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DESIGN IMPLEMENTATION AND CONTROL OF FISH LIKE ROBOTS

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Abstract: **Fish robots are widely used in the fields of underwater development, examination and environmental protection. Usually fish robots have various kinds of components such as accelerometer, depth sensor, magnetic compass, distance measuring sensor and processor circuits. In this paper we present an approach to design, implementation and control of fish like robots. All of the circuits, actuators, and processor cards are contained in a typical structure of 25x15x10 cm dimension except of fins and external covers. The swimming experiments are performed in a water tank of 240x120x120 cm where the side walls and the objects make of white board are considered as obstacles. The experiments results show the successful of fish robots remotely control by passing through differences kind of swimming paths without hitting obstacles.**

Keywords *– Fish Robot, Microcontroller, DC Motor, Servo-Motor, RF Module, Remote Control*

I INTRODUCTION

Fish robots are underwater robots and submersibles that emulate locomotion of live fish through actuated fin and/or body movements. They are increasing importance due to their potential applications such as aquatic environmental monitoring and robot-animal interactions. Many research ware done about fish robots. Most of them are related to swimming mode, control performances, obstacles identification and collision avoidance. Several kinds of sensors including accelerometers, depth sensor, e-compass, touch sensor and distance measuring sensors by infrared reflection are employed to enable the robot to be autonomous [1-4]. But in this experiment no sensor ware used to autonomous the fish robots.

In this paper, a method to design, implementation and control fish like robots is proposed. Two types of fish robots are used in this experiment, where microcontroller, DC Motor, Servo Motor, RF Module are used. The first screw type fish robot has two dc motors and one servo motor. Two dc motors are mounted in the head to make easy movement around it but not up/down. For up and down movement one servo motor is mounted in the body to control the position of the two dc motors up and down. The second fin type fish robot has two servo motor only, one is mounted in the head and another is mounted in the tail. Combination of these two servo motors the fish robot can swim all around. The control of motors for screws and fins are processed based on microcontroller MSP430F149 by Texas Instruments. Various kind of swimming paths made by white board are given to swim the fish robots. Since there are no, information about distance and has no effective algorithm for auto swimming in the fish robot. So the fish robots are used only manually remote control signal for movement all around. Finally the experiments results show the successful of fish robots control by passing through differences kind of swimming paths without collision with the obstacles.

II STRUCTURE

The fish robot should be as simple as possible. Also they should be study and modular for easy maintenance. Each part of the fish robot should be modular that means, each part can be replaced easily when broken. The fish robot has minimum number of motors to control fins or screws for 3-dimensinal movement. A radio frequency (RF) communication module is used to receive commands and send data to the user or remote control. The structures of screws and fins type fish robot are shown in figure 01 and figure 02 respectively.

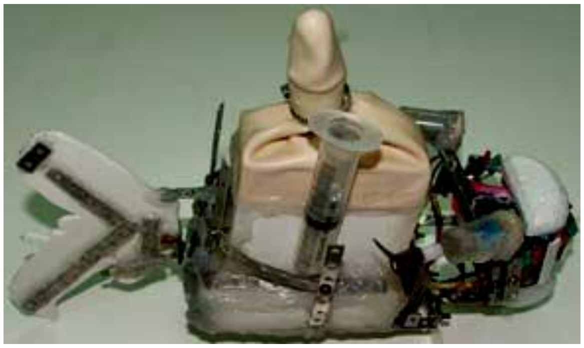


Figure 01: Structure of screws type fish robot

Figure 02: Structure of fins type fish robot

III FISH ROBOT

Several fish robots are built for various researches in our lab. In this experiment two types of fish robots are developed about 25cm long. One is fin type and another is screw type. For fin type robots only two servo motors are used, one servo for left/right and forward movement, and another for up/down movement of the fish robot. For screw type fish robot one servo motor is used for un/down and two dc motors are used for forward/backward and left/right motion. For communication between a joystick and a fish robot a RF module is used. For controlling the fish robot remotely and other devices are controlled by microcontroller MSP430F149.

Two sets of batteries are used to give stable power supply. One set of battery is used for microcontroller and communication module. The other for DC motors and one R/C servo motor. Two DC motor are controlled by the microcontroller through the motor driver. By using motor driver we can easily control the motion of the fish robot. The R/C servo motors are control by PWM signal generated by timer interrupt of the microcontroller.

