Local Path-based Obstacle Avoidance in Outdoor Environments

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Abstract − Obstacle avoidance is a fundamental task for autonomous navigation. This paper describes a method for obstacle avoidance in outdoor environments. Obstacles of terrains are detected by laser scanners. The robot builds local maps using laser range data and extracts local paths which avoid both static and dynamic obstacles. Experimental results show that the proposed method is useful for outdoor navigation.

Keywords − Obstacle avoidance, Outdoor navigation.

1. Introduction

Navigation is a fundamental and important ability for a robot to perform a task in real environments. Various techniques such as mapping, localization, path planning, and obstacle avoidance are required for navigation [1]. The robots equipped with these functions should perform the tasks, operate for themselves in particular situations, and overcome the uncertainty of environments. In order to perform such tasks, the collision with the surrounding environment should be considered. It is very important to recognize whether there are obstacles in the path of the robot and whether there are obstacles approaching the robot. Therefore, there is a need for developing an obstacle avoidance algorithm adequate for outdoor environments.

The obstacle avoidance technology of mobile robots in indoor environments has been researched for a long time by many researchers. Many methods have a high degree of completion, and the performance is verified to some degree through various exhibitions and demonstrations. Among several real-time obstacle avoidance algorithms developed until now, the vector filed histogram (VFH), curvature velocity method (CVM), and dynamic window approach (DWA) are the most widely used methods [2-4]. The VFH approach utilizes the share probability of obstacles in the one dimensional distribution centering on the robots. CVM chooses the optimal speed to evade obstacles as it includes the robots' physical constraint conditions. DWA selects the speed that can be changed by the robot as it includes the robot's kinematic constraints. Among them, DWA has lower computational complexity with fewer operations, when compared with VFH or CVM. It has greater obstacle avoidance performance, but it sometimes falls in local minima. And the performance in outdoor environments is lower than that in indoor environments because the ground is not flat and there are various types of obstacles such as curbs and trees [5, 6]. Considering that, the researches on outdoor navigation have not been done sufficiently compared with indoor navigation, and there are not much practically plausible research. In the outdoor navigation researched until now, in most cases, GPS/DGPS are used as a main sensor and various sensors such as three dimensional Lidar (e.g., Velodyne). Therefore, for enhancing the practicality of obstacle avoidance scheme, there is a need to develop the scheme which accurately recognizes the surrounding environment using the information acquired through practically meaningful sensors and reaches the goal safely.

This paper proposes a method to avoid obstacles safely in outdoor environments. Environmental data and a local map are obtained from laser scanners. Local paths are extracted from the local map and the robot avoids static and dynamic obstacles by following the local path.

2. Experimental Setup

Figure 1 shows a mobile robot system equipped with two laser scanners. One laser scanner is located at the lower part of the robot, 0.5 m above the ground. The other laser scanner is located at the top of the robot, 1.6 m above the ground. The lower scanner detects nearby obstacles and enables the robot to immediately stop in case of emergency. The upper laser scanner is used to sense far obstacles and control the robot motion. The roll and pitch angles of the robot were sensed by an inertial measurement unit (IMU) (MI-GA3350M, MicroInfinity Corp.), and the yaw angle and motion increments were sensed by the wheel encoder and IMU. The absolute position information is measured by GPS (FlexPak-G2-V1, NovaTel Corp.).

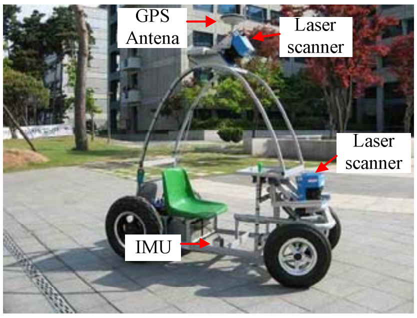


Fig. 1 Mobile robot platform and configuration of laser scanners.

3. Obstacle Avoidance

Figure 2 shows the concept of the obstacle avoidance method proposed in this paper. From the starting point to the goal, the waypoints and straight line paths connecting them are created. The environment is detected through a laser scanner and a local elevation map is constructed with the height information of the terrain. When there is an obstacle, with the use of the created local map, a local path is created for the robot to avoid obstacles and safely move.

