An Augmented Reality Motion Planning Interface for Robotics

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Abstract

With recent advances in hardware technology, autonomous robots are increasingly present in research activities outside of robotics, performing a multitude of tasks such as image capture and sample collection. However, user interfaces for task-oriented robots have not kept pace with hardware breakthroughs. Current planning and control interfaces for robots are not intuitive and often place a large cognitive burden on those who are not highly trained in their use. Augmented reality (AR) has also seen major advances in recent years. This demonstration illustrates an initial system design for an AR user interface for path planning with robotics.

1 Introduction

Designing interfaces for human-robot interaction has always been a challenge. One option is to use a joystick, controller, or touch-screen interface. However, task-based control often employs semi-autonomous robots and offers a more complex problem. Natural user interfaces, which seek to exploit innate skills such as gesture and voice, offer an intuitive method for configuring paths during task-based manipulations. They also have been demonstrated to reduce the cognitive load required when performing complex tasks [1]. This makes these interfaces an ideal tool to simplify the control of task-oriented robots.

Task-based control of robots can be viewed as an extension of path planning capabilities, where a drone is performing an action, such as image capture, in addition to traveling between points [1]. Path planning is a thoroughly studied task in robotics, and is known as the multi-agent pathfinding (MAPF) problem. A* is perhaps the most well-known algorithm that has been applied to this research [4]. A modified version of the rapidly-exploring random tree algorithm, RRT*, has also been commonly used for path planning [6]. Simulation is commonly used to validate path planning research for both robots and drones [2].

There have been investigations into novel user interfaces for controlling robots. The Microsoft Kinect has previously been implemented as one method for supporting gesture control of drones [7,10], but this required users to memorize a set of full body poses to interact with the robots. Fernandez et al. [3] developed a graphical user interface (GUI) for drone control and tested a limited number of natural user interfaces. These included having the robots follow the user, or fly along a path defined by physical markers. Unfortunately, limitations exist with this approach, including the requirement that the user and the robots be co-located, and that the user can physically navigate the environment the drone occupies. Voice commands have also been proposed as a user interface [8], but as with previous approaches, this requires the user to memorize a predefined set of non-intuitive commands before operating the system.

Augmented reality has not been formally researched as a medium for controlling drones completing task-based objectives, although the idea has been proposed [3]. However, mixed reality has been deployed as an interaction test bed [9] and has been proposed as a medium to test interactions between drones and virtual humans [5].

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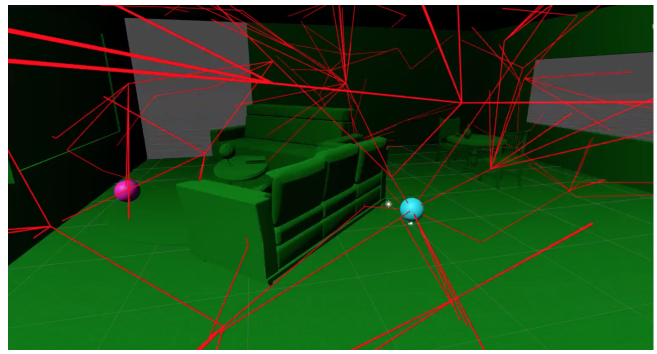

Figure 1: Visualization of the path search via RRT* from a position behind the sofa to a target near the wall.

While the interfaces described above can be called more natural than traditional computer interfaces, none of them are truly natural. They also fail to address the complexities that accompany designing an interface for task-oriented drone control. Truly intuitive natural user interfaces leverage innate human skills, rather than requiring users to memorize a set of new interactions. Augmented reality (AR) offers multiple tools that can be leveraged towards this problem. With the arrival of AR devices such as the Hololens and the Magic Leap, it is now possible to research and develop an AR system for directing semi-autonomous robots. This new system has the potential to reduce the cognitive load required to use robots and to increase the user space and applications of both task-based robots and AR devices.

2 Demonstration

To begin developing an AR system for control task-oriented robots, we have started by developing a simple "point-and-go" system for robots. This system was built in Unity 2018.1 for the Magic Leap Creator One. Using the spatial mapping capabilities of the Magic Leap, the room is converted to a mesh that can be used with the Unity Engine. It is also continuously updated as the user moves through the environment, and will be modified if any changes in the environment occur. A user can currently input a desired starting and target position through the user interface before executing the search; input is received via the Magic Leap controller. The RRT* algorithm uses the room mesh to evaluate the most optimal possible path, provided one exists. The algorithm is bounded to search within the confines of the room, and by an iteration limit. While RRT* can be used to find an optimal path, it has also been modified to return the first path with a length less than double the straight line distance between the two points. The tree generated by the algorithm can be viewed in Figure 1, which shows the system running in a virtual room to allow for iterative testing. Once a path has been generated, the user can watch a virtual robot follow the path they have created. The next step in this work is to integrate a simple robot, such as a Roomba, with the application.

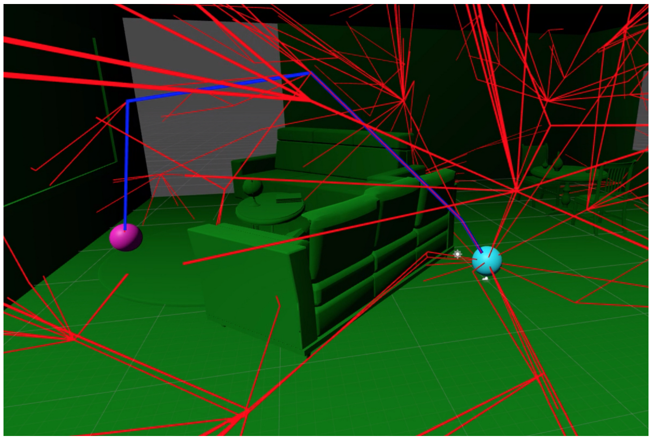

Figure 2: The resulting best path, shown in blue, for a drone capable of aerial flight.

To optimize the path computation, evaluation of the mesh is done offline on a separate device networked with the Magic Leap. The Magic Leap passes a data structure containing the mesh across the network, where it is received and processed separately. The device then receives the final computed path. This allows our process to remain device agnostic; which is important in the nascent stages of AR hardware. The system is compatible with any device that is able to generate a spatial map and mesh of the external environment. In future work, we intend to allow the user to modify a path to their specifications, rather than constraining the robot to an optimal path. We would also like to incorporate on-the-fly updating to paths based on the introduction of new objects during execution.

This system is a proof-of-concept intended to demonstrate the basic capabilities and future possibilities of an AR user interface for robot control. We have currently married path-planning algorithms with gesture-based user input received from the Magic Leap. The system also illustrates the capabilities of the device's spatial mapping features for interacting with the environment. The cognitive burden is minimized for the user, and the system requires requires minimal training. Beyond consumer applications, we envision that this system could have a strong impact on research in 3D reconstruction and photogrammetry; in particular, we believe it will make robots more accessible to researchers outside of technology fields. We hope that this type of interface, along with future iterations, will lower the barrier to entry into using robots and drones.

3 Conclusion

Research in both augmented reality and drone hardware has been advancing rapidly, providing the chance to integrate these two fields and uncover novel applications. In future research, after further system refinement, we hope to quantify and analyze the benefits and possible issues of this system through a series of user studies. We seek to design a system that can be used by even the most novice pilot, due to the intuitive and natural design.

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