

SPECIAL PROJECT

**DESIGN OF
HUMAN POWERED
BIONIC BOAT**

BY

**ASHISH CHANDEL
GUIDE :PROF V P BAPAT**

**IDC . IIT BOMBAY
INDIA .**

contents

Approval sheet
Abstract
Introduction
Data collection
Classification of fish movements
Technical classification of fish movements
how do fish turn
Physiological study of fish's muscular structure
General guidelines from the studies on fish
Study of existing products and experimental fish models
The robo-tuna project
Proteus the penguin boat
Some of the existing human powered boats
Experimental model
The mechanism
Model details
The trials
Concepts
references
acknowledgement

Approval sheet

The project titled
“Design of human powered bionic
boat” by Ashish Chandel is approved
for the partial fulfillment of the re-
quirement for the degree of
“Masters of Design”

Project Guide

Chairperson

Internal Examiner

External Examiner

Date

Acknowledgement

I would like to thank my guide Prof V P BAPAT for his constant support and encouragement in this difficult project.

I thank the entire IDC faculty for being kind enough to lend their precious time and giving valuable inputs.

my earnest regards for the IDC studios staff for doing all the hard work for me given my poor physical condition.

I wish to thank all my classmates for standing by me whenever I needed them most.

Ashish

24th march 2003

Abstract

This project aimed at utilizing the motor qualities of fishes to conceptualize a human powered boat. Such project have been studied deeply under the discipline on Bionics, however what was needed was conceptualization of the principle into a feasible product , which was ultimately the aim of the project. Initial task was to come to terms with the existing studies in this area and underline guidelines which have to be followed. As I understood form the data collection most of the work in this area has been done on scale models and have been solely devoted to perfecting the motion of fish. Little effort has been made in putting the principle into a product form. In our effort to conceptualize a product, a scale model of the boat was made and experimented upon. Useful observations were taken from our experiments with the model, however given the constraint of time in this project; the data generated is mostly qualitative.

Some concepts have been generated in this project which broadly defines the possible scope of utilization of this bionic project in various fields of aquatic- transportation. Notable among them is the human powered boat which theoretically is more efficient then propulsion powered boats and has unique turning qualities and mechanisms.

Although this project was with me for only a few months, it was undertaken under Prof V P Bapat, IDC who is an authority in the field of bionics , given his special interest in this area, the project is under development under his guidance.

Introduction

Question comes to mind as to why do we need to copy the motion of the fish to develop a propulsive mechanism?

Can a biological system made from muscle, bone, and skin legitimately guide the design of a man made system? There are a number of examples of this in the robotics community where a careful examination of the construction, dynamic behavior, and control of various biological systems led to the successful implementation of a five fingered anthropomorphic hand, a walking 6 legged insect, and a dynamic hopping kangaroo. Each of these implementations did not seek to exactly copy nature, but to distill what was fundamental to the behavior of the system and then implement that as best as was possible with available materials and technology. In effect the fundamental physics were preserved between biological model and man-made system.

The need for such a project has always been felt given the low efficiency and high turbulence created by the normal propeller mechanisms used in boats today. Especially in the case of underwater operations where underwater robots are widely used in the fields of ocean development, ocean investigation, and marine environmental protection. Requests for underwater operations to be carried out more efficiently have become pressing. In response, autonomous underwater robots have been planned. In fact several test robots have already been developed. The need for higher efficiency and propulsive performance essentially requires fish-like performance.

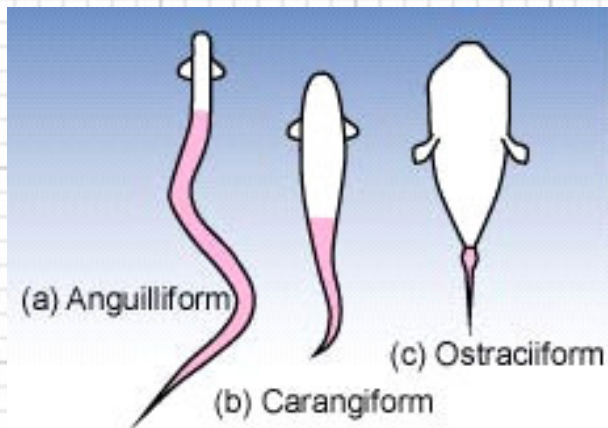
Several universities and research agencies all over the world are trying to perfect the motion of fish to utilize them into developing extremely efficient underwater and surface aquatic vehicles. Navies all the world have placed their requirements for a submarine which is as agile and efficient as a fish.

We used these existing studies to our advantages, given their easy availability given our aim to develop a product rather than perfecting the principle. The fact that some mechanism have been tried and tested shifted our focus to our areas of feasibility and ultimate manufacturing.

Here in this project we have tried to conceptualize a human powered boat which uses the motion of fish to propel itself.

In our study, we focus the focus on fish such as the pike or tuna — fast and efficient swimmers. These fish accelerate with amazing quickness, turn easily, and attain dizzying speed all while expending very little energy. These kinds of fish move by coordinated side-to-side motion of their tail fin and tail peduncle, the part of the body just forward of the tail fin.

We can say that fish swim with pushing water away behind them, though fish swim by various methods. As the well-known categories for the swimming fish, a zoologist, C.M. Breder classified into the following three general categories based on length of a tail fin and strength of its oscillation

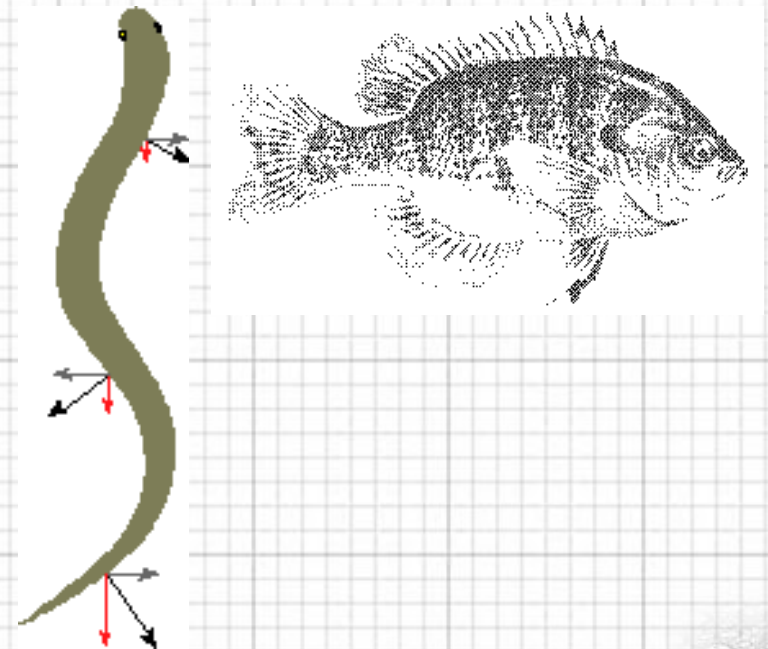


Anguilliform Locomotion

The waves of contraction going down each side of the fish cause waves of flexion of the body to travel from head to tail of the fish. If the fish is long and slender (an eel), an obvious sine wave will migrate from head to tail, exerting vector forces on the water that will cancel each other side to side but sum to a backward force exerted on the water (pushing the eel forward). The eel will appear to wiggle itself forward through the water.

Sub-carangiform locomotion

In a fish like a trout the waves of contraction from front to back are still there, but less extreme than in the eel and the increase in amplitude from head to tail is much more obvious. Forward flexions start the adjacent water moving to the rear; as it goes back each segment, having a greater amplitude, adds to the acceleration. The last edge of the caudal fin provides the greatest thrust, determining the final acceleration given the water. The broader the span of the caudal fin, the greater the mass of water that will be affected. Since everything is relative the fish moves forward as water is accelerated backwards.



carangiform locomotion

the body is almost rigid but still waves of contraction pass from head to tail. The amplitude increases toward the rear but seldom exceeds 20 % of the body length. Because of the small displacement many more waves of contraction can be traveling down the body at a time. Consequently, the tail moves back and forth very rapidly, 10 - 25 times per second and provides essentially all the force. The relative rigidity of the body permits maximum streamlining, and the short, fast caudal strokes maintain a constant thrust. Carangiform swimmers are fast (at sustained swimming) but, because of their relative rigidity, can neither turn nor accelerate as rapidly as anguilliform or sub-carangiform swimmers.

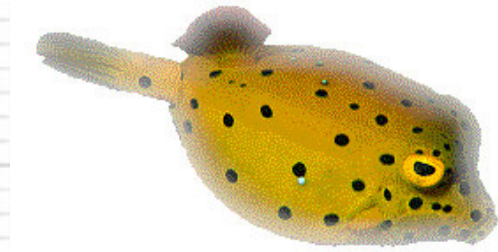


thunniform locomotion

the body is stiffened still more, but two joints, one at either end of the caudal peduncle, permit flexion of the peduncle and the caudal fin. Nesting of the myomeres is extreme and the myosepta are extended into powerful tendons which insert either on peduncular vertebrae or the caudal fin itself, allowing the peduncle to be oscillated rapidly while keeping the angle of attack of the caudal fin optimized. Thunniform swimmers are the fastest fish (again at sustained cruising) but are not well designed for rapid starts.

