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Pipe Inspection Robot

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***Abstract:** A pipe inspection robot is device that is inserted into pipes to check for obstruction or damage. These robots are traditionally manufactured offshore, are extremely expensive, and are often not adequately supported in the event or malfunction. This had resulted in associated environmental services limited. A New Zealand utilize of this equipment, facing significant periods of down time as they wait for their robots to be the repaired. Recently, they were informing that several robots were no longer supported. This project was conceived to redesign the electronics control systems one of these PIR, utilizing the existing mechanical platform. Requirements for the robot were that it must operate reliably in confined, dark and wet environments and provides a human wear with a digital video feed of the internal status of the pipes. There robot should as much as possible incorporate off the shaft components, cheap, and potentially onsite repair. This project details the redesign and constructions of such robots. Its employees their electronic boards integrated with mechanical components and provides video feedback via custom graphical interface although at the prototypes state the electronics has been successful with cost of less than a length of the original robot purchase prize.*
***Keywords:** Pipe inspection robot, prototypes, feedback, graphical interface, Electronics control systems, Digital video.*

I. INTRODUCTION

Pipeline systems deteriorate progressively over time. Corrosion accelerates progressively and long-term deterioration increases the probability of failure (fatigue cracking). Limiting regular inspecting activities to the "scrap" part of the pipelines only, results ultimately into a pipeline system with questionable integrity. The confidence level in integrity will drop below acceptance levels. Inspection of presently uninspected sections of the pipeline system becomes a must. This project provides information on the "robotic inspection technology". Pipelines are proven to be the safest way to transport and distribute Gases and Liquids. Regular inspection is required to maintain that reputation. The larger part of the pipelines system is accessible by In-Line Inspection Tools but this access is limited to the section in between the launching and receiving traps only. Unfortunately, corrosion does not have this limitation. The industry looks for means of inspecting these in-accessible pressure holding piping systems, preferably, without interrupting the operations. It is a fact that sufficiently reliable and accurate inspection results can only be obtained by direct pipe wall contact/access. If that is not feasible from the outside, we have to go inside. Since modifying pipeline systems for In-Line Inspection is mainly not practical, PIPE INSPECTION ROBOT pursues development of ROBOTIC inspection services for presently in-accessible pipeline systems. Robotics is one of the fastest growing engineering fields of today. Robots are designed to remove the human factor from labor intensive or dangerous work and also to act in inaccessible environment. The use of robots is more common today than ever before and it is no longer exclusively used by the heavy production industries. The inspection of pipes may be relevant for improving security and efficiency in industrial plants. These specific operations as inspection, maintenance, cleaning etc. are expensive, thus the application of the robots appears to be one of the most attractive solutions. Pipelines which are tools for transporting oils, gases and other fluids such as chemicals, have been employed as major utilities in a number of countries for long time. Recently, many troubles occur in pipelines, and most of them are caused by aging, corrosion, cracks, and mechanical damages from the third parties. So, continuous activities for inspection, maintenance and repair are strongly demanded. The robots with a flexible (adaptable) structure may boast adaptability to the environment, especially to the pipe diameter, with enhanced dexterity, manoeuvrability, capability to operate under hostile conditions. The wheeled robots are the simplest, most energy efficient, and have advantages in manoeuvrability with the ability to adapt to in-pipe unevenness, move vertically in pipes, and stay stable without slipping in pipes. These types of robots also have the advantage of easier miniaturization. The key problem in their design and implementation consists in combining the capacity of self-moving with that of self-sustaining and the property of low weight and dimension. A very important design objective is represented by the adaptability of the in-pipe robots to the inner diameters of the pipes. Currently, the applications of robots for the maintenance of the pipeline utilities are considered as one of the most attractive solutions available Pipe Inspection Robot is shown in Figure 1.1

