Traversal Wireless Robot using Potential Fields Technique

Mongkorn Klingajay[1], **Twatchai Jitson**[2]

[1] Faculty of Engineering, Rajamangala University of Technology Thunyabury, Pathumtanee, Thailand 12120 Email: mongkorn@rmutt.ac.th

[2] Faculty of Engineering, Pathumwan Institute of Technology, Bangkok, Thailand 10500 Email: t_jitson@hotmail.com

Abstract

The paper presents approaches to the local navigation in an unknown dynamic environment. This aims to investigate and develop the appropriated path planning and local navigation technique base on the approach of the artificial Potential Field (APF) in order to minimize collision risk in uncertain environments. APF is a powerful technique is employed that the Potential force depends on the current position with respect to the goal and distances to the obstacles. APF technique has been implemented to suit the robot actuator system and its sonar sensor system to optimize the robot navigation for monitoring system. The Potential Force is programmed and recalculated in each step of traveling. As part of the paper, the monitoring system of the above mention approaches has been prepared to attach to the top of wireless robot for the image capture, while the trajectory of the robot route before the real experiment. In addition, an RF radio link is implemented in the paper, which allows the wireless communication with robot in the remote control. This paper models the navigation approach, which can be carried out the attached cameras for the motion surveillance on the unknown environment.

Key Words: Radio-link communication, monitoring system, Potential Field, Motion/Path-Planning.

1. Introduction

Robots have become common in engineering primarily due to the quality and productivity gains resulting from automation of several industrial tasks. A robot is reprogrammed and designed as multi-functional manipulator to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks. This has led to significant innovation both in the research and development of robotic systems since the advent of modern microprocessors. The robot was designed primarily to perform simple motion tasks under the direct control of an on-board computer. The on board computer receives motion commands from an external PC. Status and sensory information is fed back to the PC. Design flexibility allows for easy modification and expansion. The simplest definition of a robot could be "a mechanism which moves and reacts to its environment", and there are many robots, which apply this definition in some form.

This can be seen as a fact file type book with a tray of electric and simple mechanical components together with an envelope of card board press out parts and stencils allowing the construction of a variety of wheeled and legged mechanisms, which are crudely able to interact with the environment. The environment can be complicated; unknown before hand; or even dynamically changing.

In the real world and unstructured environment, an autonomous robot can be designed to operate and deal with situations in that environment, which able to respond appropriately and quickly to unexpected events[1]. robots will make decisions in order to achieve its goal with the input from information on what is to be done rather than how to do it. To function properly, an autonomous robot must account for solutions to every obstacles that expect with ability to plan its motion. These robots are applicable in areas such as manufacturing, nuclear factory, space exploration, undersea situation etc.

1.1 Motion/Path-Planning

The objective of motion planning is to find the best feasible trajectory for the robot to move from the start to the end such that any collision with obstacles is avoided. Different versions of motion planning correspond to cases where the obstacles are stationary, which the robot is single/multiple parts, where the robot is a collection of sub-robots.

Motion planning may tend to look relatively simple, since humans perform it unconsciously and so take it for granted. In actual fact, simple tasks such as folding a shirt is extremely difficult to duplicate using a computer controlled robot. Recently, the most of these motions planning of robot is applied to the Wireless robots.

Conventional path-planning algorithms can be divided broadly into two categories. In the first category are the methods, which make trivial changes to the image map 's representation before planning a path. The methods in the second category make elaborate representation changes to convert to a representation, which is easier to analyze before planning the path. A potential practical is classified as the shortcoming of such methods for wireless robot navigation[2]. Path planning is a classical problem in robotics and autonomous vehicle[4]. It has been studies and many approaches have been developed to achieve certain tasks. The given task is to synthesize an obstacle-free path from starting point to goal point. However, path-planning problems are different from obstacle avoidance schemes in the point that the previous one is about pre-path planning in a known environment and the latter refers to the sense of an interactive navigation in an environment with unknown obstacles.

Most of the contribution to autonomous navigation in outdoor environments consists of reactive sense-action loops. Indeed, building and maintaining global models of such environment is quite a difficult task [5], especially without high performance sensor such as laser range finder, mapping the global environment either to localize the robot or path planning and navigation task will be complex and computationally intensive. This paper presents the strategy of navigation for autonomous wireless robot in an unknown dynamic environment by using 5 sonar sensors positioning in various degrees to detect the obstacles in a 2-D point image. The robot interacts with the navigation programmed through these sonar sensors so that it gets the command from the program to traverse and model the environment.