Ostraciiform

Oscillating only a tail fin without moving the body like the Boxfish.



Technical classification of fish motions

Technical classification of fish motions

What needs to be understood from now is how the fish actually swims given their different body structures. Apart from their biological names certain names have been given to these mechanisms which help to select the mechanism for construction of robots and concepts.

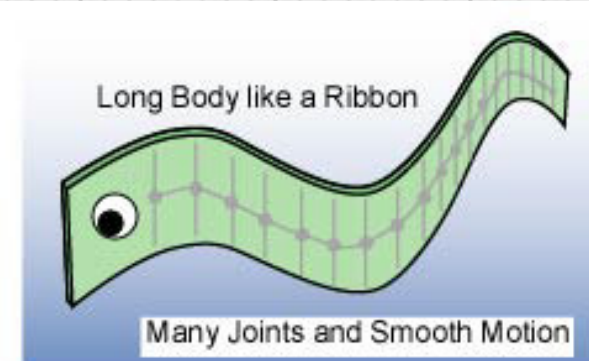
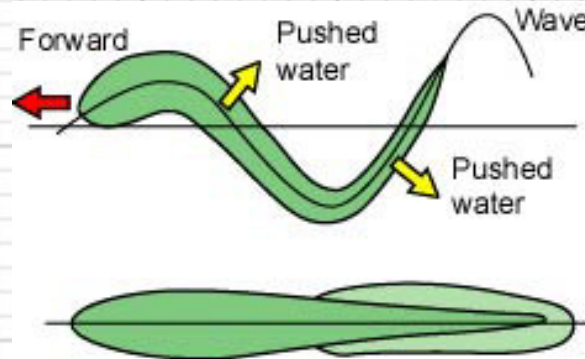
Swimming methods of fish are various and interesting; they have many specialized modes of movement. For example, an eel swims waving the whole of its body and is highly adapted to an enclosed environment. A flat fish, on the other hand, swims by waving long fins in special patterns, allowing it to hover, backup or turn quickly in any direction.

(a) Changing Wave

Fish using this method are propelled by a muscle wave in the body of the animal which progresses from head to tail. This causes the fish to be propelled by the action of its body upon the water. In order to get propulsive force, it is needed that velocity of the wave is faster than forward speed of the fish, and amplitude of the tail part is bigger than that of the head part. We find that most of these fish can reverse this wave motion, thereby enabling them to swim backwards in a similar fashion. Normally, these fish have a long body or a long fin like a ribbon.

A fish robot using this method needs smooth motion of the whole body with many hinge joints and so much complex control system for the joints. However the fish robot can realize delicate motion, and

work well in narrow water area like a coral reef, when a high quality control system is completed.



Changing Wave

Technical classification of fish motions

(b) Body Foil

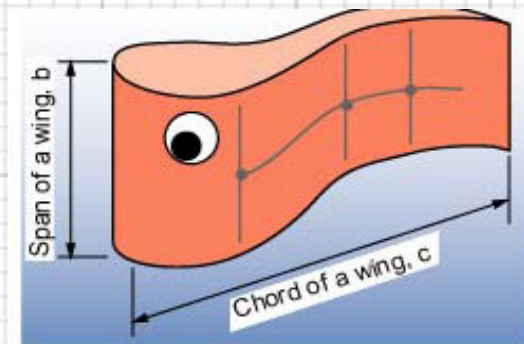
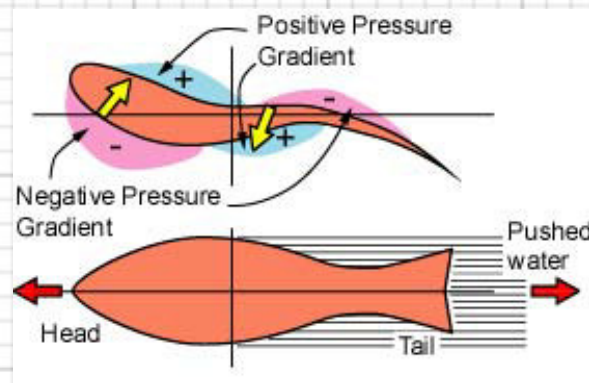
Trout and Salmon are fish typical of those using this swimming method. These fish push water away behind them with using both oscillation of a tail fin and motion of a body. (a) of the figure to the right shows pressure distribution by the motion of body conceptually. There are positive and negative pressure gradients, or we may have to say them action-reaction force, their total force then becomes propulsive force.

We can consider the characteristics of this propulsive method with aspect ratio which is often used to estimate the performance of a wing, defined the ratio of span of a wing, c and chord of a wing, b . When we consider the body to be a wing as shown in (b) of the figure boldly and extremely, the wing has low aspect ratio. Low aspect ratios are often associated with high lift devices, jumbo jet wing flaps,

multi-purpose aircraft wings (utility, trainer), towing propellers, and multi-purpose boat propellers. Because it performs well at low and medium speeds and wide range of the attack angle, it is used to multi-purpose. It can travel far but needs a bit more fuel to go great distances. Also a wing with low aspect ratio is not suitable for high speed and high propulsive efficiency, because it has large drag for a surface area of the wing. However the wing is expected to get huge propulsive force, because the wing has large surface area remarkably for a size of the fish robot. As the result, it is considered that the fish robot with the low aspect ratio can accelerate well from stationary position. As the other excellent characteristics, it is expected to have good turning performance with changing

the direction of the propulsive force, and it has no concentrated force at hinge joints with dispersing of the driving power to the whole body.

On the other hand, fish using this method such as Trout and Salmon have a triangular tail fin generally. The fish propel by the oscillation of the tail fin with the same principle of the Oscillating Wing described below. It is very interesting from the viewpoint of hydrodynamics that the triangular tail fin has lower aspect ratio than that of the Oscillating Wing.



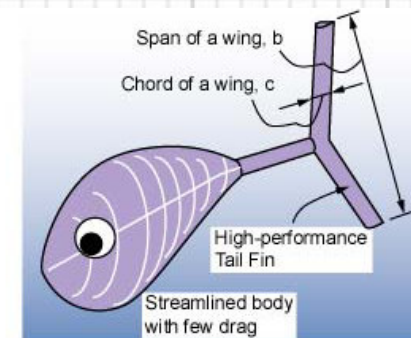
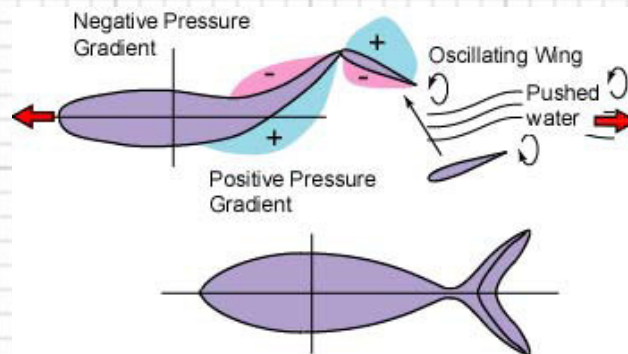
Body Foil

Technical classification of fish motions

(c) Oscillating Wing

Fish using this method derive nearly all of its propulsive force from an oscillating wing-shaped tail fin. The motion of the oscillating wing is combined heaving motion and feathering motion of the tail fin, and has about 90 degrees of phase angle between the heaving and the feathering of the tail fin. Tuna and Bonito use this method. Cetaceans also use this method, although they wave their tails up and down, not left and right. These fish have a crescent and wing-shaped tail fin. As its span is long and its chord is short, the tail fin has high aspect ratio. High aspect ratios are associated with very high lift performance in wings, propellers, helicopter rotors, high-speed motorboat propellers and hydrofoils. A wing with high aspect ratio has the great characteristics such as low drag and strong lift for a surface area of the

wing. Thus, the Oscillating Wing gets the great performance, when a high performance tail fin in hydrodynamics, a streamlined body and a slim peduncle are combined. The body with few drag and strong propulsive force by the tail fin obtain high-speed swimming. The energy for driving the tail fin is a few, because the surface area of the wing is small for a size of the fish robot. Then the oscillating wing propulsion can get high propulsive efficiency. But the fish robot with this method does not expect to get good accelerating performance from stationary position, because the propulsive force is somewhat small for the size of the fish robot. It also is important that we should design the joint at the tail fin in careful, because the strong force is concentrated at the joint.

