

Bio-Mimetic Robotic Auto-Navigation Surveillance Fish

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ABSTRACT: This project presents a study and design of a Biomimetic Robotic fish that imitates natural aquatic animals forms of Locomotion by focusing on the apparatus of swimming performances. Biomimetic refers to human-made processes, substances, devices, or systems that imitate nature. The art and science of designing and building biomimetic apparatus is called biomimetics, and is of special interest to researchers in nanotechnology, robotics, artificial intelligence (AI), the medical industry, and the military. The main focus of the project is to develop an aquatic robot that can perform all the natural motion mechanism of the fish. It is mainly concerned with vision-based target following control of an autonomous, robotic fish. Based on the successful development and effective swimming locomotion control of the robotic fish prototype, we further investigate the utility of the onboard digital camera in target following task, the output of which can be processed with the processor done. Based on the propulsion and manoeuvring mechanisms of real fishes, a tail mechanical structure with servo motors and connecting rods for fitting fish body wave is designed, which provides the main propulsion. Two pectoral fins are mounted, and each pectoral fin can flap separately and rotate freely. Coordinating the servo motors, the robot fish can simulate the movements of fishes in water. Series of movements are designed to demonstrate the natural fish- liked locomotion: manoeuvring, forward, backward, and turning. In order to obtain the necessary environmental information, several kinds of sensors (video, infrared, temperature, pressure and PH value sensors) were mounted. Finally, the realization of the robot fish is presented.

KEYWORDS: Image processing, manoeuvring mechanisms, artificial intelligence

I. INTRODUCTION

In recent years, a great variety of innovative robots have been developed through biomimetics, which attempts to create artificial systems that emulate the performance of Animals. Since the process of evolution has produced highly effective and power efficient biological mechanisms, copying nature will be a shortcut to technology innovation. Biologically inspired robots, as a product of incorporation of biology science and robotic technology, not only build a new paradigm for creative robot design but also serve as a tool for investigation of biological principles. In the aquatic realm, propulsion and manoeuvring mechanisms used by fish are being implemented on autonomous underwater vehicles (AUVs). Compared with conventional AUV technology that employs screw type propellers for thrust generation and multiple control surfaces for manoeuvring, fish achieve far superior swimming performances through coordinated control of the body and fins. The benefits that can be obtained through technology transference from fish to nautical engineering include high efficiency, great agility and station-keeping ability and reduced detection. Fish-like robots can play an important role in various underwater tasks, especially those that require operations in cluttered environments and in unsteady flow.

The astonishing swimming ability of fish has inspired many researchers to work on a new kind of aquatic man-made robotic systems, namely Robotic Fish. Up to now, majority of research work has been focused on fish-like propulsion mechanisms, fin materials, remote operation, multi-agent cooperation and mechanical structures. However, the motion

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control of robotic fish has not been investigated extensively; particularly control schemes along with modelling of carangiform fish-like swimming.

Typically, there are two main types of motions under of robotic fish: cruising and manoeuvring. Basically, cruising indicates swimming at a constant linear or angular speed, whereas manoeuvring involves actions such as acceleration, deceleration, quick turning, up/down motions, and hovering.

II. LITERATURE SURVEY

From the viewpoint of engineering, fish is a distinguished AUV prototype that is suitable for reproduction. Significant work in robot fish was initiated in the 1990s by Triantafillou and, was further investigated recently by Hirata. Based on rapid progress in robotics, hydrodynamics of fish-like swimming, new materials, actuators and control technologies, more and more research has focused on the design and development of robot fish. To build an autonomous robot fish, many fundamental issues including fishlike motion parameters, sensors, actuators, hydrodynamics, image processing, and intelligent motion control have to be investigated. A physical model of the carangiform motion can be divided into two parts: flexible body and oscillatory lunata caudal fin, where the flexible body is represented by a series of oscillatory hinge joints and the caudal fin by an oscillating foil. A swimming model for RoboTuna (typically carangiform) has been presented by Barrett et al. Whose undulatory motion is assumed to take the form of a travelling wave (1) originally suggested by Lighthill, inspired by the propagating propulsive wave underlying the fish body, in a link-based body-wave fitting for robot fish design was proposed, where a discrete body-wave is considered and time variable t is separated.

