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VOLUME I

Session 1 - Systems Engineering and Intelligent Systems

Session 2 - Advances in Control Theory and Control Engineering

Session 3 - Optimisation and Management of Complex Systems and Networked Systems

Session 4 - Intelligent Vehicles and Mobile Systems

Session 5 - Robotics and Motion Systems

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Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.
I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.

Professor Peter Scharff
Rector, TU Ilmenau

Professor Christoph Ament
Head of Organisation

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10 – 13 September 2007

M. Jacobi / T. Pfützenreuter / T. Glotzbach / M. Schneider

A 3D Simulation and Visualisation Environment for Unmanned Vehicles in Underwater Scenarios

ABSTRACT

In this paper we present the conceptual framework of a 3D simulation and visualisation tool that is particularly suitable for use with unmanned marine vehicles in underwater scenarios. We will describe the main ideas and the purpose of the software tool and discuss the principle constraints as well as the further development towards the finalised realisation. First results of the representation of underwater objects in realistic environments will be presented to document the effectivity and the lucidity of the approach.

INTRODUCTION

Marine influenced scenarios are a major application for the industrial use of unmanned vehicles. In the current research process, the level of autonomy of the unmanned vehicles is more and more raising. First team-based applications are on their way towards practical realisation.

Both scenarios demand possibilities for the simulation of different strategies to evaluate and visualise the mission execution. Especially, the last point must not be neglected because it is very hard to watch the vehicles performing their underwater missions in reality. For optimising the debugging process and visualization of results of unmanned vehicle missions to a wide audience, there is the need for a visualisation and simulation tool. In this work we introduce the concept and interfaces of a software tool that provides a realistic representation of unmanned marine vehicles in underwater scenarios. The three-dimensional area allows the user an independent movement. Furthermore, the software tool supports the simulation of the marine environment. For example it will be possible to simulate the sonar measurement of the seabed. The software will have clear defined interfaces to enable the operator to force the vehicle position using existing simulation tools that can be combined with the tool presented in this paper.

GENERAL CONDITIONS AND BASIC PARAMETERS

A main purpose within the development is the realisation of a visualisation tool that is as far as possible independent from the vehicle simulator. There are a lot of different possibilities in the modelling of marine vehicles (e.g. [1], [2]), differing both in proceeding and complexity. In the most simply case, a vehicle can be simulated by an integrator, translating velocity in position. It is also possible to consider all dynamic processes of a certain vehicle. Therefore many different simulators exist; each is adapted for the particular purpose. For this reason, the visualisation tool will not possess an own simulator for marine vehicles, but will have clear defined interfaces to enable a combination with different existing simulators, like the one described in [3].

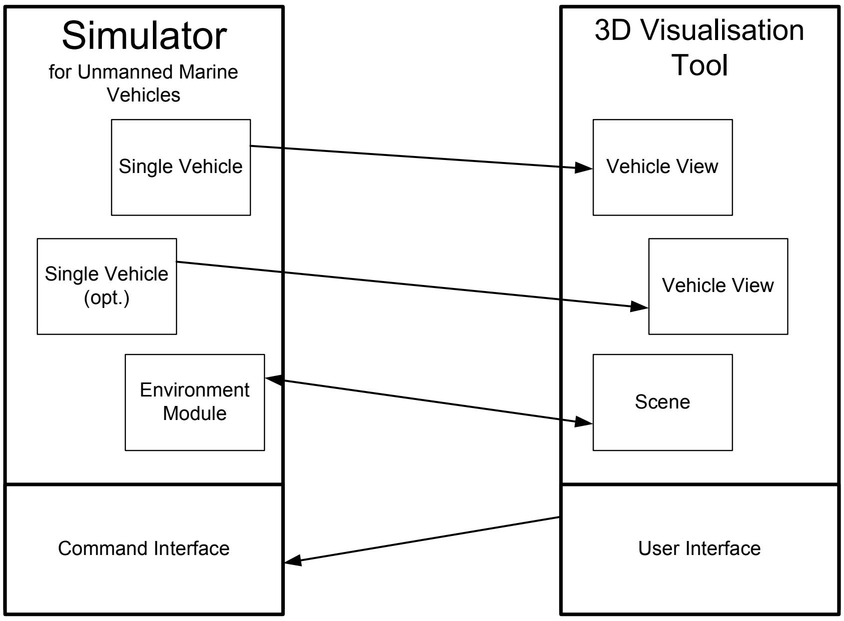

Figure 1: Connection of the visualisation tool to an existing simulator for unmanned marine vehicles

