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Oil Pipelines/Water Pipeline Crawling Robot for Leakage Detection/Cleaning of Pipes

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Abstract- **Drive control system plays important roles in pipeline robot. In order to inspect the flaw and corrosion of seabed crude oil pipeline, an original mobile pipeline robot with crawler drive unit, power and monitor unit, central control unit, and ultrasonic wave inspection device is developed. Considering the limited space, a compact hardware system is designed based on an ARM processor with controllers. With made-to-order protocol for the crawl robot, an intelligent drive control system is developed. The implementation of the crawl robot demonstrates that the presented drive control scheme can meet the motion control requirements of the underwater pipeline crawl robot.**

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I. Introduction

Robots have become important over a wide range of applications--from manufacturing, to surgery, to the handling of hazardous materials. Consequently, it's important to understand how they work, and what problems exist in designing effective robots. A robot is an automatically guided machine which is able to do tasks on its own, almost always due to electronically-programmed instructions. Mobile robots have the capability to move around in their environment and are not fixed to one physical location. This project presents a dynamic model for a novel pipeline robot which obtain sits power from *12V* battery. The robot is designed to move both against and with the flowing fluid, which makes it different from conventional solutions, which can only move with the flowing fluid. This bidirectional capability makes it very valuable to many industries, especially the oil and gas industries. This robot includes several novel mechanical features, including novel designs for its chassis and, energy-dense power transmission to enable high-speed crawling.

Industrial ductwork has been widely used in metallurgy, petroleum, chemical engineering, water supply and other special professions. The formidable work environment makes pipelines easy to be eroded or fatigued which can lead to leaking accident, so the periodic maintenance and overhaul are necessary for industrial pipelines. Absence of fresh air makes it Impossible for humans to perform maintenance task.

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As maintenance of these pipelines is nearly impossible from outside we need a machine that can crawl inside these long pipes. The crawling robot can be wirelessly steered into the long pipelines. The embedded cameras will use the complete inside picture of a long pipeline, which would help us, detect and fix the leakages or any other technical problems. The above Robot can also be used for cleaning of the pipelines.

Currently, in-pipe robot with tether, which enables the robot to have the enough energy supplies and promptly make up the power loss, still has important application value owing to avoid carrying heavier energy devices, but the noticeable friction forces of tether restrict the traction force of robot, locomotion distance away from entrance, and the steering inside pipelines with elbows. Therefore, the development of autonomous in-pipe locomotion robot without tether becomes urgent, such that the robot can be adaptive to the work of long and complicate pipeline.

One of the key techniques to develop in-pipeline locomotion robot is electrical drive. More driving spots, more flexible action, lower power consumption and other special requirements are making the motor driving technique very challengeable. Based on simulation prototype of in-pipe robot driven by wheels for inspection the inner surface of seabed pipelines, this project focuses on the drive control system of its engineering prototype without tether, including design drive control system based on engineering requirements, hardware design of the control system, intelligent crawling control and experiments.

II. Objective

Although the appearance and the capabilities of robots vary vastly, all robots share the feature of a mechanical, movable structure under some form of control. Designing a robot chassis will be the first objective of this project. The Control of robot involves three distinct phases: - perception, processing and action. Generally sensors/or command receivers are preceptors mounted on the robot, processing is done by the on-board microcontroller, and the task is performed using motors or with some other actuators. We need to design a wireless circuit which helps robot climb on the pole, can be controlled using wireless technology like RF technology. We need to design a controller and a power transmission system. We also need to design a wireless video transmission system.

III. Motivation

The making of a pipeline crawling robot and planning its responses against the signals captured from its onboard video camera supposes an excellent incentive for student's learning. The observe defect is that once the problem is stated, the student himself sets out challenges to surpass his talent and abilities in order to expand the robot with new sensors and actuators that may improve its behavior.

Compared to other conventional mobile robots used for teaching, Oil pipeline crawling robot incorporates sophisticated and diverse elements, to design the circuit, chassis and remote control via cable or via RF. It is a complete package for learning in the design of hardware-software systems, including the design of communication interfaces, adapters, power circuits, signal transmitters etc.

