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A combined navigation strategy by a steering

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A Combined Navigation Strategy by a Steering Wheel and a Mouse for a Tank Rescue Robot

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***Abstract*—This paper applies our developed novice users oriented force feedback steering wheel interface and mouse interface to navigating a tank type rescue robot. By analyzing merits and limitation of operating each interface, we propose a combined navigation strategy by the two interfaces. The steering wheel interface consists of a force feedback steering control and a six monitors' wall. Through this interface, users can navigate the tank robot like driving cars, while watching incoming videos. It provides a daily life operation method for novice users to navigate the tank rescue robot. The steering wheel interface is efficient in exploring open areas. For complex disaster fields, this interface requires users have skillful operation experiences, which take them more attention. The mouse-screen interface consists of a mouse and a camera's view displayed in a computer screen. Through this interface, users can navigate the tank robot just by mouse clicking. Path planning and low-level controlling are realized by system automatically. The mouse-screen interface can realize exact navigation, especially needed in complex structures, without taking much attention. It gives users more time to care incoming information. The two interfaces can shift into each other at any time. The combined navigation strategy adopts merits of the two interfaces and compensates limitation of each of them. It provides an efficient operation method for novice users to navigate rescue robots.**

Keywords-Human Interface; Rescue Robot; Navigation; Force Feedback Steering Wheel; Mouse; Tank Robot.

I. INTRODUCTION

Disaster sites are characterized with collapsed structures. They are often dangerous and unreachable for human to enter into. To explore such fields and to rescue wounded people, rescue robots have been developed throughout the world [1, 2, 3, 4, 5, 6, 7].

In large-scale disaster sites, such as earthquakes, professional rescuers are not enough to meet rescue tasks. We emphasize that many non-professional volunteers join in saving wounded people and mitigating losses. So in [1], we proposed a strategy of many non-professional volunteers instead of professional rescuers operating rescue robots. This strategy addresses in developing novice users oriented human interface for operating rescue robots. Reference [1] developed a prototype of a force feedback steering wheel interface. A user can navigate a robot through the force feedback steering wheel, while watching incoming local videos displayed on a six monitors' wall. Through this interface, users' operation of rescue robots is like driving cars in daily life. The force feedback steering wheel can support human's operation, hearing, and touch. The video wall can provide expanded non-distorted local motion images to support human's vision.

Having been experienced by many users, the force feedback steering wheel interface is said that while operating it, users have to frequently shift their attention from understanding incoming information into operating the wheel. Especially in complex environment, operating the robot requires a skillful experience and much attention. This would separate his attention spend on understanding incoming information. Since the system is mainly developed to collect internal information of disaster site, users should have more chance to consider the incoming information.

To solve the problem, we developed the second human interface, the mouse-screen interface. It was present in [2]. Through the mouse-screen interface, the operation of a robot is only made by a mouse clicking. When the user recognizes an object or wants to navigate it to an intended area, he clicks the mouse at the point in the screen. The robot will access the goal automatically. Because operating a mouse almost need no attention, the user can focus his attention on understanding incoming information nearly throughout the exploring process.

The force feedback steering wheel interface is efficient in exploring open areas where obstacles are not too much. The mouse interface is good at exact navigation that is needed in complex structures. Because of the respective merits and limitation of the two interfaces, we adopted a combined navigation strategy by both of them to operate rescue robots. Users can shift from one interface into the other at any time. This strategy gives users choices of efficient operation to explore different types of collapsed structures.

In this paper, we apply the combined navigation in navigating tank type rescue robot. Experiments are designed to analyze merits and limitation of the two interfaces, and to demonstrate the effectiveness of the combined navigation strategy. The following of the paper is organized as five sections. Section II introduces the

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system outline. Section Ⅲ describes the force feedback steering wheel interface. Section Ⅳ describes the mouse interface. Section Ⅴ presents the experiment results of operating the two interface and discuss them. Section Ⅵ concludes the paper.

II. THE COMBINED NAVIGATION SYSTEM OUTLINE

Fig.1 shows the outline of the developed system. A wide view camera is mounted on a tank robot. The tank robot is shown in Fig.5. The camera has a view angle of 180 degrees. The captured image is like Fig.3 (a). Video signals and data of other sensors are transferred to the receiver and passed into the data processing computer. This computer processes video signals intelligently and display them on the monitors. For useful information recognized by system intelligence, it reminds user automatically. While watching incoming videos of the local disaster site, the user can navigate the robot by operating the force feedback steering wheel or just by clicking the mouse. The instructions of direction and speed (or distance) are passed into the radio remote control and transmitted to the robot. When the robot gets them, it moves to access the intended point.