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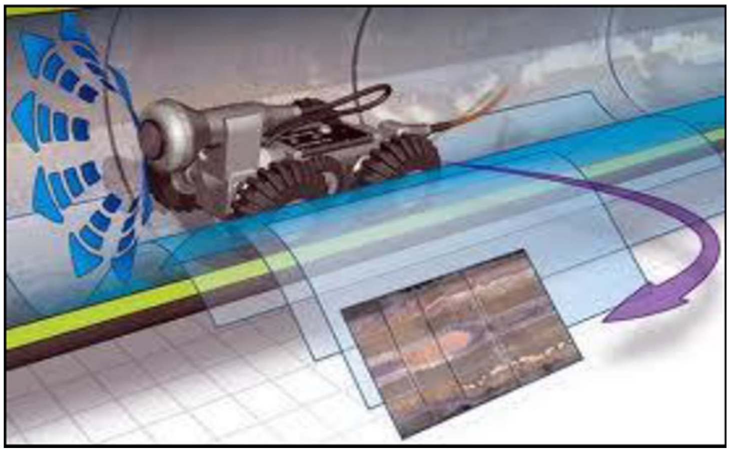

Fig. Pipe Inspection Robot (PIR)

II. OBJECTIVE

As we are observed that in industry, home, power plant etc. there are several problems occurs inside the pipe like Corrosion, Cracking , Dent Mark , Metal Losses etc. so , we are inspecting the pipe with the help of “PIPE INSPECTION ROBOT”.

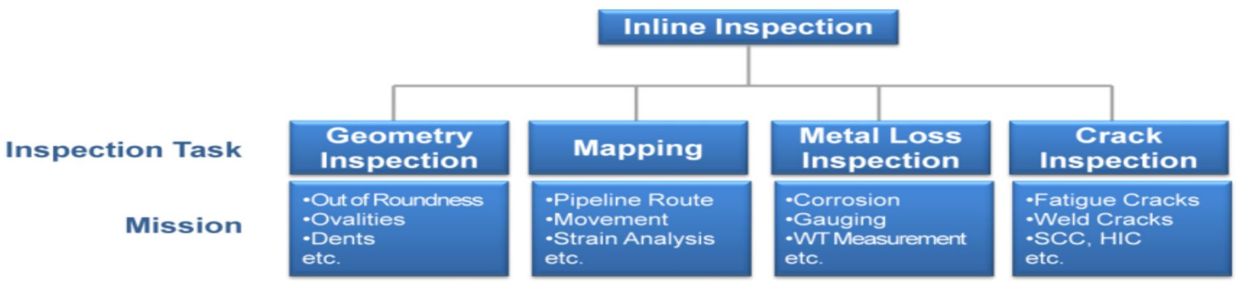

Fig. Flow chart showing scope of pipe inspection

III. DESIGN OF PIPE INSPECTION ROBOT

A. Selection of Materials

The materials used for this machine are light and rigid. Different materials can be used for different parts of the robot. For optimum use of power, the materials used should be light and strong. Wood is light but it is subjected to wear if used for this machine. Metals are the ideal materials for the robot as most if the plastics cannot be as strong as metals. Material should be ductile, less brittleness, malleable, and high magnetic susceptibility. Among the metals, aluminum is the material chosen for the linkages and the common rod, which is made as hollow for reduction in weight. However, other materials are chosen for the motor.

B. Mechanism

The mechanism involved here is a four bar mechanism consisting of three revolute joints and one prismatic joint as depicted.

$H = 2r + 2d + 2h2 \times \cos\theta$,

Where,

$h1 = 30$ mm, $h2 = 85$ mm, $h3 = 105$ mm ($h1 = OA$, $h2 = BC = D$, $h3 = CF$)

$H=2\times 36+2\times 28+2\times 85\times \cos 45$

$H=248.20$mm

Where D - Diameter of the pipe in mm, d - Distance between EE’ in mm.h1, h2, h3 are the length of the links in mm. r-Radius of the wheel, H=Height of robot outside the pipe.

