American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)

ISSN (Print) 2313-4410, ISSN (Online) 2313-4402

http://asrjetsjournal.org/

Explosives' Detection and Remote Detonation Drone

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Abstract

A device, system and method for the purposes of remotely detecting and detonating explosives by laser, whether located on ground, on an altitude or high grounds, dropped by a parachute; or on a moving vehicle. Allowing zero human interaction with the explosive and sending vital information about the size, dimensions, material, specifications and range of the possible explosion to avoid casualties, save human lives, costs, and time. The device is also waterproof to be able to operate in heavy rain, and equipped with 2 strong front LEDs to operate in the dark, and a GPS locator and hardware/software module to allow it to return to base automatically or recovered if lost.

Keywords: Drone; explosive; laser; detonation; bomb disposal; GPS.

1. Introduction

This invention intends to serve the military/police bomb disposal units, bomb squads, EOD Operators, public Safety Bomb Technicians (PSBT), and the like; the Egyptian government may utilize this art for its own usage only, without paying the inventor any fee, charge, royalty, compensation or the like . The present invention intends to minimize the casualties to zero and financial losses that might rise from destroying an expensive bomb disposal drone to the minimal. This art is of lightweight, back-packable, multi-terrain, can reach high grounds and can chase a moving explosive with high speed. Several drones can be used at once and focus the laser on a certain point to breakthrough stubborn coatings of explosives; this opens a wide varity of uses and make it a revolutionary bomb disposing art.

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2. Technical field

The invention relates generally to drones, and more particularly to a Quadcopter drone that houses an integrated camera system; an explosives' detector, and a laser driver.

The exemplary embodiments described herein generally relate to drones, cameras, processors, actuators, motors, batteries, receivers/ transmitters, and laser drivers.

3. Prior art

Referring to the prior art, there has been no art with the same capabilities. The prior art US6113343A [1], Explosives disposal robot, which is still in operation, cannot reach for high grounds; and in most cases may be damaged partially or wholly by the explosion, as it comes very close in contact with the explosive. This makes the process very costly.

That prior art deal mechanically with the explosive, handling it with a robotic arm to attempt disposing the explosive, which is not always a successful mechanism, especially if the explosive is made by a sophisticated tech, or even wrapped in a shockproof bubble bag; and requires more than a shock impact to explode.

However, this invention is not meant to replace the valuable previous art US6113343A, as it has different scope of applications.

A related art to this invention is the four-rotor aircraft CN 203318680 U [2], Remote-control flying copter and method US 20140099853 A1 [3], Quadrotor model helicopter airframe US D710453 S1 [4], Laser diode power control and modulator circuit US 4868836 A [5], Laser pointer with multiple color beams US 20020071287 A1 [6], Laser welding system US 5616261 A [7], and Apparatus and method for the detection of materials US 6344818 B1 [8].

4. Claims (14)

What is claimed as new and desired to be secured:

4.1. A Quadcopter with certain embodiments, that can detect and neutralize explosives on land, airborne (on drones) in high grounds (roofs) and vehicle-borne;

4.2. A control unit, that controls a camera, a laser drive and a bomb detector fixed to the Qadcopter of claim 1;

4.3. The control unit of claim 2 shall be adjustable to allow adding or removing certain embodiments;

4.4. A plurality of components integrated in the said unit, rechargeable batteries, actuator, a motor, a microprocessor, a camera, an explosives detector a cooler, A transmitter/ receiver and a laser drive;

4.5. The quadcopter in claim 1, equipped with control unit of claim 2 is meant to be directed remotely to examine a suspected explosive, via the detector embodied therein;

4.6. The detector of claim 4 is claimed to detect explosives from a distance of 50 - 100 meters away, estimate its weight, dimensions, and power range; transferring such information to a controller, and;

4.7. A laser drive of 7.3 mW laser is claimed to target the explosive from distance, to detonate it safely without human interaction;

4.8. The camera, laser detector as in claims 3 and 7 is fixed on a motor to be able to rotate 360 degrees;

4.9. The laser beam in claim 7 shall be targeting the center of the lens of the camera, i.e. shooting where the camera is looking;

4.10. The quadcopter and the bomb disposal unit shall be controlled by a single remote control and operated by a single person;

4.11. A software/hardware module consists of the components in claims 1, 2, 3, 7 ; shall be able to lock on a still target or a moving target, i.e. a vehicle-borne improvised explosive device (VBIED) or operate in strong winds;

4.12. The apparatus shall be waterproof to operate during rain

4.13. The laser intensity can be controlled remotely;

4.14. The Quadcopter in claim 1 shall include a GPS locator that shall be preprogrammed for it to return to base after accomplishing the mission, or if lost.

5. Structure

In view of the foregoing, the present invention relates to an apparatus and method of detecting the presence of explosives and safely detonates them.

It is an object of the present invention to provide an apparatus and method to remotely detect and detonate explosives.

Another object of the present invention is to provide remote detection and detonating system with a certain information monitoring system that can be controlled with one person.

Still another object of the present invention is to provide the Public Safety Bomb Disposal (PSBD) and the Bomb Squad personnel with a different, safer approach to disable explosives.

Still another object of the present invention is to identify the explosive and estimate the possible explosion range and possible options of disarming the explosive.

Other objects and advantages of the present invention will become more obvious hereinafter in the specification and drawings.

