Videofish: TV Worth Catching

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Abstract

The Videofish project at USF is a two-semester course which brings together students in the arts and engineering to build an underwater unmanned vehicle capable of displaying videos. As a result of accommodating the needs of the diverse populations, three novel forms of delivery have been developed: *skill workshops*, which serve to equalize the hands-on abilities of different students, *multi-media presentations*, which incorporate the excitement of advanced visual presentation techniques with engineering details, and *studio critiques*, where the presentation and style of evaluation of art, architecture, and industrial design projects are applied to engineering proposals.

Introduction

The Videofish Project at the University of South Florida is a unique interdisciplinary educational effort sponsored by a grant from the Colleges of Engineering and Visual and Performing Arts. The goal of the project is to foster interdisciplinary collaborative research and education between the two colleges by creating underwater, mobile visual art. The Videofish Project is directed by Prof. Robin Murphy (College of Engineering, Department of Computer Science and Engineering), a roboticist, Prof. Hasan Elahi (College of Visual and Performing Arts, School of Art and Art History), a visual artist, and Dr. Bill Kearns (Florida Mental Health Institute), a psychologist with an interest in animal behavior. The project is instantiated as a two semester course sequence (Fall03/Spring04) for seniors and graduate students. We expect the lessons learned from the videofish project will transfer to general robotics education and improve the incorporation of demanding robotics projects into a course.

The technical objective of the videofish project is to create a self-contained robot fish with a monitor that can operate autonomously in fresh water. The monitor opens robots in the form of *ichthyologic automata* to visual art possibilities, creating a new mechanism for expression in an unusual environment. The project itself poses many interesting technological challenges suitable for advanced undergraduate and graduate students in engineering and arts, including how to put video electronics on an underwater object, how to maintain neutral buoyancy and control, how to balance the design with power limitations, and how to incorporate micro-electrical mechanical systems (MEMS) devices. Videofish is intended to be the foundation for continuing research in engineering (especially camouflage behaviors for the military and control of multiple underwater vehicles), create a medium for a new field of visual arts, provide a hands-on interdisciplinary experience for advanced seniors and graduate students in Engineering and the Visual and Performing Arts, and produce a pod of commercializable products from use in public arenas, individual pools, and the diving and fishing industry

Bridging Art and Engineering

Throughout art history, artists have always relied on technology. Though the artists' perspective of the use of the technology generally stemmed from alternate reasons and took directions of the original innovators ideas. In short, the artist doesn't come up with the technology, but the artist merely finds a way to adapt that technology for creative purposes. If one were to look at the evolution of the technology of the print for example, one would see that in the 15th Century, our communication tools were limited to some form of a woodcut print. The technology of this tool gradually led to engravings, intaglio, lithography, and then serigraphy. The natural progression of the print as a technological tool of communication required it to embrace new technology. Therefore using video seems only natural. The medium has changed over time, the purpose has not; the essential task is still to communicate an idea and to exchange information from point of departure to point of destination. Also, throughout the better part of contemporary art history, some of the most visionary works hardly were accepted as "art" at the moment. It is only many years later that the significance of these works are acknowledged. Probably no other work than Marcel Duchamp's Fountain, an overturned porcelain urinal from 1917 embodies this transformation into art. In a similar manner, the creation of the Videofish goes into a cutting edge realm of art making, which revolutionizes the possibilities for creative expression and artistic value in the relatively untapped field of aquatic kinetic sculpture.

Participants

The Fall course was being taken by 10 students, five from Engineering and five from Visual Arts. Of the 10 students, three were women, and three were minorities.

Resources

The project was awarded a $20,000 budget to cover equipment costs (including $2,000 per student group project) and one teaching assistant for the two-course sequence.

The Videofish project did not place a large burden on facilities. The major of the classes were taught in the Visual Arts iMac cluster which had a few empty tables. This facilitated simultaneous programming and hardware construction.