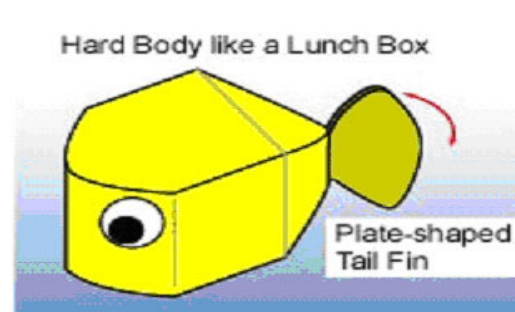
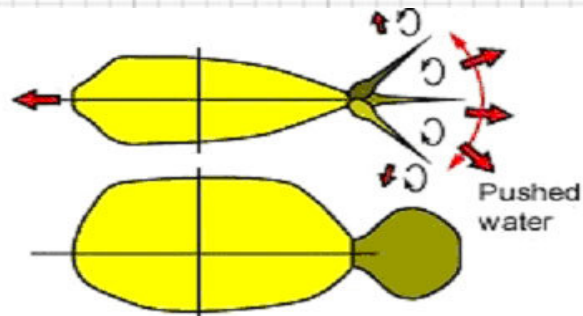


Oscillating Wing

Technical classification of fish motions

d) Oscillating Plate

Fish using this method oscillate only a tail fin like a plate without moving the body. The direction of water pushed by the Oscillation Plate may disperse to left or right, not behind the fish. As the result, this propulsive method has weak points at swimming speed and propulsive efficiency. But the method is expected high mechanical efficiency, because it has a few hinge joint with small mechanical loss. Also from the simple structure of the mechanism, it is considered that the method is the most suitable for a small-size fish robot. In addition, it is considered the elastic tail fin of this method obtains somewhat stronger propulsive force, because the direction of the pushed water may become to behind similarly



Oscillating Plate

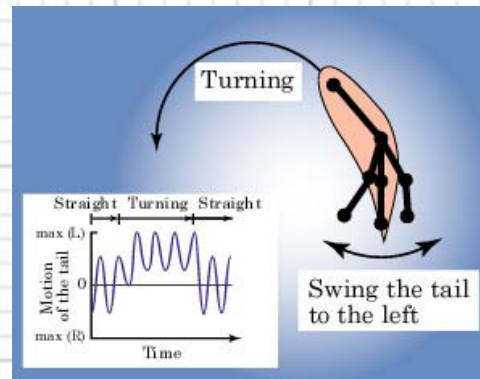
How do fish turn

Though real fish turn skillfully using not only tail fin but also pectoral fins or ventral fins, we determined a structure of a fish robot, which turns with only swing of tail fin. As the tail fin is utilized both propulsion and turning, the fish robot gets simple structure and easy control for swimming. In the case of turning with only swing of tail fin, there are three turning modes shown as follows.

Turning Mode A

The figure to the right shows the case of Mode A. The fish robot swings its tail only to one side during a turning. It is considered that this mode is the most fundamental and important turning mode, because the robot can turn with various turning diameter and speed in this mode.

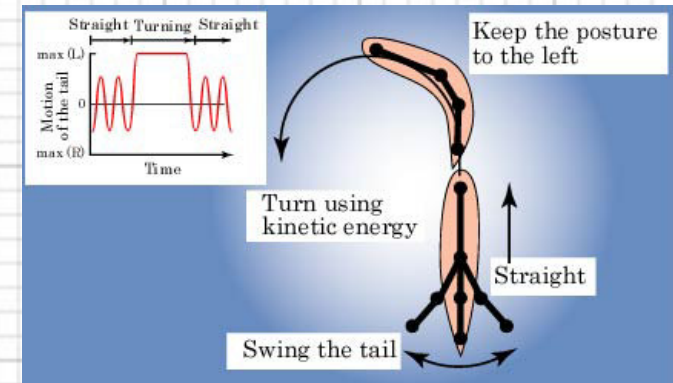
In this turning mode, a head and a body of the fish robot are equivalent to a rudder, and the tail peduncle and the tail fin are equivalent to a screw propeller of the ship. If we attend to the resemblance of these functions, we can analyze this mode and control the robot easily.



Turning Mode B

The figure to the right shows the case of Mode B. At first, the fish robot swims straight, and gets kinetic energy. Next, the fish robot turns its tail to one side, and keeps the posture to the side. Then the fish robot turns by hydrodynamics force. It is considered that this mode gets smaller turning diameter than that of Mode A.

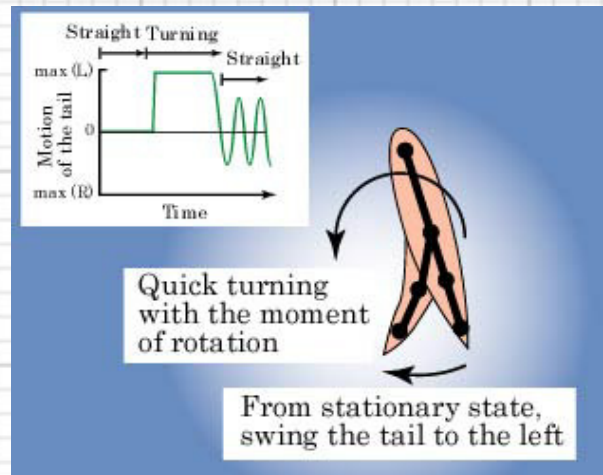
In Mode B, as the stationary posture of the fish robot with the leaning of the tail is regarded as a wing, its friction force and lift force can be estimated. It is possible to analyze the turning performance and control the movement by considering the kinetic energy at the straight propulsion.



These four propulsive methods are classified in the viewpoint of the mechanical design for boat. Thus they may not correspond to the swimming nature fish and rigorous hydrodynamics. However we can discuss design points in detail with the consideration of the classification.

Turning Mode C

The figure to the right shows the case of Mode C. The fish robot swings its tail to one side rapidly from stationary state. In this turning mode, inertia force and friction force of the moving tail and a body are changed to the moment of rotation. This mode has excellent characteristics. It is possible to turn from the stationary state, and its turning diameter is the smallest in the whole modes. However, it is difficult to control turning speed and turning angle. Also, in order to get quick turning, it is necessary that the power source for tail swing should have sufficiently high torque.

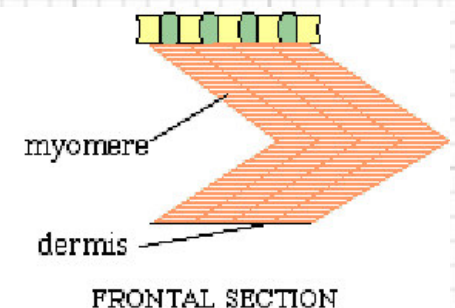
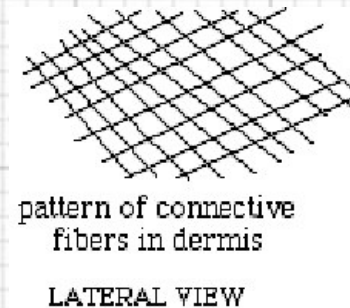
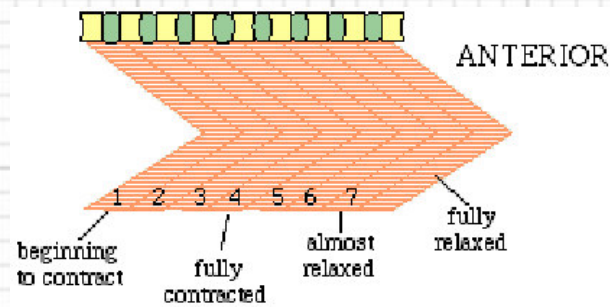


Physiological study of fish's muscular structure

The principal muscles of a fish are the trunk muscles (the fillets). Trunk muscles are arranged in segments (**myomeres** or myotomes). Contractile fibers in the myotomes are oriented roughly parallel to the long axis of the body, so that their principal insertion is the next myoseptum although the deepest ones may insert on vertebral centra and the most superficial ones insert on the skin.

Obviously, contraction of a single myomere would cause a flexion of the fish toward that side. However, myomeres form a complex set of nesting cones, some pointing forward and some back. Contraction of any one myomere will thereby produce a general flexion of an area of the trunk since the myomere reflects back across several centra and the dermal fibers further disperse the action.

When a fish is swimming the myomeres contract sequentially from head to tail so that a wave of contraction proceeds down one side of the fish. The other side is doing the same, but out of phase. About 7 myomeres are involved in each wave so that the 7th one is just beginning to contract by the time the first one is almost fully relaxed.



General guidelines from the studies on fish

The longer and faster the fish, the more frictional resistance would be encountered. A small enough fish might never encounter turbulent friction, but a large one always would. Many fish are small enough to never exceed speeds and lengths which would induce a turbulent boundary.

Mucus Small amounts of long-chain, high molecular mass polymers added to water can cause a substantial reduction in frictional drag under turbulent flow conditions. Mucus from the Pacific barracuda gave a 65% friction drag reduction with a 5% mucus-seawater mixture.

