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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. Schneider / M. Eichhorn / T. Glotzbach / P. Otto

A High-Level Simulator for heterogeneous marine vehicle teams under real constraints

ABSTRACT

In this paper, we introduce a high-level software simulator for teams of unmanned marine surface and underwater crafts. The work was performed in the framework of the European Research project GREX[1]. This project has the goal to realise cooperation between heterogeneous marine vehicles by creating a conceptual framework and middleware system. The natural constraints of marine missions must be kept in mind. In underwater scenarios there is no global positioning available like GPS. The research in underwater communication is at present time at its very beginning. For the validation of different control strategies, there is the need for a high-level software simulator that is able to evaluate different approaches and to judge them according to their requirements in navigation and communication. Therefore, the above-mentioned constraints of reality must be realised within the simulator. All interfaces in the simulator need to be the same as in reality. So it is possible to use and to test the real control software modules in the simulator und make a first step towards the laboratory tests with real vehicles that need to be performed before the missions are executed in the real mission environments.

INTRODUCTION

One focus of the research project GREX [1] is on the developing of appropriate strategies for the realisation of the vehicle’s coordination. It is a special challenge to force ‘autonomous’ vehicles to cooperate with each other. Therefore, there is the need for defined hierarchies of command and control between the vehicles. Different strategies can be imagined that will have an either more hierarchical or peripheral construction, as explained in [2].

A special challenge in marine scenarios is based on the lack of reliable global

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[1] The research project GREX, FP6-IST-2006-035223 is funded by the Sixth Framework Programmed of the European Community (see [1])

positioning and communication. As navigation and communication are key technologies in the research area of autonomous mobile systems, experiences made with land and air vehicles can hardly be transferred in underwater situations. New strategies need to be developed and tested. Therefore, there is the need for a high-level software simulator that is able to evaluate different strategies according to their requirements for communication and the accuracy of the navigation. This simulator must fit to the described constraints and use the real interfaces so it can also be use to evaluate the real control software.

STRUCTURE OF THE SIMULATOR

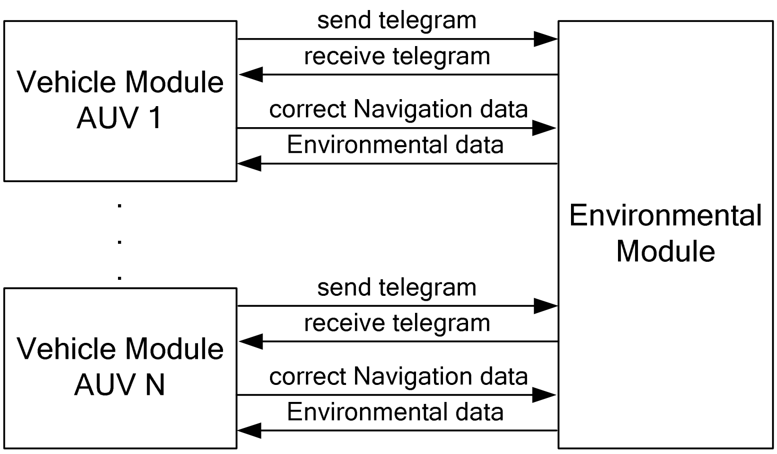

Figure 1: Principal structure of the simulator

To meet the described requirements, the simulator is made up of separated modules separating the environment as well as every single vehicle (see Figure 1). It is possible to employ the simulator under MATLAB®/Simulink® where separated blocks are used to model the mentioned modules. The blocks will be created and linked together in Simulink®. The MATLAB® based realisation enables the possibilities for an easy evaluation and presentation of the results as well as a visual evaluation with the Virtual Reality Toolbox. The use of Simulink® further guarantees an easy way to create a structure of test scenarios with the block construction method as well as the availability of all Simulink® libraries. Another possibility is the realisation as a stand-alone program whereas the vehicle modules are created and assigned to the environmental module at the program start.

To meet the already mentioned constraints, there is no data exchange directly between the vehicle modules. All data telegrams are exchanged between the particular vehicle module and the environmental module. This module stores the incoming data telegrams in a queue together with the position and the attitude of the vehicle as well as the time of the transmission. The correct navigation data are stored in the environmental module (position, location). In each time step, it is checked whether a telegram in the queue must be delivered to a certain vehicle depending on the maximum transmitting range, the position and the attitude of the transmitting and the receiving vehicle. Moreover, the environmental data like sea current, altitude over ground and concentration will be transmitted to the separate vehicles in each time step depending on the position of the vehicle.