For uniform Diameter,

Assume $D = 2r+2d+2h2\cos\theta$

$D=2\times 36+2\times 28+2\times 85\times \cos 50$

$D=237.27$mm

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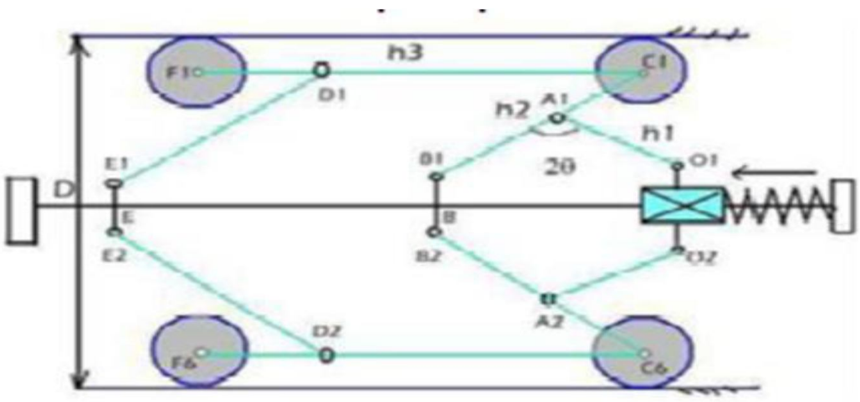


Fig. Mechanism of PIR

C. Components of PIR

1) Central Frame

Central body is the frame of the robot. It supports all other components and holds batteries at the centre of the body. The joints are brazed on the central frame at 120 degrees. The central body is drilled and its ends are threaded internally for the insertion of pencil batteries and closing with externally threaded caps. Wireless camera is fixed at one end of the frame.

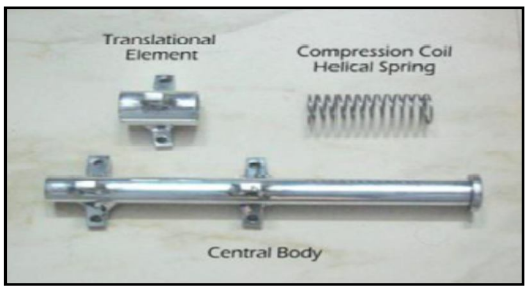


Fig. Central Frame

2) Translational Element

Translational Element is the movable part in the robot which slides along the central body for repositioning in case of pipe diameter variation. This element is drilled at the centre for the translating along the central body. This will restrict the links to some extreme angles beyond which it could not be translated. The extreme angles are found to be 15 degrees and 60 degrees. The joints are brazed on the translational element at 120 degrees for the links to be fixed onto it.

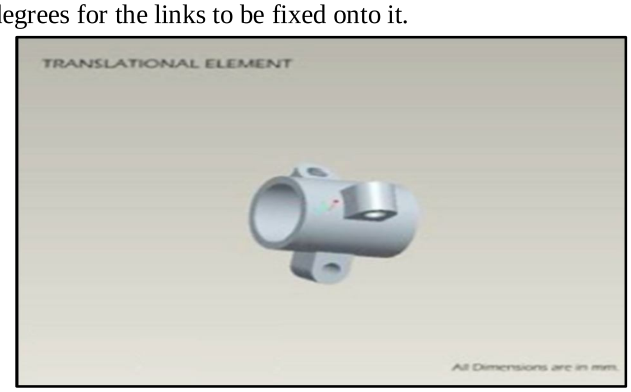


Fig. Translational Element

3) Links

Each resistant body in a machine which moves relative to another resistant body is called Kinematic link or element. A resistant body is which do not go under deformation while transmitting the force. Links are the major part of the robot which translates motion. Links are connected to form a linkage. The mechanism involved here is a 4-bar mechanism which has 3 revolute pairs and1 single prismatic pairs as depicted. Links holds the receiver, switch, and 9v battery for the camera. Also, it supports the actuator.

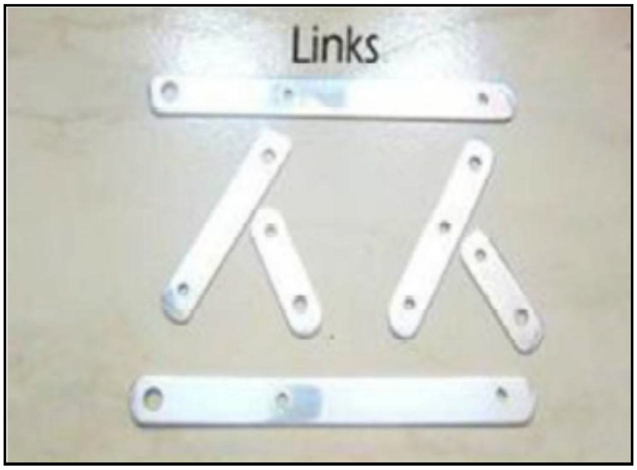


Fig. Links

4) Batteries

Batteries give supply for a motor and wireless camera. Motor and radio frequency gets 6v supply from the central body and wireless camera gets supply from a 9vbattery. And 3v batteries for transmitter which has two toggle switches. One is for motor forward and reverse control and the other one is for glowing LED's.

