Rescue Robot under Disaster Situation: Position Aquisition with Omnidirectional Sensor

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Abstract

In this paper, we describe the network system for rescue robot. We construct communication infrastructure by using commnunication tags placed dynamically by the rescue robot under the situation that exisiting infrastructure collapsed by the disaster. To get the position coordinate of the rescue robot, we use "angle" obtained from Ommnidirectional Sensor mounted on the communication tag. By using "angle", we would reduce the error than using "distance" obtained from radio waves. In this paper, ~~we~~ show that our argorithm is feasible by the simulation.

1 Introduction

We expect activity of the rescue robot under the situation that the buildings or undergroud shopping areas collapsed by the disaster (e.g. earthquake). By introducing the rescue robot, we can avoid from the involvement the secondary disaster and can acheive rescue effort more efficiently.

Under the situation of the disaster, however, the problem occures that it is difficult to communicate with the rescue robot. For instance, we can not communicate with the rescue ~~robot when the robot gets into collapsed~~ underground shopping areas. By using the existing communication infrastracture, we can communicate with the rescue robot, but the existing infrastracture probably collapsed due to the disaster. In addition, another problem also occurs that it is difficult to get the position coordinate of the rescue robot. To solve this problem, we think of the means that we place sensors beforehand, but some of them placed beforehand are probably damaged due to the disaster.

To solve these two problems, ~~we think of the means that we~~ construct the sensor network dynamically. ~~We can ensure the communication infrastructure~~ by placing the sensor nodes and constructing the sensor network. ~~Furthermore~~ the sensor ~~node that has~~ some mesure equipment, ~~to measure the location of the rescue robot, we can get the position coordinate of the rescue robot.~~ Using GPS is the most popular solution to get the position coordinate, but it is not appropriate because GPS signal is too week for ~~floors~~ and mounting the GPS on the all nodes ~~is impossible. Therefore we need to consider~~ the method to get the position coordinate in the Sensor Network whithout using GPS. ~~It is classified broadly into~~ three categories as ~~follows~~: 1)getting the position coordinate from range ~~of access~~ of beacon, 2)getting the position coodinate from the minimum value of the error between the estimated coodinate and the ~~ranging~~ value[ ], 3)getting the position coodinate from the triangulation[3]. Each of these methods computes the position coordinate using the "distance" obtained from radio waves (e.g. radio field intensity, ToA (Time of Arrival)). However, ~~distance probably yield an error caused being~~ affected by RFI (Radio Frequency Interference) in the collapsed buildings or the collapsed underground shopping areas. ~~Therefore~~, it is not appropriate to compute the position coordinate using the "distance" under the situation of the disaster.

The purpose of this paper is to construct ~~the~~ network system for the rescue robot working under the situation of the disaster. We ~~ensure~~ the communication infrastructure by placing the communication tags ~~dynamically~~, and to the position coordinate of the rescue robot, ~~use~~ "angle" obtained from the image that Ommnidirectional Sensor mounted on communication tag ~~captures~~.

This paper is organized as follows. In section 2, ~~describe~~ the problems under the situation of disaster and the outline of our approach. In section 3, ~~present~~ the details of our approach. In section 4 ~~we present~~ the results of the simulation. ~~In~~ section 5 ~~we~~ concludes this paper.

2 Localization Estimate in Disaster Area

2.1 Disaster Area

We assume that the place in which the rescue robot works is in the collapsed buildings or the collapsed underground shopping areas. In this case, the two following problems occur:

- Problem1:

  We can not communicate with the rescue robot when the rescue robot gets into the collapsed buildings or collapsed underground shopping areas. Because the existing communication infrastructure collapsed.

- Problem2:

  It is difficult to get the position coordinate of the rescue robot. Because the geographical feature in the building or the underground shopping area is probably changed.

The other problems is such that there are many obstacles (e.g. rubble) and there is the threat of the secondary disaster.

2.2 Our Approach

As describe in the previouse section, we have two problems under the situation of the disaster. Therefore we need to achive the two things as follows:

1. to ensure the communcation infrastructure

2. to get the position coordinate of the rescue robot

Constructing the sensor network dynamically is the solution for the two problems. By constructing it, We can ensure the communication infrastructure and we can get the position coordinate of sensor nodes and the rescue robot if the sensor nodes have some mesure equipment and use the mesuring algorithm.

In our approach, the resuce robot places the communication tags dynamically to construct the sensor network to solve two problems as mentioned above. We can ensure the communication infrastructure by it. As to getting the position coordinate, we use the "angel" from the image that the Ommnidirectional Sensor mounted on the communication tag captures instead of using "distance".