VEHICLE MODULE

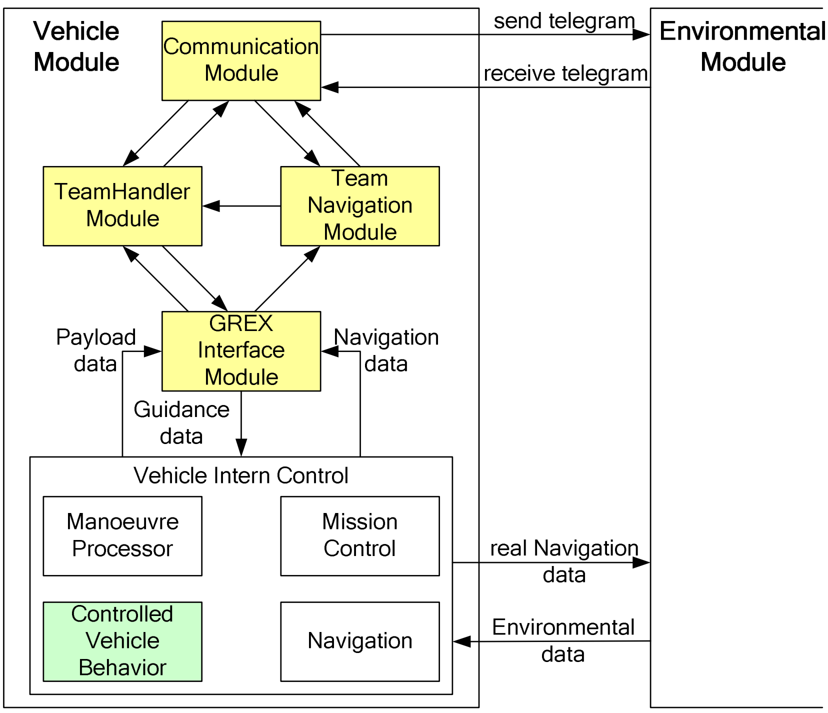

Figure 2: Components of the vehicle module

As shown in Figure 2, inside the vehicle module there are several sub-modules, which are responsible for specified, team relevant tasks. The four modules in the upper half represent the GREX-specific control software, while the Vehicle Intern Control in the lower box can be described as the single vehicle-typical control software. In the GREX-project, it can be assumed that this software already exists for every real vehicle in a different way. The GREX Interface Module describes the interface between the vehicle-own software and the new one for team coordination.

The internal control of the vehicle simulates the behaviour of the vehicle in dependence to the received guidance data like a manoeuvre list or a target position. In order to realise this actually as a sub module, the simulation of the controlled vehicle behaviour is integrated in addition to the error model for the navigation.

The modules TeamHandler, TeamNavigation, GREX-Interface Module and Communication Module will run as independent programs on the computer units of the vehicles, whereas a strict interface design of the separate modules exists and allows the consistent integration of the C++ code for the modules. The module TeamHandler, for instance, has several basic classes defining public interfaces (TeamHandler_C, InputProcessor_C, OutputProcessor_C). These classes have common references. To integrate the TeamHandler into the simulation only the classes of the data interfaces are deviated from their basic classes and their objects are implemented as s-function of the vehicle module block together with the sub-modules of the TeamHandler. During the translation, the separate libraries of the module TeamHandler are integrated into this process. This makes it possible to take over changes in the functionality locally within the TeamHandler code very easily just by a renewed translation of the Simulink®-program.

CONTROLLED VEHICLE BEHAVIOUR

To model the controlled behaviour of the different vehicle types, which are used in the project GREX, a simplistic kinematical model was designed. This model allows both a simple and a realistic simulation of the complex behaviour of the autopilot and the vehicle dynamics. In this case, only the control loop behaviour of the vehicle states *roll*, *pitch*, *heading* and *surge* will be reproduced using a time delay model. Figure 3 shows the hierarchical structure of model for the controlled vehicle behaviour.

Models for guidance tasks like the depth, track keeping and distance controllers work in combination with an algorithm to compensate for the influence of the sea current. This is possible by using known sea current and allows a simple control design for the guidance controllers (only P-controllers). The block *SeaCurrent Compensation* convert the desired set point values like course w_{course} or speed over ground w_{SoG} into the effective set points of the vehicle states w_{ψ}, w_{θ} and w_u. These set points can be determined by using the relationship of the sea current vector and the body- and earth fixed velocity vector of the vehicle as well as the intersection point between a line and a sphere as shown in Figure 4 according to the equations (1)-(3).