IV. Project Overview

For years, engineers and owners of pressurized pipelines have been seeking better ways to monitor the condition of buried pipes. In lieu of exposing pipes for inspection, pipeline owners have used various types of remotely controlled probes, cameras, and other devices to obtain information about underground pipes. The oil and gas industries have largely led the charge, driven by regulations and risks associated with catastrophic failures and explosions.

Recent developments indicate that petroleum industry techniques can be tailored for municipal applications, such as water distribution pipelines. Robotic systems are offering new capabilities in obtaining real-time data, capturing the attention of budget-conscious owners of aging infrastructure systems. The July explosion of a steam pipeline in New York City provided a wake-up call that buried utility pipes cannot be considered out of sight, out of mind.

Here we designed a robot that can be used for analyzing the conditions of the pipelines and clean them if required. The main components used in this are: DC motor, motor driver, RF transmitter& receiver, 12V battery .Basically, the robot is controlled by a RF based remote that send RF signals to the receiver i.e. installed on the robot.

Our prototype of 'Pole Climbing Robot' has the capability to move inside the pipes and perform the desired task smoothly. For moving inside pipes, robot wheel based chassis is developed. Enough pressure should be applied on wheels to create sufficient friction to hold the robot on its place.

V. Description of Working

The major concepts/components used in this project are RF technology, motor driver, Chassis-designing, power circuit and power transmission etc. We designed an RF based control system to control Robot. The signal get generated and transmitted with the help of antenna, provided on it. Now the receiving section which we already installed on the robot will receive the signals and send the received signals to the motor drive, on the basis of which motor driver will drive the robot and robot climb on the pole.

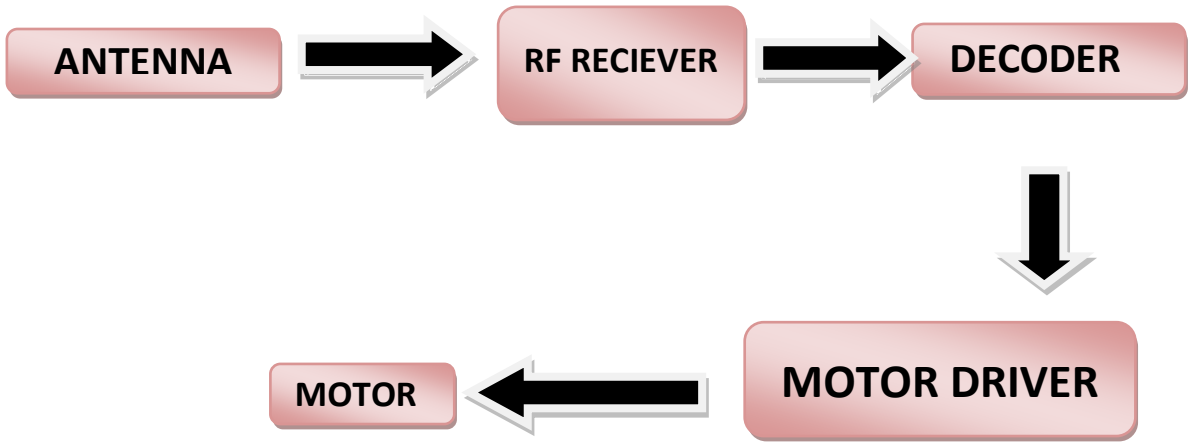
Radio Frequency is a flexible technology that is convenient, easy to use, and well suited for automatic operation. It combines advantages not available with other technologies. It can be supplied as read-only or read/write, does not require contact or line-of-sight to operate, can function under a variety of environmental conditions, and provides a high level of data integrity. In addition, because the technology is difficult to counterfeit, RFID provides a high level of security. Radio waves transfer data between an item to which an RFID device is attached and an RFID reader.

