Annual Technical Report

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Project Title: Hybrid Motion Planning with Multiple Destinations

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Project Overview:

In our initial proposal, we laid plans for developing a hybrid motion planning system that combines the concepts of visibility-based motion planning, artificial potential field based motion planning, evolutionary constrained optimization, and reinforcement learning. Our goal was, and still is, to produce a hybrid motion planning system that outperforms the best traditional motion planning systems on problems with dynamic environments.

The proposed hybrid system will be in two parts: the first is a global motion planning system and the second is a local motion planning system. The global system will take global information about the environment, such as the placement of the obstacles and goals, and produce feasible paths through those obstacles. We envision a system that combines the evolutionary-based optimization and visibility-based motion planning to achieve this end. The global system will develop motion plans for robots operating in dynamic environments with multiple moving goals.

The local motion planning system will refine the motion plans produced by the global system, or will be used exclusively when global information is not available. The main component of the local system is an artificial potential field-based planning method that is especially designed for local planning and navigation within dynamic environments. Coupled with this method will be a reinforcement learning approach that takes advantage of information gathered during the planning process to predict unseen portions of the domain. Together, these two components will produce motion plans that avoid obstacle while at the same time produce paths that approach optimal.

The major challenge in producing such a motion planning system is to develop techniques that integrate the disparate pieces. We must answer questions that deal with incorporating visibility-based planning into an evolutionary optimization problem and with melding artificial potential fields with reinforcement learning. Instead of tackling all of these myriad questions simultaneously, at the early stages of research we have chosen to focus on those that relate to combining evolutionary constrained optimization with visibility based approaches. That is, we have chosen to focus on the global motion planning subsystem.

Project Progress:

The global motion planning system incorporates evolutionary optimization and visibility-based repair. The challenge is to produce a hybrid system that can take advantage of the strengths of the two components while ameliorating their weaknesses. We have taken a very straightforward approach to combining the two sets of techniques to develop a preliminary global motion planning system.

After Dr. Dozier resigned his position and turned the project over to Dr. Clouse, Dr. Clouse began examining the various possibilities for melding the two techniques. The evolutionary optimization system can produce motion plans that violate a hard constraint by attempting to pass through obstacles. Although it is possible to consider these plans as building blocks for future plans, because the plans are seriously flawed this option was not considered. Instead, each plan that would cause the robot to pass through an obstacle is repaired via the visibility-based repair techniques discussed in the original proposal. The general process of the global planning system is as follows:

1) Generate a random population of motion plans
2) Loop until there is no improvement of motion plans
    a) Use visibility-based repair to transform all plans into feasible plans
    b) Evaluate each plan based on the length of the plan and the number and cumulative angles of the turns
    c) Produce the next population of plans based on crossover and mutation.

The early progress on this project is promising. The two graduate students, who were brought on board in the spring semester (this semester), have recently begun implementing the system as described above. Attached to this document are five screens that show the work to date. The first two screens simply show how the environment is established. The next shows the parameters for the evolutionary algorithm, and the final two show the running of the program. So far, the global motion planning system is not fully implemented: only the first simple steps of the algorithm (establishing the first population of feasible paths) have been coded.

Most of the effort this semester has been devoted to giving the graduate students the necessary background and understanding to make contributions to the research. The students have been studying robot motion planning and evolutionary optimization algorithms. After acquiring the basic necessary knowledge, the students gave a presentation entitled "Robot Navigation" to the North Carolina A&T SU Computer Science Graduate Colloquium. Based on their ability to convey the background knowledge and their research ideas to their peers, it is clear that these two students have reached the point where their contributions to the research will result in conference and journal publications. Until this point, neither student was familiar enough with the project to produce such documentation of their efforts.

The work performed to date is promising. After a difficult start with a change of principle investigator in the middle of the first semester of the project, and the inability to acquire graduate students at that time (due mostly to commitments already made by the graduate students in the department), the project got off to a good start at the beginning of the spring semester. As noted above, the two students that began work in January have progressed well in their understanding of the basic techniques used in the project and in their creative ideas for advancement of the project.

