Design and Development of Bomb Defusal Robotic Arm Coupled with Multi-Rotor Copter

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ABSTRACT

Bombs are getting fancier by the day. They are more mechanically innovative today than they ever. There is a pressing need to ensure that our bomb defusal squad is well equipped to handle any sort of scenario that might occur. From that perspective, the development of an aerial based bomb defusal system only seems mandatory. This system has the primary advantage of accessibility. It is imperative that light-weight materials, an advanced control unit and state of the art flight dynamics come in harmony to create a fully functional and effective aerial unit that is capable of bomb manipulation. This sort of system would be highly beneficial to a country which is plagued by terrorist attacks every once in a while. This system would make a valuable addition to the bomb defusal unit.

KEY WORDS: Robotic arm, bomb defusal, multi rotor copter, four bar mechanism.

1. INTRODUCTION

Conventional bomb defusal robots are terrestrial based. They use heavy robotic arms to handle bombs. Occasionally they encounter challenging terrains and in such an event the robot struggles to negotiate the terrain. Therefore, an aerial bomb defusal robot in the form of a multi rotor copter will not face similar issues. Under such a circumstance, there is a need for a light-weight, compact robotic arm that can be coupled to a drone. This aerial based system is never meant to replace the existing terrestrial bomb defusal systems. The use of the terrestrial based systems is indispensable to the bomb squad, as they are rigid and sturdy and capable of manipulating heavy duty bombs. The aerial based systems, however, are only meant to supplement the existing contraptions used by the bomb defusal squad and enable to defuse the bomb from a safer distance (Shinde Pushpa, 2016).

Multi rotor copter: Multi-rotor copters are used extensively this 21st century. Surveillance has been the primary purpose. The uses however have grown exponentially. Today, multi-rotor copters are used for all sorts of purposes. From pizza delivery to airplane inspection. The modern drone has seen it all. Multi-rotor copters essentially use a set of Brushless DC motors to propel themselves into the air. A state of the art flight controller sends appropriate signals to each motor via an electronic speed controller in order to maintain the stability of the multi rotor copter. Depending on the accuracy of the flight required, the cost of the flight controller varies. Multi rotor copters are designed with one thing in mind and such that as light as possible. And for this carbon fibre is the pretty obvious choice. But advances in material science will soon enable these drones to be made out of space age polymers. These multi-rotor copters are powered by lithium polymer batteries as of now. Soon, battery technology will also enable the use of highly energy dense batteries. All these optimisations are done to make the drone flight as efficient as possible. Applications of multi-rotor copters are many. So, corresponding development in the enhancements of these systems is also taking place in parallel.

Robotic arm: Humans have been able to effectively manipulate objects in their environment with the use of their hands. Features like our opposable thumbs have ensured utmost efficiency in the usage of hands. In the modern world, our hands may not be powerful enough for the kind of applications that we use. Moreover, it may not be safe. And as a solution to this problem, robotic arms have been in use for a while. They are designed to mimic the human hand. They are more powerful and more accurate than the human arm. They can be modified suitably for any kind of application. Robotic arms are an assemblage of links and joints. They form a kinematic chain. Servo motors are usually placed at the joints in order to bring about movement. In a robotic arm, the hand is usually the toughest part to design. This is because the movement of human fingers is very quick and accurate. And the degrees of freedom of the human hand are also very high. The human hand is also compact at the same time. In order to achieve all these simultaneously with a robotic hand, a complex design must be conceived and implemented. New developments in this field have given rise to detachable magnetic fingers. These sorts of life-like robotic arms are suitable for defusing bombs.

Design and Development: The robotic arm is developed with three things in mind to be lightweight, to have a low rotational moment of inertia to provide the maximum degree of freedom for object manipulation. Two materials have been considered to make the arm. For light weight and high strength carbon fibre makes a good choice. The other material that can be used is Acrylic. This is extremely light in weight, but may not be sufficient for rugged use. The servo motors that operate the arm are usually placed on the respective joints. But in the design of the bomb defusal robotic arm the servo motors are placed at the base of the arm, near the centre of the multi rotor copter. This reduces the effect of rotational moment of inertia as the weight of the robotic arm is

