Initialization Problem of Service Robots with Artificial Stars

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Abstract :
Many service robots which is interacting with human at home and in buildings have been developed. Few of them are shown in of the United States and of Japan. These robots are supposed to have a powerful indoor navigation performance in places where human beings live and work. The overall capability of service robots to move around in this environment is called environment correspondence, in which localization problem to find the accurate position and orientation is the most critical problem.

While users set up a proper or a best environment for industrial robots, but for services robots at home and in buildings, it is very difficult to change the environment for robots. The expanded workspace due to mobility is difficult to be covered by means of those used for industrial robots because the cost increases and human beings do not want their environment to be changed for robots. This fact has made many researchers study efficient and effective environment correspondence problems. Among these problems, localization is the most difficult. Goal of localization study includes

(1) Accurate detection of position and orientation
(2) Minimum cost of the additional devices
(3) Minimum change of human environment

In this study, as a solution of the above, we propose “Artificial Stars” which are attached on room ceiling as landmarks. In addition, we solve an adoption problem raised when a robot is delivered to a customer site and before it can perform its full navigation capability. We call this as “Initialization Problem” of service robots. We solve the initialization problem for both cases of environment with the map and without map. The proposed system is experimented and has shown how well it handles the initialization problem.

Keywords: environment correspondence, Artificial Star, Initialization problem

1. INTRODUCTION

The most of the modern robots are the indoor service types that are closely in contact with human beings. The service robots are part of our daily lives through communication. More and more service robots are in use to clean the floor, secure the building and carry the medicine at the hospital, etc. Because of its technical, economic and social implication, there have been many studies on the indoor service robots especially. Some examples of such robots include the ones from the US [11] and the home robots from Japan [3], and it is expected that they will eventually bring substantial change in our lives and make a huge market. More studies on the indoor service robots are needed because they must minimize human involvement and automatically comprehend the surrounding environment to carry out their function. They have the following characteristics: [4]

① The service robots operate under unfixed environment.
② The service robots require intelligence.
③ The service robots must guaranty safety.

These characteristics necessitate higher intelligence for the robots. In the past, the environment such as the operation domain, hallways, obstacles, doors, current and target position, etc. was made for the robots to properly operate. But it is not feasible to keep changing the house, office or hospitals just to meet the robots' requirement. Therefore, the robot must carry out its function under the given environment information. [7] The capability for the robot to successfully achieve its objective under the given environment is called the level of environment correspondence. To increase its level, the attempts have been made to improve the localization technology of the robot. But its reliability has been never high enough to be practically used at home or in the office. [5][6][10]. Therefore, the researchers stated studying ways to increase the robot's intelligence of the environment by combining the sensor with the environment. [2][9] The requirements for the robot to have high level of environment correspondence are as follows:

① Obtain the environment information quickly and accurately.
② Instruct the required work in the given position.
③ Figure out the position and direction of the robot at any change of the environment.

This paper proposes a method to increase the level of environment correspondence and satisfy all above 3 requirements by using Artificial stars which is a type of Landmark. [1] The test is carried out to compare the navigation results of the cases in which Artificial stars is applied to those with no Artificial starts. For analysis the cases were used with and without map information. The structure of this paper consists of 7 chapters. In chapter 2, current environment correspondence level is described; in chapter 3, the proposal is made to improve the level of environment correspondence; in chapter 4, the test environment is described; in chapters 5 and 6, the test method and results are described; and in chapter 7, the conclusion and the future tasks are presented.

2. ENVIRONMENT CORRESPONDENCE

Why does the robot need the high level of environment correspondence? That is because the robot performs its navigation using the accurate information of the environment. In general, the robot requires the following three technologies to perform navigation: [12]

① Localization
② Path-planning
③ Real-time obstacle avoidance

Of above three technologies, positioning technology is the key to the robot's level of environment correspondence. Its reliability is maximized when the position on the local map is same as the real-world position, and the robot can accurately carry out its function. [8][10] Whether or the robot is provided with the initial map requires the approach to the different problems. Although most of studies dealt with the cases in which the map information was available in the past, there have been more studies of the cases in which it is not available. This area still needs more studies. [7]

2.1 The Case with No Map

If no map is provided to the robot, it only has the sensor to recognize the environment. Therefore, the robot gets completely depended upon the sensors. Most of the robots are based on the encoder which is the internal sensor and the ultra-sonic sensor which is the external sensor. They use the encoder to estimate its currents position and path planning and the ultra-sonic sensor to detect the environment surrounding current position and construct the local-map using that information [10]. Having no initial map means the robot cannot detect its position. In that case, the position of the robot is fixed at a certain point on the local-map. The robot estimates its current position based on the moved distance and path using the encoder. It then acquires the surrounding environment information from the ultra-sonic sensor, infrared sensors or other external sensors. [8]

