September16, 2008

To whom it may concern,

Over the course of the next 3 months we would like to research, develop, and analyse the effectiveness of some dynamic path planning algorithms. Robotic path planning needs to be dynamic in nature in order to account for moving obstacles and targets. A large challenge in achieving fully functional dynamic path planning is accounting for real time optimization of solutions. Specifically we would like to develop two population based algorithms that achieve successful dynamic path planning in real time, and to develop a software simulation environment in which to test and analyse these algorithms to compare their effectiveness.

Thank you for you time,

Basil Debowski
Jo VandenDool
Kyle Binkley

Intro

As technology moves ever forward, us humans are becoming more and more comfortable and dependant on high-tech devices such as personal computers, cell phones, cars, aircrafts, etc. Not only are these devices becoming essential parts of our lives, but at the same time the technology in these devices is evolving to new levels. Cars are using more computer assistance, cell phones are growing more powerful and complex, and personal computers are able to handle tasks that before only super computers could tackle.

The use and development of such high-tech devices is brought on partly by our desire to allow machines to take over and automate certain tasks that were once every day parts of our lives. Another driving force is the fact that these devices greatly speed things up or increase efficiency. Keeping these driving forces in mind, one can imagine the usefulness of a robotic maid which cleans the house or cooks and serves dinner. One could also imagine a car that drives itself through rush hour on the highway, both speeding up the drive home and freeing the driver's time. One could even imagine self-driven military vehicles such as tanks or self-piloted fighter jets. All these useful possibilities could become realities in the not so distant future, and they are all share one common underlying concept, "Dynamic Path Planning".

Objectives

We have outlined 10 main objectives as follows:

0. Proposal

The proposal paper is a **deliverable** that will be submitted **Sept. 12** and serves to outline the project to be completed.

1. Genetic Algorithm

The GA work will carry on from previous work as outlined in the references section of this report. Much of the work in this component is correction for real time.

2. Particle Swarm Optimization Algorithm

The PSO will be a new approach to the problem and will be compared in benchmark tests to the GA.

3. Adaptive parameter tuning for both algorithms

Both GA and PSO can be tuned dynamically and we plan to incorporate these methods to achieve the best possible performance of each algorithm.

4. Associate Real Time Equivalence to Simulation

As we will be implementing both algorithms in simulation, real time equivalence needs to be considered. We will attempt to construct elementary system parameters in software that simulate real world physics as to achieve an accurate estimation to physical implementation.

5. Graphical User Interface Creation

Current work included with the existing GA records data of the simulation which is then read by MatLab for analysis. We plan to eliminate this process by creating a GUI in the software that displays the simulation in real time.

6. Interim Report

The Interim Report is a **deliverable** to be submitted **October 10th**. This report will discuss the progress of the work done up to this point.

7. Benchmark Tests

The benchmark tests are will be used to analyse the algorithms. Some benchmarks have already been proposed and developed, however we may choose to design and develop new benchmarks if we feel there is a more appropriate method to analyse the algorithms.

8. Analyse Results

The results will be analysed to determine the best algorithm.

9. Tabu Search (population Based)

Time permitting we will also develop a real time population based Tabu Search to test and compare to the previous algorithms.

10. Poster & Final Report

A poster display and final report are **deliverables** will be submitted on **Novovember 27th** & **December 1st** respectively.

Background

Path Planning in this case means planning a path for the car, robot, or whatever the subject may be, to travel along. We say Dynamic because we are considering a changing environment with a moving target. The environment may contain any number of moving obstacles that the subject must avoid in order to prevent collision. Also, the target may constantly be moving, changing speed and direction. It is desirable to reach this target as quickly and efficiently as possible while avoiding collision with obstacles. We have decided to deal specifically with the problem of dynamic mobile robot path planning using metaheuristic optimization algorithms.

Although there has been extensive work done in the area of robot path planning, a greater part of it has dealt with path planning in a static environment. Some works have been completed on path planning in a dynamic environment using either neural networks or various optimization algorithms, and comparisons have been made between several methods[1][2]. It is our goal to use two population-based metaheuristic optimization algorithms (GA and PSO), optimize them, implement adaptive parameter tuning, and compare them to each other and previous works completed in order to achieve a highly efficient and robust path planning algorithm that exceeds the performance of other dynamic path planning methods. It is also our goal to develop a highly realistic simulator for the algorithms to be tested in and run through various scenarios to obtain useful and applicable results. Success in these goals would provide useful tools and data for further development and testing of path planning methods. On a larger scale, these results would bring technology closer to implementing ideas such as an auto-driven car or an auto-piloted fighter jet.

The project will be an extension and enhancement of previous work completed by a master's student Ahmed Elshamli[3], and work that was done by a group of University of Waterloo students Rehman Merali, Alon Shenfield, and Alex Bingeman[4]. These previous works used a GA to perform dynamic robot path planning in a simulator created in C code on a Unix system. The GA had some minor flaws and drawbacks and did not use adaptive parameter tuning. The simulator was not highly realistic, as it did not use a real-life time scale. Attempts were made to implement the GA onto a real-life soccer robot but they were unsuccessful (partially due to the unrealistic time scale of the simulator).

