Real-Time Pipe Inspection Robot Prototype Development

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Abstract

Concrete pipes are used throughout the world in many different industries to transport wastewater. These pipes are prone to erosion which can sometimes be severe, with a large cost of repair or replacement. This presents the need to inspect the pipes for erosion. Robots that are used to detect cracks and holes in a pipe already exist, but those that are used to inspect for erosion lack the ability to inspect in real-time allowing for high-speed, fully-autonomous inspection. Furthermore, none of these systems provide a stable platform that can traverse a severely eroded pipe while passively resisting rolling. A mechanical platform capable of doing just this was designed through a mathematical study. This concept was then tested by varying key design and environmental factors such as the leg angle, starting orientation, and payload weight and offset to determine the effect on the robot's movements and ability to resist rolling. It was found that the smaller the leg angle the less likely it was for the robot to roll but the more power was required to drive the robot. A leg angle of 20 degrees was found to be a good compromise between these two factors under varying conditions, although further study should be conducted over longer pipe lengths and real operating conditions. A real-time inspection system based on triangulation of a camera image and a laser line on the pipe surface was designed and optimized for implementation on a high speed FPGA. This was then tested and it was found that the inspection system was capable of accurately measuring erosion with a 0.3-0.9mm width resolution and a 0.2-0.6mm depth resolution for pipe diameters of 200-600mm. With a longitudinal resolution of 10mm this system could inspect at five metres per minute, and this could be doubled with suitable compression. This research provides the basis for developing an accurate, real-time pipe inspection robot. It also suggests an approach for developing a prototype capable of being used in varying diameter pipes consisting of an inspection system, an anti-rolling robot platform with position sensing, and a wireless communication system, with 3D result display software. Three research articles have been published from this research. Two of the articles are based on real time image acquisition and processing [1, 2]. The third article is on pipe robot mechanical system design [3].

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AC	Alternating current
BLDC	Brushless DC
CCD	Charge-coupled device
CCTV	Closed circuit television
CMOS	Complementary metal-oxide-semiconductor
DC	Direct current
FPGA	Field programmable gate array
IC	Integrated circuit
IMU	Inertial measurement unit
MOS	Metal-oxide-semiconductor
MOSFET	Metal-oxide semiconductor field effect transistor
PAN	Personal area network
PCB	Printed circuit board
PWM	Pulse width modulation
RLE	Run length encoding
UART	Universal asynchronous receiver/transmitter
VGA	Video graphics array