Optimizing mobile robot navigation using computational intelligence

Wong Chien Sen
School of Computing
Asia Pacific University of Technology and Innovation (APU)
Kuala Lumpur, Malaysia
TP059871@mail.apu.edu.my

Chandra Reka Ramachandran
School of Computing
Asia Pacific University of Technology and Innovation (APU)
Kuala Lumpur, Malaysia
Chandra.reka@staffmail.apu.edu.my

Alvin Yap Chee Wei
School of Computing
Asia Pacific University of Technology and Innovation (APU)
Kuala Lumpur, Malaysia
yap.alvin@staffemail.apu.edu.my

***Abstract*—This research provide an overview of computational intelligence and robotics. Mapping and navigation of robotics is time consuming and often ineffective. Therefore, the goal of this research is to optimize path finding navigation of robotics using computational intelligence. Several algorithms are proposed by previous researchers such as genetic algorithm, swamp intelligence and artificial immune system. Global and local environments with static and dynamic obstacles are used to test the result. Robotic simulation is used to validate the effectiveness of the algorithm.**

Keywords—Computational intelligence, robotic navigation, genetic algorithm, swamp intelligence, artificial immune system

I. INTRODUCTION

Robotics are emerging into several sectors such as law enforcement, military, medical, space research, aircraft and many more as mentioned in [1] Robots are capable to perform various tasks, one of the basic task is to navigate in an environment, maneuver around obstacles to reach defined goals. Navigating around an area requires path planning and obstacle avoidance. [2]

There are two types of path planning for robots: global and local path planning. In global path planning, the environment and the obstacles are known to a robot, path planning can be performed without exploration. In local path planning, the environment is uncertain, navigating through unknown environment is challenging for autonomous robots. In an ever-changing environment, obstacles and goals are dynamic, obstacles vary in shapes and sizes. [3] An effective mechanism is required for robot to develop path planning and obstacle avoidance.

Algorithm for path planning and obstacle avoidance has been developed by various researchers using computational intelligence. This paper reviews previous research papers in optimizing the path planning and obstacle avoidance for a mobile robots. Heuristic technique is used by previous researchers in optimizing the solution for navigation. The algorithms used are nature inspired such as genetic algorithm (GA), particle swarm optimization (PSO) and artificial immune system (AIS).

II. OPTIMIZATION TECHNIQUES

A. *Genetic Algorithm*

GA is a heuristic technique based on natural genetics to optimize a solution based on the process of parent selection, gene crossover and gene mutation. The solution is determined by the fitness of the gene. The process repeats until the optimal

solution has been reached. Probabilistic Roadmap (PRM) method was compared with GA in global environment to find the efficiency of path finding for mobile robot [2]. Both algorithm had navigated the robot without collision. GA showed that the mobile robot travel through the path smoothly with fewer turns but requires more computational time. However, PRM requires less computational time and resources for navigation. This is due to the nature of GA to process the parameters to find the fittest values for the environment. Reference [4] proposed hybridized fuzzy genetic algorithm for humanoid robots to navigate and avoid obstacles. The proposed method are used in local environment where obstacles are not known by the robot. Data from sensors and bearing angle are used as primary input of fuzzy logic (FL) controller, then the first turning angle from the output of FL controller act as intermediate output. This intermediate output is further used as input to genetic algorithm controller and the second turning angle is obtained as the final output. The framework is verified using simulation and validated with physical robot with lab setup. The result was accepted with minimum percentage of error due to external factor such as frictional loss.

Another approach proposed by [5] was matrix-binary code in GA to solve navigation problems in a dynamic environment. The inputs from the sensors of the robot was arranged into matrix-binary code for navigation operation and GA finds the optimum solution by avoiding obstacles. The proposed method was found to perform better than FL, artificial neural network and ant colony optimization (ACO).

The genetic crossover process of GA was improved by [6] to obtain workable path with better fitness and avoid premature convergent. Parents with high fitness value will be selected for crossover. Besides that, truncation selection was proposed to allow weaker chromosome to be the parent of next generation. This step would diversify the number of population and more possible solution will be evaluated by the GA. Same Adjacency crossover was proposed to optimize the path finding solution. The improved crossover GA has optimized the navigation of mobile robot, it requires lesser number of turns and consumed less energy by the robot. The researcher proved that the proposed algorithm performs better than previous research in improvement of GA.

B. *Swarm Intelligence*

PSO is another nature inspired optimization technique. This is based on the behavior of a group of organism to achieve goals to a specific problems, such as a flock of birds.

The organism performs better in groups rather than acting individually.

In research by [7], PSO was proposed to optimize the path planning of a mobile robot. In this concept, the fitness of the individual particle was recorded in personal best, whereas the fittest of whole swamp was recorded in global best. These particles moved towards the global best by communicating the fitness result from personal best and global best. At the end of the process, the researchers demonstrated that all particles had reached the predefined goals without colliding with obstacles in shorter time and distance. In addition, for a local environment where the environment is unknown to a robot. Exploration of map is needed along the navigation system of a mobile robot. The PSO algorithm was improved by adding laser scanner as input for mapping the unknown environment as proposed by [8]. However, the researcher highlighted that the limitation of this system was unable to implement in a dynamic and complex environment. Further improvement had been introduced by [9] to include adaptive algorithm into PSO. The inertia weight or acceleration value was introduced to determine the exploration capability of PSO, the higher the value of inertia weight, the higher the capability to accept changes in PSO. The simulation in [9] had shown the effectiveness of adaptive PSO in finding shorter path and smoother navigation. It was concluded that adaptive PSO performs better than standard PSO algorithm.

