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# Basic maneuvers for an inspection robot for small diameter gas distribution mains

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***Abstract*—This video shows the design of a mechanical structure of a miniature pipe inspection robot (MPR) capable of moving trough very small pipes (up to 41 mm inner diameter) as well as a wide range of diameters (63 to 125 mm outer diameter). The requirement to negotiate bends, T-joints and steep inclinations pose another set of strict design constraints. In this video the controlled robot is shown in action.**

## I. INTRODUCTION

### A. Network

The low pressure gas distribution networks (30 mbar to 100 mbar) for local distribution occupy most of the urban area's. Therefore this network has the highest priority regarding risks for public health and safety. Detailed information on condition of the network and accurate location of leaks is vital for future safe operation.

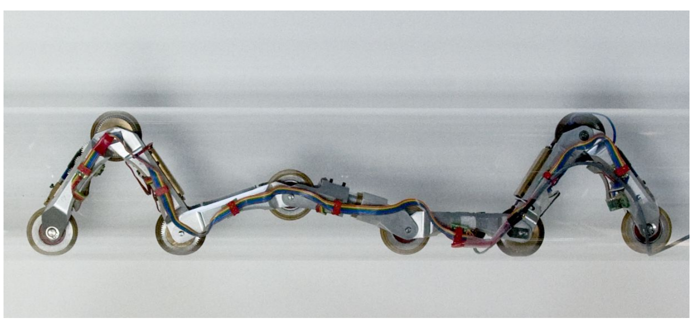

Fig. 1: 'PIRATE' - Pipe Inspection Robot for AuTonomous Exploration

### B. Related research

A number of designs exist of autonomous and semi-autonomous systems for inspection of gas distribution mains, such as the Explorer by CMU [**?**]the MRinspect [**?**] and many others [**?**] [**?**] [**?**]. None of these systems however are capable of taking a sharp mitered bend in a 63 mm pipe - which has been established as one of the key criteria for being able to operate in the given (Dutch) urban low pressure net [**?**].

## II. REQUIREMENTS

The final aim of this project is to realize a platform capable of autonomously inspecting a certain area of the gas distribution network, detecting leakes and recording the exact location and status of the pipe. The most stringent requirements are posed by the environment the robot has to operate in: the layout and makeup of the gas distribution network.

### A. Environment

The mechanical properties of the environment regarding size and shape can be listed in order of increasing complexity for a mobile robot system and are listed in table **??**.

TABLE I: Summary of Robot's environment

| **Property** | **Parametrization** |
|---|---|
| straight pipe | 63mm to 125 mm |
| inclination of the pipe | +/- 30° |
| gradual diameter change | 63 to 125 mm, ranging from 0°to 45° |
| sudden diameter change by obstacle | -10 to +5 mm |
| deformation from outside (dent, bend) | 10% increase/decrease |
| bends | $R \in [D/2, \rightarrow>$ |
| T or Y joint | choose direction[L,R] |
| Valves or shutters | 10% diameter change |
| Contaminants | dust, sand, oil, water |

## III. DESIGN

### A. Modular Design

A modular design has been chosen for the robot system.The robot consists of seven modules with specific functions: two propulsion- or driving modules, two modules to clamp the robot in the tube, two payload modules and one central rotation module. The payload modules contain the power system, control electronics and sensing equipment.

As can be seen in figure **??** the robot has a symmetric layout around the central rotation module. The maximum module size is determined by the pipe diameters and obstacles as stated in table **??**. These constraints have resulted in a curved module shape, using a wheel diameter of 40 mm and an inter-wheel distance of 90 mm.

### B. Control

An operator can manouvre the robot through the pipe by commanding *Motion Primitives*. Each robot action can be broken down to a series of these motion primitives being

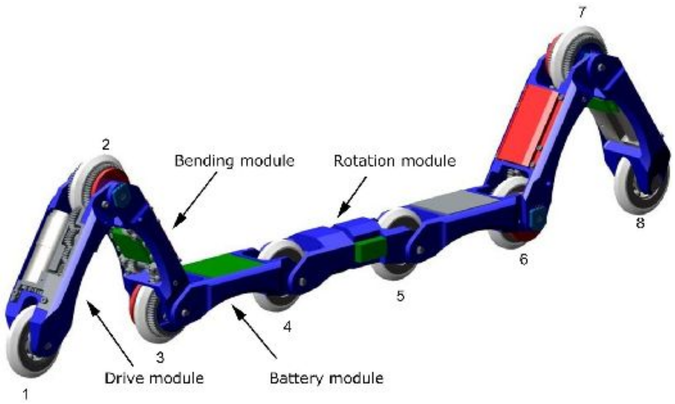


Fig. 2: Schematic drawing of the pipe inspection robot

*clamp, unclamp, drive, bend, rotate*. The following examples of basic robot actions split in motion primitives are shown in the video:

- **drive straight**: clamp front, clamp rear, drive front, drive rear
- **axial rotation**: clamp rear, unclamp front, rotate 180°, clamp front, unclamp rear, rotate 180°, clamp rear, clamp front
- **take corner**: see figure **??**.

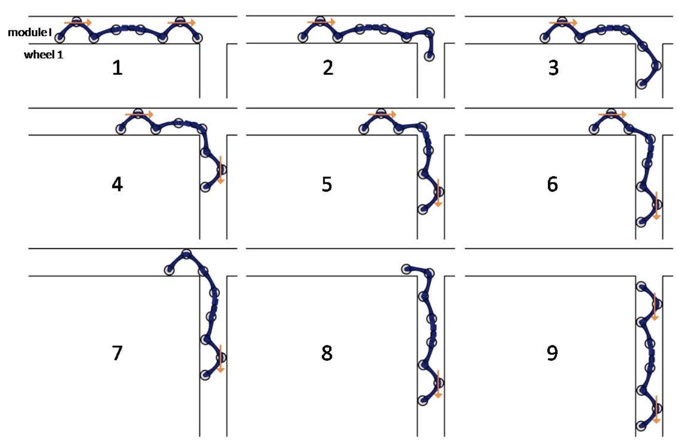


Fig. 3: Schematic overview of robot moving through sharp corner

## IV. Results

In the video the robot drives trough straight pipes, drives under angles of 30°, rotates around its central axis and takes a sharp (mitered) bend in a 90 mm pipe.

## V. Conclusions

The robot is capable performing the desired maneuvers. The velocity (5.6 cm/sec) and clamping control prove satisfactory regarding both the design and the chosen components (motors, gears). The robots mechanical setup provides an suitable test bed for further development of sensors and navigation software.

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