All mechanical and electrical devices in fish root are waterproof by flexible rubber and superglue. Most of the submarine motors do not work underwater very well because of water leakages. Motor GM-12F has gear ratio 1/30, 530 RPM at 4.5 V. Which has not leakage problem, work very well and the size is very small so it can insert with some grease into the syringe to prevent the water leakage. There are three motors to swim the first fish robot. It has two motor in the front of it and one R/C servo motor in the font side. The font motors used for turning the fish left and right and forward movement it also made backward motion. To swim up or down words the R/C servo motor is used.

For left turn the left motor is used only, because if left motor rotate reverse order then the fish turn left side but it is very slow turn. If I use right motor forward and left motor backward it turn quickly left. Right motors function also same to the left side motor for right turn. If I run the two motors left and right motor at a time anti-clock wise the fish robot moves forward direction. For quickly turn back use left and right motors altogether backward. I can control the motor speed through the PWM signal. PWM signal was produce by timer interrupt of microcontroller. The PWM signals are inserted in the inputs of the motor driver to control motors. The two R/C servo motor of the fins type fish are control by the PWM signals. The fins type fish robot cannot move backward as like screw type fish robots.

A. Microcontroller MSP430F149

MSP430F149 is chosen for the microcontroller of the small scale structure with many components to be interfaced since it requires a single 3.3V source while two 16 bit timers, eight channels of 12 bit A/D converters, two USART ports are provided internally [5]. USART port is used for wireless data communication between the robot and joystick.

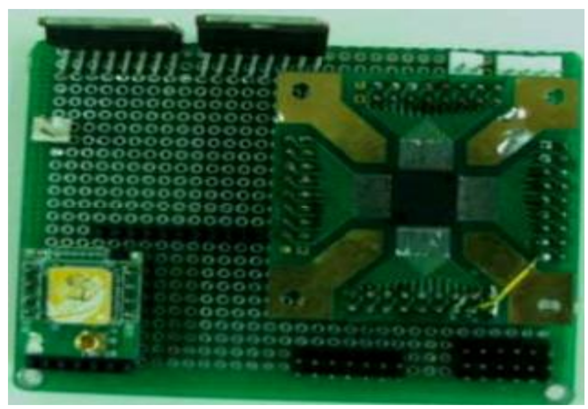


Figure 3: Microcontroller MSP430F149

B. Remote Control Joystick

Remote Control Joystick is one of the most important parts of the fish because the fish robot has no information to swim automatically it was control manually by this Remote Control Joystick. For controlling the fish robot seven touch switches are used on the Remote Control Joystick. First five switches are left, right, up, dawn, and forward swimming control and other two are used for speed increase and decrees control of the fish robots swimming. Extra two switches are used for stop the fish robot and power on/off for the Remote Control. All instructions are control by the microcontroller inside of the Remote Control and send the signal to the fish robot through the RF module.

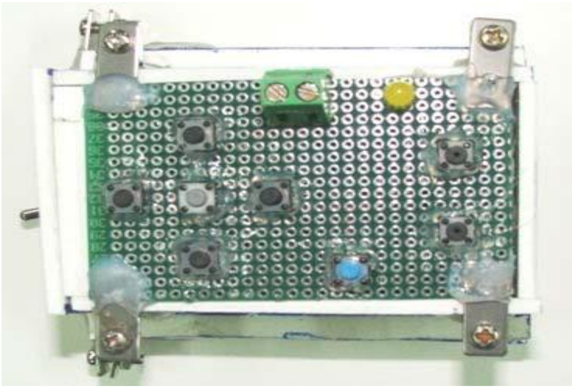


Figure 4: Remote Control Joystick

C. GM-12F Motor

The motor GM-12F has gear ratio 1/30 and 530 RPM at 4.5V [6]. Most of submersible motors do not work under water very well because of water leakage. To prevent leakage we insert the motor into a syringe with some amount of grease.

Figure 5: GM-12F Motor [6]

Two motor are used to operate screw type fish robot. This two motor are mounted in front of the fish robot. The front motors are used for turning the fish left or right sides and forward as well as backward motion. If the speed of the fish robot is fast when we want to make it immediately stop, it is necessary to run the two motors reversely. The motor speed is controller through PWM signals. The PWM signal is produced by a timer interrupt of the microcontroller MSP430F149.