6. Disclosure of the invention

Referring now to the drawings, and more particularly to FIGURE 1, a plan view of the embodiments of the present invention is shown and referenced generally by the name “RONI" or "Roni”. The components will be clearly illustrated in further drawings. Specifically, the relevant structural features of Roni shown in FIGURE 1 are a housing for the CPU, circuits and battery 1, the four propellers 2; connected to the motors 11 that run the propellers and capped with the propellers' hoops 15. An EF camera 3 with a memory is fixed on a motor 9 to be able to rotate 360 degrees, from behind the camera and as appear under it is the laser device 5 and the camera motor 9, the laser, and the detector 6 so that the camera, the detector and the laser device moves simultaneously in the same direction, allowing the laser to target exactly where the camera is looking, the explosives detection device 6 is connected to an actuator 8 to operate it and draw in/out its retractable antenna 7. The explosives detector, camera and the actuators have their own control unit, a microprocessor, board and batteries 16 housed together, different of those operating the copter to fly and hover; in order to avoid exhausting the battery of the quadcopter and to save the energy for flight and hovering. The camera may operate at night as it has two front lights above 14, and four landing skids 12 to land safely.

The steps of a method or algorithm described in connection with the embodiments disclosed herein, sending stream images from the camera to the remote control and its screen, may be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two. A software module may reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, hard disk, a removable disk, or any other form of storage medium known in the art.

FIGURE 2 is an exemplary circuit to operate Roni, to allow it to fly and hover until its mission is fulfilled.

FIGURE 3 is an exemplary drawing of a motor 1 that enables the camera, detector and laser to turn right and left three hundred and sixty degrees, placed on a mount plate 2 and a spinning cylinder 3 where the camera and laser are attached by screws 4.

The mounted detector; patented under no. US 6344818 B,1 detects the interference generated between the source energy and the characteristic energy emitted from the material. The interference signal generated between the source energy and the energy emitted from a material is a series of pulses that occur when the two signals cross. The two signals will undoubtedly be out of phase with each other. Since the two signals will be at the same general frequency, however, the interference signal will also be at that frequency. Since the characteristic energy emitted from the target material is a derivative of the characteristic energy, the interference occurs at given intervals. Even though the energy level of the signal emitted by the target material is relatively low, and can be hard to detect on its own, the interference signal is constant and does not depend upon the energy level if the signal emitted by the target source. The interference signal is constant over a wide range and can be detected because of the known parameters of the source signal and the signal emitted by the source. This detector includes a source module and a detection module. The source module generates an energy signal having a given frequency and that corresponds to the characteristic frequency of the material to be detected. The detection module detects the presence of the interference signal that is created between the source energy signal and the energy emitted from the target material at the same frequency as the source signal. The interference signal is dependent upon the characteristic frequency of the target material.

The source module includes a frequency generator that is connected to an antenna that has a given size, or length, that depends upon the wavelength of the energy signal. The source module may also include an inductor so that a multi-phase signal will be emitted.

The detection module includes a rotatable retractable antenna. To improve performance, the antenna can be connected to a signal generator that is preferably set to the characteristic frequency. It is believed that the generator connected to the detection module serves as an amplifier of the interference signal and a filter for surrounding frequencies. The detection module antenna is also connected to a coil that can be tightly wound and oriented in a vertical direction relative to ground and perpendicular to the antenna. The detection module can include a modulator that is set to a relatively small frequency as compared to the source signal. The modulator enhances the detection of the interference signal by the antenna by varying the interference field. The size and orientation of the antenna, the modulator and the detection module source generator are all configured to enhance the ability of the detection module to detect the presence of a material in any given location. It has been observed that the detection device used by the present invention operates optimally when the source generator emits an energy signal of between 100 MHz and 1.5 GHz.

In operation, the source generator is activated to emit an energy signal of a target material's characteristic frequency between 100 MHz and 1.5 GHz.

Depending on the power level of the energy source, the source module will begin to activate the electrons of any material that has the characteristic frequency generated within a given area after a few seconds. Once the target material is activated, it too will begin to emit a signal having the characteristic frequency. As will be understood by one skilled in the art, an interference signal at the characteristic frequency will occur between the source signal and the target material signal even though the energy level of the target material signal may be relatively weak.

The detection module is moved through a range between the source module and the target material. When the detection module encounters the highest energy line between the source module and target material, which is the shortest line between the two energy sources, the antenna will rotate to designate that the line has been crossed. Depending on the orientation that the detection module coil is wound, the antenna will rotate in the direction of the target material or the source. As the antenna continues to move through a range it will continue to point in the direction of the source module and the target material. Once a set of co-ordinates for the target material have been generated then the exact location of the target can be calculated. If the exact location of the material is known, as in a suitcase, the microprocessor will - through the camera - start calculating its dimensions, possible weight, and its quantity and range through the detector according to the frequencies analyzed, and then display such information on the screen of the remote control.

The method of attached the control unit to the copter is shown in the control unit (FIGURE 1 item 16) is detailed in FIGURE 4. This unit attempts to control the camera motor, detector actuator, and the laser device with screws 1.