Like it is shown in Figure 1, the Vehicle View in the visualisation gets information about the position and the alignment of the vehicle(s). Information about the scene can be exchanged with the Environmental module of the simulation. The visualisation can get information about non-vehicle objects of the simulation, but it is also possible that the simulator gets different information, for example about collision of different objects. The visualisation tool will be able to supervise different objects for collision. Not only real objects can be considered; it is also possible to detect the contact of a virtual sonar beam with an object. The 3D representation of the visualisation tool is used as base for these calculations. Hence, it will also be possible to improve the calculation power of the simulation by support of the visualisation. With the user interface, it should also be possible to send generalised commands to the simulator, like start / stop / pause simulation. The required design for the simulator is displayed in Figure 2: The vehicles are embedded in the environmental module that is responsible for collision control, communication, calculation of payload data etc. The vehicles can be controlled by KI or remote-controlled by the user.

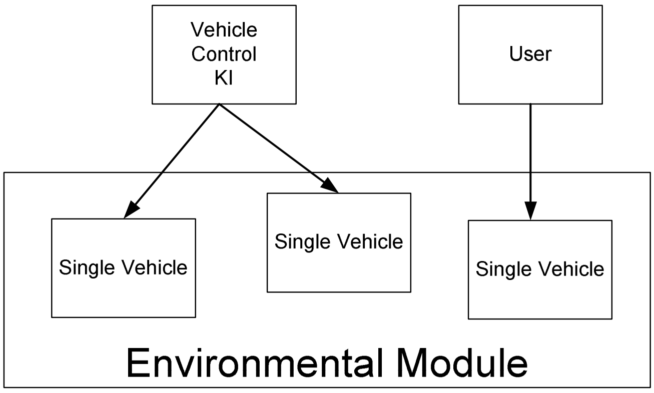

Figure 2: The required design of the simulator

SIMULATION SYSTEM

Coordinate Frames and Nomenclature

Objects moving freely in the 3D space (with 6 degrees of freedom, DOF) are often described by two coordinate frames [4]. An earth-fixed frame with an origin at the water surface is used as inertial reference system; the vehicle's position η_1 and orientation η_2 is described relative to this frame:

$$\eta = \left[\eta_1^T, \eta_2^T\right]^T; \quad \eta_1 = \left[x, y, z\right]^T; \quad \eta_2 = \left[\phi, \theta, \varphi\right]^T \ . \tag{1}$$

The second frame, the body-fixed frame, has its origin in the centre of gravity of the vehicle. In this frame the velocities ν of the body are calculated:

$$\nu = \left[\nu_1^T, \nu_2^T\right]^T; \quad \nu_1 = \left[u, v, w\right]^T; \quad \nu_2 = \left[p, q, r\right]^T \ , \tag{2}$$

where ν_1 denotes the linear and ν_2 the angular velocities. For the definition of force and momentum vectors see [4]. Using these definitions the transformation of velocity vector ν given in the body-fixed frame into the derivatives of the position and orientation vector η is described by the kinematic equation:

$$\dot{\eta} = \quad (\eta)\nu \ , \tag{3}$$

with $\boldsymbol{J}(\eta)$ as the orientation dependent transformation matrix.

The propeller rotation speed *n* is beside some propeller parameters an important measurement value for the calculation of the propeller thrust and torque. If a vehicle has more than one propeller, the vector **n** denotes the rotation speeds of all propellers.

The current of the lake or sea is typically denoted in the earth-fixed frame (ν_C^E). It changes the vehicle's position according to all three vector components:

$$\dot{\eta} = \;(\eta)\nu + \nu_C^{E} \; . \tag{4}$$

With (4) the position of a body with 6 DOF can be computed if the velocity vector ν of the vehicle is known. This calculation is, for instance, the task of the simulation model presented in the next section.

Vehicle simulation model

The vehicle simulators use the equations described above to compute the vehicle's position η out of propeller rotation speeds, flap angles and environmental conditions. For a flap-less underwater vehicle driven by four propellers and one vertical thruster the basic model can be described like follows.

