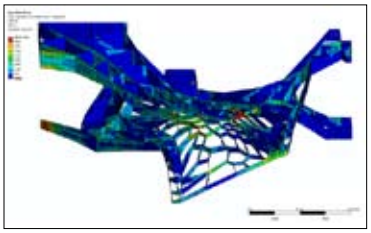
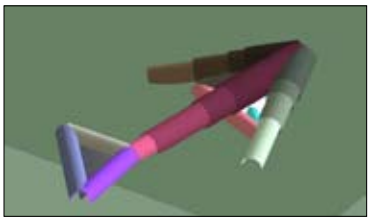
PROOF

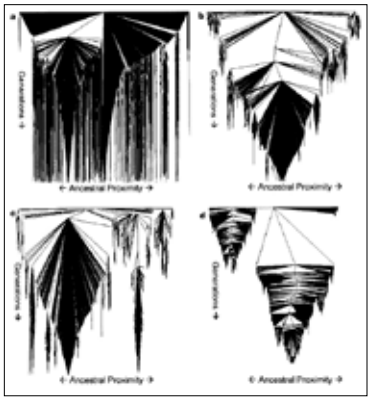
Prototyping Energy, Ecosystem, Evolutionary Computing, and Amphibious Architecture

A design studio sponsored by Esteco, Verdant Power, Natalie Jeremijenko (xDesign: Environmental Health Clinic), and SHoP Architects

Critic: David Benjamin, with Steve Sanderson







OVERVIEW

Algorithms, combined with the ever-expanding computational power of machines, promise a new language for a new phase of fine-tuned and unexpected architecture. They drive optimization of building structure and environmental systems, they generate complex forms and surfaces, and they control the fabrication and assembly of building components. But their scope and limits are still relatively unknown.

This is the territory of Proof, a **collaborative, open-ended research studio** that will explore new ground through the process of **testing**. We will learn by testing, and we will test by prototyping and by drawing on the **scientific method**. We will aim to produce **valid results** by iteratively generating hypotheses, designing experiments, conducting controlled tests, and analyzing the results. We will aim to produce **verifiable results** by documenting and sharing our experiments publicly.

More specifically, we will use advanced computational methods (evolutionary computing) and new multi-objective optimization software (modeFrontier), as well as procedures of testing through computer simulation (computational fluid dynamics) and testing through physical prototypes (digital fabrication and tow tank deployments).

While we will employ serious engineering and computer science tools, we will not limit our studies to numbers. While we will apply our techniques toward efficiency and form, we will also apply them toward complex issues of culture, infrastructure, and program that are difficult to quantify. In the process, we will have an informed, critical, and open-ended discussion about the future of architecture.

EVOLUTIONARY COMPUTING

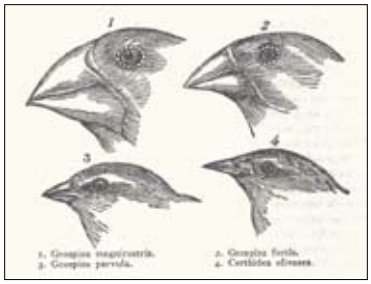
Evolutionary computing combines the power of growth through evolution with the power of rapid machine computation. In this process, algorithms simulate biological evolution in order to solve complex problems and generate new designs.

The procedure begins with the creation of a random population of designs or “organisms,” and the evaluation of each organism by a precise fitness test. Based on these results, a new generation of organisms is created through a specific combination of cross-breeding, mutation, and promotion. The cycle is automatically repeated within the computer for hundreds of generations, and through this **human-machine collaboration**, it is possible to quickly find valid solutions beyond what a human alone could design.

Images (top to bottom): DFabArch, CNC bricklayer, ETH; Dragonfly, 40-foot optimized cantilever, Emergent; The Golem Project, physical robot designed through evolutionary computing, Jordan Pollack; The Golem Project, computer-simulated robot; The Golem Project, robot evolution; Theo Jansen, walking robot designed by genetic algorithmtm.

Evolutionary computing reflects a paradigm that is gaining new prominence in research on **artificial intelligence**: rather than program machines to follow fixed and known rules, set up an emergent system to evolve new and unexpected results.

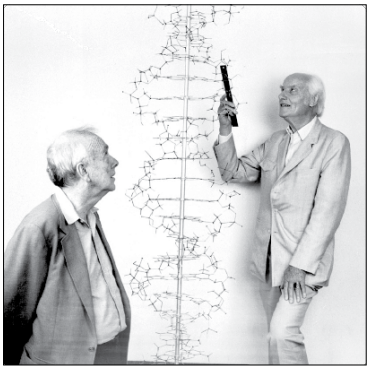
This studio will conduct research into using evolutionary computing to (1) enhance technical performance, and (2) generate architectural form.



