Control technique for Planetary rover

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Abstract

At the beginning of next century, several schemes sending a planetary rover to the moon or Mars are being planned. As part of development program, autonomous navigation technology is being studied for realizing the rover to be able to move autonomously in a long range on unknown planetary surface. In the previous study, we tried the autonomous navigation experiment on the outdoor test terrain by using rover test-bed which was controlled by a conventional sense-plan-act method. In the experiment, the problem that the rover moved into untraversable areas occurred in some cases. For improvement of this situation, new control technique have been developed that it has reaction behavior to react by the outputs of the proximity sensors. We have been trying to develop the rover test-bed system and autonomous navigation experiment were executed by newly developed control technique using the new rover test-bed. In this experiment, our new control technique was able to produce the control command effectively to avoid the obstacles and to guide it to the goal point safely in the outdoor test site.

1. Introduction

There are two main methods to navigate the rover to its destination. One is remote control by operators on the earth. The other is an autonomous navigation by a control system on-board the rover. In a practical navigation, these two methods will be used to complement each other. And so, both methods must be studied, then we have been studying the autonomous navigation technology for the rover. This paper introduces the rover navigation method applied hybrid behavior control technique and also, the results of the autonomous navigation experiment which has been executed in the outdoor terrain model are shown.

2. Basic concept of rover navigation

The basic concept of our rover navigation system is described in Figure 1. In this concept, a remote sensing satellite is sent to the orbit of the moon or Mars to collect the surface data before the rover exploration and a set of coarse map (global map) of the terrain might be compiled from the remote sensing data. Then, operators make a plan of global path on the global map to lead the rover to its destination. After that, the rover is guided along the global path and the rover observes the terrain in front of it with the Image laser range finder (ILRF) or the other 3D terrain sensors. If the rover finds out some areas where it can not go through because of limited

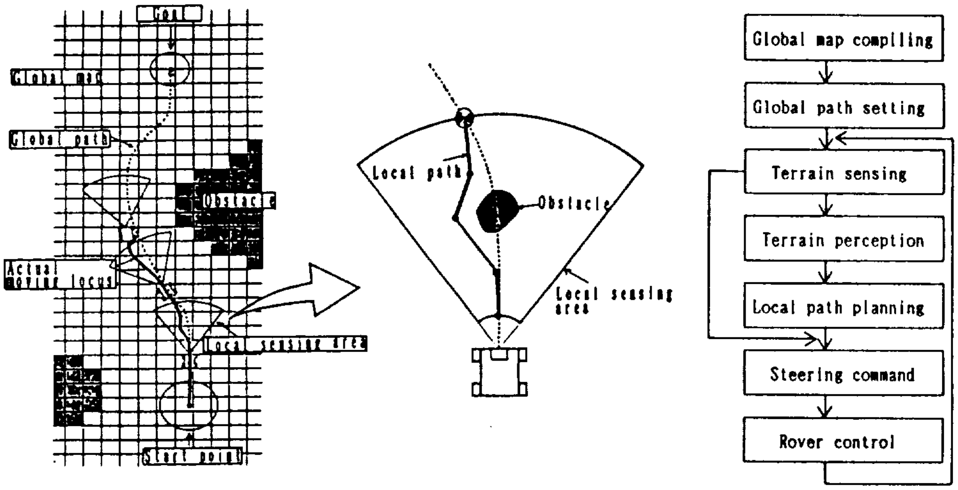


Figure 1 Basic concept of rover navigation

performance, then it executes local path planning to set up a new local route to avoid the untraversable area within the sensing area.

3. Control architecture

To realize the effective autonomous navigation algorithm for the rover, we tried to connect several functions effectively.

