Self-recofigurable hybrid robot for inspection

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***Abstract*—Replacing humans with robots is an advantage especially in repetitive or dangerous tasks such as inspection and maintenance. However, the spread of such robots is slowed down by their low fault tolerance and modest adaptability to different tasks. In these aspects, self-reconfigurable robots have proven superior performance. Here, the design of a novel modular, self-reconfigurable robot for inspection is discussed. The system consists of two independent vehicles that turn into a snake robot. This configuration extends the system range of use and enhances the performance. The system kinematics is designed in such a way that the robot can overcome most of the challenges posed in pipelines and plant inspection.**

***Index Terms*—Hybrid self-reconfigurable system, Modular robot, Inspection robot**

I. Introduction

Industries and utility companies perform planned inspections to prevent unexpected failures. Although in industrial context the trend of replacing humans has increased enormously, inspections are still largely carried out by human operators. Such approach is non optimal in terms of cost and time; and more importantly, it poses serious threats to the workers safety.

Power plants and refineries cover extensive areas and are composed by many components such as equipment, tanks, pressure vessels, pipes. Each component has to be inspected periodically for the safe and efficient functioning of plants. Pipeline networks are spread everywhere, especially in plants, and transport fluids of any kind. Damages due to aging, corrosion, fissures or cracks may occur. Therefore, the pipeline conditions have to be assessed to prevent leakages and environmental damages.

II. Related works

An increasing number of robots have been developed with the aims of minimizing the risks for human operators, and increasing the reliability of measurements. In plant and pipe inspections, inspection robots have to face many challenge. In the former case, the robots have to deal with cluttered environment, obstacles and stairs. In pipe networks, the robots move in a constrained environment and have to traverse complex segments, bends and vertical sections. In both cases, these devices are intended to perform visual inspection guided by an operator and to collect data from the sensors.

Plant inspection robots, usually, consist in assemblies of mobile platforms, robotic arms and sensors, as in [1][2]. Descriptions of pipe inspection robots can be found in [3] and [4]. These devices present a large variety of designs and locomotion methods: wheeled, tracked, legged, inchworm, snakes. Hyper-redundant structures are gaining momentum in pipe inspections, see [4], but still these devices are not very popular. Due to a slender body, snake robots can move in complex scenarios coordinating the motion of each part using different gaits, as described in [5]. The redundancy in snake robots confers a great adaptability and flexibility in constrained environments, [6]-[8], but this unchallenged mobility comes at the cost of high mechanical complexity and demanding control.

III. General description

The purpose of this project is to design a novel hybrid platform capable of performing visual and sensory-based inspections of pipelines and industrial plants.

The proposed system consists of two identical vehicles and a main base. Each mobile robot can move in pipes or unstructured environments and perform the inspection. In case of more complex operations or conditions, the vehicles can self-reconfigure into a snake robot using the autonomous docking systems that equip. In these configuration, the robot mobility performance are enhanced, and the system can overcome large obstacles, cross difficult terrains, reach targets placed in high positions and climb vertical pipe segments.

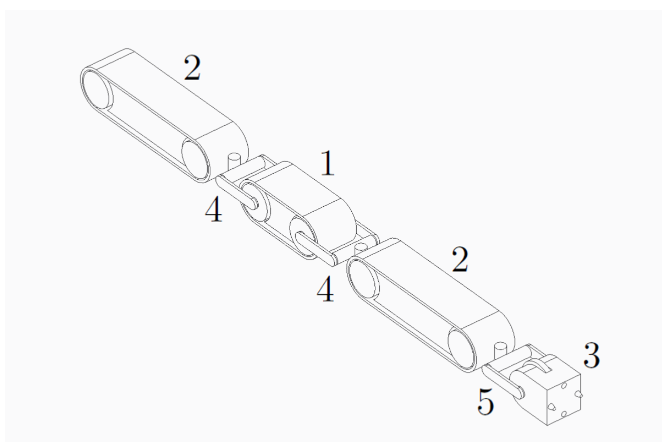

Fig. 1. Representation of the vehicle: 1 central module; 2 extreme modules; 3 docking module; 4 inter-modules kinematic chains; 5 docking module kinematic chain.

