# Autonomous Robotic Recovery System for Disaster Environments

C-951 Task 2
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## Scenario:

The robot's simulated environment is a simulated level in a collapsed multi-level parking garage. This setting represents a complex and challenging scenario due to the mix of structural elements, vehicles, and the probability of multiple survivors trapped under debris.

In this scenario, the parking structure has collapsed, presumably due to an earthquake or a significant structural failure. This collapse has resulted in large debris scattered across the area. The debris is simulated using white cylinders to represent fallen concrete pillars, parts of the building structure, and possibly crushed vehicles.

Within this hazardous environment, two survivors have been trapped and must be located and assisted. These individuals are represented in the simulation by red objects. The autonomous robot's mission is to navigate through the debris, locate these survivors as quickly and safely as possible, and then report to the incident commander once a victim is found. With its advanced sensor systems, the robot will explore the environment, avoid obstacles, and use thermal imaging (defined in this simulation as a proximity sensor) to locate the survivors based on their body heat.

This scenario pushes the boundaries of the robot's capabilities, requiring both precise maneuvering and the intelligent application of its right-hand search algorithm. The ultimate goal is to minimize response times and increase the chances of survivor recovery in real-world disaster scenarios.

### A. Disaster Recovery Environment and Obstacle Description

The selected environment for disaster recovery is a collapsed building scenario. The obstacles in this environment include a pile of debris comprising small, confined spaces and two victims. The complexity of these obstacles mirrors actual building collapse situations, highlighting the necessity for a specialized robotic system.

### B. Role of the Robot in Disaster Recovery Enhancement

The integration of our robotic system improves the efficiency of disaster recovery within the chosen environment. As firefighters and rescue techs approach the scene, they want to limit the risk to life by sending in a robot before sending in human lives to limit risk. This robotic system safely navigates through the terrain and specific obstacles, namely the confined debris spaces and fallen beams. The right-hand search pattern aids in exhaustive exploration, ensuring all potential survivor locations are covered.

## C. Justification of Modifications to CoppeliaSim's Robot Architecture and Sensor Selection

The CoppeliaSim robot architecture was enhanced with two sensor modifications: a LIDAR (Light Detection and Ranging) sensor and a thermal imaging sensor. The LIDAR sensor allows the robot to plan its path proficiently by accurately perceiving its surroundings and detecting obstacles. The thermal imaging sensor assists in identifying survivors by detecting body heat, even under debris. These additions substantially enhance the disaster recovery process.

## D. Maintenance of an Internal Representation of the Environment by the Robot

The robot utilizes the SLAM (Simultaneous Localization and Mapping) technique to maintain an internal representation of the environment. This approach enables real-time updating of the environment map based on continuous scanning from the LIDAR sensor. The robot uses this internal map for self-localization, efficient path planning, and obstacle avoidance. Future enhancements will allow the robot to follow its exact path out but in reverse.

## E. Implementation of Key Concepts for Goal Achievement by the Robot

**Reasoning:** The robot employs internal algorithms to interpret sensor data. Its sensors, including collision and thermal sensors, play important roles in navigating the environment and detecting survivors. This results in quicker survivor detection, minimizing the time people remain in hazardous conditions.

**Knowledge Representation:** Based on an enhanced version of the bubbleRob code, the robot creates an internal representation of the environment. This knowledge provides the advantage of reducing unnecessary risks for human rescue crews, as the robot can map areas and identify hazards beforehand.

**Uncertainty Management:** The robot leverages sensor data and previous experiences to make informed decisions, mitigating uncertainties from unpredictable environments. However, a limitation is that the robot may revisit areas or overlook certain parts of the environment due to this uncertainty.

**Intelligence:** Machine learning algorithms would enable the robot to learn from past operations, improving performance over time. These are not implemented in this tutorial as it is out of scope. However, future iterations could employ these processes. This continuous learning aids in increasing the efficiency and safety of rescue operations. Yet, a constraint is that the robot could malfunction or miss detecting a survivor.

**Criteria for Success:** The robot's success is assessed by its ability to navigate the environment safely, detect and locate survivors, and send a message back to the incident commander or operator upon detecting a victim. Adaptability to handle uncertainties and unexpected scenarios also forms part of the success criteria, such as navigating around debris.

## F. Recommendations for Future Prototype Improvements

Reinforced learning and advanced search algorithms can be leveraged to improve the prototype. The integration of reinforcement learning would allow the robot to learn from past experiences, enhancing its decision-making capabilities. Integrating more advanced sensors like chemical detectors for hazardous substances, oxygen sensors to understand the breathability of the air,  and improved communication systems could provide better coordination with rescuers, boosting the robot's disaster recovery abilities.

## H. Sources

I only used the bubbleRob tutorial in developing this project and did not quote or use any external resources for this paper.