C.1) Motor Driver:

Motor Driver L298 is a dual, full-bridge driver that can be used to drive two DC motors. An integrated monolithic circuit, it comes in a 15-lead Multi-watt package. It is a high voltage, high current dual full-bridge driver designed to accept standard TTL logic levels and drive inductive loads such as relays, solenoids, DC and stepping motors. Two enable inputs are provided to enable or disable the device independently of the input signals. The emitters of the lower transistors of each bridge are connected together and the corresponding external terminal can be used for the connection of an external sensing resistor. An additional supply input is provided so that the logic works at a lower voltage. The Operating supply voltage is up to 46V, total DC current up to 4A, Low saturation-voltage, Built-in over temperature protection, Logical "0" input voltage up to 1.5V (high noise tolerance) [7].

Figure 6: Motor Driver IC L298 [7]

C.2) R/C Servo Motor

The HS-311 R/C Servo motor is perfect servo for various applications like controlled models truck, boats, cars, airplanes, robots, and puppets. It is ideal for numerous robot projects because servo motor is small, compact and quit inexpensive. And easily interface to any microprocessor. The servo motors itself have built in motor, gear box, position feedback mechanism and controlling electronics. The servo motor can be controlled to move any position just by using simple pulse controlling. All Hitec servos require 3-5V peak to peak square wave pulse. Pulse duration is from 0.9mS to 2.1mS with 1.5mS as center. The pulse refreshes at 50Hz (20mS). All Hitec Servos can be operated within a 4.5V-6V range.

Figure 7: R/C Servo Motor [8]

This servo can operate 0o to 180° when given a pulse signal ranging from 600usec to 2400usec. Since most R/C controllers cannot generate this wide of signal range. Servo motors' angle rotation control by adjusting PWM signal ratio [8].

A Servo is a small device that incorporates a three wire DC motor, a gear train, a potentiometer, an integrated circuit, and an output shaft bearing. Of the three wires that stick out from the motor casing, one is for power, one is for ground, and one is a control input line. The shaft of the servo can be positioned to specific angular positions by sending a coded signal. As long as the coded signal exists on the input line, the servo will maintain the angular position of the shaft. If the coded signal changes, then the angular position of the shaft changes.

Servos come in different sizes but use similar control schemes and are extremely useful in robotics. The motors are small and are extremely powerful for their size. It also draws power proportional to the mechanical load. A lightly loaded servo, therefore, doesn’t consume much energy. Normally a servo is used to control an angular motion of between 0 and 180 degrees. It is not mechanically capable (unless modified) of turning any farther due to the mechanical stop build on to the main output gear. If the control circuit detects that the angle is not correct, it will turn the motor the correct direction until the angle is correct. When the control circuit detects that the position is correct, it stops the motor.

Servos are controlled by sending them a pulse of variable width. The control wire is used to send this pulse. The parameters for this pulse are that it has a minimum pulse, a maximum pulse, and a repetition rate. Given the rotation constraints of the servo, neutral is defined to be the position where the servo has exactly the same amount of potential rotation in the clockwise direction as it does in the counter clockwise direction. It is important to note that different servos will have different constraints on their rotation but they all have a neutral position, and that position is always around 1.5 milliseconds (ms).

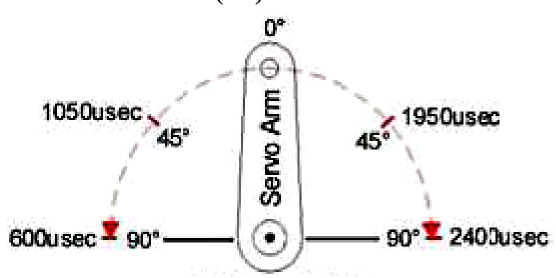


Figure 8: Angular Operation of R/C Servo Motor [8]

The angle is determined by the duration of a pulse that is applied to the control wire. This is called Pulse width Modulation. The servo expects to see a pulse every 20 ms. The length of the pulse will determine how far the motor turns. For example, a 1.5 ms pulse will make the motor turn to the 90 degree position (neutral position).

When these servos are commanded to move they will move to the position and hold that position. If an external force pushes against the servo while the servo is holding a position, the servo will resist from moving out of that position. The maximum amount of force the servo can exert is the torque rating of the servo. Servos will not hold their position forever though; the position pulse must be repeated to instruct the servo to stay in position.

