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PIPELINE INSPECTION ROBOT

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ABSTRACT
This study proposes a design for pipeline inspection robot that can detect various pipe cracks internally by using camera at very low cost. The economic value of pipelines which are used in industry for various purposes is very large. Pipeline inspection has become an important issue as replacement of defected pipeline is more costly as well as more complicated. This study gives a proposed design of Pipeline inspection mobile robot along with recovery function. Bot designing part is done by acrylic using laser cutting machine and design in SOLIDWORKS. ARDUINO UNO is used as controller and L298N-H-Bridge controller for motors. Pipeline inspection is done by taking an images internally by using CMOS micro camera. Obstacle detection is done by using IR sensor and has recovery function. Crack as well as Hole detection is done by using 3 different methods in MATLAB. Results are based on actual photographs which are taken from CMOS micro camera.

KEYWORDS:
Pipeline inspection; L298H Bridge; ARDUINO UNO; CMOS camera; IR Sensor; MATLAB.

INTRODUCTION

The pipeline inspection robots are highly useful to detect the pipelines or small tunnels internal cracks. It is more important as per the performance and life of pipelines are used. There are many pipeline inspection robot systems have been developed, and this pipeline inspection robots which are classified into several elementary forms according to the movement mechanism. Thus, many kinds of mechanisms have been developed, such as wheel type, inchworm type, legged mobile type, screw type, crawler type, PIG type, caterpillar type and passive type. Among them, wheel type and caterpillar type pipeline inspection robots were mostly popular [1] [2] [8].

If a small water pipeline bursts or leak, it can be a problem but it usually does not harm our environment. However, if a petroleum or chemical pipeline leaks, it can be the environmental and ecological disaster. In India, we can see many pipeline accidental reports at the National Transportation Safety Board's Internet site. Thus, for keeping pipelines operating safely, periodic inspections are performed to find cracks and damage before they become cause for serious concern. When the pipeline used after a period, there exist possibilities of cracking or damage, also the pipeline was gotten into siltation or squeeze that made the pipe wall making irregular varieties. Therefore, the activities for periodic maintenances are required. Because the pipeline is restricted by many environmental factors, that limit makes more difficult to inspect the pipeline. For this problem, inspecting them by using robots is considered as a good alternative. A survey of various methods of pipeline inspection is given below:

1) Visual examination using Inspection Dig.
2) External measurement such as Electrical Survey.
3) Examination of corrosion coupons or probes placed inside the pipeline.
4) Use of in-line inspection tool to identify areas of pitting or metal loss.

For example, sewerage water can be overflowed when sewer pipelines are blocked by sludgy or dirty things. In that case, blockages have to be removed from the pipe. Otherwise all areas can be spoiled by dirty water due to outflow. There are several ways to remove these things. First, blocked pipes can be penetrated with a long stick or wire but it is very difficult to do so when pipelines are bent. Second, blockages can be blown out

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using air pressure, but it doesn't work when pipe have outlets or clacks between the blockage and starting point of air pressure. Third is an excavation of the area which is suspected for clogging [1] [2] [3] [4].

The difficulty here is a finding clogged area and it also takes long time and large cost. Solution for these problems is pipeline robot. If a pipeline robot can travel, find and remove these things in pipelines, we can significantly reduce the recovery cost as well as time. We can avoid man power for these jobs. Therefore, a pipeline robot can be a strongly recommendable solution for pipeline maintenance.

OBJECTIVES

In this study, we aimed at designing a cost-effective pipeline maintenance and monitoring system. Such a system would allow frequent inspection, early detection of problems, controllable error localization and system design would be applicable for any length of PVC (dry) pipeline with 20cm as diameter.

1) Design and Construction of mechanical part of robot. (Chassis design by using SOLIDWORKS, laser cutting machine as a designing tool, acrylic as material.)
2) Interfacing of electrical part of robot. (Interfacing of motors, Arduino Uno as a controller, stepper motor for camera rotation.)
3) Detection of obstacle, localization of obstacle using IR sensor.
4) Developed an image processing system for Crack, Hole detection purpose only.

METHODOLOGY

A. Architecture of proposed bot

The robot system shown in the Figure 2 consists of control box and a robot device. Upper plate consist of control box and it is separated by standing notches so that the robot device is separable from the control box. The robot system consists of a main chassis with 2 plates, with 6 hanging notches which are used for three motors with 3 wheels and both the plates are separated by using standing notches. The width of robot is nearly 150 mm and exterior diameter of bot is 194mm. The flexible mechanism is achieved by changing the wheels and grip of the wheels. So that the exterior diameters can adjust in range from 196 mm to 225 mm.