A. The vehicles

Both vehicles consist of three modules and a docking module. All the modules are connected through active joints that form three kinematic chains. Referring to Figure 1, the system utilizes a combination of active tracks, for the rear and frontal modules (2), and a passive track for the central module (1). Both the kinematic chains, (4) and (5) in Figure 1, consist of active Cardan joints, links and pitch joints. These kinematic chains are designed to provide mobility to the vehicle, e.g. turning motions are obtained by rotating the extreme modules. The joints allow the robot also to adapt to slopes or gaps, overcome small obstacles and climb stairs. By the joint redundancy, the central module can be pushed against pipe walls increasing the vehicle grip, so the system can move in vertical pipes. With such kinematics, the robot links between consecutive yaw joints have the same length in snake configuration, see Figure 2. Therefore, it is possible to drive the snake using well-known gaits. For a detailed description of the vehicle kinematics, the reader may refer to, [9].

B. The base

The primary purpose of such system is to provide to the vehicles a recharging spot during operations. Therefore, the base has two docking interfaces, which are driven by two joints. Once connected, the vehicles can be reoriented and can be used as robotic arms, as in Figure 3. It is possible to add wheels or tracks to the base to extend even more the range of use of this inspection platform. In this way, the base can travel easily long distances and deploy the vehicles near a point of interest, if required, or use them as an inspection tool. This feature can be extremely profitable, especially when the objective is to inspect small apparatus located in wide areas.

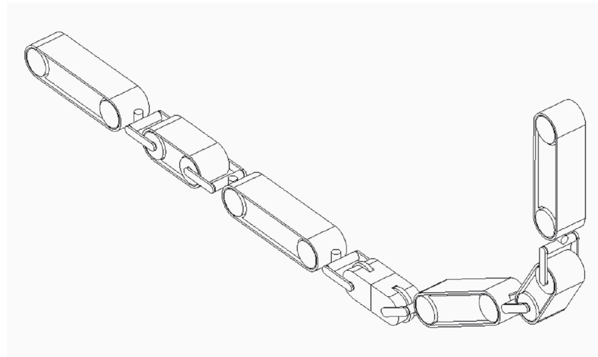

Fig. 2. Representation of two vehicles coupled together to form a snake robot. In this mode, the robot can raise segments of the body to overcome obstacles or reach high points.

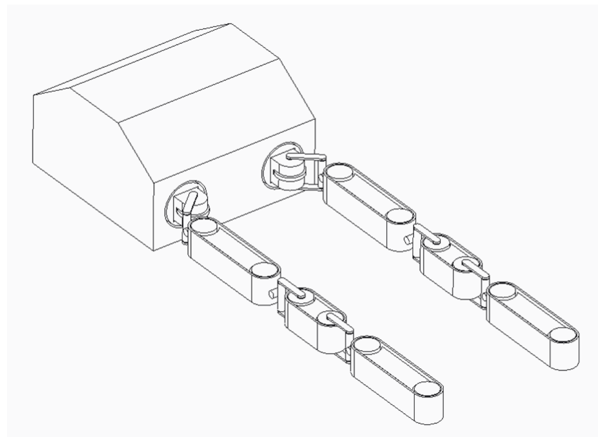

Fig. 3. Representation of the vehicles used as manipulator. Once coupled, the roll joints within the base rotate the vehicles in the double arms configuration.

IV. Conclusion

This paper describes the main concepts of a novel hybrid system for inspection. A brief introduction on the challenges posed by pipe and plant inspection is followed by the description of some of the most significant robots developed for these purposes. The hybrid system is described in its components. The two vehicles are designed to operate in pipes or plants and to perform easy tasks. Additionally, the vehicles can self-reconfigure into a snake robot to cope with complex conditions or operations. The main base is not intended just as a point of recharge, but it can play an active role during inspections, expanding the system range of use.

The design of the robot is at an early stage, [9], the dynamic models of the system are currently under development. Through these models, it will be possible to evaluate the performance of each vehicle and to determine crucial design parameters. Moreover, the dynamic equations will be used to synthesize model-base control laws for the robot.

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