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Inspection of the Nuclear Fusion Reactor Using An Autonomous Aerial Robot

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Abstract:

This paper review and discusses available nuclear fusion reactor inspection autonomous aerial robot and goes over to theoretical design, the robot will have different sensors required for inspection of the fusion reactor. The robot manipulator having 3 degrees of freedom will be mounted on the mobile robot platform having a tool that can operate valves and a guidance camera as its end effector. For the UAVs (unmanned aerial vehicle) to navigate a nuclear reactor site of 50 degree Celsius and operation of 12-15 minutes without recharging, variety of sensors and component put in place. A simulation and design of the autonomous unmanned aerial vehicle with a manipulator navigating the reactor carried out, and the results discussed.

Keywords: autonomous, motors, theoretical design, Inspection, nuclear reactor, robot, Sensors, UAVs.

1. INTRODUCTION

Basically, there are two different types of UAVs, namely (a) drones and (b) remotely piloted vehicles (RPVs). The two named above does not require a pilot, while drones are programmed to fly autonomously. RPVs, on the other hand, are actively flown—remotely—by a ground control operator. [1] UAVs

defined as a powered aerial vehicle that does not *(as shown in **Error! Reference source not found.** Figure 1)*

carry a human operator, uses aerodynamic forces to provide lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry lethal or nonlethal payloads. [2] Both types of UAVs have an individual role to play.[3]UAVs have played a significant role in almost all sectors For this study or coming back to issues at hand nuclear reactor or radiation can be very hazardous and unbearable for human working in that terrain because of the penetrating radiation produced. So, it is mandatory to develop a robot, in this case, an unmanned aerial vehicle with a manipulator or robotic arm to carry out places like this where workers cannot reach or work.

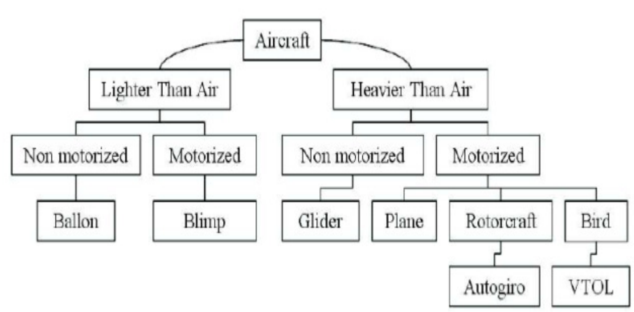


Figure2. classification of aircraft depending on flying principle and the propulsion mode. [4]

With this autonomous drone, even commercial fusion reactors would carry out their activities without many workers to keep the reactors working. The classification of these aerial robots can be of different categories considering the purpose and platform will operate. They are not limited to be a fixed-wing, a multi-rotor, a helicopter (as shown in figure 2) or a tilt-rotor. Nowadays the latest innovative platforms are used, such as the lighter than air and bio-inspired ones. A four-propeller rotor, also known as a quadrotor, was chosen for this design, which could be used outdoors and indoors. It caused for research, rescue, data collection, manipulation of objects and sensing purpose. The quadrotor aerial vehicle has a VTOL (Vertical take-off and landing) capability to work in confined or limited space. The motion of its four rotors controls the movement of such an aerial vehicle. The rotors move in a different direction to give the aerial vehicle the capability to move in all the directions. It derives a precise and realistic model for a UAV. It is essential to consider the classical dynamic equations governing the translational and rotational motions of the vehicle and the equations that describe its aerodynamic behaviour; thus, further increasing the complexity of the corresponding mathematical representation [5]. There have been various development which has helped us to pick this platform. The field of aerial manipulation has grown in recent times. Aerial robot having manipulators generally demonstrate a higher amount of flexibility and functionality. Some applications of such aerial manipulator robots include grasping, mobile manipulation, an inspection of structures capturing. [5]

The problem is such a design is that the manipulator's dynamics and the UAV are highly non-linear. The motion of the UAV will affect that of the manipulator and vice versa. [4]. Various efforts made to collaborate and generate dynamic motion equations to solve this problem.

Still, many manipulator prototypes developed. Some examples are that of parallel and series robotic manipulators. A manipulator always affects flight attributes. To minimise this, restrict the motion of the centre of gravity of the UAV [5].

Most dynamic equations are based on Newton-Euler equations, whereas new attempts made using the virtual work principle [5].