Central to the videofish project is the use of robots and artificial intelligence programming. However, the class demographics were intended for students who had no prior robotics experience and possibly no programming experience. In order to make robotics accessible, a behavioral (reactive) approach is emphasized and the Lego Mindstorms RCX was chosen as the "brains" of the autonomous fish. The first author has had reasonable success teaching behavioral robotics to both college and K-12 students using the Mindstorms kits (Howell 03, Gage 03). The course is using the Labview/Tufts language, which combines the simplicity of a visual programming language with the necessary coverage for autonomous control. The course is taught in the Visual Arts iMac lab, and students are allowed to check out RCX kits and software for home use. Part of the hands-on electronics component involves modifying servomotors and sensors to interface with the RCX.

The project uses 10 Mindstorms kits plus assorted servomotors and batteries, which are supplied by the department. As the course is currently being taught, the exact list of parts is incomplete. Each student is expected to spend about $50 for a basic electronics kit from Radio Shack.

Organization of the Paper

The remainder of the paper is organized as follows. The pedagogical underpinnings of the course is presented first, describing three novel delivery mechanisms (skill workshops, multi-media presentations, studio evaluation) and reviewing the course syllabus. Next, both the technical results of the first semester and the student feedback are discussed.

Pedagogy

The Videofish course is unique in that it attempts to integrate arts and engineering. However, in many regards, the Videofish course is an interdisciplinary design course and can serve as a model for teaching such courses with robotics.

Overall Objectives

The overall educational objectives are for students in engineering, arts, and cognitive science to apply what they've learned to a large project; learn about new ways of thinking and different viewpoints on technology, design, and evaluation; and learn more about teamwork and project management. The specific objectives by semester are below.

By the end of the Fall Semester, the students were able to:

- understand the process and benefits of studio evaluation
- understand bidding process and be able to write basic requirements
- learn history of submersibles, industrial design, and video art
- acquire basic understanding of submersibles
- be able to program a robot using a visual programming language
- build a working submersible
- create a video production for a submersible device

In the Spring, students will build and test the videofish and then exhibit the robot at an art show in St. Petersburg, Florida.

Novel Concepts in Delivery

The pedagogical challenges of the videofish project are considered similar to the incorporation of robot competition events into the classroom. The lessons learned from those events by the first author and reported in Murphy 00a serve as a foundation for the framework of the course. Rather than give a group of students a requirements specifications document and a budget and tell them to fish for solutions, the project exposes the students to the subject through a series of structured, hands-on *skill workshops*. These skill workshops form a pre-requisite for a more open, creative phase. Therefore, the videofish course was divided into 2 semesters: the first semester on building a robot and producing a video then creating an informed design, with the second semester on refining the design and construction.

In addition to the skill workshops, the Videofish course is also pioneering the use of *multi-media presentations* rather than traditional written and oral presentations and the use of *studio critiques* as a model for project evaluation instead of instructor grading.

Skill Workshops. Seven skill workshops (WS) were developed for the course. Students worked in teams of two or three, generally at least one Arts and Engineering student on each team. Each WS is described below.

WS1: Sewerbot. This introduced the Lego Mindstorms and Labview Interface. The students built the zoobot base and then programmed it to be a "sewerbot", duplicating the same behaviors (wall-follow, avoid) used by the autonomous underwater robot described in the New York Times June 7, 2003, article: What's That Swimming in the Water Supply?; Robot Sub Inspects 45 Miles of a Leaky New York Aqueduct. See Figure 1.

Figure 1 Programming the "Sewerbot"

WS2: Rewire Servos. This workshop taught students how to solder small components by having them partially dismantle and re-solder the electronics in an RC servo to make it work as a mechanical output for the RCX.

WS3: Tie into Mindstorms. Students connected the servo to the mindstorms and programmed the control loop. See Figure 2.

