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Review Article

A Critical Review of the Bomb Disposal Robot Arm

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Abstract

Disposing of any explosive materials is an extremely dangerous and risky job. Bomb disposal teams prefer to stay as far away from their work site as humanly possible, preferably only interacting via remote-controlled, expendable robots. Unfortunately, bomb disposal is also an extremely delicate job, and most robots lack the finesse to properly disarm a bomb. With recent technological advancements, robotics is likely to play an increasingly important role in various domains and segments of society, contributing to the improvement of our ability to perform a wide range of tasks efficiently and effectively. The assistive robots, particularly robotic arms, are designed to support/aid individuals in task execution, especially in situations where a person may have difficulty carrying out tasks on his own. In this research, a critical review of the bomb disposal robot arm and the application of the robots in various fields of operation is covered.

Keywords: *Assisted Operation, Robotic Arm; Explosive Device.*

I. INTRODUCTION

Increasingly, robots are being used to carry out activities in various disciplines that are normally carried out by humans, such as assistance in surgery [1], assembly plants [2], domestic activities [3], and others. However, robots used in dangerous environments, such as rescuing people [4,5], handling radioactive elements [6], space exploration [7, 8], or deactivation of explosives [9, 10], have greater prominence. In addition, development of an explosive ordnance disposal (EOD) robot location system with enhanced features is being advanced as part of the ongoing project [11, 12]. In order to achieve this, robots must have advanced mobility and manipulation skills that allow the operator to perform tasks very easily and quickly [13, 14]. Currently, the common way to control these arms is through buttons or a joystick, and because these robots perform repetitive tasks, they generate stress for the operator [15, 16]. This stress is generated because the operator tries to reach an object with the robotic arm, but by not having a clear reference of the distance at which the object is, a load of stress is generated. In addition, there is a strong pressure knowing that explosive devices are being handled [17]. The vision system provides three-dimensional information on the location of the object to be manipulated with the help of the two-dimensional location in the image that the operator provides through a touch screen, thus forming an assisted operation system. In Nadarajah's article [18], the vision system used in robot soccer systems is described in a general way. First, the positioning of the cameras in parallel configuration is listed; these are used in a robotic soccer system for both the Federation of International Robot Soccer Associations (FIRA) and Robocop's. Machine vision is classified into three types: omnidirectional, binocular/stereo, and monocular. Subsequently, the image processing algorithms and the references related to their advantages and disadvantages are explained. One of the algorithms that stands out is continuously adaptive mean shift (CAMSHIFT), an algorithm that is used to follow a moving object. For the particular case of stereovision, the distance is estimated with the stereo calibration of the cameras, the intrinsic and extrinsic parameters of the cameras are obtained, and then the distance of the objects captured in both cameras is calculated. In the paper by Zhao [19], a foldable manipulator applied to the five-degrees-of-freedom (5-DOF)