2. DESIGN AND MATERIALS USED

The aerial robot's design made in such a way that it would provide maximum stability and manoeuvrability. This is required as the robot will have to move inside a tunnel and perform a specific opening and closing valves task. A four-rotor quadcopter design with vertical take-off and landing (VTOL) capability was chosen for all this to be possible, with large propellers to provide maximum stability. The design itself, on the whole, was made small and lightweight. Some of the design's advantages and drawbacks are that it is simpler to build, more comfortable to control, and offers a better payload, whereas the energy requirement is high [1]. The material used has high endurance as they must endure a radioactive environment with high temperature. The materials should be light and meet our purpose of providing the robot with better stability and manoeuvrability. The UAV has a robotic arm manipulator that helps it perform the opening and closing of valves inside the nuclear reactor. The arm has 3 degrees of freedom. It rotates at the shoulder, which is the link between the UAV and the arm then, it moves up and down, and finally, the end effector rotates to rotate the valves. The whole arm is made up of carbon fibre to make it light.

The quadcopter frame was made in an X-structure rather than a Y or H structure as it provides the most stability, which is essential if we want it to manipulate the environment using its end effector.

The material chosen for the structure is carbon fibre as it is 1-10th the size of human hair but is three times stronger than steel. The main reason for choosing carbon fibre is its ability to withstand extreme heat and radiation. They are an attractive choice for being used inside a nuclear reactor due to its low atomic number, superior thermal shock resistance and low neutron activation capabilities [6]. [6] Experiments were done where carbon fibre exposed to radiation, and the results showed that it could withstand a considerable amount of radiation. Practically carbon fibre effectively used in jetliner's braking system because of its high temperature withstanding capability. The melting point is in excess of1200-degree Celsius. The whole structure is made up of carbon fibre to provide it rigidity. Carbon fibre also makes the structure lightweight. On the flip side, the cost rises. The landing platform made up of aluminium alloy gives it stability while landing and reduces the cost a little bit.

Description in length	Measurement(mm)
Diagonal	350
each arm	125
body	100
each propeller	250

The end effector manipulator made according to the specification of the valve that it should operate, which has 10 cm and a height of 3 cm.

The weight of the whole system came out to be near 2 kgs. With the frame being 800 grams, the end effector being 500 grams and other components such as motors, on-board systems, camera and various sensors constituting the other 700grams. All the above estimation was done using the mass property tool from Solidwork.

3. Working Principle

A quadrotor configuration can be described as a flying vehicle having four rotors or propellors in a cross configuration.

The following fig will help us to understand how various motions produced.

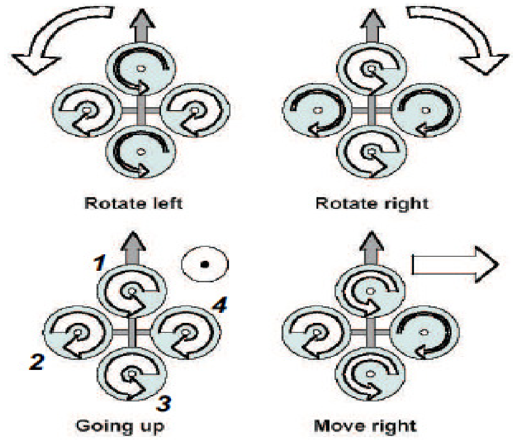


Fig 4. Quadrotor concept motion description, the arrow width is proportional to the propeller rotation speed. [1]

The adjacent pair of propellers always move in the opposite direction. If we consider fig 3. propellers 1 and 3 have a counter-clockwise motion whereas propellers 2 & 4 have a clockwise motion for going up.

The lift force can be changed by varying speed which in turn creates motion. Thus, if we increase or decrease the four propellers' speed, we can create vertical motion [1]. We can refer to fig 3 for various other motion as changing the propellers 2 and 4 speed conversely, we can produce roll rotation coupled with lateral motion [1]. Pitch rotation is done by modifying the speed of propellers 1 and 3, and yaw rotation can be created because of the difference in the counter-torque between each pair of propellers [1].