2.2.1 System Configuration

Our approach consists of the communication tags placed dynamically and the robot that places the communication tags. We equip the communication tag and the robot respectively whit the following things (see Fig.1):

- communication tag
  - Ommnidirectional Sensor
  - LED turning blink to send ID of Ommnidirectional Sensor
- robot
  - two communication tags

    The robot has the two communication tags that are the same one placed on the ground by the robot.
  - reference length : R

    The distance between the two communication tags is R, and the two communication tags are mounted on the place with certain level of hight.
- server

  The server stores the caluculated position coordinate of the communication tags or the robot. The server might make some map if necessary.

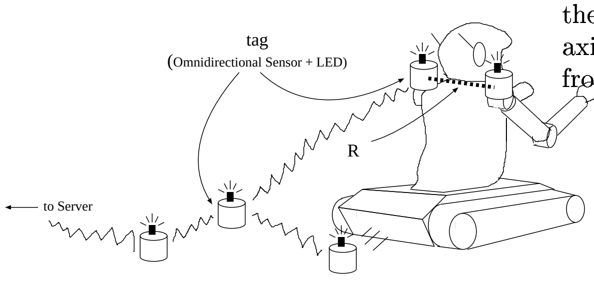

Figure 1: System Configuration

The robot gets into the collapsed buildings and places the communication tags on the ground. We can ensure the communication infrastructure thanks to ad-hoc network that the communication tags construct. Moreover, each communication tag that placed on the ground or mounted on the robot computes the position coordinate using two data as follows:

- angle to other communiation tags around onself

  To get the angle, each of the communication tags finds the LEDs of other tags in the image the Ommnidirectional Sensor captures.
- reference length : R

We will show how to compute the position coorinate using these two data the section 3.

2.2.2 Omnidirectional Sensor

In this part fo this paper, we would like to explain about the Omnidirectional Sensor that play an important role in our study. The Omnidirectional Sensor is shown in Fig.2 and can capture the image in all directions (around 360°) as the name implies. Fig.3 shows the capture image. We define the line in Fig.3 as the direction of 0° and we refer it as "sensor axis". The degree increses counterclockwise from the sensor axis (equals 0°) to 360°.

Figure 2: Omnidirectional Sensor

Figure 3: Capture Image

3 Dynamical Localization Estimate for The Disaster Area

In this section we show how to compute the position coorinate using "angle" obtained from the Omnidirectional Sensor.

3.1 Proposal Algorithm

In our approach the rescue robot places the communication tags dynamically. We can ensure the communication infrastructure thanks to ad-hoc network that the communication tags construct. In addion, we can get the position coordination along the following procedure.

1. **robot places the first tag**

   we refer this tag as "reference tag".

   - we define reference tag as the origin of the plane with the coordinate system
   - we define the sensor axis of the reference tag as X-axis of the plane with the coordinate system ($i.e$ the direction of 90° to the counterclockwise rotation from the sensor axis is Y-axis)
   - we will get the position coordinates of the robot and the communication tags that placed one-by-one on this plane with the coordinate system

2. **get the position coordinate of the robot**

   The reference tag can get the position coordinate of the robot as long as the Omnidirectional Sensor of the referenc tag can see the robot. In this papar, the position coordinate of the robot means the position coordinates of the two communication tags mounted on the robot.

   In Fig.4, node A and node B indicate the communication tags mounted on the robot. we can compute these coordinates using sine rule as follows.

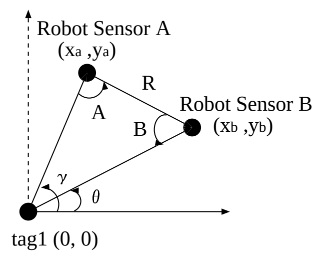

Figure 4: Coordinates of The Robot

$$
\begin{aligned}
\frac{R}{\sin(\gamma-\theta)} &= \frac{\sqrt{x_b^2+y_b^2}}{\sin A} \\
&= \frac{\sqrt{x_b^2+x_b^2\tan^2\theta}}{\sin A} \\
&= \frac{\sqrt{x_b^2(1+\tan^2\theta)}}{\sin A} \\
&= \frac{\sqrt{x_b^2\frac{1}{\cos^2\theta}}}{\sin A} = \frac{x_b}{\sin A\cos\theta} \\
\therefore x_b &= \frac{R\sin A\cos\theta}{\sin(\gamma-\theta)} \qquad (1) \\
y_b &= x_b\tan\theta \qquad (2)
\end{aligned}
$$

If θ equals $\frac{1}{2}\pi$ or $\frac{3}{2}\pi$, we compute y_b using sine rule and judge positive or negative from the value of $\sin\theta$:

$$y_b = \frac{R}{\sin(\gamma - \theta)} \sin A \sin \theta \tag{3}$$

3. **robot places the second tag**

   The second tag adjusts its own sensor axis to have the same direction as the reference tag. If the sensor axis of the second tag have the same direction as the refecence tag, the relation between θ and γ is $\theta - \gamma = \pi$. This is illustrated in Fig.5.