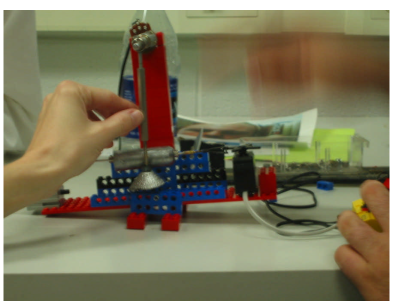

Figure 2 Control mechanisms

WS4: Building control mechanisms.
WS5: Tie into mindstorms
WS6: Materials lab.
WS7: Videoproduction. This workshop followed two lectures on Adobe Premiere, After Effects, and Macromedia Director. The students had to produce video about fish with visual effects and an audio track.

Figure 3 Waterproofing the ensemble

Multi-media Presentation for Team Projects. Each team was required to "pitch" their project in both writing and in person to the clients, in this case the instructors and the deans of the colleges of Engineering and Visual and Performing Arts. The written presentation was not a traditional report, but rather a multi-media webpage that had to 1) sell the concept, 2) cover all the technical details and 3) include video and drawings.

The oral presentation was also multi-media, emphasizing advanced electronic presentations and physical models. Unlike the typical Powerpoint slide show, the students had at their disposal an entire multimedia computer lab configured for use in the environment of an art studio. Video editing tools such as Premiere were combined with interactive tools such as Director and then taken through various steps and adapted for final presentation on the web through Dreamweaver and Flash. Students were encouraged to use the resources available in the School of Art and some created scale models in clay. Since all the student teams were comprised of at least one art student and one engineering student, the result of their ideas through these technological tools and resources led to unique multimedia based presentations.

Studio Evaluation. Projects were evaluated by the entire class and instructions. In the studio arts, being a discipline where there are no absolute correct and incorrect solutions to problem solving, the most important evaluation process is the *studio critique*. While the Art students are quite used to this type of evaluation, the format of these critique took on a very different form when the works were collaborated on with Engineering students. The discussions of the works led to directions not generally found individually in each discipline and thus this truly was an interdisciplinary approach to problem solving.

Figure 4 Student studio presentations

Speakers

The Videofish course has been fortunate in linking to events on campus and attracting a variety of speakers. In the Spring semester the class will host ADM Dan Cooper

(USN Retired) on how submarines are designed and work, Arthur Ganson (engineer and MIT resident artist), and attend the USF DNA celebration with Eduard Kac as the guest speaker and an exhibition by Jim Campbell on visual perception.

Syllabus

The syllabus for the Videofish course is shown in Figure 10. Students were given reading and writing assignments. No textbook was required but *Introduction to AI Robotics* (Murphy 00b) served as an optional reference book. The reading assignments generally fall into one of three areas: submersibles, artificially intelligent robots, and industrial design. Other assignments include writing.

Results of First Semester

The results of the first semester can be divided into technical products and the student evaluations.

Technical Results

The class divided into teams of three to produce a concept and bid for a commission for the final project to be refined and constructed in Spring Semester. The project application area had to be one of the following: Underwater visual art or art education, Underwater behavioral research using active camouflage, Fishing practice, Underwater educational displays, Decorative displays, or Other application with a clear link to visual art, engineering research, or education.

The client's metrics for award were:

- Utility and delightfulness for the identified context, Manufacturability,
- Extensibility- can add other functions/forms, use for other applications
- Cost- the teams were given a budget of $3K-8K to produce 3-4 platforms
- Potential for commercialization
- Incorporation of visual art and robotics skills developed during the semester

The results were uniformly good and were critiqued at the beginning of Spring semester. While the technical components were generally solid, a few unfeasible configurations or design flaws were detected. From a client perspective the major conceptual improvements were to add a tighter focus on a specific context and emphasize that the designs should make the vehicle look more like it fit in the environment than high tech. The use of studio critiques allowed all students to see the merits of each team's design and quickly reassemble into a single team to produce a new, final design integrating the best of each. As a result of analyzing each team's designs, the average cost of the final design dropped from an average of close to $3,000 per proposed unit to $2,000.

