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Path Optimization of Humanoid NAO using Particle Swarm Optimization

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Abstract—*Now a day in order to achieve various tasks with human capability imitation is regarded as a potential research for creating helpful assistant to human race. For quite some time the current research has been veering around the viability of use of humanoid robots in mainstream life and their navigation. As the humanoids are evolving smarter, they are using various Artificial Intelligence techniques to optimize their path and thus become more autonomous. Here in this paper focus has been given to the path optimization of a humanoid robot 'NAO' by applying Particle Swarm Optimization (PSO) technique. A program has been developed and through simulation an optimized path is obtained by using 'VREP' in an environment having static obstacles. The same program is also experimentally compared with the help of NAO in similar type of environment and good agreement is found between the results.*

1. INTRODUCTION

Nowadays robots are representatives of human being in almost all fields. The actuators are capable of moving a robot from one position to another position but in order to have a smooth navigation the implementation of Artificial Intelligence techniques (AI) are important at the same time. Many Artificial Intelligence techniques like neural network, fuzzy logic, and genetic algorithm are used for navigational problems but Particle Swarm Optimization (PSO) gives more convergent results than the other techniques [1]. So it is an evolutionary method used for the navigation purpose. Kherici et al. [2] have observed a good result on biped robot walking, using PSO algorithm. As PSO is a metaheuristic method it is a best method to use in optimization problems. This method is best suit for global path planning and our interest here also planning the path globally which is another reason of choosing this technique.

2. PARTICLE SWARM OPTIMIZATION

This technique is a population based method which basically inspired by the natural behavior of fish schooling or bird flocking. The group or the population in this technique is generally termed as swarm and its individual entities are known as particles [3].

Let the swarm is defined as a set $W=\{S_1, S_2, S_3, S_4 \ldots S_m\}$

Where S_1, S_2, S_3, $S_4 \ldots S_m$ are 'm' numbers of particles in the population.

As our study is focused on moving of birds or fishes so it is assumed that the particles are moving in the environment. In the definite search space the particles are moving and the positions of the particles after every movement is recorded and updated with an appropriate shift of position called as velocity [4].

Now considering the positions of 'm' particles as: $\{p_1, p_2, p_3, p_4 \ldots p_n\}$ and their corresponding velocities are as: $\{v_1, v_2, v_3, v_4 \ldots v_n\}$

As per the theory of the technique every particles memorizes the positions and velocities of themselves. All the particles save the best positions of them inside a definite search time. Then it is updated by the communication of particles in the population or swarm. There are 'm' numbers of best position values for total particles in the population or swarm.

Let P_{pbest} is best position recorded by each individual particle. Now considering the fitness values for each particle global best position can be computed. The global best position is estimated by the mutual communication of their saved local best position data. Then the particle having best fitness value is estimated as global best position and denoted as P_{glbest}. Once getting the P_{glbest} symbolizes the accomplishment of first iteration of the PSO method. The iterations are to be continued till we reach the goal. In case of the humanoid robot it has to calculate the local best position and global best position in each step and cover the path until it will reach the destination. After getting the values of P_{pbest} and P_{glbest} of swarm the value of position and velocity has to be updated. For the updating of the same the governing equations are given below [5].

$$v_i(\mathrm{j}+1) = v_i(\mathrm{j}) + D_1 \times ran1 \times (\mathrm{P_{pbest}} - p_\mathrm{i}) + D_2 \times ran2 \times (\mathrm{P_{glbest}} - p_\mathrm{i}) \ldots\ldots(1)$$

$$p_\mathrm{i}(\mathrm{j}+1) = p_\mathrm{i} + v_\mathrm{i}(\mathrm{j}+1) \ldots\ldots.(2)$$

Where j is counter for the iterations, *ran*1 and *ran*2 are random variables and *D*1 & *D*2 are social and cognitive parameters.

To apply the PSO method in navigation problem first fitness function has to be defined following the transformation of the same to optimize the problem by minimizing the path. The proficiency of the path planning is depends on two aspects. The first one is the robot has to create the path by avoiding the obstacles properly and the second one is the achieving the goal position by less path travelled in a less possible time. To achieve the above two conditions fitness functions has to be designed and developed. While moving in the environment if the robot is not sensing any of the obstacles it will move to the destination without applying any optimization method, as that path will be the most optimized path for the robot. But the tedious task is to find out the optimized path while sensing obstacles. There the PSO based algorithm is applied to plan the optimized path avoiding all the obstacles.

2.1. Development of the fitness function

The navigating robot requires sensing a random number of obstructions Oobs within the space created by the range of its sensors. The objective of the controller is to create a swarm of particles around the obstacle it senses to be nearest to it. Each of the particles knows its distance from the robot and from the obstacle. The distance between the robot and the obstructions can be expressed by the simple Pythagorean formula:

$$R_{dist} = \sqrt{(X_{rob} - Xobst_i)^2 + (Y_{rob} - Yobst_i)^2}$$

$$For 1 \le i \le O_{obs} \text{..................}(3)$$

Where *(Xrob,Yrob)* is the robot position and *(Xobst,Yobst)*is the obstacle position

Then the fitness function taken here is given below

$$Fi = G_1 \times H + G_2 (1/\mathrm{K}) \ \ldots\ldots\ldots \quad (4)$$

Where, G_1 and G_2 are constants of proportionality which are also the controlling parameters of the fitness function

H =distance between the robot (particle in swarm) and the destination position

K= the distance between robot and nearest obstacle

Simulation using PSO

VREP is simulation software best suited for single as well as multi robot walking with versatility in sensor implementation. It follows the programming language LUA, which is based on ANSI C language. VREP is chosen here for the simulation of humanoid due to its properties like collision detection, minimum distance calculation and better path or motion planning. By taking the PSO algorithm and the fitness function explained above, a program has been written in LUA language and simulation of the NAO humanoid robot has been carried out in VREP software and a path has been obtained as explained in the Fig. below [6].