Project Future:

The new project year will begin with a change in the principle investigator. Dr. Clouse has resigned his position at North Carolina A&T State University, and Dr. Huiming Yu has agreed to take over the project. The project will continue as described in the initial proposal. Proposal plans for next year will be carried out in three parts that are research, education and publication. We will describe each of these parts in the following section.

1) Research Plan

We will continue the proposed research to: 1) develop a hybrid motion planning with multiple destinations system model, 2) design and implement a global motion planning subsystem, 3) design a local motion planning subsystem. The global motion planning subsystem will include representations of various environments, visibility-based search, visibility-based repair, and an evolutionary constrained optimizer. An environment will be dynamic with moving obstacles and moving destinations. A graph could be a complete or partially visible environment representation. We will start to design the local motion planning subsystem that will be used to smooth out paths developed by the global motion planning subsystem.

2) Education Plan

a) Develop an Undergraduate Course

We plan to develop a undergraduate course titled "Introduction to Robotics". This course will include lecture notes, project assignments, homework assignments, and recommended textbook. We will offer this course in the fall 1998. This will be the first time a robotics related undergraduate course is offered in the Department of Computer Science at NC A&T State University.

b) Develop a Graduate Course

We plan to develop a graduate course titled "Intelligent Robots" that will include lecture notes, project assignments, homework assignments, and recommended textbook. We will offer this course during the academic year 1998-1999. This will also be the first time to offer a robotics related graduate course in the Department.

c) Organize a Research Group

We will organize a robot motion planning research group that will include several undergraduate and graduate students. The group will meet on a weekly basis starting May 15, 1998. Under NASA support at least two undergraduate students and four graduate students will join this group. Graduate students will work on their thesis or project in the robot motion planning area during this academic year. We expect three of them to finish their research and defense before May 1999.