Student Evaluations

Mandatory USF student evaluations of the first semester course were performed. The evaluations were positive, with 8 out of the 10 students responding. The overall ratings from the 4 engineering students responding were higher than the ratings for the 4 art students. The art student ratings were actually higher than normal.

	ENG	ART
1 Description of course objectives and assignments	4.75	4.25
2 Communication of ideas and formation	4.75	4.00
3 Expression of expectations for performance	4.75	3.75
4 Availability to assist students in or out of class	4.75	4.25
5 Respect and concern for students	4.75	4.50
6 Stimulation of interest in course	5.00	4.50
7 Facilitation of learning	4.75	4.00
8 Overall rating of instructor	4.75	4.50

Table 1 Summary of Student Evaluations

The students constantly commented on how much they were learning from the skill workshops and each other. Also, by the end of Fall semester students stopped using terms like "the art guys" or "the engineering guys" to refer to other members of the class. Instead each student was a valued team member with unique skills that were needed to make the project successful.

Another metric of how well the students liked the course is retention. Seven of the ten students continued onto the second course. Of the three students who did not continue, one had been a strong performer but graduated, the second had been a good student but felt could not accommodate the additional load of the "extra" course, and the final student had been a marginal performer in the class and dropped out.

Other Components of the Course

The first semester of the Videofish course was also rich in hands-on demonstrations. A hyperbaric test chamber and one of two submersible systems were designed and built by one of the instructors (Kearns) who is an amateur machinist. The first of the submersibles was a complex device built in pieces. The sensor interface and ballast system are key components and described below. The second submersible was a less complex remotely operated vehicle tested in a USF swimming pool at the first of the semester, taking advantage of the warm Florida weather.

Hyperbaric Test Chamber

A hyperbaric test chamber (Fig 5) was built for demonstrating to the students the impact of a poor submersible design on underwater performance. The test chamber, shown partially filled with water, is made from 4" diameter clear schedule 40 polyvinyl chloride (PVC) pipe. Each end is sealed with threaded caps of PVC available from Home Depot, and a low pressure gauge has been attached to the top cap via a 1/4"barbed brass fitting which has been cemented to the cap using JB Weld. Also attached to the top cap is a shrader valve (basic automotive type) to which is connected a bicycle tire pump. Small clear mockup submarine hulls (about 3" in length) are inserted into the chamber, and deliberately flooded by increasing the pressure in the chamber with the tire pump. Reducing the pressure in the chamber causes the mockup "submarines" to expel the water forced into them at high pressure and, if they are of a good design, they rise to the surface. Poor designs remain on the bottom.

Materials
1 3' length of 4" diameter clear schedule 40 PVC pipe
2 4" diameter threaded PVC end fittings (female)
2 4" diameter threaded PVC end caps (male)
1 1/4" threaded hose barb (brass) mates to pressure gauge
1 pressure gauge (30 psi)
1 shrader valve
1 bicycle pump
1 2' section of 1" diameter clear PVC pipe to make mockup submarine hulls
1 sheet of clear styrene plastic (to seal the ends of the mockup submarine hulls)
1 PVC cement
1 PVC primer

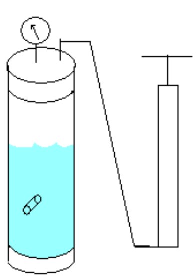

Figure 5 Hyberbaric chamber

Pressure Sensor Interface

Figure 6 shows the electrical schematic for the pressure sensor interface to the RCX. The Motorola MPX4250A is powered by 5.02 VDC, which is derived from a 6 VDC power pack (5 AA Nickel Metal Hydride cells) which is reduced through a 21 Ohm resistor and regulated by a Zener diode to 5.02 VDC. The output from the MPX4250A powers an LED whose input current is adjusted by a 10k potentiometer and whose brightness varies as a direct function of pressure at the transducer. This LED is physically connected to a photoresistor so that variations in light output from the LED cause linear changes in the resistance of the photoresistor, which is directly fed into the RCX and is interpreted as a temperature change.

