Autonomous Radiation Survey with Augmented Reality for Hazardous Environments

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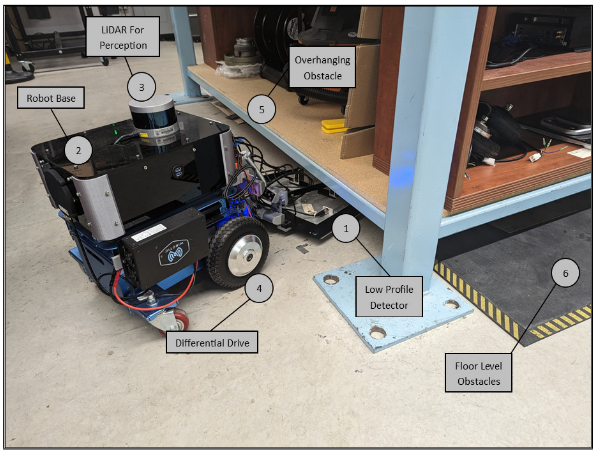


Fig. 1: Augmented Magni Robot from Ubiquity Robotics

I. INTRODUCTION

Mobile robots are ideal candidates for routine survey tasks, thanks to their ability to repeatably measure, record and report sensor readings over long periods. Many industrial facilities require such routine surveys to check equipment readings, monitor potential corrosion buildup, or detect harmful material leaks. One such application is the routine survey for radioactive particles in nuclear facilities. Unconfined nuclear material presents a significant health risk to workers, and must be promptly found and removed whenever it exists.

The Magni robot [4] in Figure 1 has been augmented to perform survey for radioactive particles which emit alpha radiation. This particular type of radiation cannot be detected except at very close distances, necessitating the placement of the sensor just above ground level. This configuration also allows the robot to survey under overhanging obstacles to maximize survey coverage. Upon detecting radiation above safe levels, the robot sends out a signal for trained personnel to approach and cordon off the area for cleaning.

To facilitate the job of a radiation cleanup crew in the event of radiation contamination, we propose the use of a HoloLens augmented reality (AR) headset to provide improved situational awareness. This AR interface shows an operator salient information such as the pinpoint location of the contaminated material, as well as which parts of the workspace have already been surveyed and are therefore safe to traverse. Doing so not only increases worker safety, but also increases their efficiency, allowing facility operation to resume with minimal downtime.

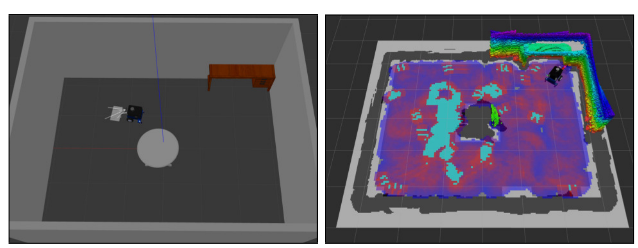
Find the video presentation for this abstract at https://www.youtube.com/watch?v=4HVGrSGlOro

II. PATH PLANNING

The Magni robot runs a custom online complete coverage path planner when performing surveys. This planner is novel in the sense that it plans for a tool location that is simultaneously a collision object and is also offset from the robot center of rotation, whereas existing literature [1] assume either that robot center is the tool location or that the extended sensing range is not a collision object. As an online algorithm, it is able to react to dynamic and unmapped obstacles. Additionally, to prevent the spread of microscopic radioactive particles, this algorithm only places pose setpoints within previously surveyed areas so that the wheels never come into contact with contaminated or unknown material. It achieves this behavior by defining two different obstacle sets, physical obstacles and planner obstacles. Physical obstacles are the normal case whereby LiDAR and depth camera scans detect the presence of objects which are fed to the coverage planner and local planner. Planner obstacles, on the other hand, comprise of all unsurveyed locations on the workspace floor and apply only to the wheels of the robot. In this way, the sensor is unimpeded by these new obstacles but the robot is prevented from traversing unsurveyed areas.

This semantic based obstacle model has uses outside of just radiation survey. Any task in which the previously visited areas hold special significance can be augmented with this model. Some notable examples include a minesweeper robot, which similarly cannot drive over unexplored terrain, and a floor painting robot which cannot drive over painted areas.

The efficacy of the coverage planner was demonstrated in a simulated Gazebo [2] environment. All available coverage cells were visited by the robot, including those under overhanging obstacles (Figure 2). Additionally, the robot never allowed its wheels to traverse unsurveyed space. This provided the desired proof-of-concept before implementing on the real system to incorporate augmented reality.