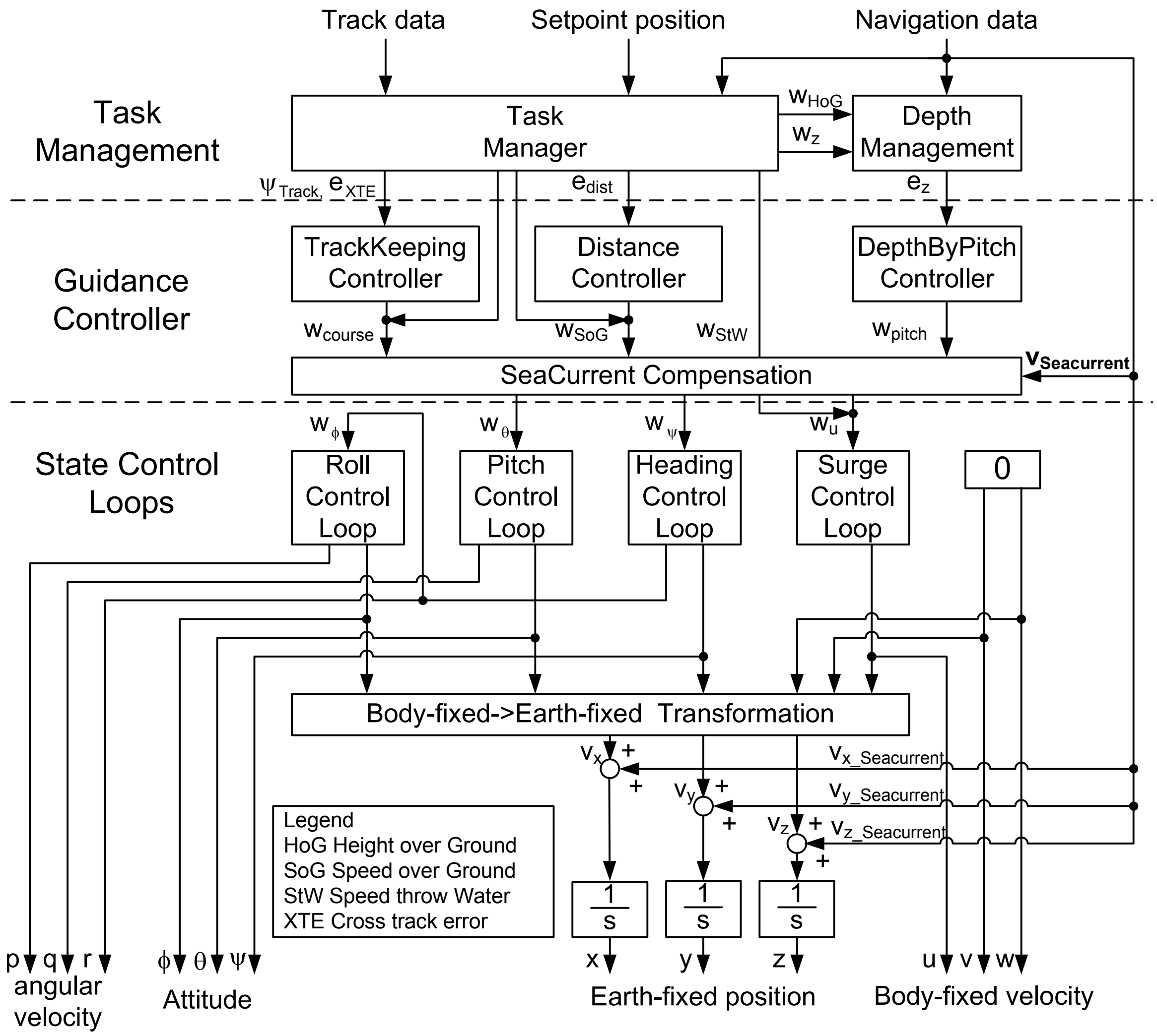

Figure 3: Structure of the controlled vehicle behaviour model

$$line:\ \mathbf{x}\left(w_{SoG}\right) = w_{SoG}\underbrace{\left[\cos\left(w_{course}\right)\cos\left(w_{pitch}\right) \quad \sin\left(w_{course}\right)\cos\left(w_{pitch}\right) \quad -\sin\left(w_{pitch}\right)\right]^T}_{\mathbf{v}^0_{veh\_ef}} \tag{1}$$

$$sphere:\ v^2_{veh\_bf} = \left\|\mathbf{x} - \mathbf{v}_{Seacurrent}\right\|^2$$