5) Transmitter

The extension cable which attached the camera with output device transmits the video and picture.

IV. CONSTRUCTION AND WORKING OF PIR

A pipe inspection robot consist of central element having 12.7 mm dia, , 3 mm thickness and 176 mm in length , one translational element having 15mm dia. 3mm thick & 20mm in length. There are 12 links out of which 3 links are 105mm (A1, A2, A3),6 links of 85mm(B1,B2,B3,B4,B5,B6) & another 3 links of 30mm(C1,C2,C3).The spring is 90mm in length. The central element are joined to the 6 links the length of 28mm.On the central element links are attached to fulcrum with pin joint on the periphery with 120° lateral spacing at the points 1,2,3 resp. as shown in fig. Also 3 links are B4,B5,B6 are attach to another point 4,5,6 which are 50mm from point 1,2,3 as shown in fig. in the same way as in previous point. The one end of the three links which are 30mm in dia.(C1,C2,C3) are attach to the translation element in outer side to fulcrum with pin joint which are 120° in lateral spacing & the another end is attach to the links B4,B5,B6 at point with pin joint as shown in fig. The another link with length (A1, A2,A3) is attach to the end of the links (B1,B2,B3,B4,B5,B6) at the distance as shown in fig. The motor & wheels are mounted on the links (A1, A2, A3) as shown in fig. The front end of the structure is attached with the swiveling & turning head consist of camera & fitted with BO motor.

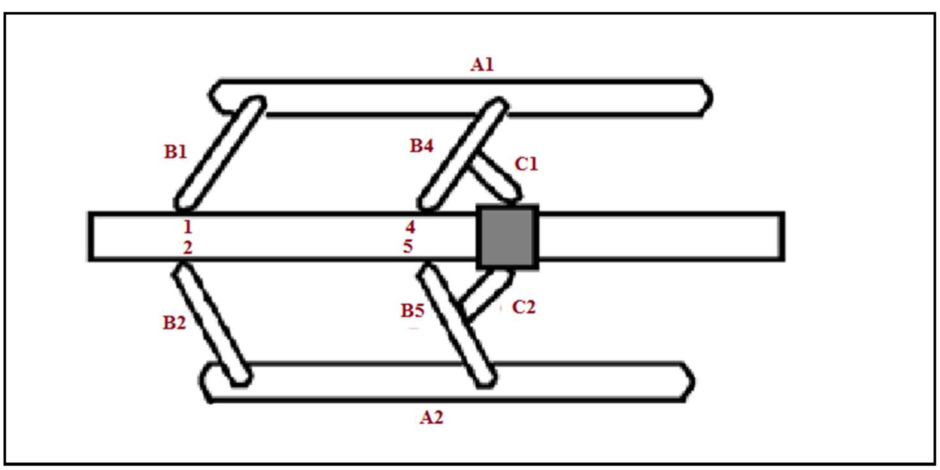


Fig. Construction of Links

The camera & lights are mounted in a swiveling head are attached to the cylindrical body. The swiveling head are integrated to the lighting device a typically used in LED. The LED is used to illuminate inside the pipe line. The camera is pan & tilt by remotely. The motor wiring as shown in fig. are supply with 12v dc power supply through adaptor. The 3v dc power is supplied to the BO motor of camera. Operate the motor wheel the robot remote is connected. The camera is connected to the display equipment(output) via long cable wound upon a winch There are 6 wheels the dia. Of wheel 72mm.There are 6 D.C motor having 10rpm & 12v.There are 2 BO motor having 60rpm & 3-9v. The BO motor is used for actuate the camera & light and it is fixed to the front side of the robot. The spring is attached to the end of the robot and it provide expand & compression motion to the links with the help of translational element.

