Intelligent Detection and Elimination of Blockage in Sewage pipes using a Robot

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Abstract - *This paper presents a robotic mechanism for detecting and eliminating blockages in sewage pipes. This robot is designed to replace human sewage cleaners in order to ensure their health and hygiene. The proposed robot moves through the pipeline, detects the blockages if they are present and clears them by pumping water with high pressure or cuts through the blockage and moves forward. The robot operation is monitored and controlled manually by the sewage worker using a laptop or palmtop computer. The operator can monitor the insides of the pipe via a wireless camera attached to the robot. The various sensors attached to the robot helps to determine the distance of the block from the robot and the presence of poisonous gases inside the pipeline. The pumping mechanism pumps water or air into the pipeline with high pressure in order to loosen and clear the block. The rotating mechanism consists of a fan like structure with sharp blades that penetrate through the blocks by cutting them. This robot is used to inspect various pipeline elements of different size.*

Key words - sewage; pipeline; blockage; clearance; pumping; rotating.

I. INTRODUCTION

Every day hundreds of men descend into the putrid, foul smelling sewage for cleaning without any safety gear. Workers who handle the maintenance and cleaning of sewage pipes are at increased risk of serious diseases like Hepatitis A. Many deaths occur due to drowning, trench collapses, falls, and exposure to chlorine or Hydrogen- sulphide gas. Those who die during the duty are replaced by others, waiting to put their lives in danger just to earn a living for themselves and their families. Every week, young men line up for Rs 200 that they get to clean 20-25 gutters, putting their precious lives at risk.

While sewage cleaning has become mechanized in some parts of the country, the government figures suggest nearly 8,00,000 people still work as sewage cleaners.

In Metro cities, sewage travels across nearly 5,600-kilometer long sewer lines at the speed of one meter per second. Reports suggest that nearly 23,000 men and women die in India every year doing various kinds of sanitation work. A research at Tata Institute of Social Sciences has found that 80% of the sewage cleaners die before age 60 because of work-related health problems.

So, it is high time to replace human sewage cleaners with high tech robots in order avoid these unfortunate deaths and save their precious lives. This robot paves way for the sewage workers to monitor and clean the pipes without getting into the drainage. This will not lead to unemployment instead it helps the workers to finish their job easily with the help of robot. This ensures the health and hygiene of the sewage workers.

II. PIPELINE MONITORING

A. Inspection of sewage pipes.

Pipeline is the major tool of transportation of oil, sewage, water etc. Many types of pipes are being used to construct important lifelines such as water and gas supply all over the world. Also pipes are widely used in chemical industries and in Gulf countries for carrying fuels like petrol, diesel, oil etc. But the disadvantage is that many problems like cracks, breakage and blocks are occurring in the pipelines because of natural calamities and mechanical damages from third parties which cause great loss. Thus scheduled proper inspection must be done on these pipelines for their maintenance. The manual cost of doing this inspection is very high and it requires lots of resource and time. If robots inspect inside the pipes, fast and accurate examination at low cost is possible. This has been addressed in [1].

Pipeline Assessment Devices called pigs are available which use ultrasonic technology to determine pipeline wall cracks. Pigging operations include inspecting and cleaning the pipelines. This is accomplished by inserting the pig into a "pig launcher"-an oversized section in the pipeline, reducing to the normal diameter. The launching station is then closed and the pressure-driven flow of the product in the pipeline is used to push the pig along down the pipe until it reaches the receiving trap - the "pig catcher" or "receiving station".

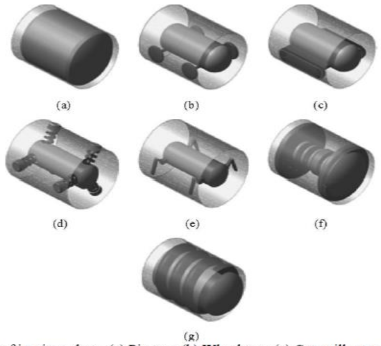


Fig. 1 Classification of in-pipe robots. (a) Pig type (b) Wheel type (c) Caterpillar type (d) Wall-press type (e) Walking type (f) Inchworm type (g) Screw type [1]

The same algorithm can be used to inspect the sewage pipes but clearing blockages in the pipeline will not be possible by this method. This is because the flow of pig will be interrupted by the different types of blockages present in the pipe. The blockages might include plastic waste, mud, stones, waste clothes etc. In order to determine the type of blockage, wireless cameras are attached to the robot Ultrasonic sensor can be used to determine the distance of the block from the robot. The wireless camera helps the operator to monitor the pipeline continuously.

B. Determination of the position of block inside the pipe.

The robot moves through the pipe by balancing on its wheels. Ultrasonic sensor HCSR04 is assembled in the robot. Ultrasonic sensors are non-intrusive in that they do not require physical contact with their target. Ultrasonic sensors are based on the measurement of the properties of acoustic waves with frequencies above the human audible range, often at roughly 40 kHz. They typically operate by generating a high-frequency pulse of sound and then receiving and evaluating the properties of the echo pulse.

