Robotic Inspection of Oil and Gas Plants by Hybrid Unmanned Vehicle and Mobile Ground Support Platform

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***Abstract* — Safety risks and high costs of human inspection of oil and gas plants drive towards the adoption of robotic inspection. The challenging cluttered inspection environment and the constraints dictated by legislation on potentially explosive atmospheres implying energy-efficient solutions suggest the use of an inspection-tool-equipped hybrid rolling-flying unmanned vehicle and of a mobile ground platform supporting the connected inspection robot. These two design choices together with their development are described in this article.**

I. Introduction

In oil and gas plants, pipes and vessels are exposed to product, environment and mechanical demand and thus suffering degradation. To avoid leaks or catastrophic failures of the components, it is important to inspect their condition. The loss of thickness due to corrosion is one of the most damaging effects observed in pipes. Non-destructive testing (NDT) through ultrasonic testing (UT) is commonly used in routine inspection for thickness measurements.

Fig. 1. An example petrochemical processing plant in Grangemouth, Scotland (CC Public Domain, Source: pxhere.com). Oil and gas plants are characterized by a large number of pipes subject to atmospheric and processing elements, causing corrosion.

Oil plants include a large number of pipes, single pipes and pipe racks, with complex arrangement (Figure 1). Thickness measurements and visual inspection, when done by humans, implying the use of man-lifts, cranes, scaffolding and rope access, is dangerous and costly.

A robotic inspection system may lower the cost and foremostly decrease the exposure of humans to risks. However, the above complexity of the environment poses challenging requirements on the system. Pipes to inspect have different diameters, even varying diameters, they may be isolated or in tight racks, and sections may be horizontal, vertical, elbows or tee joints.

The rest of this article is structured as follows. Section II describes the robotic inspection system responding to the above needs and including the hybrid robot and the mobile ground support platform. Section III discusses testing, and finally Section IV provides the conclusions and outlines the future work.

II. Robotic Inspection System

To cope with all these, the HYFLIERS (HYbrid FLying-rollIng with-snakE-aRm robot for contact inSpection) EU Horizon 2020 project [1] has designed a dedicated system (Figure 2).

A. Tool-equipped Hyrbid Robot

As outlined, the entire circumference of the pipe needs to be inspected, including the bottom of the pipe at hours 6. Reaching those points in the case of pipe racks or cluttered areas is challenging, especially considering that pipes may be magnetic but also with a non-magnetic insulating coating. Specific solutions to bring the sensor to the inspection target are needed.

Replacing unmanned aerial vehicle (UAV) batteries takes time from the actual measurements, since it must return at home position. More importantly, for our case of oil and gas plants, batteries cannot be swapped if not outside an ATEX (atmosphères explosives, French for explosive atmospheres) area [2][3]. This means that the UAV must be brought further from the operating zone, thus causing an even longer stop time. To reduce these overheads. Since flying time is the most energy-intensive activity of an UAV, it is clear that its minimization is key in endurance extension. Moving along the various inspection points not necessarily involve flying if the robot is capable of rolling over the pipe. This motivates the adoption of a hybrid inspection robot. For alternative designs, see e.g. [4].

A range of prototypes with flying and rolling capabilities and various tools to reach the inspection target with the ultrasound sensor have been developed. The articulated rover presented in [4] is capable of moving over a pipe along straight and curved portions. The platform is equipped with an inspection arm and stabilizes itself over the pipe, counteracting for example unbalance caused by the movement of the center of gravity due to movement of the arm, winds, etc., see also [5]. The unmanned aerial vehicle presented in [6] is dedicated to the inspection of pipe racks.

B. Mobile Ground Support Platform

The inspection process involves flying the unmanned vehicle to the inspection location and performing the actual inspection on the pipe. These two operations are typically in charge of distinct professionals, an authorized drone pilot, and an expert inspection engineer. In order to provide the information relevant to them, including dedicated human machine interfaces (see [7], e.g.), and to allow them to control the robot, a multifunction ground support platform has been introduced.