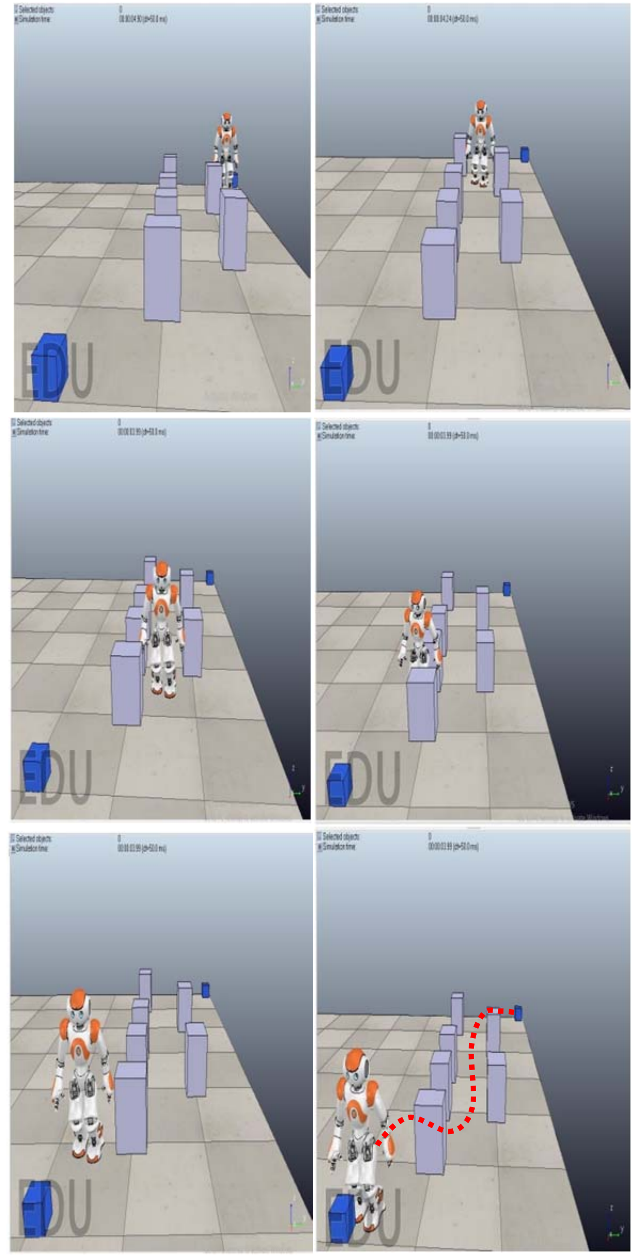

Fig. 1: Simulation result of NAO using PSO

3. EXPERIMENT USING PSO

To validate the results obtained from the simulation of the robot, a similar environment has been designed having same dimensions such as 6000 mm length and 1500 mm width. The no of obstacles and positioning of source and target is selected exactly same as chosen in the simulation.

Fig. 2: Experimental result of the NAO

With the same logic and PSO algorithm, a program has been designed and implemented in the real NAO humanoid robot and experiments have been carried out. In Fig. 2, the experimental setup is explained with the path travelled by the NAO by avoiding the obstacles [7, 8].

4. RESULTS AND DISCUSSIONS

With the same environment size and same number of obstacles, five different obstacle positions have been designed and the simulations as well as experiments have been carried out. After the simulations and experiments, the time taken and the total path travelled have been calculated. The photos of the environment at some positions have been taken by a camera and represented in figures whereas the same is captured from the simulation window in computer for simulation. The path length of the robot was measured in the real environment as well as in the simulation. And the time required for the path travelled from the source position to the destination position for experiment is measured by a stop watch and the same for the simulation is taken from the VREP window directly. Then all the information is tabulated that is shown in Table 1.

Table 1: Experimental result of the NAO

Env. Sl No	Simulation Result		Experimental Result		% of Errors	
	Path Travelled in cm	Time Taken in Sec	Path Travelled in cm	Time Taken in Sec	Path travelled	Time taken
1	315	38.0422	321	39.55	1.90	3.96
2	319	37.5236	324	38.42	1.57	2.39
3	325	39.4213	328	40.32	0.92	2.28
4	312	36.5266	318	37.33	1.92	2.20
5	322	40.4255	327	40.98	1.55	1.37

5. CONCLUSION

The simulation of the PSO technique in VREP revealed that the path taken by the humanoid NAO in all situations is different for all the five environments. However the robot was successful in avoiding the obstacles in the path and was successful in reaching the goal position. The comparison between simulation and experimental results for all the 5 environments showed a good agreement with a minimum percentage of errors.

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