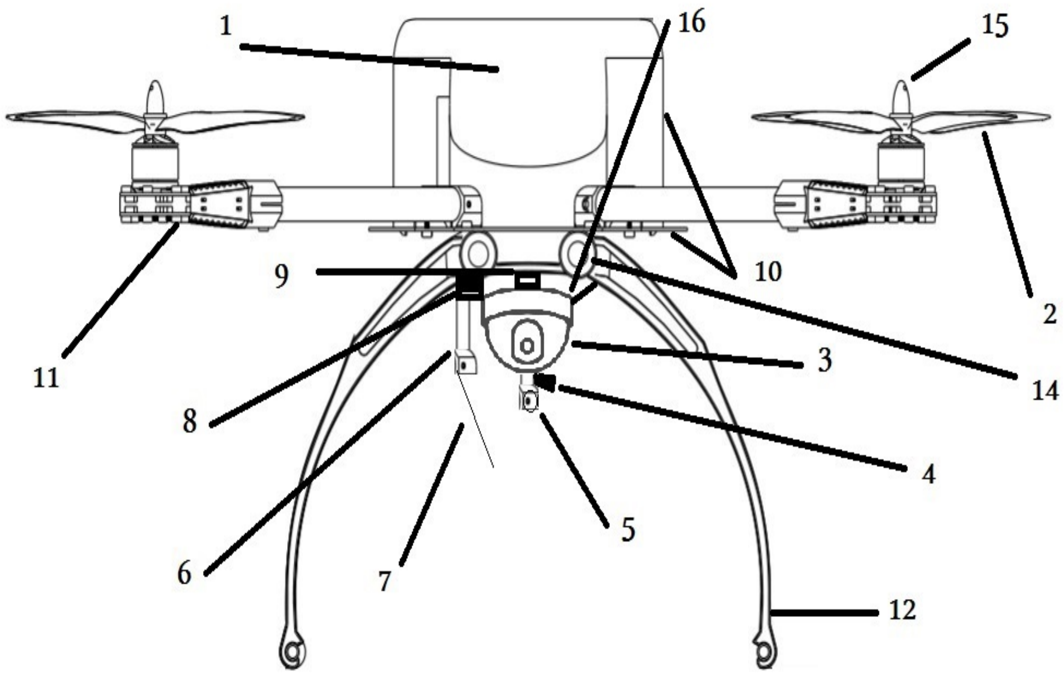

Figure 1: a plan view of the present invention showing the Quadcopter, the housing for the CPU, circuits and batteries 1, the four propellers 2; the motors 11 that run the propellers capped with the propellers' hoops 15. An EF camera 3 fixed on a motor 9, under it is the laser device 5 and the camera, detector and laser rotation-controlling motor 9, the laser 4, and the detector 6, an actuator 8 to operate it and draw in/out its retractable antenna 7. A housing 16 for the embodiments and two front lights above 14, and four landing skids 12.

As clearly illustrated in the drawings, the batteries controlling the motor are different of those powering the 7300 mW laser device up to 1.5 W. The laser device uses a red laser diode of 650 nanometers (nm) wavelength, and four 26650 4.2 V Li-ion rechargeable batteries. The laser device FIGURE 5 consists of a power supply unit (FIGURE 5 item 1), transferring power to an adapter (FIGURE 5 item 2), which operates the laser driver (FIGURE 5 item 3) to emit the laser beam. In the same Figure (FIGURE 5 item 4) is a small dedicated actuator to act as a focusable mechanism, to control the beam from the pointer (FIGURE 5 item 6), a fan (FIGURE 5 item 7) cools the laser chamber, and all are housed in a metal housing (FIGURE 5 item 5).

