International Journal of Scientific Research in Computer Science, Engineering and Information Technology
© 2019 IJSRCSEIT | Volume 5 | Issue 1 | ISSN : 2456-3307
DOI : https://doi.org/10.32628/CSEIT195186

# A Novel Approach on Prevention of a Mobile Exploration in Machine Using AI

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**ABSTRACT**

This paper deals with a low cost solution to problem avoidance for a mobile machine using just a single Artifical Intelligennce. It allows the machine to navigate smoothly in an unknown environment, avoiding collisions, without having to stop in front of problems. The problem avoidance process is made up of three distinct stages - the mapping algorithm, the core problem avoidance algorithm, and the steering algorithm. The mapping algorithm takes the raw Artifical Intelligennce readings and processes them to create higher resolution maps from the wide-angle Artifical Intelligennce. The problem avoidance algorithm is based on the potential field theory which considers the machine to be a test charge that is repelled by all the problems around it, and which moves in the direction of the resultant of the forces acting on it. An algorithm which steers a mobile machine based on the differential drive system is also discussed.

**Keywords :** Mobile Machine, Problem Avoidance, Autonomous Navigation, Ultrasonic Range Sensor.

## I. INTRODUCTION

Problem avoidance is a primary requirement for any autonomous mobile machine. The machine acquires information about its surroundings through sensors mounted on the machine. Various types of sensors can be used for problem avoidance, as detailed below.

### A. Types of Sensors:

**Bump sensors**, which are micro-switches activated when the machine touches an problem. This is a simple, inexpensive method of problem detection, but operates only on contact, which makes it useful only for slow moving machines.

**Infrared proximity detectors**, which detect the presence of an object in front of the sensor. They consist of a combination of an infrared light emitting device and an infrared light sensor. These sensors are merely proximity detectors, they cannot determine the range of the problem in front. The range of these sensors is also limited to a maximum of 80cm.

**Ultrasonic range sensors**, which determine the range of the object in front of it. They work by sending a short burst of ultrasonic waves, and measuring the time taken for the echo to be received. They have a wide beam angle, typically 30. These sensors have ranges of up to 6m.

**Laser range finders**, which work on the same principle as ultrasonic range sensors, except that they use LASER instead of ultrasound. Laser range finders have a range of upto 30m, and are very accurate, having an angular resolution of upto 0.25.

However, they are very expensive compared to other sensors of these, the ultrasonic range sensor was found most suitable for our requirement because of its low cost and ranging capability.

## II. MAPPING

An ultrasonic range sensor detects the range of an object in front of it by sending a short burst of ultrasonic waves, and measuring the time taken for the echo to be received. These sensors typically have a wide beam angle of 15 to 30 As a result, the cone gets wider with increasing distance from the transmitter. This increases the uncertainty in the spatial dimensions of the problem. Most mobile machines which use ultrasonic range finders for problem avoidance have 12 or 24 sensors in a ring around the machine, to cover all directions. This is not very cost-effective, and moreover, all of them cannot be triggered at once due to crosstalk and interference problems. A maximum of 4 sensors which are at 90 to each other can be triggered at a time. Our solution was to use a single sensor mounted on a stepper motor to pan the sensor across 180. This can be expanded to 4 sensors mounted at 90 to each other on the stepper motor for maximum scanning speed and full coverage. Such a setup also provides the flexibility to perform fine scanning of an area for a more accurate map of the environment, with an angular resolution of the minimum step size of the stepper motor, as opposed to the 30 resolution of the sensor.

## III. MACHINE SCANNING ALGORITHM

A single range reading from the sensor implies that the area in a 30 sector in front of it with a radius of the range value contains no problems. A reading of a range of 1m. This reading covers angles -15 to +15. Beyond the range value, there may be problems somewhere along the arc, but it is not certain at which positions the problems are present.
Figure 1 shows the next sensor reading, which is obtained after rotating the sensor through a certain angle, say 5. This reading, with a range value of 1.2m covers angles -10 to +20. After obtaining this reading, we are certain that there is no problem between these angles for a range of 1.2m. Thus, in the overlapping region, the larger distance value is chosen over the smaller one.

If a subsequent overlapped reading is smaller than the existing value, then we have to consider the 'age' of the existing information. If the existing large range value is very recent, then the overlapped area is taken to have the larger range, because it can be assumed that no object moved into the intersecting area between the two scans. If the existing large range value is old, then the smaller value is taken, because the machine may have moved within that time, or a moving problem may have appeared.

Using this technique, the accuracy of the ultrasonic range information can be greatly improved upto the step size of the stepper motor. However, there are some cases where the information is still not accurate. Consider the case gap between problems A and B can never be detected by the sensor at that distance. Once the machine moves closer to these problems, the gap can be detected.