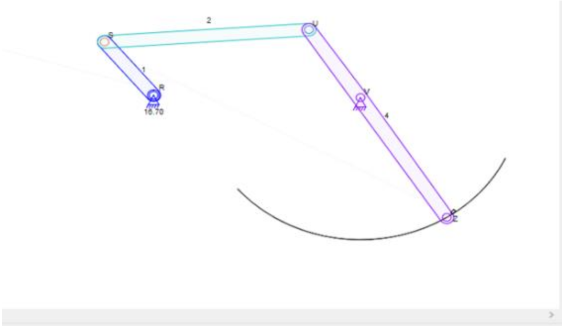

Figure.1. Path to be traced by the arm end

concentrated towards the centre of the multi rotor copter. The joints are operated via kinematic chain. In this case, the kinematic chain is a four-bar mechanism. Common robotic arms make use of servo motors at the respective joints. This disturbs the stability of the flight of the drone as the centre of gravity moves away from the centre. The proposed arm will have the joints activated by two four bar mechanism. In this scenario, the servo motors are placed at the base of the arm to activate the four-bar link. Hence the centre of gravity is maintained almost at the centre of the drone and rotational moment of inertia is lowered. The four-bar mechanism is designed so that the arm passes through specified points as shown in Figure.1.

Figure.2. 3D models are shown which represent the two four bar mechanism of the robotic arm

The arm may be given a maximum number of degrees of freedom in order to enable required object manipulation. Ideally a five degree of freedom arm would be perfect, but a minimum of three would be sufficient. One for shoulder movement, one for elbow movement, one for gripper movement. Three of these servo motors are located near the centre of the multi rotor copter (Aparna, 2016)

The aerial based system is designed to add versatility to the bomb defusal squad. This enables them to be prepared for any sort of situation that their everyday job might throw at them. This is a system that is capable of identifying bombs by giving the bomb squad an aerial view. It is designed to quickly access the bomb and perform necessary bomb manipulations in order to diffuse the bomb. The drone is going to act as a carrier of the robotic arm. And the arm in other hand is designed using four bar mechanism to have a minimum effect on the stability of the drone. The arm can be attached either on the top or at the bottom of the drone, preferably at the bottom. Attaching the arm at the bottom gives an added advantage to manipulate the bomb while it hovers over it. The defusing unit is the arm and the drone is designed to handle the vibrations caused by the operation of the arm. The stability of the drone is controlled by the sensors in the flight controller like the Gyroscope, Accelerometer and GPS sensors on board in the flight controller. This would make a valuable addition to the arsenal of the bomb squad. The design and development of this kind of aerial based bomb defusal system is just the beginning.

Once developed and properly implemented, this will pave the way for more advanced systems which employ cutting edge technology to enhance bomb defusal. By proper improvements in sensors and processors, the analysis of incoming transmitted data from the controller as well as the data that is obtained from on board sensors can be done, for effective flight and to maintain the stability (Roger Clarke, 2014). Advancements in branches of mathematics such as control theory enable us to design a drone whose flight is extremely stable under all sorts of conditions. Be it bad weather or bombs that are difficult to manipulate. The possibilities are many in this particular field. The multi-rotor copter will be designed with a nylon glass-fibre frame. This material provides the necessary rigidity and reduced mass required by an aerial contraption. The multi-rotor copter, in this case a quad copter, has the following specifications: 4 x 750 kV BLDC motors, 4 x 30 amps ESC, 10 x 1.5 propellers (4 numbers), 2000 mAh Li-Po battery, KK 2.2.1 Hobbyking flight controller.

System Design:

Controller Unit: There are two independent command inputs which are given to this aerial based bomb defusal unit. One input controls the flight of the quad while the other input is to control the robotic arm beneath it. This way the drone operator as well as the bomb squad personnel can operate in tandem to defuse the bomb. The two control units are:

KK 2.2.1 Hobbyking Flight controller: This flight controller provides an optimum control of the quad in order to provide a stable flight. This controller essentially uses a gyroscope and accelerometer. The accelerometer measures the acceleration of the system while the gyroscope measures the orientation of the system. These inputs are combined by the Atmega644PA IC. This IC send appropriate signals to the electronic speed controllers which vary the speed of the brushless DC motors in order to bring a stable flight. A more advanced system uses a magnetometer a well. This aids in a more precise flight control.