TABLE 2

Bill of Material

Material	Quantity	Price	Weight (g)
ARM Cortex-M3based Arduino Microcontroller	1	£40	25

AtXmega controller	1		
RN-41 bluetooth module	1	£15	10
Scorpion HK-3020 1000kV motor	4	£119	153
APC 8.8*9.25 inchpropellor	4		
Scorpion commander 15V 15A ESC	1	£25	18
LiPo 6500 mAH 3s 11.1v battery pack	1		

IMU Mongoose	1	£75	5
Camera CMOS Linsprite Jpeg Colour.	1	£35	20
Ultrasonic sensor	1	£10	5
Gyroscopic sensor	1		5
Sensor suite	1		300

Before this robot, which vary from the robots used in excavation assistance, robotic devices have camera systems and a sensor mounted at the top to enable detection of dangerous gases and other unwanted materials. The primary aim of autonomous mining robot in underground mining is a point in time when the miners in the field find it difficult to enter the blasted areas for two primary reasons which are) The presence of unpleasant, dangerous or harmful fumes and ii) dry powder consisting of tiny particles from the blast, and the increased seismic activity present after a blast. Other obstacles are not limited to man-made, or things found naturally in the environment. [2]. Robots' involvement will not remove or discard human miners, and rather it will alter their job description from arduous and hazardous ones to safe and intellectual ones. Let analyse some robot in the mining industry.

RecoverBot

The RecoverBot(shown in Figure 2) is a 150-pound force, volume, snagging rectangular unit that comprises a planned and regulated movement arm with grippers and the box frame open with power sections, the cameras and the controllers have their distinct unit protected with metals shield. When in action, the focus shaft lowered to initialise a recovery, the arms push the body by lifting and dragging into the second lowered net with a telerobotic eye.
The debris falling are protected from hitting the robot by "aeroshell" during the lowering activities. The activities monitored from two points of view: the overhead camera and the deep shafts. After its mission accomplished, the robot reaches the surface, and the camera and the victim withdrawn. [3].

Groundhog

Graduate student in Carnegie Mellon's Mobile Robot Development class created Groundhog [4] (as shown in Figure 3) a mine-mapping robot that weighs 1,500 pounds. For accuracy in mapping its Multi-Chassis ATV 4WDuses laser rangefinders. For the accomplished mission, the information or data build its map from sensors and function autonomously. Regarding where to go, it is getting to the destination, and its priority is how to return. From the map developed and the output of its inspection, the robot should contain computer interfaces to help facilitate the view of the exploration outcome. The robot uses key technologies called SLAM (Simultaneous Localisation and Mapping) which Carnegie Mellon developed. The use of Groundhog had some disadvantages, which are framework and electronics, localisation and plotting simultaneously and finally, navigation.

Alexander

Alexander (Figure 4) designed to meet demands (Grehl et al., 2015a). The robot's primary task or aim, which was prepared with sensors to measure environmental parameters like radioactivity and wind, laser scanners and different cameras, are monitoring and plotting environmental parameter underground. It can navigate autonomously with the flexible light system. The colour images give the miner the tendency to generate a textured 3D model of the underground mine's post-processing. [5]

AIR-K

TOTAL and ANR hosted in 2017 the challenge in 2017 (shown in figure 4) robot designed to take part in the ARGOS (Autonomous Robot for Gas and Oil Sites). The five teams that participated were given three years to design and build robots, especially meeting the ATEX/IECE standards. [6]. The robot was meant to operate in but off-shore and on-shore. The robot autonomously performs inspection and carries out the inspection in isolated areas and unassessed sites in its normal conditions. Furthermore, in case of emergency, the robot can detect anomalies, gives the operators field back by transmitting data and images immediately. In the steps and climbing, the robot is equipped with four auxiliary tracks and two main tracks.

The robots also equipped with sensors during inspection teleoperate the condition of things. This robot's striking factor is its explosion-proof design, flameproof battery, and tendency to keep the external air from internal air in the system. [6]

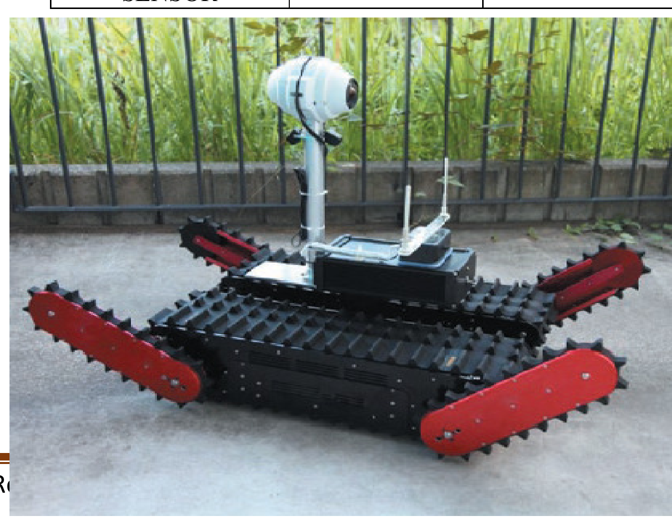
SYSTEM DESIGN

The robot's theoretical design was based on the AIR-K robots designed above but slight changes in the wheel. Although all the robots reviewed above can perform the inspection in the mines. The concept in this design are