III. BLOCK DIAGRAM

The control system is depicted in Fig.2.1 MCU sends PWM signal to the motor driver to control the tail motor's speed, and thus the oscillatory frequency of the tail is controlled by the duty ratio of the PWM signal. The MCU may communicate with the upper console by the wireless module. When the robot fish performs a task in complex underwater environments, it needs to perceive the environment. For this purpose, multiple sensors are equipped with the robot fish to gather environmental information, i.e. water depth, neighbouring obstacles.

According to the characteristics of sensors, CCD camera, a temperature transducer, infrared sensors are chosen.

The biomimetic robot fish may make decisions intelligently based on the sensors information to a certain degree. Avoiding obstacles is one of the premises of swimming safely. In the sensors system of the robot fish, the infrared sensors are used to detect nearby obstacles. As described above, there are three infrared sensors mounted on right (SIR), middle (SIM), left (SIS) side of the fish head. The robot fish may make decisions based on the states of sensors. The logic rules set gives the relationships between motions of robot fish and states of sensors, and it is performed by the MCU module of the robot fish.

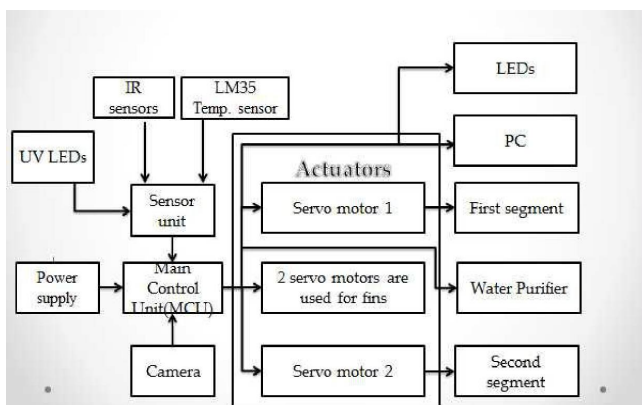


Fig: Control system of the fish

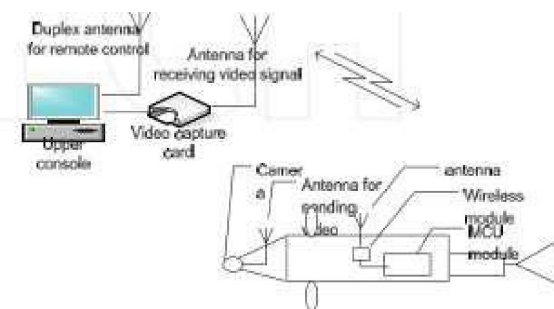


Fig2.2 The schematic of signal transmitting system

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The CCD camera is mounted on the head of the robot fish and it provides video information to upper console by wireless in high frequency for displaying and processing. The upper console receives the video signal by a video capture card and then extracts the valid information based on a threshold-adjusting image segmentation algorithm. The schematic of signal transmitting system is given in Fig.2.2