2.1.1. Problem

At the beginning, the robot can make the move using only the encoder. Therefore, the problem arises from accumulation of the errors due to the distance error between the wheels, and skidding on the slippery floor. As the result, it is very difficult to accurately detect the current position of the robot and degrade the initial level of environment correspondence. [5] Therefore, various attempts have been made to increase the localization accuracy using the various external sensors. [7][8] But accurate position detection still remains as the task to resolve when there is no initial map. [10]

2.2 The Case with Initial Map

When there is the initial map, the robot detects its current position on the world-map by matching the given world-map and the sensor data. Then the local-map is constructed by acquiring the information on the environment of the current position. The initial world-map is usually in the form of drawing such as CAD with scaled down information of the environment. The information includes the size of the environment, size and position of the obstacle, position of door, etc,. and the robot carries out its navigation based on the world-map of such information. Once the initial position on the world-map is given to the robot, it detects its new position by acquiring the surrounding information and comparing it with the world map. The new local-map is then constructed using the new position information and used for the robot to make decision using the surrounding information.

2.2.1 Problem

When there was no initial map, the problems were localization and map-building. The latter is solved with the given world-map. Many studies have been made to solve this localization problem. To reduce the error, Kalman filtering is the most widely used to improve reliability of the sensor. [8] For estimating the robot position, there are two popular methods. Markov method requires large amount of memory and processing time as it must calculate all lattices. The Monte Carlo method is based on probability, but it still requires much processing time until it has the accurate data. [7]

3. Proposal to Improve Environment Correspondence

To improve environment correspondence of the robot, two problems must be solved:

① Without the initial map: difficult to accurately estimate the current position
② With the initial map: long processing time to accurately estimate the current position

These problems occur as the robot is depended upon the sensors to detect the environment. [5][10] However, if the accurate environment information is given to the robot, the error due to the sensors can be minimized, and the robot's initial level of environment correspondence be improved. There have been some studies of how to provide the environment information to the robot. [6][7] For this paper, the indoor navigation method using Artificial stars to satisfy the three requirements of Environment Correspondence and solve above two problems is proposed.

3.1 Proposed Navigation architecture

To minimize the error due to dead-reckoning under the traditional navigation method, the structure using Artificial starts to correct the position as shown in Fig. 3-1 is proposed.

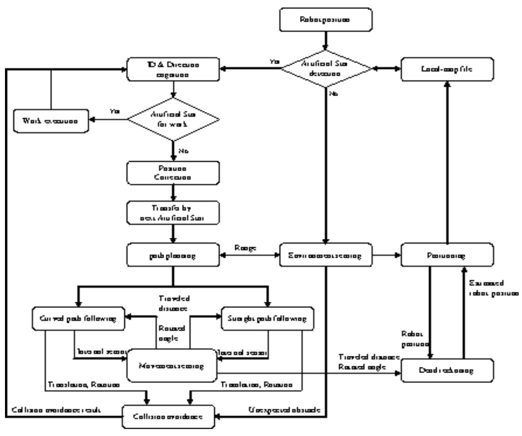


Fig. 3-1 Navigation with No Map

To minimize the processing time required to calculate the accurate position when there is the initial map, the structure using Artificial stars to speed up the calculation time by using its spacing and direction as shown in Fig. 3-2 is proposed.

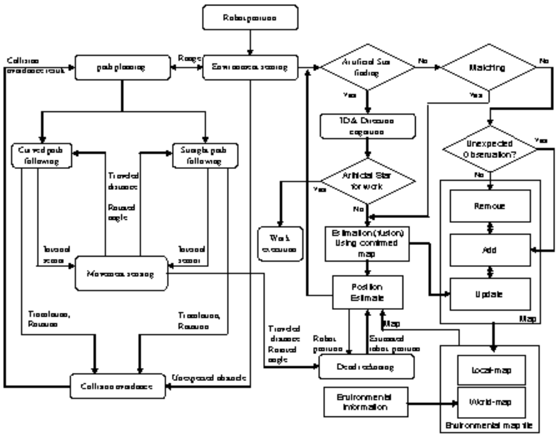


Fig. 3-2 Navigation with Initial Map

3.2 Recognition of Artificial stars

Initially, the robot teaches the location and navigation path sequence to Artificial stars. After that, once the robot is given the target, it navigates toward the destination, and once it reaches there, the robot performs the given operation. It continually corrects its position during navigation. Once the operation is completed, the robot moves to the next target.

