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# Self-localization Using Plural Small Rovers for Asteroid Wide-area Exploration

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*Abstract*— **This paper presents a new robot system consisting of plural small size rovers for an asteroid exploration. Each rover can communicate with others using radio, and a wireless mesh network is configured on an asteroid's surface. Our proposed system has the following three advantages against a conventional exploration system using one or two rovers: (1) It is possible to explore a wider area of an asteroid. (2) Since the mesh network has redundant communication paths, it has more robustness against some troubles. (3) It is possible to estimate the relative distances among plural rovers by using the mesh network. This relative distance estimation is useful for asteroid analyses using sensors that rovers have. Simulation results reveal the validity and effectiveness of our proposed rover system with the wireless mesh network and the relative distance estimation method.**

## I. INTRODUCTION

An exploration of asteroids is one of the active research areas in aerospace fields. It is expected to clarify the origin and evolution of the solar system by analyzing samples of the asteroids. Hayabusa (MUSES-C), an unmanned asteroid explorer developed by the Japan Aerospace Exploration Agency (JAXA), had launched in 2003 and approached the asteroid Itokawa in 2005, and returned samples of Itokawa to Earth in 2010 [1]. JAXA plans to launch the improved Hayabusa-2 [2] to the asteroid "1999 JU3" [3] that has features of C-type. The National Aeronautics and Space Administration (NASA) has also proposed that the OSIRIS-REx spacecraft will be launched to the asteroid "1999 RQ36" in 2016, and it will pluck samples from the asteroid and return them to Earth [4][5]. The sample return is one of the most important missions for these projects.

Meanwhile, MINERVA (the Micro/Nano Experimental Robot Vehicle for Asteroid) [6], a small planetary exploration rover, also traveled to Itokawa aboard Hayabusa in the original Hayabusa mission. The mission of Hayabusa was to bring samples back to Earth and to realize detailed analyses of the materials on Earth. On the other hand, the mission of MINERVA was to explore on the surface of Itokawa. In the Hayabusa 2 project, the improved MINERVA-II is going to be mounted on Hayabusa-2.

There are some research topics for a small planetary exploration rover like MINERVA. One is research and development for a movement mechanism that is suitable to explore under a microgravity environment [7][8][9][10]. It is said that a hopping mechanism is suitable for a microgravity environment in some papers. However, it is difficult to control an orientation of a rover at a landing point. The other is a proposal for a self-localization method for a rover. Yan, et al. proposed the self-localization method using asteroid surface images captured by plural cameras mounted on the rover [11]. Kanata, et al. proposed the self-localization method based on round-trip propagation delays derived when a rover on a asteroid and a mother spacecraft communicate with radio waves [12].

So, we propose a new robot system consists of plural small size rovers for an asteroid exploration in this paper. Each rover can communicate with others using radio, and a wireless mesh network is configured on a surface of an asteroid. Our proposed system has the following three advantages compared with a conventional exploration system using one or two rovers. Two antennas allow a crude form of direction finding.

(1) It is possible to explore a wider area of an asteroid.
(2) Since the mesh network has redundant communication paths, it has more robustness against some troubles.
(3) It is possible to estimate the relative positions among plural rovers by using the mesh network.

This mesh network is also able to be utilized as a sensor network system, moreover the results of the self-localization are useful for asteroid analyses using sensors that rovers are equipped with.

Our proposed rover is equipped with plural antennas of the diversity antenna system. When the rover as a communication node receives a packet from another one, RSSI (Received Signal Strength Indicator) can be obtained at the same time. The rover automatically selects two antennas from plural ones based on the strength of the RSSI values. This means that the rover can always communicate with others using a pair of antennas while selecting them in a good communication condition.

The RSSI values are also used for estimating the positions and orientations of the rovers. It is known that the relation among the RSSI values and the distances between two antennas is nonlinear because of the multipath propagation [13]. So, we make a mathematical model that expresses the relations among the RSSI values and the distances based on the actual RSSI values measured with the prototype rovers.

