Developing Autonomy for USV by Using Virtual Environments

S. K. Gupta, Bob Kavetsky, Steve Lubard, Max Schwartz, Petr Svec, and Atul Thakur
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Motivation

- USV may need to perform a large number of missions
  - Some of the missions can be quite complex and may involve many different tasks
  - Different tasks require different algorithms
  - Handling contingencies requires additional effort
- The process of humans conceiving the strategy for autonomous operations and coding them requires significant effort!
- Can USV develop a robust navigation planning strategy from a large number of simulations for a given mission?
- Planning strategy will be expressed in terms of high level control commands
  - These commands then can be automatically translated to a programming language
  - No need for any human programming for a specific task or contingency

A mission planning system for automatically generating navigation strategy for USV

- The current version of the system is able to generate human-readable navigation strategies and improve already existing ones
  - A *blocking strategy* was automatically discovered in a simulation environment with two competing boats
  - The USV training is performed using a computer-generated skilled intruder
  - The systems evolves the USV's and intruder's strategies simultaneously in an emergent co-evolutionary process


Unmanned surface vehicle (USV)

Intruder's intended path
USV

Intruder
USV's blocking maneuver
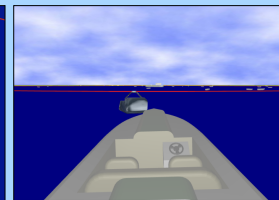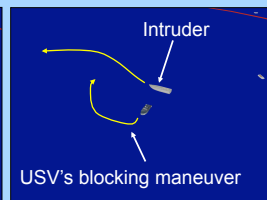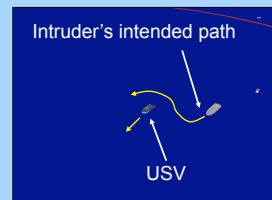
  - *An obstacle avoidance strategy* was automatically discovered by a simulated evolutionary process in a static scene

Oil tanker
USV
USV's intended path
Moving obstacles

Project Goals

- A mission planning system which can automatically generate a human-readable navigation strategy for a given USV and its mission
  - The system should produce a strategy that leads to the USV behaviors that are at least 80% as efficient as the behaviors exhibited by the human-driven USV
    - The efficiency of the human-generated strategy should be easily compared to the efficiency of the computer-generated strategy using a virtual environment based benchmarking tool
    - The benchmarking tool should be able to automatically record human player's strategy which can be further integrated into USV's navigation strategy
  - Navigation strategy should be represented in a high-level programming language which can be directly interpreted on a low-level controller and can enable human verification

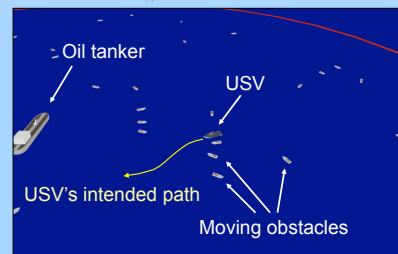## Simulation Based Discovery and Innovation Example
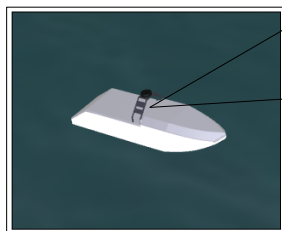
Let me try moving left and see what happens

USV explores possible actuator actions to avoid collisions in the virtual environment

USV finds a navigation strategy to successfully avoid obstacles
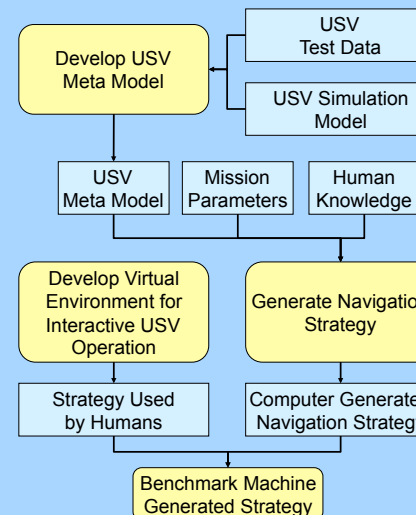
```
if distance < 20 then
  rudder angle = 30;
  throttle = 30;
  ...
  ...
```

Physics Based Meta Model

- Due to high computational requirements, the physics-based simulator cannot be directly used for generating navigation strategy
- Need to use its simplified version generated using physics-based simulations

Overview of Overall Approach

USV Test Data
Develop USV Meta Model
USV Simulation Model
USV Meta Model
Mission Parameters
Human Knowledge
Develop Virtual Environment for Interactive USV Operation
Generate Navigation Strategy
Strategy Used by Humans
Computer Generated Navigation Strategy
Benchmark Machine Generated Strategy

Strategy Benchmarking

- Developed a benchmarking tool where two humans or a human and a computer can compete against each other
  - This tool was used to compare the efficiency of the human-generated blocking strategy to the computer-generated blocking strategy
  - In the current benchmarking setting, the resulting USV's blocking strategy is better than average human players
  - We expect the system to generate navigation strategies comparable in quality to the human-generated ones for even more complicated tasks