A New Algorithm for Complete Coverage Path-Planning of Cleaning Robots

청소 로봇을 위한 경로 계획의 새로운 알고리즘

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Abstract - Completer coverage path planning requires the robot path to cover every part of the workspace, which is an essential issue in cleaning robots and many other robotic applications such as vacuum robots and painter robots. In this paper, a novel Water Flowing Algorithm (WFA) is proposed for cleaning robots to complete coverage path planning in unknown environment without obstacles. The robot covers the whole workspace just like that water fills up a container. First the robot goes to the lowest point in the workspace just like water flows to the bottom of the container. At last the robot will come to highest point in the workspace just like water overflows from the container and simultaneously the robot has covered the whole workspace. The computer simulation results show that the proposed algorithm enable the robot to plan complete coverage paths.

Key Words : Cleaning robots, complete coverage path planning, unknown environment, water flowing algorithm

1. Introduction

Path planning is a fundamentally important issue in robotics. Complete coverage path planning (CCPP) of cleaning robot is a special type of path planning in a 2-dimensional environment. It requires the robot path to pass through every area in the workspace. In addition to cleaning robots, many other robotic applications also require complete coverage path planning, e.g., painter robots and window cleaners [1,2].

For a cleaning robot to navigate completely in an unknown environment, two basic requirements, map representation and path planning, are needed. The former requirement is provided by the on-board sensory system that gathers information about both the robot itself and the surrounding environment. The later requirement is met by motion planning which enables a robot to navigate the global workspace completely.

There are also many kinds of method for CCPP such as neural network approach proposed by Yang and Luo [3], triangular-cell-based map approach by Oh, etc [4].

In this paper, a new algorithm called Water-Flowing Algorithm (WFA) to complete coverage path planning is proposed. In this algorithm, the robot is represented by a circle but not a point. The workspace is considered as a container. The process that the robot navigate completely in the workspace is just like that water fills up a container.

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2. The Proposed Algorithm

The reason we call the proposed algorithm as Water Flowing Algorithm is that it takes the properties of water: first, it always flows from higher point to lower point; second, if the quantity of the water is enough, it can overflow from any container without cover. In this algorithm, the goal point is always set to be the highest value without considering the obstacles or walls by the Goal Function:

$$Goal = 0.1 - w\sqrt{(x_{current} - x_{goal})^2 + (y_{current} - y_{goal})^2}$$

Higher *Goal* value means nearer to the goal point, vice versa. $w = 1 \times 10^{-4}$ is an empirical value. $(x_{current}, y_{current})$ is the coordinate of the current point and (x_{goal}, y_{goal}) is the coordinate of the goal point. From this function we can see that: the nearer to the goal point, the higher of the Goal Value. So we can use contour map and 3-D map to show the idea as shown in Fig.1 and Fig.2. When the robot gets to the goal point then the work space has been completely navigated.

The whole process of WFA is illustrated in the Fig.3.

Step 1 starts the algorithm. In step 1, the start point and goal point is set and the work space is set like a container just as shown in Fig.1 and Fig.2. Step 2 is the main part of WFA. Before the robot moves, it will sense its surrounding. The sensed area is a circle divided into 16 points. The robot senses the points one by one along counterclockwise direction. All the points in the wall have the same value and the value is much higher than that of points out of the wall. After 16 calculations of the Goal Function, the robot will choose the lowest value point as the next point to move among them. This means that the robot will move to the point which is farthest to the goal point compared with the other 15 points. It also means that the robot will flow to the lowest place. But if there is no this kind of point, the robot will choose the point whose Goal Value is same with the current Goal value as the next point to move. If there is still no such kind of point, it means that the robot meets the wall. Then the robot will move along the wall one step which will be realized by Step 3 which we call "difference method". We can see that in Step 2 and Step 3, we set the previous robot position to high value 0.2 (empirical value). The reason is that we don't want the robot to go back to clean the area where has been cleaned.