## IV. PROBLEM AVOIDANCE

All mobile machines feature some kind of problem avoidance. The algorithm could be as simple as stopping if an problem is detected in front of it. This is common in track-following machines, where the machine follows a pre-determined track. Another solution is wall-following, in which the machine moves alongside a wall at a fixed distance, following the contour of the wall till it reaches its destination.

In the case of an exploration machine, the environment is unknown and problem avoidance h as to be dynamic in nature. Our approach is an adaptation of the potential field method or VFF method in which the machine is considered as a test charge which is repelled by problems which are considered as like charges. Section II explains our mapping methods and an algorithm to obtain accurate data from the wide angle ultrasonic range sensor. Our potential field method adaptation is discussed steering control for the differential drive machine based on the output of the potential field algorithm is described.

Information about the ranges of problems around the machine obtained from the mapping technique is stored in a table which is continuously updated. This range information is then used to calculate a destination direction which the machine must move towards. This calculation is performed using our problem avoidance algorithm based on the potential field method.In the potential field method, the machine is considered as a test negative charge. All the problems are considered to be negative charges which repel the machine, and the target is assigned a positive charge which attracts the machine. The forces of all these charges on the machine are calculated in accordance with Coulomb's law, i.e. the force is proportional to the charge and inversely proportional to the square of the distance.

$$F \propto \frac{q}{r^2}$$

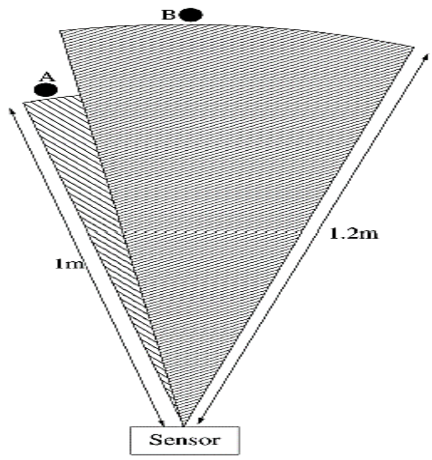


**Figure 1 :** The second reading from the ultrasonic range finder overlapping the first

The machine is then steered in the direction of the resultant of all the forces added up. This results in motion of the machine similar to a charge moving in a potential field - avoiding like charges and moving towards the unlike charge. For the case of an exploration machine without a target, the algorithm has to be slightly modified. A threshold limit is set beyond which the charge assigned to the range is positive and attracts the machine. Thus, problems which are close by to the machine will repel it, and the free spaces attract the machine.

$$\vec{F}_\theta = -\frac{k}{\left|\vec{r}_\theta\right|^2} \cdot \hat{r}_\theta$$

This is the basic equation representing the force exerted on the machine by a single problem at a distance r and an angle from the machine. k is a numerical constant selected to bring the force into the required range. The charge q is not present in this equation because different angles do not have different charge values. This equation is modified to make near ranges repel the machine and far ranges attract, as shown in the following equation.

$$\vec{F}_\theta = k\left(\frac{1}{t^2} - \frac{1}{\left|\vec{r}_\theta^{\,2}\right|}\right) \cdot \hat{r}_\theta$$

Here, t is a threshold distance at which the problem neither attracts nor repels the machine, and ranges beyond the threshold distance are attractive. The total force on the machine is obtained by vectorial addition of all the individual forces.

$$\vec{F}_{total} = \sum_{\theta=0}^{2\pi} \vec{F}_{\theta}$$

$$\vec{F}_{total} = k\sum_{\theta=0}^{2\pi}\left(\frac{1}{t^2} - \frac{1}{|\vec{F}_{\theta}|^2}\right)\cdot \hat{r}_{\theta}$$

This is the expression for the resultant of all the forces acting on the machine. The machine is steered in this direction in order to avoid problems. The magnitude of the vector can be used to control the speed of the machine. This results in slow movement in a cluttered environment, and faster motion when there are fewer problems surrounding the machine.

## V. STEERING CONTROL FOR A DIFFERENTIAL DRIVE SYSTEM

A mobile machine which uses differential drive has separate speed and direction control for the left and right sets of wheels. Such a system is very flexible for a mobile machine because it does not have a minimum turning radius, it can execute a turn around its own center. Arc turning is achieved by driving the left and right wheels at different speeds. Driving one set of wheels forward and the other set backward results in in-place turning.

An algorithm was designed to convert the force vector obtained from the problem avoidance algorithm into the left and right wheel speeds required for the differential drive system. The magnitude and direction of the force vector is plotted as a point on a graph, after being normalized so that the maximum possible magnitude is 1. Thus, all possible force vectors will lie in a unit circle around the origin, as shown in Figure 2.1.

