

MODULAR DISPOSAL TELEOPERATED ROBOT

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The modular disposal teleoperated robot (MDT Robot) can replace man to recognise, remove and deal with explosive bombs or other unknown articles in a dangerous environment. The design uses a modular robot composed of a platform mobile vehicle, an articulated mechanical arm, a teleoperated control system, vision system and a wireless communications system. The MDT Robot is developed to replace a human bomb disposal expert with an apparatus with high manoeuvrability and strong capacity to defeat obstacles, stairs, etc. It can be used in urban areas and in wild environments of sand, grass and soft soil, etc. The robot design is a very low cost robot constructed with several commonly industrial parts, which they can be recycle to further uses in a low cost robot.

1. Introduction

Disposal teleoperated robots have been the focus of research especially in modern society; they require complex algorithms and knowledge in different fields like mechanical design, electronics, image processing, kinetic control, sensor technology and communication. These robots are required to achieve complex missions and some time deal with complicated explosive devices.

There are many tasks which are hazardous to human life which could be conducted remotely using teleoperated robots. A disposal robot is an unmanned machine operated remotely with the intention of removing or making safe of unknown package. Most of these robots are teleoperated machines that can recognise, dispose, climb, search, lift and handle dangerous explosives. [1] [2]

Currently a teleoperated robot is completely operated in manual mode and requires constant human intervention, such as image interpretation, manoeuvrability from one place to another or a simple object manipulation. In the future, most of this robot will be fully autonomous to carry out complex operations in shapeless environments without human intervention. [3] [4] [5]

This paper describes the development of a modular disposal teleoperated robot using recycled technology parts with the purpose of constructing a basic device composed of a mobile crawler platform, 5 degrees of freedom manipulator arm, wireless communications and a vision system. This robot has been developed with a very low cost budget and its aim is to have an expendable machine where if it is destroyed or lost, its cost doesn't affect the bank balance and the deactivation troops can have even a kamikaze machine.

2. The Robotic Device

The robotic device is composed by four main components, the mobile platform, the manipulator arm, the camera scissor lift mechanics and the control and vision system, see figure 1. The mobile platform is a robot vehicle which has 4 driver motors controlled by one dual motor controller. These motors are mounted in the main structure and provide the lineal, rotational and climbing motion capacity of the system. The manipulator arm is composed by a number of similar modules, where links and joints are attached serially and mounted on top of the robot platform. The manipulator contains 5 revolute joints and one gripper placed at its end, which allows the system to grasp any object of maximum 60 mm width. The main controller and the operator PC/Laptop have a client-server relationship via a graphics user interface (GUI). The operator can access and control wirelessly the mobile platform, the manipulator arm, the camera scissor lift mechanics and the camera itself. The GUI makes the connections straight forward with the main motor controllers permitting brake, move and adjust the camera by individual control of each joint and also obtains error signals from the 9 motors and their corresponding servo drives.

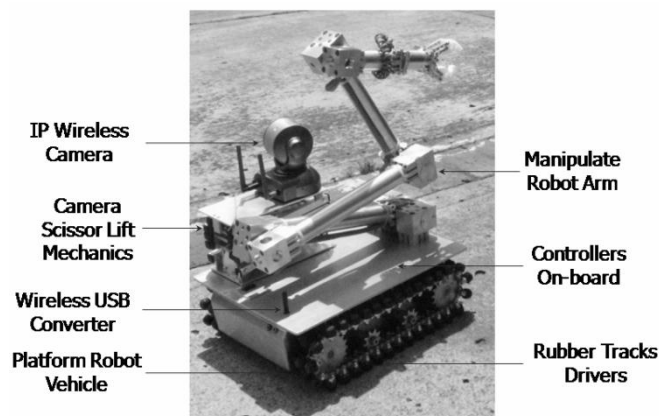


Figure 1. Main parts of the modular disposal teleoperated (MDT) robot.