B. The designing of bot

The designing part is done by Building a model in SolidWorks version 2016 with a 2D sketch. The sketch consists of bot design with upper and lower plate in circular shape and notches for support and wheels are also designed in sketch. Dimensions are added to the sketch to define the size and location of the geometry. The dimensions in the sketch can be controlled independently, or by relationships to other parameters inside or outside of the sketch. After that in an assembly section, the analog to sketch relations are mates. Figure no 2 shows the final design in SOLIDWORKS [10]. The material used for bot chassis is acrylic. Different types of materials are available. In this section we selected acrylic as material for experimentation purpose only. It is preferred because of its moderate properties, easy handling and processing, and low cost.

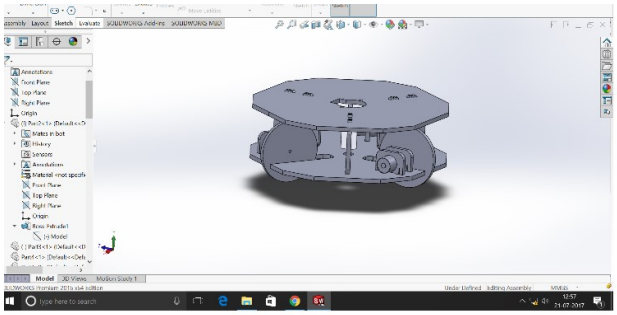

Fig.1.final chassis design in SOLIDWORKS

C. Implementation.

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The robot control is executed by a serial communication. In this system, we use ARDUINO UNO (Atmega328P). It control the motor speed by producing a PWM signal. It can control all of the DC motors by using UP and DOWN function. All the motor drives and UNO are integrated in the control box. The view of the pipeline is provided to the user by using a Micro CMOS camera mounted in front of the robot body. This camera module makes it possible to inspect the condition inside the pipeline [4]. IR sensor is used for obstacle detection. In this design, obstacles are considered in terms any other objects, T-shaped and Y-shaped connectivity of pipe. Some LED's for illumination effect. For testing we used normal DC power supply unit (12 V, 3 A). This proposed design is implemented on the basis of parameters, PVC pipeline, functionality of robot, hardware component, environmental conditions of pipe etc.

Fig.2.final bot

RESULTS AND DISCUSSION

Flow Chart of Operating Functions of Bot and its working as followed.

BotTesting part: Place a robot at entrance of the pipe. As the total length of the bot is 200 mm, it skips a distance of 200 mm from starting point. So now robot is going to inspect only 80 cm out of 100 cm of pipe length. When we power up then, first motors start to run and move in forward direction inside pipeline for 10 cm then camera start to rotate in 360 degree for 1 min and take a video. Then again motor starts and move in the forward direction inside pipe. Forward action is set for 1 sec and it covers 10 cm. At the same time, IR sensor counts the steps (there is no obstacle) so that we get distance travelled by bot. After that again camera starts to rotate and repeats the process for 7 times. In next forward mode, count starts from previous value of count. But in between above process if any obstacle is encountered (Bending of pipe, any hard object like stone etc., T-shaped and Y- shaped connectivity of pipeline), by the IR sensor which is mounted near to idle wheel detects the obstacle. If obstacle is detected then it stop for 1 sec and start to move in backward action by reducing the steps. This action occurs till step count reaches to zero. Distance calculation: the diameter of idle wheel is 5 cm. so it covers 15.707 cm in one revolution. For 1 revolution IR sensor count steps as 4. It means 4 count = 15.707 cm distance. Maximum revolution for 100 cm pipe = 100cm / (15.707 cm/rev)= 6.36 rev. Maximum count for 100cm = 25.46

Detection part: Crack detection and hole detection is done on available database by using MATLAB. MATLAB GUI is implemented for crack detection as well as for hole detection. Database contains 30 images (15 for crack and 15 for hole detection).The proposed design is verified by using PVC pipeline with 200mm diameter. Input image is selected from the available database. Then crack detection algorithm is divided in 3 parts first part is pre-processing of image. Where Grey Scale and Complement of image is done. Second part is segmentation where morphological openings are done and third part is application of detector. Here we use 3 different detector Canny, Sobel, Prewitts for crack detection. Canny operator use a Gaussian function to smooth

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image firstly. Then the maximum value of first derivative also corresponds to the minimum of the first derivative. Thus these two thresholds are used to detect strong edges and weak edges. So Canny algorithm helps to detect weak edges. Compared to Canny detector, Sobel and Prewitts are very sensitive to noise. Therefore Canny is best among them. Similarly we analyzed 15 images for crack detection. Maximum pixels are detected by canny detector.

Final GUI is implemented for better visualization. Where we get complete algorithm in one app which is in user interface form. So we can select any image from the input database and applied detection methods and get results in one window.