Materials:
1 MPX4250A absolute pressure sensor (Motorola)
5 AA size nickel metal hydride batteries
1 5 V. Zener diode (Radio Shack)
1 5 V. LED (Radio Shack)
1 Photoresistor (Radio Shack)
1 RCX connector with wire (Lego)

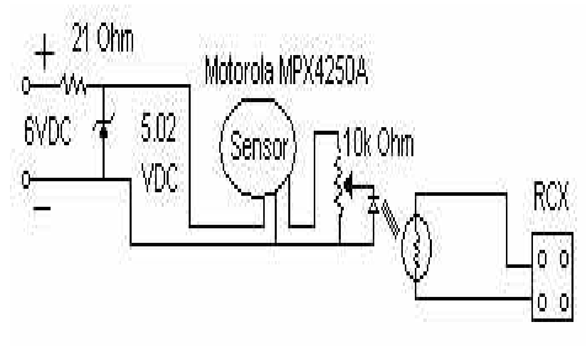

Figure 6 Pressure sensor interface to RCX

Electromechanical Ballast System

The electromechanical ballast system connects to an RCX output channel and is used to dynamically alter buoyancy of a submersible in response to inputs from depth (pressure) sensor (MPX4250A) connected to the RCX (see Figure 7). Volumetric changes are accomplished by varying the amount of water drawn into a 60 CC syringe via a worm drive made from a 1/4" diameter threaded shaft connected to the syringe's plunger. A modified radio control servo motor (consisting only of the drive motor and gearing but no electronics), drives the worm drive through a 4/1 gear reduction. The result are very smooth and slow volume changes which in practice have allowed RCX powered test devices to submerge to depths of 9' and return to the surface reliably.

Materials:

1 60 CC syringe (polyethylene)
1 stainless steel luer lock fitting
2 sheets of 3" square by 1/8" thick aluminum
1 gear set (4/1 reduction) Hobbytown USA
1 1/4" x 12" steel shaft 28 threads/inch (Home Depot)
3 1/8" diameter x 12" threaded (24 tpi) steel shaft

18 steel nuts for 1/8" diameter rod (above)
1 futaba RC servo (Hobbytown USA)
2 microswitches
1 spool 24 gauge electrical wire (Radio Shack)
1 3" x 3" x 1/8" thick length of extruded aluminum right angle bracket
1 roll double sided servo tape (Hobbytown USA)

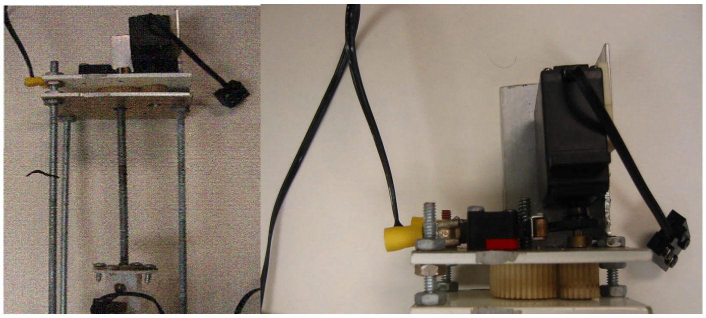

Figure 7 Electromechanical ballast system

Inexpensive ROV

An underwater remotely operated vehicle (ROV) was constructed for approximately $50 and demonstrated. The ROV is based on the "Sea Perch" from Bohm [97] and is visible in Figure 8. The original ROV was teleoperated.

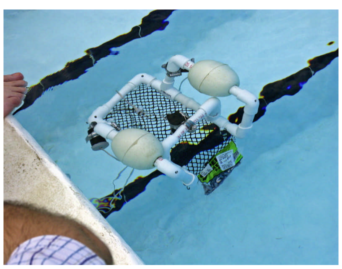

Figure 8 Inexpensive ROV "Sea Perch"

The course made one modification in order to be interfaced to the RCX and programmed for autonomous behavior. Figure 9 shows 2 of 6 relays. The relay function is complementary. Plus 6 volts on the RCX output turns on one relay, while -6 volts on the same output turns on the second relay. Both relays are off when RCX output is zero. Current flow to relays is determined by light emitting diodes which also have a signal function to the user. Rated capacity of 1.0 amps on relay contacts permits use of motors drawing 12 watts continuous in the current configuration. The major benefit is that this unit isolates the RCX from drive motors, stray currents, and allows higher power output to motors with minimal current draw from RCX's outputs.

