CS 7649 - Robot Intelligence Planning

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Human Aware, Dynamic Robot Path Planning

Abstract

The Robots Are Coming! Yes, it is true, the Robots are no longer confined to dark, dingy workshops or hard factory floors; they are coming out in large numbers to become part of our families. Staying secluded from the outside world, perfecting their practical skills, the Robots have lagged behind in developing their social skills and ways in which they interact with humans in a more real-world context. Though the Robots are highly proficient in building our cars, and our smartphones; they still struggle when put in a setting involving humans and similar social animals. Our aim is to help the Robots in their quest to become part of our homes and we aim to provide them with a mechanism to successfully navigate their path in an 'home-like' environment that includes not just the static obstacles like the television or the sofa, but also independently functional and dynamically moving obstacles such as humans and their pets in the household.

Introduction

As Robots become increasingly versatile, their adoption in our social environment is bound to see an exponential growth. As the Robots start sharing our physical and social space, some of the challenges, especially in the area of efficient and secure navigation, will become increasingly important.

Traditionally, Robot Path Planning has focussed on collision avoidance, and optimal path generation strategies. But the limitations of bipedal walking in the case of humanoid Robots becomes more pressing, especially in cases of navigation in a social space (such as a home, school or an office). This problem is more complicated than movement in an industrial or laboratory environment, as the uncontrolled variables in an unstructured state space are numerous and highly unpredictable.

We will focus on Bipedal Walking as applied to a Humanoid Robot and broadly cover the application of Dynamic Motion and Path Planning for such Robots in a social set up involving humans and other autonomous / independently moving bodies (such as pets, other Robots), as well as static obstacles and common interference and boundary conditions such as steps, doorways etc. We also want to impart our model with dynamic weighting criteria that would help the Robot avoid some high risk areas such as the space around a toddler, fragile glassware, spilled liquids or expensive electronic items. This capability may be added to the experiment scope in future.

We hope that our solution will make the Robot path planning in a social setup very efficient and dependable, and help allay any fears that might impede adoption of Robots in our homes.

Review of Literature

A lot of recent research in the field of Social Robots has focused on Robot navigation in presence of humans and other dynamic obstacles in their surroundings. Sisbot et. al [1] have discussed a Human Aware Motion Planner (HAMP) that not only provides safe Robot paths, but also synthesizes good, socially acceptable and legible paths. Ferrer et. al [2] have developed a Robot navigation approach based on Social Force Model (SFM), by mapping a Robot navigation environment to a graph map and using a MCMC Metropolis-Hastings algorithm to learn parameter values for the method. Svenstrup et. al [3] have designed a system for motion planning of a mobile social Robot using a Kalman filter-based algorithm and Case-Based Reasoning approach to build a navigation system that uses a potential field to derive motion paths that respect the person′s social zones and perceived interest in interaction. We plan to extend the discussion by Garimort et. al [4] in the field of “Humanoid Navigation with Dynamic Footstep Plans” [5] [6] [7] by including humans in the experiment environment.

Project Description

Problem Statement

The first Robots that worked in factories had to be physically separated from human factory workers in order to avoid injuring them. With Robots leaving the factories and entering everyday life, it is increasingly important that Robots can safely occupy the same space as humans. While the field of human-Robot interactions (HRI) has done much to decrease the immediate danger of Robot movements, there is still no way for Robots to reliably navigate in unstructured environments that are shared with humans.

One variety of Robots that has real-world applications is humanoid Robots. Since the world was designed for humans, Robots that look and move like humans have an advantage over Robots that were designed with other purposes in mind. Since humanoid Robots aim to inhabit the same world as humans, the problem of path planning among humans is even more relevant for this variety of Robot than for others. Therefore, the problem we have chosen to solve is this:

How can a bipedal humanoid Robot successfully navigate an unstructured social environment that includes humans?

Project Objectives

We aim to accomplish the following key research objectives:

- Develop Path Planning Method for bipedal walking as applied to a Humanoid Robot
- Dynamically adjust the path plan to autonomous actors in the environment
- Dynamically adjust the path plan to uncontrolled variables in the environment
- Ensure the dynamic path plan minimizes the risk of collisions
- Develop method to dynamically weigh plans against set thresholds in case of conflicts
- Test the method under different commonly occurring social situations

Research Approach

We have decided to approach the problem of bipedal dynamic path planning through simulation, rather than immediately trying to set up the scenario with real Robots. This will allow us to maintain a higher level of control over the experiments than what we could achieve otherwise. Under simulation, we can fully define and control the dynamic states of the world, quickly and repeatedly set up new world configurations to test the different aspects of our algorithms, and also avoid hurting any humans, pets or Robots in the process while we refine or tweak our algorithms. It also helps that simulations are economical (we do not need an expensive, physical Robot to test with), allow for flexible experimental setup (we can run many simulations in a shorter time period without the need for researcher intervention between trials, such as resetting obstacles by hand), and do not require identifying and engaging human participants for the experiments.

The platform that we have chosen for this simulation is the GRIP visual planner development environment, which was developed in the Humanoid Robotics Lab (HRL) at Georgia Tech. This environment works in conjunction with the DART C++ library, also developed in the HRL. In order to test algorithms using this framework, users must develop C++ plugins that are compatible with the GRIP environment. Users are then offered a high level of control over parameters in the simulation through a graphical user interface (GUI). This tool seems appropriate for our experiments as it offers all the control mechanisms and the flexibility required to meet our research objectives.

Our path planning plugin will implement dynamically weighted assessment of the path, other autonomous bodies in the environment and static obstacle and will seek to minimize the possibility of collision. We will look at the option of building generalized geometric reductions of human and other obstacle forms to plan a path that maximizes distance between human and Robot while still moving towards the goal.

Project Deliverables

There will be four deliverables for this project:

- The code for the GRIP plugin
- Videos of the output of our simulations depicting the experimental outcome of our algorithms
- A conference-style research paper summarizing our experiments and results
- A presentation to the class summarizing our process and results

Limitations / Constraints

The primary constraint on this project is that, though both team members have experience programming and some previous experience with Robotics, neither of us has ever worked on a simulation of the type that we will be developing. However, based on initial investigations of the GRIP simulation environment and DART library, we are optimistic that we can learn the necessary skills in order to achieve a meaningful outcome from this project.

Evaluation / Methodology

We will run our simulation model for Dynamic Path Planning (DPP) the Robot in following scenarios:

1. Static obstacles and stationary human (seated) intersecting Robot path
2. Static obstacles and stationary human (standing) intersecting Robot path
3. Static obstacles and moving human (straight-line trajectory) intersecting Robot path
4. Static obstacles and moving human (randomized trajectory) intersecting Robot path
5. Static obstacles and intermittent human movement intersecting Robot path
6. Restricted motion scenarios (Doorways, Steps etc.)

The results will be evaluated on the following metrics:

1. Accuracy of DPP in building a path
2. Completeness of DPP in building a path
3. Safety Margin of DPP in building a path
4. Environment Complexity

We will run multiple simulations on a given scenario and compare the results on the metrics defined above.

Next Steps / Future Work

- Optimize dynamic path planning algorithm based on A* or similar heuristic based search
- Develop generalized geometric reductions of different human and pet forms
- Add weighted handicaps to the planning algorithm based on obstacle fragility

References

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