Introduction

Open-ended human environments, such as pedestrian streets, hospital corridors, train stations, etc., are places where robots start to emerge. Hence, being able to plan safe and natural trajectories in these dynamic environments is an important skill for future generations of robots.

A new approach for adaptive motion control is developed based on the human to human proxemics described by Hall [1]. This control strategy is inspired by [2] and utilizes the cost function of the robot to be executed.

An example of an RRT through the environment is shown in Fig. 3. The planner must take into account the dynamics of the environment, i.e. the predicted human motion. The trajectory must be adjusted online if the environment changes.

Objectives

The objective is to plan a trajectory through a dynamic human environment, where the goal is not a specific point, but to get forwards through the environment.

The trajectory must have a safe and natural formation. The person must be able to move through the environment without collisions. The trajectory must be adjusted online if the environment changes.

Methods

Potential field derivation:

A sum of four centered bi-variate Gaussian distributions is used to represent the desired spatial motion of the robot, with respect to each human (see [4]). The distributions represent a cost function with high cost in the area where the robot should be.

The cost function is derived using Hall’s proxemics zones [3] (Fig. 2). The standard RRT is shown in Algorithm 1. The modified version of a Rapidly exploring Random tree (RRT) algorithm is used to minimize the cost of traversing the potential field landscape.

Simulations and Results

In Fig. 5 an example of an RRT through the environment from Fig. 4 is shown. It is seen that the RRT covers the configuration space well, and especially in the near area. After 10-15 in the density of the tree is lower, but since a new trajectory is already calculated when the robot gets this far, it is less important. The green line on the figure shows the path, i.e. the minimum cost trajectory.

The RRT algorithm has been implemented and demonstrated in an experiment, where the robot plans the trajectory through a simulated pedestrian street. The environment has been simulated with a Poisson distributed number of persons entering and leaving the environment and with the persons not taking into account the motion of the robot.

Fig. 6 shows a scene from the simulation. Through 50 simulations of a one minute period, the robot never runs into any persons. Fig. 7 shows in which zone the closest person is how much of the time. It can be seen that in approximately 90% of the time the robot is at least 1.5m from the nearest person, which is the distance between the pedestrian and the social zone according to Hall’s social distances [1]. This demonstrates that the algorithm is able to plan a trajectory, which is safe and natural, through an uncertain open-ended human environment.

Discussion and Conclusions

The simulations of the trajectory generation algorithm have shown that the robot is capable of navigating in a highly dynamic environment, which is in this case populated with humans. Together with a dynamic model of the robot, an MPC scheme is used to enable the planner to continuously plan a safe and reachable trajectory on an on-line system.

The algorithm is challenged when the environments become very densely populated, but are as humans. Human robot by mutual adaptation and allowing violation of the social areas. This is not done here, where the robot takes on all the responsibility for finding a safe trajectory. But even so, the robot manages to avoid human contact.

Future work include real life experiments, and incorporation of human to human motion correlation into the algorithm.

References