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LOW COST DESIGN OF AN EXPLOSIVE BOMBS DEACTIVATOR ROBOT

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The explosive bomb deactivator robot (LOCO-EBD Robot) can replace man to recognize, remove and deal with explosive bombs or other dangerous articles in a dangerous environment. The design is composed of a platform mobile vehicle, an articulated mechanical arm, a tele-operated control system, vision system and a wireless communications system. The LOCO-ERD Robot is developed to replace a human deactivator 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 enables a very low cost robot to be constructed and uses several commonly available industrial recycled parts to further reduce costs.

1. Introduction

Explosive bomb disposal robots have been the focus of recent research in the robotics field. Development of these robots 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.

An explosive deactivator robot is an unmanned machine operated remotely with the intention of removing or making safe dangerous explosives. Most of these robots are tele-operated machines, which can recognise, dispose, move, climb, search, lift and handle dangerous explosives or unknown suspect packages.[1] [2]

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There are many tasks which are hazardous to human life which could be conducted remotely using tele-operated robots. The operator uses multiple cameras with the purpose of obtaining different views from a safe distance of the artefact. However, tele-operated robots are completely operated in manual mode and require constant human intervention, for both high level tasks, such as image interpretation and low level tasks for movement from one place to another and simple object manipulating tasks. In the future, fully autonomous robots will be available to carry out complex operations in shapeless environments without human intervention. [3]

The research into EOD (explosive ordnance disposal) robots began in the 1960s with the global situation of terrorism attacks and has been increasingly used in war to make safe weapons. These robots have used stereoscopic vision systems to performing inspection, grasp and destroy tasks. [1] [4]

A large number of companies, universities and research institutions are working in EOD robots. Some of them are in the United States: Remotec, irobot, Wolstenholme; In United Kingdom: ABP, Allen; in France: Cybernetics, DM Corporation; in Canada: Inuktun, Pedsco; in China: Beijing University of Aeronautics and Astronautics and in Germany: Telerob. Etc. [1] [2] [5]

The key part of an EOD robot is the mechanical construction to provide it with the ability to operate in various terrains such as roads, fields, and to cope with obstructions, stairs, etc. It needs to be light weight to increase speed and operate in rough terrain, be operated easily with a good amount of autonomy and be easily repairable.

This paper describes the development of a low cost tele-operated Explosive Deactivate Robot using recycled technology parts with the purpose of constructing a basic device composed of a mobile crawler platform, a 5 degree of freedom manipulator arm, wireless communications and a vision system. This robot has been developed with 5000 Euros budget. 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 troupe will be able to obtain other one without worrying about cost of the robot and can keep saving lives.

2. The Robotic System

The robotic system is composed of mainly five components (see figure 1), which are the robot platform, the robot arm (manipulator), the camera arm, the extend arm and the controller. The robot platform is a mobile vehicle which has 4 driver motors controlled by the JRkerr SC motion controller. These motors are mounted in the main structure and provide the linear motion, rotation and climbing capability of the system. The serial link robot arm is mounted on top of

the robot platform. It has 4 revolute joints and one gripper placed at its end, which allows the system to grasp any object of maximum 100 mm width.

The robot arm is controlled by JRkerr SC motion controllers, which provides the possibility to use the Denavit–Hartenberg algorithm kinematics model to manipulate the robot arm [6] [7]. The controller and the operator PC/Laptop have a server-client relationship via a graphics user interface (GUI). The operator can access and control both robots (robot platform and robot arm) wirelessly or by a cable with an Ethernet protocol and delegate the tasks or commands to the robot easily.
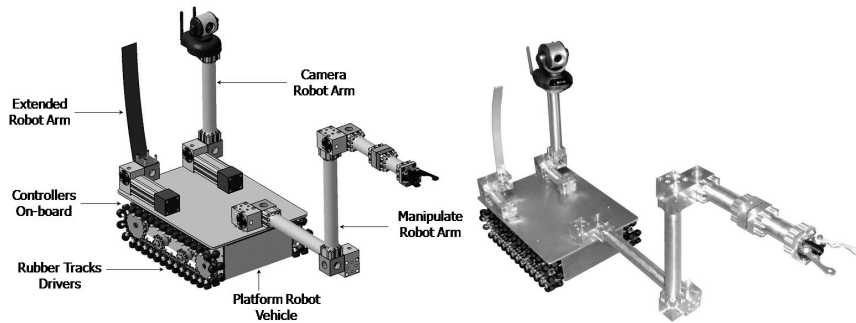

Figure 1: Tele-operated explosive bombs deactivator (EBD) robot.