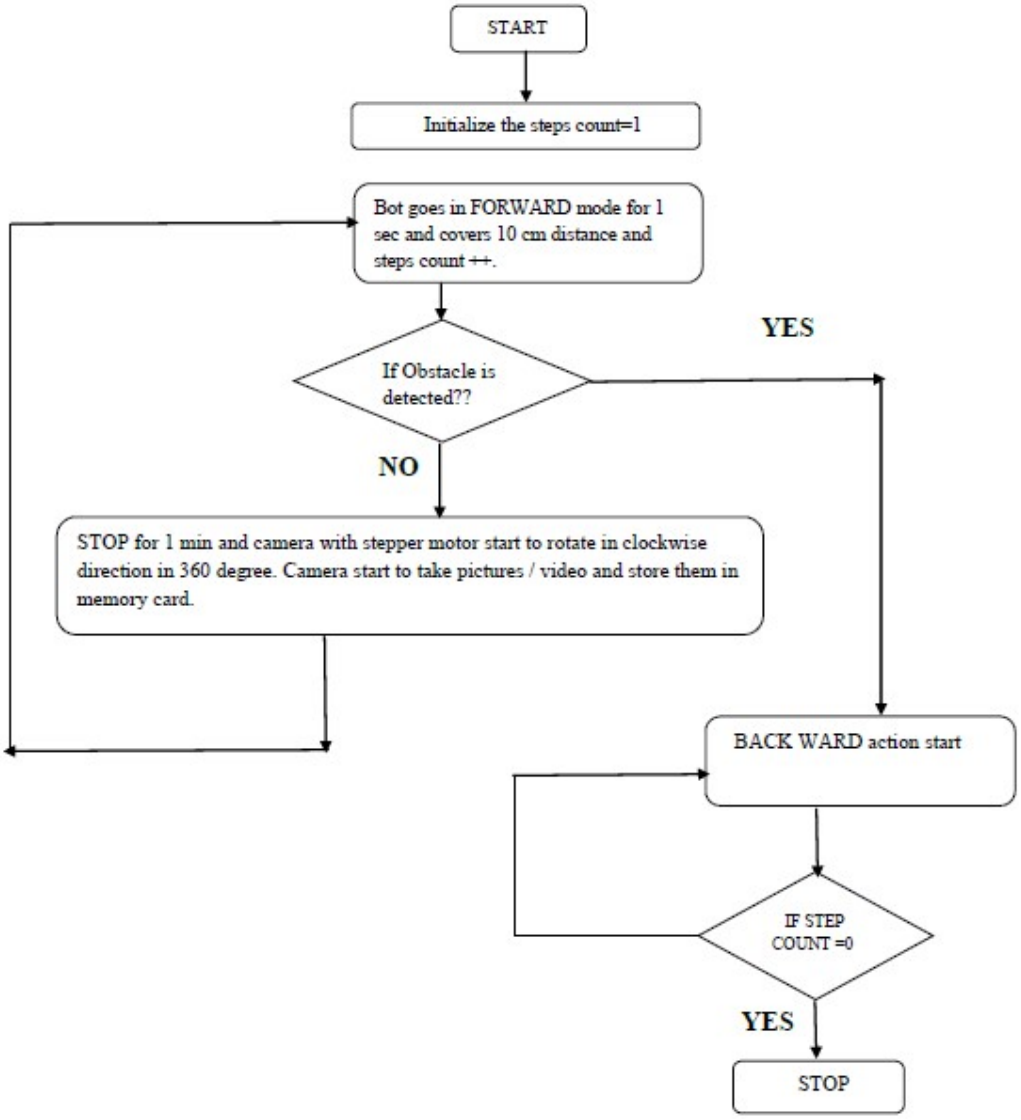

Fig.3.Flow chart of bot functionality.

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Some flaws occurred during testing:

	Theoretically	Practically	Remark
Image clarity	3.2 mega pixel with 120 degree focal angle. Should be clear.	Due to light effect inside pipeline. Images are slightly blurred.	Due to light effect in pipeline.
Speed	0.25m/sec (at PWM= 255)	Average 0.18m/sec (at PWM= 255)	Due to slippage.
Blind spot	Frame size = 7*6.5 cm. There should not be any blind spot	Average distance – frame size = 8.5 – 7=1.5 cm. 1.5 cm blind spot occurred.	Due to mark of single encoder and design issues.
Inclination	40 degree	30 degree	Due to slippage.
Distance covered (120 PWM)	0.12 m/ sec	Average 0.08m/sec	Due to slippage.

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CONCLUSION

A low-cost, portable Pipeline inspection robot design has been proposed and developed. In this system we have used one camera with 3.2 Mega pixel in the front module of robot and crack detection is done using MATLAB. Obstacle detection is done by using IR sensor and then retrieval function is implemented in the design. Limitation of design is if the robot gets slip inside pipeline and it is stuck inside the pipeline then the robot needs to be taken out of the pipeline by using some retrieval function. Further, one more camera with high quality resolutions can be implemented in order to provide better visual information to the user or by using some other techniques like ultrasound, thermal imaging. For further upgrade of design the concept of using a clutch is a good solution for realization of the retrieval function. With the same design we can implement robot by using another materials like metal then by using some modification according to the environmental conditions and requirement of system we can upgrade the robot according to functionality.

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