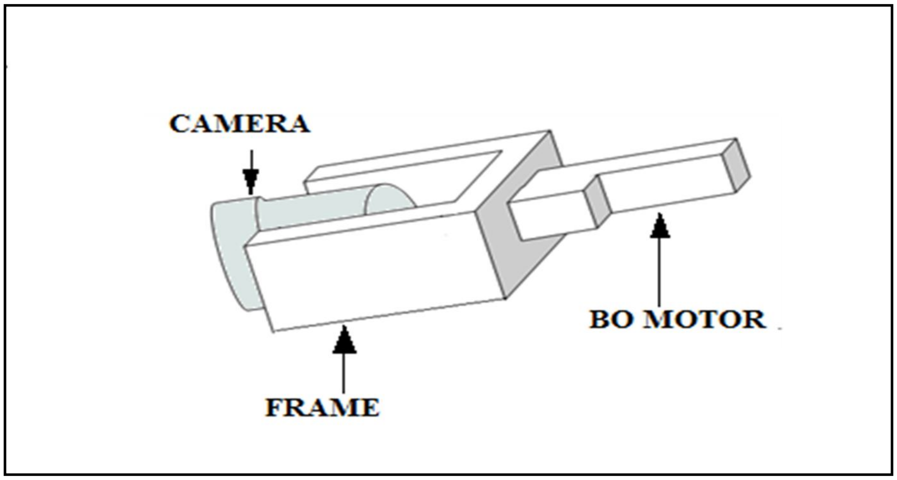
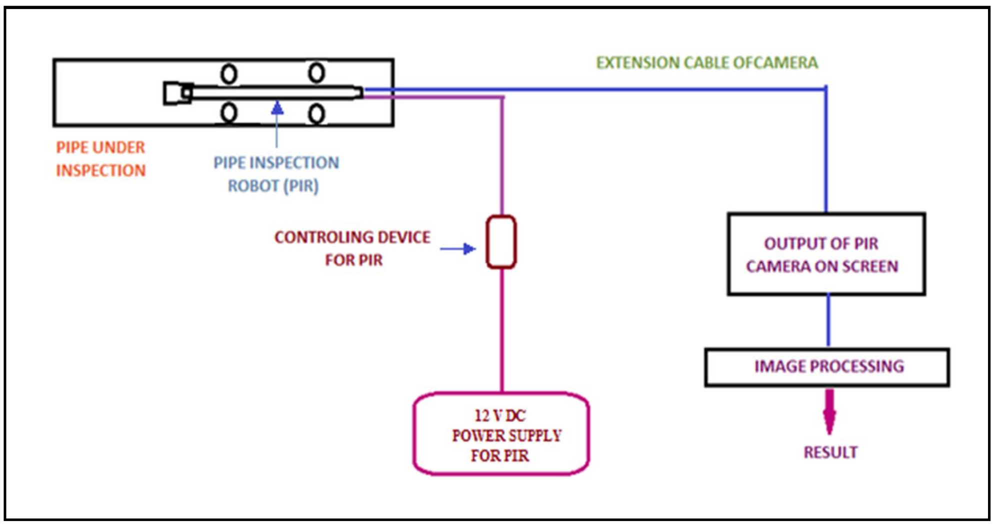


Fig. Camera head

Working:

Pipe Inspection Robot is designed mainly for circular bore pipes, it have ability to move inside any bore diameter pipes ranging from 8 inch to 10 inch (203mm to 254mm). Suitable mechanisms are provided so that it gains ability to move inside the bends and tapered pipes. The PIR have ability to see inside the dark pipes where no human eyes can see. This made possible by mounting the surveillance camera and LEDs on head of the PIACR. The output is sent to outside screen where the digital hi-quality image can be received. Working of PIR is starts from its insertion in pipe. The front three arms are compressed by hand and then inserted in the pipe and then back three arms is inserted by pushing the PIR.



The motors driven are the first six arms mentioned here, they pull whole setup. PIR is about 175 cm in length and to move it freely inside the bend pipes, a 2 degree of freedom joining is provided at the middle so that it can turn easily. As switch is on and current is flowing through wires, wheels start moving and forces PIR to propel forward. Using the friction between wheels and pipe, the motion of wheels become possible.