The device can contain commands for robot. RF technology uses frequencies within the range of 50 kHz to 2.5 GHz. An RFID system typically includes the following components:

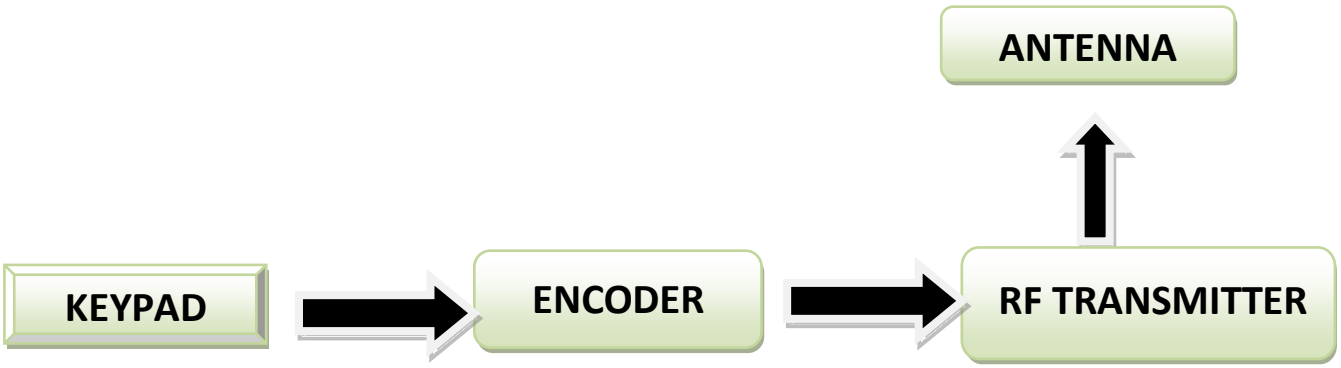
- An RF devices (transponder or tag) that contains data about an item/location
- An antenna used to transmit the RF signals between the reader and the RFID device
- An RF transceiver that generates the RF signals
- A reader that receives RF transmissions and passes the data to a host system for processing. To control robot a remote is designed which has a number of switches on its control board. As soon as you press any button it transmits signals that are received by receiving section then it decodes it and on the basis of signals, motion takes place in the robot like forward, backward. Robot receives this signal with the help of antenna present on the head of the robot.

VI. Block Diagram

➢ *Device:*



➢ *Remote Control:*



VII. Description

The constructed robot is designed in such a way that it can move in pipe very efficiently having a given range of diameter. The robot is RF controlled. The complete working of RFI based system can be divided in the following blocks for easier understanding:

a) Components list

- HT12 E
- HT12D
- L293D
- DC MOTOR
- RF MODULES(434 MHz)

i. *RF Transmitter Unit*

This 4 bit data is essentially a RF transmitter that transmits encoded signals. It can be further classified into following parts:

❖ *DATA 4 bit through switch*

This part is unique for every RF. It creates a 4-bit data that is used to identify when the data is read by RF reader.

❖ *ENCODER*

This part converts the data into an encrypted data that can be transmitted over RF channels. The encoder used here is HT12E which can be used to encrypt 4 bit data. The encrypted data is a serial digital signal.

❖ *TRANSMITTER*

This part takes the encrypted data from transmitter and transmits it in form of Radio Frequency. The transmitter used here is ASK 434 MHz RF-TX modules.

❖ *POWER SUPPLY BLOCK*

This consist a 12V power supply source and a power regulator (7805) to get 5v power supply. This 5v supply drives the transmitter and the encoder.

ii. *RF data RECIEVER*

This reader is basically a RF receiver that receives encoded signals decodes them and. It can be further classified into following parts:

❖ *RECIEVER*

It receives the encrypted data in form of RF waves and converts it into electronic signals. The receiver used here is ASK 434 MHz RF-Rx modules.

❖ *DECODER*

This part decrypts the data to yield the 4-bit data. This data is fed into the circuit. HT12D has been used here which is compatible with HT12E module. The output is the 4 bit data format.