EOD robot is presented, and the Denavit-Hartenberg parameters (D-H) method is used to introduce the virtual joint in order to establish the direct kinematics model of the manipulator. In this way, they demonstrate that a 5-DOF robotic arm is adequate to perform this task. In [20], a system was developed that controls a robotic arm to grab an object through stereo vision in parallel configuration and with a fixed camera (the camera is not mounted on the robotic arm but placed on a turret that has a view of the arm). In addition, object tracking is achieved due to distance estimation through the triangulation method. The system is checked with some operations described in the document. In another article [21], the triangulation method is also incorporated through a stereo vision system, which grabs an object with a robotic arm that uses the CAMSHIFT algorithm to provide better tracking. A stereo vision system placed on a robotic arm in an eye-in-hand configuration [22], together with a target selection system through a touch screen [23, 24], could provide an interesting solution to the problem that operators have to bring the robotic arm closer to a specific location without generating stress load. This article presents a system that controls the movement of a robotic arm in order to grab an explosive device using non-convergent stereo vision, as part of the multimodal system developed for this project [25]. First, the police officer of the explosive disposal unit (UDEX, by its acronym in Spanish) selects the explosive device to be hit with the proposed user interface (UI). The coordinates (X, Y, Z) of the target are calculated: coordinate Z by the two camera configuration and triangulation method, and X and Y by perspective relations. Subsequently, the CAMSHIFT algorithm maintains the tracking of the object during the movement of the arm and, at the same time, detects the corresponding characteristic (center of mass of the object) in both images. The advantage of this proposal is that the autonomous detection of some characteristic of the object to be manipulated is no longer necessary. The possibility of false positives due to disturbances such as shadows, excess or lack of lighting, among others, is eliminated due to this system, which is robust and useful in field applications [26]. Finally, the position of the target is sent to the block of the inverse kinematics of the arm, previously calculated, using geometric techniques that reduce the computational cost. The assistance system is evaluated from the point of view of usability and user experience using the NASA-TLX (NASA task load index) [27] and the evaluation method SUS (System usability scale) [28] to verify that this proposal reduces operator stress levels. The study focused on the operator assistance system, using design techniques and procedures related to vision system configuration, camera and robot calibration, and system performance analysis [29]. In this study, a novel approach is presented to enhance bomb disposal capabilities through the integration of artificial intelligence (AI) and a 6-degrees-of-freedom (6-DOF) robotic arm. Two major challenges in bomb disposal robotics are addressed: firstly, the need for precise manipulation of explosive devices, and secondly, the requirement for reliable autonomous detection. The high maneuverability and precision offered by the 6-DOF robotic arm enable effective handling of bombs in various orientations. Simultaneously, the AI-based automatic bomb detection system utilizes advanced image processing techniques to identify explosive threats autonomously. This dual innovation significantly improves the accuracy, efficiency, and safety of bomb disposal operations. A comprehensive system architecture, including mechanical design, AI integration, and motion control analysis, is provided in this study, showcasing the potential of combining AI with robotics to create advanced solutions for hazardous tasks. The findings highlight the importance of continued technological advancements in explosive ordnance disposal robotics to enhance operator safety and operational effectiveness [30]. In this paper, a mechanical arm algorithm based on the inverse kinematics of a robot is presented. The relative position of the bomb is input by the electromagnetic induction device to guide the mechanical arm to the corresponding position. After obtaining the bomb, the deviation angle of the mechanical arm is input in real time by the gyroscope to achieve the relative stability of the object transportation. The experimental results indicate that the explosive disposal robot has certain practical significance [31]. Military support and rescue robots are becoming increasingly important in modern warfare and disaster response efforts. These robots can perform tasks that are too dangerous or difficult for human soldiers or first responders. They can also gather and transmit crucial information in real-time to help commanders make informed decisions. This abstract will discuss the key features and capabilities of military support and rescue robots, as well as their potential applications. One of the primary functions of military support and rescue robots is to assist soldiers and first responders in dangerous situations. These robots can be used to search for and extract wounded soldiers, identify and disarm explosive devices, and provide cover fire for advancing troops. They can also be equipped with sensors and cameras to gather intelligence and provide real-time situational awareness to commanders. In disaster response scenarios, these robots can assist in search and rescue efforts, locate and extract survivors from collapsed buildings, and provide aid and medical assistance to those in need. They can also be used to survey damaged infrastructure and assess the extent of the damage. Military support and rescue robots are typically equipped with advanced sensors and communication systems to enable them to operate in a variety of environments. They can be designed to operate on land, sea, or air and can be adapted to handle different terrains and weather conditions. Some robots are also capable of autonomous operation, allowing them to navigate and complete tasks without human intervention. Overall, military support and rescue robots have the potential to greatly enhance the effectiveness of soldiers and first responders in dangerous and challenging environments [32]. This paper is majorly concerned with the designing and developing an intelligent system (bomb detection robot) capable of sensing, monitoring, capturing real-time events, and transmitting the data obtained from respective improvised explosives sensed wirelessly to a remote server for further analysis. The work x-rays the design and implementation of a bomb detection robot using a wireless sensor network in the detection of explosive devices that will help improve our campus (Nnamdi Azikiwe University Awka and its environment) security system against terrorists, suicide bombers, and other similar activities. This bomb detection robot incorporates multiple sensors, such as gas and metal sensors, which can detect gas concentrations from 200 to 10000 ppm and a distance of seven to eight millimeters from the target for the metal detector. The wireless bomb detection robot has a control graphical user interface to control the robot remotely. The bomb technician controls the bomb using customized software at the control site or remote location. Input from the user is transmitted to the receiver, and the functions are given to the appropriate modules in the robot to act according to system specifications. The robot is made up of a robot chassis, a wireless camera, an omni-directional antenna, and other components. This robot can be deployed in schools, hospitals, churches, checkpoints, and other public places without risking the life of bomb expert personnel too. Hence introducing the safest way for detecting the explosives to save the life of an environment with ease [33].

II. How robots are used to handle explosives

1. Explosive Disposal

A robot can handle devices that could detonate with the help of wireless communications and a trained professional. If there is an unexpected threat, these machines can hear and see environmental changes to react according to programmed emergency protocol.

2. Demining

Clearing land mines doesn't have to be a human's job anymore. Robots can go onto dangerous lands and make devices go inert without risking people's lives. They can also take care of unexploded or volatile ordinances for workers who may be present in the area. Robots can power these machines down, remove ammunition, or transport them to a safer location for analysis.

3. Explosive Detection

Engineers and robotic designers may embed sensors and other detection systems into robots so they can spot bombs. They can use multiple images processing tools, scanning systems, and cameras to pinpoint explosives in luggage, cars, and more. The military sector is the most obvious industry to bank on this advantage, as it protects troops no matter where they are. It's more sensible to send a robot into unknown territory than risk a life. Explosive material identification is crucial for robotic mine clearance vehicles, which survey areas during or after a conflict. Industries looking to repurpose or rehabilitate the land must know its stability and composition, and these robotic cars are perfect for that.

