A Method of Map Building Based on Sonar and Infrared Sensors in Unknown Environments

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***Abstract* — This paper proposed a method of map building combined sonar and infrared sensors. Firstly, the robot builds the boundary of an unknown environment by its sonar and infrared sensors, and then a user controls the robot to walk forward, back, left and right so that the robot is able to close to one of obstacles. Once sonars detected an obstacle, the robot will build the boundary map of the obstacle by sonar and infrared sensors autonomously. By this way, the robot builds the map of all obstacles in the environment one by one. The proposed method is implemented on the platform "FutureStar". The map built by this algorithm is used for complete coverage path planning on intelligent cleaning robot. The experiment shows the proposed method is easy to operate and achieve, at the same time the map is almost accurate.**

Keywords - Map Building, Sonar, infrared, Grid map, Human-Robot Interaction

I. INTRODUCTİON

The map of the environment is needed for a wide range of robotic applications including search, rescue, automated vacuum cleaning, home assistance, and service tasks. For example, the cleaning robot is required to move through an entire workspace; furthermore, the overall travel must cover the whole region with the smallest overlapping space. When a cleaning robot enters a new environment, it needs to build environment model firstly in order to work efficiently. Because the cleaning robots for domestic home environments are simple and cheap, few of them can build map. This kind of robots is already sold in large numbers; however, people are still unsatisfied with their performance. There have been some studies in map building and its implementation in coverage path planning [1-3]. Some approaches use neural networks for robot map building and map learning [4, 5]. These methods need a learning procedure, so the robot must depend on prior complex environmental information. It is not suitable for real-time and online map building. The cleaning robots will not become mass products until their effectiveness, performance, efficiency, and total attendant costs make them superior to manual cleaning.

Therefore, the map building in an unknown environment is a key issue for autonomous robots. This issue has been widely studied by robot researchers over the last decades. The autonomy and efficiency of an algorithm is usually conflict each other. Hence, we are trying to pursue a balance between them. This paper proposes a fast and effective map building approach via sonars, infrared sensors and a little human-robot interaction. First, a robot builds a boundary map by sonar and infrared data by Internal Spiral Coverage (ISC). Sonar detects obstacles in front, whereas infrared sensors detect obstacles to the left or right. And then a user controls the robot to walk forward, back, left and right so that the robot can find obstacles as soon as possible. Once sonars detected an obstacle, the robot will build the boundary map of the obstacle by sonar and infrared sensors autonomously. By this way, the robot builds the map of all obstacles in the environment one by one until all obstacles are detected. The proposed method is implemented on the platform "Future Star". The map built by this algorithm is used for complete coverage path planning on intelligent cleaning robot. The experiment shows the proposed method is easy to operate and achieve, at the same time the map is almost accurate to satisfy task requirements.

II. RELATED WORK

Studies have been conducted on map building and its implementation [1-3]. Gutmann et al. presented an approach to learn occupancy grid maps including elevation information with Sony humanoid QRIO using stereo vision [6]. In that context, they consider mapping is mainly a local problem to support collision avoidance or path planning tasks. They do not address issues such as loop-closing or place-revisiting. A system that performs real-time localization and mapping with humanoid robot was developed by Ozawa et al. [7]. Their approach which is based on 3D visual odometry uses dense feature maps to estimate the position of the camera. A well-known drawback of this incremental approach is the drift created by the accumulation of errors. Davidson et al. [8] presented an approach to develop from a monocular vision using a sparse set of images to recognize some critical landmarks. They then use these to develop the SLAM. However, they require a frame rate of 30 per second from the camera for efficiency. Hornung et.al [9] applies Monte Carlo localization to globally determine and track a humanoid's 6D pose in a 3D world model, which may contain multiple levels connected by staircases. However, to achieve a robust localization while walking and climbing stairs, a 2D laser range finder was mounted on Nao, it is very expensive. Certain approaches use neural networks for robot map building and map learning [4-5].These methods require a learning procedure, so the robot must depend on prior complex environmental information. Such a process is unsuitable for real-time and online map building.

The rest of this paper is organized as follows: in Section 3, the map building algorithm is presented, including boundary map and obstacles map. Experiment results are shown in Section 4. Conclusions are drawn in Section 5 as well as future work is given.

III. MAP-BUİLDİNG ALGORİTHM

This algorithm includes two sections: the room boundary detection and obstacles detection.

A. Boundary detection algorithm

A robot builds a boundary map by fusing the sonar and infrared data. Sonars detect obstacles in front, whereas infrared sensors detect obstacles to the left or right. The robot moves according to Internal Spiral Coverage (ISC) algorithm. If the robot moves clockwise, it only uses its sonar and left infrared sensor.

