AN ULTRASONICALLY CONTROLLED ROBOT SUBMERSIBLE FOR PIPE INSPECTION

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1. INTRODUCTION

State of the art pipe inspection devices are generally four wheeled, camera carrying, umbilically controlled, motorised carriages that are mainly constructed from brass (specific gravity » 8) and hence are much more dense than the watery environment in which they operate. This property gives them good stability and grip and the ability to be largely unaffected by the umbilical which is trying to upset the stability of the tail of the carriage. These carriages are fed into a pipe, and actuation power and signals are passed down the umbilical to control the travel of the carriage. Mounted on the carriage are a TV camera and lights which illuminate the inside pipe wall. The signals from the TV camera are relayed along the umbilical to an operator. An umbilical management system is used to feed the umbilical in or out in response to the carriage movement, so as to minimise the force between the carriage and the umbilical.

It is the object of the robot submersible described here to eliminate the requirement of an umbilical. This will increase the manoeuvrability of the submersible and decrease the system cost, because the umbilical management system has a significant cost. However, these advantages present new challenges and problems. For example, the umbilical can be used to retrieve the submersible if control is lost. So there must be a retrieval contingency plan for the submersible without an umbilical. Another problem to solve is the transmission of the wide bandwidth TV signal from the submersible to the operator. Also, instructions and data must be reliably transmitted down water filled pipes with changes of sections and bends. Ultrasound is used because radio waves cannot penetrate sea water, due to its high conductivity. However, the submersible described here can be controlled by radio waves, since low conductivity tap water is used for the floating medium.

2. OVERVIEW OF ROBOT SUBMERSIBLE SYSTEM

It is the intention of the authors to build an inspection submersible that will operate in a water filled pipe of 500 m in length and approximately 1 m in diameter. However, before this objective is achieved, a stepping stone is required. The pipe test rig shown in Fig. 1 serves as this stepping stone. The pipe is 4 m in length and 300 mm in diameter, with two, open top, end tanks, which serve as access points. The pipe and end tanks are made from transparent acrylic, which allows the submersible to be easily seen whilst operating in the pipe. An ultrasound transmitter is mounted at one end of the pipe test rig. The transmitter is a piezo-electric transducer and transmits data using an amplitude modulated 1 MHz carrier frequency.

Fig. 2 illustrates the robot submersible layout. The presently constructed submersible only possesses the receiver (Rx) circuit and the two pairs of legs. The other systems shown will be added in due course. The two buoyancy tanks are independent and, if driven in sympathy, will raise or lower the depth of the submersible. If driven differentially, the tanks will cause pitch up or pitch down attitude change. The rotating mass causes the submersible to roll about its longitudinal axis. It will be possible to invert the submersible, such that the wheels and leg modules can be used to either walk or drive on the pipe floor, or walk or drive on the pipe ceiling. A TV camera mounted in the nose of the vessel will be used to transmit back pipe inspection pictures. Two d.c. motor driven propellers mounted in the rear of the submersible cause forward, reverse and yaw motion by being driven in sympathy or dif-