3.4 Artificial stars Installation

Artificial star always looks north. North here is defined as the forward path of the robot using the direction of artificial star. All artificial stars afterward is always installed at north of the initial artificial star as shown in Fig. 3-3. The reason is just like the human navigation. When people do not have the map, they look upon the sky and use the asterism to decide the direction. Likewise, the robot uses the artificial stars to estimate its position. In that regard, ID of the artificial star is the constellation.

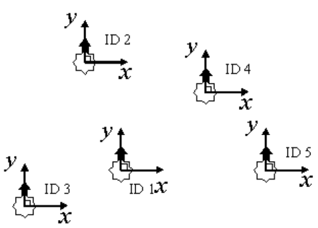
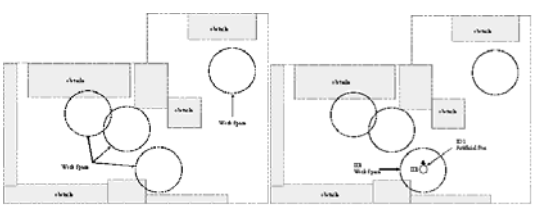


Fig. 3-3 Installation of Artificial Stars

3.5 Installation Procedure of Artificial Stars

3.5.1 Without the Map

Installation sequence is described below. To install the artificial stars, the distance between each star must be measured. After the initial artificial start is installed, the next one is installed at a certain distance.



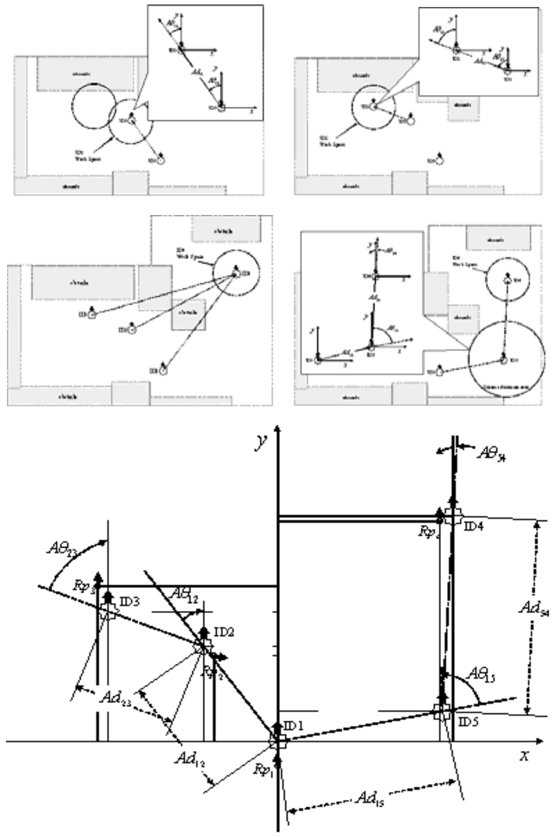


Fig. 3-4. Installation Artificial Stars-map with no map

3.5.2 Installation Procedure with Map

The final world-map with the initial map, Fig. 3-5, looks similar to the artificial stars-map with no initial map, Fig. 3-4.

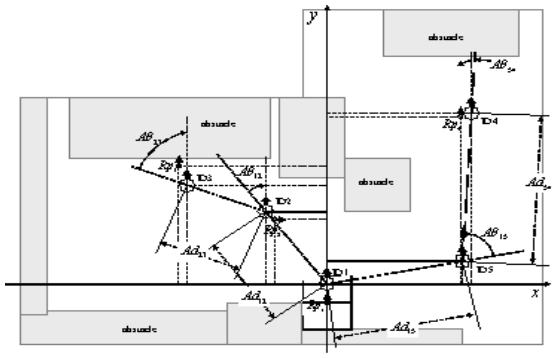


Fig. 3-5 Final world-map using the artificial stars with the initial map

4. Mobile Robot Structure and Test Environment

4.1 Mobile Robot Structure

The robot used for testing is the transfer robot system for the handicapped and has the same structure as [2].

4.2. Test Environment

The test was performed at Intelligent Sweet Room in Human-friendly Welfare Robot System Engineering Research Center, KAIST. In this area, the robots such as the Autonomous Wheel-chair for the elderly and disabled, Intelligent Bed Robot for the Weak and the Handicapped and Robot System for Transferring the Disable between Bed and Wheel-chair are installed. Each system has the fixed initial position as shown in Fig. 4-1. From this position, the system is operated by the management system for intelligent residential space via home network.