The robot is run inside pipe by forward and reverse motion of the wheel which has the speed of 10 rpm. This constant slow speed is to insure better inspection because of the high speed there may be possibility to miss the any defect. The camera is tilted by another button provided camera head motion on the remote control. The swiveling of camera can be achieved for 180 degree in addition two 180 degrees for tilting and thus in combination the envelope of 180 degree can be easily seen through the camera. The output image from camera is send to Computer screen which may be laptop, monitor, TV or any such device which gives the visual picture. The camera sends this picture to the output screen with help of extension cable as shown in figure.

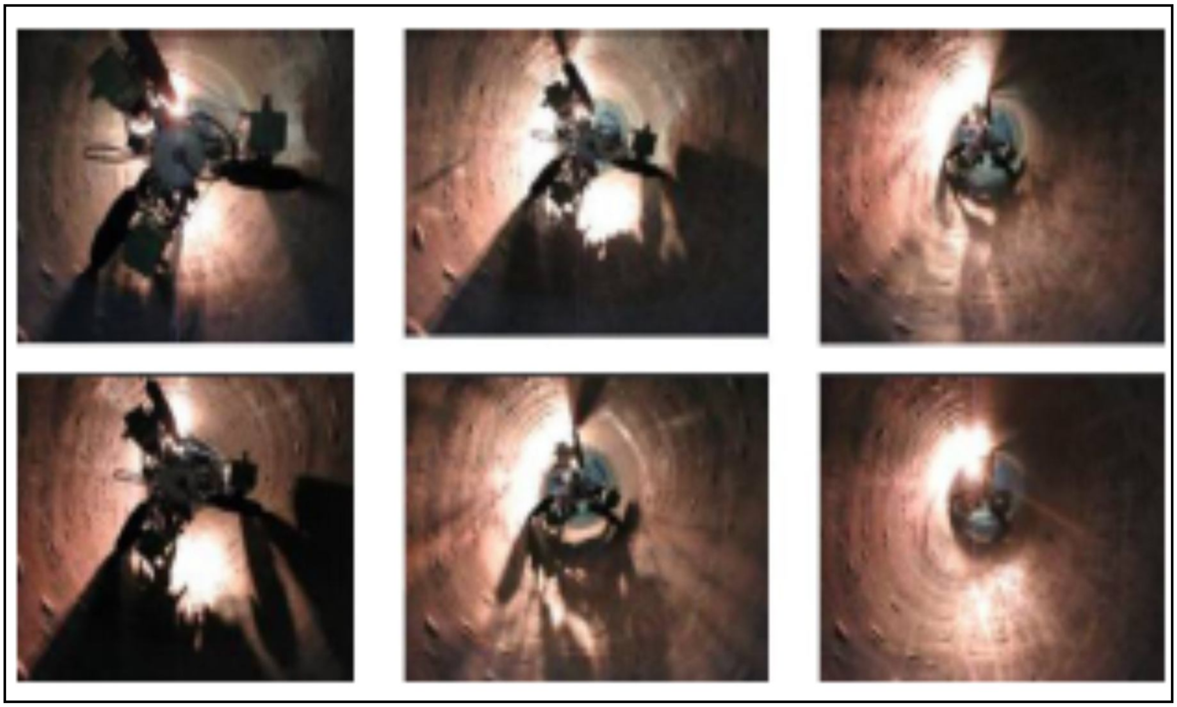


Fig. Picture showing working of PIR inside the pipe

The inspection can be done on the basis of video and pictures inside the pipe provided by camera. The result can be obtained directly on the basis of these pictures or with the help image processing. The various steps required for any digital image processing applications are listed below:

1) Image grabbing or acquisition
2) Pre-processing
3) Segmentation
4) Representation and feature extraction
5) Recognition and interpretation

