# Novel EOD Robot Design with a Dexterous Gripper and Intuitive Teleoperation

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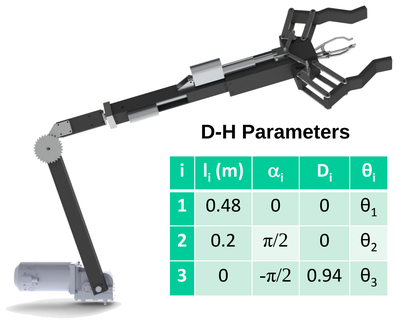
**Abstract -** This project focuses on the design and implementation of an intelligent Explosive Ordinance Disposal (EOD) robot to provide law enforcement agencies with a cost effective and reliable robotic platform. The key features of the robot include an intuitive user interface which provides additional sensor feedback and enhanced visual awareness compared to existing systems, an onboard three degree of freedom manipulator arm providing an enlarged workspace, and a dexterous gripper allowing for the removal of detonators. The flexible and modular robot design utilizes commercial off the shelf components for ease of maintenance and repairs. The robot provides a safe distance threat assessment and increased capacity for explosive ordinance disposal, improving the effectiveness of bomb disposal teams. The robot's low-cost, intuitive operation and ease-of-maintenance promote its widespread appeal, thereby saving the lives of both law enforcement personnel and civilians.

## Robot Design

**Arm** - The robot's three DOF manipulator arm is designed for multi-mission use, providing a long reach and good mobility. These features allow the arm to manipulate a target with many different approach vectors, thus increasing the probability of success in disposal operations.



### D-H Parameters

| i | $l_i$ (m) | $\alpha_i$ | $D_i$ | $\theta_i$ |
|---|---|---|---|---|
| 1 | 0.48 | 0 | 0 | $\theta_1$ |
| 2 | 0.2 | $\pi/2$ | 0 | $\theta_2$ |
| 3 | 0 | $-\pi/2$ | 0.94 | $\theta_3$ |

### Arm Motion Control

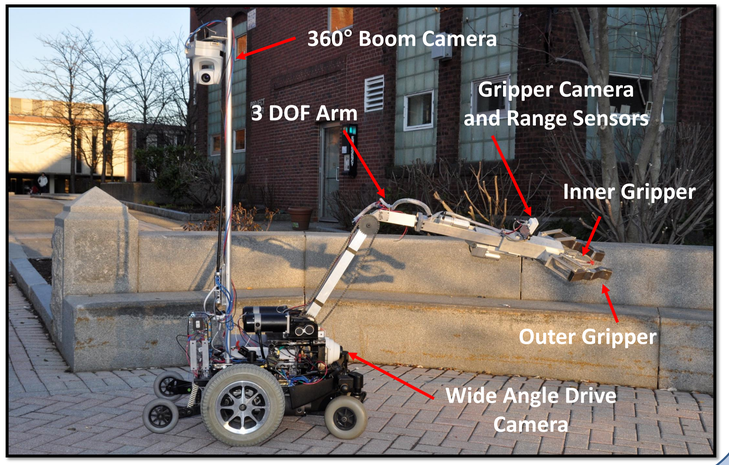
| Joint | Drive Method | Rotation |
|---|---|---|
| 1 | Worm-gear gearbox | 200° |
| 2 | Chain drive through worm-gear gearbox | 270° |
| 3 | Planetary Gearbox | 360° |

**Gripper** - The gripper is one of the novel features of the robot and is designed to allow access to the target as well as the ability to manipulate it. The gripper is specifically designed to allow for blasting cap removal by utilizing a dual gripper system. This is comprised of a small, three-clawed inner gripper and a large outer gripper that is controlled using a series of linear actuators. This setup provides the ability to lift, drag and carry objects as well as a means to resist the pulling motion of the inner gripper. These two grippers can be used together to improve the overall dexterity and manipulation capabilities of the robot.

### Inner Gripper Functionality

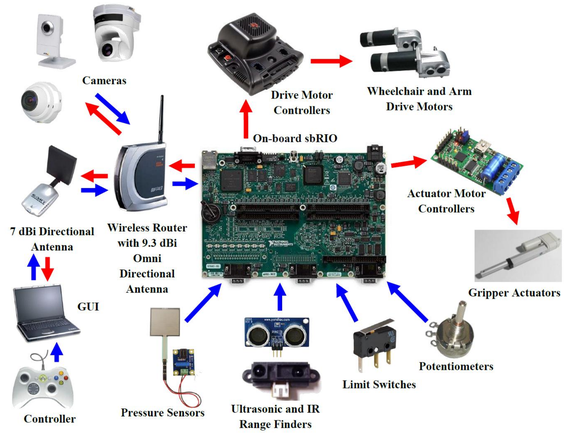
**Base** - The mobile platform to which everything else is mounted is a modified electric wheelchair base, featuring a two-wheel differential drive system with two castors and two support wheels.

## EOD Robot Prototype Design



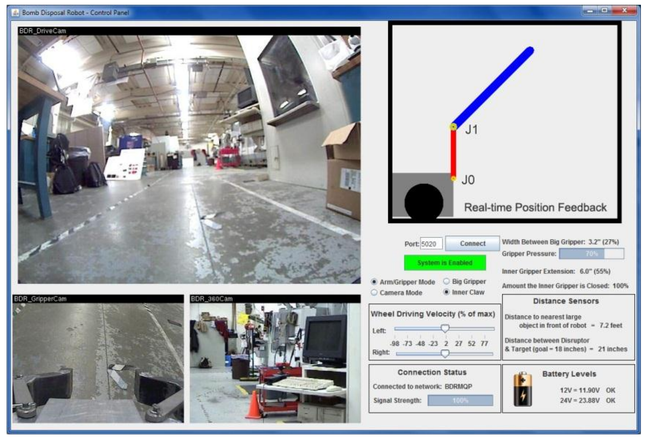

## Hardware Architecture

The robot has a stand-alone control system equipped to run all the motors, actuators and sensors as well as actively monitor the conditions of the robot. The onboard control operation is run by a National Instruments single-board RIO, model 9612 (sbRIO). This small but powerful board is capable of processing the signals from the robot's sensor suite comprised of potentiometers, limit switches, infrared and ultrasonic range finders, and pressure sensors. The sensor suit also includes three onboard cameras providing visual feedback to the user. The modular design of the robot makes it possible to mount additional mission-specific sensors as needed including X-ray or ultrasonic imaging equipment or a Geiger counter.




## Communication and Controls

The feeds from all three cameras are visible to the operator at any given time through the Graphical User Interface (GUI), which is best described by dividing it into four quadrants. There is one "main camera" that is displayed in full size in the upper left quadrant to provide the user with a high resolution stream from the camera currently showing the most important view. The two remaining camera feeds are displayed in reduced size in the lower left quadrant. The three camera feeds can be easily cycled through using the controller. Additionally, a graphical representation of the robot arm is presented in the upper right quadrant of the GUI to provide real-time feedback to the operator on the position and orientation of the robot arm. Finally, the lower right quadrant incorporates additional control features and useful sensor feedback.




### Network Communication Specifications

| Sub-system | Description |
|---|---|
| Wireless communication architecture | 802.11b |
| Directional antenna at controller | Increase distance and throughput capability |
| Wireless router on robot | Customized firmware for increased transmission power beyond factory defaults |
| High gain omnidirectional antenna on robot | On robot to increase distance and throughput for any orientation |
| UDP protocol | Limit bandwidth used to send and receive packets |
| Custom packet structure | Remove excess overhead data transmission |