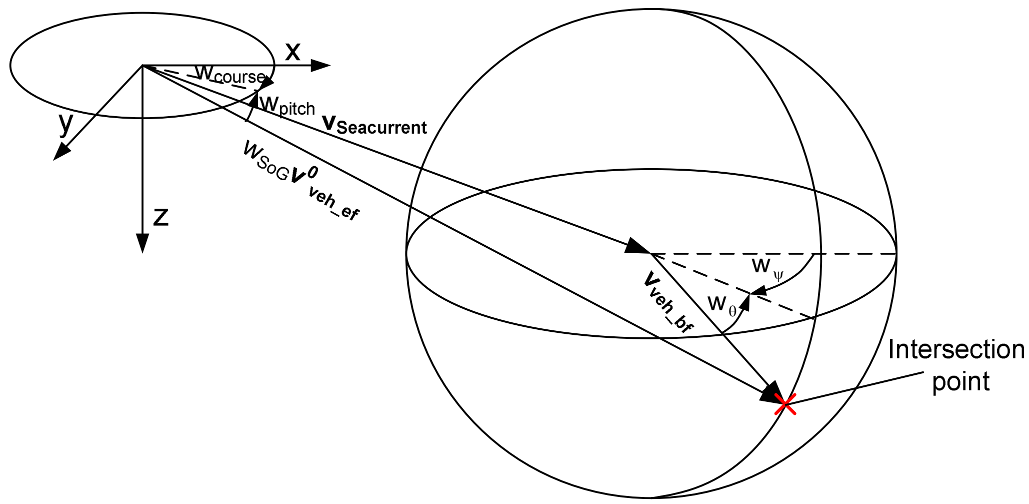

Figure 4: definitions of the velocities

$$
\begin{aligned}
&disc = \left(\mathbf{v}_{veh\_ef}^{0\ \mathbf{T}} \cdot \mathbf{v}_{Seacurrent}\right)^2 + w_{u\_max}^2 - \mathbf{v}_{Seacurrent}^{\mathbf{T}} \cdot \mathbf{v}_{Seacurrent} \\
&(\text{disc}<0) \quad \text{unpossible to hold the desired vector } \mathbf{v}_{veh\_ef}^0 \\
&(\text{disc}>0): \begin{cases} w_{SoG\_min} = \mathbf{v}_{veh\_ef}^{0\ \mathbf{T}} \cdot \mathbf{v}_{Seacurrent} \\ w_{SoG\_max} = \mathbf{v}_{veh\_ef}^{0\ \mathbf{T}} \cdot \mathbf{v}_{Seacurrent} + \sqrt{disc} \end{cases}
\end{aligned} \tag{2}
$$

$$
\begin{aligned}
&\left(w_{SoG} > w_{SoG\_max}\right) \rightarrow w_{SoG} = w_{SoG\_max}, \quad \left(w_{SoG} < w_{SoG\_min}\right) \rightarrow w_{SoG} = w_{SoG\_min} \\
&\mathbf{v}_{veh\_bf} = w_{SoG}\mathbf{v}_{veh\_ef}^0 - \mathbf{v}_{Seacurrent} \\
&w_\psi = \text{atan2}\left(\frac{\mathbf{v}_{veh\_bf}(y)}{\mathbf{v}_{veh\_bf}(x)}\right), \ w_\theta = -\text{atan2}\left(\frac{\mathbf{v}_{veh\_bf}(z)}{\sqrt{\mathbf{v}_{veh\_bf}(x)^2 + \mathbf{v}_{veh\_bf}(y)^2}}\right), \ w_u = \left|\mathbf{v}_{veh\_bf}\right|
\end{aligned} \tag{3}
$$

CONCLUSION

The described high-level software is able to meet the requirements that arise of the specific situation in marine environments. The natural constraints due to the problems of underwater communication and navigation are considered by the object- orientated approach. The interfaces are orientated on the real conditions, and thus the simulator cannot only be used to evaluate different strategies, but also to test the control software prior to its employment on the real vehicles. The environmental module contains considerable functionalities and allows the incorporation of many real aspects. The simulator will also be a good base for advanced research activities in the interesting field of Multiple Unmanned Marine Vehicles

ACKNOWLEDGEMENTS

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[2] T. Glotzbach and J. Wernstedt: "A Proposal for the Control of Teams of Autonomous Underwater Vehicles (AUVs) in Hierarchical and Peripheral Modes using the Concept of Adaptive Autonomy," 25th International Conference on Offshore Mechanics and Artic Engineering (OMAE), Hamburg, Germany, 2006

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