❖ POWER SUPPLY BLOCK

This consist of a 12V power supply source and a power regulator (7805) to get 5v power supply.

b) Component Details

i. *RF Module*

Radio Frequency Module is an integral part of boarder security system together with a control module or unit and an antenna it is used for wireless identification. Main tasks of the RF module are to send an energizing signal via the antenna. The RF module delivers a digital data stream and a clock signal for further processing to its control unit or module.
Furthermore a field strength dependent digital output is available for synchronization purposes. The RFM is tuned to resonance with the antenna by adjusting the inductance of the tuning coil at the RFM's output stage.
RF Module can be categorized into two parts:

- Transmitter
- Receiver

a. TRANSMITTER

This wireless data is the easiest to use, lowest cost RF link we have ever seen! Use these components to transmit position data, temperature data, and even current program register values wirelessly to the receiver. These modules have up to *500 ft range* in open space. The transmitter operates from 2-12V. The higher the Voltage, the greater the range - see range test data in the documents section. We have used these modules extensively and have been very impressed with their ease of use and direct interface to an MCU. The theory of operation is very simple. This is an ASK transmitter module with an output of up to 8mW depending on power supply voltage. The transmitter is based on SAW resonator and accepts digital inputs, can operate from 2 to 12 Volts-DC, and makes building RF enabled products very easy.

Features

- 434 MHz Transmitter Operation
- 500 Ft. Range - Dependent on Transmitter Power Supply
- 2400 or 4800bps transfer rate
- Low cost
- Extremely small and light weight

b. RECEIVER

This receiver type is good for data rates up to 4800bps and will only work with the 434MHz transmitter. Multiple 434MHz receivers can listen to one 434MHz transmitter. This wireless data is the easiest to use, lowest cost RF link we have ever seen! Use these components to transmit position data, temperature data, even current program register values wirelessly to the receiver. These modules have up to 500 ft range in open space. The receiver is operated at 5V. We have used these modules extensively and have been very impressed with their ease of use and direct interface to an MCU. The theory of operation is very simple.

Features

- 434 MHz Operation
- 4800 bps transfer rate
- Low cost
- Extremely small and light weight

ii. *MICRO SWITCH*

A micro switch, also known as snap-action switch, is a generic term used to refer to an *electric switch* that is actuated by very little physical force, through the use of a tipping-point mechanism. They are very common due to their low cost and durability, greater than 1 million cycles and up to 10 million cycles for heavy duty models. This durability is a natural consequence of the design. Internally a stiff metal strip must be bent to activate the switch. This produces a very distinctive clicking sound and a very crisp feel. When pressure is removed the metal strip springs back to its original state. Common applications of micro switches include the door *interlock* on a *microwave oven,* leveling and safety switches in *elevators, vending machines,* and to detect paper jams or other faults in photocopiers. Micro switches are commonly used in tamper switches on gate valves on fire sprinkler systems and other water pipe systems, where it is necessary to know if a valve has been opened or shut.

The defining feature of micro switches is that a relatively small movement at the actuator button produces a relative large movement at the electrical contacts, which occurs at high speed (regardless of the speed of actuation). Most successful designs also exhibit *hysteresis,* meaning that a small reversal of the actuator is insufficient to reverse the contacts; there must be a significant movement in the opposite direction. Both of these characteristics help to achieve a clean and reliable interruption to the switched circuit.

The first micro switch was invented by *Peter McGall* in 1932 in *Freeport, Illinois*. McGall was an employee of the Burgess Battery Company at the time. In 1937 he started the company MICRO SWITCH, which still exists as of 2009.

The company and the *Micro Switch* trademark have been owned by *Honeywell Sensing and Control* since 1950.The trademark has become a widely used description for snap-action switches. Companies other than Honeywell now manufacture miniature snap-action switches.

Micro switches are applied in appliances, machinery, industrial controls, vehicles, and many other places for control of electrical circuits. Micro switches are usually rated to carry current in control circuits only, although some switches can be directly used to control small motors, solenoids, lamps, or other devices. Micro switches may be directly operated by a mechanism, or may be packaged as part of a pressure, flow, or temperature switch, operated by a sensing mechanism such as a *Bourdon tube*. A motor driven cam and one or more micro switches form a timer mechanism. The snap-switch mechanism can be enclosed in a metal housing including actuating levers, plungers or rollers, forming a *limit switch* useful for control of machine tools or electrically-driven machinery.

iii. *MOTOR DRIVER*

Here we used L293D to drive the motors. whatever signals it receives from the on the basis of that it will drive the motors.

a. DC MOTOR

A direct current (DC) motor is a fairly simple electric motor that uses electricity and a magnetic field to produce torque, which turns the motor. At its most simple, a DC motor requires two magnets of opposite polarity and an electric coil, which acts as an electromagnet. The repellent and attractive electromagnetic forces.

