Path Planning with Risk Consideration by Hopping Mobility for Long Distance Traversability

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ABSTRACT

In this paper, a navigation method for a small size hopping rover with advantages on its mobility is discussed by considering with some uncertainties caused by jumping behavior and measurement error. By extracting obstacles from environmental data and constructing triangular polygons it is possible to form paths. the algorithm considers with safety of collision with obstacles, roughness of terrain and failures of hopping action, and then could generate safer path based on A* algorithm.

1 INTRODUCTION

In recent years, the surface exploration of the moon and the planet has been carried out with a rover. Most of the rover is a wheel type like the NASA Mars probe "Curiosity" [1]. Generally, heavy wheel rovers have more disadvantage in their mission. The launch opportunities tend to decrease at more intervals due to launch costs and development period. Also, since there is only one rover, its mission plan may be in a vicious circle because the system requires a lot of resources for safety measures. So, we need to find other approaches. One possibility is the introduction of a light and compact exploration robot agent, and it is possible that multiple types of agents work together in one system. Various roles (functions) can be played on various kinds of equipment, and all of them can constitute one exploration system as shown in Fig.1. By allocating the same function (equipment) to some or many of them, it is possible to ignore some percentage of the agent's loss rate, so that risk can be distributed to the system and the mission and there is a high possibility of obtaining higher efficiency.

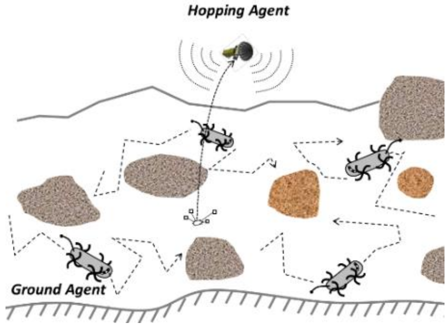

Figure 1: Multi Exploration

A small size rover has been studied at many places in recent years [2][3], and most of them show us much possibility and advantages caused with their size and weight. However, its size causes problems on its traversability and measurement ability. From our discussion to cope with disadvantage on small size body, we have introduced hopping mobility to obtain higher traversability and wider measurement range [4]. Especially under low gravitational environment such as other planet or satellite, it indicates higher performance [5], e.g.Thus, it can jump over a long distance upon terrains and obstacles, adopt a short-cut path without a detour of a wheeled type as shown in Fig.2, and also measure an environment from higher position in the air of jumping trajectory.

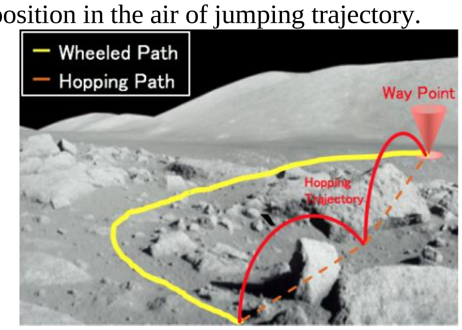

Figure 2: Advantage of hopping mobility Jump

2 ISSUE AND OBJECTIVES

Introduction of two types of rovers is being considered in the exploration system. One is a land-based agent and a stochastic existence region is given in the search region, contributing to the search of the ground surface. The other is hopping rover. the rover that makes path planning taking advantage of sensing from high places while moving the exploration area together with the ground moving rover plays an important role. I am considering this system using multiple small machines, but hopping rovers have problems to consider before. For a hopping rover, though a lot of jumping hardware designs have been studied, its software e.g. navigation algorithms have been discussed hardly. Nevertheless, some researches have been conducted, for example, they are discussed but which mainly use other mobility such as rolling function [6][7]. So, the navigation method hasn't been established by taking advantage of hopping mobility such as jumping over obstacles or a long distance yet. In this paper, a navigation method for a small size hopping rover with advantages on its mobility is discussed with some risk considerations on its mobility and measured data.