Lastly, we also propose a self-location estimation method. Since the relations among the RSSI values and the positions and orientations of the rovers are nonlinear, the genetic algorithm (GA) is used to solve this problem. Some simulation

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results reveal the validity and effectiveness of our proposed rover system with the wireless mesh network and the self-location estimation method using the GA.

## II. Wireless mesh network configured by plural rovers

### A. *Concept of exploration system consisting of plural small size rovers*

We propose a new robotic system consisting of plural small size rovers for an asteroid exploration. Figures 1 (a)(b) show our proposed exploration system. This system consists of plural rovers whose dimension is 30 $\sim$ 60 [mm] on a side in our plan. Each rover spreads apart and descends to an asteroid as shown in Fig. 1 (b).

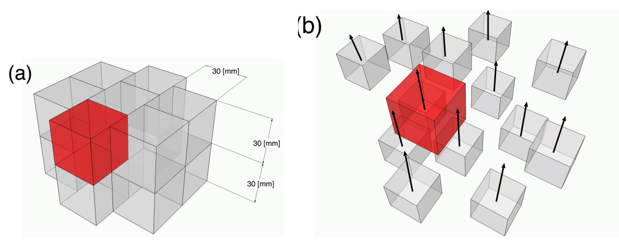


Fig. 1. Asteroid exploration system consisting of plural small rovers

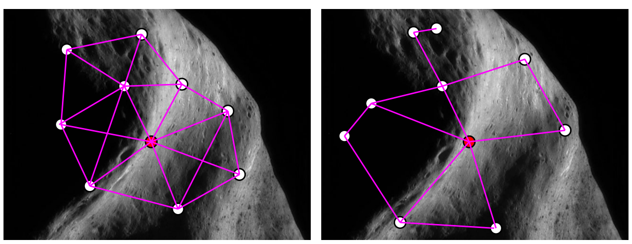

Fig. 2. Dynamic and redundant wireless mesh network configured by plural rovers

The rovers communicate with each other through a wireless network and establish a mesh-type network on the asteroid surface as shown in Fig. 2. The wireless mesh network offers multiple redundant communications paths through the network. If a network link or a rover as a network node fails for any reason, the network automatically routes messages through alternate paths. This means that the exploration mission can have high robustness against several troubles such as failures of a part of plural rovers. Moreover, the rovers can explore a wider area of the asteroid surface efficiently while changing the network topology as shown in Fig. 2. These ideas are useful for an asteroid exploration.

### B. *Rovers configure mesh network using ZigBee*

A rover equipped with a hopping mechanism [6][9] has a high mobility and it is effective to explore under a micro-gravity environment such as an asteroid's surface. However, when this type of rover lands on an asteroid's surface after hopping, it is difficult to control the orientation of the rover while hopping. Moreover, the position of the antenna from a ground is low because of the small size of the body, the orientation of the body sometimes gives some bad influences to communication quality. So we designed a rover equipped with twelve antennas using a diversity scheme as shown in Fig. 3. The rover can always communicate with others under the good condition by selecting a pair of antennas shown in the same color on the top side. For example, when the side where two antennas in light green are mounted is top as shown in Fig. 3, these two antennas are selected to communicate the other rovers. Here, let the selected antennas be the antenna $a$ and $b$ respectively.

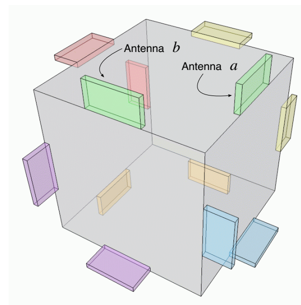


Fig. 3. Rover equipped with twelve antennas that can keep communication condition better