VIII. Background of the Robot and Hardware Design of The Control System

a) Introduction of the crawling robot

In order to inspect the seabed petroleum pipelines of Oil Field, a robot is developed. The overall length of pipeline is long range, and the inner diameter of the pipe is greater than 8 inches. In order to locate the pipe defects, the inspection process is divided into two steps: firstly, the oil differential pressure drive type and the supersonic inspection principles are utilized to realize the on-line inspection; secondly, based on the information of first step, using the in-pipe robot completes the real-time localization inspection. This project is belonged to the second step, and the main technique indexes are:

- Normal crawling speed is optimum.
- Driving wheels can adapt to various diameters of the pipelines automatically.
- The robot can operate in water with 2MPa pressure safely.

Based on the design indexes, motors and their drivers should be smaller and better performance. As shown in Figure 1, the in-pipe robot inspection system contains ten units, including crawler unit, drive unit, central controller unit, battery unit and ultrasonic inspect unit, etc. The drive control system receives motion commands and drives the robot forward and backward. The magnets provide the torque that causes the DC motor to turn.

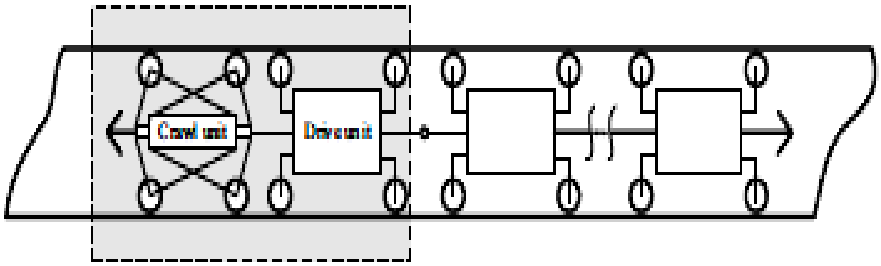


Figure 1 : Overall structure of the in-pipe craw1 robot

b) Hardware design of the control system

The control system has an advantages of high communicating efficiency, reliable, stable, and easy to set up, which makes it feasible to the 4D (Dull, Dirty, Difficult and Dangerous) workplace like in-pipe inspection. Considering space limitation and low energy cost, an ARM processor. The drive control system is shown in Figure 2. In order to realize the locomotion control of the robot, the peripheral AD, DA, DI and DO are designed to control the motors. Real-time current detection for the motors guarantees the safe operation of the motors and intelligent motion control of the robot.