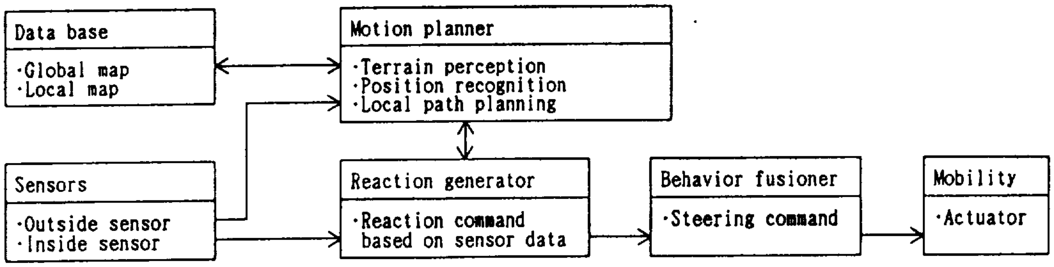


Figure 2 Block diagram of control architecture

The block diagram of newly developed control architecture for the autonomous navigation system is shown in Figure 2. Our control architecture consist of two layers and one behavior fusioner. The upper layer is called motion planner which has the role of deliberative task execution such as perception of the terrain condition in front of the rover, proper local goal searching in the sensing area for local path planning and executing local path planning and so on. The lower layer executes reaction control task, if the on-board sensors detect some dangerous situation, this layer immediately produces the reaction command to escape this situation. The reaction command will rescue the rover from collision with obstacles, tipping over, stack in loose ground and so on. The computational load of this layer must be kept as low as possible because the reaction command must be produced in a very short time. The behavior fusioner has the function as follows,

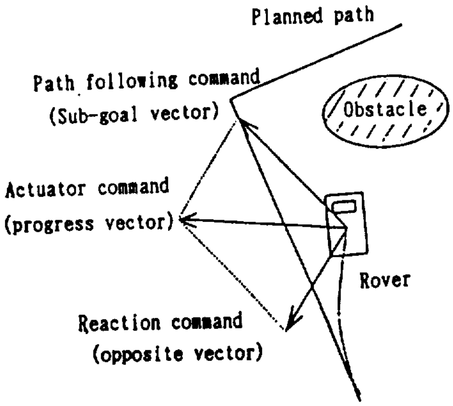
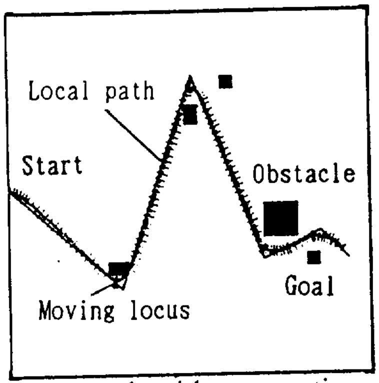
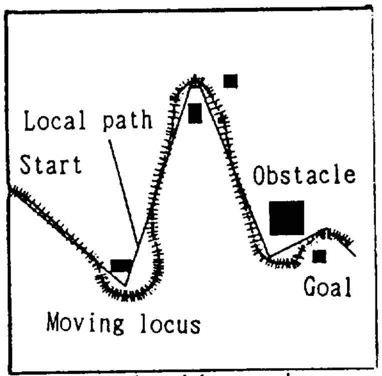


Figure 3 Command combination method

the behavior fusioner executes to combine the behavior command from upper layer and the reaction command from lower layer. In newly developed control method, a sort of potential method as shown in Figure 3 is used to combine the commands. In this figure 3, the behavior fusioner produces an actuator command to steer the rover with respect to progress vector which is a sum of sub-goal vector and opposite vector produced in the upper and lower layer. Before installation of this method into the rover test-bed, evaluating efforts for this method was done through computer simulation.



(a) Result without reaction



(b) result with reaction

Figure 4 One of the computer simulation results

The result of this simulation is shown in Figure 4. In case of no reaction control, when the planning path was very close to the obstacles, the rover collided with the obstacles as shown in Figure 4(a). While, by using reaction control, the rover could avoid the obstacles and arrived safely at a goal as shown in Figure 4(b).

4. Rover test-bed for autonomous navigation Experiments

We developed new rover test-bed for autonomous navigation experiments in the natural terrain. The characteristics of rover test-bed is described in Table 1 and the configuration of rover test-bed is shown in Figure 5.