Flexibility to bend the body into a strong arc provides a power thrust from a standstill Large dorsal and anal fins, located far back on the body (pike style) maximize the force exerted on the water in such a jump start. In a pike or barracuda

The long body provides lateral resistance to prevent the head end from swinging too far out of line. Shorter ambush predators (for example smallmouth bass) Often have a relatively large spinous dorsal fin fairly well forward to stabilize lateral movement. The spinous dorsal is lowered to reduce resistance as soon as the fish is well in motion.



NEOSHO SMALLMOUTH

Prominent dark spot on rear of gill cover. Jaw extends slightly farther back than that of the northern smallmouth, almost reaching the rear of the eye. Found mainly in tributaries of the Arkansas River in Oklahoma, Arkansas and Missouri.

General guidelines from the studies on fish

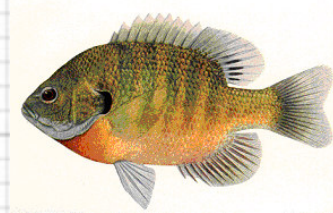
Maneuverability Specialists

Small-item resources are overall much more abundant than large prey. Small items don't move fast, but require delicate, focused movements for capture. Accordingly, many species of fish are specialists for maneuverability rather than speed. A short, rounded body with sculling or undulating fins nearly all the way around it maximizes maneuverability. Compressing the body laterally provides a wide surface to exert force on the water for quick escape movements. The pumpkin-seed or disk shape is one of the Most common in the fish world

Additional notes on fin swimming:

Pectoral fins are handy for braking or steering, but can also be employed in a powerful "breast stroke" as an aid in jump starts (sculpin). Many slow-cruise, precise maneuvering, fish employ elongate, somewhat diamond shaped pectorals in a vertical, figure-eight sculling. (Examples include bluegill and surfperch.)

Elongated dorsal and/or anal fins can provide propulsive force by an undulating wave traveling their length. While much less powerful than body-flexion swimming, it none-the-less provides some advantages. The body can remain rigid to improve sensory systems such as electrical detection, or facilitate sneaking up on prey. Movement can be equally facile in either direction (knifefish, bowfin).



Study of existing products and experimental fish models

The MIT robo tuna

There is currently an increased interest in the use of long range/long duration Autonomous Undersea Vehicles (A.U.V.'s) for oceanographic observation, military surveillance and commercial search missions. Existing A.U.V.'s are relatively small vehicles for three reasons; low cost (fully autonomous vehicles have a significant probability of being lost), ease of deployment (to allow operations from conventional ships), and safety (to minimize the danger to manned ships and installations). They are powered by small rotary propellers driven by electric motors. The propellers typically operate at fairly low efficiencies and suffer from serious lag times in transient response. The space required for the batteries often approaches 70% of the hull

volume. These problems lead to short mission times, restricted payloads, and control problems.

Consider the fish: highly maneuverable and an effortless swimmer, this animal 160 million years in the making is superbly adapted to its watery environs.

Now, in work that could lead to mini submarines with similar attributes, MIT engineers have developed the first robotic version of Nature's piscine wonder. Three summers ago the researchers' creation, patterned after a bluefin tuna, took its maiden swim down the MIT Testing Tank. That swim and others since have been flawless, reinforcing the engineers' belief that the Lycra-sheathed robot could become an important tool toward understanding the physics of swimming and more.

The fundamental objective of the RoboTuna's control system is to produce a dynamic body motion that

can realistically recreate the type of flow field that exist about and behind a swimming biological tuna.

This is a difficult task for a number of reasons. The actual dynamic shape of a swimming tuna has never been accurately measured, so there is no well defined target to aim for. In any case, the RoboTuna's body is only a low-order copy of a vastly richer biological system, and so it's not clear that attempting to precisely reproduce the biological motion is either practical or desirable. On the other hand attempting to derive the proper motion by purely analytical means is arrested by two problems. The dynamic interaction of the RoboTuna's undulating body with the passing fluid is (currently) too complex to accurately model. And the hyper-redundant planar kinematic chain nature of the body itself creates a situation in which there are an infinity of possible solutions as to how to move the body from



one kinematic position to the next. In spite of these difficulties and effective body motion controller was developed. With this controller fully operational, the fundamental questions of: Can flow past an undulation body propelled by an oscillation foil be “tuned” such that the body’s drag is reduced and its thrust is enhanced in a beneficial way? What are the parameters which control this tuning? What is the maximum beneficial way? What are the parameters which control this tuning? What is the maximum benefit that can be achieved? and Can a man-made (non-biological) system successfully exploit this phenomenon? could be fully experimentally explored. The “robotuna” project began about six years ago with the overall goal of developing a better propulsion system for A.U.V.’s,” said Michael S. Triantafyllou, a professor in the Department of Ocean Engineering who is leading the research team. The work is funded by the Advanced Research

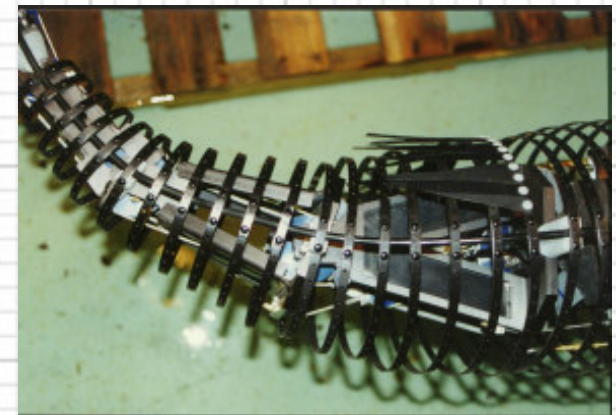
Projects Agency, the Office of Naval Research, the MIT Sea Grant College Program, the Woods Hole Oceanographic Institution, and MIT’s Undergraduate Research Opportunities Program.

The RoboTuna, designed and built by David Barrett, is a revolutionary undersea vehicle, with a flexible hull, propelled by an oscillating foil. It is, in effect, a carefully instrumented, precisely engineered robotic fish and was developed to explore the hydrodynamic mechanisms employed by a biological fish for propulsion. It is unique not only in its biologically inspired design, but in its ability to learn to swim with high performance.

Design Details

Incorporating all of the sophisticated engineering suggested by a live biological tuna into a man-made robotic vehicle capable of autonomous free swimming and maneuvering in an ocean environment is a daunting task. Rather than attempt to attain this goal in one giant leap, it has been perused in a number of shorter pragmatically achievable steps.

The first such step is to design, build and experimentally test a full sized, carefully instrumented robotic tuna in the M.I.T. Testing Tank. This is suspended from a single surface piercing streamlined mast from the Testing Tank’s carriage in a fashion commonly used to test the hydrodynamics of undersea vehicle models. As such its gross body motion will be constrained by the Testing Tank’s carriage to be in a straight line over the length of



the tank at the midway depth between the tank's bottom and the free surface. The tuna's body however is able to rotate freely about its center of mass in a plane parallel to the water's free surface. The experimental apparatus that makes up the testing tank consists of 2 major mechanical subassemblies; the robot fish body itself and the support structure which attaches it to the testing tank's carriage.

The robot's body design closely parallels that of the biological tuna. As such it must fit into the carefully prescribed volume of the biological Tuna-form shape.

The major structural component of the robot fish is a segmented backbone made up from 8 discrete rigid vertebra connected with low friction ball bearing joints. As in the biological fish this is the

framework on which all the other subassemblies are mounted and the orientation of these vertebra to each other defines the overall curvature of the fish's body.

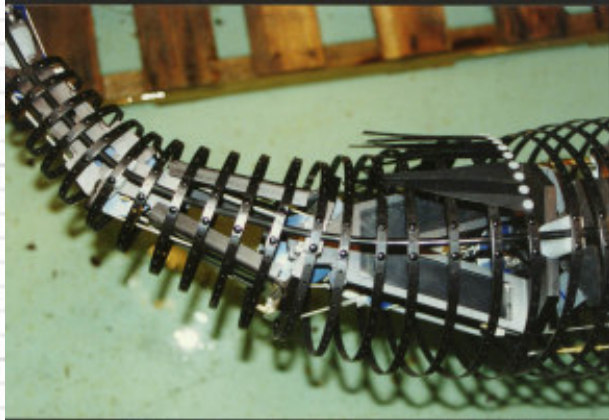
These 8 vertebra are driven through an elaborate system of pulleys and cable tendons by 6 brushless DC servo motors mounted outside the fish above the waterline inside the carriage support structure. These tendon drives are the mechanical analog of the biological fish's muscles.

In between each discrete vertebra is strung a flexible spring steel spline element on which are mounted lightweight body ribs that define the overall tuna form shape of the outer hull. As the discrete vertebra move with respect to one another these spline-rib assemblies bend to provide smooth continuous structural support for the flexible outer hull much as the real fish's ribs do.