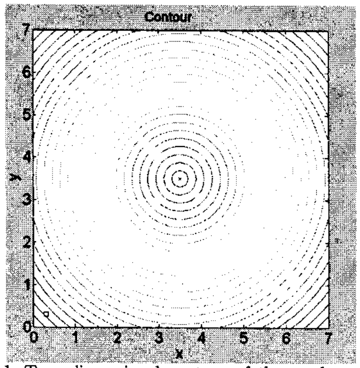

Fig.1. Two-dimensional contour of the work space
the green cross represents the goal point
the blue square represents the start point

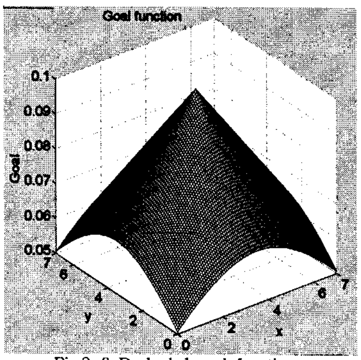

Fig.2. 3-D shaded goal function

Here we will explain the "difference method" in details: we subtract "the value of the current sensed point" from "the value of the point sensed before it" and then we get 15 differences. Only when the "current sensed point" is out of the wall and the "point sensed before it" is in the wall, we can get the largest positive difference. If the robot chooses this "current sensed point" to move, the movement along the border of the wall will be realized. When the robot senses the 16 points along clockwise, the robot will move along counterclockwise direction, vice versa.

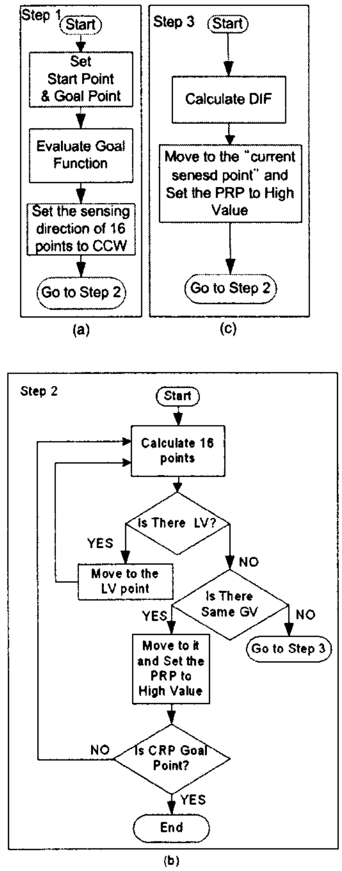

Fig.3. Flow chart of the WFA

CRP: Current robot position.
PRP: Previous robot position.
LV: The lowest value.
DIF: The difference calculated by difference method.
GV: Goal Value (function).
CCW: Counterclockwise direction.

3. The Simulation Results

Computer simulations have been performd to test the proposed algorithm in a normal environment.

Here are some enactments;

1. The work space is 2-D. Size: 7*7*m*.
2. The shape of the robot is circle whose radius is 0.12*m*.
3. The cleaned area is also a circle whose reaius is 0.3*m* and its center is the center of the robot.
4. The coordinates of the start point and goal point is (0.3, 0.3) and (3.5, 3.5), respectively.

The simulation results is shown below.

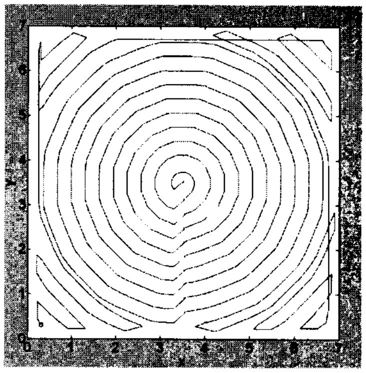

Fig.4. The blue line is the track of the center of the robot

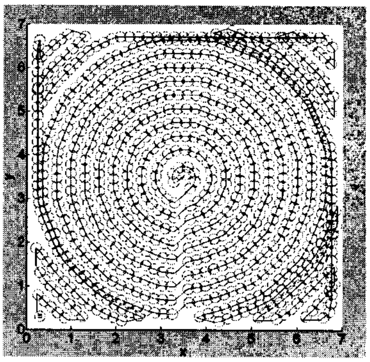

Fig.5. The red circles are the track of the robot

4. Conclusion and Future Work

In this paper, a new algorithm called Water Flowing Algorithm has been proposed to complete coverage path planning for cleaning robots. According to WFA, the course that the robot covers the whole work space just like that water fills up a container.

In the future, we will apply this algorithm to the unknown environment where there are normal and special obstacles which other approaches [3,4] can't solve.

Acknowledgment

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