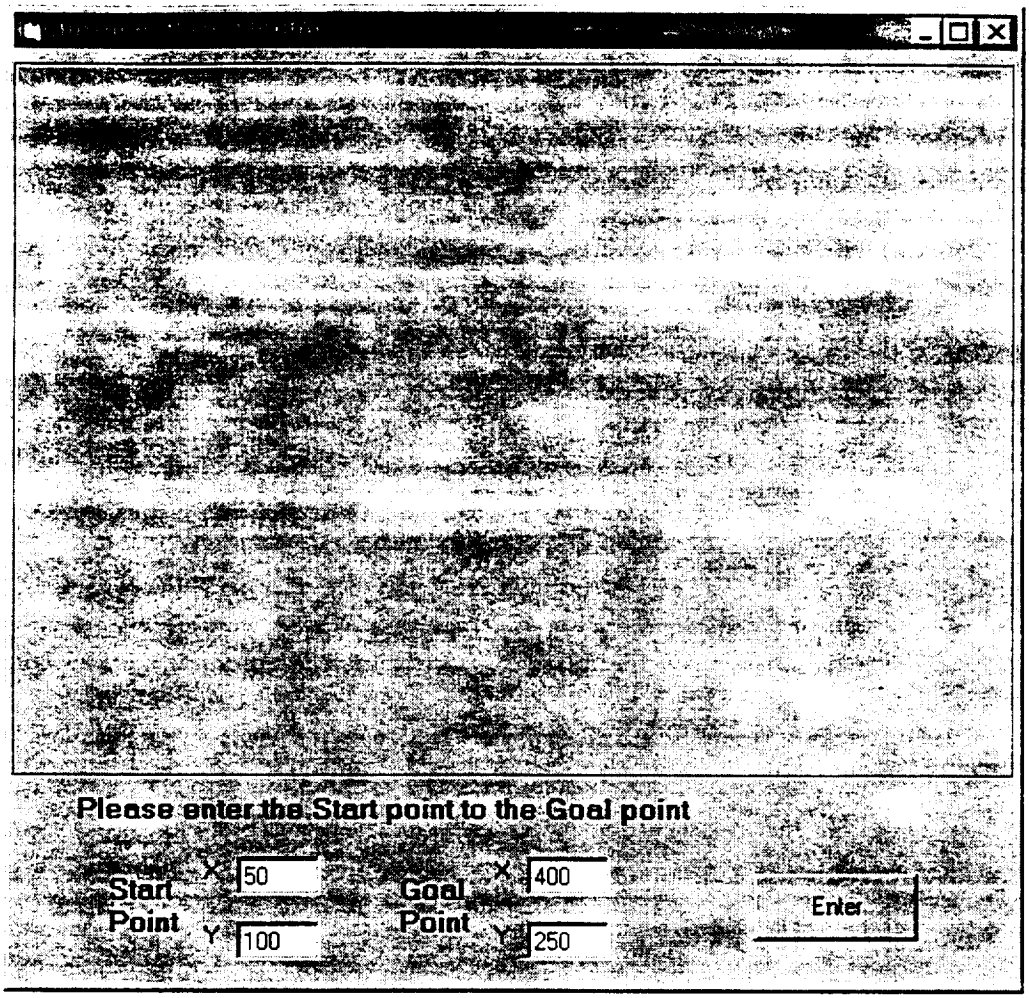
3) Publication Plan

a) Attend a Conference

We will organize several graduate and undergraduate students who work in this research group to attend one conference. This conference will include a student section. Research papers will be published at this conference.