The robot fish's outer hull consists of a thin layer of flexible reticulated foam covered by a conformal Lycra sock. The foam acts as the analog of the biological fish's flesh, the Lycra sock as it's skin, to provide a smooth continuous hopefully wrinkle free flexible outer hull.

The body itself is suspended from the support structure by a single surface piercing streamlined mast which both supports the body and acts as a conduit through which all the tendons and sensor wires pass. This mast in turn is mounted to the support structure in a fashion which will allow it to rotate up out of the water for robot maintenance and storage.

The support structure consists of a rigid welded aluminum space frame which attaches



to the to the existing testing tank carriage. In addition to supporting the mast and fish it also houses the servo motors and various bits of sensor electronics.

Connecting all these subsystems and subassemblies together are two experimental apparatus controllers (one for the fish and one for the testing tank's carriage), and two data collection systems (one for the coarse real time data viewing and one for the precise high speed data collection). These for systems work together in parallel to both produce fish like motion by the tuna and to record the output from its sensorsystems while it swims down the tank. The end result is a vehicle that both looks and moves like a real biological fish.



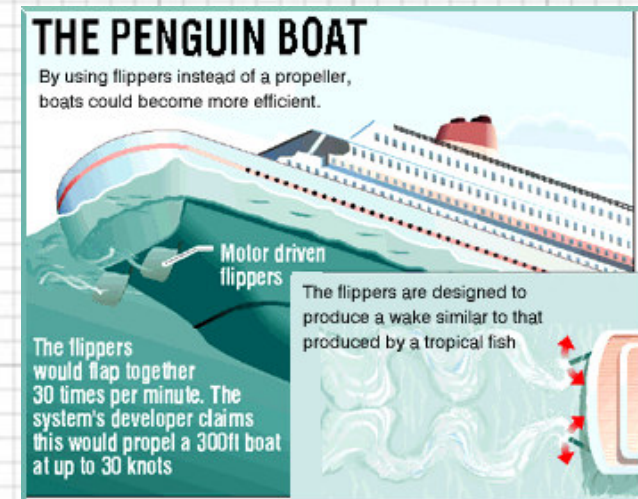
PROTEUS THE PENGUIN BOAT

A boat that swims like a fish. Just as a penguin or sea turtle are a rigid body with fish-like flapping fins, Proteus is a boat that propels itself with two oscillating foils. The Proteus project is the challenge of pragmatically applying highly efficient natural fish propulsion technologies to conventional vessels.

One hundred and fifty million years of evolution has enabled fish to develop extremely efficient technologies for aquatic propulsion and maneuvering. Recent experimental, MIT Robo-tuna, and computational studies confirmed this. However, because these studies were based on models with undulating bodies, direct application to ships and submarines is not possible. Our goal was to apply the promising “fish” technologies to conventional

marine vessels pragmatically. Success could mean the savings of millions of marine transport dollars and subsequent environmental damage, autonomous ocean research vessels covering more territory, and military submarines evading their foe because their “fish wake” is difficult to detect. An extensive literature review and discussions with marine hydrodynamics experts showed that efficient propulsion may be obtained by the oscillation of a foil without an undulating body. For example, large whales and other oscillating foil propelled animals requiring high efficiency employ the thunniform mode of swimming, which consists primarily of tail oscillation. Other animals, such as marine turtles or penguins, obtain efficient propulsion by pectoral flipper oscillation alone. In this spirit, a boat foil propulsion design was developed with two foils moving out of phase so that thrust would be the only net force and vertical foil orientation allowing for

the possibility of thrust maneuvering with thrust vectoring. The challenge of actuating the foils with the appropriate “fish” motion was first met with a prototype mechanical device capable of oscillating two foils with limited independent adjustment of the foil’s heave, pitch, frequency and phase between the motions. First-ever autonomous operation and wake visualization experiments were conducted and yielded useful results. The shortcomings of the first mechanism where met with a remote controlled four-degree of freedom robotic mechanism. Advanced mechanical design and state of the art electronics allow this 3.4 meter long oscillating foil propelled boat to produce accurate efficiency measurements over a wide range of operating parameters. Results from preliminary experiments are very encouraging.



Some of the existing human powered boats

The WaveBike is the first and only pedal-powered watercraft to employ an active balance fin and separate steering fin, thus mimicking the balance, feel and speed of a land bicycle. Although it looks difficult to ride to the uninitiated, the WaveBike is amazingly stable. It's really just like riding a bicycle! The balance system works so well, the WaveBike can be ridden on all kinds of water including the ocean. The WaveBike combines the fun of being on the water with the efficiency and exceptional exercise qualities of cycling. If you are a competitive cyclist interested in the concept of practicing your art on the water, or a water sports enthusiast, or just someone who wants to follow the progress of a truly new and original idea.

This study was undertaken to understand the possible seating postures and to assess the alternative propulsion mechanisms. This was an opportunity to understand basic boat constructions also.

Points to observe in this concept are the braking mechanism which consist of two scissor action floats which act as a kickstand also And can be successively flared out and retracted



Hydro bikes

With little effort you can maintain a cruising speed of 4-6 miles per hour, and you can accelerate up to 10 mph. On a Hydro-Bike you're comfortably seated upright for great viewing as you cruise by canoes, kayaks, and paddle boats.

Features and Benefits

Peace and quiet: The Hydrobike is engineered for silence. It won't disturb wildlife habitats- or fishing holes.

Strong, fast, and light: The Hydrobike's pontoons were scientifically developed by a professional canoe designer for optimum bouyancy, speed, and maneuverability. That means you will have a smooth ride even in very choppy water.

Steady and sturdy: Stable enough to dive from, the

Hydrobike can also handle rough water conditions, including five foot ocean swells.

Propeller-driven for the fastest performance: This is no slow paddle boat. The Hydrobike's computer-designed propulsion system features a 90% efficient propeller which allows you to achieve cruise speeds of 4-6 mph with minimum effort.

Shallow water is no problem: Ideal for narrow and shallow water, the Hydrobike can operate in less than one foot of water. If the drive train and propeller encounter rocks or sand, it automatically pivots up and over the obstacle. You can even pedal right up onto the beach without damaging the propeller or rudder.

High-performance propulsion system: The lower drivetrain is sealed water-tight, providing protection even in salty seawater. The chain uses

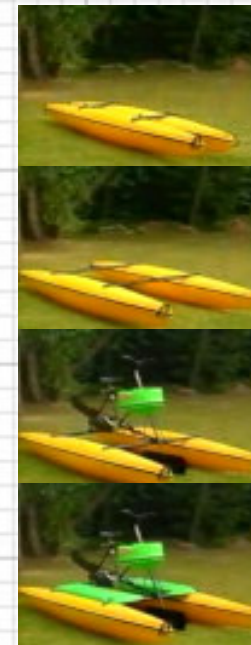
environmentally friendly lubricants.

Built-in storage compartment: Stow extra clothes, beverages, and cargo. There are even two cup holders.

E-Z carrying straps: optional, these straps make it easier to tow the Hydrobike in and out of the water.

Hand tool assembly: One person can assemble and disassemble the Hydrobike in minutes, without any tools.

The hydrobike is basically an elemental construction in individual pontoons and seats



Some other boats are as shown

The bathtub ... pedal powered , tubular chassis



The MIT decavitator which hold the water speed record for the fastest human powered boat. I have used the recumbent seating posture for the scale model and have suggested the same in the concepts also because ergonomically it has scope for providing maximum push.



the decavitator uses the airfoil effect to lift itself out of water to reduce drag.



Pedal powered propeller boat, monocoque FRP construction



Recumbent face to face position for a double seater craft . helps to dynamically balance the boat



A pedal wheel boat



The Flying Fish II

The traditional cycle posture . Substantially high centre of gravity makes it unstable. Require braking and parking pontoons.



These pictures are of the “New
Fisics”: FREE ENTERPRISES “orbital”
type hand / foot powered hydrofoil
that won the U S national 100m
sprint competition in 1997



Double seater arrangement



Tubular chassis construction with foam floats .
propeller powered.

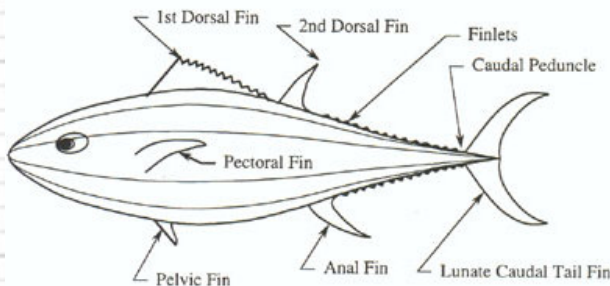


Water buggy . pontoons and wheels combined .



Why tuna ?