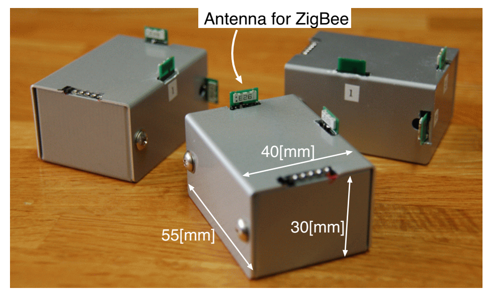


Fig. 4. Prototype of rover equipped with three antennas

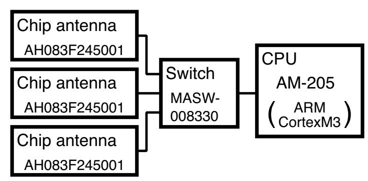


Fig. 5. Hardware configuration of prototype rover

Figure 4 shows prototypes equipped with three antennas. The hardware configuration of this prototype is shown in Fig. 5. It is composed of an onboard microcomputer, three chip antennas and a switch for selecting a antenna. The microcomputer (AM-205, Air Micro, Inc.) is suitable to control the rover totally, the features are listed bellow.

(1) The size is small as shown in Fig. 6.
(2) Electrical power consumption is low.
(3) It is compliant to 2.4 GHz band ZigBee/IEEE802.15.4 MAC protocol stack, and it is easy to configure a mesh network.
(4) It has enough input/output ports to control a movement mechanism, some devices and sensors and process several kinds of signals from plural sensors.

When the ZigBee module receives a packet from another one, RSSI is included in the packet. Two antennas with the strongest links are selected from combinations of the RSSI values based on RSSI strengths.

TABLE I
COMMUNICATION CONTENTS FROM ROVERS TO EARTH

| Node ID | Antenna | 1 $a$ | 1 $b$ | 2 $a$ | 2 $b$ | 3 $a$ | 3 $b$ | 4 $a$ | 4 $b$ | 5 $a$ | 5 $b$ | ··· |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | $a$ | — | — | $r_{1a\_2a}$ | $r_{1a\_2b}$ | $r_{1a\_3a}$ | $r_{1a\_3b}$ | $r_{1a\_4a}$ | $r_{1a\_4b}$ | $r_{1a\_5a}$ | $r_{1a\_5b}$ | ··· |
| | $b$ | — | — | $r_{1b\_2a}$ | $r_{1b\_2b}$ | $r_{1b\_3a}$ | $r_{1b\_3b}$ | $r_{1b\_4a}$ | $r_{1b\_4b}$ | $r_{1b\_5a}$ | $r_{1b\_5b}$ | ··· |
| 2 | $a$ | $r_{2a\_1a}$ | $r_{2a\_1b}$ | — | — | $r_{2a\_3a}$ | $r_{2a\_3b}$ | $r_{2a\_4a}$ | $r_{2a\_4b}$ | $r_{2a\_5a}$ | $r_{2a\_5b}$ | ··· |
| | $b$ | $r_{2b\_1a}$ | $r_{2b\_1b}$ | — | — | $r_{2b\_3a}$ | $r_{2b\_3b}$ | $r_{2b\_4a}$ | $r_{2b\_4b}$ | $r_{2b\_5a}$ | $r_{2b\_5b}$ | ··· |
| 3 | $a$ | $r_{3a\_1a}$ | $r_{3a\_1b}$ | $r_{3a\_2a}$ | $r_{3a\_2b}$ | — | — | NG | NG | $r_{3a\_5a}$ | $r_{3a\_5b}$ | ··· |
| | $b$ | $r_{3b\_1a}$ | $r_{3b\_1b}$ | $r_{3b\_2a}$ | $r_{3b\_2b}$ | — | — | NG | NG | $r_{3b\_5a}$ | $r_{3b\_5b}$ | ··· |
| 4 | $a$ | $r_{4a\_1a}$ | $r_{4a\_1b}$ | $r_{4a\_2a}$ | $r_{4a\_2b}$ | NG | NG | — | — | $r_{4a\_5a}$ | $r_{4a\_5b}$ | ··· |
| | $b$ | $r_{4b\_1a}$ | $r_{4b\_1b}$ | $r_{4b\_2a}$ | $r_{4b\_2b}$ | NG | NG | — | — | $r_{4b\_5a}$ | $r_{4b\_5b}$ | ··· |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋱ |

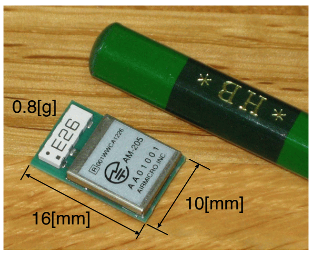


Fig. 6. Onboard microcomputer with ZigBee communication module

## III. SELF-LOCALIZATION USING MESH NETWORK

### A. Communication contents

When the rover as the communication node receives a packet from another one, RSSI can be obtained at the same time. Table I shows an example of the communication contents related to RSSIs. Where, $r_{ai\_bj}$ is a RSSI value from an antenna $a$ mounted on a node ID $i$ to an antenna $b$ mounted on a node ID $j$, and NG means communication failure. Let the number of the rovers be $n$. Since two antennas per the rover are used for communication as described in the previous subsection, the number of the RSSI values is $4n(n-1)$ combinations. Let the data size of RSSI be 1 [byte] and the number of the rovers be $n = 10$, the data size of the RSSI values is only 360 [byte]. Of course, since the rover transmits and receives observation data collected by onboard several sensors, an actual transmission data size increases. The calculation of the self-location estimation is complex, and it is not suitable for the low power consumption onboard microcomputer in the rover to calculate it. In our plan, all the RSSIs obtained among rovers are transferred to Earth, complex calculations are executed on a more powerful computer on Earth.

### B. Relation between RSSI and distance

The actual RSSI values were measured on the wide and flat field in order to clarify the relation among the RSSIs and distances as shown in Fig. 7. A pair of AM-205 ZigBee modules were placed opposite each other, and the distances and RSSI values were measured while changing the distance between two ZigBee modules. The distances were measured by a laser range finder (LRF).

The measurement results are shown in Fig. 8. It is known that a relation between a RSSI value and a distance is nonlinear because of the multipath propagation in radio signals when a pair of antennas have a certain degree of height [13]. However, when the antenna level is lower than the wavelength, the influence of the multipath disappears. Since the wavelength for 2.4 [GHz] is 125 [mm] and the level of antenna was 33 [mm] high, we could get the linear characteristics of RSSI as shown in Fig. 8.

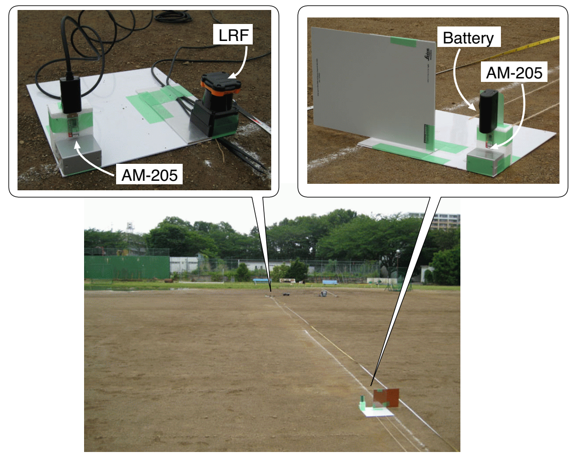


Fig. 7. RSSI measurement experimental environment

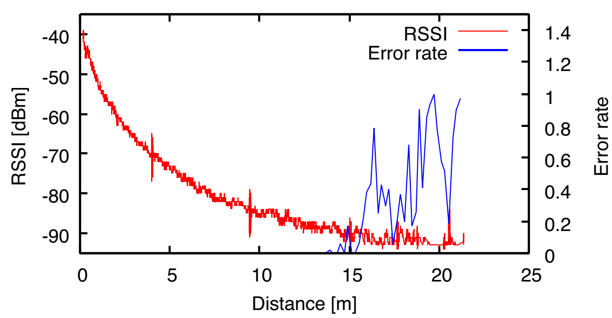


Fig. 8. Relation among RSSI values and distances

Figure 9 shows the relations among the RSSI values and the horizontal angles of the antenna. One antenna was fixed and the other one was turned around at a fixed velocity by a motorized rotation stage made of plastic. We measured the RSSI values at the distance of 5 [m] and 10 [m]. When a pair of the antennas were placed opposite each other, let the angle be 0 [deg]. The RSSI value changes in the range of about $\pm 2.5$ [dBm] regardless a distance between two antennas. So we can design a mathematical model related the based on these characteristics of this antenna as shown in Fig. 10.

