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SWARM ROBOTICS

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ABSTRACT

Trajectory planning is a prime method in the research on mobile robot navigation. Sampling-based algorithms can generate trajectories which help the robot to reach the target avoiding obstacles. In this proposed work, an Enhanced Artificial Potential Field (E-APF) generates the trajectories for mobility of mobile robots and simultaneously guarantees the effectiveness and continuity of the trajectory. Aiming at the problem that the classical APF cannot adapt to the complex trajectory planning and fall a as prey to the local optimal solution, E-APF method is proposed for Swarm robot route planning. The repulsive potential is built by repulsive function for discretizing outline of an arbitrarily shaped obstacle with their boundary points. This process describes the workspace of the wheeled mobile robot more precisely. The reliability is proved for most of the cases by discussing the convergence of this proposed technique. Finally, an efficient obstacle avoidance-based action has been performed in the chosen navigable trajectory. Trajectories that have been generated using the proposed E-APF satisfy constraints approach of the direction on both the starting and goal points. Consequently, the trajectories that are generated by the Wheeled Mobile Robot(swarm robots) are geometrically and dynamically feasible. Simulation results performed confirm the viability of the proposed E-APF algorithm that it can be effectively utilized in trajectory planning of wheeled mobile robots and can be applied in real-time scenarios.

KEYWORDS: *E-APF, CI, ANNs, FS, EC.*

I. INTRODUCTION

Nature has always inspired researchers. By simple observing we can sometimes notice the patterns, the set of rules that make seemingly chaotic processes logical. How do we think and how do we memorize? Why is evolution so important for the survival of species? How do the social insects know how to follow the path to a source of food without the global knowledge? These questions are partially answered by computational intelligence (CI). Partially, because answering some questions we are usually faced with new ones to answer.

CI as a part of broader field of artificial intelligence (AI) comprises of the paradigms that relate to some kind of biological or naturally occurring system. These paradigms are artificial neural networks (ANNs), fuzzy systems (FS), evolutionary computing (EC) and swarm intelligence (SI). ANNs are computational models of the human brain. Important characteristic of ANNs is capability to learn from the environment and to retain information. FS approximate human reasoning using imprecise, or fuzzy, linguistic terms. They offer solutions to a disadvantage of ordinary rule-based expert systems that cannot handle new situations not already explicitly covered in their knowledge base. EC is based on Darwin's evolutionary theory principles. It refers to computer based problem-solving systems that use computational methods of evolutionary processes (selection, reproduction, mutation) as the fundamental components of such computational systems. SI is modelled on the social behavior of insects, fish and birds. The benefit of cooperation among individuals in a swarm can be significant in situations where global knowledge of environment does not exist. Figure 1 show the diagram of CI paradigms where the hybrid approaches exist as well. CI is generally applied to optimization problems and many problems that can be converted to optimization problems.

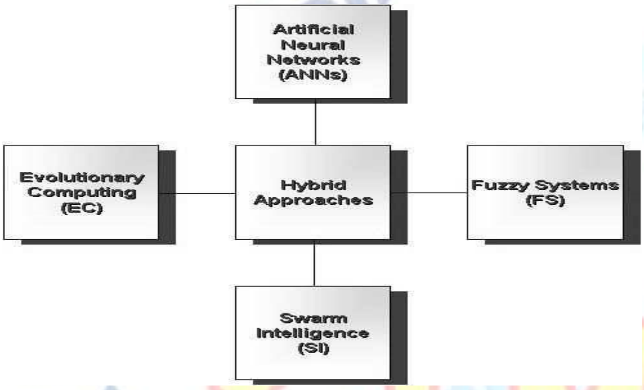


Figure 1: Computational Intelligence Paradigms.

II. AN OVERVIEW ABOUT ROBOTICS

Robotics as a discipline is often described as an interdisciplinary field constructed from Mechanical Engineering, Electrical Engineering, Industrial Engineering and Computer Science. It is fairly new as an academic area and mostly grew out of Mechanical or Electrical Engineering programs. Previously, various aspects of the robotics trade was found in subjects such as kinematics, dynamics, controls, mechatronics, embedded systems, sensing, signal processing, communications, algorithms and planning.

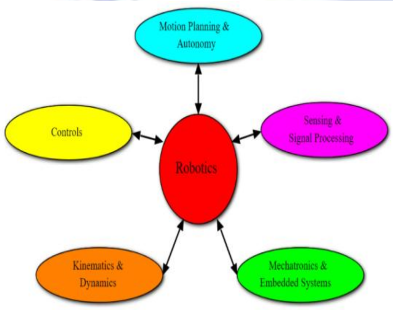


Figure 2: Robotics is a blend of mechatronics, embedded systems, controls, sensing, signalprocessing, kinematics, dynamics, communications, algorithms and planning.