III. THE FORCE FEEDBACK STEERING WHEEL INTERFACE

The force feedback steering wheel interface is developed as a novice users oriented human remote operation method. It consists of a steering control and a

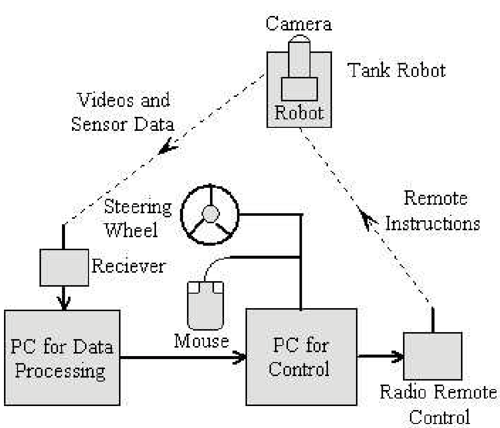
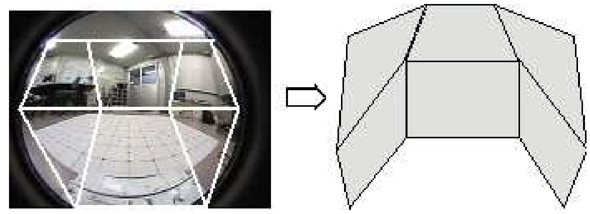


Fig.1 The system outline

(a) (b)

Fig.2 The force feedback steering control



(a) (b)

Fig.3 The local view-rebuilt strategy

Fig.4 The steering wheel interface

Fig.5 The tank rescue robot

six monitors' wall. Fig.2 (a) shows the wheel for the control of direction. Fig.2 (b) shows the two pedals for the control of speed and direction (forward and backward). Fig.3 (a) shows a captured camera view of the tank robot. The images of transverse and longitudinal parallels show the distortion of the captured camera view. Fig.3 (b) shows the strategy of transferring camera view into expanded non-distorted videos. We divide the camera's view into six parts. A computer is used to process each part of the camera's view and display them on six monitors with no distortion. Fig.9 shows the transferred images in the monitors' wall. Fig.4 shows the complete interface.

While watching local information displayed in the monitors' wall, the user can operate the wheel and the two pedals to navigate the tank robot. The expanded non-distorted local videos support the user's vision strongly. The operation of the robot like driving cars in daily life adapts to novice users. Any user who has experiences of riding a car can operate the steering wheel interface easily. Even if he has no driving experiences, he can learn to operate it quickly.

IV. THE MOUSE INTERFACE

The principle of the mouse interface was present in [2]. It consists of a mouse, a camera's view displayed in a computer screen, like Fig.6, and some intelligent modules. We designed an artificial neural network to obtain 3D world position from the clicked target point's position in 2D camera's view. A path-planning module is used to plan a straight-line path for the tank robot. A tracking module is developed to realize low-level control to the tank robot. Local site videos are displayed on a monitor, like Fig.3 (a) and Fig.6. When the user recognizes a goal or wants to navigate the robot to a certain position, he clicks the

Fig.6 The mouse interface

goal's image. The system obtains the clicked point's window position and input it into the artificial neural network. The neural network processes the data and indicates its world position. Knowing the goal's position, the path-planning module generates a straight-line way. The tracking module sends instructions of direction and speed (or distance) to the robot and initiates its moving.

The mouse interface requires the user select a non-obstacle path. In the case that obstacles exist between object field and robot's current position, the user can plan a folded-line path to avoid them.

V. EXPERIMENT RESULTS AND DISCUSSION

A. Experiment of the Force Feedback Steering Wheel Interface

We designed an experiment to test the effectiveness of the steering wheel interface in different simulated disaster fields. Fig.10 shows a simulated disaster site. There are three tall obstacles marked with a, b, and c respectively, like Fig.10 (1). The tank robot must avoid them. There are many short obstacles that the tank robot can move over. The tank robot locates at one side of the site. The goal is the green ball locating at the other side of the site. The operator is required to navigate the tank robot to the green ball, while running through the narrow space between the obstacle a and the obstacle b, and avoiding the obstacle c.

