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REPTILE (Robot Engineered for Photography and Telemetry in Lame Environments)

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Abstract- **The sewer inspection robot REPTILE (Robot Engineered for Photography and Telemetry in Lame Environments) is a semi-autonomous robot, drivenby wheels. The robot has to be navigated semi autonomouslywithin sewer systems. It's major task is to navigate through sewer pipes and manholes, and to analyze it onboard. Thus enabling the detection of the blocks and cracks inside the pipes. The user can investigate the visuals inside a pipe. The detection of cracks can be done with the help of any customized sewage monitoring software for example, Wincan.**

I. INTRODUCTION

Sewer systems are prone to damage due to aging, excessive traffic, geological change, earthquakes and chemical reactions. In Current conventional methods, the sewer pipe inspection is undertaken using a cable-tethered robot with an on-board video camera system, completely, tele-operated by human operator. All commercial sewer inspection robots have platforms with limited range of working in lame environments. Inspecting the sewage pipes using the state of the arts inspection methods by the current robots is costly, mostly human cost, and not fast enough to check and inspect the amount of sewage pipes will grow stronger than it has actually happened, especially in India. In order to realize inexpensive and effective inspection system, an autonomous pipe inspection method should be introduced to improve the inspection efficiency by reducing the time and manpower in the inspection process. The development of a semi-autonomous pipe inspection system, requires design and development of a mobile robot equipped with the required components for proper pipe assessment and damage detection, and capability of navigating, completely, semi-autonomously inside of sewer networks including different types of pipe-bends such as curves and junctions, REPTILE (Robot Engineered for Photography and Telemetry in Lame Environments) presented in this paper, is the prototype of a passive-active intelligent, semi-autonomous, robot which can effectively used for blockage and crack detection in sewer pipes with diameter greater than 10inch. Reptile prototype robot, including a novel passive-active intelligent moving mechanism, can move into the straight pipe and. In order to realize a semi-autonomous inspection robot, any kind of sewage monitoring softwares can be adopted for the purpose of block and crack detection. The robot is equipped with a hardware structure which is capable of holding a ip66 camera at the middle with which the visuals of the pipe can be seen. It moves with 6 wheels, with 4 on one side (2 wheels diagonally powered). The other two wheels on the other side attached to a scissor lift, hence, with aid of this mechanism, the robot can be made perfectly fit into the circumference of the pipe and such that the camera attached can be made to be fit at the exact centre of the pipe.

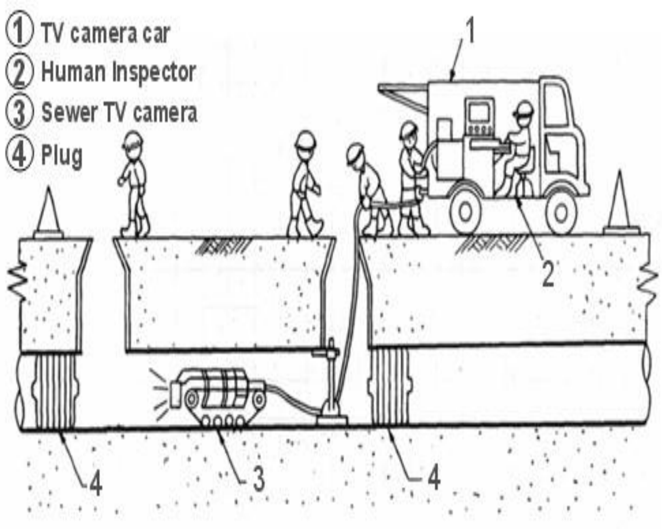


Fig. 1. the inspection of sewer pipes is undertaken using a cable-tethered robot with an on-board video camera system. An operator remotely controls the movement of the robot including a video system

II. GENERAL CONSIDERATIONS

A. Different qualitative degrees of autonomy in sewer robots

The exact definition and description of “autonomy”, related to the sewer maintenance robots, can lead us to compromise what are the necessary required sensors, hardware and computing equipments for developing an fully autonomous mobile robot (described in next sub-section). In general the degree of autonomy in developed inspection pipe robots is classified as follow:

No autonomy: The robot is completely tele-operated, usually via a tether cable, by a human operator. The pipe condition is assessed by the human operator who watches the sensor data (usually video) as the robot drives through the pipe. Mostly all the commercial sewer inspection robots are not autonomous system.

Semi-autonomy: The tethered robot is partially controlled by automatic control programs and modules, or the assessment of the pipe condition is partially performed by sensor data interpretation programs. There is a number of researches and developments of the robots with the semi-autonomous function capability, e.g., “PIRAT” for the quantitative and automatic assessment of the sewer condition [3], “Pipe Rover/Pear Rover” for water filled pipes and ducts developed in 1996 [4], [5], and “KARO” as a cable-tethered carrier for sewer inspection and testing sensory equipment [6], [7].