1. The autonomous operation of the robots
2. The tendency to perform his assigned duties in 80 degree celcius.
3. It can travel 1 mile within a period of 30minutes without recharging.
4. It can access deep mine through a lift that will take it directly to the mine environment.
5. Meet the specified size of 0.24mby 0.34m by 0.45mand the arm at full length 0.54m.

With the above concept, different components were selected in view if limited availability and important

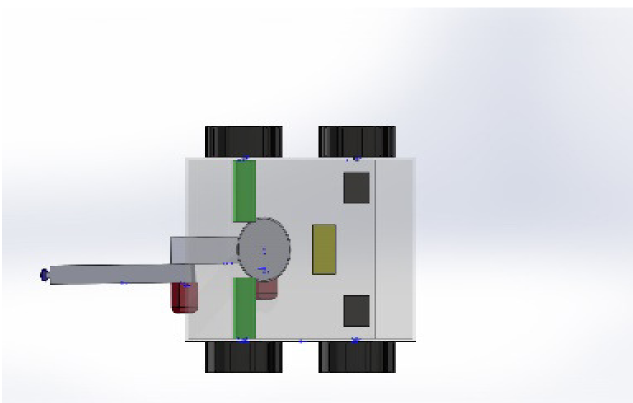
Components	Number	Price (Pounds)
IDX-ELITE DUO C98 Battery	2	456
Teknik servo motor M-3432	2	300
RKI Beacon Model 410	1	411
Atsama5d3-xpld Development Board	1	170
Power Integrations, BD70522GULBuck Convertor	4	3
OM-90 SERIES PortableTemperature & Humidity Data Loggers	1	100
SONOCHEK DBS10	1	350
SONOCHEK DBS10	1	200
VAISALA TEMP SENSOR	1	40



Selection of the major component was made, the quantities and cost estimated. The above components were the most durable components for such underground mine exploration robot.

ACTUAL DESIGN

After the component selected, the 3D CAD, Solidworks was used to model the component. The robot and check for their compatibility. The images are shown below;

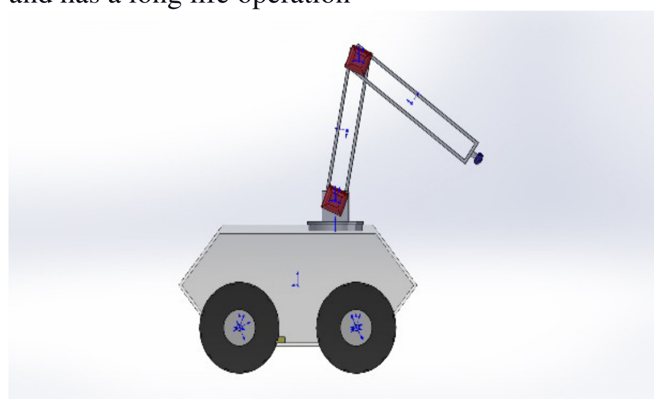


Top view of the robot (figure 6)

In the top view, the various components with different colours shown within the robot for easy identification. The robotic arm shown in deep ash colour has a camera and light with 250g. the links are driven by the two servo motors attached at each joint painted black. The length and weight of the robotic arm calculated. The robot at the rear has two motors driving the wheels the motor painted black. Using the AIR-K method, the robot incorporated the Ex d and the Ex p principle of protection to show it can survive the stipulated temperature. The battery is a volatile component has a flammable proof enclosure. A flow-restricting body of robot encapsulation applied for enclosures that, with a reasonable degree of probability, prevent the atmosphere inside the enclosure (explosion caused by friction, sparks.) from becoming explosive atmosphere surrounding the enclosure is explosive on rare occasions and for a short time only. [7]. The robot's external component can survive at the stipulated temperature while the EX p is a principle that includes pressuring the area of interest.

Isometric view of the robot (figure 7).