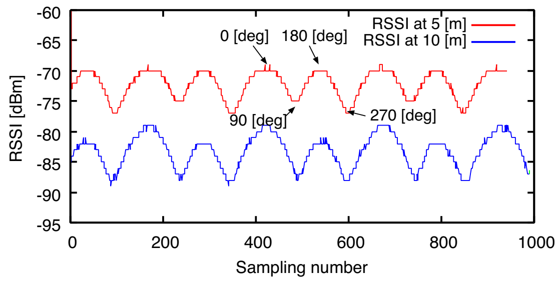


Fig. 9. Relation among RSSI values and horizontal angles of antenna

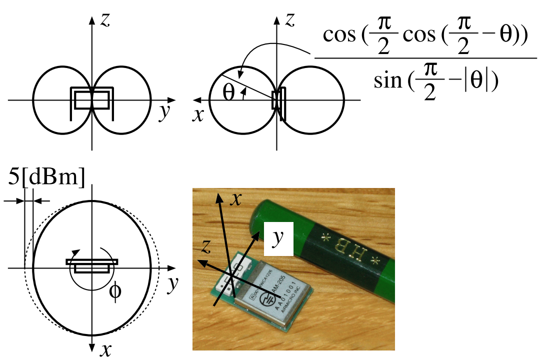


Fig. 10. Characteristics of antenna mounted on rover

We describe the relations among some coordinate systems set on the rover and antennas before designing the mathematical model based on these measurement results. The rover $i$ $(i = 1, ..., n)$ has a coordinate system $\Sigma_i$ as shown in Fig. 11, and two antennas $ai$ and $bi$ mounted on the rover $i$ also have coordinate systems $\Sigma_{ai}$ and $\Sigma_{bi}$ respectively as shown in Figs. 10 and 11. Here, let $\Sigma_{m1}$ of the rover 1 be the reference coordinate system for the other rovers. ${}^1\boldsymbol{p}_{ai} \in \boldsymbol{R}^{3\times 1}$ means the position of the antenna $ai$ mounted on the rover $i$ in $\Sigma_1$, and ${}^1\boldsymbol{R}_{ai} \in \boldsymbol{R}^{3\times 3}$ means the orientation of the antenna $ai$. So, for example, the relative positions between the antenna $ai$ of the rover $i$ and the antenna $bj$ of the rover $j$ are shown in the following equations.

$$\left\{\begin{array}{lcl} {}^1\boldsymbol{p}_{ai} &=& {}^1\boldsymbol{p}_{bj} + {}^1\boldsymbol{R}_{bj}{}^{bj}\boldsymbol{p}_{ai} \\ {}^1\boldsymbol{p}_{bj} &=& {}^1\boldsymbol{p}_{ai} + {}^1\boldsymbol{R}_{ai}{}^{ai}\boldsymbol{p}_{bj} \end{array}\right. \quad (1)$$

$$\Leftrightarrow \left\{\begin{array}{lcl} {}^{ai}\boldsymbol{p}_{bj} &=& {}^{ai}\boldsymbol{R}_o({}^1\boldsymbol{p}_{bj} - {}^1\boldsymbol{p}_{ai}) \\ {}^{bj}\boldsymbol{p}_{ai} &=& {}^{bj}\boldsymbol{R}_o({}^1\boldsymbol{p}_{ai} - {}^1\boldsymbol{p}_{bj}) \end{array}\right. \quad (2)$$

Next, let the angle of the horizontal direction from the antenna $ai$ to the antenna $bj$ be ${}^{a_i}\phi_{b_j}$, the elevation angle be ${}^{a_i}\theta_{b_j}$ as shown in Fig. 12. ${}^{a_i}\phi_{b_j}$ and ${}^{a_i}\theta_{b_j}$ can be shown in the following equations using the relative position ${}^{ai}\boldsymbol{p}_{bj} = ({}^{ai}x_{bj} \ \ {}^{ai}y_{bj} \ \ {}^{ai}z_{bj})$.