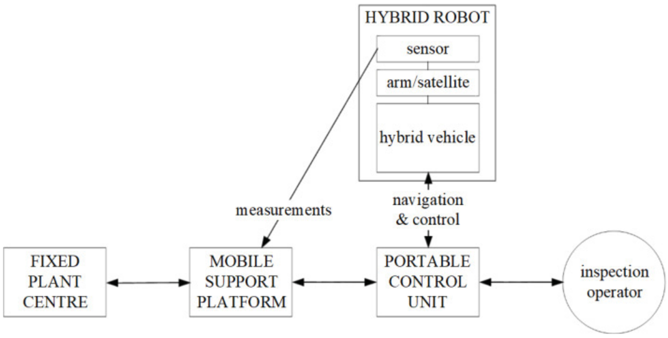

Fig. 2. The HYFLIERS system. The hybrid robot with flying and rolling capabilities collects readings through its sensor. Both robot inspection control and measurement data are managed through the ground support platform, which also communicates with the plant center.

The ground platform also interfaces with the plant center exchanging both ways inspection data. Communication between the hybrid robot and the plant center through the support platform allows alleviating transmit power requirements, thus improving endurance of the weight-limited unmanned vehicle. For this reason, the ground support platform is mobile and follows roughly the location of the unmanned hybrid robot.

For both ways inspection data exchange with the plant center, the mobile support platform uses long range communication (for example third, fourth or fifth generation mobile network). The platform communicates with the hybrid robot through short range communication (WiFi). Rich control data are provided to the pilot, see Figure 3.

It has been outlined the issue of UAV battery recharge. The mobile support platform may provide the aerial vehicle with battery energy management, compatibly with ATEX (explosive atmospheres) zone operation [8].

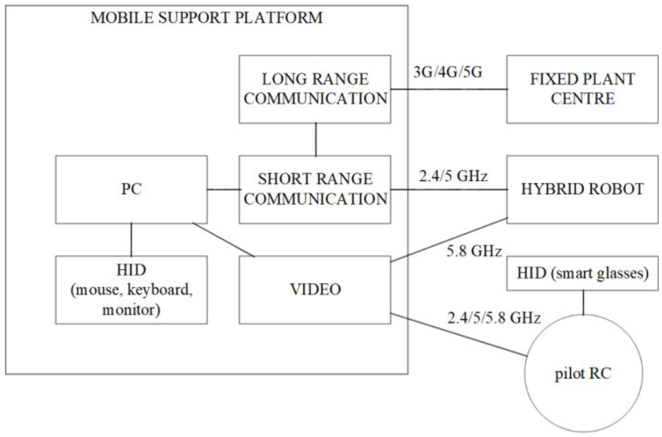

Fig. 3. Internal architecture of the mobile ground support platform for communication and control with the hybrid robot and the plant center. Human interface devices (HID) enable the control of the computer (PC) on-board the support platform and aid the pilot operating the unmanned aerial vehicle through the remote controller (RC). Dedicated radio interfaces are used for the different functions depicted in the figure.

III. Tests

The mobile ground support platform has been successfully tested in Oulu, Finland, at Ouluzone+ Research and Training Center [9]. Testing in realistic industrial settings has been impossible due to prevailing pandemic infection from coronavirus disease (COVID-19) and the consequence travel restrictions. Tests in oil and gas refineries are currently being planned again, as the travel restrictions are being lifted.

IV. Conclusion

The abstract has outlined, and the article has deepened the insight in the needs and requirements set by robotic inspection of cluttered pipings. A hybrid rolling-flying unmanned vehicle allows saving energy by reducing flying as a means of reaching inspection location and its tooled inspection arm flexibility allows reaching all required inspection points of the pipe.

Communication between the connected hybrid robot and the plant center occurs with the aid of a mobile ground platform, following the location of the hybrid robot to reduce its transmit power requirements, thus further contributing to endurance extension of the unmanned aerial vehicle. Further, the mobile ground platform may provide the hybrid robot help in energy management.

From what discussed in Section III, it is clear that future work includes the testing in realistic industrial environment, which has been impossible until now. In addition, the data management subsystem, only outlined in this article, will be further developed and tested.

Acknowledgment

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