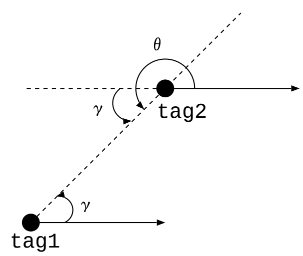

Figure 5: $\theta - \gamma = \pi$

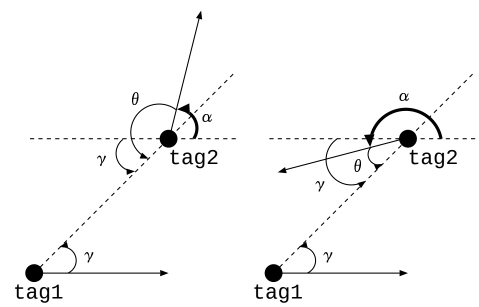

Figure 6: $\theta - \gamma \leq \pi$

   There are two possible situation. The first situation is a) $\theta - \gamma > \pi$ and the second situation is b) $\theta - \gamma \leq \pi$. We show how to compute α that indicate difference between the sensor axes of the reference tag and the second tag:

   (a) if $\theta - \gamma \leq \pi$ (Fig.6)

$$\begin{aligned} (\theta - \gamma) + \alpha = \pi \\ \therefore \alpha = \pi - (\theta - \gamma) \end{aligned} \tag{4}$$

   (b) if $\theta - \gamma > \pi$ (Fig.7)

$$\begin{aligned} \theta - \gamma - \pi + \alpha &= 2\pi \\ \therefore \alpha &= 3\pi - (\theta - \gamma) \end{aligned} \tag{5}$$

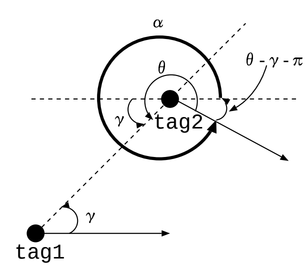

Figure 7: $\theta - \gamma > \pi$

   After adjusting its own axis, the second tag computes its own position coordinate using the angle and the position coordinate obtained from two around commnication tags that have already known own position coordinate (Fig.8).

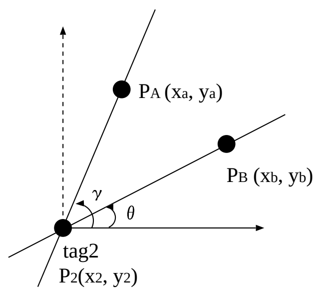

Figure 8: Compute Own Coordinates

In Fig.8, we compute the position coordinate of the node P_2 on the assumption that we have already known the position coordinates of node P_A and node P_B.

The straight line passing through node P_2 and node P_A is

$$y = \tan\gamma(x - x_a) + y_a$$

and the straight line passing through node P_2 and node P_B is

$$y = \tan\theta(x - x_b) + y_b$$

Therfore we can get the position coordinate of node $P_2(x_2, y_2)$ by computing the intersection point of these two lines:

$$\begin{cases} x_2 = \frac{(x_a \tan\gamma - y_a) - (x_b \tan\theta - y_b)}{\tan\gamma - \tan\theta} \\ y_2 = \tan\gamma(x_2 - x_a) + y_a \end{cases} \tag{6}$$

If θ (or γ) equals $\frac{1}{2}\pi$ or $\frac{3}{2}\pi$, we can get the position coordinate of node $P_2(x_2, y_2)$ as follows:

$$\begin{cases} x_2 = x_a \\ y_2 = \tan\theta(x_a - x_b) + y_b \end{cases} \tag{7}$$

As shown here, the second tag computes its own position coordinate asking two communication tags around that have already known own position coordinate. However there ara only reference tag around the second tag, so the second tag must ask one of the commnication tag mounted on the robot. Therefore the robot needs to get own position coordinate just before placing the second tag.

4. **robot places more tags**

   To get the position coordinate we repeat procedure 3.

We have explained the procedure for getting the postion coordinate. Equation (1)∼ equation (7) show that we can get the position coordinate using "angle". It is important to note that we can not compute the postion coordniate if the three communication tags lie on same line because neither equation (1) nor equation (7) are usable.

3.2 Consideration

In this section, we consider the advantages and disadvantages of using "angle" obtained from the Omnidirectional Sensor.

- advantage
  - reduce error

    We can get the accurate "angle" using the Omnidirectional Sensor.
  - get the topographical features

    In our study, the Omnidirectional Sensor can capture the upper side image. Therefor it is happens that Omnidirectional Sensor A can see find Omnidirectional Sensor B, but B can not find A (Fig.9). We can get the topographical features using this particularity.

    In Fig.9, we can get the topographical features that B is placed on the higher position than A.