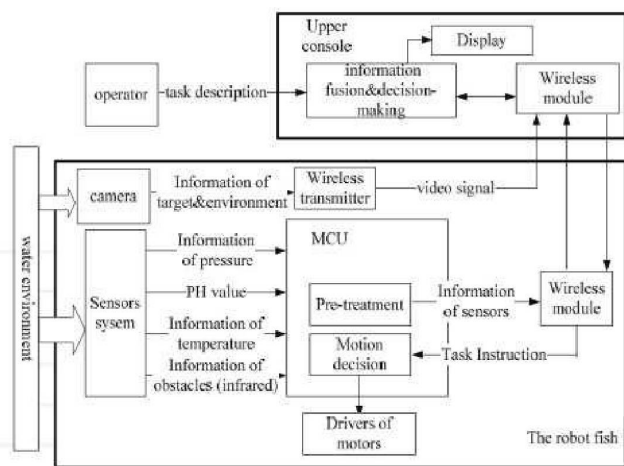


Fig 2.3 The control Architecture of Robot fish

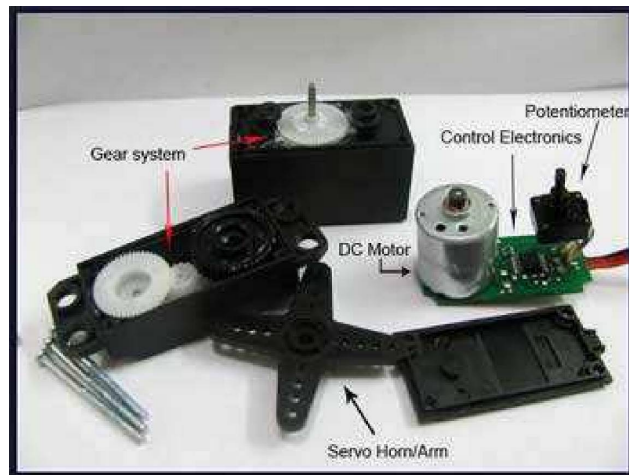


Fig: Servomotors

To acquire the water temperature, a temperature transducer is adopted. The robot fish may analyse the variation rule of environmental temperature. Based on the sensors chosen, the system architecture of the robot fish is proposed, which is shown in Fig.2.3 The sensors information may be sent to the upper console by wireless and the operator may send wireless instructions to control the robot by observing the related information. The robot fish may make decisions intelligently based on the sensors information in some cases or execute the task by combining the commands from the upper console.

SERVO MOTORS:

A servomotor is a rotary actuator that allows for precise control of angular position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors. Servomotors are not a specific class of motor although the term servomotor is often used to refer to a motor suitable for use in a closed-loop control system. Servomotors are used in applications such as robotics, CNC machinery or automated manufacturing.

IV MECHANISM OF FISH MOVEMENT

As the name suggests, a servomotor is a servomechanism. More specifically, it is a closed-loop servomechanism that uses position feedback to control its motion and final position. The input to its control is some signal, either analogue or digital, representing the position commanded for the output shaft. The motor is paired with some type of encoder to provide position and speed feedback. In the simplest case, only the position is measured. The measured position of the output is compared to the command position, the external input to the controller. If the output position differs from that required, an error signal is generated which then causes the motor to rotate in either direction, as needed to bring the output shaft to the appropriate position. As the positions approach, the error signal reduces to zero and the motor stops. The very simplest servomotors use position-only sensing via a potentiometer and bang-bang control of their motor; the motor always rotates at full speed (or is stopped). This type of servomotor is not widely used in industrial motion control, but it forms the basis of the simple and cheap servos used for radio-controlled models.

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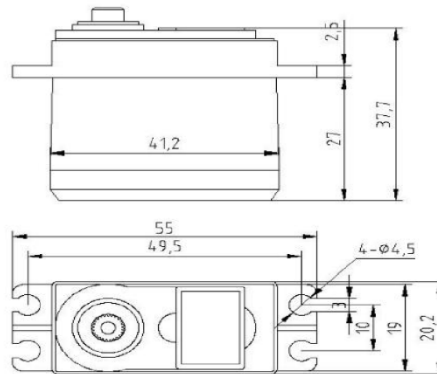


Fig: Motor used for the movements of the fins and tail

More sophisticated servomotors measure both the position and also the speed of the output shaft. They may also control the speed of their motor, rather than always running at full speed. Both of these enhancements, usually in combination with a PID control algorithm, allow the servomotor to be brought to its commanded position more quickly and more precisely, with less overshooting.

WORKING PRINCIPLE OF SERVO MOTOR

A servo motor is basically a DC motor (in some special cases it is AC motor) along with some other special purpose components that make a DC motor a servo. In a servo unit, we can find a small DC motor, a potentiometer, gear arrangement and an intelligent circuitry. The intelligent circuitry along with the potentiometer makes the servo to rotate according to our wishes.

