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Competence management with EuroSim centred CACE working environments

A.A. ten Dam and R.J.P. Groothuizen

Nationaal Lucht- en Ruimtevaartlaboratorium
National Aerospace Laboratory NLR

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Summary

There is a growing need to handle large aerospace projects in a systematic manner: transfer of knowledge between people on a case by case manner is a time-consuming and costly process. Computer based simulation is recognised as one of the tools that can support production cycles leading to shorter development times. Usually aerospace projects are executed in international teams where companies are responsible for specific subsystems. Nowadays, it has become essential that co-operating engineers and managers can use computer networks where software tools and software models can be accessed easily. With simulation comes the opportunity to reuse existing knowledge and the need to preserve newly acquired knowledge in a structured way. The necessity for working environments in which the computer network can be used as one virtual computer is apparent.

Working environments allow engineers to concentrate on a task at hand and at the same time shield information that is not relevant for users. Working environments are useful also across boundaries of projects as they facilitate technical cross-fertilisation. At the National Aerospace Laboratory NLR, the SPINE system is used for construction and operational use of functionally-integrated working environments. Working environments can be made suitable for specific engineering goals such as Computer Aided Control Engineering (CACE) by incorporating specific engineering tools. EuroSim, a generic and highly configurable simulator tool, is such an engineering tool.

The present paper discusses the advantages of NLR's working environment ISMuS: a EuroSim centred working environment that facilitates CACE competence management. Two projects will be presented to illustrate CACE competence management issues: TRaCE and Simultaan. Both projects focus on modelling and simulation of controlled contact between two or more physical systems. The application domain however is very different. TRaCE deals with robotic manipulators whereas Simultaan deals with vehicles. The working environment ISMuS enables among other things technical cross-fertilisation across boundaries of projects in an efficient manner.

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(17 pages in total)

1 Introduction

The National Aerospace Laboratory NLR supports engineering of aerospace systems. Aerospace systems are complex systems that contain many subsystems, each with its own specific function. More often than not, aerospace systems are designed in international projects, where companies are responsible for specific subsystems. Moreover, aerospace projects usually last a number of years and exists of several consecutive phases. It is not unusual that new insights lead to changes in requirements. Since each project phase requires application of different knowledge many different people with different backgrounds and fields of expertise contribute to projects for a certain period of time. Transfer of knowledge between people on a case by case manner is a time-consuming and costly process already within one project, let alone between different projects. And yet, knowledge transfer, accumulation and accessibility are crucial for an enterprise to survive.

NLR applies Information and Communication Technology (ICT) to transfer knowledge. The focus is on aerospace applications with knowledge transfer to other areas.

In many cases the environment in which a final aerospace system will operate is not readily accessible. This fact is obvious (at least today) for systems that will operate in space, such as a planetary rover or a space-borne robotic manipulator. Simulation offers the opportunity to gain experience with the system to be designed at an early stage of a project [1]. In addition, simulation allows for early testing of various interactions between subsystems, and for early testing of the control laws that are being designed to direct the system.

Accumulation and exploitation of know-how are necessary for an enterprise to realise continuity with engineers entering and leaving different project teams or the enterprise itself. Competence management is concerned with the continuous effort of directing and acquiring the qualities and skills within an enterprise to successfully deliver products on time, on budget and with the quality required by the customer. Competence is concerned with [2]

- know-how,
- know-why,
- the ability to apply know-how in a flexible way in the business process, and
- the ability to apply the know-why to adapt the enterprise to the changing environment.

Competence management should be a cornerstone of an enterprise as it affects the work of in-line managers, project managers and engineers alike. Competence management at NLR means that people conserve know-how and know-why in software, data and documents, accumulate know-how and know-why in computer-based engineering infrastructures, use tools to access know-how and know-why, and work in a way that is directed towards accumulation and re-use of knowledge. One of the benefits of competence management is that when people enter the organisation the time to familiarise themselves with the company’s know-how is reduced. The present paper discusses the advantages of NLR’s CACE working environment ISMuS: a EuroSim centred CACE working environment that facilitates competence management in aerospace projects.

The remainder of this paper is as follows. In section 2 it is described how a working environment helps in managing software projects and stimulates (re-)use of tools and models that are already available in an organisation. A working environment can also be shared between and accessed by a number of enterprises; creating a virtual company. EuroSim, being a generic simulation tool, can be used to transfer knowledge between companies. EuroSim is capable of handling models on source code level. In section 3 we show that embedding EuroSim in a CACE working environment enhances, in an implicit manner, the capabilities of EuroSim as a simulator tool. In section 4 we briefly discuss an example of competence management in and across the boundaries of two CACE projects: TRaCE and Simultaan. In both projects control of the interaction between physical systems a key issue. However, the application domain of TRaCE differs from the one in Simultaan. TRaCE deals with robotic manipulators that come in contact with their environment (e.g. payloads, space station). Simultaan deals with road vehicles, including the interaction with the terrain. Competence management ensures amongst others technical cross-fertilisation between different application domains. Concluding remarks can be found in section 5. References are collected at the end of this paper.