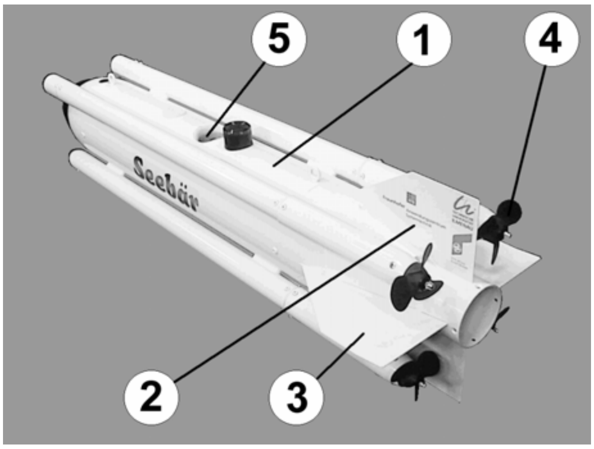

Figure 3: Components of the ROV "Seebaer"

The behaviour of the underwater vehicle is described as a physical model. All forces and moments affecting the vehicle are computed separately according to origin and impact [5]. For this purpose models were created for the main components of the ROV as shown in Figure 3.

The model for the propulsion engines (4) calculates the propelling forces and moments using the rotation speed of the propellers, the vehicle's speed through water and the characteristics of both the electrical engines and the propellers. The vertical thruster (5), which is responsible for stabilizing the position and depth changes at low velocities, is modelled the same way.

Forces and moments resulting from hydrodynamic drag and buoyancy are computed individually for the vehicle body (1), the vertical tails (2) and the horizontal tails (3). Together with other forces and moments due to the linear and angular movement of the vehicle the system model is formed by a force and a momentum equation.

This model is used to compute the velocity vector ν in the body-fixed frame. For other vehicles models can be constructed in the same manner.

Environment module

The simulation of the vehicle's environment basically incorporates the sea's current (two- or three-dimensional), the elevation of the seabed (as height maps), constructions like quay walls, ships and other vehicles. If necessary, other information like temperature or salinity can be simulated if this is required by the vehicle's tasks to be solved.

Visualisation module

For direct user interaction and mission evaluation a 3D visualisation tool has been developed using open source 3D engine [6, 7]. The decision to use an open source engine depends on the ability to enhance the engine for own demands. An underwater sample scenario is shown in Figure 4.

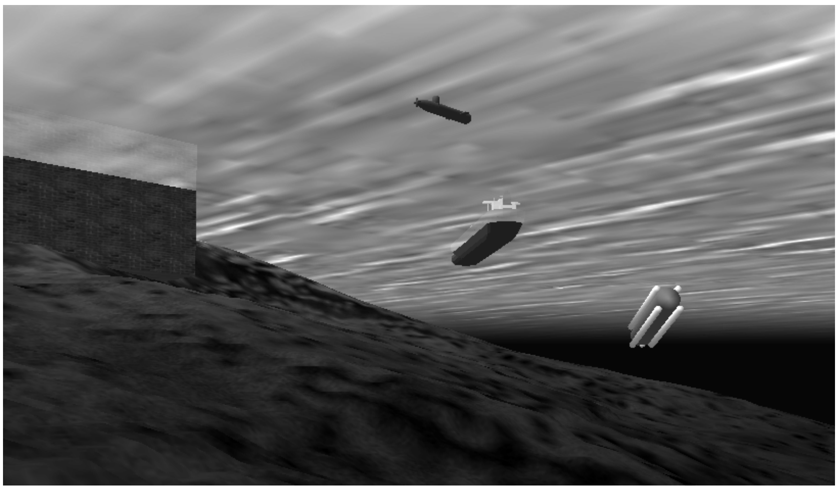

Figure 4: Underwater scenario

The visualization tool is also complete separated from the simulator as shown in Figure

1. The communication between simulator and visualisation tool is done by message exchange over a socket connection. When an object in the simulator is moving, a message is send to the visualisation tool, and the object in the 3d environment moves also. To handle the communication gaps a simple motion model for each object is implemented.

The underwater environment and the vehicles have to be modelled for the 3D visualization using 3D modelling tools and data converter for the environment description used in the simulator. For this modelling issue, a “3D model production pipeline” had to be introduced [8]. This pipeline describes the process of using the different modelling tools in a specific way to create the 3D underwater environment.

CONCLUSION

The proposed visualisation tool for unmanned marine vehicles in underwater scenarios is an ideal extension for each existing software simulator. It allows a presentation in a seasonable design in a three-dimensional virtual reality and helps to demonstrate simulating results in an appealing manner. Furthermore, it is able to support the simulation software for all calculation concerning collision between graphical objects. Due to the clear defined interfaced it is guaranteed that the visualisation tool can easily be adapted to existing simulator software.

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