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Design and development of a wheged nuclear robot

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***Abstract*—This paper explores the design and development of a foldable robot to survey and characterize nuclear facilities accessible only via 125mm diameter entry ducts. The enclosed legacy facilities at the Sellafield nuclear site have limited access. The condition, radioactive characteristics and accessibility of the enclosed environments is unknown and for decommissioning to take place, these environments must be mapped and characterised. For a robot to carry out this task, one of the key requirements is the ability of the robot to traverse rough terrain and obstacles that could be found inside the facility. To accommodate this while fitting through the entry duct, the chosen design utilizes morphing wheel-leg systems for locomotion. These are shape-changing wheels that can open out into a set of legs that rotate around an axle, allowing greater traction, diameter, and object traversal ability than wheels alone. The design and morphology of a morphing wheel-leg robot for nuclear characterisation, as well as the manufacture of a prototype is discussed in this paper.**

***Index Terms*—Robot, Nuclear Decommissioning, Folding, Wheg, Sensing**

I. Introduction

With use, nuclear facilities are exposed to radiation and over time become radioactive themselves. This makes them dangerous places for humans to work [1]. At the end of their working lives these facilities must be decommissioned and made safe [2]. There is the potential to use robots in the decommissioning process to lower costs and to reduce the risk posed to humans by the environment [3]. At the Sellafield site in Cumbria, many facilities are only accessible via 125mm diameter access ducts [4]. Information must be collected about the inside of the facilities and a robot is being designed for this purpose. To prevent the spread of radioactive dust, a ground based mobile robot has been chosen.

II. Morphing Whegs

For wheeled robots, the ability to traverse over objects has a direct correlation with the diameter of the wheels. Without significant lateral force to provide traction, wheeled vehicles are not able to traverse obstacles larger in size than the wheel's radius. In practice this ratio is much smaller. Wheel-leg systems, or 'Whegs', are systems comprised of a set of legs that rotate around an axis. This allows for much greater traction and object traversal ability as the whegs can hook onto objects and 'pull' the robot over [5]. The size of the duct limits the diameter of the wheels or whegs that can be entered into it. To maximize the obstacle traversal ability of the robot, 'morphing whegs' have been chosen [6]. These are wheels that can be transformed into whegs when required, with the legs opening out from the wheel's radius [7].

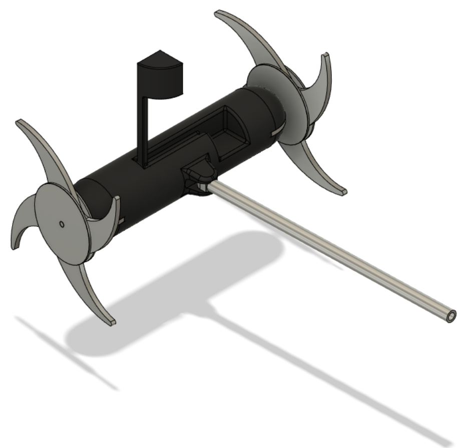

Fig. 1: The robot with deployed whegs and sensing equipment

III. Proposed Design

To fit through the duct, a folding design was selected. Two wheel, differential drive designs are seen in many wheged vehicles and robots. The basis of this design is two whegs mounted parallel to each other along an axis, with a 'tail' protruding perpendicular to this axis from the midpoint between the two wheels. The whegs provide forward motion and steering by altering the speeds of the whegs relative to each other, the tail provides stability, aids steering and is required to oppose the moment about the wheel axis while under power, providing traction through the whegs. The two wheeled robot is simple both in design and in control. The robot in its unfolded state is shown in figure 1. The tail is actuated to fold parallel to the robot body. When folded, the robot has been designed to fit into the 125mm duct, with attention given to minimise its projected area. The folded position allows the robot to be pushed into and through the duct. The robot is able to move on smooth ground while in the wheel configuration, before opening up the whegs to traverse rougher terrain. The wheel configuration allows for more accurate odometry and faster, smoother movement compared to when in the wheg configuration. Sensing and imaging equipment can be deployed via a hinged arm that swings out above the robot and provides an overhead vantage point, as shown in 1. This allows unobstructed sensing and imaging for characterisation and operator feedback.

IV. Present Work

A prototype of the robot has been designed and manufactured. This robot uses a 'wire pull' mechanism to actuate the whegs. A central motor rotates a capstan that tensions a wire running through the centre of the two hollow axles. In the hub of the wheg, this wire splits into three separate wires that each attach to the base of a 'leg'. When the wire is retracted by the motor and capstan, the force applied by springs acting to close the legs is overcome and the legs rotate to open out. Rotational movement of the whegs is controlled by two Dynamixel smart servos that drive the axles via toothed belts and pulleys. A rotating coupling is used in the wheg actuation wire to allow for continual rotation without the wire becoming twisted or tangled.

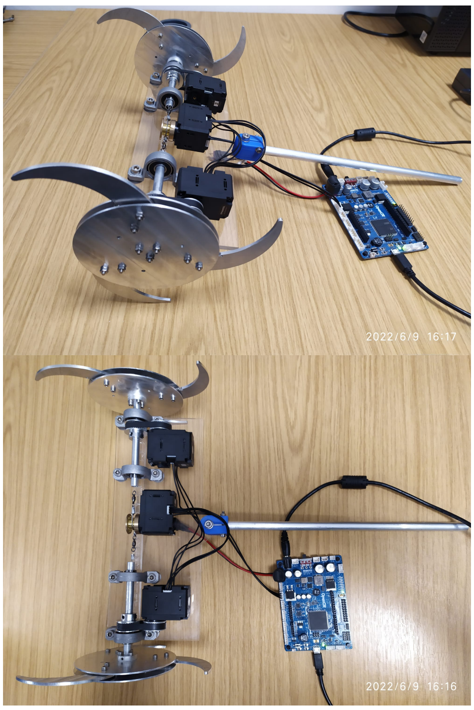

Fig. 2: Initial prototype

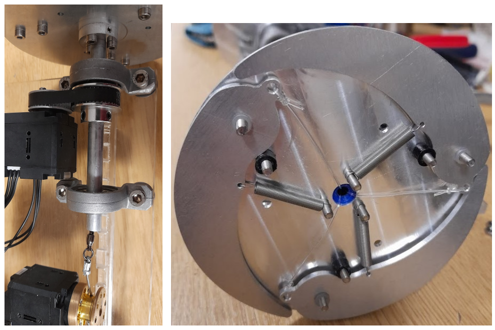

Fig. 3: Wheg actuation mechanism

At present, the individual mechanisms have been tested and have been shown to work as expected. Future work expected to be undertaken is to mount a Raspberry Pi computer running ROS2 on the robot chassis, along with a camera and LIDAR. This will be used to teleoperate the robot via a controller.

V. Conclusion

A folding robot utilising morphing whegs has been designed to fit through a 125mm access duct for the purpose of nuclear decommissioning. Morphing whegs will allow the robot to traverse over objects that may be found in a legacy nuclear facility. This obstacle traversal ability is required for the robot to move about the facility and capture information for characterisation. The basic mechanical systems of the robot have been tested and have been shown to work well. Further work is planned to enable teleoperation of the system.

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