a disordered floor condition in a construction site, despite knowing that the wheeled vehicle is the most stable carrier with heavy weight cargos. I have to answer those righteous question.

It is clear that the weakest point of a wheeled vehicle is the necessity of a flat floor. I have to apply again the divide and conquer principle to this problem. My principal idea is shown in Fig. 9.

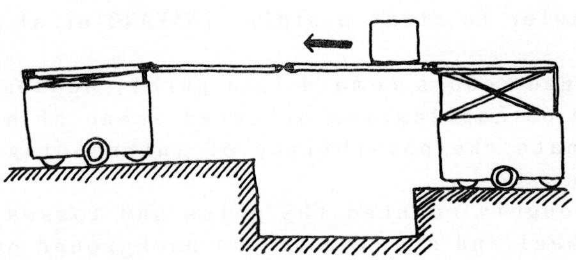

Fig. 9 Changing vehicles.

First, the whole construction site is divided into territories, to one of which some vehicles are assigned. At the border part of two neighboring territories like one shown in Fig. 9, cargos are passed from one vehicle to another. This is the basic structure of the system I propose, and as you can see this is the most natural extension of the belt conveyer system.

In fact, as shown in Fig. 10, if there is a territory which can not

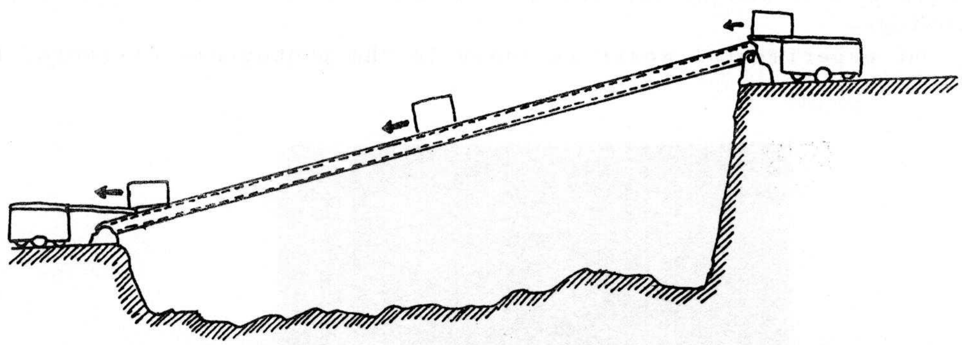

Fig. 10 A combination of a belt conveyer and a wheeled carrier.

run wheeled carrier, a belt conveyer is used in this territory. Similarly, Fig. 11 shows the usage of a belt conveyer over the obstacled territory.

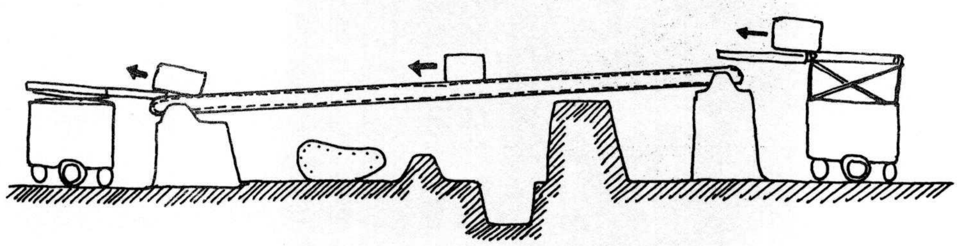

Fig. 11 A belt conveyer over an obstacle-full territory.

We had a dream to fly in the air like a bird, which leads us to build an airplane. But it has completely different powering mechanisms. Likewise, to design a humanoid of Fig. 1 is an ideal but a waste of time. A combination of belt conveyer and wheeled carts is my answer to the automation of the construction process.

3. Conceptual design of the automated vehicle system

A report [NILSSON et al.,1973] has been published about an automated vehicle which gives us a base for starting a research about a robotic mover. We have added following changes to their proposals;

1. Color TV cameras for the recognition of scenes of construction sites,
2. Artificial guidance marks for reliable and safe operations of robotic carts.

We have done a great deal of experiments on this type of robotic vehicle, whose results are reported elsewhere [OKAWA, Y. and GOTO, H., 1985], [OKAWA, Y. and OGURA, K., 1985]. Their outlines are summarized in the followings.

Our experimental mover is shown in the photograph of Photo. 1.