Tuna is among the fastest swimmers in the aquatic kingdom with maximum speeds of
Speed = 80 km/h = 22.2 m/s = 50 MPH
Length = 3.0 m
V/L = 7.4



A tuna is able to do this because it derives nearly all of its propulsive force from an oscillating wing-shaped tail fin. The motion of the oscillating wing is combined heaving motion and feathering motion of the tail fin, and has about 90 degrees of phase angle between the heaving and the feathering of the tail fin. This fish has a crescent and wing-shaped tail fin. As its span is long and its chord is short, the tail fin has high aspect ratio. High aspect ratios are associated with very high lift performance in wings, propellers, helicopter rotors, high-speed motorboat propellers and hydrofoils. A wing with high aspect ratio has the great characteristics such as low drag and strong lift for a surface area of the wing. **Thus, the Oscillating Wing gets the great performance, when a high performance tail fin in hydrodynamics, a streamlined body and a slim peduncle are combined.** The body with

Experimental model

few drag and strong propulsive force by the tail fin obtain high-speed swimming. The energy for driving the tail fin is a few, because the surface area of the wing is small for a size of the fish robot. Then the oscillating wing propulsion can get high propulsive efficiency. But the fish robot with this method does not expect to get good accelerating performance from stationary position, because the propulsive force is somewhat small for the size of the fish robot. It also is important that we should design the joint at the tail fin in careful, because the strong force is concentrated at the joint.

actual dynamic shape of a swimming tuna has never been accurately measured, so there is no well defined target to aim for. Like the RoboTuna it will be a low-order copy of a vastly richer biological system, So our approach in experimenting with a scale mechanism is to assess the scale and possible locations of seats and propulsion mechanism.

However we kept some presets

The seating arrangement will be recumbent so as to provide maximum push from the legs at possible dead centers which are quite possible in the reciprocating systems.

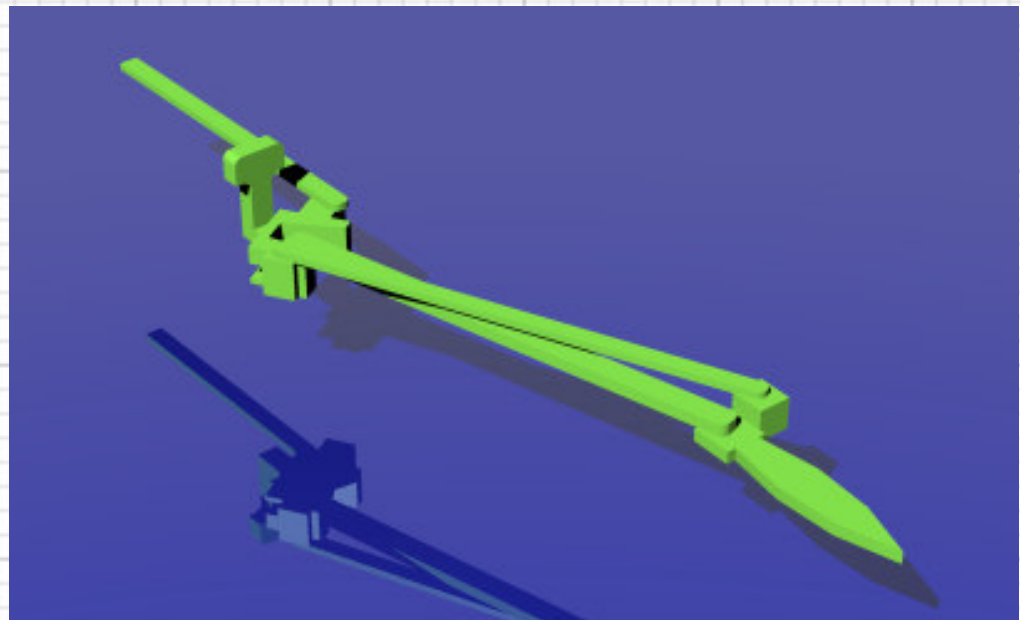
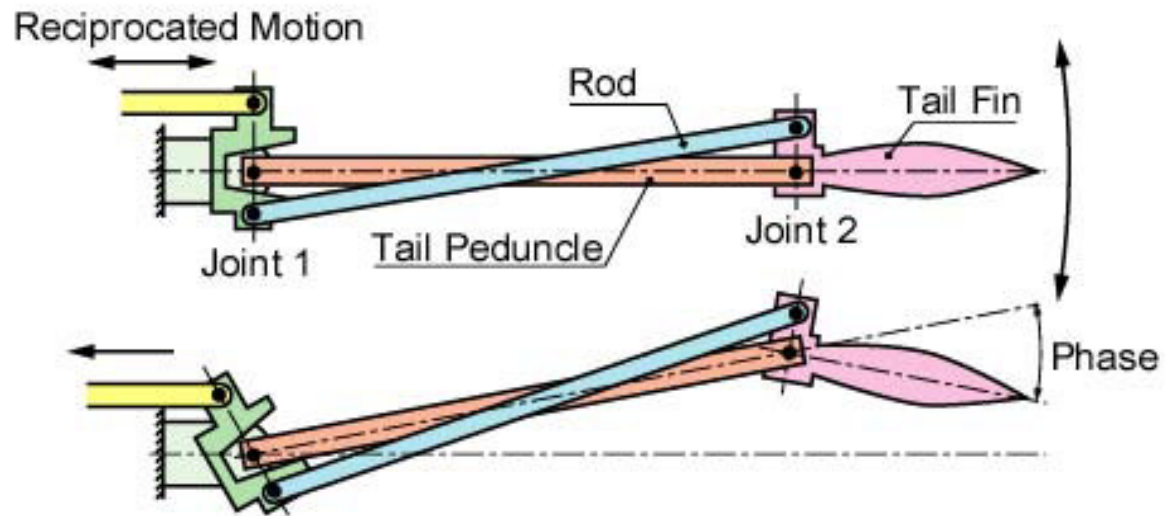
it will be a single seater craft with either a pedal to be operated by legs and steering system also.

Mechanism

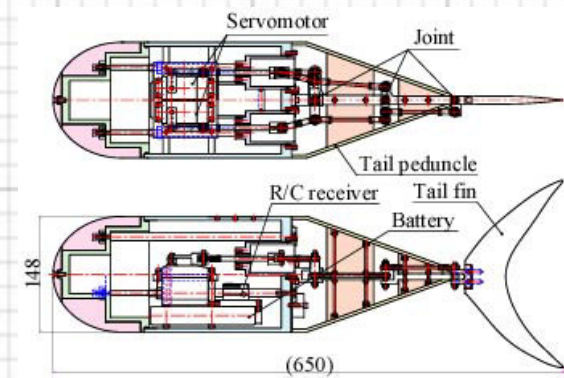
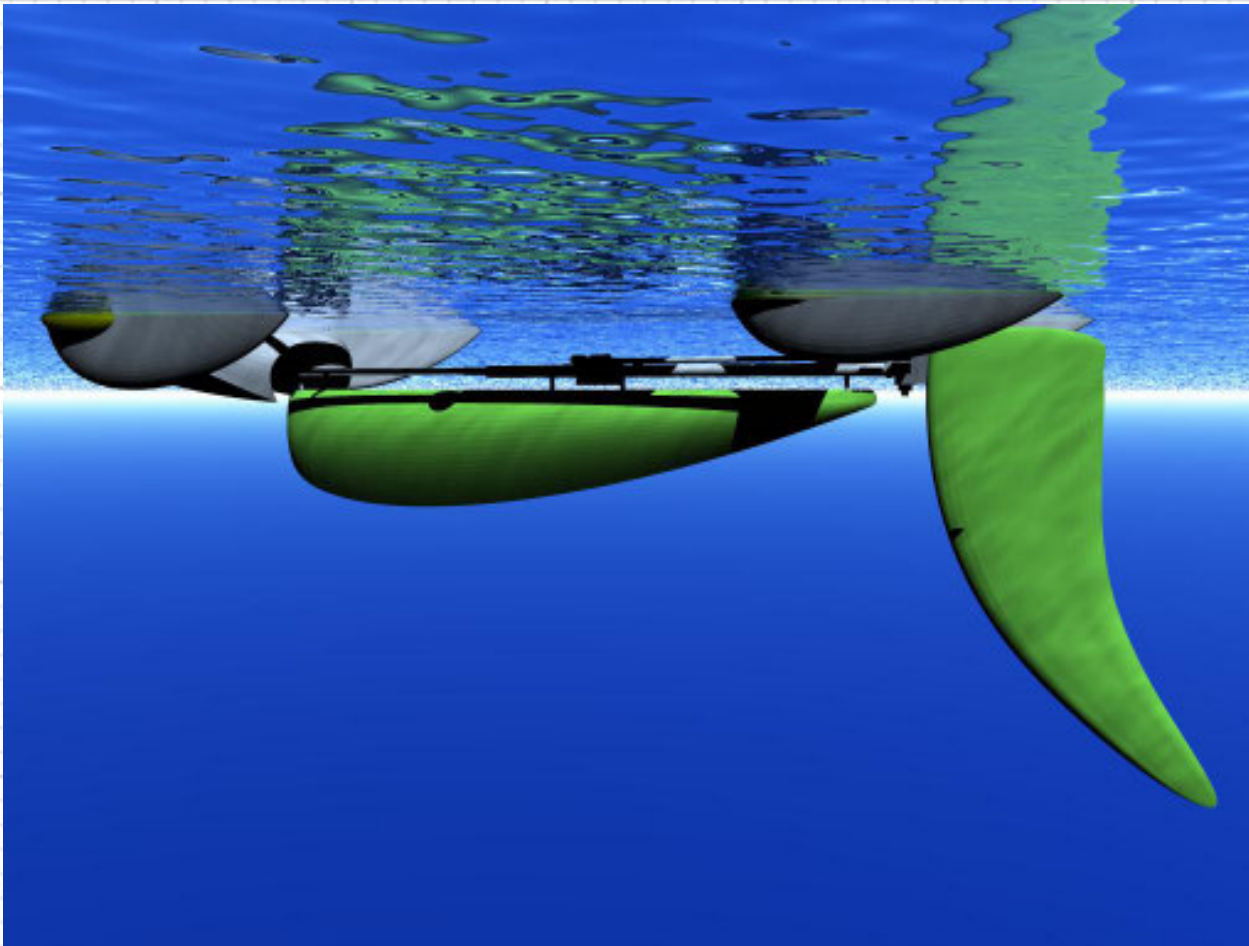
The mechanism to be used in the inverted pantograph mechanism which creates the desired phase difference in the tail peduncle and the fins.

