An Experimentation Framework to Support UMV Design and Development

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The Cedessa Framework

- An experimentation framework supporting the design of Uninhabited Maritime Vehicles (UMVs) and Uninhabited Air Vehicles (UAVs) has been developed.
- This framework, which is called “Cedessa” is being applied by DSTO and Swinburne University of Technology on a number of projects in both the UMV and UAV domains.
- The framework consists of tools for performing experiments in which both simulation models and/or vehicle control/flight systems software is exercised, evaluated and/or optimised.
The Cedessa Framework

- Experimentation can be undertaken on systems implemented either strictly in simulation or arbitrary combinations of simulated and hardware-in-loop systems.
- The framework is based on a simulation infrastructure that is capable of both distributed and low-overhead non-distributed off-line operation.
Simulation in the Cedessa Framework

- Unlike the majority of UMV simulation toolsets, the Cedessa framework components allow an experimenter to model and simulate not just a single vehicle, but multiple UMV's and their entire operating environment.

- This means that experiments can be conducted in which simulated vehicles autonomously and collaboratively work on complex tasks.

- There are three standard components to the Cedessa simulation subsystem: The multi-body dynamics engine “ODESSA”, the six degree of freedom flight vehicle model “VSIM”, the lightweight connectivity system “Centrale”.
Virtual World Management: ODESSA

- The multi-body dynamics engine ODESSA allows complex worlds to be modeled.
- The initial implementation was based on the Open-Source ODE framework. ODE is a high-performance software library designed for implementing realistic physics in computer games.
- DSTO revised the original source code considerably, with an emphasis on making the engine reliable for engineering work whilst performing a number of important performance optimisations.
Virtual World Management: The ODESSA Toolkit

- ODESSA enables simulation of multiple bodies interlinked by various joints.
- It handles kinematics and collisions.
Virtual World Management: ODESSA

- The ODESSA multibody universe is currently defined by means of an XML file, plus GUI based editors are in development.
- The engine can run in either an off-line mode or an interactive real-time mode. In the interactive mode, an OpenGL based scene visualiser is available.
- The engine can be interfaced to a variety of systems implementing specific models. By linking it to VSIM for example, multiple vehicles can be simulated.
- Live interfaces to Matlab, GNU Octave, HLA, and Centrale are available to permit auxiliary simulation models to influence bodies in the world.
Connectivity: The HLA

- Multiple ODESSA simulation “islands” can be distributed across the network by enabling a connectivity mode that allows it to interface seamlessly with either a Centrale or a HLA federation.
- Likewise, distributed simulation federates implementing specific functions can be interfaced with ODESSA, allowing for simulation of active participants in the simulation.
Connectivity: Centrale

- In addition to using the HLA either to interface simulation entities to ODESSA, or for ODESSA itself to interface with distributed simulations, a second connectivity system called “Centrale” can be used.
- Centrale is a lightweight connectivity system supporting basic distributed simulation functionality. It can be used to integrate software modules that implement either simulations or flight software systems on board the vehicle.
Connectivity: Centrale

- Importantly, it allows easy conversion of systems from distributed to non-distributed systems that incur no communications overhead.
- The first mode is ideal for large scale real-time distributed simulation. The second mode is also very useful for off-line, automated experimentation.
- Centrale achieves this flexibility by using a flexible software hub architecture. Software modules are developed as plug-ins that attach to a hub that both synchronises them and also provides a common data store.
- Optional network relays link different software hubs across a network, allowing for creation of virtual distributed hubs.
Connectivity: Centrale

[Diagram of connectivity network with nodes and modules connected to Centrale Hub and processors.]
Flight Vehicle Simulation: VSIM

- ODESSA itself performs only simulation and visualisation of the multibody universe. To bring that universe to life, ODESSA must be interfaced to other simulations or software systems.
- One important standard simulation model that is shipped with ODESSA is VSIM.
- VSIM is an extremely modular six degree of freedom flight model developed in the Matlab Simulink environment.
Flight Vehicle Simulation: VSIM

- VSIM can be used as a stand-alone model in the Simulink environment, or can be converted to native code and compiled into a Centrale plugin for use with Cedessa.
- The system is structured as a series of shell modules, allowing for new vehicles of different kinds to be implemented with very little effort.
- To date a number of vehicle system models have been developed implementing simulations of both underwater vehicles and air vehicles.
Automated Experimentation: Scripting

- Cedessa supports large-scale real-time simulations allowing for operator training, real-time systems testing and other conventional applications of distributed-simulation based experimentation.
- In addition, the flexible nature of the Centrale connectivity system allows the same distributed simulations to easily be converted to lightweight integrated software systems.
- These software systems can be executed in a faster than real-time mode permitting repetitive off-line execution under scripted control.
- Currently, software tools are provided with Cedessa to aid users in creating these types of experiments.
Automated Experimentation: Optimisation

- Experimentation via scripts can result in powerful tests, however this approach alone will not always result in a desired result.
- Increasingly, optimisation is being used as an effective experimentation mechanism. Conventionally, it has been used to improve performance of flight systems.
- It can and has, however also been used as an approach for testing robustness by searching for fault states.
Automated Experimentation: Optimisation

- Given the usefulness of optimisation in this context, Centrale itself supports an operating mode in which a software hub and its attached modules implements the cost function in an optimisation process.
- Currently, the optimiser uses the Particle Swarm Optimisation (PSO) technique. Shortly, support for a Genetic Algorithm and Simulated Annealing will be Added.
- All of these methods have been shown to provide good performance on highly non-linear multivariate problems.
Sample simulations:

- A simulation of the *Wayamba* research vehicle (control is via keyboard input)
Sample simulations:

- A simulation of a mine disposal ROV operating off a Mine Hunter
Sample simulations:

- A simulation of a replenishment at sea operation
Conclusions

- The Cedessa framework has been observed to streamline and simplify the process of creating both manual and automated simulation-based experiments.
- These time savings are being realised at DSTO on a number of projects in both the UMV and the UAV domains.
- The key software components of Cedessa, namely Centrale, ODESSA and VSIM are in the process of being prepared for public release under open-source licences. Interested readers are encouraged to contact the author for availability information.
Further Information

- A website is in the process of being constructed with further information about this project, and in the near future will include binary and source code downloads of the software.
- Please contact the following email address for updates on this development:
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