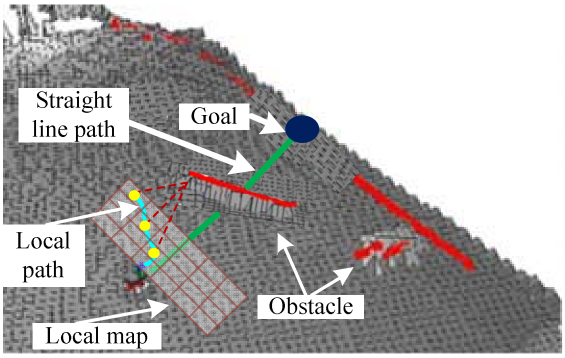


Fig. 2 Concept of generation of local path.

3.1 Generation of global path

The first step of the obstacle avoidance method proposed in this paper is to generate the waypoints (midway destinations) which help the robot reach the goal safely and accurately. The distance between waypoints is determined in consideration of the uncertainty of the environment and the performance of the sensors. In order to prevent the robot from breaking away from the path, it is set to around 20m ~ 30m. A straight line path is created between the waypoints, and the robot travels basically along this straight line path. The straight line path is also used to return to the straight line path again when the robot creates a local path in order to avoid obstacles.

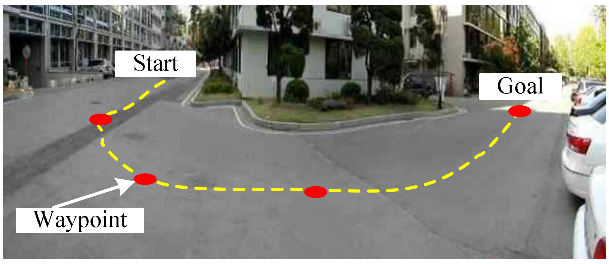


Fig. 3 Experimental environments and way points.

3.2 Generation of local map and local path

After the straight line path is created to the waypoint, when the robot starts navigation, it detects obstacles with two laser scanners. As shown in Fig. 4, two laser scanners recognize the surrounding environment within the boundaries of 5m and 2m, respectively, and the laser scanner at the bottom is used to detect obstacles close to the robot.

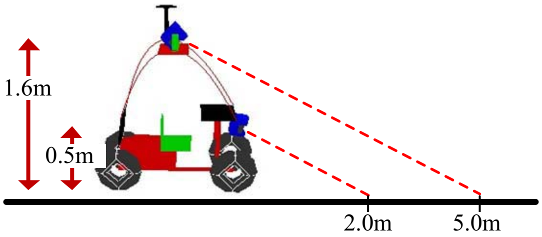
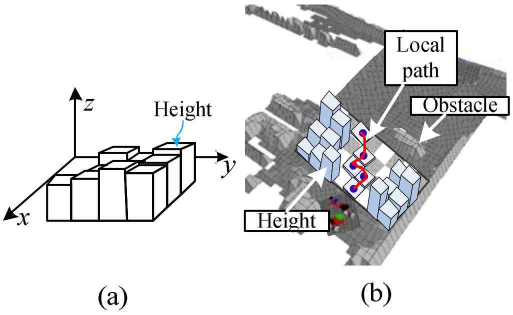


Fig. 4 Detection ranges of two laser scanners.

During navigation, the robot detects the environment to avoide obstacles, and it builds a local elevation map using range data obtained by the two laser scanners. As shown in Fig. 5(a), the height information of the terrain acquired through the laser scanners is stored in the map. The size of the local elevation map is 10m X 5m. Through the upper laser scanner, the height information within 5 m is acquired and through the lower laser scanner, the height information within 2m is acquired, obtaining more accurate height information. The local elevation map created in this way is used to generate the local path when an obstacle blocks the straight path. Because the distance bewteen the robot and the obstacle is measured by the scanners, the path is created in consideration of the radius of curvature (in this case, 1.5m). In addition, as shown in Fig. 5(b), by utilizing the height infornation stored in the local map, the robot can safely move and selects the cells whose distances to the obstacle is longer than 1.5m.



(a) (b)

Fig. 5 Generation of local path: (a) stored height in local map, and (b) local path generated using local map.

When the robot choose a grid as a local path to avoid the obstacle, the height value of the nearest 8 grids of the robot and the distance between the grid and the waypoint are acquired as shown in Fig. 6. The robot selects the grid that is the closest to the waypoint with the lowest elevation. The grids within the distance of 1.5m from the obstacle are ignored. And at the chosen grid, the above mentioned process is repeated. The robot avoides the obstacle by moving along the local path.