Metaheuristic optimization methods attempt to solve problems approximately rather than exactly. They are used in combinatorial optimization problems where finding an exact solution is impossible or impractical due to time restrictions. They do not gaurantee finding the best solution, however, when implemented properly will find good solutions quickly. Population-based metaheuristic methods such as GA and PSO create and manipulate multiple solutions at the same time (unlike single population methods such as Tabu Search and Simulated Annealing). GA is a population-based metaheuristic which simulates the concept of evolution in nature. Solutions are mapped as genetic material and compete with eachother in order to breed an optimal solution. PSO is population-based metaheuristic which simulates the concept of a group of social beings working together to reach a common goal. Solutions move around in the solution space and communicate with eachother in order to reach the global minimum.

These metaheuristics have been chosen for two reasons. Since they are population-based, they should prove to be more adaptable to a changing environment where a solution that was optimal in the last time sample, may become infeasable or un-optimal in the next time sample. Having a population of various optimal solutions allows the algorithm to select another feasible solution when this situation occurs. Also, having one algorithm that uses competitive behaviour and another that uses co-oporative behaviour should provide for a useful comparison and interesting results.

Proposed Work

The existing simulator and physics engine will be modified to more accurately simulate a robot in real-time motion by implementing a realistic time scale, and accurate robot and environment dimensions. Also, a physics engine for realistic robot movement will be created. The existing GA will be used and modified by adding adaptive parameter tuning and addressing any existing problems with the algorithm. A PSO algorithm with adaptive parameter tuning will also be created. The two algorithms will be tested, optimized, and finally compared against each other through the simulator. Existing simulator benchmarks will be used for the testing along with new ones that will be created. The created benchmarks will be designed to push the algorithms to their limits in situations that can be applied to real-life mobile robots. Results obtained will be highly analyzed and well documented. Criteria and Constraints for the project are as follows:

Criteria:

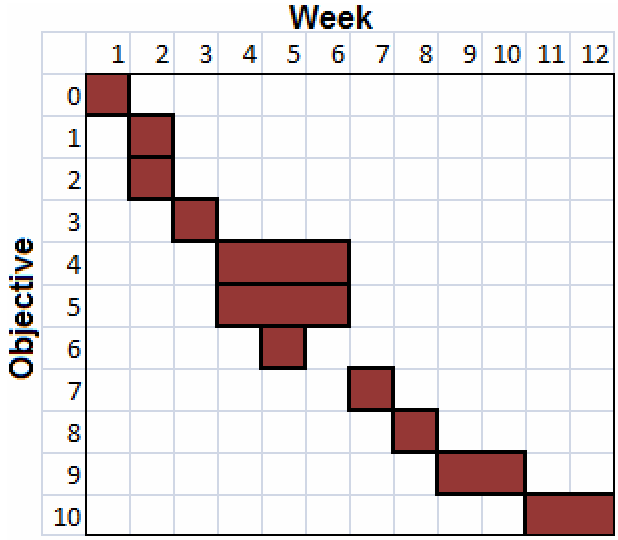
- Minimize the time to reach the target
- Minimize the energy/effort to reach the target
- Minimize the memory size of the path planning algorithm
- Maximize the realism of the simulator
- Maximize the applicability of the algorithms to real-life robots
- Maximize the efficiency and robustness of the algorithms

Constraints:

- Robot must not collide with any obstacles
- Robot must reach target

Schedule

Each objective has been assigned a time frame in which it will be completed. The following chart and table outline this schedule.



	Objective	Dates
0.	Proposal	September 10th – 12th
1.	Genetic Algorithm	September 14th – 20th
2.	Particle Swarm Optimization Algorithm	September 14th – 20th
3.	Adaptive parameter tuning for both algorithms	September 21st – 27th
4.	Associate Real Time Equivalence to Simulation	September 28th – October 18th
5.	Graphical User Interface Creation	September 28th – October 18th
6.	Interim Report	October 5th – 10th
7.	Benchmark Tests	October 19th – 25th
8.	Analyse Results	October 26th – November 1st
9.	Tabu Search (population Based)	November 2nd – 15th
10.	Poster & Final Report	November 16th – December 1st

References

[1] Aydin Sipahioglu, Ahmet Yazici, Osman Parlaktuna, and Ugur Gurel, “Real-time tour construction for a mobile robot in a dynamic environment”, in Robotics and Autonomous Systems 56(2008) pp. 289-295.

[2] Di Zu, Jianda Han and Dalong Tan, “MILP-based Trajectory Generation in Relative Velocity Coordinates”, Proceedings of the 46th IEEE Conference on Decision and Control, New Orleans, LA, USA, Dec. 12-14, 2007.

[3] Ahmed Elshamli, “Mobile Robots Path Planning Optimization in Static and Dynamic Environments”, Thesis Presented to The Faculty of Graduate Studies of University of Guelph, August, 2004.

[4] Rehman Merali, Alon Shenfield, Alex Bingeman, “Mobile Robot Path Planning in Unknown Dynamic Environment with Proactive Collision Avoidance”, Final Report Submission for Course SYDE 422 at University of Waterloo, April 18, 2008.