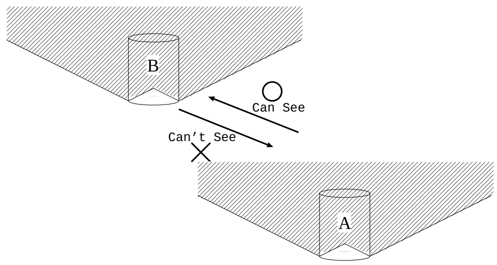

Figure 9: Characteristic of Ominidirectional Sensor

- get the additional information from the capture image

  We can get the additional information from the image the Omnidirectional sensor captures. We can utilize this inofrmation to get the situation of disaster.

- disadvantage

  - place the communication tags in hollow

    In the situation of the disaster, the ground probably rise in the collapsed building or collapsed underground shopping area. If the rescue robot places the communication tags respectively in the defference hollow of the ground, these communication tags can not get own position coordinate because they can not find two communication tags around them. Therefore to avoid this case, the rescue robot must take care to places several sensors on the hill.

4 Simulation

In this paper, we show that our algorithm is feasible by the simulation. We make the simulation server that knows all the position coordinates of the robot and the communication tags for this simulation. The simulation server works as follows.

- store all the position coordinates of the communication tags and the robot when the robot move or places the communication tag.
- return the angle computed from stored postition coordinates to the requestor.

When the robot or the communication tag compute the postion coordinate, they request the angle to the simulation server. Then they compute the postion coordinate using the angel given from simulation server.

We show the result of the simulation in Fig.10∼Fig.12. Two nodes and the straight line that connects those two nodes indicate the robot, and single node indicate communicatation tag. The communication tag have a short straight line that indicate sensor axis.

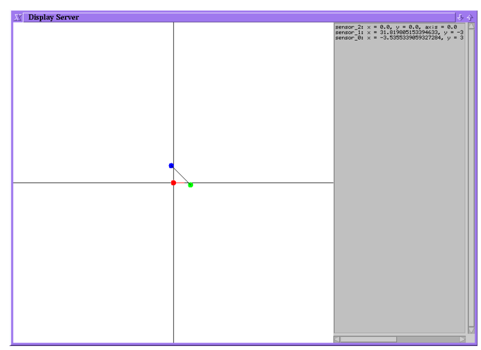

Figure 10: Simulation-1

Fig.10 shows that the robot places the reference tag and get own position coordinate. This is procedure 2 in section 3. We see that the sensor axis of the reference tag is equal to X-axis of the screen. The robot computes own position coordinate using the angle to the reference tag, angle from the reference tag and reference length R the robot has.

Fig.11 shows that the robot places the second tag and the third tag. The robot compute own position coordinate asking $(n-1)$th tag $(n \geq 2)$ just before placing the nth tag. Threfore the second tag can compute own position coordinate asking the reference tag and one of the communication tag mounted on the robot.

Fig.12 shows that the robot places ten communication tags repeating the previous procedures.

The result of our simulation shows that using "angle" to get position coordinate is feasible.

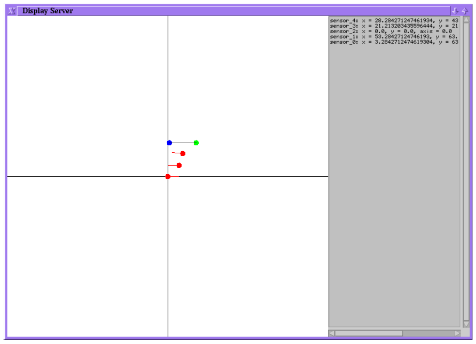

Figure 11: Simulation-2

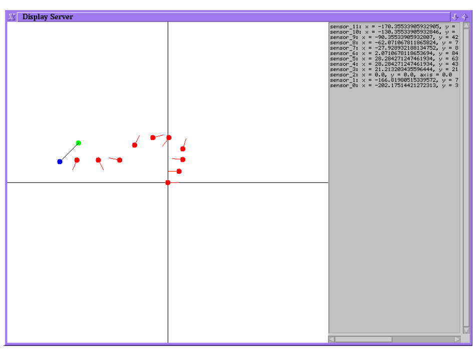

Figure 12: Simulation-3

5 Conclusion

In this paper, we described the network system for rescue robot. We ensured the communication infrastructure by placing the communication tags dynamically, and to get position coordinate of the the rescue robot, we used "angle" obtained from the image that the Ommnidirectional Sensor mounted on the communication tag captures. By using "angle", We would reduce the error than using the "distance" obtained from radio waves. We showed that our argorithm was feasible by the simulation.

Currently, we are mounting our proposal system on the hardware. We are using the PC/104+ board to make the communication tag. We will examine our system in disaster field as soon as we finish to mount our system to the hardware.

References

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