3. Mobile Platform

The mobile platform of EOD robots are mostly wheeled units, tracked units, or a hybrid of these. This project had develop a tracked robot which has the advantage especially in climbing stairs and crossing mixed terrain environments and high friction contact with the surface but weakness of heavy weight structure.

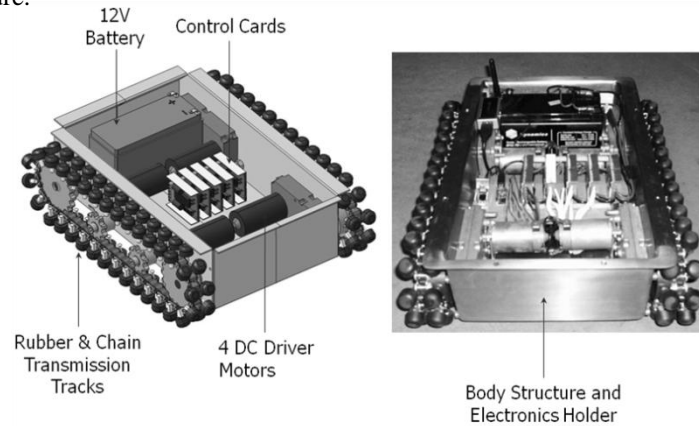


Figure 2: Mobile teleoperated robot platform.

The platform vehicle shows in figure 2 is light weight device of 13 kg; this mobile vehicle is composed by a body structure, four driven motors, two flexible steel chain tracks, four driven pinions and four supported pinions. The body structure was made with stainless steel material and it is a light design to reduce machining problems, decrease the size of the vehicle and also make it stronger to support the driven motors placed on the sides of the vehicle. It uses a dual crawler differential drive; each track is driven by two pinions attached to one geared motor with the intention of increasing power in the vehicle.

On top of the platform are placed a manipulator arm and a camera scissor lift mechanism, which are the main instrument to the teleoperated device. The manipulator arm handled the unknown package and the camera scissor lift mechanism raises/lowers the vision system. These both arms can be controlled by the operator and they can be deploying when is necessary to grasp any object and/or change the vision angle.

4. The Manipulator Arm

The manipulator arm of the disposal system; it has been developed in modular principle in order to provide a great deal of flexibility to reach a given point

inside its workspace to collect any unknown object or possible obstacles. The arm is composed by four similar modules on each revolute joint, one rotated joint and one interchangeable gripper. It has redundant joints; its weight is 6 kg including driven motors. Its structure is totally made in profile aluminium; its frames have been made from modified recycled pneumatic cylinders; normally these actuators are thrown away after being used in automated machines or used as support structures, These are extremely light and strong and can be very easily replaced in case of failure or total damage.

The frames are united by the module joints made in aluminium to keep the arm as light as possible, and also these modules are mechanically similar to reduce the cost of the arm and simplify its construction and maintenance. In its fully extended position the manipulator arm can reach about 1.2 metre length and 1.5 metres high, it has the capability to carry 2 kg in its gripper.

The manipulator arm is driven with 5 DC motors which are positioned inside of each frame and they are controlled independently. The description of the developed arm can be displayed using the following parameters of Denavit-Hartenberg algorithm kinematics model [6] [7]. This specific kinematics model for the manipulator represents the transformation from the base coordinate to the gripper coordinate. The result is a matrix, which transforms the first coordinate into the last coordinate by the settings of the joint angles. See figure 3.

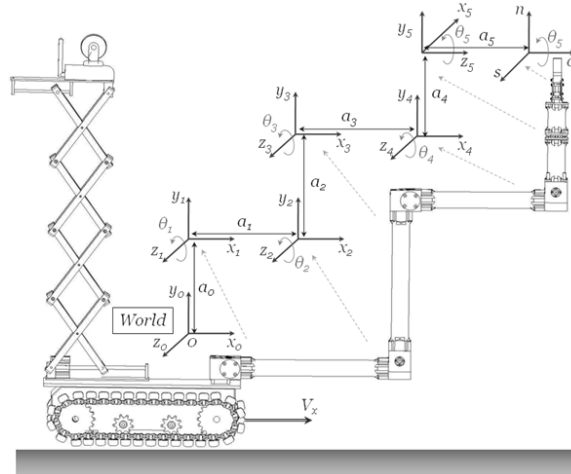


Figure 3: The five degree of freedom kinematics model manipulator arm.