2 Working environments

Know-how and know-why of an enterprise is embodied in application programs, data, documents, and personal skills. Time and budget constraints, and an increased multidisciplinary approach result in the necessity to accommodate simulation programs and simulation tools developed elsewhere. To be competitive, these results must be made available with minimal overhead. For this, NLR has made a number of working environments (depending on the application) to combine know-how, know-why and tools to support teams in realising project goals on time and on budget. In previous publications competence management for Multidisciplinary Design Optimisation [2] and Computational Fluid Dynamics [3] were described. This paper concentrates on competence management for Computer Aided Control Engineering.

At NLR the SPINE system is used for construction and operational use of functionally-integrated working environments. SPINE is developed by NLR for NEC [4]. SPINE relies on the industrial standard on application level, the client-server approach. SPINE supports the following functions (see also [4] and [5]):

- access to computer facilities and know-how as if everything is located on a PC (the virtual computer approach); this includes a graphical windows based user interface and tools to execute standard or routine chains of activities;
- environment management, enabling customisation of personal environments;
- know-how management, such as software version management on distributed computers.

Moreover, SPINE can be augmented with specific tool sets, such as tools for porting applications to the SX-4 at NLR, which acts as the central computing facility for large, demanding (both with respect to through-put time and memory use) application jobs. To enable programs to function transparently within distributed environments, this approach will be implemented in the near future using the emerging CORBA industry standard.

Computer based simulation is recognised as one of the means that can support production cycles leading to shorter development times. In case of digital simulation, the need for mathematical models is apparent. A decomposition of models into submodels simplifies modelling and makes the original model(s) more flexible and easy to adapt. This modular approach to modelling facilitates the possibility to exchange models for subsystems. Decomposition into submodels implies that one should build libraries of models. These libraries are also useful in the case where a number of models are available that describe the same physical phenomena but differ in complexity. In this case widely accepted models can be (re)used. Reusability has become a key factor in reducing the time needed to accomplish a design task. Design of a model such that it can be reused should be incorporated as a requirement at the start of a project.

The CACE competence of an enterprise, i.e. application know-how and know-why can (and must) be stored in a CACE working environment.

3 EuroSim embedded in the CACE working environment ISMuS

Today, a large number of commercial CACE tools is available on the market. Control engineers use these tools for a wide range of activities. Typically, these activities will result in a number of models, documents and simulation results. As a result, the control engineer will inevitably need to answer questions like:

- Which models can be used in a specific simulator?
- Where are the right models located?
- Which set of s/w belongs to a set of simulation results?

ICT can provide solutions via computer-based working environments. Computer-based working environments can be made suitable for specific engineering goals by incorporating specific engineering tools and models

NLR's CACE working environment ISMuS consist of know-how and know-why of simulation for CACE in the form of application software, data and documents, and the SPINE software package. ISMuS gives designers of mathematical software access to distributed tools, models, data and documents as if they are residing on their desktop computer. Moreover, ISMuS connects distributed processes in the computer network.

ISMuS facilitates competence management by making available ICT tools for a.o. software configuration and version management (SR), setting up a Data File Repository using a Data-File Management System (DFR), project resource management (SiFrame), and internet/intranet access (the help function of ISMuS is implemented in html, allowing easy access by browsers). ISMuS has an open structure: it can easily be modified and new tools can be added easily.

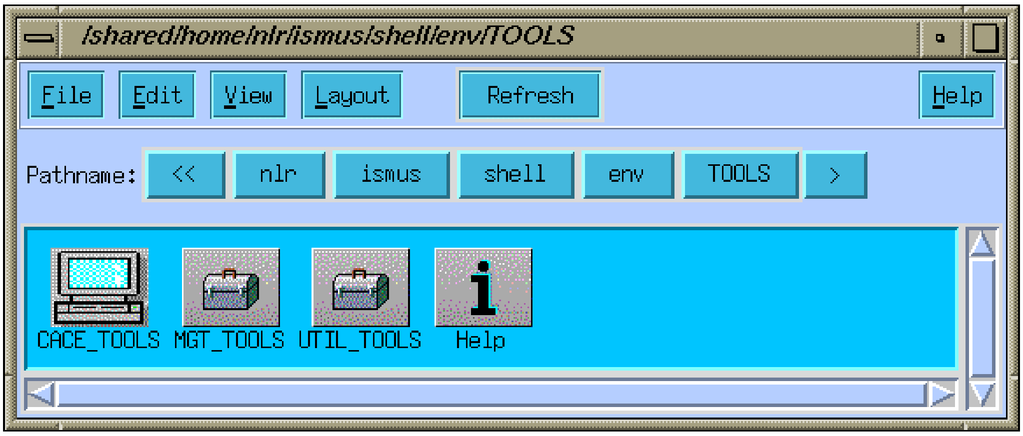

Fig. 1 Screen dump of the management tool selection window in ISMuS.