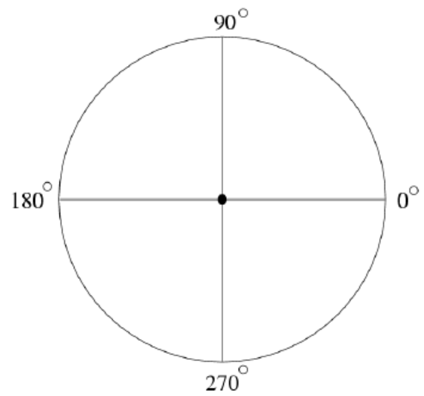


**Figure 2.1 :** Unit circle in which all possible force vectors lie

On this circle, a point at 90 indicates that the machine has to move straight, a point at 0 indicates that the machine has to turn right in-place, and at all points in between, it has to exhibit varying degrees of turning.

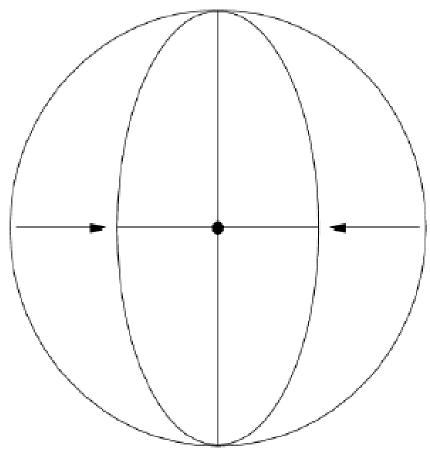

**Figure 2.2 :** The unit circle shrunk into an ellipse

This unit circle is shrunk into an ellipse as shown in Figure 2.2, by dividing the x coordinate by a constant. This ensures that the wheel speeds of the machine are lower while turning and faster when moving straight. Turning at high speeds can result in slipping and inaccurate turns, this prevents it from happening.

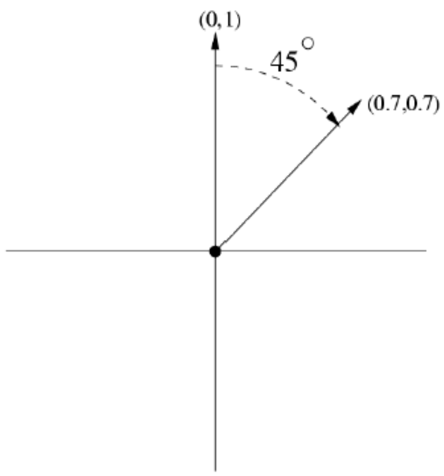


**Figure 2.3 :** Rotation of the force vector

Now the existing force vector is rotated clockwise by 45, as indicated in Figure 2.3. The new coordinates of the vector are then taken as the left and right wheel speeds respectively (after normalization). This result in the machine turning in the required direction based on the direction of the original force vector. This dynamic steering algorithm ensures that the machine doesn't have to stop in front of an problem to go around it, instead it navigates smoothly to the required direction.

The force vector is updated every time new range information is obtained,which is approximately every 20 or 30 milliseconds, and the wheel speeds are also correspondingly modified every time. Modifications in the wheel speeds will not be abrupt, because every reading changes the range associated with only a narrow angle, resulting in a very small change in the resultant force vector. Since the wheel speeds vary smoothly according to the sensor information, and the speeds are updated almost in real time, the machine follows a smooth course around the problems present in the environment, while still being able to respond immediately to changes in the environment like dynamic problems.

## VI. EXPERIMENTAL RESULTS

The mobile machine we designed and constructed, and implemented the problem avoidance algorithms on. It uses a differential drive system for mobility, but uses tracks instead of wheels, like a tank. The drive motors used are stepper motors. It has a single ultrasonic range sensor mounted on a stepper motor in front which can pan across an angle of 180 in steps as small as 0.45. The machine is controlled by a computer through the parallel port connected to the required driver circuits on the machine itself.

RTLinux was chosen as the software platform because real time functionality was required, especially to measure the sonar range timing, and to trigger the stepper motors. The default interval at which ultrasonic range readings are taken is 15, which provides 12 readings over 180. Each reading overlaps the previous by 15. This provides for fast scanning of the environment -- an average of 500ms to scan 180, and thus the machine can move at high speeds without danger of collision. If an area needs to be mapped more accurately, or in case of a highly cluttered environment, the step size is reduced and the maps obtained are of higher resolution, which can help in navigating precisely through smaller pathways.

## VII. CONCLUSION

This traveler machine can explore in any unknown environment smoothly avoiding problems. Thus it can be used even in exploring other planets using very precise sensors. This method of avoiding problems is very useful in army, military applications. These kinds of machines hold the technology for the coming future.

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**Cite this article as :**

J.Antony Daniel Rex, S.Dinakaran, S. Muthukumaran, "A Novel Approach on Prevention of a Mobile Exploration in Machine Using AI ", International Journal of Scientific Research in Computer Science, Engineering and Information Technology (IJSRCSEIT), ISSN : 2456-3307, Volume 5 Issue 1, pp. 349-356, January-February 2019. Available at doi : https://doi.org/10.32628/CSEIT195186
Journal URL : http://ijsrcseit.com/CSEIT195186