3. Mobile Robot Platform

The mobile platform of EOD robots are mostly wheeled units, tracked units, or a hybrid of these. The wheeled robot, as the most common mobile unit at present, has the advantage of creating simple lightweight, structures, small wheel rolling friction resistance, and high mechanical efficiency. On the other hand, the tracked robot has the advantage especially in climbing stairs and crossing mixed terrain environments but the disadvantage of heavy weight structure and high energy consumption.

The platform vehicle shown in the figure 2 is a tele-operated mobile robot with rubber tracks to drive the vehicle. These tracks are basically a mixture of steal chain transmission and rubber caps fixed together to increase surface friction and reduce vibrations. The platform vehicle is 15 kg in weight, this mobile robot is composed by a body structure, four driven motors, two flexible steel chain tracks, four driven pinions and four supported pinions. The body structure is a light design to reduce machining problems, decrease the size of the vehicle and also make it strong enough to support the driven motors placed on the sides of the vehicle. It has been made in stainless steel material.
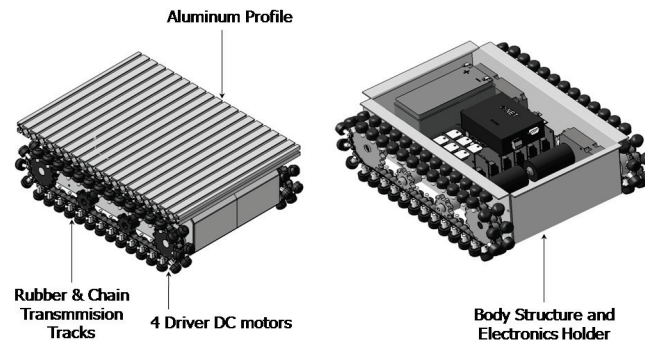
Figure 2: Mobile tele-operated robot platform

The platform vehicle uses a dual crawler differential drive; it has two main drive tracks, independently controlled to make vehicle movement. This drive scheme is very simple, reduces mechanical design and control systems but motion is not very accurately controllable. The electronic control cards, batteries and the Ethernet wireless converter are placed on-board with the advantage of increasing the mass and hence the vehicle grip to give it enough drive force and stability.

On top of the platform are placed three robots arms. The main manipulator arm handles the explosive devices. A camera arm raises/lowers the vision system. This arm can be controlled by the operator and it can be raised when it is necessary to change the vision angle. The third robot arm is a support extension arm. It is deployed when climbing stairs with the purpose of increasing the wide base of the robot platform to avoid the overturning moment.

4. The Robot Arm

The robot arm, see figure 3, was developed to provide a great deal of flexibility to reach a given point inside its workspace and to reach and collect any explosive object, unknown package or possible obstacles. The robot was constructed with an additional redundant joint and is therefore a four axis arm and gripper, its weight is 4 kg including driven motors.

Its structure is totally made in 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 cylinders are extremely light and strong and can be very easy replaced in case of failure or if totally damaged by a bomb. The frames are united by a module joint made in aluminium to keep the arm as light as possible,

and also this module has been used in the entire articulated joints to reduce the cost of the arm and simplify its construction and maintenance. In a fully extended position of the robot arm, it can reach about 1 metre length and 1.20 metres high. See figure 3.
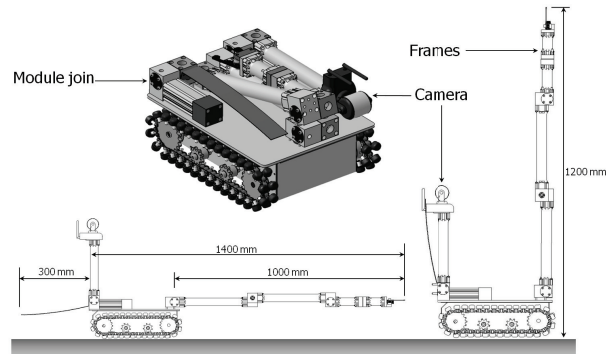

Figure 3: The 4DOF robot arm fully extended and contracted.