2.1 Swarm Robotics

Swarm robotics (SR) refers to the application of swarm intelligence techniques to the analysis of activities in which the agents are physical robotic devices that can effect changes in their environments based on intelligent decision-making from various input. The goal of this approach is to study the design of robots (both their physical body and their controlling behaviors) such that a desired collective behavior emerges from the inter-robot interactions and the interactions of the robots with the environment, inspired but not limited by the emergent behavior observed in social insects.

SI techniques as ACO and PSO can be used as a control algorithm for distributed robot swarms, but a good problem-solving system does not have to be biologically relevant. However, the remarkable success of social insects in surviving and colonizing our planet can serve as a starting point for new metaphors in engineering and computer science.

2.1.1 Criteria for Swarm Robotics

What makes a system swarm-robotic?

Autonomy – It is required that the individuals that make up the swarm-robotic system are autonomous robots. They are able to physically interact with the environment and affect it. **Large number –** A large number of units is required as well, so the cooperative behavior (and swarm intelligence) may occur. The minimum number is hard to define and justify. The swarm-robotic system can be made of few homogeneous groups of robots consisted of large number of units. Highly heterogeneous robot groups tend to fall outside swarm robotics.

Limited capabilities – The robots in a swarm should be relatively incapable or inefficient on their own with respect to the task at hand.

Scalability and robustness – A swarm-robotic system needs to be scalable and robust. Adding the new units will improve the performance of the overall system and on the other hand, losing some units will not cause the catastrophic failure.

Distributed coordination – The robots in a swarm should only have local and limited sensing and communication abilities. The coordination between the robots is distributed. The use of a global channel for the coordination would influence the autonomy of the units.

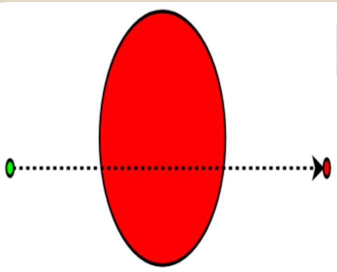
Though these criteria are not to be used to determine whether a system is swarm-robotic or not, they can be used to measure the degree to which the term” swarm-robotic” might apply

III. Methodology

Assuming we have a simple obstacle map, how should we proceed? Try the following thought experiment. Pretend that you are in a dark room with tall boxes. Also pretend that you can hear a phone ringing and you can tell what direction it is. How would you navigate to the phone? Figuring that we can feel my way, we would start walking towards the phone. We keep going as long as there are no obstructions in my way. When we meet an obstacle, without sight (or a map) we can’t make any sophisticated routing decisions. So, we decide to turn right a bit and head that way. If that is blocked, then we turn right a bit again. We can continue turning right until the path is clear. Now we should take a few steps in this direction to pass the obstacle. Hopefully we clear and we turn back to my original heading. we head in this direction until we run into another obstacle and so we just repeat my simple obstacle avoidance approach.

3.1 Basic Motion Algorithm

```
Set heading towards goal
while Not arrived at goal do
   while No obstacle in front do
      Move forward
   end while
   count = 0
   while count <= N do
      while Obstacle in front do
         Turn right
      end while
      Move forward
      incr count
   end while
   Set heading towards goal
end while
```



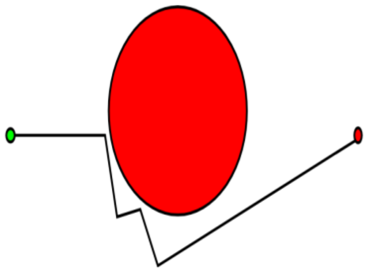


Figure 3. The direct path to the goal Path using the Basic Motion algorithm.

Figure 3 illustrates the idea. This algorithm is not completely specified. The amount of right turn and the distance traveled in the move forward steps is not prescribed above. Assuming values can be determined, will this approach work? We expect success when faced with convex obstacles but not necessarily for non-convex obstacles, Fig4. Using Fig5as a guide, we can construct a collection of convex obstacles which still foil the algorithm; this is expressed in Fg5. The robot bounces from obstacle to obstacle like a pinball and is wrapped around. Leaving the last obstacle the robot reaches the cutoff distance and then switches back to the “motion to goal” state. However, this sets up a cycle. So, the answer to the question “does this work” is not for all cases.