b) Publication

We plan to publish three conference papers and submit one journal paper based on research conducted during this academic year.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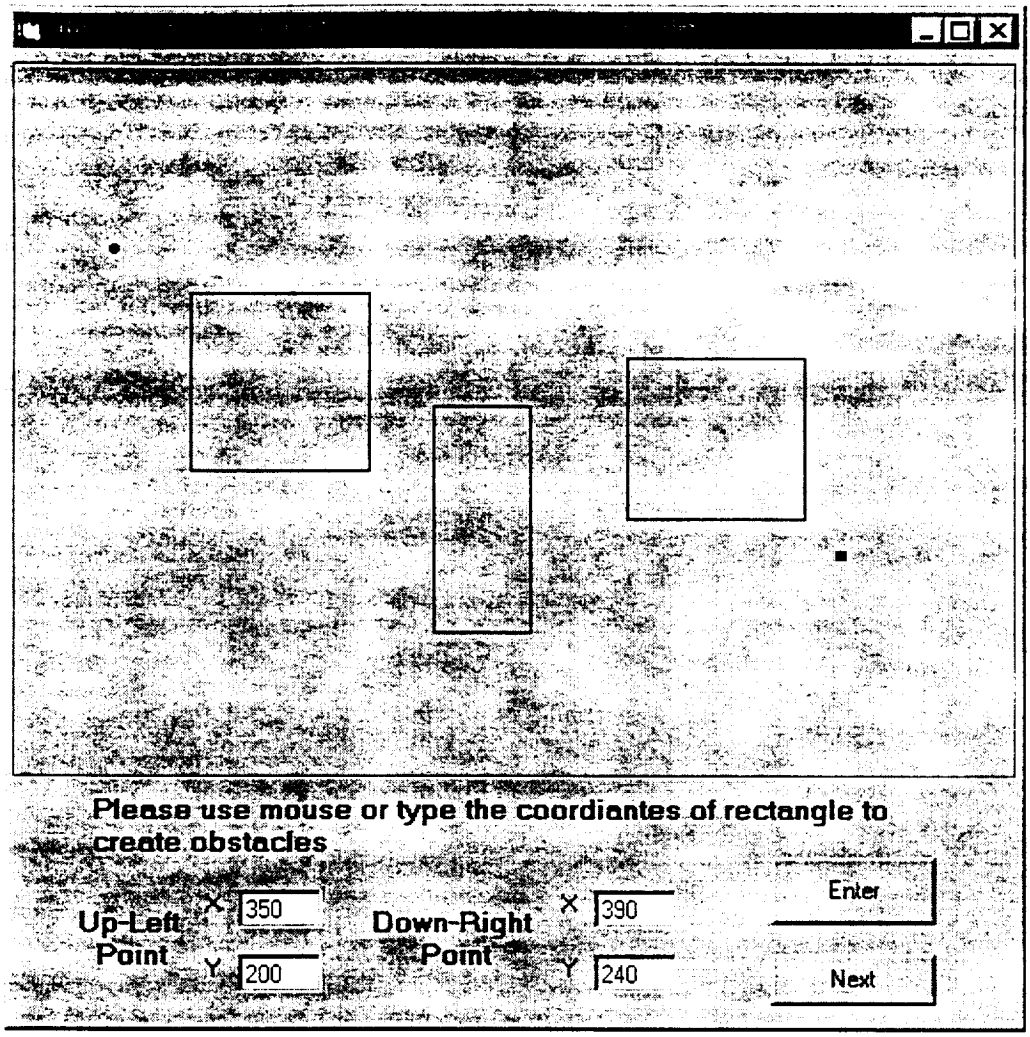
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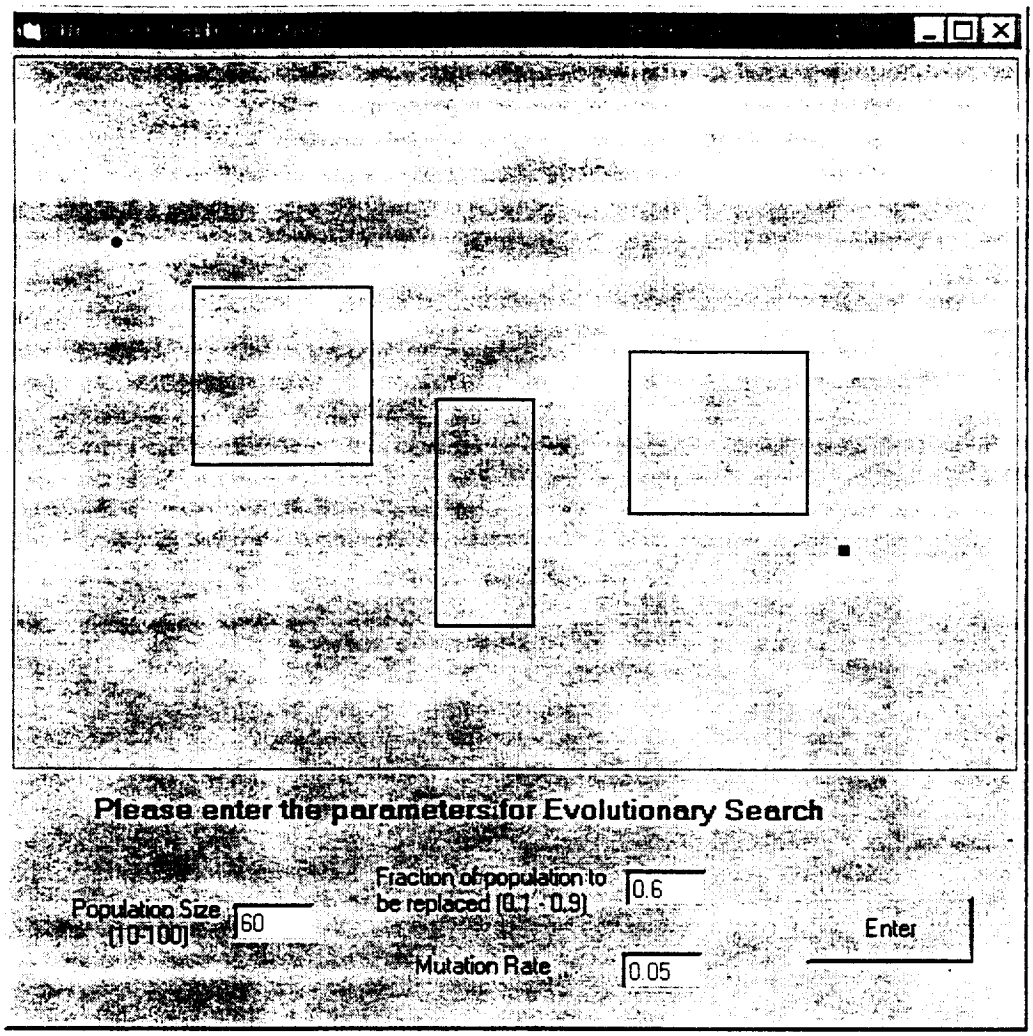
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