Fig.9 (1) to (2) show the operation by a user using the force feedback steering wheel interface. In Fig.9 (1), the operator finds that the green ball is at somewhere of the right-front side of the tank robot. In Fig.9 (2), he operates the steering wheel and navigates the tank robot to the green ball. Fig.10 (1) to (9) show the moving process of the tank robot. From these photos we can see that by watching local videos, the tank robot can be navigated to access wanted fields through the force feedback steering wheel.

Nearly all of the users can navigate the tank robot skillfully at the outside of the three tall obstacles. However, they exhibit differences in operation skill when they navigate the robot through the three tall obstacles. Some users can quickly navigate the robot to the green ball. Some users have to try many times to avoid the three tall obstacles. The experiment shows that in open areas where there are not too many obstacles, novice users can navigate the tank robot quickly. In complex structures, to quickly navigate the tank robot while avoiding obstacles needs high operation skills.

While operating the interface, especially navigating in complex structures, the user said he has to frequently shift his attention into operating the steering wheel. The user's motion of operating the interface is analyzed in Fig.7. He watches videos displayed on the monitor wall to understand the disaster site environment and to see if there are useful information. When he finds a victim or wants to navigate the robot to a certain place, he considers a suitable path and operates the steering wheel to send instructions to the robot. When the robot accesses the goal, he stops his operation and watches it. If he fails to navigate the robot to the goal (it means he plans a wrong way or gives wrong operation although the planned way is right), he would have to repeat these works again. From the flow of user motion, we can see that the user nearly does all of the work needed to navigate the tank robot. Especially he has to plan a non-obstacle path and give suitable low-level control (this means the user's operation of the wheel and the two pedals to navigate the robot along the planned path). Moreover, in complex environment, the operation to the steering wheel requires skillful experiences. Especially, if the user wants to adjust the robot to run an exact distance or to turn an exact angle, he would have to try many times. These works also take time and human attention. The system is mainly developed for collecting information of disaster site. It would be better to give users more chance to understand incoming information.

B. Experiment of the Mouse Interface

We also designed an experiment to test the effectiveness of the mouse interface in different simulated disaster fields. Fig.12 shows the simulated disaster site. There is a tall obstacle that the robot must avoid and some short obstacles that the robot can move over. The tank robot locates at one side of the tall obstacle, like Fig.12 (1). The goal is a point at the other side of the tall obstacle. It is marked with number 1, like Fig.12 (6). The user is required to navigate the tank robot to the goal by the mouse interface, while avoiding the tall obstacle.

User's operation of the mouse interface is shown in Fig.11 (1) to (6). The motion of the robot is shown in Fig.12 (1) to (6). We can see that the user successfully navigates the tank robot to the object field. With such an operation interface, the user selects a non-obstacle folded-line path for the robot. He navigates the tank robot to the target point while avoiding the obstacle only by several mouse clicking.

In this experiment, every user quickly navigates the robot to avoid the tall obstacle. The user's motion of operating the mouse interface is figured out in Fig.8. When the user finds a goal or wants to navigate the robot to a certain place, he clicks the object's image with a mouse. The path is automatically generated. The tracking module of the controlling computer gives instructions to the robot. If the robot accesses the goal, the user watches