Full autonomy: The un-tethered robot carries all required resources on-board. Navigation is performed completely by control programs running on on-board computing equipment.

Status messages may be communicated to a human inspector over a radio link. Assessment of the pipe condition may be performed partially on-board, or offline after retrieval of the recorded sensory data. A few research have been done in development of a fully autonomous mobile robot for pipe inspection. “KURT”[8] and “MAKRO”[9] are two robot platforms[1]were designed for autonomous navigation in roughly cleaned sewer pipes with in diameter range of 300 to 600 millimeters at dry weather condition in Germany. KURT with capability of turning at ground level pipe junctions was designed for autonomous navigation in a test field with a specific map data loaded to the robot from start to the goal. MAKRO’s case design, consisting of six segments connected by five motor-driven active joints, allows for simultaneously climbing a step and turning in the pipe junctions. The goal of the MAKRO project was to prove that a robot is able to navigate completely autonomously inside sewer pipes under the above mentioned condition.

[1] Using the term “platform” means to emphasize the fact that the respective systems do not include sensors for finding damages or assessing the pipe state, but just sensors to warrant their safe navigation and control. Such pipe-related sensors maybe be implemented on autonomous platforms.

The degree of development of complete autonomous sewer robots presently does not warrant to use them safely and robustly in sewers. Most of these robots have a complex moving mechanism and multi-sensor equipment for navigation and motion control. These complexities in mechanism and data processing make not easy to realize reliable commercial products specially for small range of the pipes up to 300 millimeter in diameter.

B. Difficulties of developing a fully autonomous inspection mobile robot

Fully autonomous sewer robots must include sensors for their own control, navigation and localization, not only those for sewer state assessment and damage detection. In addition, localization is an issue not only for the proper robot control, so that the robot knows where it is, but also for inspection, as detected damages have to be reported with their location. In this concept, navigation and localization for the sewage inspection robots, as a whole, can be classified in two main groups: “Motion-Navigation” used for control of robot locomotion and “Fault-Navigation” applied for reporting the location of happened faults in the pipe interior. Consequently, the robot sensory system should be consisted of three groups of sensors: inspection sensors for gathering the pipe state information, sensors for Fault-Navigation, and sensors using in Motion-Navigation. The sensors used for motion-navigation may overlap with the inspection sensors (e.g. a camera may be used for both motion-navigation and damage detection). Motion-navigation sensors, mostly, should mounted in the front side of the robot that it makes complex design to avoid the overlapping of their workspace with the workspace of sensors using for inspection and fault navigation. As a summary, the necessary requirement to design a fully autonomous inspection mobile robot can be itemized as follows:

1) An un-tethered robot must carry *all required resources on-board*.
2) *Motion-Navigation* must be performed completely by control programs running on on-board computing equipment.
3) *Assessment of the pipe condition* and *Fault-Navigation* may be performed partially on-board, or offline after retrieval of the recorded sensory data.
4) Status messages may be *communicated to a human inspector* over a radio link.

All the necessary hardware, robot platform, sensors, and computing equipment should be designed and selected based on the above requirements satisfaction.

Hence, Reptile is made to be semi-autonomous as to reduce the effective cost of production.

III. REPTILEARCHITECTURE

REPTILE is designed as a SEMI-autonomous, un-tethered robot, which fits to the pipes above diameter of 3inches. REPTILE's semi-autonomy and its kinematic abilities extend its potential mission range enormously, comparing to conventional inspection equipment

Fig2: Vehicle movement at bending of pipe

that is limited by the cable and poor kinematics. REPTILE carries all the necessary resources on-board. Standard lithium polymer batteries provide the power for its 4 motors, the sensors, the light and electronics, including a developed computer system and an optical underground wireless communication module, allowing for an autonomous up time of about one hour. To realize a reliable, robust robot and an easy maintenance system, REPTILE is designed to have a complete modular architecture in its mechanic, hardware and software. REPTILE, consists of two main modules: Bottom, SCISSOR lift mechanism and Upper box modules. Bottom box and a battery pack, can be presented as a robot platform. Electronic boards, the sensors and light are installed in upper box which be connected via the main connector to the bottom box. In addition, REPTILE has IP66 waterproof standard that it achieved by waterproof design of REPTILE's modules including the upper and bottom box, motor boxes and battery pack.

A. *Platform of working*

The REPTILE is made on arecatangular metal frame with 4 wheels. In order to reduce the size of the robot, two motors are used, each being on either side making it diagonally powered. Diagonal power not only reduces the width of the frame but also enables REPTILE to tackle situations where only one (either front or back) tyres gets obstructed by sewer conditions. It is also connected with two other wheels along a scissor lift mechanism. A scissor lift comes into play, as it helps to customise the size of the robot, so as to fit the robot exactly into smaller pipes and also to act against the pressure of water flow against its motion. Motors of considerable stall torque can be used for this purpose.