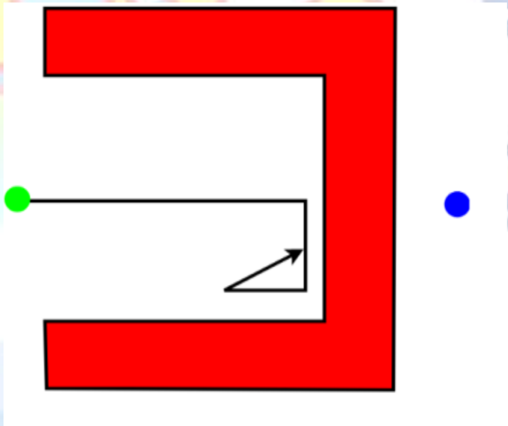


Figure.4 **Getting trapped in a non-convex solid object.**

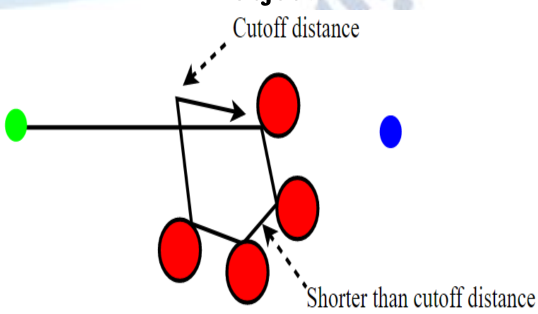


Figure 5: **A collections of convex objects can mimic a non-convex obstacle.**

3.1 Potential Functions

A potential function is a differentiable real-valued functions.

U:$R^m \rightarrow$R.Wemaythinkofitasanenergyandthusthegradientisaforce. Thegradient

$$\nabla U\ (q) = \begin{bmatrix} \frac{\partial U}{\partial q\_1} \\ \frac{\partial U}{\partial q\_2} \\ \cdots \\ \frac{\partial U}{\partial q\_n} \end{bmatrix} = \vec{F}$$

The gradients can be used to act on the robots like forces do on charged particles,the vector fields (gradients) may be used to pull a robot to a particular goal or push a robot away from an obstacle.

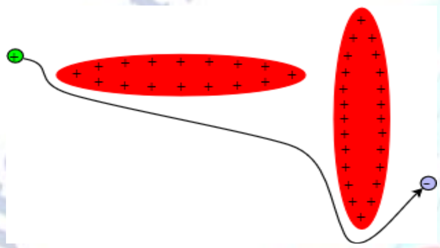


Figure 6: Potential Function Navigation.

Vectors are seen as velocity not forces so this is a first order system.

The robot can move downhill using gradient descent:

$$\dot{c}(t) = -\nabla U(c(t)),$$

$$\frac{dx}{dt} = \frac{\partial U}{\partial x}$$

$$\frac{dx}{dt} = \frac{\partial U}{\partial y}$$

$\nabla U(q)$,qstart,Sequence $q_1, q_2, q_3, \ldots\ldots. q_n$

$q(0)=q_{start} i=0 q(i+1)=q(i)-\alpha(i)\nabla U(q(i)) i{+}{+}$

It will stop when it reaches a critical point. ,q^*: $\nabla U(q^*)=0$.

This point is a maximum, minimum or saddle point. It depends on the eigenvalues of the Hessian.

$$H(U)=\begin{pmatrix} \frac{\partial^2 U}{\partial q_1^2} & \cdots & \frac{\partial^2 U}{\partial q_1 \partial q_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial^2 U}{\partial q_n \partial q_1} & \cdots & \frac{\partial^2 U}{\partial q_n^2} \end{pmatrix}$$

The Hessian is symmetric so the eigenvalues are real. Thus we get:

IV. Conclusion

The proposed Enhanced Artificial Potential Field (E-APF) generated the trajectories for navigation of mobile robots and also simultaneously guaranteed the effectiveness and continuity of the trajectory that was traced. The proposed E-APF algorithm is composed by merging the grid method with the artificial potential field technique. The prime aim of proposing this method was to overcome the problem that the classical APF could not adapt to the complex trajectory planning and falling as a prey into the local optimal solution. The edge holding technique was utilized to solve the problem of getting trapped into local minima scenarios. The proposed E-APF method did not consider the influence of traditional attraction and repulsive forces. The repulsive potential was built by repulsive function for discretizing the outline of an arbitrarily shaped obstacle with boundary points which provides the means for describing workspace of the wheeled mobile robot more precisely. The reliability was proved for the entire scenario considered because of the convergence of this proposed technique. Finally, an efficient obstacle avoidance-based action was performed in the chosen navigable trajectory. Trajectories that had been generated using the proposed E-APF method satisfied the directional constraints approach on both the starting and goal points. Consequently, the trajectories that were generated by the Wheeled Mobile Robot were also geometrically and dynamically feasible.

All the simulations were carried out in recursive U-shaped, long wall, unstructured, maze-like and cluttered scenarios. Simulation results that were performed show the viability of the proposed E-APF algorithm that it can be effectively utilized in trajectory planning of wheeled mobile robots and can be applied in real-time scenarios. The prime benefit of the proposed EAPF algorithm is that the algorithm adapts well in both simple and complex environments with minimal time of travel.

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