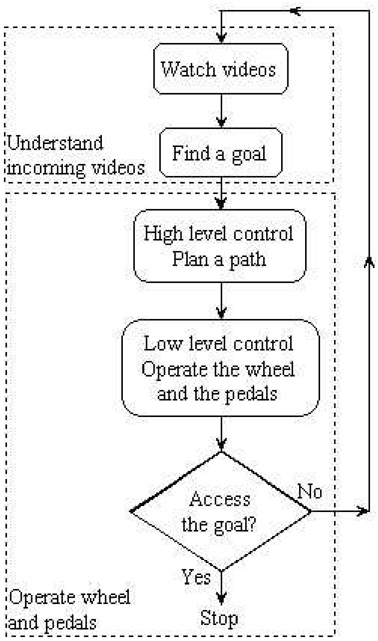


Fig.7 User's motion in operating the steering wheel interface

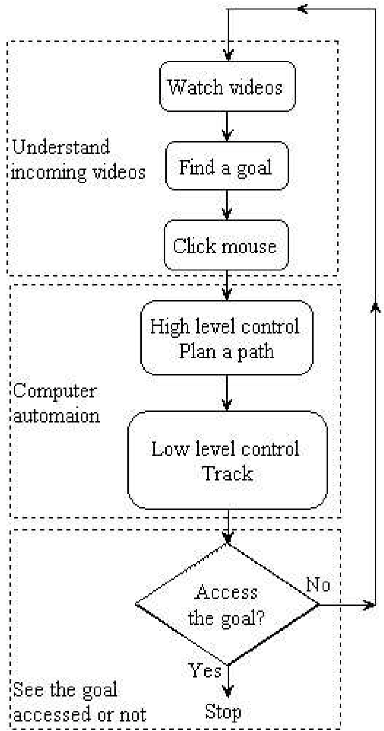


Fig.8 User's motion in operating the mouse interface

it. If not, he need only watches the goal's image and clicks it again. Compared to user's motion of operating the force feedback steering wheel depicted in Fig.7, the path planning and the low-level controlling by mouse interface are realized by computer automatically. The user's motion is only to click the image of an object and see whether the robot accesses the goal or not. Even to operate a mouse nearly need no attention. So the user can focus his attention on understanding the incoming information.

By using the mouse interface, the exact navigation can be realized quickly. Because the computer is good at computation, it is better to give exact low-level controlling instructions than human does. In complex environment of a disaster site where exact navigation is needed, the mouse interface shows superiority over the steering wheel interface.

Having been experienced by some users, the mouse interface is said that the navigating speed is lower than that of the steering wheel interface. This is mainly because we set the tank to turn and run at respective constant speed in the prototype. It needs a complex low-level controlling model and many testing data for constructing it to enable the mouse interface to have a speed-adjustable ability. We will do these works to improve the prototype of the mouse interface in the future research.

C. The Combined Navigation by the Two Interfaces

From the two experiments of steering wheel interface and the mouse interface, we can see that they have respective features. The steering wheel interface provides a daily life operation method. It has the merits of support user's vision and operation. It is good at quickly navigating a rescue robot in relative open areas. When navigating in complex structures, skillful operation technique is required. The mouse interface in fact provides a semi-automation navigation method. The user indicates a goal for the robot. The robot moves to the goal automatically. It is good at realizing exact navigation that is needed in complex structures.

Both the steering wheel interface and the mouse interface have the ability navigating the tank rescue robot. To absorb merits of the two interfaces, we design to make the two interfaces be able to shift into each other at any time. The combined navigation can be described as following:

Case 1, there is only one operator

In relative open areas where obstacles are not too many, he uses the force feedback steering wheel interface to navigate the robot quickly. When the robot meets with many obstacles, he shifts to use the mouse-screen interface, and go on to navigate the robot exactly.

Case 2, there are two operators

One (operator 1) of them is in charge of operating the force feedback steering wheel interface. The other operator (operator 2) is in charge of operating the mouse-screen interface. In relative open areas, operator 1 navigates the robot. In complex structures, operator 2 navigates the robot.

VI. Conclusion

In this paper, we present a combined navigation strategy for novice users to navigate a tank rescue robot.

The developed system has two interfaces, the force feedback steering wheel interface and the mouse interface. Both of them have the ability for navigating the tank robot. The force feedback steering wheel interface makes the operation to the robot like driving cars in daily life. The six monitors' wall displays the videos captured by wide view camera in easily understanding form. It supports user's vision strongly. From the designed experiment, the force steering wheel interface is demonstrated to be good at quickly navigating the tank robot in open areas of disaster site. The mouse interface provides a mouse clicking operation for users to navigate tank robot. When the user clicks a target point in the screen, the tank robot moves to the target automatically. Path planning and low-level controlling to the robot are executed by system automatically. The designed experiment shows that mouse interface is good at exact navigation that is needed in exploring complex structures. While navigating in such structures, it liberates users from having to frequently shift his attention into operating robots, and gives users more chance to understand collected information.

The two interfaces are designed to be able to shift into each other at any time. The combined navigation strategy adopts merits of the two interfaces and compensates limitation of each of them. It provides an efficient navigation method for novice users to operate the tank type rescue robot.