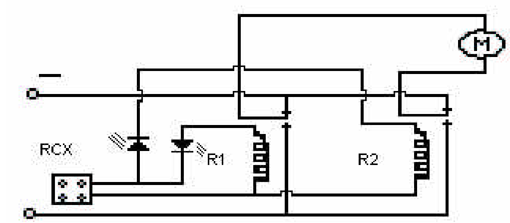

Figure 9 Relay motor controller for RCX

Summary and Conclusions

In summary, we believe the Videofish course shows that engineering and arts students can work effectively together. As a project class, the Videofish course contributes three important methods of delivery. The skill workshops allowed students to gain hands-on skills and gives them more insight to real design constraints, supplementing their more abstract classes. The quality of the designs was much higher than expected or previously encountered in either engineering or visual arts classes. Second, requiring students to prepare multi-media, web-based presentations produced much more readable and comprehensible reports. Students began to see presentations not as an onerous requirement but as a means to getting their project accepted and approved, which we believe will be of great benefit to their careers. Third, the use of studio critiques appears to be a much more effective and thought provoking way of evaluating group projects.

The Videofish course itself maybe difficult to replicate, due to the cost. However, almost half of the budget was for the teaching assistant. The equipment expense was largely the video monitor; a submersible autonomous vehicle could be built for much less, possibly on the order of $800 or less.

If the Videofish course is reproduced, we offer the following recommendations. The group size should not more than 15, but we recommend actively recruiting students from the arts and engineering who are capable and enthusiastic. We would restructure the course so that every student built a complete simple UUV to keep, rather than just pieces of a complicated one. This would give each person something to "take home at the end of the day." While the entire course could not have been taught by any one of the instructors, it is recommended that the instructors having more of a common ground before hand. Often we could not help with classes being taught by the other instructor. And finally, we recommend: take more fishing trips.

Acknowledgments

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Appendix: Useful Links

The class materials and lectures are available upon request. Although we didn't duplicate the work at Tufts in submersible Lego robots, the following websites may come in handy:

Chris Rogers' home page http://www.tufts.edu/~crogers/

http://www.princeton.edu/~crogers/Talk/Talk.html

Intro to Chris Rogers' class.

http://www.princeton.edu/~crogers/motor/

(waterproofing a lego motor)

Chris Roger's gallery of robots at Tufts

www.ceeo.tufts.edu/robolabatceeo

Part I: General Introduction		
1	M	introduction- what to expect
	W	history of submersibles
2	*M*	*labor day*
	W	Robotics
3	M	ws1: robotics
	W	history of video art
4	M	parts & control of submersible
Part II: Hands-on Intro to Submersibles and Video		
	W	buoyancy
5	M	ws2: rewire servo
	W	ws3: tie into mindstorms
6	M	ws4: building control mechanisms
	W	ws5: tie into mindstorms
7	M	history of industrial design
	W	how to conduct trade studies
8	M	ws6: materials lab
	W	waterproofing the ensemble
9	M	*in the swimming pool!*
	W	Videoproduction
10	M	videoproduction part 2
	W	video devices
11	M	ws7: videoproduction content critique
Part III: Propose Your Videofish		
	W	Handout: project/studio presentation and eval.
12	M	bid processes & group dynamics
	W	team day
13	M	aquarium field trip
	W	team day
14	M	Skycraft field trip
	W	team day
15	M	Home Depot field trip
	W	bid proposals for new version
16	F	studio evaluation of project

Figure 10 Syllabus and assignments for Fall03