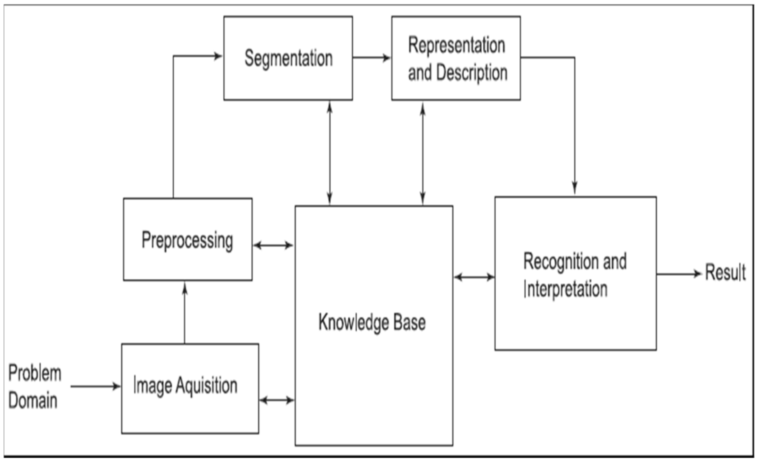


Fig. Image Processing

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V. PROJECT ESTIMATION

Table I
Bill of Materials

SR. NO.	NAME OF MATERIAL	QUANTITY
1.	M. S. round bar	02
2.	Acrylic sheet 1*2 feet	02
3.	Screw	40
4.	Nut	40
5.	M.S. plate	01
6	Sheet metal (pipe) 8 feet	01
7.	D.C. Motor	12
8.	Bo Motor	02
9.	CCD Camera	01
10.	Extension cable of camera	01
11.	Remote	01
12.	Robot wheel	12
13.	10 core wire 15 feet	01
14.	Spring	02
15.	Adapter (12V)	01
16.	Supply wire 10 feet	01
17.	Washer	40

Table II
PROJECT COST

SR. NO.	NAME OF MATERIAL	QUANTITY	AMOUNT
1.	M. S. round bar 12.7mm dia. ×3mm thick	2	60
2.	Acrylic sheet 3mm thick	2	160
3.	Screw 12.7mm	40	20
4.	Nut	40	20
5.	M.S. plate	1	20
6	Sheet metal (pipe) 8 feet×9”	1	1500
7.	D.C. Motor 12v/10 rpm	12	2000
8.	Bo Motor 3v/60 rpm	2	325
9.	CCD Camera 12 mega pixel	1	650
10.	Extension cable of camera 10m	1	150
11.	Remote 3 switch	1	90
12.	Robot wheel	12	480
13.	10 core wire 15 feet	1	150
14.	Spring	2	60
15.	Adapter (12V)	1	450
16.	Supply wire 10 feet	1	30
17.	Washer	40	20
	TOTAL		4800 Rs.

VI. ADVANTAGES AND DISADVANTAGES OF PIR

A. Advantages

1) The pipe inspection robot inspects situation inside the pipe which will be recorded and displayed on the monitor screen, it also facilitates working personnel for effective observation, detection, quick analysis and diagnosis.
2) Save comprehensive investment, improve work efficiency, more accurate detection.
3) Reduce the frequency of entering into the testing environment.
4) Operating cost related to other method is low.
5) Cost of manufacturing of this robot is relatively low.

B. Disadvantages

1) Pipe inspection robots have such limitations as their ability to turn in a T-shaped pipe or move in a plug valve.
2) Another drawback of earlier robots is that the friction between the pipe and the cables for communication and power supply makes it difficult to move a long distance. A fiber optic communication system can reduce the friction.
3) This robot does not work in water.
4) This robot works only in empty pipe.

VII. CONCLUSION

Robots play an important role in inside pipe-network maintenance and their repairing. Some of them were designed to realize specific tasks for pipes with constant diameters, and other may adapt the structure function of the variation of the inspected pipe. In this project inside pipe modular robotic system are proposed. An important design goal of these robotic systems is the adaptability to the inner diameters of the pipes. The given prototype permits the usage of a mini-cam for visualization of the in-pipe inspection or other devices needed for failure detection that appear in the inner part of pipes (measuring systems with laser, sensors etc). The major advantage is that it could be used in case of pipe diameter variation with the simple mechanism. We developed a pipe inspection robot that can be applied to 203mm- 254mm pipeline. A real prototype was developed to test the feasibility of this robot for inspection of in-house pipelines. The types of inspection tasks are very different.