The table 1 shows the parameters and the characteristic representation of the arm and consists of two joint parameters and two link parameters. For an articulated robot whose joints are revolute the joint angle (θ_n) is the only

variable parameter. The fixed parameter is the joint angles that varies and lets the robot move its links as preferred. The joint distance (a_n), the link length (d_n) and the link twist angle (α_n) are also fixed parameters.

The link twist angle α is the rotation, which is necessary to transform z_{n-1} to z_n by rotating about x_n . And the joint angle θ is the rotation around the z-axis at will to match the x-axis of the previous coordinate frame x_{n-1} with the one of the following frame x_n .

Table 1. The resulting characteristic table for the revolute manipulate arm.

| Axis (Joint) | Joint | | Link | |
|--------------|--------------------------------------|------------------------------------|----------------------------------|---------------------------------------|
| | Angle (θ_n) - variable - | Distance (a_n) [mm] - fixed | Length (d_n) [mm] - fixed | Twist angle (α_n) - fixed |
| 1 (Base) | θ_1 | 345 | 0 | 0 |
| 2 (Shoulder) | θ_2 | 345 | 0 | 0 |
| 3 (Elbow) | θ_3 | 310 | 0 | 0 |
| 4 (Wrist) | θ_4 | 90 | 0 | 0 |
| 5 (Roll) | θ_5 | 0 | 0 | $\pi/2$ |

The global world coordinate is assigned to the base so that the z-axis represents the axis of rotation. The z-axes are set to align it with the axis of rotation. The x-axes are selected so that they are orthogonal to z_{n-1} and z_n . Because the z-axis and x-axis of the coordinate frame are determined, then the y-axis is defined. The last coordinate frame is set at the gripper tool tip. The origins of the other coordinate frames are located in the point of intersection of the z-axis, so the joint 1, 2, 3, 4 are parallels with the z-axis but joint 5 rotated 90 degrees.

5. The Control and Vision System

The robot device is carrying a several number of control cards which conform to the control system on-board. These cards are dual motor driver controllers composed of five DC servomotor cards and amplifiers embedded on it. These are based on PID control running independently, where all cards are connected to the main driver control card. The system can control velocity and position of each motor by sending PWM signals through the main driver controller. These signals are sent by an USB adapter which communicates with the main control wirelessly, but the video picture between main computer and the robotic system is being sent by Ethernet wireless communications.

The remote control terminal has been programmed in C++, it has graphic user interfaces (GUI) which control the mobile platform, the manipulator arm, camera scissor lift mechanics video system, see figure 4.

The control system is used to send control commands to run the movements and the manipulation of the robotic system. Various commands are created by combining a number of separate buttons and are divided into the control commands as follows; platform backwards/forward, turn left/turn right and stop movements, up/down/stop movements of each joint in the manipulator arm, up/down camera lift mechanics, video system. The operator can modify manually the speed independently of the platform and the manipulator arm.

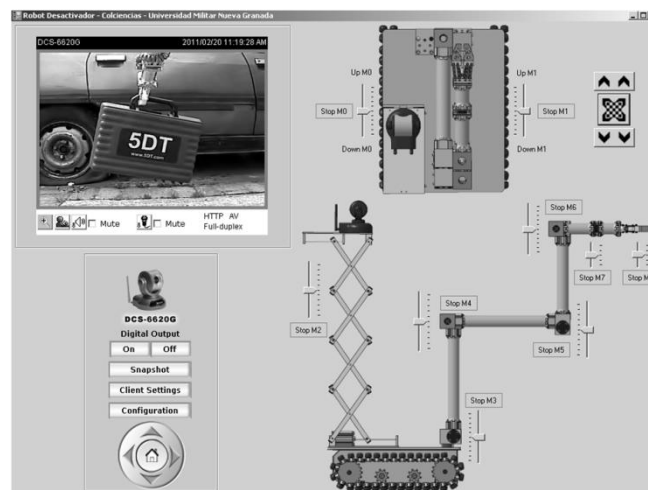


Figure 4: Graphic user interface of the modular disposal teleoperated robot.