S and I are considered the values of sonar and left infrared sensor, respectively. If S equals 1, an obstacle is in front of the robot. Similarly, if I equals 1, an obstacle is on the left side of the robot. Four S and I combinations are possible. The move rules are shown in Table I.

Table I. TURN RULES OF THE ROBOT

Infrared	Sonar	Turn rules
0	0	Turn left
0	1	Turn left
1	0	Go straight
1	1	Turn right

Figure 1 represents an indoor environment. The robot R moves clockwise along the boundary of an environment based on the move rules of Table 1.

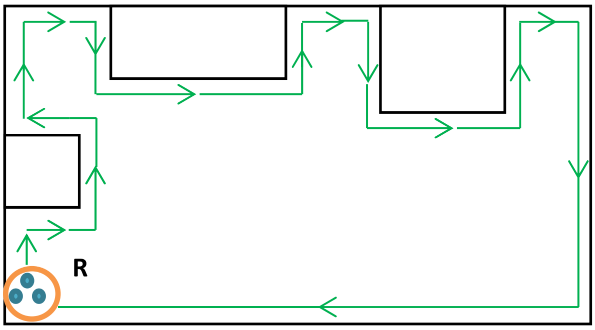

Fig.1 Path of Robot R along the Boundary

Boundary detection algorithm

Step 1: The robot is placed on a random point next to the boundary, with the boundary at its left. The robot should move clockwise.
Step 2: Sonar and infrared sensor are activated.
Step 3: The robot obtains the values of sonar and infrared sensor, and then moves one grid following the rules of Table 1. The robot skips Step 4 if the next grid is the start point.
Step 4: The robot performs Step 3.
Step 5: The algorithm ends.

B. Obstacle detection algorithm

After boundary detection, the robot detects environmental obstacles individually. The robot is led to the front of an obstacle by human-robot interaction to reduce obstacle search time. A state transition diagram of robot movement is shown in Figure 2.

Obstacle detection algorithm

Step 1: The robot moves randomly via human-robot interaction and obtains sonar value.
Step 2: The robot detects an obstacle if the sonar value is 1. The robot turns right and enters the next state (i.e., moves along the obstacle).
Step 3: The robot moves anti-clockwise following the rules of Table 1 until the current obstacle detection ends.
Step 4: When "Building map" is clicked, the algorithm will fill the obstacle using a filling algorithm.
Step 5: The robot turns right, leaves the current obstacle, and then enters a random move state.
Step 6: If all obstacles are detected, the user stops the robot and proceeds to Step 7 or returns to Step 1.
Step 7: The algorithm ends.

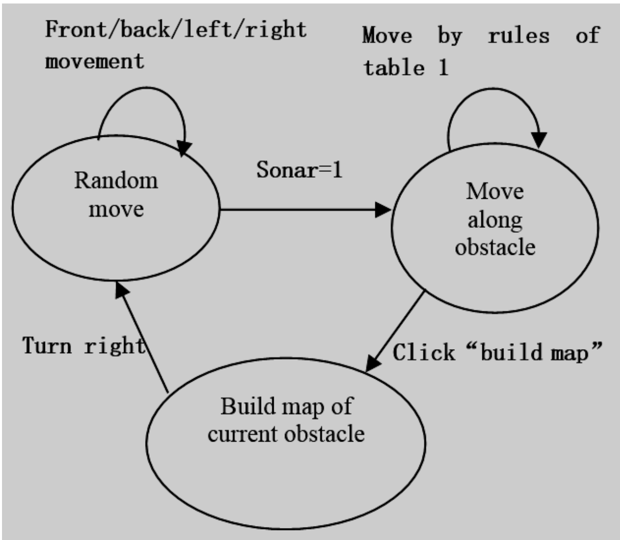

Fig.2 State Transition Diagram of Robot Movement

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IV. EXPERİMENT AND DİSCUSSİON

The experiment is conducted on a "Future Star" platform (Figure 3).

Fig.3 "Future Star" robot

This robot moves and turns relatively accurately, so we can get the relative coordinates of the robot by accumulation. Figure 4 is a photograph of the real indoor environment. A rectangular boundary is set and two boxes are placed in the room. The robot is set at a corner. Firstly, the robot runs the boundary detection algorithm and then the user controls the robot to the front of an obstacle. The robot runs the obstacle detection algorithm autonomously until all obstacles are detected. Figure 5 is the map of the real environment shown in Figure 4. Green grids represent obstacles.