A modular design was considered for easily adapted to new environments with small changes. Presence of obstacles within the pipelines is a difficult issue. In the proposed mechanism the problem is solved by a spring actuation and increasing the flexibility of the mechanism. The robot is designed to be able to traverse horizontal and vertical pipes. Several types of modules for pipe inspection mini robot have been presented. Many of the design goals of the Pipe inspection robot have been completely fulfilled.

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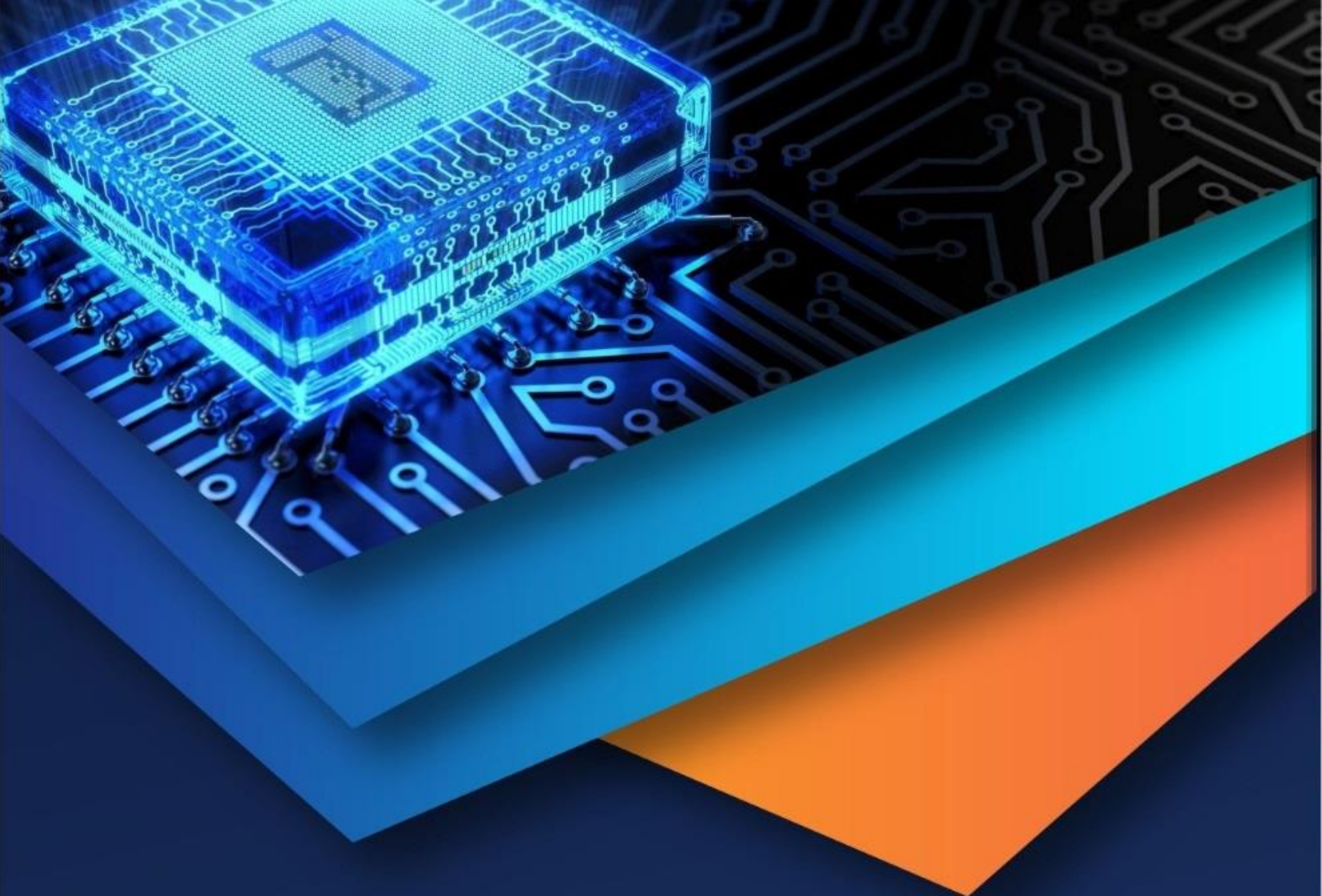

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