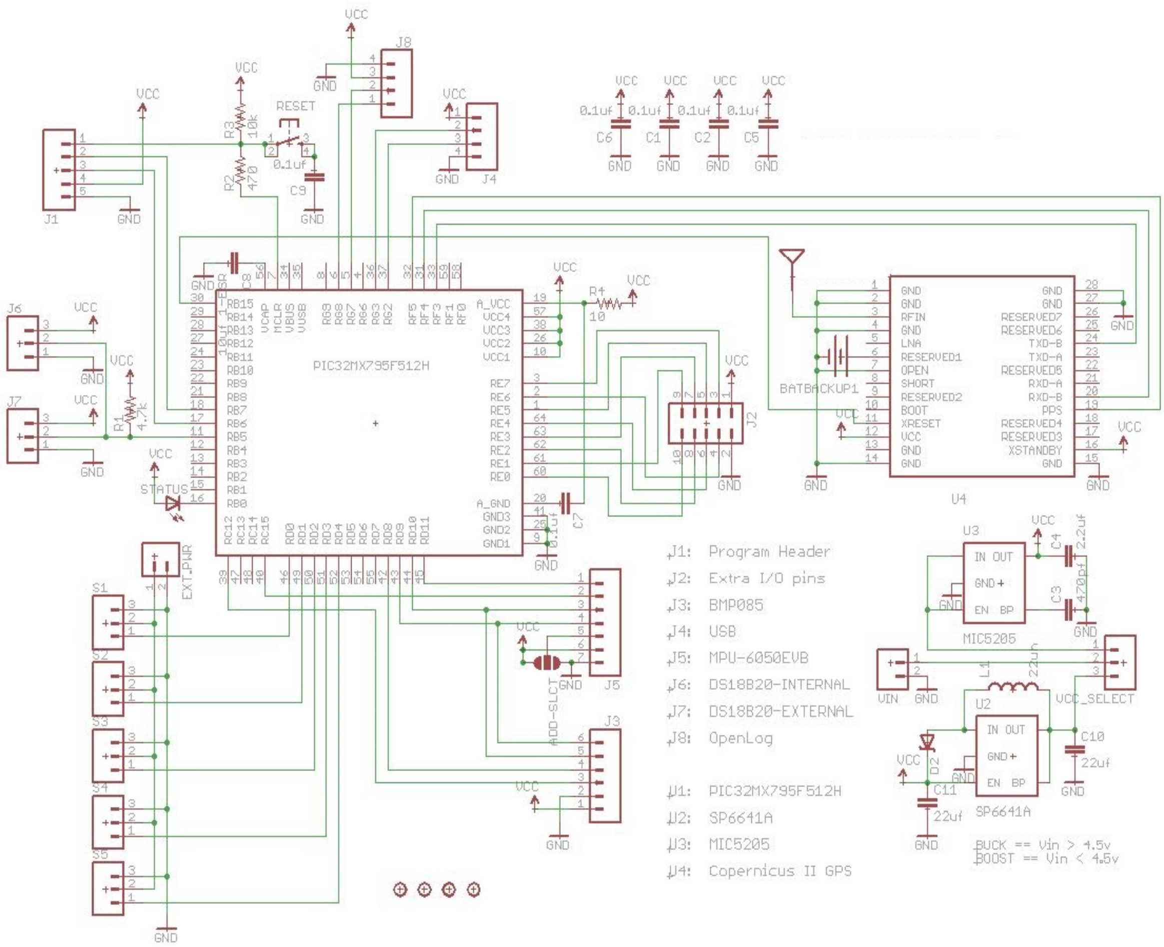

Figure 2: an exemplary circuit to operate Roni

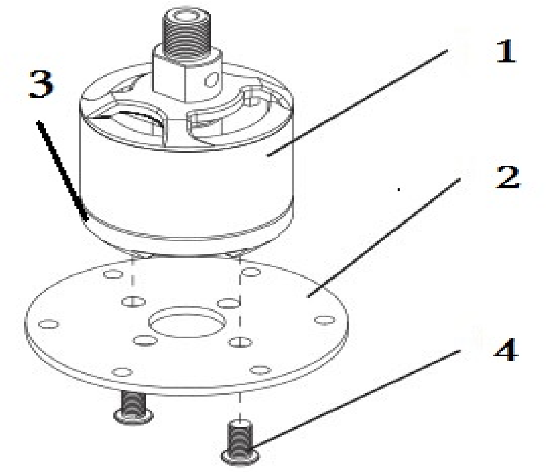

Figure 3: an exemplary drawing of a motor 1 that enables the camera, detector.

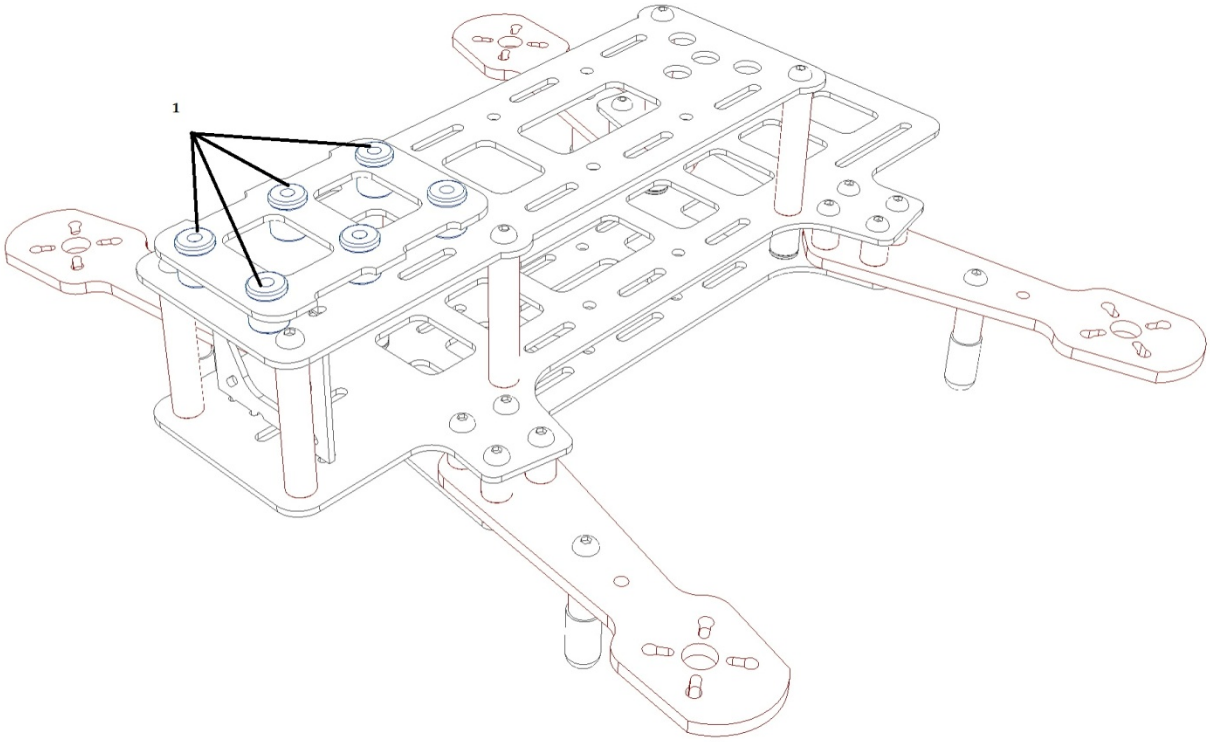

Figure 4: a schematic detailed drawing of the hull and the place of installing the control unit

FIGURE 6 shows an exemplary circuit for the laser driver. Such laser devices and circuits are well known by skilled artisans and are not intended to be protected per se in this document.

In an upside-down view FIGURE 7 shows another method to fix the control unit to the copter, there are variety of methods to install the unit to a drone, and this document does not intend to limit such installation model to a certain form. The control unit 1 attached by screws to the hull of the copter, to which is attached the engine 2 that rotates the camera 3, the explosives detector 5 and enables it to draw its antenna 4. The laser 6 is also moving automatically with the mechanism, to focus its pointer 7 on the desired target.

FIGURE 8 is an exemplary drawing showing the Quadcopter and the control unit 1, and its different parts 5, the laser 2 the explosives’detector3 and its antenna 4.