$${}^{a_i}\phi_{b_j} = \arctan\left(\frac{{}^{a_i}y_{b_j}}{{}^{a_i}x_{b_j}}\right) \quad (3)$$

$${}^{a_i}\theta_{b_j} = \arctan\left(\frac{{}^{a_i}z_{b_j}}{\sqrt{{}^{a_i}x_{b_j}^2 + {}^{a_i}y_{b_j}^2}}\right) \quad (4)$$

The mathematical model $r$ of the RSSI can be expressed in the following equations using Eqs. (2)(3)(4) and the antenna characteristic shown in Fig. 10.

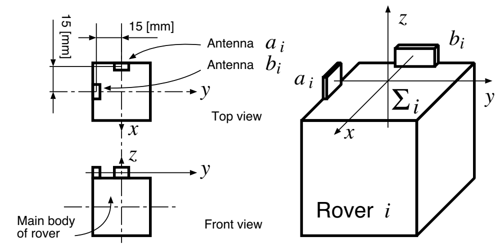


Fig. 11. Layout of two antennas

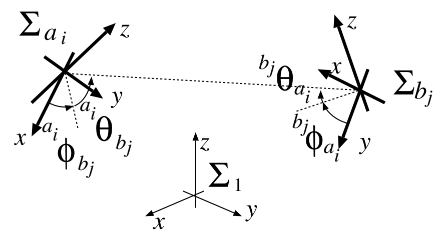

Fig. 12. Relation between coordinate systems related to two antennas

$$\begin{aligned} r({}^{ai}x_{bj}, {}^{ai}y_{bj}, {}^{ai}z_{bj}, {}^{ai}\phi_{bj}, {}^{ai}\theta_{bj}, {}^{bj}\phi_{ai}, {}^{bj}\theta_{ai}) = \\ r'({}^{ai}x_{bj}, {}^{ai}y_{bj}, {}^{ai}z_{bj}) + \\ r_h({}^{ai}\phi_{bj}) + r_h({}^{bj}\phi_{ai}) + \\ r_v({}^{ai}\theta_{bj}) + r_v({}^{bj}\theta_{ai}) \end{aligned} \quad (5)$$

where,

$$r'(x, y, z) = -14.69\log_{10}(\sqrt{x^2+y^2+z^2} + 0.31) - 49.17 \quad (6)$$

$$r_h(\phi) = 2.5(\cos(2\phi) - 1) \quad (7)$$

$$r_v(\theta) = 25\left(\frac{\cos\left(\frac{\pi}{2}\cos\left(\frac{\pi}{2} - \theta\right)\right)}{\sin\left(\frac{\pi}{2} - |\theta|\right)} - 1\right) \quad (8)$$

Equation (6) is the approximate equation derived from the actual measured values as shown in Fig. 8. When $\theta = 0$ [deg] and 45 [deg], $r_v = 0$ [dBm] and -10 [dBm] from the specification sheet [14] of the chip antenna (AH083F245001, Taiyo Yuden Co., Ltd) used in this paper. Besides, since this chip antenna is an inverted F, $r_h(\phi)$ is designed as shown in Eq. (8).

Of course, since radio propagation in space is different from one in the atmosphere, we are going to make a more precise mathematical model again after considering a space environment in the near future.

### C. Self-localization using Genetic Algorithm

When the rover communicates each other on an asteroid, the onboard microcomputer automatically selects two antennas from twelve ones based on the strength of the RSSI values. Two antennas on the top side of the rover are normally selected. In the case of the orientation of the rover shown in Fig. 3, a pair of the antennas in light green are selected. Because the level of these antennas is the highest and these orientations are better for the gain and directionality of the antennas. When the antenna $a$ mounted on the rover $i$ receives a packet sent from the antenna $b$

mounted on the rover $j$, let the RSSI value be $r_{ai\_bj}$. When $n$ rovers communicate each others, $4n(n-1)$ RSSI values are obtained. However, since both $r_{ai\_bj}$ and $r_{bj\_ai}$ have the same value in theory, $4 \times {}_nC_2$ RSSI values are used for self-localization. This means that when the positions and orientations are estimated on the two dimensional plane, the least number of the rovers is two. And when they are estimated in the three dimensional space, the least number of the rovers is three.