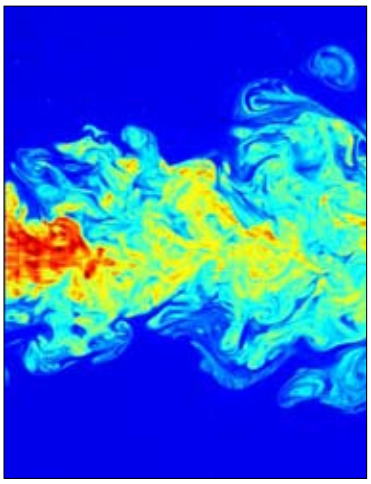
TESTING: SOFTWARE SIMULATION AND OPTIMIZATION

Our main operational strategy will involve **testing**. In two complementary processes, we will test with computer simulations and test with physical prototypes.

For our computer simulations, we will use **parametric modeling** software to create adaptable three-dimensional models and we will use **computational fluid dynamics** (CFD) software to test the performance of these models underwater.*



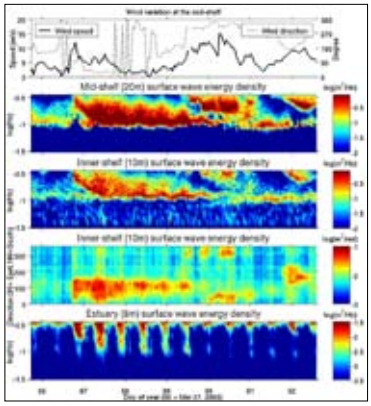
Then, we will be among the first people in the world to apply to architecture the multi-objective optimization software **modeFrontier by Esteco**. This is a new software package for managing complex simulation and optimization processes. The software will allow us to generate, evaluate, and evolve thousands of possible designs through the use of evolutionary computing and genetic algorithms.



TESTING: DIGITAL FABRICATION AND PHYSICAL PROTOTYPES

For testing with physical prototypes, we will use the Avery Digital Fabrication Lab—including the **CNC milling machines** and the **waterjet cutter**, as well as the **rapid prototyping machines**—to create part-scale and full-scale prototypes.

This is a **digital fabrication studio** with the premise that fabrication must be linked to testing. In our experiments, production and assembly techniques will be necessary but not sufficient. We will produce and assemble, and then we will test. Rather than focus on a single prototype or design, we will focus on trends and features of designs. Rather than create a single model, we will create multiple models with strategic variation.



We will **test our prototypes in a tow tank**—a large tank of water with sensors and actuators that can simulate marine conditions and measure hydrodynamic performance. We will also **test our prototypes through controlled deployments in the East River**.**

While computer simulation will be used to quickly explore a large field of possible design solutions, physical prototyping will be used to carefully study the performance of a small number of successful designs under real conditions that are difficult to model in the computer.

*For more about performance underwater, see “Program and Site.”
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Images (top to bottom): Evolution of Charles Darwin’s finches; James Watson and Francis Crick with a diagram of the double-helix of DNA; Visualization of computational fluid dynamics (CFD) performance testing; Visualization of CFD performance testing; Tow tank testing facility.

PURE RESEARCH AND APPLIED RESEARCH

In this studio, we will use advanced engineering and computer science techniques, but this will not be an end in itself. The goal of the studio is not simply to master the technical skills of scripting, optimization, fabrication, and testing. Instead, the goal is to **test the techniques themselves**, and to have an informed and critical discussion about their role in architecture.

Towards these ends, the studio will combine pure research and applied research. We will be **radically experimental** in our studies of software and computation, but also **radically practical** in our studies of urgent urban and architectural issues.

ENERGY

Water comprises 70% of the Earth's surface and 90% of its inhabitable volume. *Fortune Magazine* recently said, "Water promises to be to the 21st Century what oil was to the 20th Century: the precious commodity that determines the wealth of nations."

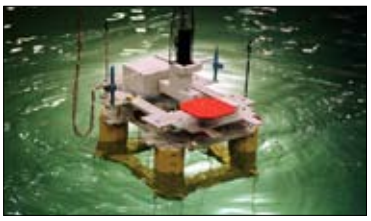
But beyond its role as a natural resource, water holds power—literally. The movement of water in oceans and rivers can generate electricity when its kinetic energy is converted to mechanical energy and then to electrical energy. **Low-impact kinetic hydropower** involves the harnessing of energy from the water without the creation of civil infrastructure such as dams. Worldwide, this hydropower has the potential to generate 2.5 million megawatts of power per year. This could replace 100 million tons of coal and 340 million barrels of oil per year, eliminating 85 million tons of CO2.

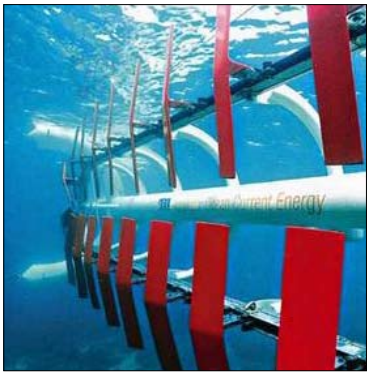
In the East River in New York City, off the east side of Roosevelt Island, Verdant Power is conducting the most advanced pilot project in the world for harnessing this type of energy. With its deployment of six turbines, each with a five-meter diameter rotor, the company is currently collecting 1,000 kilowatt hours of power per day. The plan to deploy a field of 300 turbines would create 200 megawatt hours of power per day—enough to supply 8,000 homes and to begin to decentralize the energy supply in New York City.

