Robot based Smart Water Pipeline Monitoring System

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Abstract. Water scarcity is a serious challenge posed on us and the cost of providing fresh potable will provoke over time. The adoption of robots for the water transportation is inevitable for the productive rehabilitation. Real-time water pipelines monitoring is one of the potential application where robotics play a major role. Monitoring the huge long water pipelines is the biggest challenge. Thus a robust and reliable artificial water pipe monitoring and cleaning robot is proposed to monitor the pipelines of various diameters that interconnect the distributed network for leaks and clogs and to remove the debris. The automated system can be made smart by providing online water leakage or block audit is feasible through a web Socket based application program interface in the cloud platform. An early warning dashboard will be enabled for the water supply management team. This prototype when implemented on a large scale will have potential applications in multipurpose industrial huge oil or gas pipelines along with water pipelines.

1. Introduction
Water is a precious asset to our Country to be conserved. A report says that approximately 163 million Indians do not have access to clean drinking water and 21 percent of the communicable diseases are associated with unsafe drinking water. Every day children die because of diarrhea in India due to the consumption of unclean water. At present, 50 percent of potable water supplied to a city is going waste due to the blocks or leaks in huge long water pipelines. Water is a precious resource and using the water supplies wisely is our prime duty. Pipelines are part of our infrastructures since ages that provides a more comfortable mode of water transportation. The health of the pipelines to be monitored regularly without human intervention. We have to preserve the water supply infrastructure from innumerable number of problems in the delivery pipelines to meet the global consumption. Leakage, mechanical damage, corrosion and blocks are the major problems encountered by a water distribution network. Velocity and pressure of the flow may vary because of these problems encountered. More underwater pipeline systems are utilized for various applications. In the near future, around the world more pipeline projects are planned where advanced health monitoring of pipelines, both underground and above the ground should be carried out without human intervention.
2. Robots for water pipeline Monitoring
In-pipe flexible, mobile robot is a cutting-edge innovative technology for water pipe lines monitoring application. Implementing, operating and maintenance costs for underwater pipelines are very high. There are more risks of accidental failures or damages. In this situation, robots can provide a robust solution for long-distance water pipeline monitoring systems, to detect the leakage and its exact location. Most of the pipelines are lying underground and most of them are huge and cannot be monitored frequently by the concerned people. To keep the pipeline systems functional on a daily basis and prevent forthcoming disaster. Robot prototype developed, carrying all sensors will move inside the pipeline with the help of the wheels designed and powered by a DC to identify the blocks or leakages before they create a disaster, infect the freshwater and creating health hazards. The shapes of the industry pipelines are not common and sometimes due to corrosion chemicals present in the iron pipes coating may cause the release of poisonous gas. Robots are a suitable choice to clean those pipes. Metallic and non-metallic materials are used for pipelines. Of these most commonly used for water supply are galvanised iron, unplasticized polyvinylchloride (PVC), polyethylene (PE) and chlorinated polyvinylchloride (CPVC). Without some form of control in installation, damages to the pipes or blocks may arise which can ultimately pollute the potable water or lead to water loss. An in-pipe handy mobile service robot is the best solution to facilitate for water pipelines inspection for blocks or cracks and regular cleaning.

3. Related Work
Significant research has been carried out in recent years by researchers to overcome the long distance water pipeline issues faced by the PWD. Most of the researchers worked on sensors, data acquisition systems, mathematical formulas and data processing algorithms. Norbert Elkmann et al(2006) [1] developed prototype for motion through the sewer and achieved a new inspection system to audit the damage level. For the Emscher sewer system, an automatic pipe inspection and cleaning system was developed. Changlong Ye et al (2010) [2] developed a robot for a central air-condition named PCV-1 for the pipe environment adaption. They verified the movement by conducting a few experiments. A pipe cleaning vehicle was designed that can move both in the upward and downward direction. The robot completed a variety of pipeline movements successfully. Nguyen Truong-Thinh et al (2011) [3] proposed a new cutting method for cleaning and underwater inspection. The authors discussed a communication method for inspection and cleaning and evaluated their performance through computer simulations. Yoon-Gu Kim et al (2011) [4] focussed on the design of implementation for a pipe navigation system and to overcome the situations inside steel pipes. Authors focussed on navigation ability without slipping and various control tests were performed for the driving test. The robot proposed by them offers adaptability to different pipe diameters. Anthony Harris et al (2012) [5] proposed a concept for pipe traversing robot and its end product. The document describes the design and fabrication of a robot traversing dryer ventilation to clean it. Speed, weight, effectiveness and cost are the parameters considered in the design. Mohammed S. BenSaleh et al (2013) [6] presented a wireless sensor networks based technology for water pipeline monitoring scenarios. Even though manual sweepers were ruled out in 2013, hundreds of people die due to underground water pipelines cleaning work. To provide a solution for this tedious problem automated sewer robot “Bhrutiartan” was used.