It is necessary to solve the nonlinear simultaneous equations shown in Eqs. (5) $\sim$ (8) to estimate the positions ${}^1\boldsymbol{p}_i$ and orientations ${}^1\boldsymbol{R}_i$ of all the rovers. So, in this paper, we use the genetic algorithm (GA) to solve this problem. Let the measured and estimated RSSI values $(i = 1, \cdots, n)$ be $r_{m\_ai\_bj}$ and $\hat{r}_{ai\_bj}$ respectively. When a distance between two rovers is long, since the precision and distance resolution of RSSI become low, the evaluation function $f(r)$ of the GA was designed as shown in the following equation.

$$f(r) = \sum_{i=1}^{n} \sum_{j=i+1}^{n} \{(r_{ai\_bj} - \hat{r}_{ai\_aj})^2 + (r_{ai\_bj} - \hat{r}_{ai\_bj})^2 + (r_{bi\_aj} - \hat{r}_{bi\_aj})^2 + (r_{bi\_bj} - \hat{r}_{bi\_bj})^2\} \quad (9)$$

## IV. Experimental Results

In this section, we describe conditions of the experiments and show some simulation results of the self-location estimation to evaluate our proposed method.

### A. Conditions of genetic algorithm

GAlib [15], the C++ library of genetic algorithm components, was used to implement the GA. The conditions of the GA is shown in Table II. Currently, it is not enough to adjust these parameters, and a solution with high accuracy is not always estimated. So the generational process is repeated 1000 times, and the best solution is chosen from the 1000 solutions as the estimation values.

TABLE II

Conditions of GA

| | |
|---|---|
| Generation | 20000 |
| Population | 20 |
| Crossover rate | 0.9 |
| Mutation rate | 0.02 |
| Crossover | Single-point crossover |
| Selection | Roulette wheel selection |

Each search range for the rover position ($x$, $y$, $z$) is -20 [m] $\sim$ 20 [m] respectively, and search ranges for the rover orientation (roll, pitch, yaw) are $\pm\pi/4$, $\pm\pi/4$ and $\pm\pi$ respectively.

Two antennas are set on the top of the rover and their positions and directions are shown in Fig. 11.

### B. Self-localization using three rovers

First, we performed an experiment under a simple condition. Three rovers were placed on the $x$-$y$ plane as shown in Fig. 13. The number of rovers is a smallest value to estimate all relative positions and orientations of the rovers.

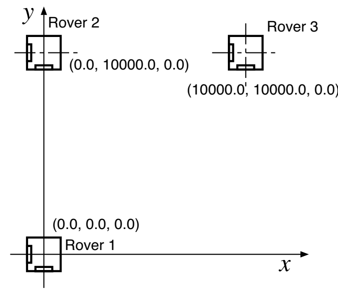


Fig. 13. Positions and orientations of three rovers

We found that accuracies of estimated orientations of the rovers were not good because of the nonlinear characteristics of the antenna through preliminary experiments. Then we evaluated the relative distances among the rovers. Table III shows the estimated distances $d_{ij}$ between each two rovers. The distances $d_{ij}$ are estimated within the error rate 2.3 [%].

TABLE III

Estimated distances among three rovers

| | True value [mm] | Estimated value [mm] | Error rate [%] |
|---|---|---|---|
| $d_{12}$ | 10000.0 | 9980.0 | 0.2 |
| $d_{13}$ | 14142.1 | 14004.2 | 1.0 |
| $d_{23}$ | 10000.0 | 9771.2 | 2.3 |

### C. Self-localization using five rovers

Next, we performed an experiment under a little more complicated condition. Five rovers were placed on the $x$-$y$ plane as shown in Fig. 14.