Fig.4 Real Environment

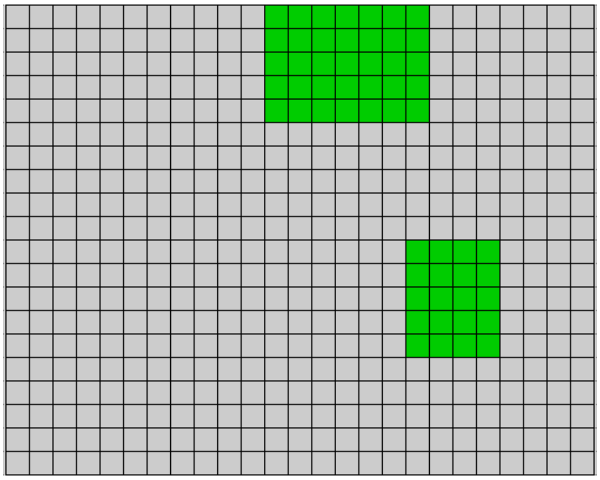

Fig.5 Environment Map

In order to test the accuracy and efficiency of the map, the complete coverage path planning for the cleaning robot is run on the grid map. This paper proposed an efficient complete coverage path planning algorithm combined Internal Spiral Coverage (ISC), Grassfire and A*. Algorithm procedure is as follows.

Step 1: the robot adopts ISC coverage by clockwise.

Step 2: if the grid in front of it has been covered or occupied by obstacles, the robot will turn by priority rules in Table 2.

Step 3: if the robot gets into a dead-corner, switch to Step 4, otherwise switch to Step 1.

Step 4: Search the nearest not-covered grid by the grassfires algorithm, if not found, indicating that the map has been complete covered, goto Step 7, otherwise goto Step 5.

Step 5: Call A * algorithm to plan a shortest path from the current position to the searched grid, and then the robot arrive at the not-covered grid along this path. There will be a certain amount of duplication of coverage at this time, but the re-coverage rate is relatively low because the A* algorithm attains a shortest path.

Step 6: the robot continue to its coverage from the new start point, goto Step 1.

Step 7: algorithms end.

TABLE II. TURN RULES OF ISC ALGOROTHM

Current direction	*switch to direction*
down	*right* *down* *left* *up*
up	*left* *up* *right* *down*
left	*down* *left* *up* *right*
right	*up* *right* *down* *left*

The Figure 6 shows the complete coverage path planning result. Red grids represent covered grids, whereas gray grids represent repetitively covered grids. The coverage rate is 100%, and the repetition rate is 2.4%. Current cleaning robots clean the room without a map. Therefore, robots only clean according to some simple path policies, such as go straight, turn randomly when detecting an obstacle, zigzag, circle and so on. As a result, the robot cannot clean completely and at the same time the robot cleans the same location many times. However, if the cleaning robot has a map, it will adopt efficient path planning algorithm. Experiments show the proposed map building algorithm greatly improved Cleaning efficiency.

V. CONCLUSIONS AND FUTURE WORK

With the development of robotics, service robots can be used for housework in the coming years. When a robot enters a new home, it needs to get familiar with the environment first like a servant to serving better. If the robot builds the map autonomously, it will need more time, more energy and better configuration. However, if human can give the robot a little help, it is very easy to implement for building the map. With many practical applications of robots, a fast and effective map building algorithm is needed. The proposed algorithm will accelerate robots into the practical applications

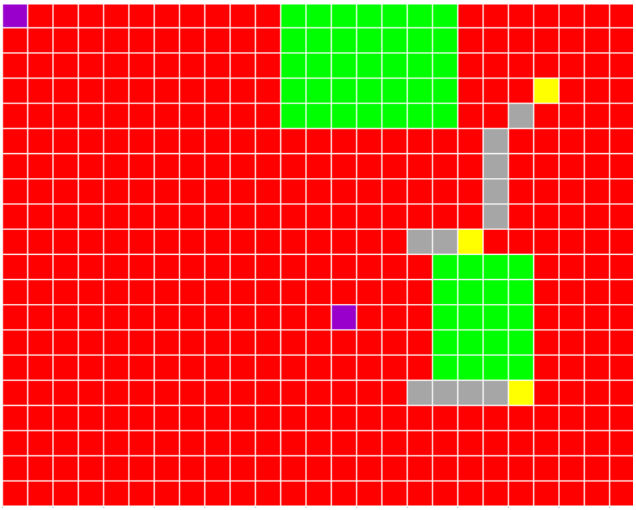

Fig.6 Result of complete coverage

In future, we will develop an accurate localization system, if the robot can self-localize, it will find obstacles by random walk or some search algorithm. So the autonomy of map building algorithm will be improved.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflicts of interest.

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