FIGURE 9 is a schematic of the control unit, clearly showing a light metal housing 1 with a mechanism to adjust its dimensions 2, to enable the user to make it bigger to add other embodiments or smaller if it is possible to remove certain embodiments. This housing is fixed to the Quadcopter base with screws through screw cases 3, comprising a batteries ‘housing 4 for the laser drive, which will host four 26650 4.2 V Li-ion rechargeable batteries 5, and another housing 6 for the batteries 7 operating the camera, detector 11, laser rotating mechanism and its motor 9, and also the linear actuator 10 controlling the detector's antenna 12. The laser drive 13, will be adjusted to shoot the laser beam through its barrel 14 and pointer 15 exactly where the camera is looking. A CPU 16 controlling the unit will require an active cooling 17 mechanism using cooler fans. The mechanism, rotating, and laser shooting is controlled remotely; via a receiver/transmitter 8 planted therein and connected to the CPU.

The position and velocity of the quadcopter in the inertial frame as:

$x = (x, y, z)^T$ and $\dot{x} = (\dot{x}, \dot{y}, \dot{z})^T$, respectively.

Similarly, as stated by Andrew Gibiansky, in the research of quadcopters dynamics; we define the roll, pitch, and yaw angles in the body frame as $\theta = (\varphi, \theta, \psi)^T$, with corresponding angular velocities equal to $\dot{\theta} = (\dot{\varphi}, \dot{\theta}, \dot{\psi})^T$. However, note that the angular velocity vector ω 6= $\dot{\theta}$. The angular velocity is a vector pointing along the axis of rotation, while $\dot{\theta}$ is just the time derivative of yaw, pitch, and roll.

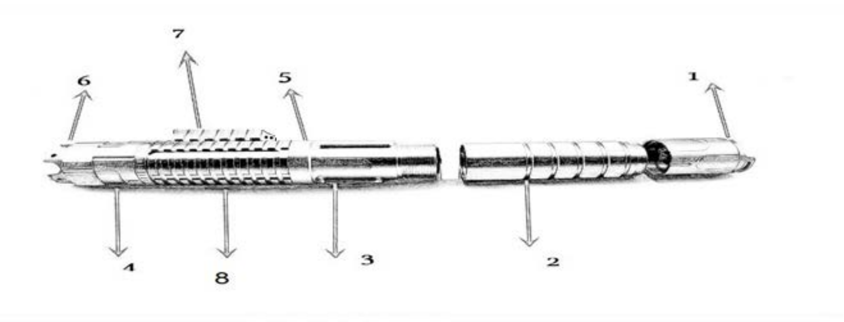

Figure 5: laser device, which consists of a power connector unit 1, an AC adapter 2, a laser driver 3, small dedicated actuator 4 to act as a focusable mechanism, to control the beam from the pointer 6, a cooling fan 7 to cool the laser chamber 8, and all are housed in a metal housing 5.

Note that adjacent propellers, however, are oriented opposite each other; if a propeller is spinning "clockwise", then the two adjacent ones will be spinning "counter-clockwise", so that torques are balanced if all propellers are spinning at the same rate.

Brushless motors are used for all quadcopter applications.

For our electric motors, the torque produced is given by $\tau = K_t(I - I_0)$ where τ is the motor torque, I is the input current, I_0 is the current when there is no load on the motor, and K_t is the torque proportionality constant.

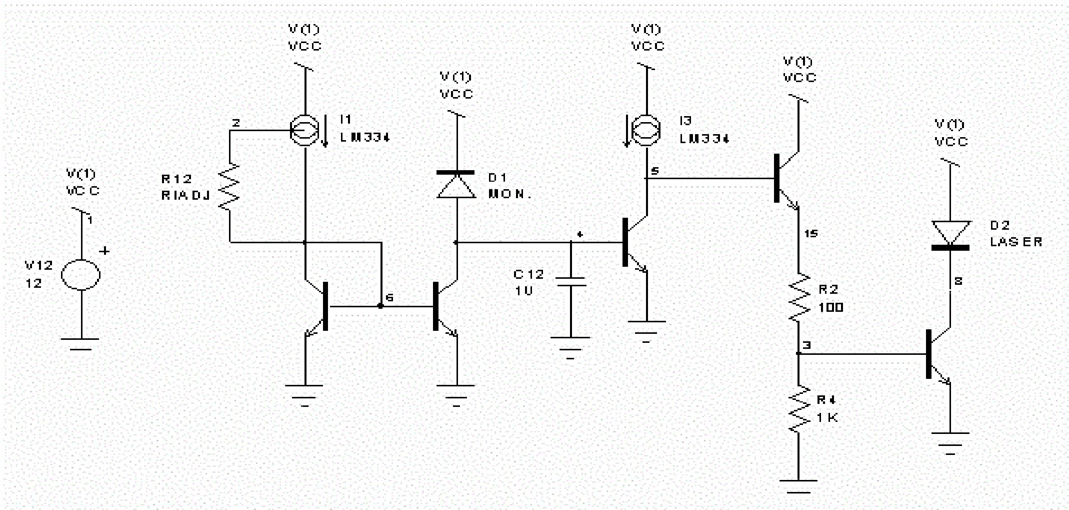

Figure 6: an exemplary circuit for the laser driver.

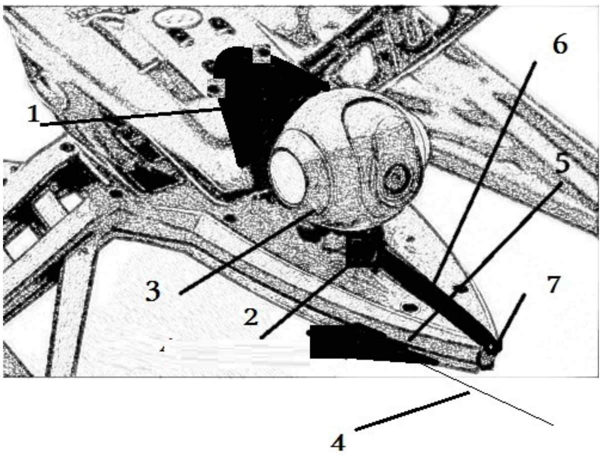

Figure 7: upside-down view of the present invention, showing an exemplary installation method.