As we know, a small DC motor will rotate with high speed but the torque generated by its rotation will not be enough to move even a light load. This is where the gear system inside a servomechanism. The gear mechanism will take high input speed of the motor (fast) and at the output, we will get a output speed which is slower than original input speed but more practical and widely applicable.

Say at initial position of servo motor shaft, the position of the potentiometer knob is such that there is no electrical signal generated at the output port of the potentiometer. This output port of the potentiometer is connected with one of the input terminals of the error detector amplifier. Now an electrical signal is given to another input terminal of the error detector amplifier. Now difference between these two signals, one comes from potentiometer and another comes from external source, will be amplified in the error detector amplifier and feeds the DC motor. This amplified error signal acts as the input power of the dc motor and the motor starts rotating in desired direction. As the motor shaft progresses the potentiometer knob also rotates as it is coupled with motor shaft with help of gear arrangement. As the position of the potentiometer knob changes there will be an electrical signal produced at the potentiometer port. As the angular position of the potentiometer knob progresses the output or feedback signal increases. After desired angular position of motor shaft the potentiometer knob is reaches at such position the electrical signal generated in the potentiometer becomes same as of external electrical signal given to amplifier. At this condition, there will be no output signal from the amplifier to the motor input as there is no difference between external applied signal and the signal generated at potentiometer. As the input signal to the motor is nil at that position, the motor stops rotating. This is how a simple conceptual servo motor works.

As per the picture given above the output electrical voltage signal of the amplifier, acts as input voltage of the DC motor. Hence the motor will stop rotating after the shaft rotates by 45°. The motor will be at this rest position until another command is given to the system for further movement of the shaft in desired direction.

Although in practical servo motor control system, instead of using simple potentiometer we use digital or analog position sensor encoder.

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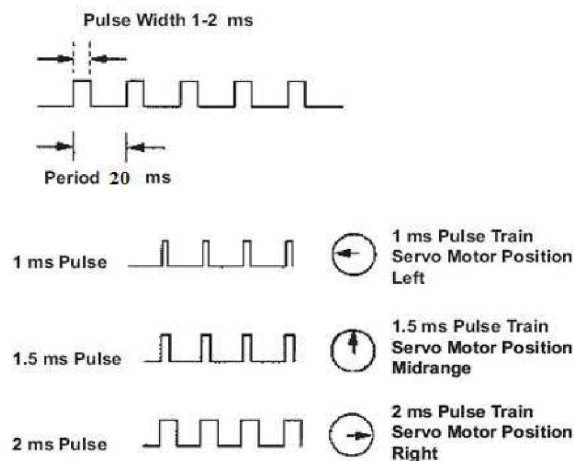
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From this basic working principle of servo motor it can be concluded. The shaft of the servo is connected to a potentiometer. The circuitry inside the servo, to which the potentiometer is connected, knows the position of the servo. The current position will be compared with the desired position continuously with the help of an Error Detection Amplifier. If a mismatch is found, then an error signal is provided at the output of the error amplifier and the shaft will rotate to go the exact location required. Once the desired location is reached, it stops and waits.

Servos are controlled by sending an electrical pulse of variable width, or pulse width modulation (PWM), through the control wire. There is a minimum pulse, a maximum pulse and a repetition rate. A servo motor can usually only turn 90° in either direction for a total of 180° movement. The motor's neutral position is defined as the position where the servo has the same amount of potential rotation in the both the clockwise or counter-clockwise direction. The PWM sent to the motor determines position of the shaft, and based on the duration of the pulse sent via the control wire the rotor will turn to the desired position. The servo motor expects to see a pulse every 20 milliseconds (ms) and the length of the pulse will determine how far the motor turns. For example, a 1.5ms pulse will make the motor turn to the 90° position. Shorter than 1.5ms moves it to 0° and any longer than 1.5ms will turn the servo to 180°, as diagrammed below.