4. Proposed Model
The proposed design involves an in-pipe mobile flexible robot that audits the supply lines for leaks and clogs. The robot has both a hardware and software interface. It is being tested for a PVC domestic pipe of 300mm inner diameter. The battery is the heaviest part in the housing and it needs a strong and stable housing. The software interface is created for the robot.
movement section. The entire housing is done with water-proof material to avoid shocking. A fusion of sensors is mounted on the robot body with the camera. Flow sensors and obstacle detecting sensors will detect the leak and clog. The robot with four wheels is driven by the DC motor.

Figure 1. Block diagram of full prototype.

The figure illustrates the block diagram of the model proposed, Raspberry pi acts as the gateway that takes data from the camera and it’s controlling actions such as Trach, power screw and clean mechanism are given through the mobile app. The body of the robot accommodates sensors, camera, DC motor to drive the wheels and the power supply. The robot is designed to move inside a pipe of diameter 8 inches using PVC material to make the whole body feel lightweight. The four wheels powered by DC motor will touch the ground for increased traction and grips. For a stable and strong attachment, the wheels are screwed using aluminum clamps.

The robot takes a peristaltic motion inside the pipe multiple gripping and contraction units. With the help of the DC motor, the gripping unit moves in a radial direction and generates friction with the pipe tightly. A brush is attached at the front end of the robot, as the robot moves forward, it will scrape off the block on the inner surface of the pipe and a camera is mounted at the top, for the remote monitoring of the cleaning process. The speed of the hard pipe is determined by the number of movements in one cycle of the robot per second.

Figure 2. Robot motion control mechanism.
4.1. Analysis
The prototype is tested on two cases (i) No pipe leak (ii) with pipe leak (1.5 mm). Based on Bernoulli’s principle water pressure is related to flow rate. If there is a leakage, there will be more water pressure and less flow value. Water pressure and vibration are inversely proportional.

4.2. Data Flow Graph (DFG) for the Robot movement
The data flow graph DFG (figure 3) is created based on the cleaning process and it is a software interface for robot movement using Arduino programming. Real-time monitoring of the robot movement is viewed in the cloud environment using ESP8266 Node MCU. If the test movement is a success, then through Node MCU mobile dashboard is connected. If there is any error, the process will be repeated again.

![Data Flow Graph](image)

**Figure 3.** Data Flow Graph (DFG) for the Robot movement.

4.3. Mobile App for Robot movement control
Figure 4 shows the dashboard of the mobile app for the Robot movement. When the power button is “ON” the robot can be moved forward or reverse and the pipe cleaning is done through a motor sliding approach.
5. Conclusion
Water is an essential natural resource to be protected to meet out the global increasing consumption. To provide water security, we have to preserve the health of water Infrastructures through continuous real-time monitoring without human intervention. A robust, effective, customizable, scalable and reliable smart robot prototype is built and tested. Pipeline Infrastructures are used in transporting oil, gas and other liquids apart from water, where the leakage is risky. On a large scale, the proposed robot prototype can be implemented for the oil and gas industry to monitor the leakage. Overall, the proposed robot-based water leakage monitoring along with a mobile app provides a great advantage by avoiding human involvement. Thus the service robot has enabled the pipelines to work efficiently with minimum cost. In the future, we can use LoRa sensors deployed on the surface of the mobile robot to reduce overall power requirement and for wider coverage.

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