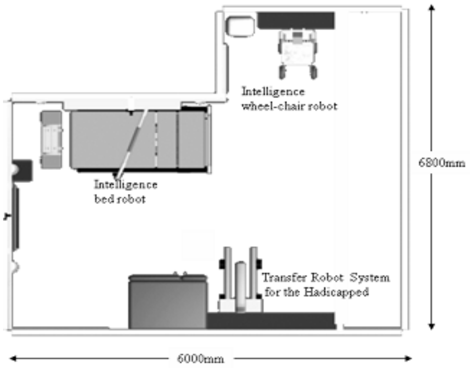


Fig. 4-1. Intelligent Sweet Room in Human-friendly Welfare Robot System Engineering Research Center, KAIST

5. Performance Improvement Test with No Map

5.1 Test Method and Procedure

The first test analyzed the case of applying the artificial stars with no initial map. Fig. 4-1 shows the test environment. The artificial stars are installed based on dead-reckoning as shown in Fig. 5-1. Once the position information is provided to the robot, it is ready to start its work.

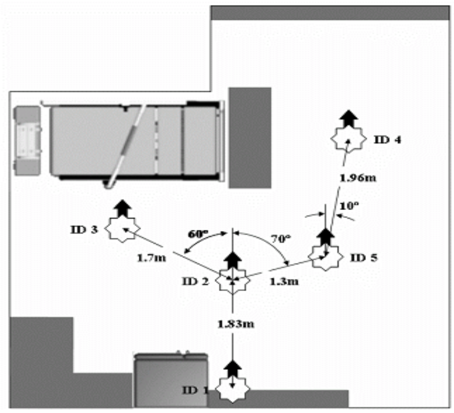


Fig. 5-1. Test environment with artificial stars map

The robot is given the work to move to ID3 as shown in Fig. 5-1, open and close the bar, and then move to ID4 to complete its task.

The test is to check if the robot accurately navigates along the artificial stars and if the generated local-map and robot's taught positions are accurate. When there is no initial map, the following tests are performed.

① Install the artificial stars in the work positions.
② Teach the robot the position and work.
③ Test the cases before and after the artificial stars are applied.

5.2 Test Results

To compare the navigation paths, we can see that the error due to the encoder is less for the robot using the artificial stars (Fig. 5-3) than the one moved with dead-reckoning along (Fig. 5-2). The error gets smaller as the artificial stars are installed closer to each other. The overall angle of the robot is shown in Fig. 5-4.

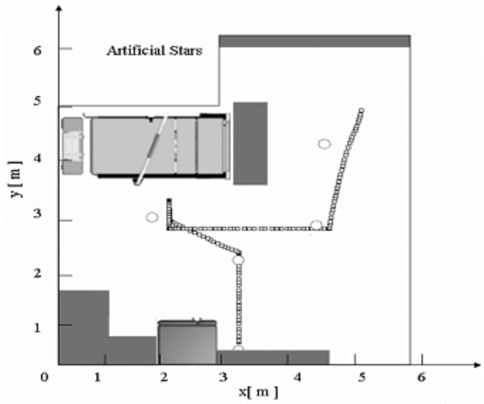


Fig. 5-2 Navigation path before applying the artificial stars

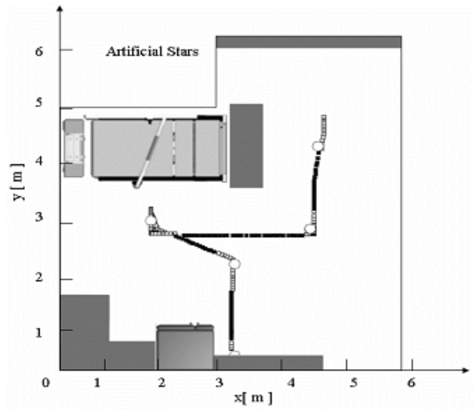


Fig. 5-3 Navigation path after applying the artificial stars

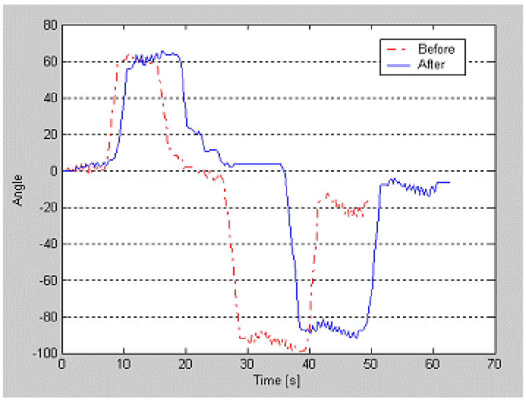


Fig. 5-4. Angle value with the artificial stars applied

Table 5-1. The result of position teaching

	ID3	ID4
Teaching angle	10˚	0˚
Before	0˚	18˚
After	5˚	7˚

As for the angle, ID3 position from the initial starting point of the robot is 10˚ and ID4 position should be 0˚. Table 5-1 shows the test results.