The video camera displays a single screen pictures and can be controlled its tilt/pan/zoom; it also has the possibility to send/receive audio from the robot device and some other features of the camera itself like I/O command and darkness. The operator can conduct manual zooming, pan and tilt rotation of the camera wirelessly, to obtain video, images, sound, etc. The operator can also realise actions of the robot's movements, including speed, direction and manoeuvre joint angles of the manipulator arm. The remote control operator gets the information of the robot through the interface, and operates the robot's movements and actions by the main system. The control data and the images are transmitted by the separate wireless transmission module.

Considering the safety features the operator need to be a least 200 meters away of the robot but for absolute security it would be best for them to keep 500

meters away from the unknown package. The wireless communications system of the robot just covers a few metres, but has been increased by around 300 meters with an amplification antenna to achieve the required communication distance. In addition the system has 100 metres cables for a backup communications purposes.

6. Future Work

The prototype robot system has been tested in different environments and surface but most of them can be called lab trials. See figure 5. The robot requires a several tests even in real hazardous environments where mixing pressure is under gone.

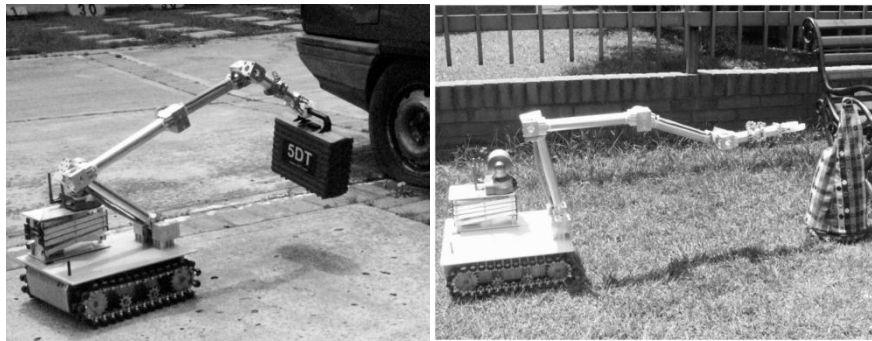


Figure 5: Modular disposal teleoperated robot trial.

The maximum distance that the system can operate remotely, accuracy and repeatability of the robot system needs to be constantly evaluated. The system also require some other cameras to increase the view of the operator where multiple cameras gives the operator a clear view of the robot and its surroundings to ensure optimum safety and improve situational awareness, but actual cameras have perform very well in the lab trials.

7. Conclusions

The project has achieved a modular design with recycled materials in the manipulator structure keeping costs low. It has sufficient functionality and the required basic technology to do the required tasks. The robot is cheap enough to be easily expendable and lightweight to be easily transported and deployed.

The robot can be used to recognise inside buildings, sewers, drainpipes, caves and courtyards, perimeter security using on-board motion and sound

detectors. Can be used also like bus/train/plane inspector, hostage negotiation and explosive ordnance disposal (EOD)

The robot can replace humans to dispose explosive bombs and remove the excuse of having to use an expensive device robot. The robot design proves that a modular robot can be developed with the purpose of reducing cost but yet having high enough capacity to realise complex tasks, cross obstacles and dispose bombs.

The robot contains some capabilities and features which allows for ready use of a laser pointer and some other accessories that can be attached. In addition, the robot's manipulator is able to support multiple types of instrument for different industrial applications a wide range of detecting sensors.

Acknowledgments

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