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Introduction

An increasing need for power distribution in the modern era requires more efficiency when inspecting the areas that are responsible for power delivery. Underground electric vaults are one of those areas and can be perilous to the normal man even with rigid safety procedures in place. A demand has grown for unmanned inspection of these high voltage vaults which range anywhere from eight feet deep with a volume of 340 cubic feet to 30 feet deep with a volume of 30,000 cubic feet [1]. Therefore, the use of an efficient control system for the robot's function is imperative. Teleoperation has proved to be advantageous by removing the dependency on a physical umbilical cord, but lack of signal strength can contribute to signal latency. A tethered approach provides immediate connection yet limits mobility in areas littered with obstacles. This technical research paper is a synopsis of the various robotic control systems present in search and rescue robots, which are also subjected to similar conditions that are exhibited in power vaults.

Commercial Applications of Various Robotic Control Systems

Currently there are very few examples of commercial applications for search and rescue robots outside of aerial drones, however, there is a plentiful presence in academia and scientific research fields. A better commercial comparison can be drawn within the mobile robot industry. One example would be the Turtlebot 3, which is currently supplied by Robotis for academic and research applications. Depending on the hardware composition and model of the Turtlebot 3 it can range from $282.00 to $1,399.00 in price. For example, the Turtlebot 3 Burger model is capable of a 15 kilogram payload with a run time of two hours and 30 minutes on a full charge, a translational velocity of 22 centimeters per second, and it is equipped with the OpenCR embedded controller and a Raspberry Pi 3 to execute controls. This model is capable of running teleoperated commands through the open source platform of Robotic Operating System (ROS) to perform a variety of scenarios, whether it is autonomous exploration or path following. [2] Tug T3 by Aetheon, which is a commercial autonomous mobile robot designed for mobile material and supply transport in various environments, is a much larger counterpart of the Turtlebot 3. Rather than its use being employed in academic research environments, its primary domains are hospital, hotel, and warehouse floors. Some of the differences present in the design are a heavier payload of 1000 kg, omnidirectional movement, a faster movement rate of 76 centimeters per second, while control scheme is a bit more limited due to the reliance on an internal map using LIDAR, sonar, and infrared sensors. [3]

Technology of Teleoperation and Tethered Robotic Control Systems

Functionality

Considering a tethered approach an example of a lightly tethered unmanned autonomous vehicle has been used for artic shelf exploration. [4] This situation calls for complex subtasks, which require very consistent real-time human operation. In this environment the possibility of using a remote operated vehicle is possible, yet it requires the inclusion of an armored tether or umbilical, which supplies the power generation and control signals for the vehicle. Consequently the travel is limited based on the length of the tether (in this case it was 500 meters), yet it can alternate between teleoperation and complete autonomous control depending on the situation. Control sequences will be delivered over a three kHz acoustic link, which will transmit within a range of 50-100 bits per second. [4] Alternatively a teleoperated approach removes the impedance of the umbilical but trades it in for a decreased signal reliability. Teleoperation is dependent on master-slave synchronization between robots, which based off of transient performance of the signals, a proposed method of improvement for is impedance matching. This entails controlling the value for the proportional gain in the feedback control system. [5] One research group used orthogonal perception along with vision, sound, and other sensors to detect human survivors in a disaster scenario. Using the deliberative, reactive, and hybrid control structure coupled with the feedback received despite various debris arrangements, human subject poses, and illumination levels the system had a success rate of 90% and above with identifying the targets in the environment. [6]

Implementation of Teleoperation and Tethered Robotic Control Systems

Within these environment schemes there exists uncertainty around where certain items and tasks are located. The robot must determine the series of actions in a hierarchal manner based on when things are approached. This problem is not simple due to the varying complex nature of each environment. When addressing the Optimal Control Problem (OCP) it is assumed with a uniform distribution of objects in the environment or a worst-case scenario for positioning. Past methods for tackling this issue have been confining a robot to a fixed trajectory or deferring to a hierarchical approach. [7] The robot could still be operated with a semi-autonomous approach, thus requiring directives from human operators and sensory input to communicate with the robotic actuators after the information has passed through the deliberator. [8]

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