Remote Disposal of Explosive Anti-Tank Mine Fuzes using Indigenous Mobile Robot System

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This paper received the DAE Group Achievement Award for the Year 2009

Abstract

A large number of ammunition boxes, containing potentially explosive anti-tank mine fuzes, were stored at Ordnance Factory Khamaria, Jabalpur for a long time. Using an indigenous remote-controlled mobile robot system, we safely disposed all the fuzes, after transporting them to a remote site. The system consists of a six-wheeled vehicle, an articulated manipulator and a mechanism for removing the fuzes from the ammunition boxes. The article describes the problem and the methodology adopted to solve the problem.

Introduction

About 300 boxes containing more than 13,000 rejected fuzes of anti-tank mines, were lying in two storage rooms at Ordnance Factory Khamaria (OFK), Jabalpur, for more than 25 years. Based on past experience, it was felt that some of these fuzes could have become very sensitive and might explode at the slightest disturbance. As their presence in the factory premises was a threat to the people, the factory and the surroundings, the boxes had to be removed from the site and their contents had to be disposed off at the earliest. Remote handling option was adopted, to avoid possible injury or loss of life during handling of these boxes. Based on a request from the Centre for Fire, Environment & Explosive Safety (CFEES), Delhi, we developed a mobile platform with an on-board manipulator for remotely transporting the boxes from the storage rooms to the disposal site. Another remote controlled mechanism was developed for opening the ammunition boxes at the disposal site and removing the fuzes from the boxes. All the fuzes were disposed off by burning them in a controlled manner, after transporting them from the storage room to the disposal site, in the year 2006.

Problem Description

The site layout showing the storage rooms and disposal site are given in Fig. 1. The buildings and disposal site are connected through an over-bridge and cemented pathways. The buildings are separated by traverses, which are earth walls constructed to protect the buildings from accidental explosion in adjacent building.

The fuze boxes containing rejected fuzes were stacked up to a height of 1.5 m in two adjoining rooms, as shown in the Fig. 2. Two types of boxes, with dimensions of 600 mm x 250 mm x 320 mm height and 645 mm x 345 mm x 200 mm height, were stacked in the rooms. They were made up of 1 mm thick steel and weighed about 30 kg with their contents. Each box had a body, a lid,
two spring-clips and two hinges. The lid was retained in position by two spring clips.

We had to build a robot to remotely pick up a box from the stacks, bring it to the disposal site along the road and the over-bridge, open the spring clip of the box and pour its fuzes into a pit for disposal. This had to be done carefully to avoid any possibility of explosion.

**Design Philosophy**

Although robots are manufactured and sold all over the world for disposal of explosives, they were not found to be suitable for our application, due to the size and weight of the ammunition box, the space constraints and the safety requirements. Although the users had approached a few robot manufacturers for development of ordnance disposal systems, the cost of development was prohibitively high. This prompted us to work towards an indigenous solution.

We decided to set up the control station in one of the available buildings, which was protected by traverses and was close to the storage rooms and the disposal site, as shown in Fig. 1. Wireless stations were setup on the top of the traverses, to ensure proper connectivity within the working zones. A full scale mock-up facility was set up in another room, to test and qualify the operation of the scheme.

We also developed a pneumatic device, for remotely removing the spring-clip of the box and then tilting the box to pour its contents into the disposal pit. Both the robot and the unclipping device were to be operated remotely from the control station. The robot was connected to the control room PC through wireless Ethernet. Video feedback was available to the operator sitting in the control room, from cameras mounted on the mobile robot, the storage rooms and the disposal pit. The operator issued commands for the mobile robot and the manipulator, based on the video feedback.

Safety was given prime consideration in the scheme. Some of the safety considerations are given below:

- Avoid direct handling of the ammunition box by the operator.
- Provide sensors and interlocks on the vehicle to prevent the collision of the vehicle with the explosive boxes, walls or any other objects.
- Ensure that the robot joints would remain in their positions, during power failure.
- Ensure that the gripper would not drop the box, in case of power failure.

**Mobile Platform**

A six-wheeled battery-powered vehicle with on-board manipulator designed for handling and transportation of ammunition boxes, as shown in Fig.3. Each side of the vehicle had three wheels, which were powered by a single motor and coupled by chains and sprockets. By controlling the relative speeds of the left and right sets of wheels, the vehicle could be made to move in a straight line, move over an arc or take a turn around itself. The combination
of motions helped in manoeuvring vehicle in cramped spaces, like storage rooms and room entrances.

Bumpers were provided around the vehicle to stop the vehicle during inadvertent collisions. Two Pan-Tilt-Zoom (PTZ) cameras were mounted on the vehicle, to monitor its path. One camera was mounted on the manipulator to view the gripper and box handling. The cameras sent video signals to the control room using wireless transmitters.

**Manipulator**

A four-axis articulated manipulator was developed for handling the ammunition boxes. It had a big gripper with 800 mm opening, to hold the ammunition box. Using a set of 4-bar mechanisms, the gripper was mechanically constrained to remain in vertical orientation, to prevent it from getting tilted during movement. Although the manipulator had a reach of 2 m radius from its base, it could be folded back to accommodate in the vehicle. Electromagnetic brakes were provided on the joints to prevent uncontrolled movement of the manipulator, during accidental break in the power supply to the motors.

**Remote Box Opening Mechanism**

The lids of the ammunition boxes were retained in position by a pair of spring clips. A setup was designed for opening the spring clips and removing the fuzes from the boxes, as shown in the Fig. 4. It has features for locating the box, clamping the box, opening the spring clips and rotating the box for removal of the fuzes. All these operations were done remotely from the control station.

**Control Architecture**

The overall control architecture of the Robot is as shown in Fig. 5. The on-board Single Board Computer (SBC) formed the master controller for the system, in which the high level application of the robot was executed. The SBC has a wireless Ethernet link with the host computer. The host, which is a standard desktop computer, executed the application on the SBC, via the VNC (Virtual Network

![Fig. 3: Mobile robot with manipulator](image)

![Fig. 4: Setup for spring clip opening and unloading of fuze box](image)

![Fig. 5: Control architecture of the system](image)
Computing) server installed on the SBC. The SBC issues commands to the controller of the vehicle and the manipulator through two serial ports, as per instructions from the Human Machine Interface (HMI) programme.

One of the serial ports of the SBC was used for Pan-Tilt-Zoom controls of the on-board cameras of the mobile robot. The PTZ movements could be controlled from the same HMI of the robot. The video signals from the on-board cameras were directly transmitted through a wireless video link to the display, which is a standard television set. This display is used for the navigation of the robot throughout the operation.

Another serial port of the SBC was used for connecting to the SICK Laser Range Finder (LRF). The LRF generated range data over an angle of 180° in front of the robot. This data could be used for building a line map of the area.

Human Machine Interface for Control and Monitor

Figs. 6 and 7 show the graphical interface on the host computer, for the remote operation of the mobile robot.

It has provisions for driving the platform forward, backward and taking a turn. In addition, the interface displays the status of the battery, position and orientation of the mobile platform and a line map of the area in front of the platform.

The Fig. 8 shows the interiors of the control room setup for the operation and monitoring of the system.

Conclusion

We have developed a mobile robot system for remotely disposing the potentially explosive fuzes, stored at Ordnance Factory Khamaria, Jabalpur. The system was to be used for a specific application over a limited period. In a short time, we have developed a remote handling system with available know-how. The 25-year old problem of the Factory was solved by disposing all explosives safely, using this indigenous system.

Acknowledgements