D. FR Modules (Radiomatrix 173-250-10)

For communication of the fish robot to a remote control joystick, FR module is used. It is wireless communication module. It has two parts, one is transmitter TX1 and another is receiver RX1. Frequency standard is 173.225 MHz. Data rate is up to 10kbos with 25kHz channel spacing [9].

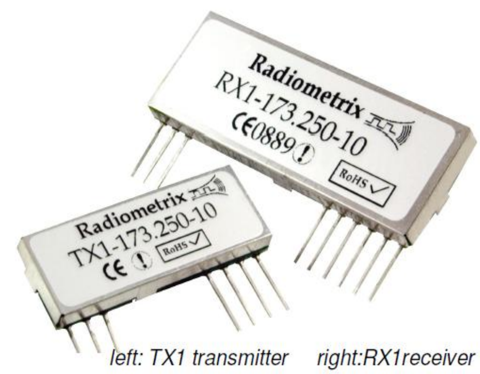


Figure 9: RM Modules [9]

The TX1 module is a two stage crystal controlled NBFM transmitter operation between 2.2V and 12V at a current of 9.5mA. At 3V supply it delivers nominally +10dBm RF output. The style TX1 measures 32x12x3.8 mm excluding the pins [9].

The RX1 module is a single conversion NBFM receiver capable of handling data rates of up to 10Kbps. It operates from a supple of 2.7V to 12V and draws 12mA when receiving. A signal strength (RSSI) output with greater than 80dB of range is provided [9].

E. Water Leakage Prevention

Water leakage prevention is the one of the most important part for fish robot or underwater vehicles. For water leakage prevention, Super Glue, Tubes, Glue gun, Syringes, Rubbers and Grease are used. The Super Glue is used for make the box of the fish robot main control circuit and other modules circuits. Tube is used for leakage prevention of the wires. Glue gun is also used for water leakage but it is not so strong. By using glue gun we can remove it very easily. For permanent or better water leakage prevention super glue is used. The syringes and grease are used for water leakage of motors. The motor mounted inside the syringes but some water in through the font hole, so using the grease it can prevent water leakage easily, the motor works very well under the water.

To prevent the water leakage of the moving part of the motors mainly for the Servo motor rubbers sheets are used. That mounted around the moving part of the servo motor. The moving part of the servo motor mounted by the rubber was light and more space inside the rubber to move the motor easily otherwise motor cannot move or rubber will be leakage. At first the rubber sheets joined with the motor body with the super glue and for more security of water leakages, it's outside surrounding by the glue gun.

Figure 10: GM-12F Motor inside the Syringes

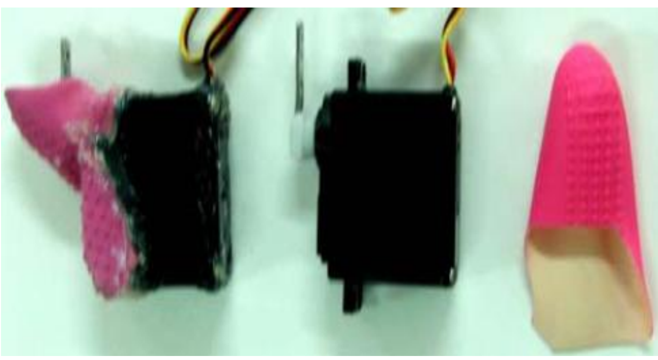


Figure 11: Servo Motor Prevent from Water Leakage

F. Balance of the Fish Robot

After complete of making fish robot it need to balance in under water. Without balancing, the fish robot will not able to swimming properly. Make overall balance of the fish robot body. After complete this balance the fish robot can swim but not fully accurate. For overall balance consider the weighted part and light part of the fish robot. The weighted part of the fish robot must be downward and the lighter part must be upper part of the fish robot. Otherwise the fish robot body not stable underwater. If upper part more weighted it goes downward the robot look like death fish. At the designing time tries to put the weighted part like batters, main circuit of the fish robot put under the fish robot body. If it needs to add extra weights add down part of the fish robot. And if it needs to make the fish robot lighter then I tries adding lighter matter beside the fish body or upper part of the fish robot. In the same way it can be balance front and back part of the fish robot. The metals used to overall balance are iron, steel, syringes, blank air bottle etc.

