https://doi.org/10.31256/Ei2Ak4A

Simulation of Fire fighter swarm robotics in MATLAB and robot e-puck2 development

Jiacheng Chen
Materials and Engineering Research Institute
Sheffield Hallam University
Sheffield, UK
jchenshef@gmail.com

Lyuba Alboul
Materials and Engineering Research Institute
Sheffield Hallam University
Sheffield, UK
l.alboul@shu.ac.uk

Ningrong Lei
Materials and Engineering Research Institute
Sheffield Hallam University
Sheffield, UK
n.lei@shu.ac.uk

***Abstract*—Robots are one of the most useful tools created by humans, which can replace humans for tasks such as exploration and search and rescue. In daily life, people often encounter fires. By using robots for firefighting work, the damage of fires to firefighters can be greatly reduced. We proposed a 2D simulation environment to test the functionalities of robots, using artificial potential field method to avoid obstacles. At the same time, the algorithm is combined with the actual robot, and the test will be carried out after updating the control system of e-puck2.**

Keywords—robot, swarm robot, simulation

I. Introduction

According to the disaster incident report released by the UK Home Office, from June 2020 to June 2021, the England Fire and Rescue Service handled a total of 529,101 disaster incidents, of which 149,799 were fire incidents [1]. The death toll from fires incidences reached 249 [1]. In order to reduce unnecessary casualties and improve fire-fighting efficiency, we produced a scenario of a warehouse on fire, and developed a prototype of a swarm robots' operating system. Also, we tested the search and rescue functionalities of robots in a simulation environment.

II. Background

A. *Artificial Potential Field*

In the field of artificial intelligence, there are a variety of path planning algorithms, but in the case of unknown and dynamic environments, the Artificial Potential Field is proved to be the most useful one. In a single-robot environment, the algorithm treats obstacles and targets as objects that have repulsive and attraction forces on the robot respectively. In a swarm robotics environment, robots regard other robots as moving obstacles.

There are two kinds of forces in the artificial potential field, one is the attraction force generated by the target point to the robot, and the other is the repulsive force formed by the obstacle to the robot. The robot moves along the combined force of the attraction force and the repulsive force, that are the gradients of the corresponding potential functions [2] [3].

$$U(q) = U_{att}(q) + U_{rep}(q) \quad (1)$$

In Eq. (1) U represents the resultant potential received by the robot, U_{att} and U_{rep} represents the attraction potential that guides the robot to move toward the target point, and the repulsive potential that leads the robot to avoid obstacles respectively, also q represents the current position (coordinates) of the robot.

The most commonly used functional expressions for the attraction and repulsive potentials are the following ones:

$$U_{att}(q) = \frac{1}{2}\eta_a d^2(q, q_{goal}) \quad (2)$$

where η_a is the potential attractive constant, $d(q, q_{goal})$ represents the distance between robot and goal [2][3].

$$U_{rep}(q) = \begin{cases} \frac{1}{2}\eta_r(\frac{1}{D(q)} - \frac{1}{Q^*})^2 & D(q) \leq Q^* \\ 0 & D(q) \geq Q^* \end{cases} \quad (3)$$

Here η_r is the potential repulsive constant, $D(q)$ represents the closest distance between the robot and obstacle and Q^* is the distance limit of potential repulsive influence [3]. In the repulsive force field, the size and range of the repulsive force depend on the properties of the obstacle itself, so the robot will only receive the repulsive force when it enters the influence range of the obstacle and will not be affected by the repulsive force beyond this range [2].

In addition to the artificial potential field method, there are other robot path planning algorithms, such as A*, D*, BUG, etc. In an unknown dynamic environment, if the BUG algorithm of forward search is used, it is necessary to keep trying to obtain the optimal path, which greatly increases the running time [4]. Although the D* algorithm is a reverse search, it cannot guide the search direction to the target point every time it searches [5]. At the same time, in order to obtain a smoother running path, the artificial potential field method is far better than A* algorithm.

B. *E-puck2*

The e-puck is a small mobile robot jointly designed by GCtronic* and the Swiss Federal Institute of Technology and is widely used by organizations [6].

The e-puck's compact size and diverse functions make it suitable for testing developed algorithms in simulations. It comes with two stepper motors, eight infrared proximity sensors, three microphones and a camera. The motors are used to drive the e-puck to move. By adjusting the speed of the motors, the e-puck can be turned or reversed. Infrared proximity sensors are used to detect obstacles, while microphones and cameras are used to collect environmental information.

In addition to these basic functions, the e-puck can also be equipped with other plug-in modules. The Range and Bearing Board with 12 infrared transmitters and receivers can not only obtain better information, but also realize the communication between swarm robots. It can also be used to measure the distances between robots.

If the robot wants to convey information to humans or to other robots, it needs a module installed above the e-puck named RGB Display Panel. It consists of 3*3 light groups composed of 9 RGB LED lights, which can use different

GCtronic* is a company devoted to electronic and mechatronic development. It is a spin-off of the Autonomous System Lab at the EPFL (Swiss Federal Institute of Technology Lausanne).

combination to convey different information. In a word, robot e-puck is easy to use to test and validate the algorithms.