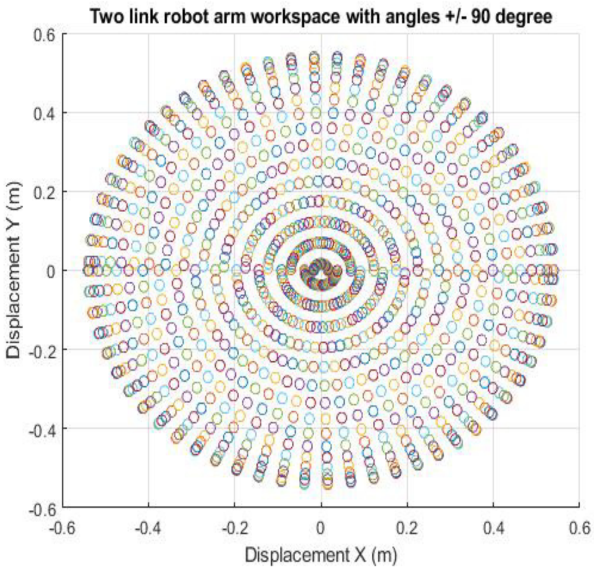
The wheels operated by two brushless DC motor characters characterised by Achieves high performance in various power ranges, Provides smooth, efficient operation at various speed ranges, low maintenance costs, very easy to install, and has a long life operation



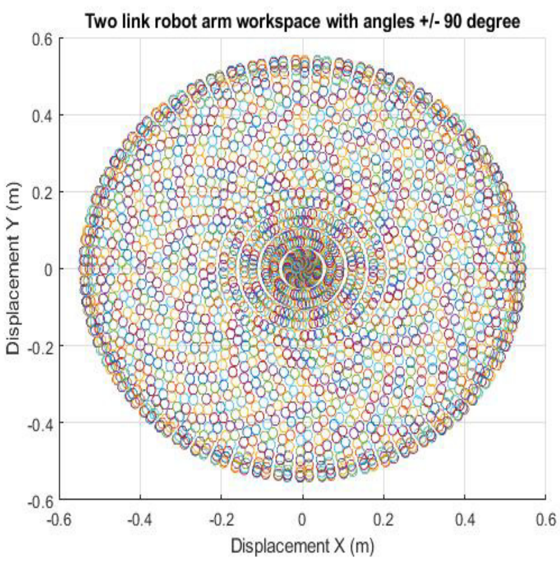
durable. [8] . The height of wheels of the robots is higher than the height of the rail at maximum. The robot must have an increase in torque applied which is a function of the angle of inclination of the robot to the horizontal ground to reduce acceleration due to gravity.

Design in MATLAB

For the robotic arm to work efficiently, Denavit-Hartenberg notation was applied and the forward kinematics. With the maximum length of the robotic arm specified in the abstract, we could model it in the MATLAB workspace, as shown below.



The figure above is when the two arms are with +/- 90 degrees, and designed in the Matlab workspace environment.



The figure above is for angles at 180

CONCLUSION

This paper has shown the theoretical design of a mobile inspection robot. It is proven theoretically, and further work needs to be done in terms of wheels and the weight of the robot when ascending and descending and most especially when the mobile robot when is above this temperature the components might not survive

REFERENCES

[1]Homeland Security: Unmanned aerial vehicles and Border SurveillanceChad C. HaddalSpecialist in Immigration PolicyJeremiah GertlerSpecialist in Military AviationJuly 8, 2010

[2] United States Department of Defense, Dictionary of Military and Associated Terms, Joint Publication 1-02, April 12, 2001, p. 557.

[3] "UAS", or Unmanned Aerial System, refers to the UAV combined with the data links, control station, and software needed to fly it.

[4] Bouabdallah, S., Murrieri, P. and Siegwart, R. (2005). "Towards Autonomous Indoor Micro VTOL". *Autonomous Robots*, 18(2), pp.171-183.

[5]Modelling and Control Aspects of a UAV with an Attached ManipulatorYiannis Stergiopoulos, EfstathiosKontouras, Konstantinos Gkountas, KonstantinosGiannousakis and Anthony Tzes24th Mediterranean Conference on Control and Automation (MED)June 21-24, 2016, Athens, Greece

[6] https://www.gmv.com/export/sites/gmv/DocumentosPDF/Eventos/Challenge_Argos_EN_web.pdf

[7] http://docplayer.net/42490927-Principles-of-explosion-protection.html