4. Remote Handling

Remote operations are the most significant benefit of robotics in the explosives industry. This ability makes one of the most treacherous professions on the planet safer. Robots are skilled at expertly navigating rough terrain, which may be hazardous in more ways than being combustible. This makes robots extremely versatile. They are quick to deploy, and computer vision makes it easy to see streets, fields, or homes. Law enforcement and emergency responders appreciate a robot's accessibility and speed when scoping a dwelling with a potential homemade bomb or executing tactical plans. Robots also help during disaster response by finding survivors of an attack, earthquake, or flood.

5. Explosive Dismantling

Sectors won't replace humans with robots, but it makes sense to put them in charge of neutralizing bombs and explosive devices instead of people. Robots can snip wires, use disruptors or pour water on contents, depending on the type of combustible material. They can identify components and deploy the correct strategy without making a costly mistake.

6. Making Explosives

Laboratory and manufacturing environments can find numerous ways to employ a robot to make bombs and other explosives. Robotic arms, cameras, and sensors become more precise every day, identifying defective parts and testing for quality. They can rapidly assemble materials in areas without human intervention until they're safe enough for people to interact with them. It makes production operations more compliant with safety standards and improves workers' well-being. Peace of mind skyrockets when employees don't feel their lives are at stake every time they show up for work. Companies benefit from this boost with reduced absenteeism and turnover, making operations more consistent and profitable.

7. Storing Explosives

Leaving explosives to rest on shelves may incite an out-of-sight, out-of-mind mentality. However, they need oversight and care like any other storage facility items. Robots serve a multitude of purposes in this area, including environmental monitoring. Combustibles are sensitive to temperature and conditional changes, and robots can send notifications to businesses to ensure they know when something is awry. Additionally, robots can track inventory. They can record images and metadata about each explosive, its quantity in storage, its location, and whose responsibility it's currently under. Thanks to these scanning and tracking capabilities, tracing sensitive materials has never been easier.

8. Testing Effectiveness and Safety

Robots can do more than store and disarm an explosive. They are also invaluable for research and data collection purposes. Manufactured products must be assessed for quality and safety. Their effectiveness may also need to be tested on the field, which can happen in a controlled environment without a human actor.

9. Explosive Transportation

Assembling an explosive is one safety risk. Transporting it is another. One bumpy ride could cause a catastrophic butterfly effect of incidents, and organizations want to prevent this at all costs. This is why robots should move explosives, whether to a work zone or into warehousing. Autonomous guided vehicles that follow programmed paths are ideal for manufacturing environments. Devices carrying the combustible item can have built-in sensors and an emergency protocol if the explosive's integrity gets compromised. In the field, it's faster and more stress-free to have them delivered to the necessary site than to do so manually. Explosives may also need to be transported on aircraft. Shippers identify the HAZMAT class, which determines how it needs to be packed. Robots could handle this, using programmed standards from ICAO and IATA to guide the process so it's ready for a cargo plane.

10. Standard and Drone-Based Observation

Robots can have basic or advanced visual capabilities, depending on cameras, sensors, and algorithms. They can build maps of potentially dangerous environments, surveying and marking areas where threats may be. They can also enter tighter spaces, providing more comprehensive information if humans can't reach certain areas. This also applies to drones, which extend the line of sight for locating explosives. Bomb squads could use this before a job, assigning expectations to the force. This means they can pack the right gear and more confidently control the situation. It can also advance intelligence gathering, executing quicker and more thorough investigations without alerting unwanted parties.

11. Underwater and Subterranean Applications

Taking explosives underwater is even more dangerous than moving them on land. Biodiversity is at risk, and one mishap could leave operators struggling for air. Remotely operated robots are built to endure high pressures and cold temperatures, becoming the ideal courier for setting up combustibles underwater. Advanced robotics can scan the regions where they will work, sending analytics back to technicians. Germany has issued robots to investigate the North and Baltic Seas for lingering weaponry from World War II. This allows humans to make informed decisions about underwater operations without the conventional risk profile. Robots can also replace humans in other environments. Cave systems, tunnels, and other dry underground structures are potential cave-in or avalanche sites if people mishandle explosives.

12. Simulations

Robots are compatible with countless other technologies, including virtual and augmented reality. Combining robots with these resources to train employees can provide the most hands-on experiences in history. Many workers need upskilling to adapt to digitization and robotic integration. Simulated training environments are a tactile way to improve technological literacy while providing meaningful educational resources. Workforces will simulate interactivity in safe environments but gain the experience of working with genuine explosives. There are no real-world risks when personnel can remotely direct a robot to power down a land mine or drive a virtual vehicle with a precious payload to safety [34-54].

III. CONCLUSION

Numerous developments in robotics technology for bomb disarming were covered in this study. We have observed the diverse approaches taken by numerous writers as well as their most recent technological developments. The use of robots for disarming bombs in general and its many applications were also covered in the study.

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