Arduino UNO R3: This is an open source platform with the advantage of customizability. With proper coding, we can appropriate proper servo motor control. Transmitter unit: Wireless video transmission, 2.4 GHz transmitter to control the drone, Android application control for the robotic arm. Receiver unit: Video receiver, 6-channel receiver, Long range Bluetooth module. Flight system: Nylon glass fibre frame, 4x 750KV Brushless DC motors, 30A Electronic Speed Controllers, 3000mAh Lithium Polymer battery.

Prototype: The following images below are that of the working prototype that has been fabricated. From the images, it is clear that size of the robotic arm has been a major consideration during the design stage. An oversized arm would hurt flight dynamics. The objective is to identify an optimum size and make a fully functional lightweight robotic arm that can be coupled to a drone. There are provisions on the base of this robotic arm such that it can be easily mounted on to the frame of a multi-rotor copter. From the images, one can also observe the four-bar mechanism that will be used to operate the arm. The motors are kept close to the base in order to maintain the centre of gravity. The arm has been tested for strength, range and payload capacity. The results are satisfactory.

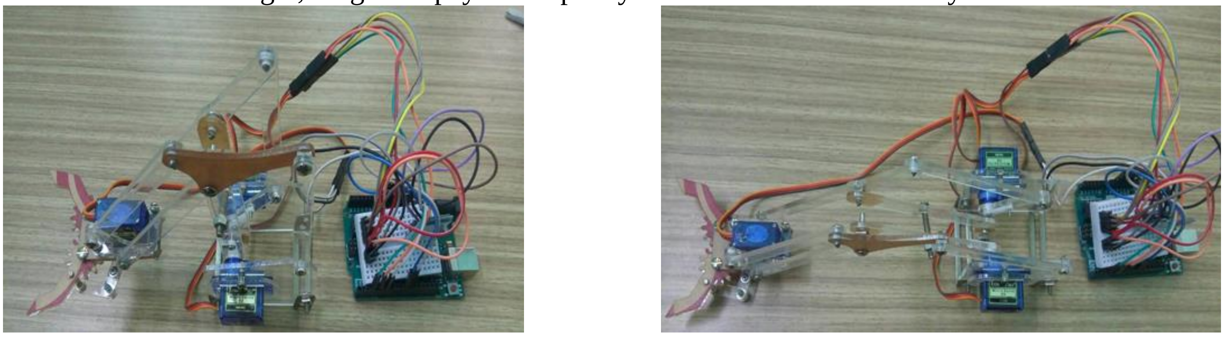

Figure.3. Prototype of the arm

DISCUSSION

An aerial based system lacks a rest state like a conventional system that moves on land so it is imperative that the system can always stay airborne and not crash land. In the event of a failure of any sensor or power fluctuations, the drone must possess a back-up autonomous function which will ensure that the aerial system does not crash land, thereby causing harm to the people in the vicinity.

This aerial based system is one with high power requirements. The battery is the power source of this system and it needs to power the rotors, the robotic arm, the flight controller and other peripherals such as the video camera, etc. So, from this it is easy to get a sense of the massive power requirements. At the same the battery should be light weight. A heavy battery would only be counterproductive to the cause of the drone. And so, the need for a high-energy density battery can’t be highlighted more. Innovations in battery technology will soon produce high energy density batteries. Lithium air batteries are said to have a theoretical energy density of 11,140 Wh/kg. In comparison lithium ion batteries have an energy density of 265Wh/kg. (Xiangzhong Ren, 2017).

Applications: The following are the application: To access bomb within buildings. In this case, the terrestrial system would struggle to manoeuvre past obstacles. These systems are very quick compared to their terrestrial counterparts, thereby saving some valuable time. Its compact form enables it to navigate through tight spaces. It can reach heights which other bomb defusal system can’t.

Future applications of this project work: With proper enhancements, the drone will even be able to lift the bomb to another safe location in case the operator fails to defuse the bomb. Advancements in 3D laser scanners producing 3D feedback and relaying the information back to the control room help in better manipulation and neutralization of the bomb (Janusz Będkowski, 2009).

4. CONCLUSIONS

This design has gone through its initial testing phase. The results look promising. With proper enhancements done, this system will be capable of living to its full potential. Through the stages of optimisation and analysis future applications can prove extremely useful to society.

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