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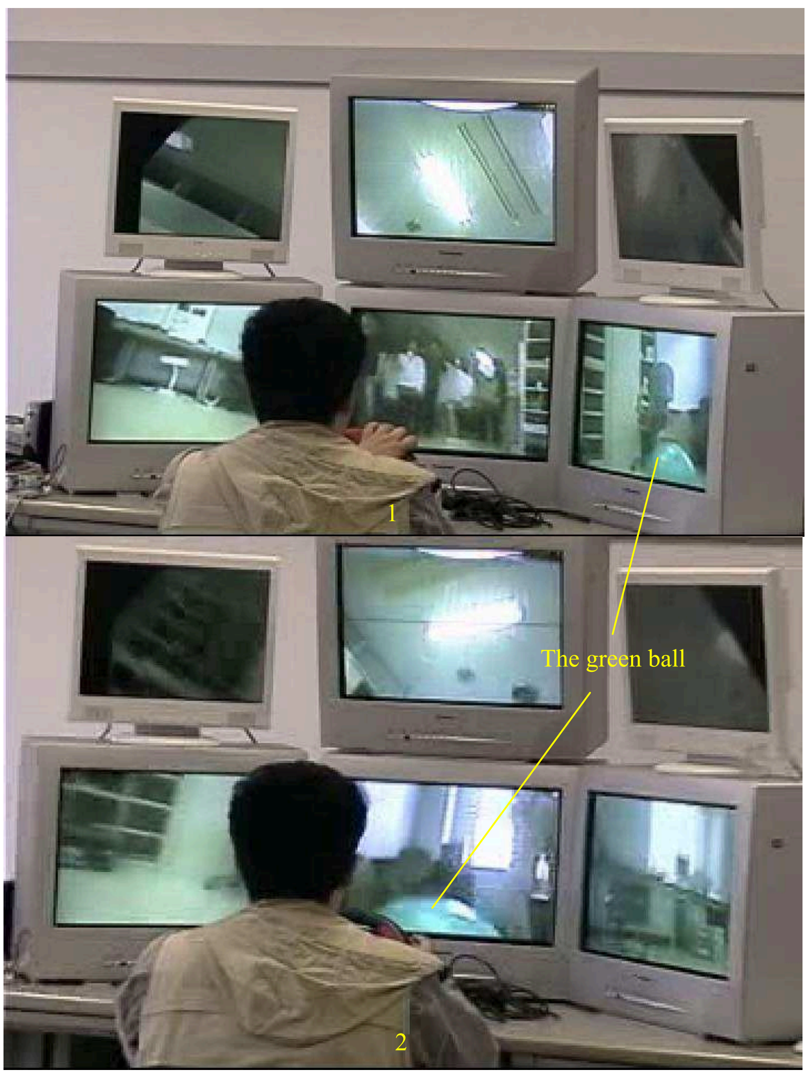