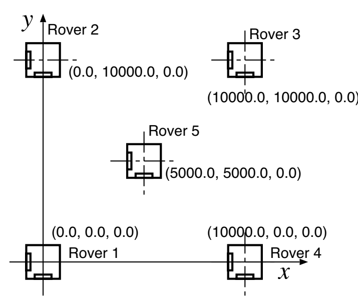


Fig. 14. Positions and orientations of five rovers

Table IV shows the estimated distances $d_{ij}$ between each two rovers. Although the estimate accuracies were a little lower than the previous experimental results, the worst error rate was 6.2 [%].

TABLE IV

Estimated distances among three rovers

| | True value [mm] | Estimated value [mm] | Error rate [%] |
|---|---|---|---|
| $d_{12}$ | 10000.0 | 9379.5 | 6.2 |
| $d_{13}$ | 14142.1 | 13620.6 | 3.7 |
| $d_{14}$ | 10000.0 | 9846.9 | 1.5 |
| $d_{15}$ | 7071.1 | 6809.2 | 3.7 |
| $d_{23}$ | 10000.0 | 10114.9 | 1.1 |
| $d_{24}$ | 14142.1 | 13609.3 | 3.8 |
| $d_{25}$ | 7071.1 | 6864.8 | 2.9 |
| $d_{34}$ | 10000.0 | 9549.0 | 4.5 |
| $d_{35}$ | 7071.1 | 6859.3 | 3.0 |
| $d_{45}$ | 7071.1 | 6842.3 | 3.2 |

### D. Discussion and future works

These estimation results show that our proposed method works well. However, the following problem was revealed.

- The real and estimated relative positions and orientations of some rovers are sometimes symmetric about the $x$, $y$ and/or $z$ axes.

Figure 15 shows one example of this problem. Although the distances among the rovers were estimated well, the estimated positions are symmetric about the $y$ axis. The reason is that since the relation among a rover's distance, position and orientation as shown in Eqs. (6) $\sim$ (8) has the nonlinear characteristics, there are some approximate solutions (local minimums) in the symmetric positions or orientations.

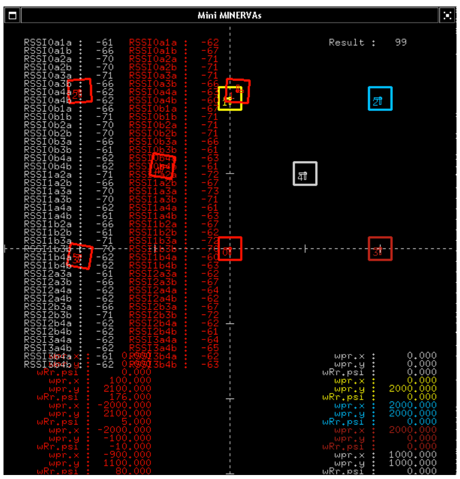


Fig. 15. Estimated position of rover symmetrically

In the present situation, it is not clear whether the rover's orientation is important for an asteroid exploration or analysis or not. Moreover, although we believe that we could get good distance estimation results, it is not sure whether these results are enough good or not. So, we are going to investigate an accuracy required for an asteroid exploration during taking advice from some experts of asteroid analysis. At the same time, since the number of the rover was only five in this paper, we are going to increase to fourteen rovers as shown in Fig. 1.

Some plans for the next stage are described below. First, we will perform self-location estimation experiments using the prototypes of the rover made in this paper. Second, since the antenna characteristics were measured on the flat place, we have to evaluate our method under more realistic conditions, such as an uneven place. Third, although 2.4 GHz band ZigBee was used in this paper, since it is said that 900 MHz is more robust against a problem of occlusion between two antennas, we would like to evaluate a communication system using 900 MHz.

## V. Conclusion

We have proposed a new robot system that consists of plural rovers. The plural rovers connect each other with a wireless network, and is able to construct a mesh network. We also have proposed a self-location estimation method using the genetic algorithm. Some simulation results revealed the validity and effectiveness of our proposed method.

Our proposed system can be utilized to a sensor network for and analyzing an asteroid, and also explore a wider range on an asteroid surface efficiently and execute tasks robustly against troubles.

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