The mechanism is as shown below.

Since the boat model has to be based on a 1:5 human scale the mechanisms have to be suitably scaled to fit the entire length of the boat chassis. To start with we decided to use the entire length of the boat to fit the mechanism. With further experiments we cannot deny the possibility of scaling it down.



another mechanism which has been used in experimental fish models, which always maintains the phase shift



model details

The final model looked like this.

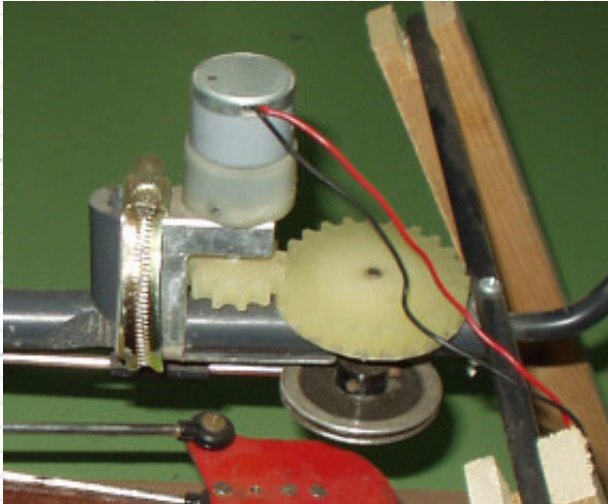


The contraption was placed on the thermocol float before putting in water. the float are generating maximum buoyancy in the front and back and the sides generate the resistance to reduce the sway .



model details

The model is powered by a 12 V DC motor which is umbilically attached to the power unit.



This detail was used to provide the necessary frictionless drive to the fins as well as to bear the load of the fins. This same detail can be used in the real scale model. Essentially consist of a thrust bearing which is supported on both sides. However the detail will not sustain the same load because once inside the water the buoyancy will bear most of the load.



The fins have been shaped according the airfoil profile, templates for which are easily available



The trials

Following observations were noted during the trials on the model conducted in the artificial pool in IDC studios.

Too much transvers sway which needs to be arrested because it is dissipating the power developed

The model is fairly balanced by provision of floats along the front and rear and on the sides.

The sailor should be preferably situated above or close to the pivot of fins.

The dead centres occurs on the ends of amplitude of the fins. More torque is required at these ends.

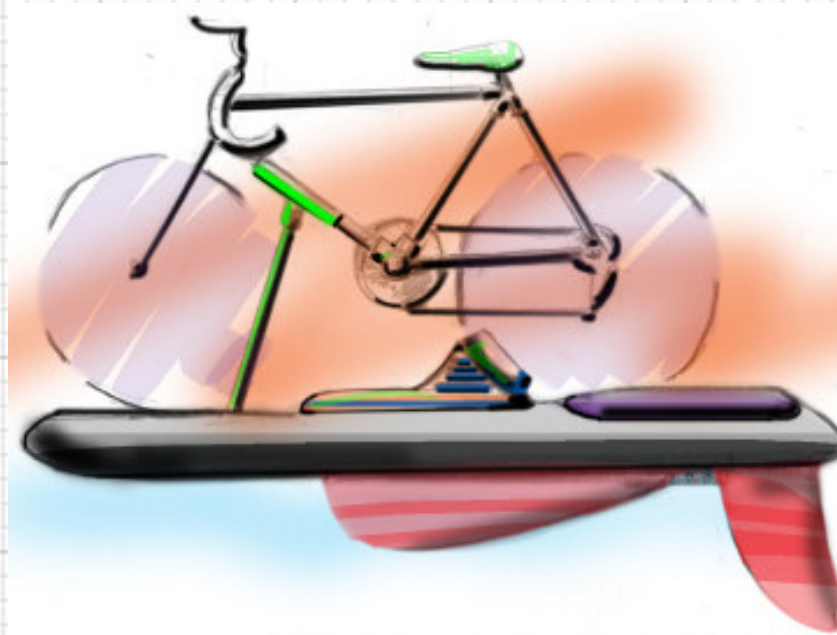
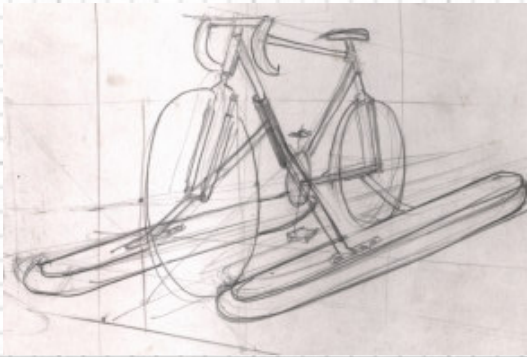
This is the desired motion in which the rear fin leads the front peduncle by a phase angle of 90degrees. While the drawings suggest a shift at the dead centers only however once put in water the fish the shift will be more gradual due to resistance of water and inertia of the fin material which will act in opposite direction of its motion.



Concepts

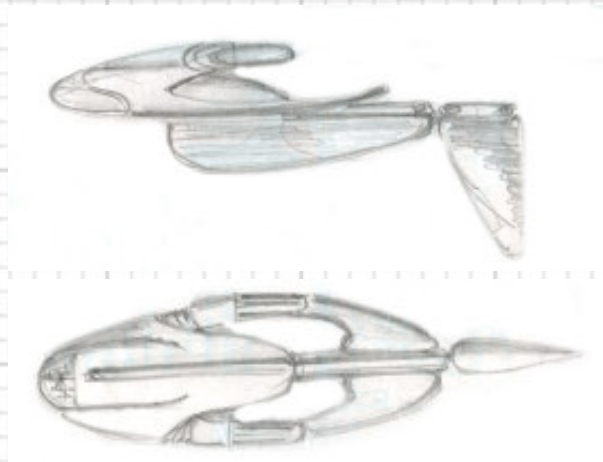
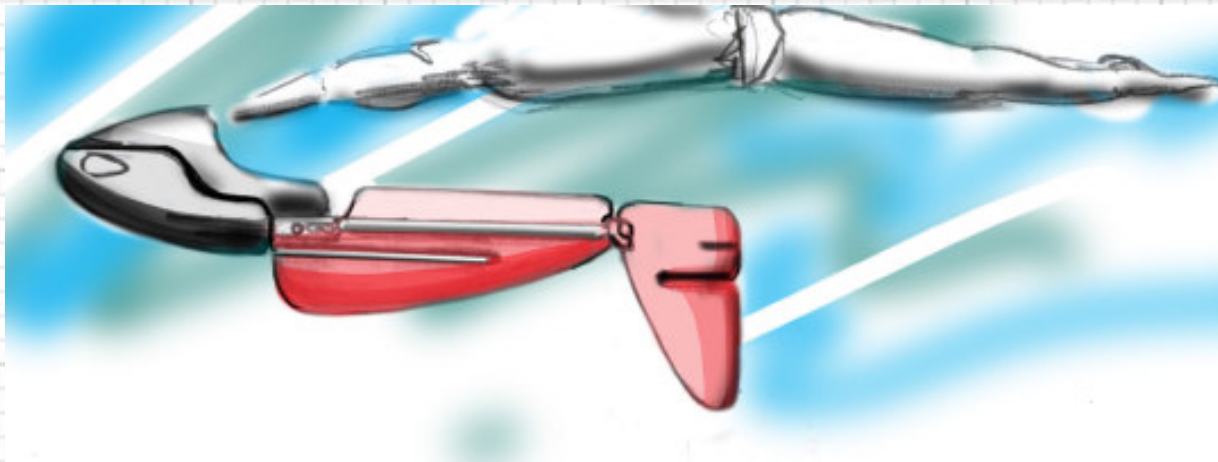
These concepts are product forms which are designed around the mechanism. They are proposals for both under and overwater applications of this bionic principle.