Users can access know-how and know-why in ISMuS both on the level of models and on the level of CACE tools.

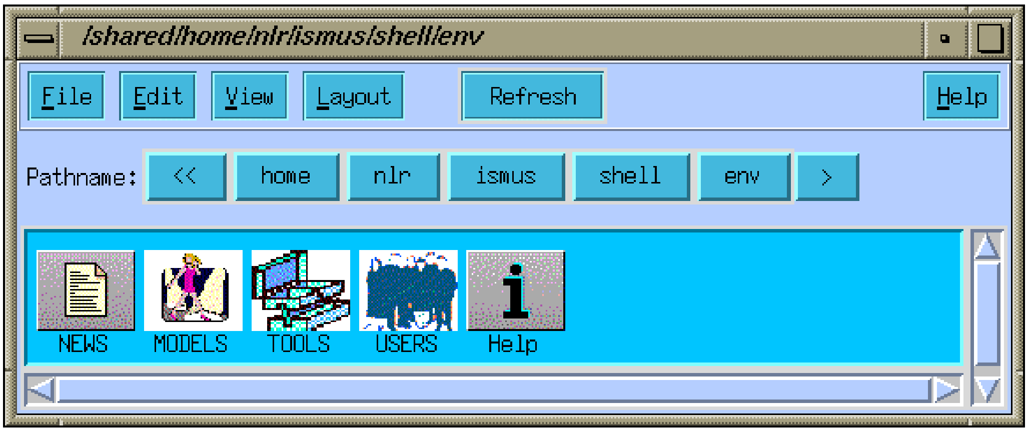

Fig. 2 Screen dump of the initial selection window in ISMuS.

ISMuS provides control engineers with CACE tools for modelling of dynamical systems, designing controllers for dynamical systems, performing simulation studies of controlled dynamical systems, and storage and retrieval of the input and output of all aforementioned activities. Currently, the following CACE are available: Maple-V, MATLAB/SIMULINK, ProSim, EuroSim, PVWAVE. (Note that the particular choice of CACE tools incorporated in ISMuS is already a competence issue.)

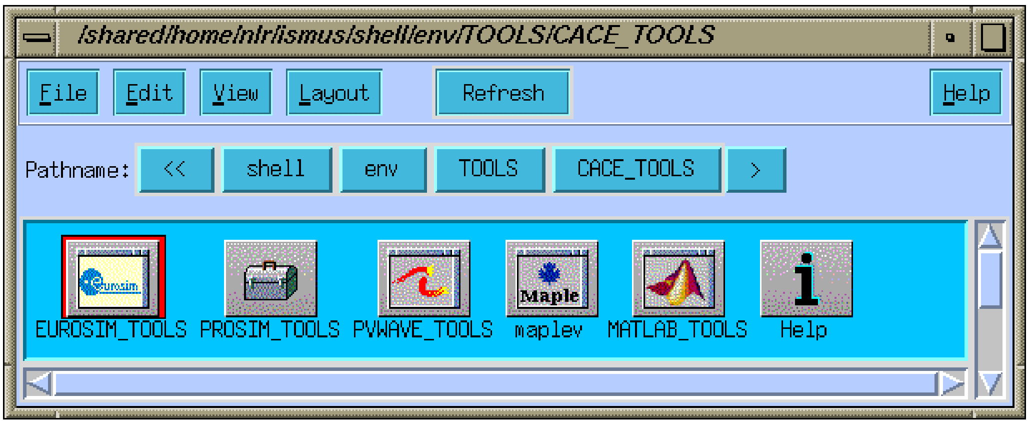

Fig. 3 Screen dump of the CACE-Tools selection window in ISMuS.

Not only the tools themselves can be selected. Expertise on the usage of tools, e.g. which tools are most suitable for specific engineering jobs is also present. This knowledge is based on past experience of aerospace projects executed at NLR.

EuroSim is a configurable simulator tool that can be used to support all phases of space and non-space programmes through real-time simulations with a person and/or hardware-in-the-loop, and allowing re-use of existing model software where available.

NLR's expertise in simulation middleware has been incorporated in EuroSim through a number of projects concerning simulation engines (HSFP, NARSIM, NSF), and through active involvement of NLR personnel in the making of EuroSim. EuroSim provides a framework to share and transfer source-code.