3 PATH PLANNING FOR HOPPING MOBILITY

3.1 Selection of Jumping Target Position

The uncertainty factor of hopping rover's jumping motion is the initial speed change, jump distance, jumping direction, bound after landing, failure of leap. Since these factors increase the risk of jumping motion, it is necessary to select the landing point. As shown in Fig. 3, to select a point distant from the obstacle, each obstacle captured by sensing is connected and the observation area is divided into triangles. By using Delaunay triangulation on the observed obstacles, we can set the landing point. In geometric figures, the point which is generally away from each vertex is the center of gravity, but in the case of triangle it is the outside heart. Since the outer heart is equally distant from each vertex, it can be said that it is safe if a certain margin can be secured.

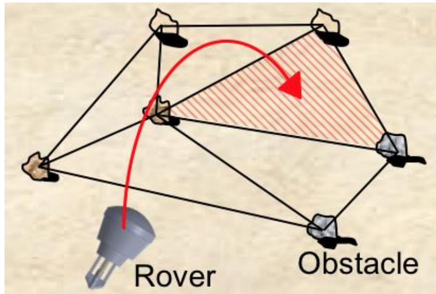

Figure 3: Landing Point: LP

Safety distance is secured by creating a circumscribed circle so as not to include other obstacles in the circle as shown in Fig. 4 when deciding the outside heart from the three obstacles.

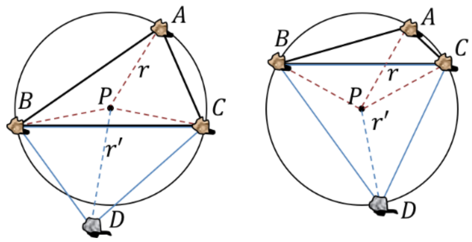

Figure 4: LP on circumcenter

3.2 Candidate Path Network

The Voronoi diagram is a method of dividing the region by joining the outer centers formed by Delaunay triangulation. As shown in Fig. 5, it can be confirmed that there are no obstacles on the sides of the Voronoi diagram enclosing the obstacles and safe nodes can be generated.

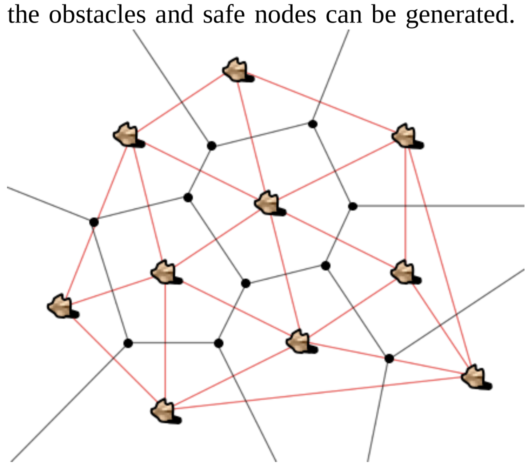

Figure 5: Possible Path Net

3.3 Add Uncertainty

The hopping rover assumes that it takes an ideal parabolic trajectory, but, there is uncertainty at the jumping movement and it contains an error. The error is generally given in the form of a normal distribution, which rides on the initial speed, the jumping angle, and the direction angle, respectively. These are accumulated each time the jumping movement is repeated. The position of the rover can be indicated as the existence probability, and generally takes a shape called an error ellipse. Fig. 6 shows the error ellipse at the position of the rover.

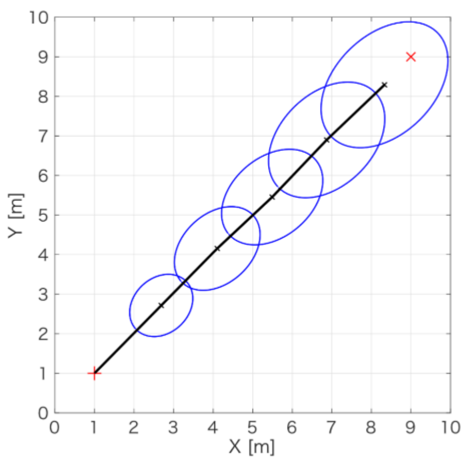

Figure 6: Rover Position and Error Ellipse

4 SIMULATION OF PATH PLANNING

We verified whether the hopping rover can be guided to the destination by the path planning by the proposed method. The simulation conditions are shown below.