(a) Simulation Environment

(b) Final state of simulated coverage showing time spent measuring the floor space

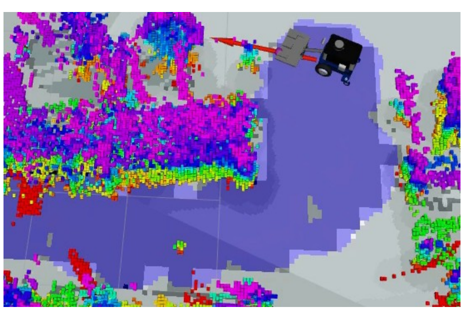
Fig. 2: Simulation Testing Results

Restricting the movement of the robot to only surveyed areas introduces additional motion planning considerations to be addressed by the coverage planner. Movements need to maximize area coverage as in typical coverage applications, while additionally maintaining the maneuverability of the robot. Failure to do so can lead to instances of "self-entrapment" whereby the robot navigates into positions that it cannot easily escape due to large unserveyed areas in the local vicinity. As such, the coverage algorithm encourages large sweeping motions of the robot which clear as much of the local area with minimal translation of the robot base.

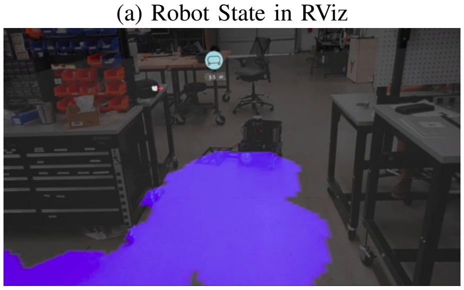
III. DEPLOYMENT

The radiation detection system was deployed in a cluttered lab space to test its oeprability in a real-world environment. Despite the increase in obstacle density and complexity, the robot was still able to survey the majority of the space autonomously. As an ongoing research project, there are still issues with the self-entrapment issue mentioned in section II stemming from localization inaccuracy, as well as with reliable detection of low profile obstacles which are often filtered out as being part of the floor. Due to these issues, a complete survey result will not be presented, but partial results in our testing environment will be highlighted.

In previous work, we developed an AR system to facilitate human-robot teaming called AugRE, Augmented Robot Environment [3]. AugRE was developed to increase the situational awareness of workers alongside cooperative robots by providing a framework to monitor and interact with robot states, tasks, and short term planning goals. Figure 3 shows the state of the robot as viewed from the robot's control station alongside the operator view from the AR headset.

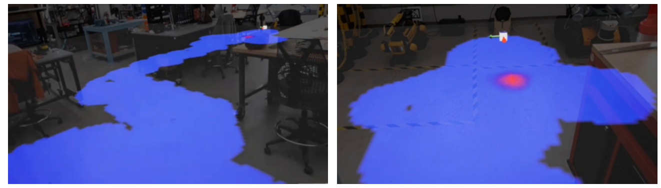


(a) Robot State in RViz



(b) Robot Viewed Through HoloLens 2

Fig. 3: Comparison of Survey Progress viewed from Base Station and AR Headset



(a) AR Headset Shows Safe Path to Contaminated Area (b) Radiation Hot-Spot Easily Identified

With the help of the AR environment, an operator is able to quickly scan the room to identify the simulated radiation leak, depicted by red on the radiation heatmap in Figure 4b. Since the headset also shows which areas have been surveyed and were found clean, shown in Figure 4a, the operator is able to restrict their movements to only this safe area while navigating to the contaminated site.

IV. CONCLUSION AND FUTURE WORK

We presented a novel online coverage path planner which accounts for an offset coverage tool with collision geometry, and additionally actively prevents the spread of contaminated material by the robot agent. This system was deployed successfully in simulation, and shows great promise for imminent real-world deployment. To complement this system, an AR situational awareness tool was created that allows rapid and intuitive consumption of survey results at the time and location that they are needed in facility operation.

Going forward, in addition to improving perception and planning around complex obstacles, we would see this system deployed on multiple robots. The end goal is to have a team of cooperative robots that can map and survey not only the 2D facility floor, but also the 3D contact surfaces in the environment. Improved AugRE user input would give operators finer control over survey tasks, and AR interactions would allow operators to command robots to perform alternate inspections or tasks tangential to a survey, such as making space for facility workers carrying large or heavy loads. This full-stack solution for routine survey will provide reliable and repeatable quantitative measures for facility operators, increases worker safety, facility efficiency, and the flexibility of human-robot interaction.

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