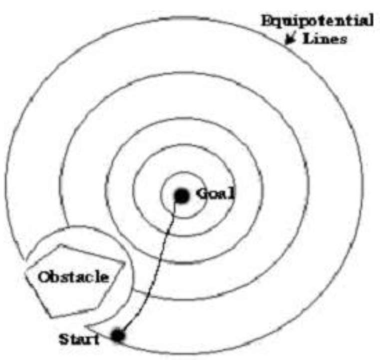


Fig. 1: The obstacles a "repelling" field

1.2 Wireless Robot Fundamentals

The wireless robotic systems are much more difficult to engineer the environment and it is often necessary for the adapt system to operate in a largely unstructured and dynamic world. This leads to a requirement for improved ability and sensing for the system to cope with uncertainty.

Wireless robots need to navigate and perform tasks without human intervention. However, because the inevitable errors in wireless robot as being the open-loop controller, in most experiments of the wireless robot could not follow the desired trajectories. In many real-life applications it is necessary for an autonomous agent to find a path between two points. The wireless robot applications mean the repeated traversal with changing the environment between predefined start and goal points [3]. For example, a wireless robot could be used to deliver the image signals to the pattern recognition center. This task implies repeated traversal between the sensor, camera and warning system. A wireless robot can also be used for the surveillance system. This task implies visiting certain checkpoints on a closed territory in a predefined order.

2. Artificial Potential Fields Algorithm

In this section, a controller design based on Artificial Potential Fields control (APF) is presented. Potential field is used as basic platform for the motion planning since it has the advantages of simplicity, real-time computation. In algorithms of this class, the idea is to associate with the goal configuration an "attractive" field (to attract the moving objects), and with the obstacles a "repelling" field (see Fig.1). These fields are mathematical expressions that are usually determined. Hence, theoretically, the moving objects are always attracted to configurations that are closer to the goal configuration, while being repelled farther from the obstacles. The collision-free path is determined by constantly seeking configurations with the highest overall attractive potential or the smallest overall repelling potential. This algorithm is applicable in 2-3 dimensional situations and in problems with an arbitrary number of degrees of freedom. It is also suitable for online trajectory generation. This method does not guarantee a collision-free path will always be found if one exists. In other words, algorithms of this class are not complete. Choosing adequate potential functions can be a very complex task.

In this paper, APF technique has been employed with the wireless robot in the several experiments in order to investigate the appropriate navigation approach for the high technology of the wireless robot application such as the mobile surveillance.

The APF uses to represent collision free paths. This approach uses the mathematical equations to present the reactive force on goal point and obstacles. Reactive navigation using APF is one of the most contributions to the robot navigation in such an unknown environment. The trajectory of navigation depends on an attractive force to the goal and repulsive force from the obstacles, which is generated by the mathematical equations. However, as it is mention before, this approach has the traditional problem with the U-shape obstacle, which is the dead-end of the wireless robot.

2.1 Potential Function

The principle is quite simple, the Artificial Potential Field (APF) consists of 2 terms:

$$U(X) = Ug(X)+Ur\ (X) \quad (1)$$

Where, $U(X)$=Resultant potential field, $Ug(X)$=Goal potential field, $Ur(X)$ = Obstacle potential field Attractive potential field *(Ug)* will be maximum at the start point and decreasing to the goal position. On the other hand, the potential field will be increased by the function of repulsive field *(Ur)* from the obstacle where it is decreasing while the robot comes close to obstacles. If we divide an environment 's map into small grid cell which center at the current robot position and calculate the resultant potential field *(U)* of each node, the minimum one would guarantee the collision-free route that robot will travel to reach the goal position.

In the cartesian coordinate, the function X of Potential Field is function of *(x,y)*. Hence, X represents the current x,y position of the robot. The resultant force is then:

$$F(X) = Fg(X) + Fr(X) \quad (2)$$

Where, $F(X) = -\Delta U(X)$ and $Fg(X)$ attractive force guide the robot to the goal and $Fr(X)$ is the repulsive force push the robot away from the obstacle.