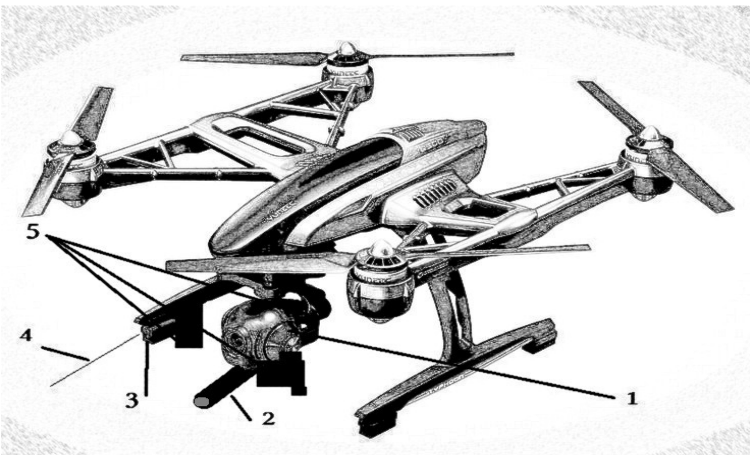

Figure 8: an exemplary drawing showing the Quadcopter and the control unit 1, and its different parts 5, the laser 2 the explosives'detector3 and its antenna 4.

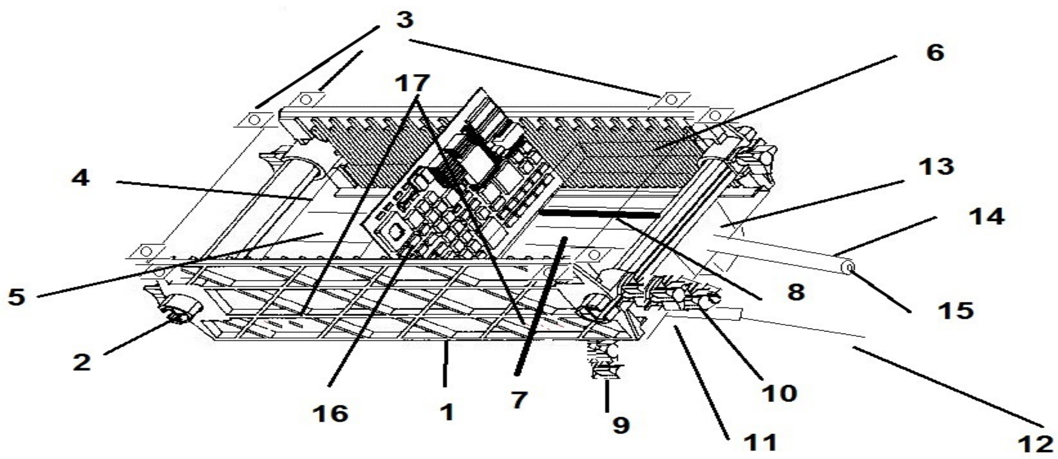

Figure 9: a schematic of the control unit, of a light metal housing 1 a mechanism to adjust its dimensions 2, screw cases 3, housing 4 for the laser drive, four 26650 4.2 V Li-ion rechargeable batteries 5, housing 6 for the batteries 7, detector 11, motor 9, linear actuator 10 , antenna 12, laser chamber 14, pointer 15 , CPU 16 , an active cooling 17 mechanism using cooler fans, a receiver/transmitter 8 planted therein and connected to the CPU.

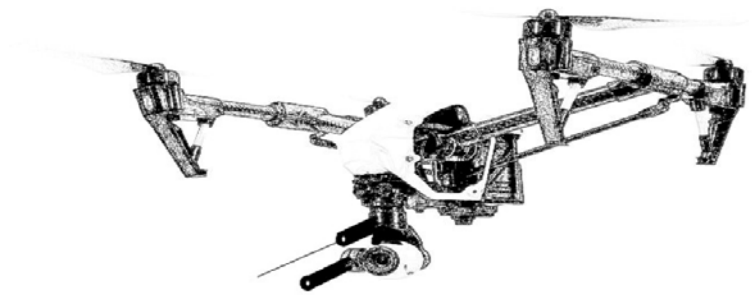

Figure 10: an exemplary final drawing for the present invention.

The voltage across the motor is the sum of the back-EMF and some resistive loss: V = IRm + Kvω where V is the voltage drop across the motor, Rm is the motor resistance, ω is the angular velocity of the motor, and Kv is a proportionality constant (indicating back-EMF generated per RPM). We can use this description of our motor to calculate the power it consumes.

\ Now that we have computed the forces on the quadcopter, we would also like to compute the torques. Each rotor contributes some torque about the body z axis. This torque is the torque required to keep the propeller spinning and providing thrust; it creates the instantaneous angular acceleration and overcomes the frictional drag forces. The drag equation from fluid dynamics gives us the frictional force: FD = 1 2 ρCD Av2 .