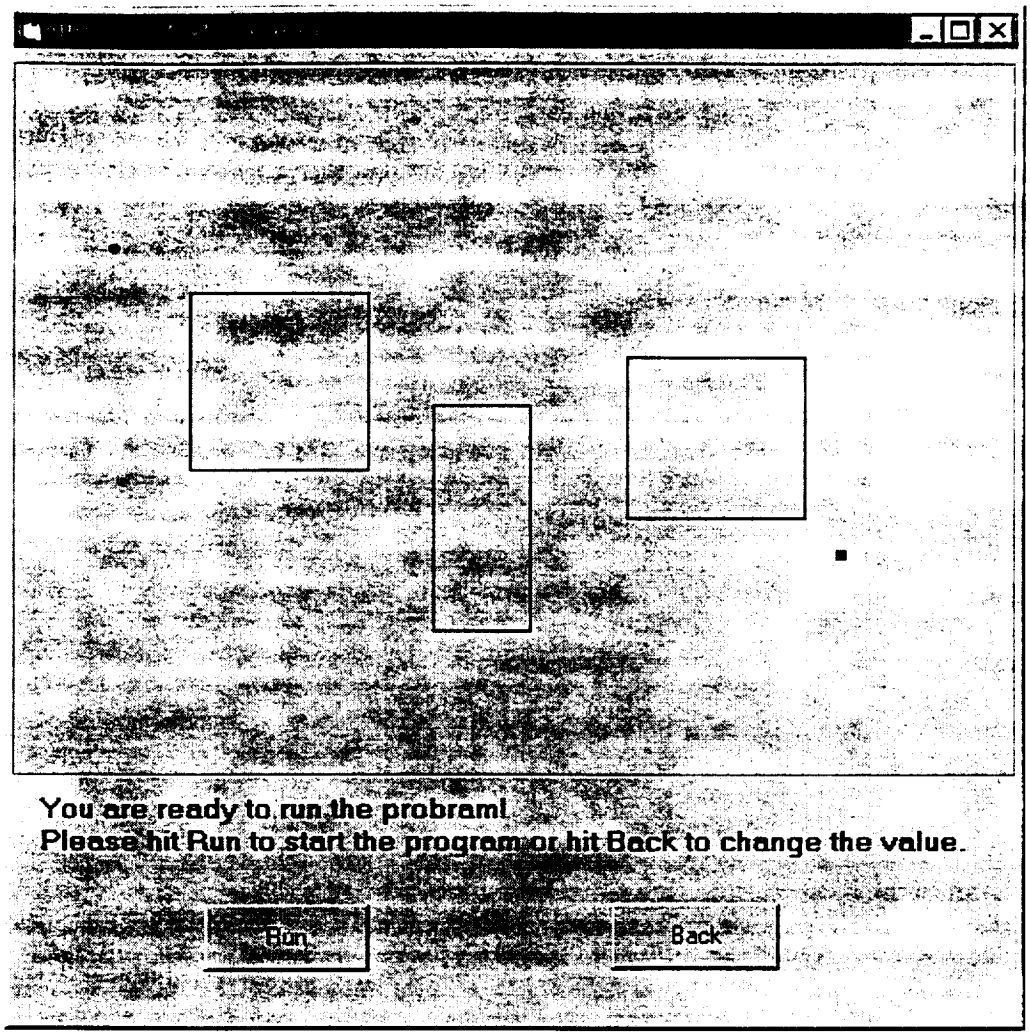
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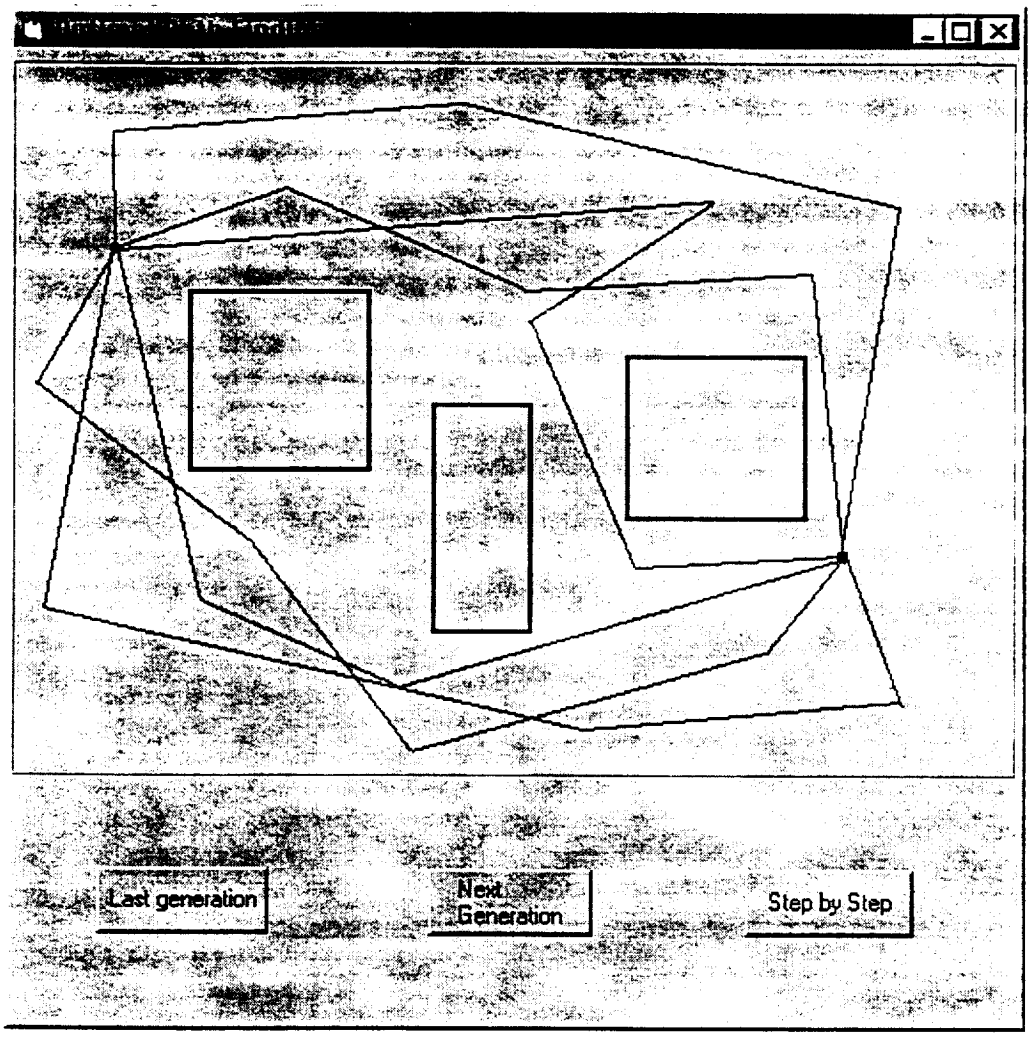
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