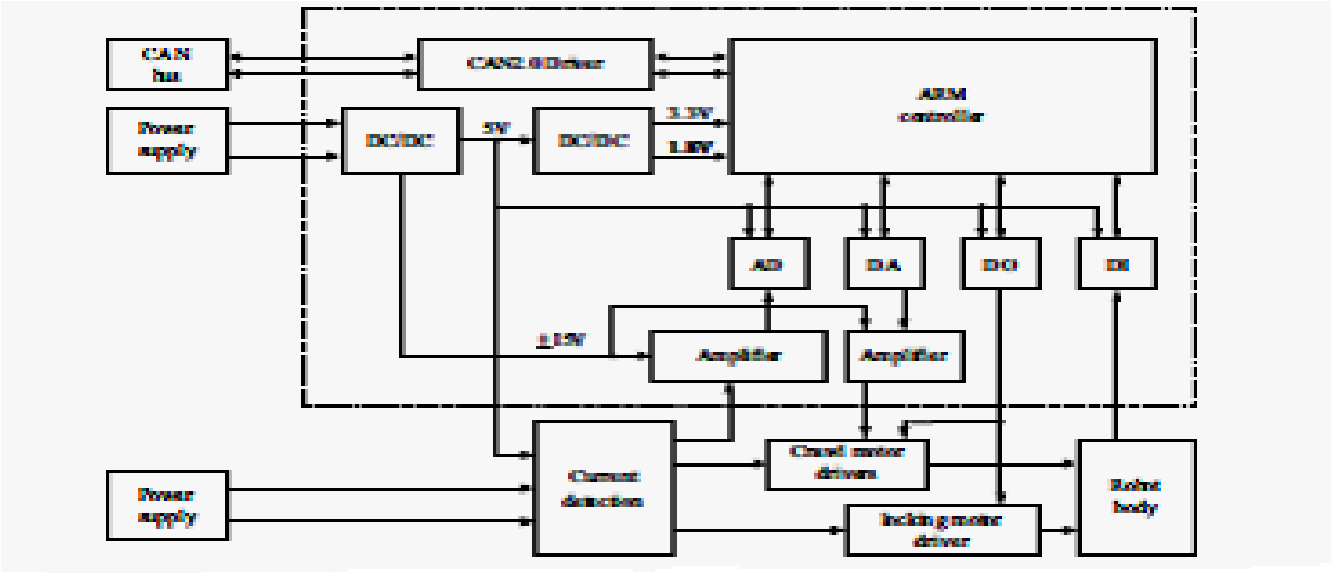


Figure 2 : Hardware connection of control system

c) Crawling control

The fundamental function of crawling control system is communication between crawling units and central controller. Generally, crawling drive unit executes the command from central controller and reports its operational results in time. The software of drive control system is developed with ADS1.2 and mainly consists of CAN communication, locomotion control, and current detection. Figure 3 shows the workflow of drive control of the robots.

- CAN communication: When the system is electrified, drive control system begin self-testing, and successful self-testing result will be reported to the central controller which means the following work can run, otherwise system default. Among the following work, drive control system will keep communicating with other nodes to guarantee its teamwork.
- Locomotion control: Locomotion control is the key job of drive control system. Actions of the robots include locking, unlocking, micro-locking, micro-unlocking, crawling forward, crawling backward, pause crawling, stop crawling, accelerating and decelerating. The locking state of the mechanism is related to the maximum drive force, so the micro-locking is designed to insure the best locking of the mechanism. After the successful locking of the mechanism, drive control system will carry out the appropriate locomotion. Among the crawling job, soft start-up, slope speed setting, and soft stoppage are considered to make the motion more reasonable.
- Current inspection: Current detection for locking motor is helpful to realize the best locking gesture, protect motors, and achieve the three crawl modes, namely, unification drive mode, grouping drive mode and independent drive mode. The three drive models are design to make the robot adapt to the straight, curved and slope pipelines.

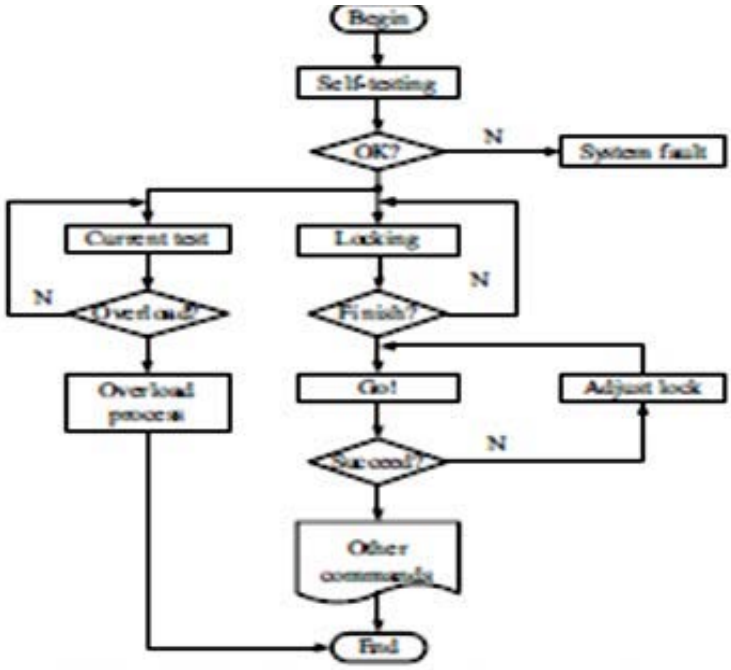


Figure 3 : Workflow of the crawling control

IX. Applications

This locomotion can be used in various applications; some of them are as follows:

- Pipeline maintenance work
- Fixing of any leakages
- Cleaning of the pipelines
- Maneuvering in hazardous environment

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