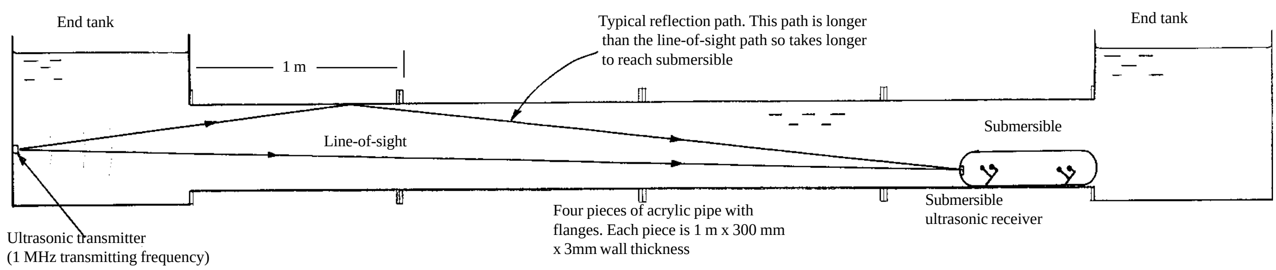

Figure 1: Pipe test rig layout

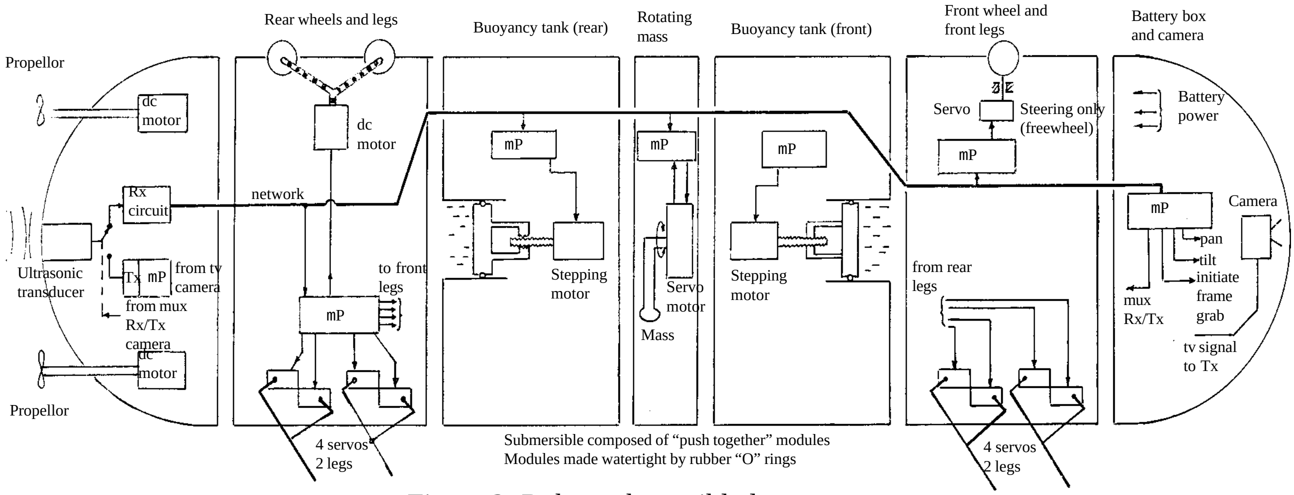

Figure 2: Robot submersible layout

ferentially. Basic Stamp microcomputers [1] are networked together and control individual systems.

3. DESCRIPTION OF ULTRASOUND COMMUNICATION

Fig. 3 shows the ultrasound transmitter. The transmitter produces a series of encoded 1 MHz bursts which carry the serial data in a form suitable for ultrasonic transmission. Reference to Fig. 4 shows the action of the receiver. The ultrasonic communications system is based upon work previously published [2,3,4,5]. The received signal is first amplified and then passed through a comparator to remove the noise. Finally the signal is passed to a retriggerable monostable multivibrator which reconstructs the initial serial data from the transmitter. The signal is now placed on a single wire network which addresses a plurality of Basic Stamps. Note that the Basic Stamps will only accept data if their own name is called out on the network. An individual name is given beforehand to each Basic Stamp by downloading it into its EEPROM memory.

4. DESCRIPTION OF LEG OPERATION

The robot possesses four legs. Each leg has two degrees of freedom and two model aircraft servos are used to actuate each leg. Four servos are mounted together in one block to actuate one pair of legs. The resulting eight servos are controlled by a Basic Stamp II microcomputer which is connected to the submersible network. Three gaits have been devised. These are:

(i) galloping horse gait, in-phase; all legs move together in synchronism clockwise through a foot locus. For reverse motion the legs still move in synchronism but in a counter clockwise direction. This gait moves the submersible at half its potential speed but

