國立臺北大學電機工程學系專題報告

無線充電機器人開發

Development of Wireless Charging Robot

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1. 摘要(Abstract)

Our project is aim to develop a testbed based on well-known algorithms including Travel Salesman Problem, Probabilistic Roadmap and Fuzzy C-means Clustering. The testbed is constructed by Arduino Uno, Arduino WIFI Shield, Go-between Shield by Mayhew Lab and Polulu Zumo robot for Arduino Ver.1.2. All the algorithms are coded by MathWorks MATLAB and Simulink. The core of the wireless charging robot is to optimize the best performance for single robot to charge multiple devices. Owing to the computation restriction of the mobile robot, the calculation will be done on remote server and communicate with the robot through Wi-Fi connection. By this, the computation load on mobile robot can be reduce as well as improved the efficiency. A real-time feedback system is also build to promote accuracy in actual environment. After the development of improved stability and flexibility, the robot can be brought to real life.

關鍵字：Mobile robot, Wireless charging, Travel Salesman Problem, Probabilistic Roadmap

2. 簡介(Introduction)

Nowadays, people rely more and more on mobile device such as smartphones, smartwatches, tablets and etc. Power transmission becomes a significant issue while more energy is needed for individual mobile devices user. We can see people trying to find plugs for their devices in public. Instead of letting people to find the plugs, it is much more convenient for a robot to bring the energy to the user. By this, we develop a wireless charging robot which carried power bank and equipped with Qi charging transmitter use for charge devices support Qi charging. The main idea of our research is to combine two existing technologies of wireless charging and mobile robotics in order to have optimum charging performance in static and dynamic environment for single or multiple nodes according to the state of the art in robotics and wireless charging. The robot could use probabilistic roadmap which solves the problem of determining a path between a starting point of the robot and a goal while avoiding collisions. With the Travelling Salesman Problem, we can extend our system to multiple device. Wireless charging robot gets the command from server and complete the charging mission with considering to spend least time and consume minimum power. Although mobile wireless charging robot is highly flexibility, there are many restrictions to the hardware. In order to reduce to computation load of the system, we aim to make the trajectory planning and navigate the robot to arrive to the destination precisely via Wi-Fi connection. The main computation would be on the server and each mobile robotic node would follow the instruction for wireless charging. We not only use the camera to capture the environment but also as an indoor localization resource. In addition, the camera become real-time feedback system and send data to the server to reduce inaccuracy occur in real environment. After developing a working test bed prototype and improvements, such system can be used in various environments such as office, lab, campus, air-ports, train stations.

Fig. 1. Wireless charging robot and human interact with each other.

3. 專題進行方式(Method)

In this chapter, we will explain the process of our system separately.

3.1 System Description

The case presented in this paper is to charge a mobile phone by wireless charging robot. For this purpose, a wireless charging robot was assembled with Arduino Uno, Arduino WIFI Shield, Go-between Shield by Mayhew Lab and Polulu Zumo robot for Arduino Ver.1.2(See Figure 2). In order to make the system works, an ideal environment include a gray plane and a camera above it was set for the robot to accomplish this mission.

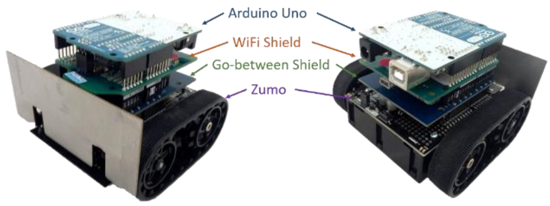


Fig. 2. Inside view of the robot (without power bank and Qi transmitter)

On the gray plane which was set as the moving range for the robot, a few white blocks represent the barrier and black dots represent the mobile device need to be charged was placed. In the beginning, the camera captures a picture of the environment for the computer to build the map. The computer calculates the possible way for the robot and send moving command to the robot through Wi-Fi. The red and blue rectangles on the robot are feature points for the computer to recognize the direction which the robot is facing.

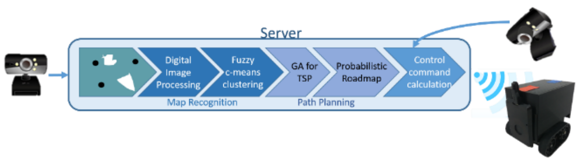


Fig. 3. Flowchart of the system processing steps

3.2 Robot design

During the tests, we design different prototypes. Owing to the restriction of the localization system we designed, the robot should be whole black. In the beginning, we covered the robot with a simple black box which is light but not attractive. Furthermore, this design cause too much friction because it touches the floor and drag by the robot. Soon we finished our second design which improved the cons of first prototype.