Where ρ is the surrounding fluid density, A is the reference area (propeller cross-section, not area swept out by the propeller), and CD is a dimensionless constant. This, while only accurate in some in some cases, is good enough for our purposes. This implies that the torque due to drag is given by:

$$\tau_D = \frac{1}{2} R\rho C_D A v^2 = \frac{1}{2} R\rho C_D A(\omega R)^2 = b\omega^2$$

Where ω is the angular velocity of the propeller, R is the radius of the propeller, and b is some appropriately dimensioned constant. Note that we've assumed that all the force is applied at the tip of the propeller, which is certainly inaccurate; however, the only result that matters for our purposes is that the drag torque is proportional to the square of the angular velocity.

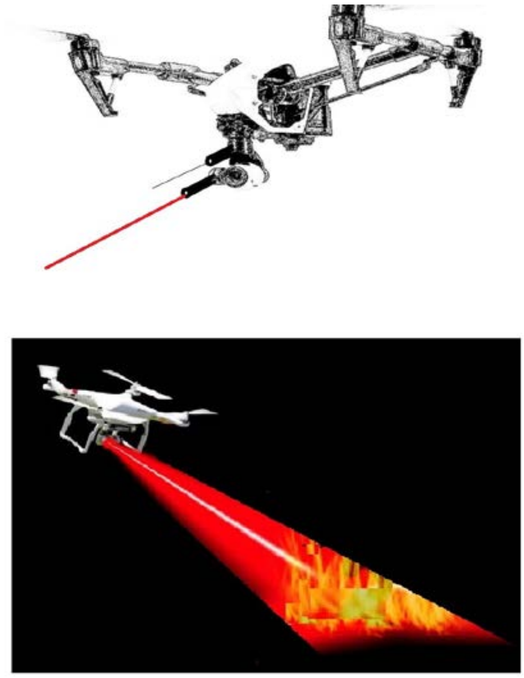

Figure 11: compilation of images for the invention in its final form.

We can then write the complete torque about the z axis for the ith motor: $\tau_z = b\omega^2 + I_M\dot{\omega}$ where I_M is the moment of inertia about the motor z axis, $\dot{\omega}$ is the angular acceleration of the propeller, and b is our drag coefficient. Note that in steady state flight (i.e. not takeoff or landing), $\dot{\omega} \approx 0$, since most of the time the propellers will be maintaining a constant (or almost constant) thrust and won't be accelerating. Thus, we ignore this term, simplifying the entire expression to $\tau_z = (-1)^{i+1} b\omega_i^2$. where the $(-1)^{i+1}$ term is positive for the ith propeller if the propeller is spinning clockwise and negative if it is spinning counterclockwise. The total torque about the z axis is given by the sum of all the torques from each propeller: $\tau_\psi = b\left(\omega_1^2 - \omega_2^2 + \omega_3^2 - \omega_4^2\right)$.

The roll and pitch torques are derived from standard mechanics. We can arbitrarily choose the i = 1 and i = 3 motors to be on the roll axis, so $\tau_\varphi = \sum r \times T = L(k\omega_1^2 - k\omega_3^2) = Lk(\omega_1^2 - \omega_3^2)$

While it is convenient to have the linear equations of motion in the inertial frame, the rotational equations of motion are useful to us in the body frame, so that we can express rotations about the center of the quadcopter instead of about our inertial center. We derive the rotational equations of motion from Euler's equations for rigid body dynamics. Expressed in vector form, Euler's equations are written as $I\dot{\omega} + \omega \times (I\omega) = \tau$

Now that we have complete equations of motion describing the dynamics of the system, we can create a simulation environment in which to test and view the results of various inputs and controllers.

Although more advanced methods are available, we can quickly write a simulator which utilizes Euler's method for solving differential equations to evolve the system state. In MATLAB, this simulator would be written as follows.

```
% Simulation times, in seconds.
start_time = 0;
end_time = 10;
dt = 0.005;
times = start_time:dt:end_time;

% Number of points in the simulation.
N = numel(times);

% Initial simulation state.
x = [0; 0; 10];
xdot = zeros(3, 1);
theta = zeros(3, 1);

% Simulate some disturbance in the angular velocity.
```

```
% The magnitude of the deviation is in radians / second.
deviation = 100;
thetadot = deg2rad(2 * deviation * rand(3, 1) - deviation);

% Step through the simulation, updating the state.
for t = times
% Take input from our controller.
i = input(t);

omega = thetadot2omega(thetadot, theta);

% Compute linear and angular accelerations.
a = acceleration(i, theta, xdot, m, g, k, kd);
omegadot = angular_acceleration(i, omega, I, L, b, k);

omega = omega + dt * omegadot;
thetadot = omega2thetadot(omega, theta);
theta = theta + dt * thetadot;
xdot = xdot + dt * a;
x = x + dt * xdot;
end
```

We would then need functions to compute all of the physical forces and torques.

We would also need values for all of our physical constants, a function to compute the rotation matrix R, and functions to convert from an angular velocity vector ω to the derivatives of roll, pitch, and yaw and vice-versa. These are not shown. We can then draw the quadcopter in a three-dimensional visualization which is updated as the simulation is running as shown in figure 12:

