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An Experimentation Framework to Support UMV Design and Development

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June 2005

The Cedessa Framework

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- 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

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- 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

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- 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

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- 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

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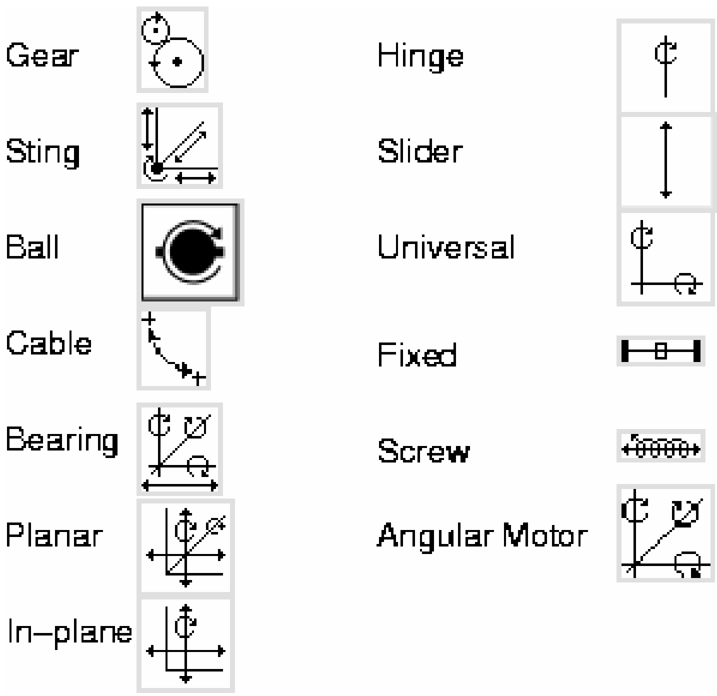
- ODESSA enables simulation of multiple bodies interlinked by various joints.
- It handles kinematics and collisions.



Virtual World Management: ODESSA

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- 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

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- 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

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- 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

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- 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

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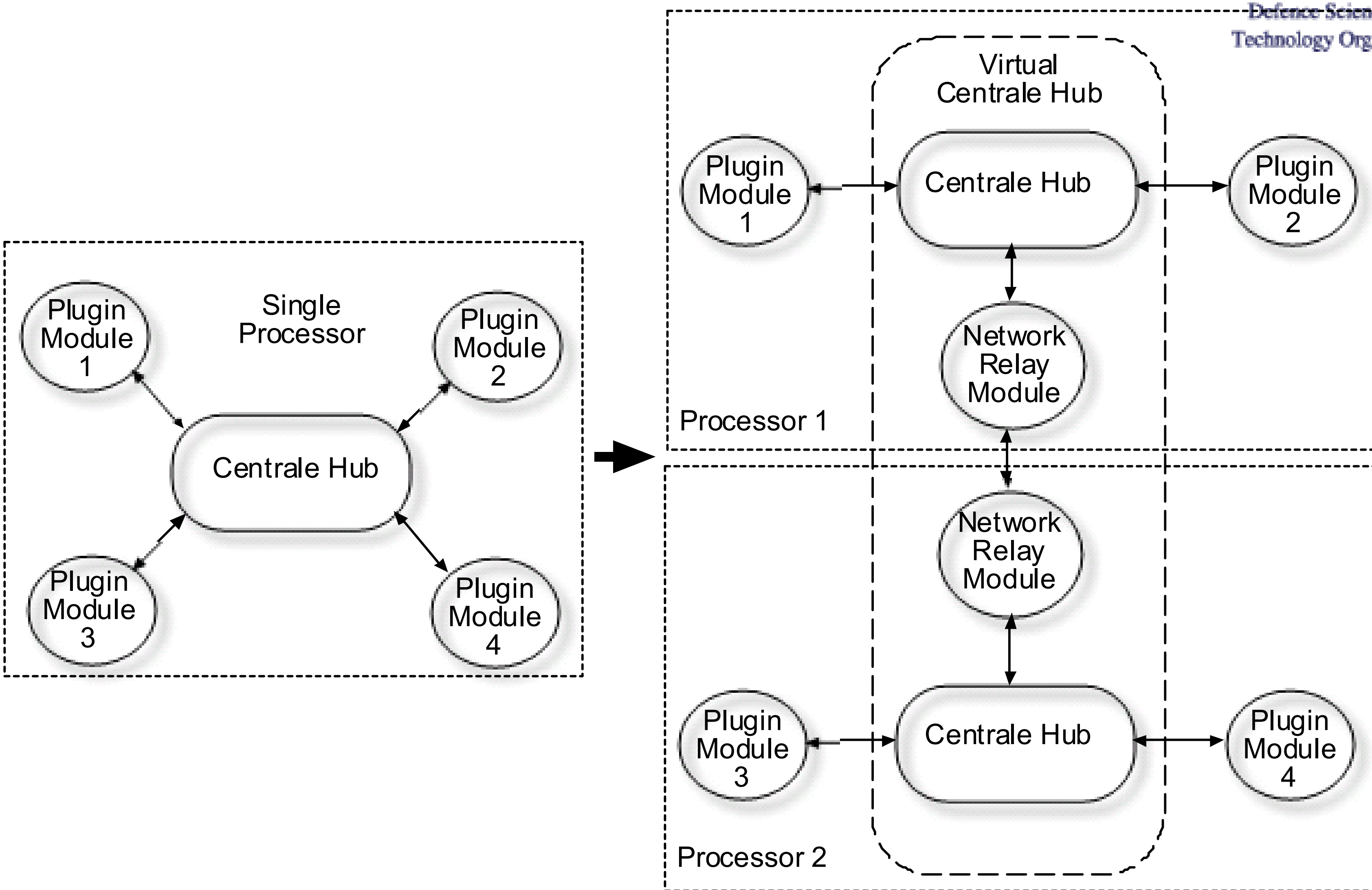