- Simulation field shall be an area of 10 × 10 m. In addition, it is an ideal environment in which errors such as bounces do not occur.
- The initial position is (1,1) and the destination is (9,9).
- 50 obstacles are randomly generated at intervals of 1 (m).
- The hopping distance of the hopping rover is $R = 2$.

The simulation result is as shown in Fig. 7. The triangle in the figure is an obstacle, the circle is the node generated by the proposed method, and the green side is the rover path. From the result, it can be confirmed that Rover is guided from the start point to the destination according to the Path planning. Triangular obstacles are defined as points, but hopping rover can jump over obstacles and continue the path planning by A*algorizm, even if the obstacle is the size of the black part of the figure.

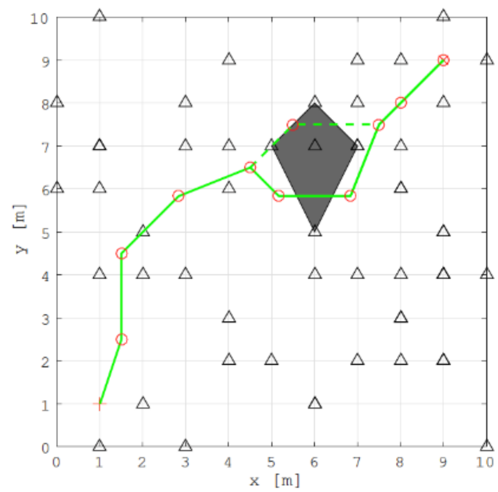

Figure 7: Simulation Result

Simulation was also carried out in the virtual lunar environment created based on the rock distribution collected by “Surveyor 7” of NASA. The landing area of “Surveyor 7” is steeper than the general landing point. Fig. 8 shows the dangerous zone where rocks are given a rover's radius of 15 cm and observation area of 10 cm in size and unnecessary nodes overlapping the rocks are removed. The simulation of the path planning in consideration of error accumulation results in the result of Fig. 9. When the occupancy rate of the obstacle in the error ellipse exceeds the threshold value, the rover performs self-position estimation. Accuracy has been restored by self-position estimation when the route is formed without problems and when the aircraft risk exceeds the threshold value in 6th leap.

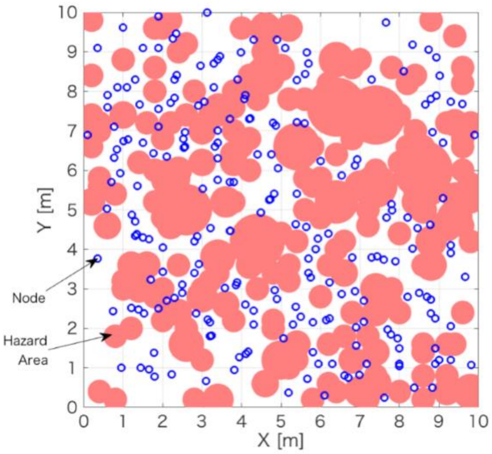

Figure 8: A Virtual Lunar Environment that Considers Dangerous Areas

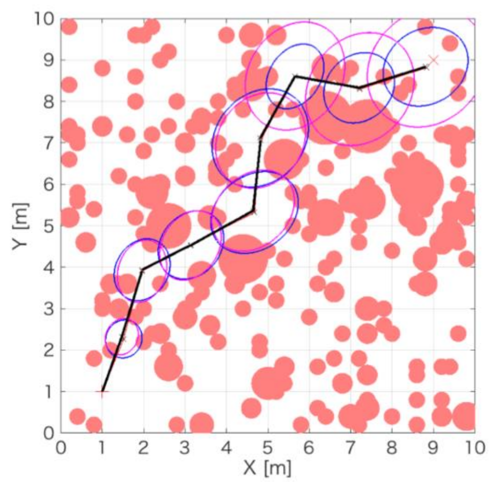

Figure 9: Path planning with Error Accumulation

5 CONCLUSION

The results of this research are summarized below.

- In consideration of the uncertainty of the hopping rover, we were able to determine a safe landing point.
- By performing self-position estimation in the virtual lunar environment, it was possible to induce Rover while suppressing position error. The effectiveness of the proposed method is shown in this result.

Acknowledgement

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