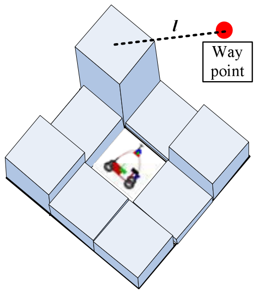
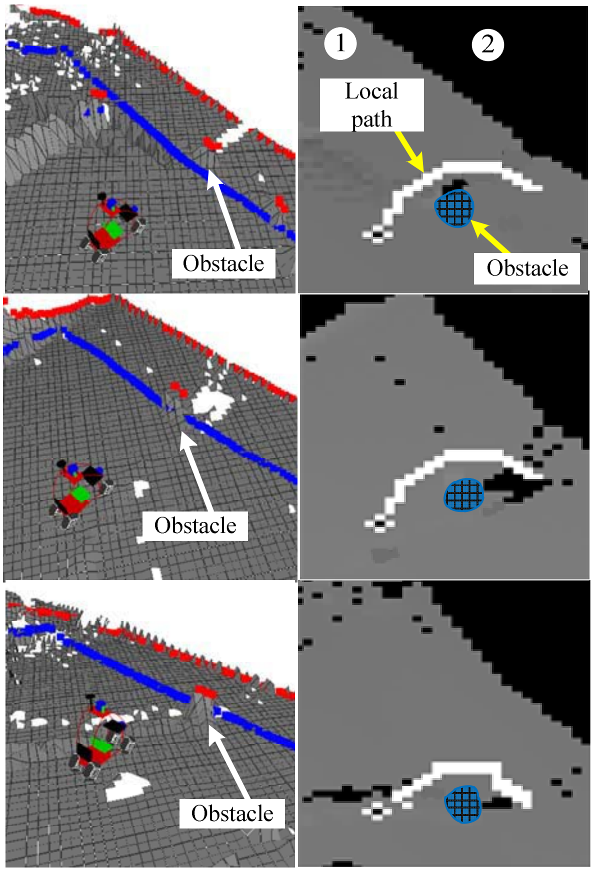


Fig. 6 Heights around the robot and distance to the waypoint.

4. Experiments

Figure 6 shows the local paths with the proposed method. Figure 6(a) shows the elevation map, which was built with the height value of the terrain through the laser scanners, and the obstacles. Figure 6(b) shows the local maps around the robot. Area 1 is the place where the surface was detected through the scanners and area 2 is the place that the laser scanners failed to recognize. In the local maps, it is shown that the path was created with some distance apart from the obstacle in consideration of the radius of curvature of the robot when an obstacle was detected.



(a) (b)

Fig. 7 Simulation results: (a) elevation map, and (b) local map.

5. Conclusions

This paper proposed a method to generate a local path and avoid the obstacles when the robot moves to the goal. The robot can safely avoid obstacles with this local path. In further research, the stability and performance of the proposed algorithm will be improved. In addition, a new obstacle avoidance scheme for the low-height and complex-shaped obstacles will be developed.

Acknowledgements

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References

[1] R. Siegwart and I. Nourbakhsh, Introduction to Autonomous Mobile Robots, The MIT Press, Cambridge, 2004.

[2] Borenstein, J., Koren, Y., “The Vector Field Histogram – Fast Obstacle Avoidance for Mobile Robots,” IEEE Transactions of Robotics and Automation, Vol. 7, No. 3, pp. 278-288, 1991.

[3] Simmons, R., “The Curvature-Velocity Method for Local Obstacle Avoidance,” Proc. of IEEE Int. Conference on Robotics and Automation, Vol. 4, pp. 3375-3382, 1996.

[4] D. Fox, W. Burgard, and S. Thrun, “The Dynamic Window Approach to Collision Avoidance,” IEEE Transactions on Robotics and Automation, Vol. 4, No. 7, pp. 23-33, 1997.

[5] T. M. Howard, and A. Kelly, “Optimal rough terrain trajectory generation for wheeled mobile robots,” Int. Journal of Robotics Research, Vol. 26, No. 2, pp. 141-166, 2007.

[6] T. M. Howard, C. J. Green, and A. Kelly, “State Space Sampling of Feasible Motions for High-Performance Mobile Robot Navigation in Complex Environments.” Journal of Field Robotics, Vol. 25, No. 6-7, pp. 325-345, 2008.