The robot arm is driven with 5 DC motors which are positioned inside of each frame and they are controlled independently. The description of the developed robot arm can be displayed using the following parameters of Denavit–Hartenberg algorithm kinematics model. This specific kinematics model for the robot arm 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 4.
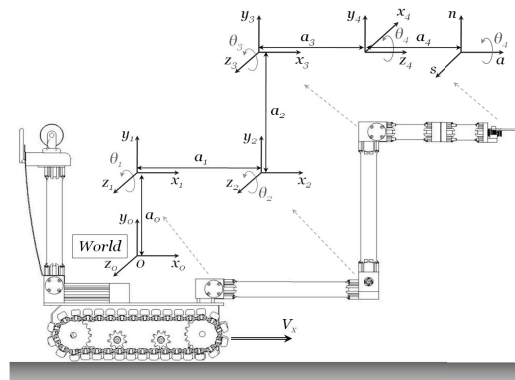

Figure 4: The four degree of freedom kinematics model robot arm.

The table 1 shows the parameters and the characteristic representation of the robot 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.

Table 1: The resulting characteristic table for the revolute manipulate robot 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 (Roll)	θ_4	0	0	$\pi/2$

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.

The global world coordinate is assigned to the base so 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, are parallels with the z-axis but joint 4 rotated 90 degrees.

A commanded position of the robot´s gripper generates the control system to make use of the kinematics matrix and determine the right joint angles of all four joints in order to achieve the demanded orientation and position of the robotic arm. The position control system drives each motor optimally to reach a precise placement of each joint. These commands can be run manually or can be a predetermined task already set in the software.

5. The Control System

The control system uses Jkerr Controllers composed by nine DC servomotor cards and amplifiers embedded on it. It is based on PID control running independently on any number of cards up to 32 cards including I/O cards.

The system can control velocity and position of each motor by sending PWM signals via RS232. These signals are sent by an Ethernet converter which communicates with the main control wirelessly.

The PWM signals send the data to all cards at the same time and the information is collected by the named card. The control system has been divided to use 9 servo DC motors, which have been organized to control the left track, right track for mobile platform, base joint motor, shoulder joint motor, elbow joint motor, roll joint motor and gripper drive motor for the manipulator robot arm; and two additional control cards lift the camera and deploy the extended arm for climbing stairs.

6. Remote Control System

The remote control terminal has been programmed in C++, it has graphic user interfaces (GUI) which control the mobile platform, the manipulator arm, camera arm, extended arm and collect video data from the robotic system. Inside the remote control terminal is an embedded processor connected with the communication machine to accept the data and images from the mobile platform.

The control system is used to send control commands to run the movements and the manipulation of the robotic system. The operator can modify manually the speed and move independently of the platform vehicle and the robot arms.

7. Vision System

The camera video display system on the main control operates a single screen display. 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 manipulate joint angles of the robot arms. The safety radius to keep operators safe from an explosion is around 300 meters. The wireless communications covers around 200 meter distance, so the main control has an amplification antenna to achieve the required communication distance. In addition the system has 200 metres cables for a backup communications purposes.

8. Future Work

The prototype robot system is about to undergo extensive trials to measure its performance. The maximum distance that the system can operate remotely and the accuracy and repeatability of the robot system need to be evaluated especially in the robot arms which have to return to a particular defined position

and repeat the task. It is envisaged that the system will require some other cameras to increase the view of the operator and modifications to the structure may be necessary to increase its autonomy.

9. Conclusions

The project has achieved a low cost bomb deactivator robot design with recycled materials in the structure and robotic arms. 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 enough to be easily transported and deployed.

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 application and production of it can be done in the future.

Acknowledgment

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