Flight Vehicle Simulation: VSIM

- 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

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- VSIM can be used as a stand-alone model in the Simulink enviroment, 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

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- 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

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- 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:

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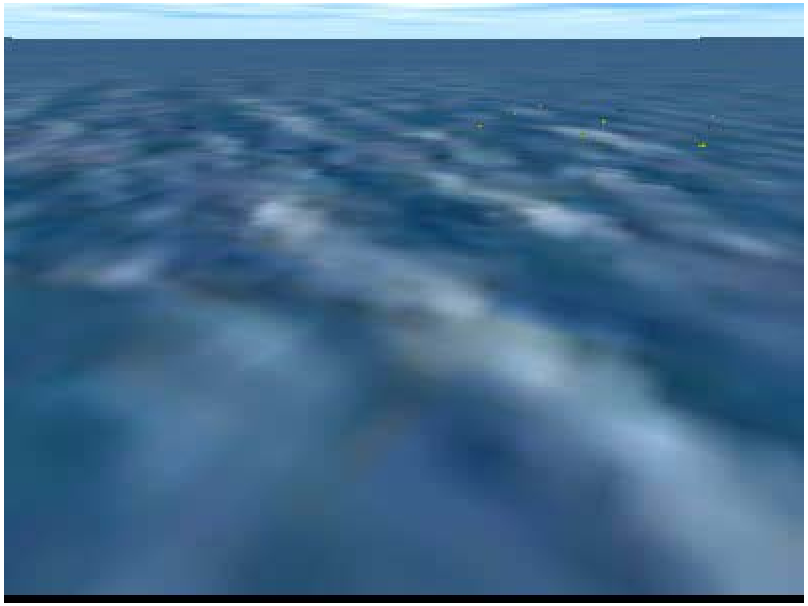
- A simulation of the *Wayamba* research vehicle (control is via keyboard input)



Sample simulations:

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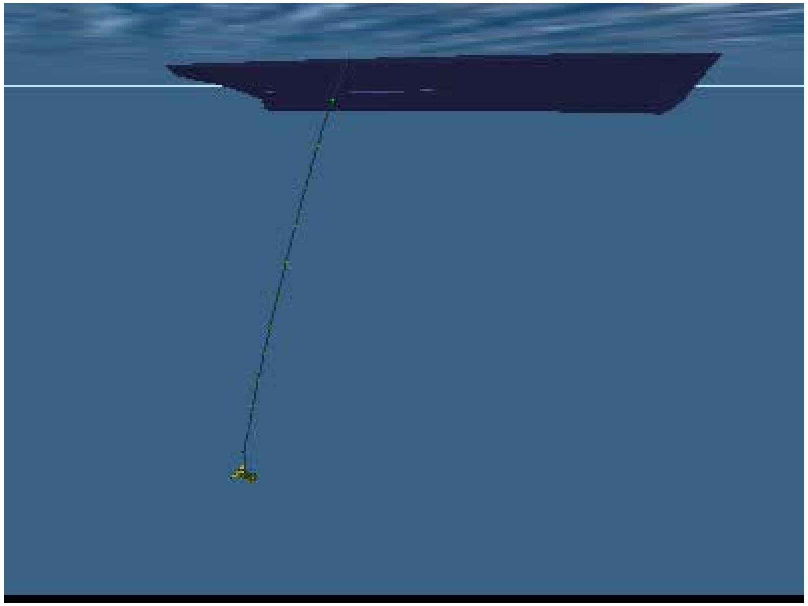
- A simulation of a mine disposal ROV operating off a Mine Hunter



Sample simulations:

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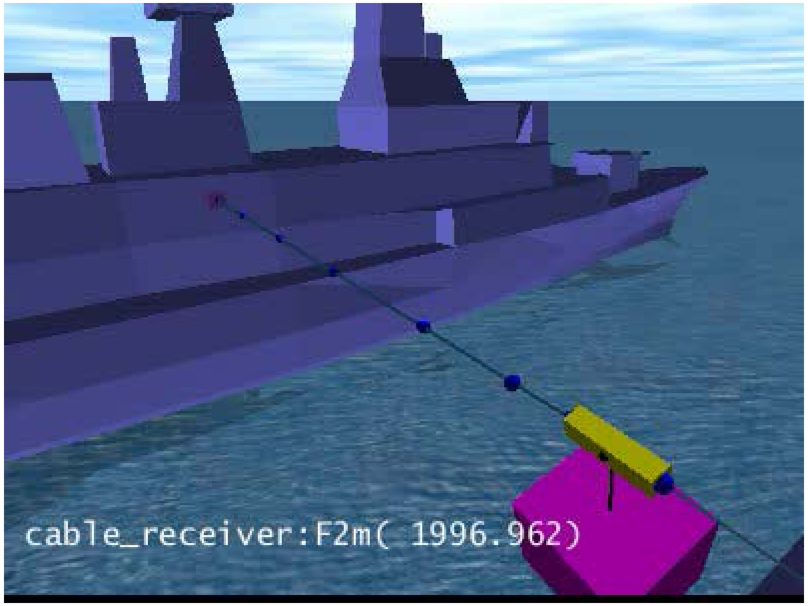
- A simulation of a replenishment at sea operation



Conclusions

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- 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

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- 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:
  - francis.valentinis@dsto.defence.gov.au