Fig.9 Operation by the force feedback steering wheel interface

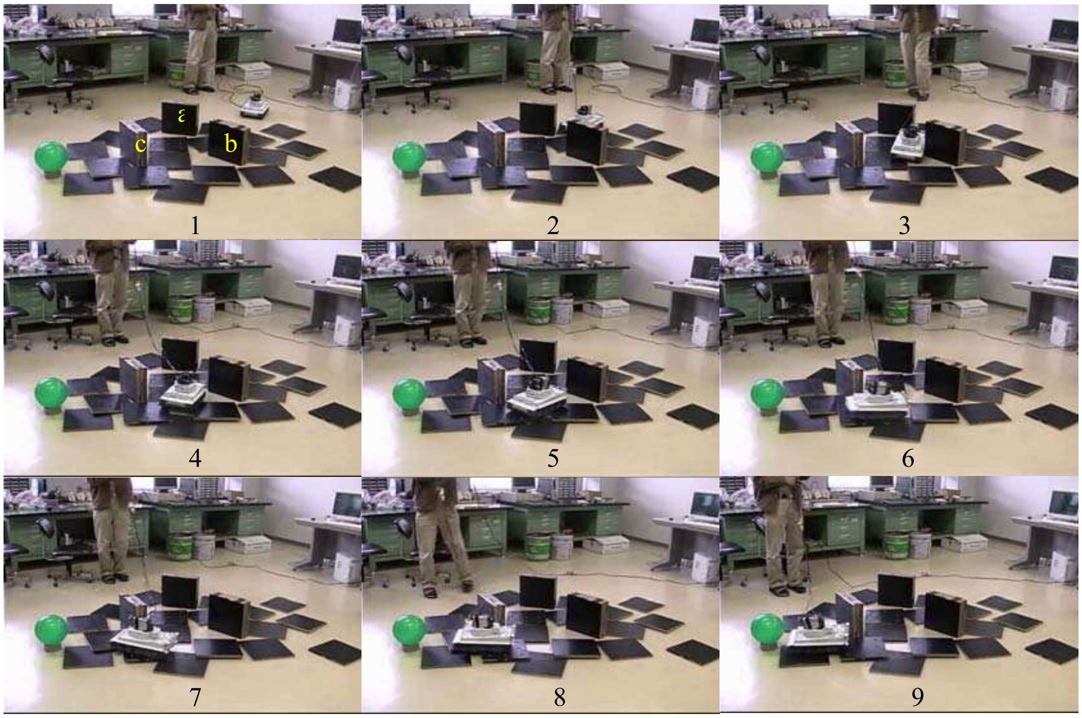

Fig.10 Motion of the tank robot by the steering wheel operation

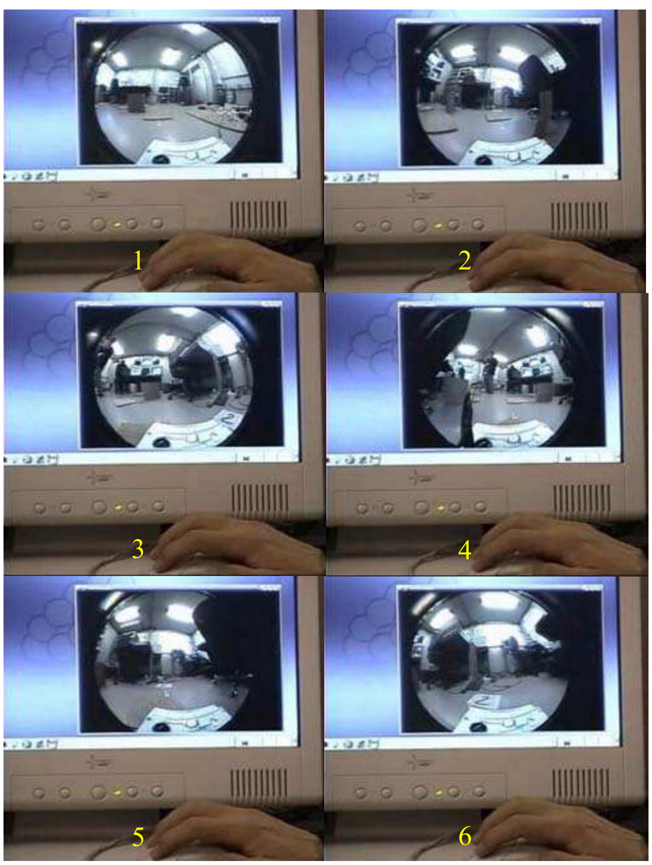

Fig.11 Operation by the mouse-screen interface

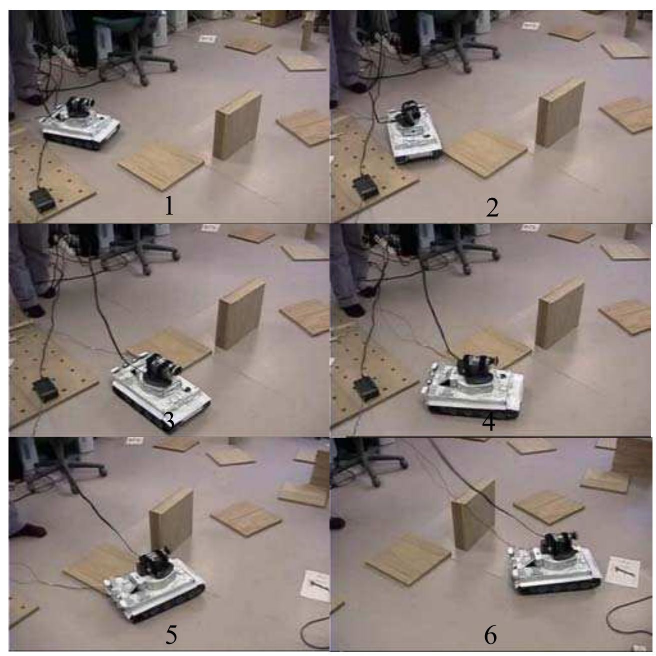

Fig.12 Motion of the tank robot by the mouse operation