In this the perfected mechanism will be mounted on a platform which can be fitted with virtually any make of bicycle using minimal support geometry and pivots. The rear tyre will provide drive to a friction platform which further transfers the drive to the contraptions below. Steering will be achieved by the normal rudder system.



Concepts

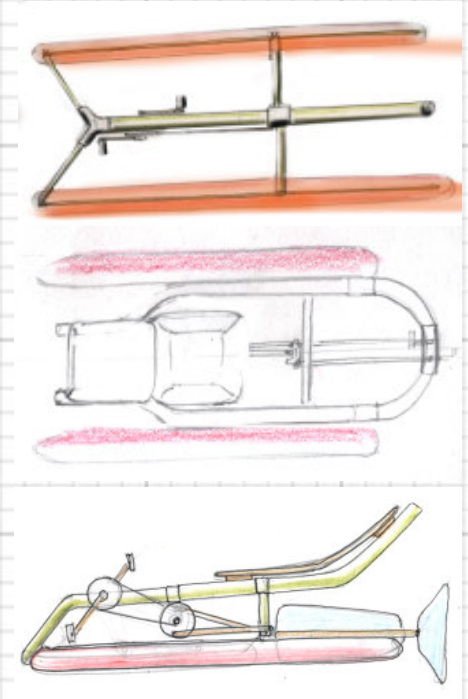
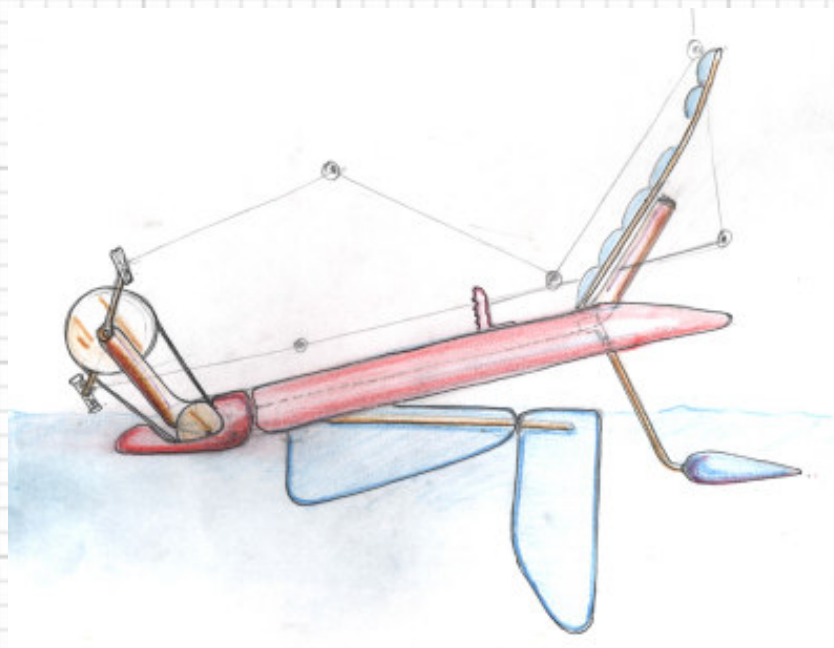
Personal water craft which is less noisy and turbulent then the normal propeller driven under water crafts. This allows you to get closer to the natural underwater world which is not so comfortable with propellers.



Concepts

Some other configurations for the tubular chassis

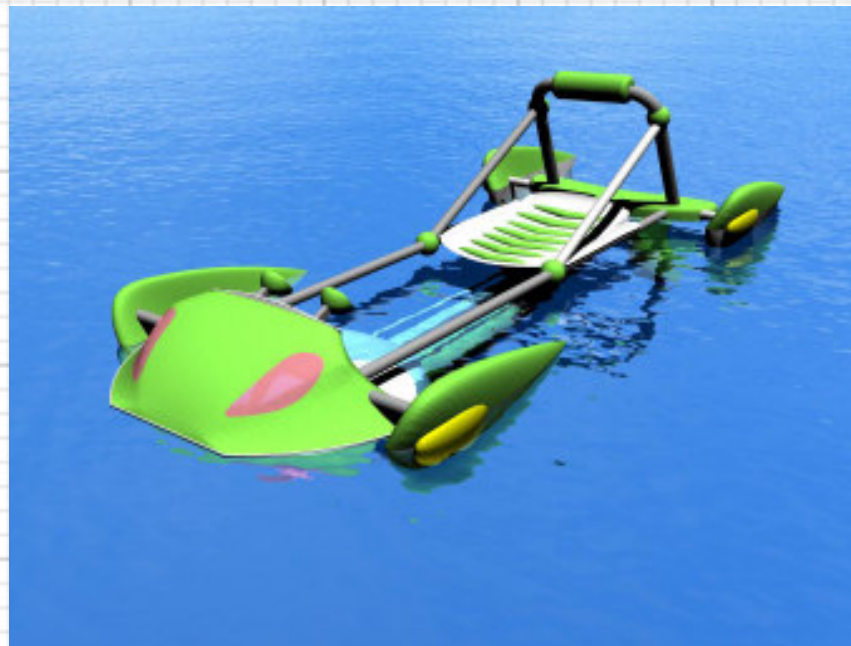
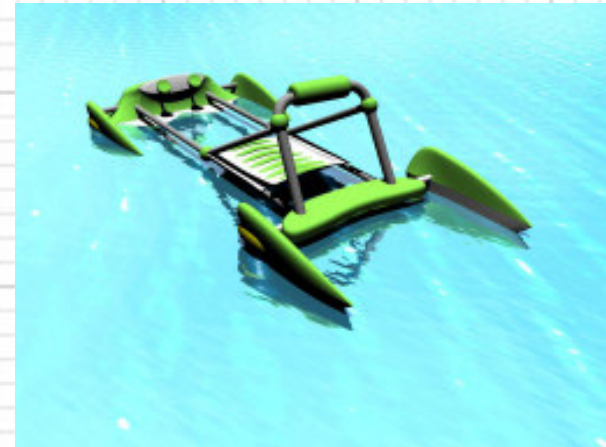
A craft based on the mechanism provided with airfoil which lifts the craft above the water so that the friction is reduced. The drive is through pedals which driver a crank.



Concepts



A much more refined product form can come out as something like this. The four floats on the sides have been shaped to minimize sway. The seat can be shifted for the right posture. The front portion is bloated to provide extra buoyancy for the mechanism weight. The boat is pedal powered and steering is obtained by pushing the pedal on the desired direction successively while arresting the other one at the dead centre. The construction is in FRP with tubular inserts. The caps at the end can be pulled out to attach two or more boats together.



References

Books

- Locomotion II, Thrust, Ichthyology, the study of fish, Biol. 261, Paul E. Maslin, California state university press, 1988
- C.A. Marchaj, "The Aero-Hydrodynamics of Sailing", International Marine Publishing Company, ISBN 0-87742-993-6
- S.F. Hoerner, "Fluid Dynamic Drag", "Fluid Dynamics Lift", direct mail from Hoerner's widow:
- Decavitator vs. Flying Fish" July 1993 , Popular Science (page 66)
- Human Power (volume 9, issue 3-4; fall/winter 1991-1992)
- Bruce Kelly "Building in Fiberglass". Yacht Racing/ cruising, p. 71-73: July/ AUG, 1982
- Decavitator; Mark Drela & students MIT , 1988

Useful web sites

Design details of MIT robo tuna

(<http://web.mit.edu/towtank/www/tuna/brad/design.html>)

PROTEUS THE PENGUIN BOAT

(<http://web.mit.edu/towtank/www/flapfoil>)

Recumbent Cycle Projects

(<http://www.ihpva.org/people/tstrike/home.htm>)

Video archives for human powered boats

(<http://www.wavebike.com/usfiles/vidarc.htm>)

Early "Flying Fish" probably 1983; Source: MIT "Decavitator" files:

<http://lancet.mit.edu/decavitator/VideoClips.ff.html>

Archive of design details and videos of model fish robots developed at national marine research institute, Tokyo, Japan

(<http://www.nmri.go.jp/eng/khirata/fish/model/modele.htm>)

Robotic and other interesting links

(<http://www.nmri.go.jp/eng/khirata/fish/others/otherse.htm>)

BIONIC BOAT

This project aimed at utilizing the motor qualities of fishes to conceptualize a human powered boat. A scale model of the boat was made and experimented upon which provided useful observations. Concepts have been generated in this project which broadly defines the possible scope of utilization of this bionic project in various fields of aquatic- transportation. Notable among them is the human powered boat which theoretically is more efficient than propulsion powered boats and has unique turning qualities and mechanisms.