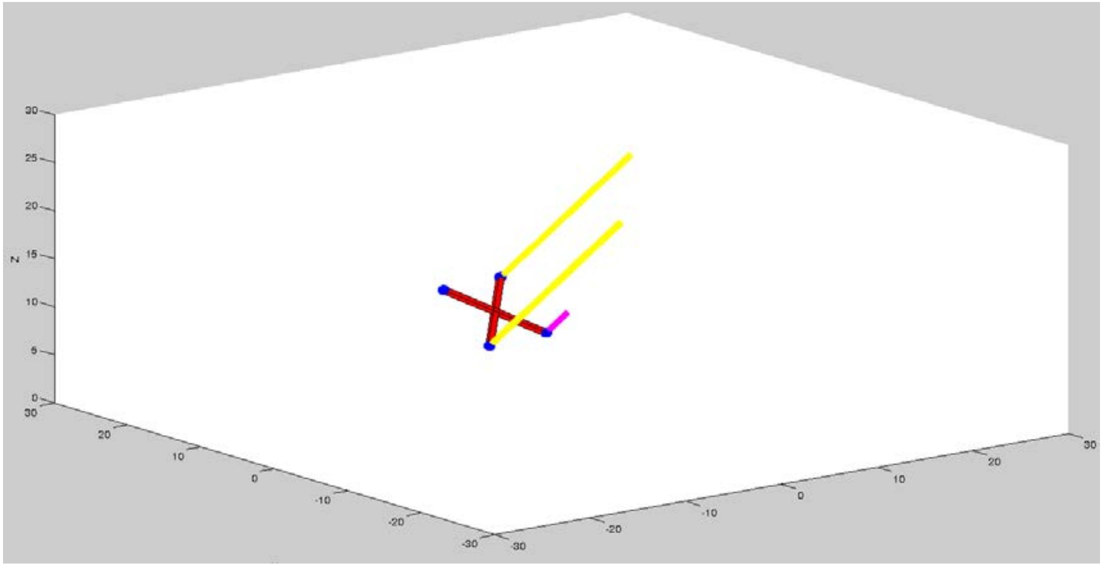

Figure 12

In order to control the quadcopter, we will use a PD control, with a component proportional to the error between our desired trajectory and the observed trajectory, and a component proportional to the derivative of the error. Our quadcopter will only have a gyro, so we will only be able to use the angle derivatives φ˙, ˙θ, and ψ˙ in our controller; these measured values will give us the derivative of our error, and their integral will provide us with the actual error. We would like to stabilize the helicopter in a horizontal position, so our desired velocities and angles will all be zero. Torques are related to our angular velocities by $\tau = I\,\ddot{\theta}$, so we would like to set the torques proportional to the output of our controller, with $\tau = Iu(t)$. T

Although PID control has the potential to perform very well, it turns out that the quality of the controller is highly dependent on the gain parameters. Tuning the parameters by hand may be quite difficult, as the ratios of the parameters is as important as the magnitudes of the parameters themselves; often, tuning parameters requires detailed knowledge of the system and an understanding of the conditions in which the PID control will be used. The parameters we chose previously were tuned by hand for good performance, simply by running simulations with many possibly disturbances and parameter values, and choosing something that worked reasonably well. This method is clearly suboptimal, not only because it can be very difficult and labor-intensive (and sometimes more or less impossible) but also because the resulting gains are not in any way guaranteed to be optimal or even close to optimal. Ideally, we would be able to use an algorithm to analyze a system and output the "optimal" PID gains, for some reasonable definition of optimal. This problem has been studied in depth, and many methods have been proposed. Many of these methods require detailed knowledge of the system being modeled, and some rely on properties of the system, such as stability or linearity. The method we will use for choosing our PID parameters is a method known as extremum seeking. Extremum seeking works exactly as the name implies. We define the “optimal” set of parameters as some vector ~θ = (Kp, Ki , Kd) which minimizes some cost function J(~θ). In our case, we would like to define a cost function that penalizes high error and error over extended durations of time.

Coming to the laser; If strong temporal beam smoothing is used, i.e., the laser coherence time, Tc, is short enough to suppress speckle self-focusing, cs Tc < F0 , then the laser intensity at beam spray onset is given by the equation in figure 13:

$$\frac{I_{\text{onset}}}{W/cm^2} \approx 2.7\times10^{15}\left(\frac{T_e}{keV}\right)\left(\frac{\mu m}{\lambda_0}\right)^2\frac{V_{\text{ia}}}{F^2}\frac{n_c}{n_e}\operatorname{Re}\left\{(2.2-0.31i)\left[1+\frac{Z^*\left(\frac{k_0\lambda_e}{4F}\right)^{-2/3}}{1-i2.7\sqrt{Z^*\phi}\left(\frac{k_0\lambda_e}{4F}\right)^{1/3}\frac{c_s}{\mathrm{v}_e}}\right]^{-1}\right\}$$

Figure 13

7. Best mode

A best mode for the Quadcopter is a water proof device, to be operable in rain. The housing of the embodiments is not desired to add an extra weight or size to the copter, however, the copter should be designed to carry an extra weight of at least 2.7 kilograms. The housing may be of light aluminum.

A microprocessor is the best mode for the present invention; the processor may be 3.5GHz Core i7. The processor, mechanism, and software module should allow the drone to lock and fire on a certain target in case of chasing an explosive planted on a moving vehicle or the copter suffered strong wind while hovering. The rotating mechanism of the camera, detector, and laser should be able to tilt as well as rotate.

The remote control, software module should include all in one remote controlling device. The software/hardware module shall also be able to estimate the weight, dimensions of the explosive and the power of the explosion, giving an estimate to the explosion range.

The laser power may be increased to 4 W laser, which shall require elevating the power source in order to avoid power loss during the process.

Those of skill in the art are sure aware that safety goggles might be necessary while dealing with the present invention with such laser drive.

Adding a safety locking mechanism to the laser by skilled artisan would be recommended to avoid unfortunate accidents while recovering the drone.

A "Cloud" OS platform should be the best recommendation, being able to control and handle multiple Quadcopters at a time, if the process so requires. The software/hardware module may include a GPS to allow the copter to return to base automatically if lost or accomplished its mission.

This best mode above does not intend to restrict skilled artisans from any better solutions. The inventor confirms that based upon the written description disclosed; the best mode is flexible for this patent so that a person skilled in the art could practice.

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