6. Performance Improvement Test with Initial Map

6.1 Test Methods and Procedures

The first test analyzed the case of applying the artificial stars with the initial map. Fig. 4-1 shows the test environment. Based on the map, the artificial stars are installed as shown in Fig. 5-1. Once the position information is provided to the robot, it is ready to start its work. The actual test procedure is the same as the cases without the initial map.

6.2 Test Results

To compare the navigation paths, we can see that the error due to the encoder is less for the robot using the artificial stars (Fig. 6-2) than the one moved with dead-reckoning along (Fig. 6-1). The error gets smaller as the artificial stars are installed closer to each other. The overall angle of the robot is shown in Fig. 6-3.

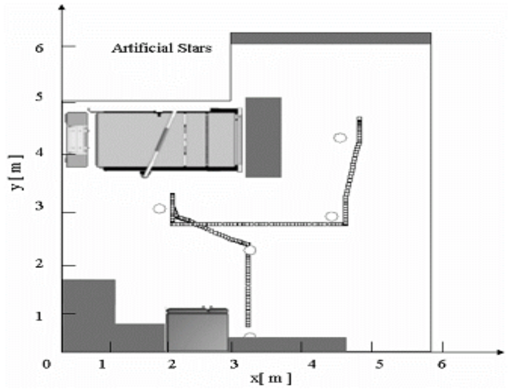


Fig. 6-1 Navigation path before applying the artificial stars

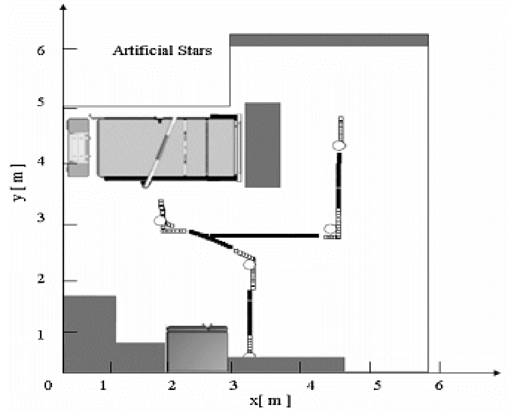


Fig. 6-2 Navigation path after applying the artificial stars

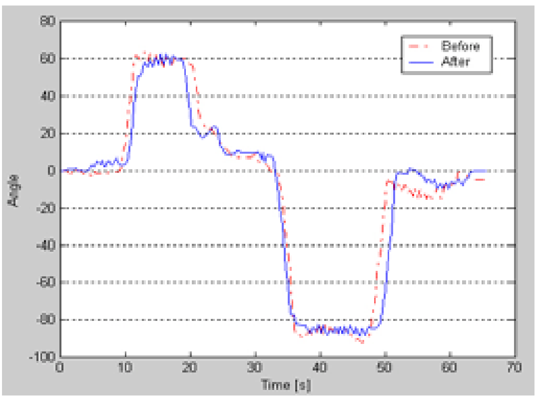


Fig. 6-3. Angle value with the artificial stars applied

Table 6-1. The result of position teaching

	ID3	ID4
Teaching angle	10˚	0˚
Before	9˚	7˚
After	10˚	0˚

As for the angle, ID3 position from the initial starting point of the robot is 10˚ and ID4 position should be 0˚. Table 6-1 shows the test results.

7. CONCLUSION

In this paper, Artificial Stars has shown how it improves the level of environment correspondence of the robot. The tests were performed to compare the cases of applying the artificial stars and those of not applying them both with and without the initial map.

The result shows that applying the artificial stars yielded the accurate robot position, map information and the angle to the final target except for the built-in error during installation. This was true for the cases with and without the artificial stars because they used the same information concerning the artificial stars.

In conclusion, it is proved that using the artificial stars satisfy the three requirements of high level of environment correspondence for indoor navigation with or without the initial map. And it is cheap and few changed of human environment. Because it just needs to attach the landmarks of artificial stars on the ceiling of the room. Therefore, we satisfy to three terms that are accurate detection of position and orientation, minimum cost of the additional devices and minimum change of human environment.

For the future, the studies of attaining a wide area of field of view for each artificial star and reducing the man made error when installing the artificial stars are needed. Another area of study of interest is the exchange of information between the robot and the artificial stars under the ubiquitous environment.

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