ECOSYSTEMS

While low-impact kinetic hydropower reduces environmental degradation caused by power plants, there is still concern about the impact of these projects on ecosystems and marine life. In order to address these concerns within the East River, Verdant Power has spent two years and millions of dollars researching the effects of its turbines on rare fish. Yet the type of research mandated by state and federal agencies is conservative and outdated.

Rather than prohibit intervention after years of causing damage, the city might transform the urban/aquatic interface to create productive, ecologically-remediative





Images (top to bottom): Tow tank testing facility; Same as previous; Natural gas processing plant as part of the centralized energy industry; Deployment of Verdant Power low-impact kinetic hydropower turbine in the East River; Oceana Energy tidal energy harvesting; Open Hydro Group energy harvesting.

interaction. Natalie Jeremijenko and xDesign: Environmental Health Clinic have developed a vision for amphibious architecture through an underwater park in the East River. The park will be programmed to **produce visibility** of ecological and technological systems. People will be able to observe the interaction of marine life and energy-harnessing turbines, and they will also be able to trace the movement of contaminants from coal-fired power stations (the predominant source of mercury for the estuary inhabitants) to the fish habitat and into fish and human bodies.

The park will also be programmed to **productively interfere with the tidal forces**, providing diverse sheltered areas for microhabitats and breeding facilities. The interior spaces of the park will be optimized for humans, and the exterior effects of the park will be optimized for their effects on non-humans.

PROGRAM AND SITE

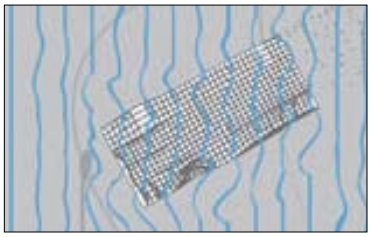
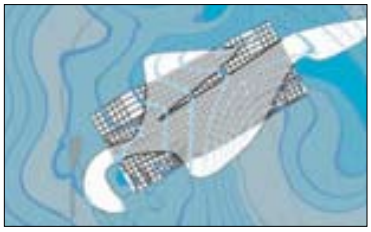
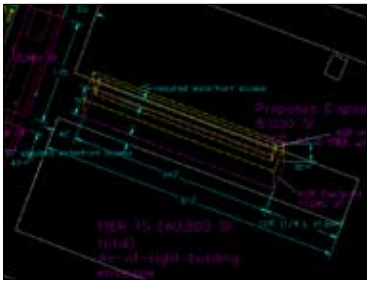
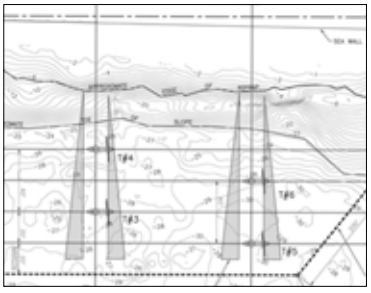
This studio will explore the occupation of the water—that huge domain of the Earth's occupiable volume—in the context of urban energy and ecosystems. Our program will be a low-impact kinetic hydropower deployment and an underwater park. Our site will be Manhattan's Pier 15 in the East River. As one of the few over-water areas approved for reconstruction by state and federal agencies, Pier 15 is a critical component of New York City's East River Waterfront Plan. The Plan, currently in schematic design with SHoP Architects and ARUP, calls for the revitalization of the East River Waterfront by improving a two-mile-long, city-owned public open space connecting the Whitehall Ferry Terminal and Peter Minuit Plaza at the south to East River Park at the north. With few alternative locations for new open space and waterfront access in the area, the Pier 15 site is essential for generating new waterfront experiences.

COLLABORATORS

The studio will be sponsored by several companies and organizations outside of the School. All of them are personally invested in the studio. Over the course of the semester, we will present our research to industry (energy, software, and architecture), to academia (computer science and environmental studies), to government (state and city), and to the local community (non-profit neighborhood organizations). Our collaborators will include:

Nader Fateh (North American representative, Esteco)
Jordan Pollack (Professor of Computer Science, Brandeis University)
Michael Reed (Developer, Blue Sky Studios, and Professor of Computer Science, Columbia)
Trey Taylor (Cofounder, Verdant Power)
Dean Corren (Director of Technologies, Verdant Power)
Natalie Jeremijenko (Director, xDesign: Environmental Health Clinic; Professor of Art, Environmental Studies, and Computer Science, New York University)
SHoP Architects (Architect, East River Waterfront Plan)
Ken Kirkland (CFD expert, Stevens Institute of Technology)




Images (top to bottom): Natalie Jeremijenko, Amphibious Architecture, Aquarium; Jeremijenko, interface between humans and fish; Jeremijenko, study of pier creating productive interference with the tides; Same as previous; Zoning envelope of Pier 15; Engineering study of East River flows; Jeremijenko, Ooz, interaction between robot and goose