Rolling Prevention Mechanism for Underground Pipe Erosion Inspection Robot with a Real Time Vision System

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ABSTRACT

Pipe inspection is one of the areas that have attracted high research interest for robot applications especially in oil and chemical industry and civil engineering. Robot body rolling while it travels within a pipe has been a problem for accurately collecting inspection data. Under certain circumstances where vision systems have to be employed, robot body rolling may cause vision inspection data to have little value as it is difficult to know where exactly the camera was looking at. This paper proposes an anti-rolling mechanism to hold consistent camera orientation. By changing the position angle of the robot legs, the mechanism is able to adjust the resistance to rolling within a pipe, therefore preventing robot rolling happening. The design makes use of the friction force caused by the gravity force of the robot to prevent the robot body rolling. The design analysis quantifies the effect of pipe radius, robot weight, payload, and payload offset distance in robot rolling. A test model was built based on the design concept. The experimental results obtained from the test model match the predication of the computational analysis. A real time vision system has been developed using FPGA and the algorithm of the structured laser light stripe configuration in the context of pipe inspection. The real-time hardware implementation of the algorithms on the robot itself removes the need to transmit raw video data back to an operator.

Keywords: Anti-Rolling Mechanism, Field-Programmable Gate Array (FPGA), Image Processing, Pipe Inspection, Robot Body Rolling, Robot Design

Concrete wastewater pipes are commonly used in chemical and process industries. As concrete is susceptible to acid erosion, when the PH of the wastewater is below 6.5, erosions occur on the wall of the wastewater pipes and gradually lead to the contents of the pipe leaking to the surroundings. Erosion of wastewater pipes is a huge problem for many chemical and process industries. As wastewater pipes are often underground and hard to access, repairing or replacing the eroded pipes is both timely and costly especially if the actual need for repair-
ing is unknown. A robotic system that is able to inspect the erosion inside of the pipes can provide a clear understanding of the situation, determine the location of the eroded areas, and make an accurate assessment of the damage before taking any corrective action.

Repairing or replacing concrete wastewater pipes requires extensive excavation of the pipes. However, any assumption that the pipes always have a bottom for the robot to run on is not appropriate for this case. As most of the time wastewater pipes are not run full, only the bottom surface of the pipes is most frequently in contact with wastewater and the damage often occurs only on the bottom of the pipes. In severe cases, the bottom surface of the pipes can be completely eroded away as shown in Figure 1. This sets a challenge for a robot with a vision system to accurately locate the eroded areas and determine the extent of erosion. The capability to travel inside a wastewater pipe with no bottom surface and provide a steady platform for real time vision system become the essential requirements for a pipe inspection robot.

This paper presents a proof of concept design for a pipe robotic system that has a potential to be used for concrete wastewater pipe inspection. The data captured must provide a profile of the erosion to map the position and the extent of the eroded areas. This requires the robot platform stably holding its orientation while it travels through the pipe to prevent the vision system rendering any results irrelevant. The research has been focused on wastewater pipes that are straight sections of horizontal pipes and joined at regular intervals from 15 to 50 meters with a manhole. The diameters of the pipes range from 250 to 400mm. The required accuracy of the erosion profile is set to be one millimeter for the depth measurement and one to two millimeters and 5-20 millimeters for the position of the erosion across the pipe and along the pipe centre line respectively.

ROLLING PREVENTION MECHANISM

Conceptual Design

Research study shows a rich content of pipe robot design for different applications (Roman et al., 1993; Yaguchi & Izumikawa, 2012; Roh et al., 2001; Pfeiffer et al., 2000; Ryew et al., 2000), but few are really applicable for this research. To meet the specific requirements, the conceptual design of the robot’s mechanical system has a rectangular platform supported by four wheeled legs as illustrated in Figure 2. The four robot legs are identical and interchangeable, as are the wheels. The legs are assembled with the robot platform through two rotational joints located at the centre of the two ends of the platform.

Figure 1. Pipe erosion concentrated at the bottom of the pipe
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