After overall balance it need to fine tuning. Fine tuning is done by using syringe. It is also manual tuning like overall tuning. In fine tuning the fish robot was tuning fully and its weight become one in under water. Syringes are mounted front side, back side and beside the body. By air balance the syringes the fine tuning is done. Most of the time fish robot needs this fine tuning because some place of fish body blocked some air and after some time swimming the blocked air goes out it need again fine tuning.

After complete the overall tuning and fine tuning some time the fish robot may or may not need the final or mechanical tuning. This tuning is done by automatically when fish robot swimming. When fish robot goes more depth the presser of the water increase and the air volume of the fish robot body decrees by using mechanical tuning which increase the air volume or decrease the weight. So the weight of fish robot become same all the time means one. When fish robots come back over the water, the mechanical tuning again change the weight of the fish robot and make it one.

G. Power Source

The electrical components of the fish robot are batteries, MSP430F149 (microcontroller), RF module, touch switch, servo and DC motors with motor driver. Batteries are used how much it need to be stable power supply. If more devices are used in fish robot then it need to separate power supply to micro-controller and others electrical components. Motor need more current when more motors run at a time if same batteries are used then some time MSP430F149 become unstable. At that situation separate power supply is used for the microcontroller. MSP430F149 microcontroller needs 3.3V power supply. It must be provided stable power supply to the microcontroller. In the same way for the communication module, switches, and motors need proper power supply. Suppose DC motor can access up to 12V but servo motor maximum voltage 5 volt, so if it needed to use 12v for DC motor then 5v regular used for servo motor. I also used 3.3v voltage regulator for microcontroller.

IV IMPLEMENTATION OF FISH ROBOT

A. Hardware Implementation of Fish Robot

MSP430F149 microcontroller, RF module and motor driver for GM-12F Motor speed control circuit are on the same PCB board. The PCB also has a JTAG download port which is reserved to facilitate the programmer to download updated program. MSP430F149 is an appropriate choice for a small scale structure with many components to be interfaced since it requires a single 3.3V source while two 16 bit timers, eight channels of 12 bit A/D converters, two USART ports are provided internally. USART port is used for wireless data communication between the robot and joystick. Motor GM-12F has gear ratio 1/30, 530 RPM at 4.5. Control by generating of PWM signal passes through motor driver L298/BA6208 from Microcontroller. The controlling scheme is very easy to implement with some electronics. MSP430F149 makes PWM signals to control one RC servo motors. The block diagram shown below:

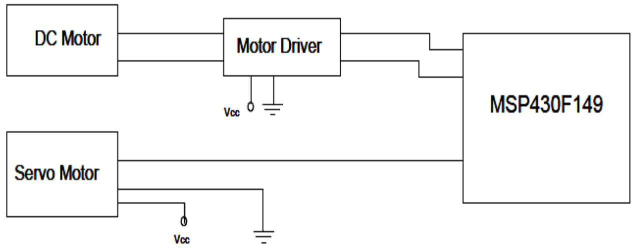


Figure 12: Block Diagram of DC Motor and RC Servo Motor with Microcontroller

B. Software Implementation of Fish Robot

MSP430F149 ultra-low power microcontroller is programmed using the IAR Embedded workbench, C-language development via the MSP-FET430P140 Flash Emulation Tool and the implementation of software routines for MSP430F149 microcontroller: Timer B is interfaced with motor driver to control the left, right and tail DC motors