2.2 Attractive Potential

The simple attractive potential field equation is proposed as Conic well function.

$$Ug = Kg * dg \quad (3)$$

Where, dg denoted the distance from the current position to goal and Kg is a positive gain constant. Therefore,

$$Fg = -Kg * \frac{\partial dg}{\partial X} \quad (4)$$

2.3 Repulsive Potential

The simple repulsive potential field equation is propose as

$$Ur \begin{cases} p(x) & \text{if } d<do \\ 0 & \text{otherwise} \end{cases} \quad (5)$$

Where, $p(x) = \frac{1}{2} * Kr * (1/d - 1/do)^2,$ (6)

d distance between robot to obstacles, do laser sensor range.

The force gradient of repulsive potential field *(Fr)* can be calculated by Matlab. In this case, $p(x)$ has a quadratic behavior $[1/f(X)]^2$; $X\epsilon\{x,y\}$ which influences the neighbor cell of the obstacle surface to guarantee the collision free. Function $p(x)$ is getting bigger while the d getting smaller, in other word, the robot is getting close to the obstacle. Indeed, the resultant potential field will be increased as the robot close to obstacle and it is decreasing as the robot travels to the goal point. The minimum resultant potential field is shown the non-collision path leading to the goal position. It is acted like the object free fall from the high place to the lower place.

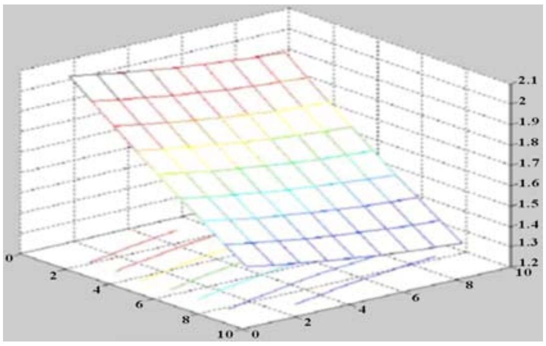


Fig.2: Attractive Potential Field from start to goal point.

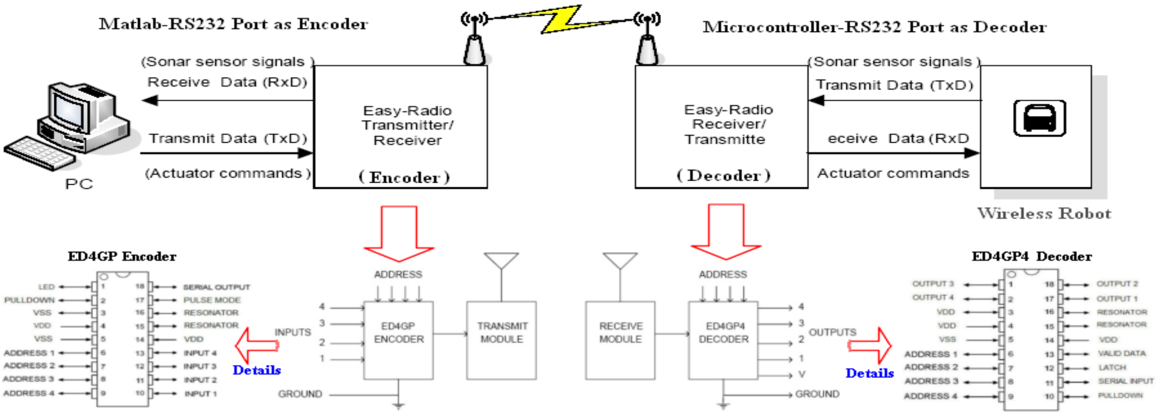


Fig. 3: Transceiver Technique (Transmitter/Receiver)

3. Radio Frequency Communication

The navigation programmed as planner to control on the wireless robot in the remote area where cables could not reach. The RF module of radio communication would be normally applied to transfer due to the reliability and long data transfer distance (up to 250 meters) and low power consumption (5.5 mA)[10].Alternatively, wireless LAN communication with onboard PC on the robot and the host computer could be used to make the data communication. But there is one draw back, which the robot has to carry heavy weigh of the onboard PC.

Transceiver 2(Robot site) Transceiver 1(PC site)
Fig.4:Radio communication between the robot and PC

Data is transferred and received by the radio link through the standard RS232 serial port with the speed up to around 9.6Kbps. The speed may depend on product specification of each company and the module type of the radio link we use. There are many modules on the market such as AM/FM type with two types of radio frequency: 434 and 868 MHz. The radio frequency communication is implemented with Matlab 's Mex-file as it has done with cables.