B. *Scisssor lift*

Scissor lift is a mechanism introduced primarily to adjust the height of the camera module within various pipe dimensions. It enables the camera to stay along the axis of pipe of any given diameter. Maintaining the camera at the axis is a important factor when the image processing comes into play. On top of the scissor lift, there are two extra wheels that can support at the inner top side of the pipe to hold the REPTILE steadily and securely against any flow inside the pipe or any other abruptions that can restrict its movement. Scissor lift is basically made of two rectangular shaped channel pieces connected with each other in the middle so as to form a scissor like mechanism. Enabling a horizontal movement on one side of one rectangular piece while fixing the other side of the second rectangular piece will cause the free sides of both rectangular pieces to rise into air. Both free ends are joined together to form a base upon which camera module can be fixed. Thus the camera can be raised to desired height as required. Fixing a pair of tyre on the top base will enable further locking of the REPTILE to the top of the pipe as mentioned earlier.

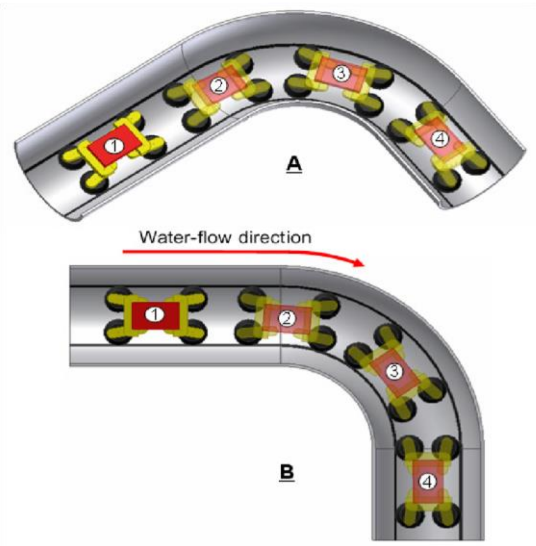
C. *Mode of commuinication*

REPTILE uses wired connection for communication. This ensures the interference less transmision of data and power. Data from video camera is transmitted through cat5 (ethernet) cable in digital format. This video is acquired on a computer which is imported into particular analysis software. Required power is given to all the motors via direct DC connection from a 12V battery fixed outside. Using wired connection has another advantage which is the elimation of a digitial tachometer. Distance can measured on wire and the distance moved by the robot inside can calculated easily.

D. *Specifications*

Specifications of REPTILE include :

1) Main motor: 60 rpm brushless Dc motor with 32 kg stall torque and 10000rpm base motor.



2) Camera motor: 10rpm side shaft plastic motor with plastic gears and 5 kg stall torque
3) Scissor lift motor: 30rpm dc brushless, 12kg stall torque and 1000 base motor.
4) Camera: 720p IP66
5) Transmission cable : Cat 5 cable
6) Power cable: 120mm copper wire

E. *Software*

A convienient pipeline inspection software can be used to acquire and process the incoming video to produce the required output. This video can be used to analyse the conditon inside the pipes and take sufficient measures accordingly. A typical example of this type of software is wincan. Wincan has the capability to import data, section by section from the video and create logs and files accordingly. Wincan can also be used to create a 3d view of the pipe by combining all the incoming images. This 3d view can be very helpful as it will help in the easy analysis of each section. Cracks can be detected and marked in the software which also records distance at which the particular crack has occurred. Since this is using a manual method to analyse cracks, there is very less chance of false detection.

IV. CONCLUSION

In this paper we proposed an innovative, fast and robust sewer inspection method by using a passive-active intelligent, semi autonomous robot, called “REPTILE”, which can effectively used for blockage and crack detection in sewer pipes with diameter greater than 10inch. Reptile prototype robot, including a novel passive-active intelligent moving mechanism, can move into the straight pipe and. In order to realize a semi-autonomous inspection robot, any kind of sewage monitoring softwares can be adopted for the purpose of block and crack detection. The robot is equipped with a hardware structure which is capable of holding a ip66 camera at the middle with which the visuals of the pipe can be seen. It moves with 6 wheels, with 4 on one side (2 wheels diagonally powered). The other two wheels on the other side attached to a scissor lift, hence, with aid of this mechanism, the robot can be made perfectly fit into the circumference of the pipe and such that the camera attached can be made to be fit at the exact centre of the pipe.

We still have to perform further experiments in real world sewer pipe network with different in size and state pipe condition. Improving the offline fault detection software to get high accuracy is on the future work.

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