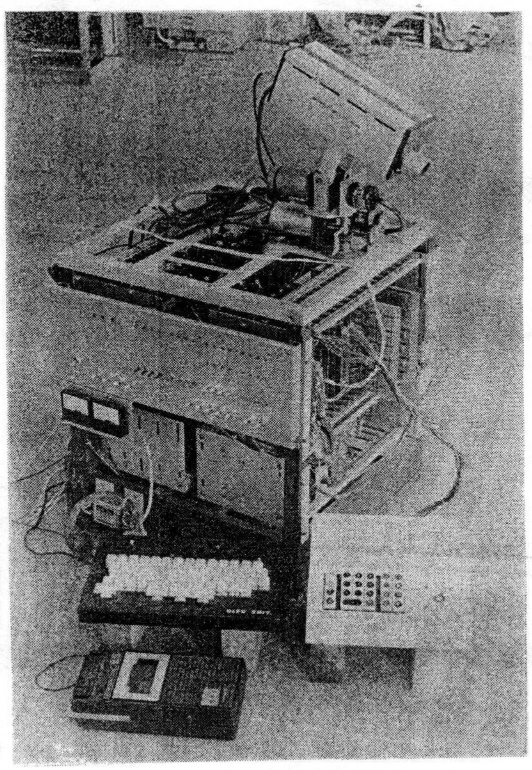

Photo. 1 An overview of our robotic carrier.

According to my already stated philosophy, the power is supplied from the outer source. The vehicle has two color TV cameras, one of which is clearly seen in Photo. 1, and the other is installed in the body of the cart looking down directly onto the floor surface. Actuators are D. C. servo motors whose arrangement is seen from the rear view of Photo. 2.

Our primary problem is to guide the vehicle from one place to another with sufficient safety and reliability. Without this condition our proposal will never be realized.

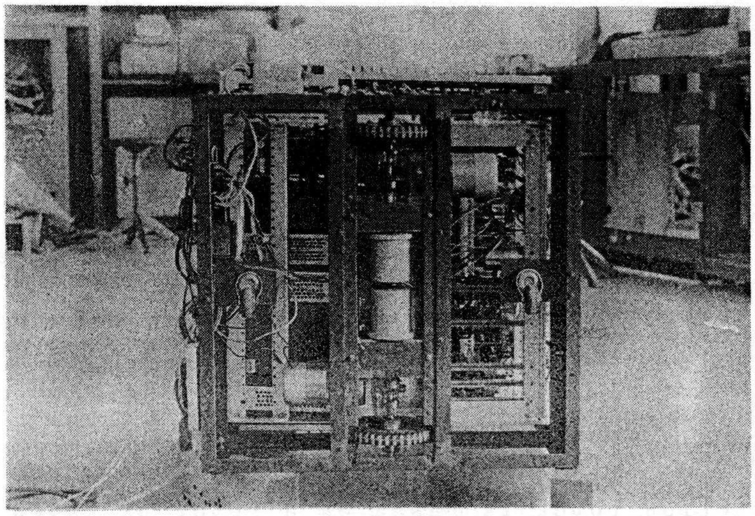

Photo. 2 The rear view of our experimental carrier.

Our contributions to reliable transportation are listed below;

1. Usage of artificial (or man-made) guidance marks,
2. Guidance marks are colored so that both robotic vehicles and human workers can easily recognized, and
3. As to the recognition problem of the robotic vehicle we adopt a so called dual system, that is to use two TV cameras. One is a forward looking, and the other is a look down camera.

There are many reports on the usage of TV camera (or in other words picture processing technology) to control robotic carts. But they are only from research interest, and do not provide us with satisfactory reliability. While we have to advance the research works in picture processing toward the natural scene recognition, we also must be very careful to introduce such technology into a real situation considering any error of the transportation system in a construction site results in a tragic accident. By this reasons I adopt artificial guidance marks for the material transporting problem in a construction site.

I predict that the work done in a construction site could never be fully automated, because they need very sophisticated movement of body, arms or fingers with also considerable power. Then, in the near future construction site human workers and robots must coexist, where guidance mark must be able to be recognized by both of them. For example, a bar code which is only for machine reading but impossible for human perception is very difficult to adopt.

By these reasons I propose a color marker to our guidance problem. Color is a very easy device for human perception, which has been proved , for example, in a usual hospital corridors for human guidance. For the robotic side we have to do some efforts to do a real-time processing of color markers, which is not so difficult since the shape of markers is artificially designed.

4. Conclusion.

I have proposed a realistic robotic system for construction job automation. You may think that the system I proposed is a result of compromise, but I do not. The reason comes from the safety and reliability first principle.

The basic structure of my system consists of two different categories;

1. Construction robot and
2. Transportation robot.

My construction robot is based on a robot packaged in a box principle. It is, in other words, a movable robot, whose movement is not essential. It is fixed at a specified point, to do some jobs, and then moved to another place.

My transportation robot is a natural extension of ordinary belt conveyer system often seen in construction sites. My idea is to add free going carriers to the belt conveyer system. To ensure reliability of the system, I introduce color guidance marks and the dual perception mechanism.

I believe this type of robots is the possible robotic system in a complicated construction site.

5. References

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