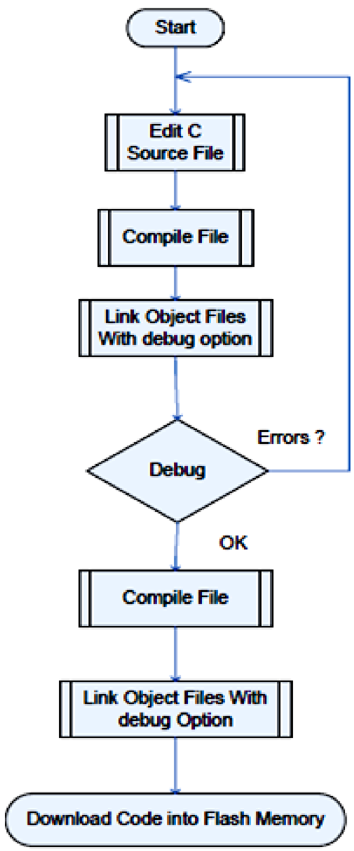


Figure 13: Flow Chart of the Development Cycle

The IAR System C compiler of the IAR System Embedded Workbench for the MSP430F149 offers the standard features of the C language, plus many extensions designed to take advantage of the MSP430F149 facilities. The compiler is supplied with the IAR System Assembler for the MSP430F149, with which it is integrated and shares linker and librarian manager tools. By applying steps of rules a proper turn makes the fish robot swims continuously without collision. The flow chat of the development cycle is given in figure 13.

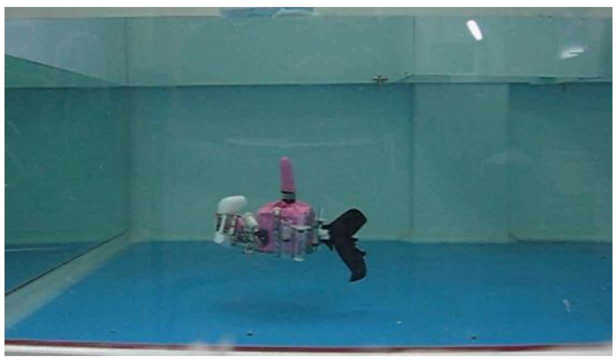
V CONTROL PERFORMANCE

Fish robots move rather slowly compared to floor type robots. But fish robot control performances have delicate problems since they are basically the problems in 6-DOF. Therefore, in addition to the basic requirements of accuracy and fastness, maintaining balance during a turning motion and keeping natural movement patterns are quite complex problem. Moreover, the characteristics of actuator usually differ from one another. Because of slow water leakage in the motors they tend time to time varying systems. Four air bladders of syringe type are used to keep balance and to make specific gravity to be close to one.

By setting some target position and make the fish robot pass the trajectory without touching the obstacles. The test of the fish robot swimming is done in a water tank of 240x120x120 cm. The side walls and the objects made of white board are considered as obstacles. The swimming of the fish robots are control by the joystick remotely. The following various swimming test shows the control performance of the fish robots swimming.

A. Swimming Test

It is simple line swimming and under water swimming are tested, where the speed of the fish robot and communication between fish robot and the remote control are checked.



Under Water Swimming Test Fin type Fish robot

Under Water Swimming Test Fin type Fish robot
Figure 14: Simple Swimming Test

B. Turning Swimming Test

The turning direction and speed of the fish robot are tested in this swimming test

Figure 15: Turning Swimming

C. Obstacle Passing Test

In this test the fish robot passing a given channel and come back to the starting point again without touching the obstacles.

Figure 16: Channel Passing Swimming

D. Passing Wriggly Channel

The goal of this test is passing a wriggly channel and come back to the starting point, where the left/right movements of the fish robots are checked more appropriately.

Figure 17: Wriggly Obstacle Passing Swimming

E. Critical Obstacle Passing Test

The most complicate swimming is tested in this stage. Here the fish robot passes through some critical obstacles path and came back safely to given points.

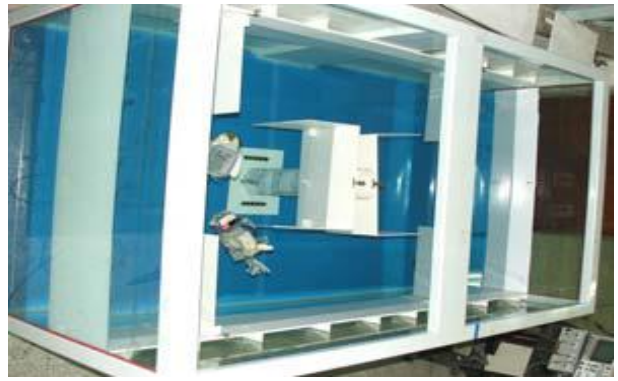


Figure 18: Critical Obstacle Swimming

VI CONCLUSIONS

The fish robots are successfully designed implemented and controlled. Since there are no distance, navigation and obstacle information available only manually joystick control signal is applied for the movement of the fish robot. The satisfactory control outputs result have been obtained from fish robots swimming test without hitting obstacles.

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BIOGRAPHY

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