III. MAIN RESEARCH AND UPDATE

A. *MATLAB Simulation*

We simulated a flat 2D warehouse environment with blocks in different colours as obstacles and two fire points as target locations. The aim is to first detect obstacles and fire points by the exploration robot and pass the information to the fire robots. Then the fire-fighting robots reach the fire points and extinguish the fire according to the received information and return to the initial position after confirming that there is no more fire.

The starting point of the robots is at the bottom of the field. Figure 1 shows the simulation set up.

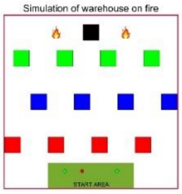

Figure.1 Simulation environment.

The exploration robot is equipped with infrared sensors that can detect temperature, and it can determine the closest ignition point based on the difference in temperature. After successfully avoiding all obstacles and finding all fire points, it returns to the starting point and transmits the location information to the fire robot. The moving path is shown in the red line in Figure 2.

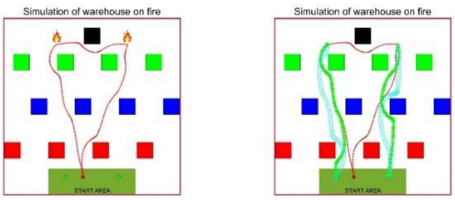

Figure.2 Exploration robot (left) and fire fighting(right) robots moving path.

After receiving the location information, the two fire-fighting robots move directly to the fire points and carry out the fire extinguishing work. After a period of observation, if the infrared sensor detects no abnormality at the ignition point, it proves that the fire has been extinguished and the robot returns to the initial point.

The robots' moving paths are shown in Figure 2. The green line represents the travel path of the fire extinguishing robot to the ignition point, and the blue line is the return route of the robot after the fire extinguishing is completed.

B. *Simulation ideas and further upgrades*

- First of all, we intend to design a 3D simulation environment in subsequent improvements. In a fire field, the ground is not ideally flat, so an uneven ground environment can be pre-set in the 3D simulation. This requires the robot to be equipped with a gyroscope. The robot can record and adjust its position according to the measurement changes of the gyroscope.
- Exploration robots need to detect obstacles and ignition points before they can determine general information. In the previous study, we developed a robot control interface that displayed detailed about the robots in real time. We plan to add the function of environmental input in subsequent practical tests. If the fixed obstacles in the environment are predicted in advance, this will greatly reduce the working time of the exploration robot. The data can be transferred to the fire-fighting robot directly for carrying out the work.

C. *E-puck2*

Engineers at GCtronic have released open-source MATLAB-based code on GitHub, but it only works with the e-puck. It does not apply to the external modules of e-puck2. So we improved the code that controls the robot.

E-puck2 has two operating modes, one is the binary mode where commands can be parallelized, and the other is the ASCII mode where commands are read line by line. We have successfully updated the e-puck kernel in the binary mode, created an e-puck kernel in the ASCII mode and tested a portion of the code, which can be adapted to the e-puck2's onboard functions and RGB display panel.

The updated control system is currently being used by graduate students in Robotics at Sheffield Hallam University. This system was also uploaded it to GitHub and received many inquiries and suggestions [7].

IV. CONCLUSION

We proposed a simulation environment and got the desired results by using the artificial potential field algorithm. We also created and updated two control kernels of robot e-puck, which can already be used to test the obstacle avoidance function and the information display function of RGB panel. The current work is to develop the functions of the Range and Bearing board, it can be used to gather more environment information in details. We are confident in the development of the project, and also hope to contribute to the field of swarm robotics applications.

ACKNOWLEDGMENT

Thanks to Sheffield Hallam University for the experimental opportunity, and to Professor Penders*, Dr Alboul and Dr Lei for their great support to the project. Also thanks to the engineers at GCtronic for their help.

REFERENCES

[1] T. Cracknell, "Fire and rescue incident statistics: England, year ending June 2021", Retrieved from: https://www.gov.uk/government/statistics/fire-and-rescue-incident-statistics-england-year-ending-june-2021/fire-and-rescue-incident-statistics-england-year-ending-june-2021, 2021.

[2] Iswanto, M. Alfian, W. Oyas, and C.I. Adha, "Artificial Potential Field Algorithm Implementation for Quadrotor Path Planning", IJACSA, vol. 10, No. 8, pp. 575-585, 2019.

[3] L. Alboul, "Robot Motion Planning Lecture 2", Sheffield Hallam University, 2018.

[4] H. Choset, "Robotic Motion Planning: Potential Functions", Retrieved from: https://www.cs.cmu.edu/~motionplanning/lecture/Chap4-Potential-Field_howie.pdf.

[5] F. Fahimi. "Autonomous robots: modeling, path planning, and control", New York: Springer, 2008

[6] GCtronic, "e-puck education robot", Retrieved from: https://e-puck.gctronic.com, 2018

[7] J. Chen, "Epuck2 Kernel", Retrieved from: https://github.com/JCInvoker/epuck. 2021

Jacques Penders*, Professor of Artificial Intelligence and Robotics at Sheffield Hallam University, has passed away recently.