Three different properties of the received echo pulse may be evaluated, for different sensing purposes. They are:

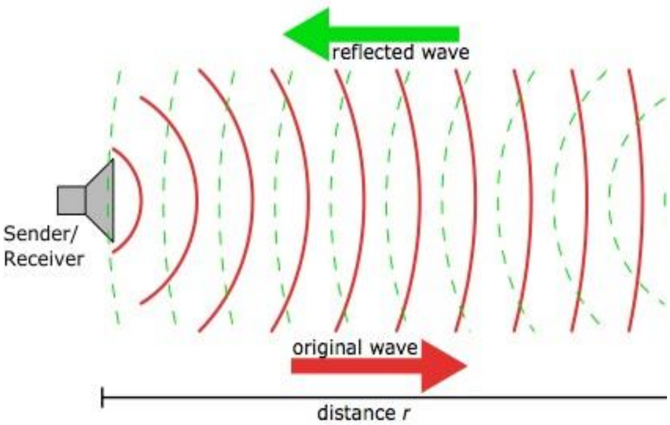
- Time of flight (for sensing distance)
- Doppler shift (for sensing velocity)
- Amplitude attenuation (for sensing distance)

1) Time of Flight

a) 1A. Reflection Mode

In reflection mode (also known as "echo ranging"), an ultrasonic transmitter emits a short burst of sound in a particular direction. The pulse bounces off a target and returns to the receiver after a time interval t. The receiver records the length of this time interval and calculates the distance travelled r based on the speed of sound c:

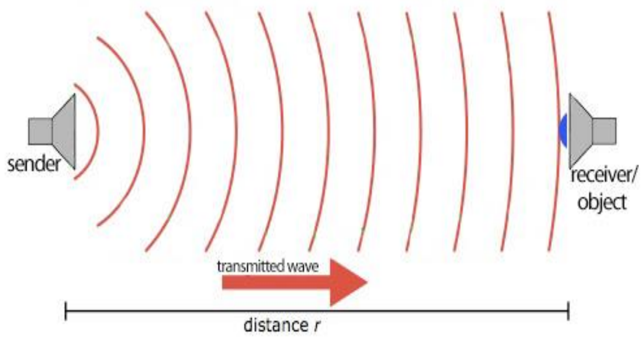
$$r = c * t$$



Very often, separate transmitting and receiving transducers are placed immediately next to each other, housed as a single unit. In these cases, the distance calculated will be twice the distance from the sensor to the target.

b) 1B. Direct Measurement Mode

In this mode of operation the transmitter and receiver are two separate units that move relative to each other. For example, the receiver can be fixed to a target that moves relative to a stationary transmitter, or vice-versa.



Multiple transmitters can be used to increase the directionality of the transmitted pulse, whose signals were received by multiple receivers in the performance space, enabling a computer program to triangulate the performer's position.

2) Doppler Shift

When a wave reflects off of a moving object, its frequency is shifted by an amount proportional to the velocity of the object. This fact can be exploited in ultrasonic sensing by having the receiver measure not the time of flight but the frequency of the returning echo pulse. Knowing f_e and f_r, the frequency of the emitted and received pulse, respectively, the velocity v of the target may be calculated.

$$f_e - f_r = 2 f_e (v / c) \cos(A)$$

Here, **A** is the angle between the target's and the pulse's lines of motion.

3) Amplitude Attenuation

Ultrasonic sound attenuates much faster than audible sound when propagating through air. By measuring the intensity of the returning pulse, an estimate of the distance travelled can be made using the following equation:

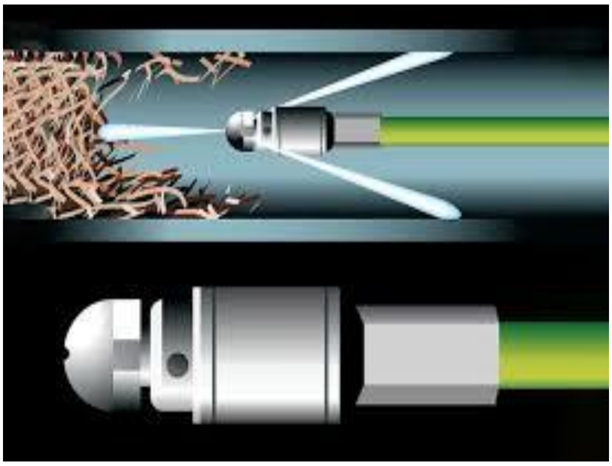
$$I = I_0 e^{-ax}$$

where I and I_0 are the received and the original intensities, respectively, and where a is the attenuation coefficient (a property of the medium) and x is the distance travelled by the wave.