Table 1 Characteristics of the test-bed

Mobility weight		75kg
Payload weight		45kg (battery included)
Size		length 1500mm
		height 1300mm
		width 1200mm
Driving mechanism		Servo motor Speed reduction gear
Velocity		15cm/sec
Climbable slope		30°
Maximum climbable height of obstacle		30cm
Sensor	Terrain sensor	Image laser range finder
	Posture sensor	Inclinometer (pitch, roll)
	Position sensor	Inertial sensor
	Proximity sensor	Laser proximity sensor ×5
On-board computer (signal treatment)		PC/AT (HOST) ×2 DSP ×4
Ground computer (environment perception action, planning)		Sun SS-10
Communication		Ethernet (optical fiber)

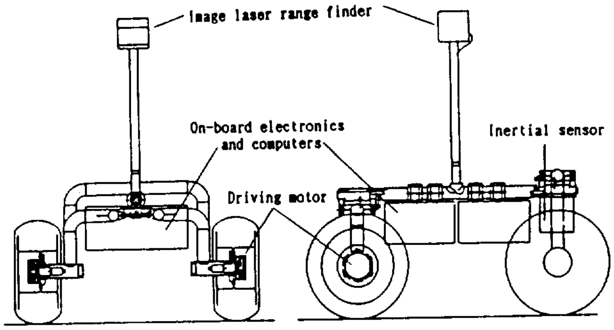


Figure 5 Configuration of the rover

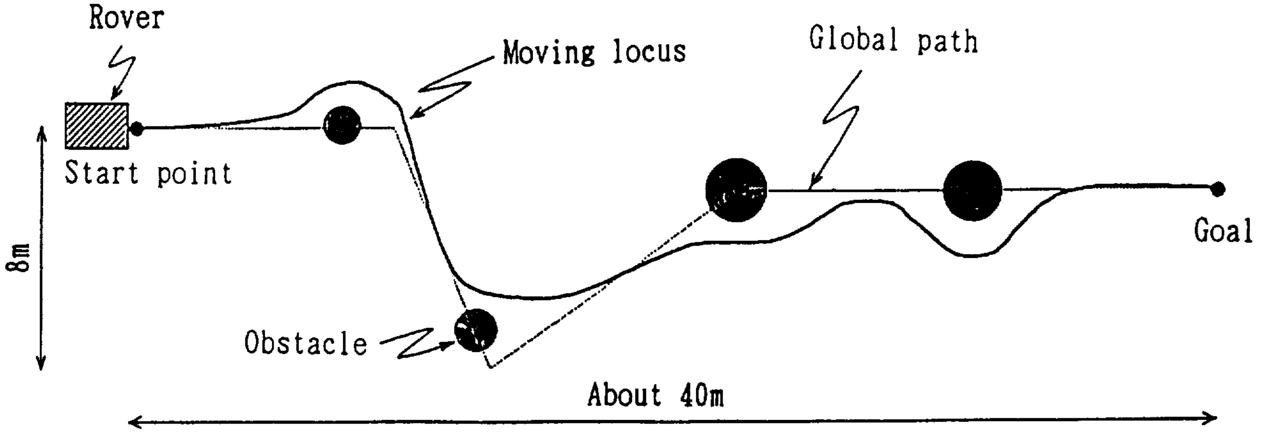


Figure 6 One of the autonomous navigation experiments results

5. Autonomous navigation experiments

The autonomous navigation experiments to evaluate the control method were executed using the rover test-bed in the outdoor terrain model. One of the experimental results is illustrated in Figure 6. In the experiments, the new control architecture was found to effectively work to avoid the untraversable area by generating reaction commands. As a result, the rover could arrive at the goal safely and it took about 20 minutes to move for about 40m.

6. Conclusion

In this study, the control technique for autonomous navigation to guide the rover to its destination area in outdoor environment has been developed. As we executed the actual autonomous navigation experiment, we could understand the characteristics and problems of our control technique and confirm the effectiveness of the hybrid method of two behavior commands newly adopted to improve the control performance. In next step, we will try to study to realize the higher level of autonomous navigation system with the performance which adapts to various situations that the rover would meet in the planetary environment.

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