In this design, we considered the structure including the space for Qi transmitter and power bank. The bottom of the case is lifted from the floor so the friction problem was solved. During the test, a serious problem occurred. The design was too heavy for the Zumo robot to carry and the robot does not move as we expected. To solve all the problem that founded during the tests, we modified the localization system. A simplified design was introduced after the localization system can filter the noise which cause by the robot's components.

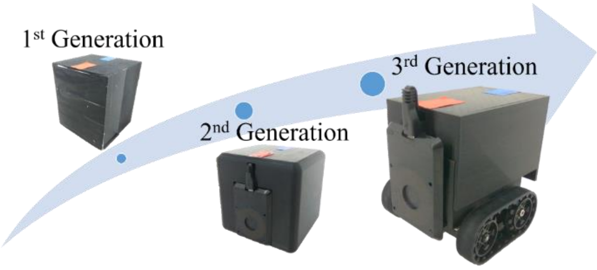


Fig. 4. Prototype evolution

3.3 Recognition of the map

Digital image processing.

In the beginning, the camera takes a bird's eye view picture of the whole environment. To recognize the goals and obstacles, digital image processing is applied to filter the information which we needed. First, a high pass filter is applied to the image to enhance the contrast ratio: make bright part brighter and dark part darker. Next step, the enhanced image is convert into gray scale which makes the value of all pixel become 0 to 255. By this, we set the value larger than 210 become obstacles and value lower than 30 become goals. After this process, the salt and pepper noise might occur. To remove the noise, average filter is applied to both goal and obstacle image.

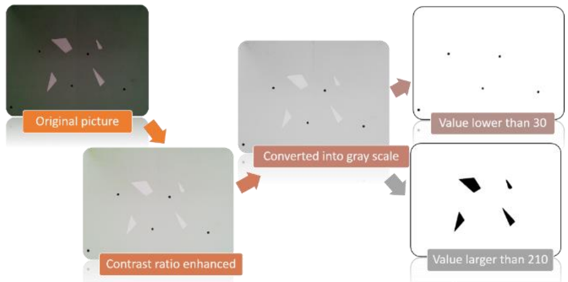


Fig. 5. Flowchart of digital image processing

Fuzzy c-mean clustering.

After the image processing, fuzzy c-mean clustering is applied to calculate the center of each goal. In this step, we applied `fcm` function in MATLAB. `fcm` performs the following steps during clustering:

1. Randomly initialize the cluster membership values, μ_{ij}.
2. Calculate the cluster centers:

$$c_j = \frac{\sum_{i=1}^{D} \mu_{ij}^{m} x_i}{\sum_{i=1}^{D} \mu_{ij}^{m}}. \qquad (1)$$

3. Update μ_{ij} according to the following:

$$\mu_{ij} = \frac{1}{\sum_{k=1}^{N}\left(\frac{\|x_i - c_j\|}{\|x_i - c_k\|}\right)^{\frac{1}{m-1}}}. \qquad (2)$$

4. Calculate the objective function, J_m.
5. Repeat steps 2–4 until J_m improves by less than a specified minimum threshold or until after a specified maximum number of iterations. [4]

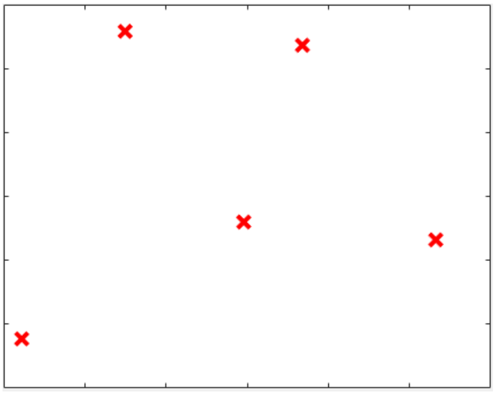


Fig. 6. Centers calculates by `fcm` function

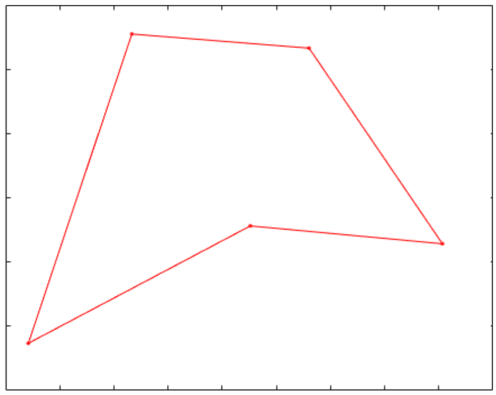


Fig. 7. Sequence decided by GA for TSP

3.4 Path planning

By obtaining the map which process form camera image, the computer is able to know the goals and obstacles in the environment.

Genetic Algorithm for Travelling Salesman Problem.