Another approach of swamp intelligence propose by [10], which is simplified swamp intelligence (SSO) to enhance the path planning of robot. The path finding algorithm was simplified by finding neighbor position of robot when encounter obstacles. The researcher simulated that the SSO optimized path finding of the robot in shorter distance and lesser turning angle, the result had shown SSO performs better than PSO, without navigate through the obstacles in irregular path. The researcher highlighted that SSO algorithm can be applied on global environment.

Firefly algorithm was proposed by [3] to solve navigation problems in local environment where the surroundings is uncertain to the robot. The proposed algorithm was designed to navigate around dynamic and static obstacles. The firefly algorithm was activated when obstacles approaches to avoid collision. The concept of firefly emitting lights was adapted in this algorithm to find the optimal path when surrounded by obstacles. In goal finding approach, the fitness was based on maximum distance from the obstacle and the minimum distance of the current position from the goal, this process repeats until the goal is achieved, this approach was adapted by [3], [9] Euclidean distance is used to calculate the distance (Dgi) between current position and the goal, the equation is shown in (1). Where xg and yg are X and Y coordinate of the goal, xi and yi are X and Y coordinate of the current position of the firefly.

$$D_{gi} = \sqrt{(x_g - x_i)^2 + (y_g - y_i)^2} \tag{1}$$

Equation (2) is used to calculate the distance (Dob) between current position and the obstacle. Where xob and yob are X and Y coordinate of the obstacle, xi and yi are X and Y coordinate of the current position of the firefly.

$$D_{ob} = \sqrt{(x_{ob} - x_i)^2 + (y_{ob} - y_i)^2} \tag{2}$$

Firefly algorithm was compared with neuro-fuzzy, genetic algorithm and fuzzy-neural network, and showed that firefly algorithm perform better in travelling shorter path and lesser time.

Hybrid Cuckoo Search-Bat Algorithm was proposed by [11]. This approach was inspired by the parasitic behavior of cuckoo in searching and bat echolocation behavior in finding the optimum path.

Research in [12] further improve bat algorithm namely Modified Frequency Bat (MFB) algorithm and Hybrid Particle Swarm Optimization-Modified Frequency Bat (PSO-MFB) algorithm in optimizing path finding algorithm for mobile robot in static and dynamic environment. The MFB which is developed from standard bat algorithm, adapted the echolocation of the bat, which produces sound waves echo from reflection of obstacles while flying. The loudness and pulse emission changes when the bats have achieve the goal. PSO was merged to introduce hybrid method in path finding, this is to optimize the exploration and exploitation process in path finding. The researcher conclude that the hybrid PSO-MFB performs better than MFB alone, it finds the shorter path and safer path to be free from collision due to adaptive capability of the algorithm in PSO.

Furthermore, hybridization of invasive weed optimization and improved PSO (IWO-IPSO) was proposed by [13]. The improved PSO is dependent on the inertia weight to perform exploration and have the opportunity to generate local optimal solution and slow convergence. IWO was introduced to improve the velocity and position of PSO. IWO was adapted from agriculture by colonizing wide area in given environment with seeds and reproduce. In the hybridized system, IWO controlled the evolution and the IPSO performed exploration and exploitation. The researcher experimented with multiple robots with IWO-IPSO in optimizing the navigation with collision free path way. It was proved that hybridized system performed better than individual IWO and IPSO algorithm.

C. Artificial Immune System

AIS in computational intelligence is based on the immune system of human body. The antibodies carried by B - cells in the immune system protects the body against foreign particles such as pathogens and antigens. The B- cells act as an agent to detect antigens that are found in the system, it has the ability to clone itself when it is useful to detect the antigen. This method of defense is known as clonal selection. Another defense is called idiotypic network theory when suppression of antigen will trigger the stimulation and suppression of antibodies. [14]

A hybrid AIS approach proposed by [14] to optimize the navigation problem of mobile robot in unknown environment. Idiotypic network theory and clonal selection was proposed for obstacle avoidance and path finding. In the hybrid algorithm, idiotypic network theory was effective in avoiding obstacles, however when there is a trap-like obstacles, the network theory fails to overcome local minima situation. At this point, clonal selection was switched to overcome trapped situation by using wall following algorithm. After overcome the trapped situation, the clonal selection was switched back to idiotypic network theory of AIS. Simulation and experimental result showed that the robot navigate through obstacles and achieve the goal successfully. The proposed

hybrid AIS system performs better than other algorithm from previous research, it was proved that hybrid AIS navigated in shorter and smoother path.

On the contrary, [15] results showed that ACO performs better by achieving the defined goal in a reliable way, AIS algorithm did not get to the goal in some cases. However, AIS has shorter computational time compared to ACO. In this research, two proposed algorithm is used to compare the time and length of path required to reach the goal. Three different environment is introduced with different difficulty and layout. The result shows that ACO performs better by achieving goal in a reliable way, in contrast to AIS which do not achieve the goal in several environment. However, AIS shows faster results when it achieve the goal. Future recommendation in applying these algorithm for aerial environment

III. CONCLUSION

The previous reviewed journals are summarized in TABLE 1. Previous research had proposed various methods in path planning and obstacles avoidance by using nature inspired algorithm. The three main categories are genetic algorithm, swamp intelligence and artificial immune system. Hybridized algorithm are proven to perform better than individual algorithm in optimizing navigation of robots. Local and global environment has to be addressed, the proposed solution could be used in known and unknown environment. Furthermore the proposed algorithm can be adaptive to maneuver around static and dynamic obstacles to reflect in real world situation.

There was lack of research on AIS in mobile robot navigation. Therefore, future research can be done by hybridize AIS with other computational technique as suggested by [14].

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