4. Test Environment Navigation Area

In this paper, the environment experiments have shown in Fig. 5.

(a): Obstacles on navigation area

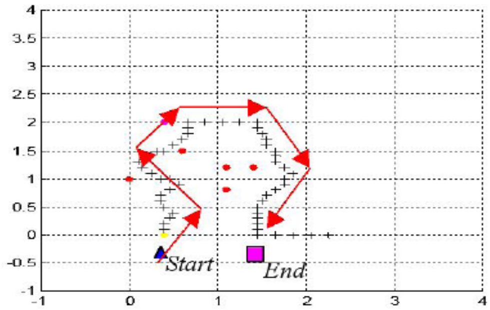
(b): Camera attachment
Fig.5: Environment Navigation of Wireless robot

The environment boundary is assigned as 3x2m^2 (Height x Width), which is Surface with hard and smooth concrete floor. The Obstacles in this environment are rectangle paper boxes and plastic boxes. Obstacle is size of 3D shape with various dimensions as following :

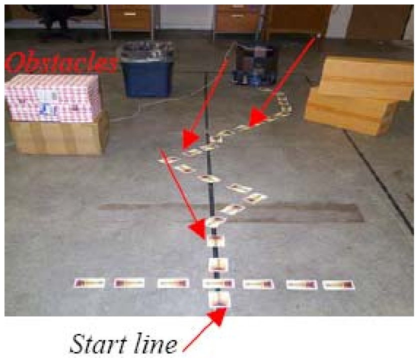
- Width : approximately 30-40 cm
- Height : approximately 30-60 cm
- Depth : approximately 20-40 cm

5. Experimental Results

The experimental result has presented in Fig. 6 for the actual and simulation path of wireless robot.



→ Robot trajectory; * Path Obstacles; + Updated
(a) Navigation path obstacles



(b) The traverse of the wireless robot
Fig. 6: The robot traversal using APF algorithm

In this test, all area navigations are implemented with 5 obstacles. The Potential Field navigation program has been adapted to run the robot in the zigzag motion and also update the robot's position on the plot. It is assumes that the robot has to run upward and then reverse the direction to run downward so as to achieve this task. As we can see, on the way upward, the robot set off the navigation at (0.4, 0) and it avoids two obstacles to reach the Y-axis boundary (the goal point) around 2.0m. Note that for the approach the robot comes close to 2 obstacles on the upward navigation. The result may not be satisfied while the gaps are too small.

6. Discussion and Conclusion

The Artificial Potential Field Navigation in such an unknown environment, APF with U-shape obstacle where the goal point set right behind it. This method, further improvement could be carried out such as Dead-End Reckoning, for example, the performance of these algorithms can be considered by factors as following:

- Smoothness of the path.
- Gap between obstacles.
- Speed of Navigation

The smoothness of the path reflects the performance of how the robot can deal with the disturbance from the obstacles. In fact, the more fluctuated trajectory, the less amount of keeping on track will be and the more risk of bumping others obstacle. This approach has shown the good performance in terms of speed and gaps between obstacles in an intense area. In other word, the robot finds the free paths to avoid the obstacle and move to the goal point successfully with reasonable time.

7. References

[1] Stefan B. Williams and Gamini Dissanayake, "An Introduction to Mobile Robotics", Lecture noted, Australian Centre for Field Robotics, J04, The University of Sydney, Australia, 2005.

[2] Subbarao Kambhampati, Larry S. Davis, "Multiresolution Path Planning for Mobile Robots", IEEE journal of robotics and automation, Vol. RA-2, No. 3**,** September, 1986.

[3] Maarja Kruusmaa, Jan Willemson, "Covering the Path Space:A Casebase Analysis for Mobile Robot Path Planning", Knowledge Based Systems, Elsevier Science, Vol. 16. No. 5-6, July, 2003, pp.235-243.

[4] C. Vasudevan and K. Ganesan, "Case-Base Path Planning for Autonomous Underwater Vehicle", Kluwer Academic Publish, 1996, pp. 79-89.

[5] Maarja Kruusmaa, "Global Navigation in Dynamic Environment using Case-Base Reasoning", Kluwer Academic Publish, 2003, pp. 71-91.