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 called 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.

V FISH STRUCTURE MODELLING

Fish exhibit a large variety of swimming behaviours that are generated by undulatory or oscillatory movements of their body or fins whose configuration can be seen in Figure. In general, fish swimming can be viewed in two different angles. One is propulsion mechanisms and another is temporal features. In terms of propulsion mechanisms, some fish bend their bodies and/or caudal fins (BCF) and other fish use their median and/or paired fins (MPF). Both BCF and MPF propulsion can be further divided into undulatory and oscillatory propulsion. Four types of undulatory BCF propulsion (anguilliform, subcarangiform, carangiform, thunniform) and one type of oscillatory BCF propulsion (ostraciiform) are shown in Figure. In undulatory BCF propulsion, the propulsive wave traverses the fish body in a direction opposite to the overall movement and at a speed greater than the overall swimming speed. Some fish use 2/3 body and others use less body plus caudal fins.

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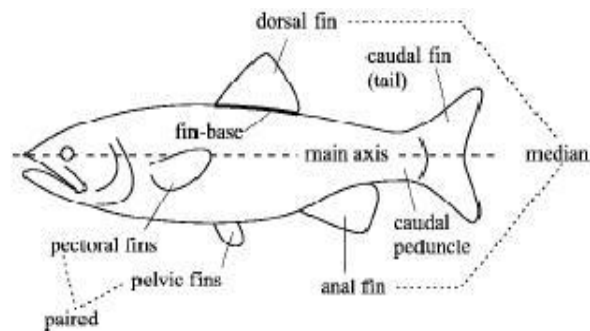


Fig Fish Model

Steady swimming has traditionally been the centre of scientific attention among biologists, mathematicians and robotics researchers. In fact, swimming at uniform velocities along a straight path is rather exceptional among fishes. The unsteady swimming actions play an important role in fish life, in which body movements are very significant and characterised by high accelerations such as fast start and sharp turning. Some biologists have recently cast light on the kinematics of fish. Note that both steady and unsteady swimming behaviours of fish are based on BCF, MPF or the combination. This reflects the complexity of fish swimming movements.

VI EXPERIMENTAL RESULTS

Experiments with the robotic fish were carried out in an indoor water tank with the size of 2250 mm × 1250 mm and with still water of 800 mm in depth. The range of IR detection was 2 cm approximately and the IR sensitivity value was in a range from 5mm to 40 mm. The 3 UV LED's takes roughly 20 min to purify 1 litre of water and using more the time can be reduced to a great extent.

For post-analysis of the experimental result, the robotic fish is marked with specified colors and the information within the swimming tank is captured by an overhead CCD camera. The image is transmitted to a personal computer and the two dimensional trajectory of the robotic fish can be extracted and recorded. The fish having a weight of almost 2.5 kgs was driven by the motors and functioned properly as expected with all the desired features. The full operation time is about 45 min whereas normal time is 2 hours and stand by for 36 hours.

VII. CONCLUSION

An experimental closed-loop control system for a 2-link and free-swimming biomimetic robotic fish has been developed based on the proposed simplified propulsive mode for carangiform swimming. The fish's motion control task is decomposed into online speed control and orientation control, and corresponding algorithms are implemented on the actual system. The experimental results have demonstrated the good performance of the robotic fish using vision-based positional feedback. However, our proposed motion control algorithms did not take fish dynamics into account, only the fish's motion kinematics was considered, which has to be improved in the future.

Further research will focus on the development of expanded closed-loop control, and a full planar motion-planning algorithm for complex and cluttered environments based on visual feedback. At the same time, some sensors (visual, ultrasonic) are planning to be embedded into the fish body so that the robotic fish is able to react to the change in the environment and have certain local autonomy. A new degree of freedom (up/down) is also planned to add into the robotic fish by using pectoral-fin mechanism, which enables the robotic fish navigate in a 3-Dworkspace. Eventually, an autonomous robotic fish that can swim skillfully (high efficiency) and intellectually will be realized

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