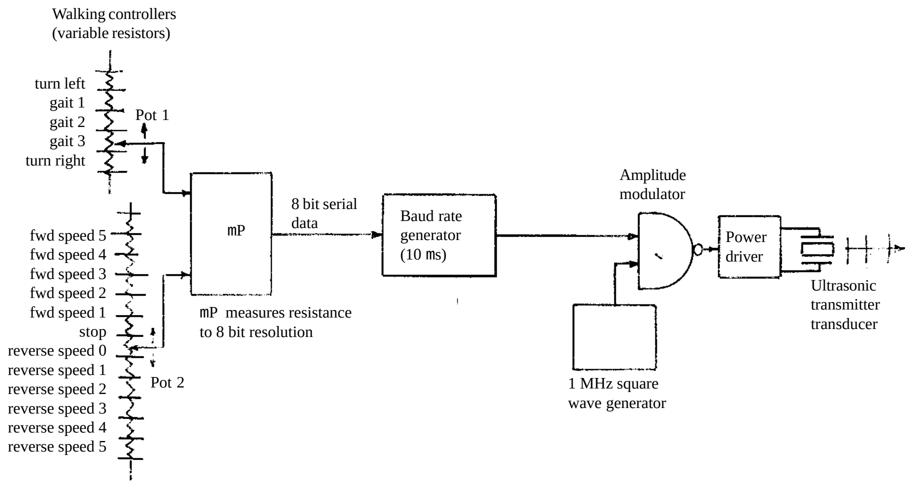

Figure 3: Ultrasonic transmitter (Tx)

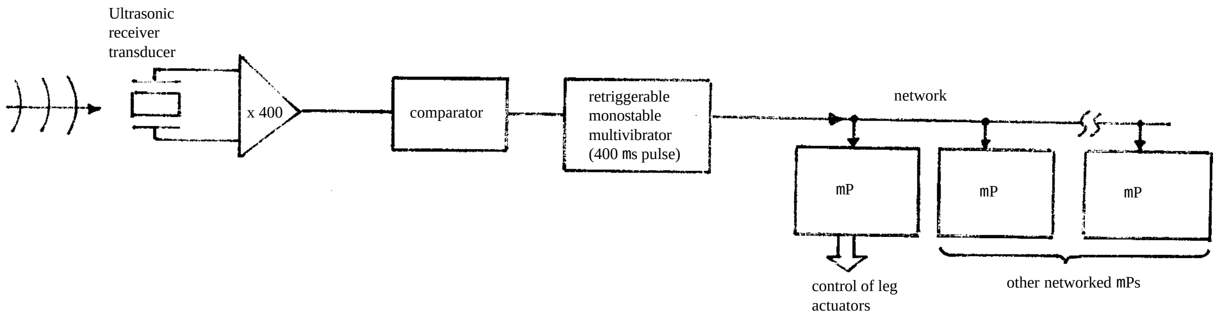

Figure 4: The ultrasonic receiver (Rx)

has full tractive effect.

(ii) Galloping horse gait, out-of-phase; same as (i) but the rear pair of legs lags the front pair by 180°. This gait moves the submersible at its full potential speed but only half of its potential tractive effort.

(iii) Diagonal dog gait; one pair of diagonally opposed legs are driven synchronously and the other pair of diagonally opposed legs are driven synchronously but lags the first pair by 180°. This gait is similar to (ii) but gives smoother motion.

The submersible can turn left and turn right by driving the left legs in synchronism and the right legs in synchronism but the left side moving forward (or backwards) and the right side moving backwards (or forwards).

5. RESULTS AND FUTURE WORK

The ultrasonic communication system works well in the pipe test rig under laboratory conditions but more work must be done for longer pipes with bends. The Basic Stamp microcomputers are very good devices for autonomous robots. The leg software needs to be improved to use the Basic Stamp on-board EEPROM to store the servo angles. This will give an improved foot locus and give faster response to the operator's commands. A mechanical cam system should be considered at a later date to drive the legs.

The submersible is data reception sensitive to the angle at which the ultrasonic wave strikes the transducer. Hence work must be done to permit the submersible to work freely whilst aaalways receiving data. A pipe system will be constructed which is a few hundreds of diameters long and which has bends, branches and changes in section. This pipe system would serve to evaluate tranmission of data using ultrasonics.

6 REFERENCES

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