For the first step, the computer decides the order of the goal by using Genetic Algorithm for Travelling Salesman Problem. The aim of using this technique is to move from one node to another exactly once and end the journey with minimum total distance. For this case, express the problem in math is solve $\arg\min_{x} f(x)$.where x is the path. $f(x)$ is the distance of path x. Our target is to find the x which makes minimum $f(x)$.

The Genetic Algorithm stands on natural evolution rule, Survival of the fittest. It is a method which does not need to explore every possible solution in the feasible region to obtain a good result. Encoding, evaluation, crossover, mutation and decoding are the steps of GA process.

Probabilistic Roadmap.

After decided the sequence of the goals, the computer calculate the way for the robot by Probabilistic Roadmap to avoid collision. In the beginning, random nodes are generated in the free space in the map (blue nodes in Figure.8). Connections between each node are created and avoid crossing occupied space (gray lines in Fig.8). The number of random nodes is carefully tuned after tests. Increasing the number of nodes can increase the efficiency of the path by giving more feasible paths. However, the increased complexity increases computation time. The additional nodes increase the complexity but yield more options to improve the path. The final path is created by finding an obstacle-free path using this network of connections with the shortest total distance. [5][6]

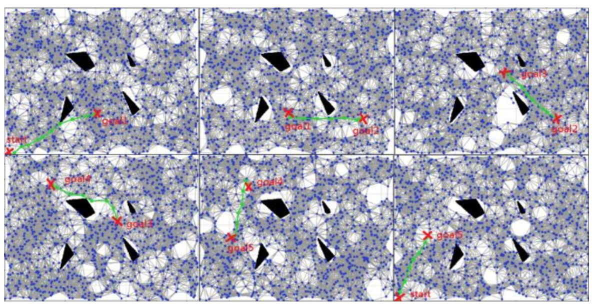
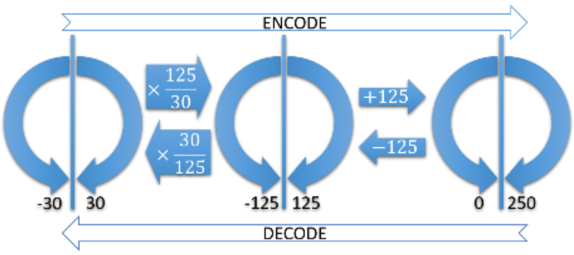


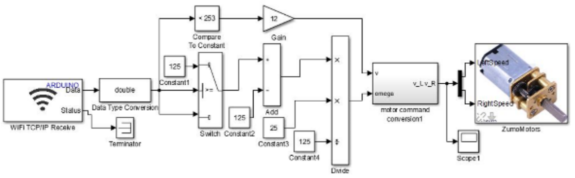
Fig. 8. Path decided by Probabilistic Roadmap

3.5 Robot control

In the final step, it is time to bring the simulation to reality. The Zumo robot is driven by two separate motors. The speed of the right motor is $v + \omega$ and the left is $v - \omega$. By adjusting the ω, we are able to change the direction which Zumo robot faced. The same method as calculating the centers of the goals was used to calculate the centers of the feature points which is use for knowing the location and the direction of the Zumo robot. Owing to the constrain of data type which the Wi-Fi shield supported, we need to encode the ω calculated by the computer and decode in Zumo robot (See Figure 9(a)).



(a)Encode and decode process



(b)Simulink model of Zumo Motors control

Fig. 9.

4. 主要成果與評估(Result)

We have done many tests and adjust the variables to optimize the performance. We have measured and compared the execute time with different scenario including goal number and placement. According to the data acquired from tests, we found that the more concentrate the goals are, the less time is needed for path planning.

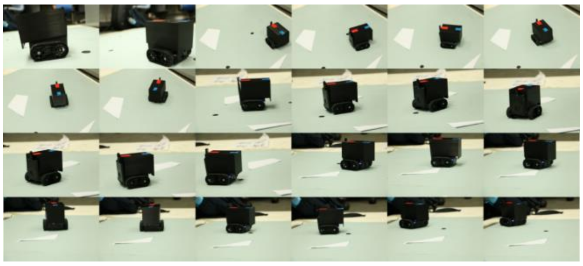


Fig. 10. Wireless charging robot performance in an indoor environment

Our work has been accepted by ICR2016 and will have a presentation during the conference.
-Yi-Shiun Wu, Chi-Wei Chen, Hooman Samani, Development of Wireless Charging Robot for Indoor Environment based on Probabilistic Roadmap, International Conference on Interactive Collaborative Robotics, Budapest, Hungary, August 24-26, 2016. To be published in Springer LNCS.

5. 結語與展望(Conclusion&Future)

To improve the charging performance, we are planning to extend our system to multiple robots. Furthermore, the localization system will be modified or changed to fit the environment which is similar to the reality. We believe that after modification, the wireless charging robot can be widely use in our smart society.

6. 銘謝(Acknowledgement)

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