III. BLOCK CLEARAGE MECHANISM

Once a block is identified and its distance is measured using the ultrasonic sensor, the next step is to clear the block using a pumping mechanism which comprises of a high pressure washer. High pressure washers have been developed with the aim of removing stubborn dirt under tough working conditions. Efficient flow rates are achieved using high flow rate and high pressure.

Water gets things so clean because its molecules have a slight electrical polarity (one end is positively charged and the other is negatively charged). Detergents (soap chemicals) help water to do its job even better by breaking down gunges and grease and making it easier for water to flush away. But some kinds of ground-on dirt just won't budge, no matter how hard we try. That's when a pressure washer is used. It uses a narrow, high-pressure jet of hot or cold water to blast dirt free. Because the water is traveling fast, it hits the dirty surface with high kinetic energy, knocking dirt and dust away like a constant rain of tiny hammer blows. It's only water, though, so it doesn't damage most hard surfaces.

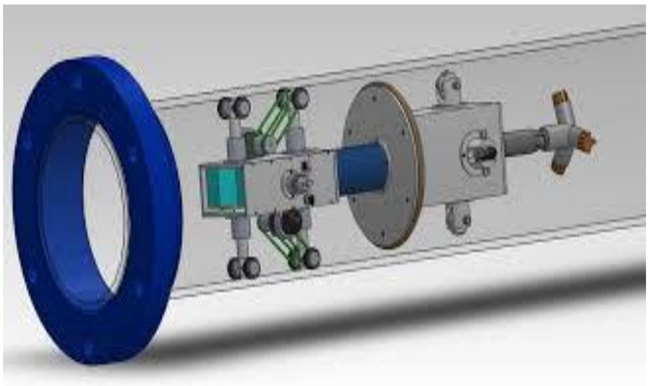


Once the block is cleared using the high pressure pump, it is indicated to the robot by using the ultrasonic sensor distance measurement and the robot proceeds to clear the next blockage along the length of the pipe.

IV. CONTROL OPERATION

All the activities of the robot are controlled by a centralized microcontroller attached with the robot. This controller is interfaced with the wheel motors, wireless camera, ultrasonic sensor, gas sensor, driver circuit, UART and Zigbee modules. Micro controller does the following function.

1. When the operator turns on the robot, the microcontroller enables the driver circuit.
2. The driver circuit enables the motion of robot inside the pipeline by turning on the motors. The operator can control the movement of robot as per pre-programmed instructions.
3. The wireless camera continuously transmits the information to the controller which shows it in the user's display device.
4. The ultrasonic sensor sends its output values to the controller periodically. When the controller senses an abrupt deviation in these values, it confirms the presence of a blockage. The controller now interrupts the driver circuit and turns on the pumping mechanism.
5. The pumping mechanism is operated till the output values of ultrasonic sensor return to normal. Once the block is cleared, the controller returns back the control to driver circuit for the forward motion of robot.
6. A rotating mechanism is used for stubborn blockages such as wood pieces, thick sheets etc which cannot be removed by pumping mechanism. It consists of a rotating fan like structure with very sharp blades. This is capable of cutting the wood pieces, covers, boxes etc. Thus the robot penetrates into the block by cutting down it into pieces. Later, pumping mechanism can be used to clear the remains of the block.
7. The display device is interfaced with the controller and it helps continuous monitoring by the user.
8. The gas sensor is turned on only in a rare case if both pumping mechanism and rotating mechanism are unable to remove the block. In such a case, the output of the gas sensor is used to determine whether poisonous gases such as chlorine or carbon monoxide are present inside the pipeline. This provides precautionary measures for the sewage workers before getting into the drain.



V. DISCUSSIONS

A. Advantages

a) The proposed robot eliminates the need for human workers to get into the drainage in order to clean it. The health and hygiene of sewage workers is preserved.

b) The robot is easy to design and implement. All the components used have simple operation and is very simple to program.

C) The cost of robot is economical that might cost few thousands. The maintenance is also cheap.

d) The robot is highly user friendly. One can easily operate this robot like a remote car.

e) The additional details provided by the wireless cameras and sensors are also of great help to the users.

B. Disadvantages

This robot is not fully automated. Though this robot eliminates the need for workers to get into the drain, it still needs workers to control its operation

VI. CONCLUSION

The proposed robot is designed with the motive of helping the sewage cleaners to prevent them from getting affected by serious diseases because of entering the drainage. The death rate of sewage cleaners is alarming. It is high time that this robot should be implemented to clean the sewage pipes all over the world. Moreover, this robot will help to find the poisonous gases inside the drain which will help the authorities to curb the dumping of untreated raw waste from the industries into the drains. This will not lead to unemployment of sewage workers but will just make the job easier and healthier for them. When this robot would be implemented in real time, it will save thousands of poor people's lives who come forward to clean the drainage just to earn few bucks a day. In this modern society, a human cleaning the sewage waste shows that very less attention has been given to those people's lives due to their poverty. Hence, this robot helps to have a clean and hygienic drain systems everywhere.

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