At NLR EuroSim has been made available, i.e. tool and documents (e.g. SUM), through ISMuS.

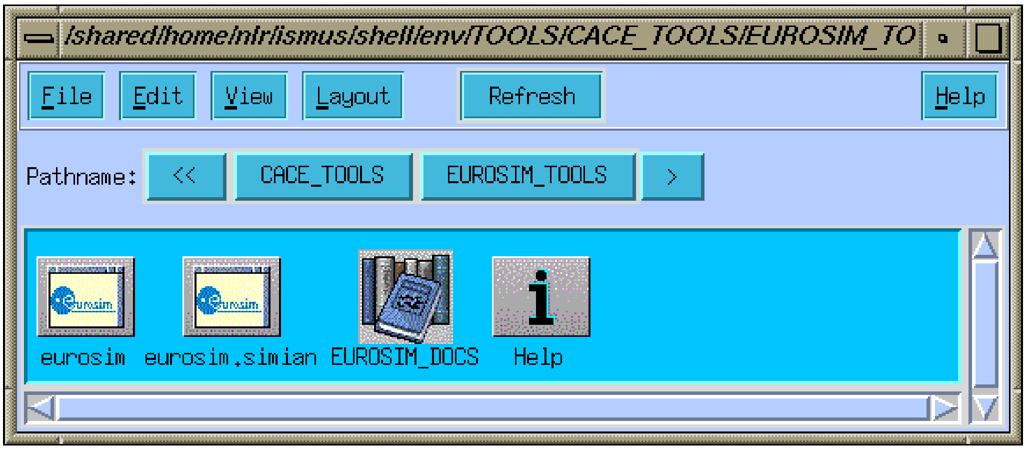

Fig. 4 Screen dump of the EuroSim-Tools selection window in ISMuS.

EuroSim is attractive to use as it has a number of interesting features.

- There is an Application Programming Interface (API) for models.
- Dynamic scheduling and scheduling support is available.
- It is based on a client/server architecture.
- It is easy to define and submit discrete events using the Mission Definition Language (MDL).
- Configuration control for source code is integrated.
- Interfaces with external hardware and other simulators are possible.

Moreover, since EuroSim is becoming well established in industrial environments, it can also serve to transfer knowledge, implemented in source code, between enterprises. An example of knowledge transfer between enterprises is the use of ESF (see also section 4) at Fokker Space and NLR. At NLR ESF is used for research purposes and at Fokker Space ESF is used a.o. for engineering purposes.

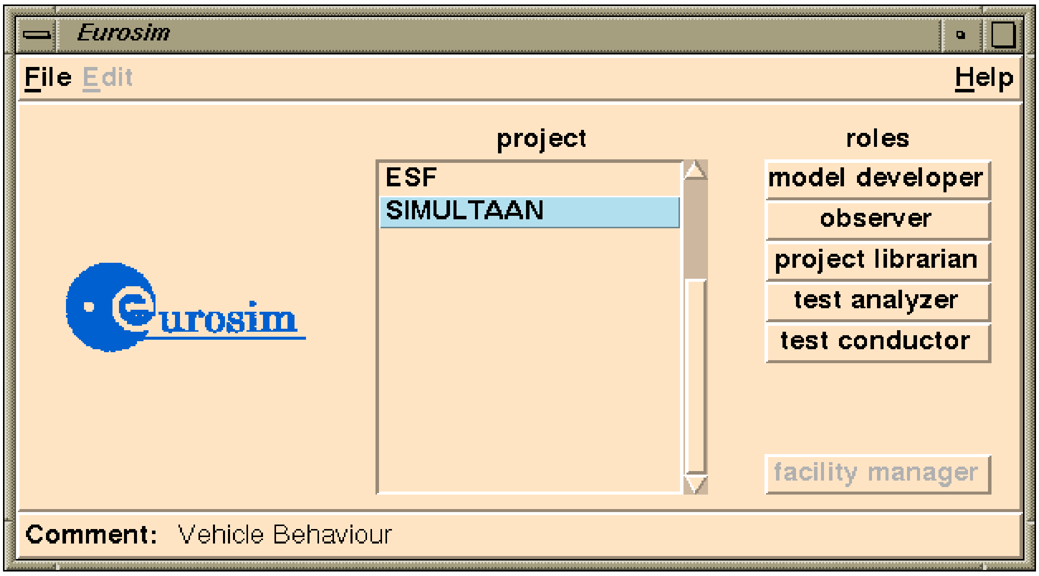

Fig. 5 Screen dump of a EuroSim-Model selection window in ISMuS.

EuroSim is especially well suited when (model) source code is already available. Embedding EuroSim in a CACE working environment makes available to EuroSim users the power of tools for symbolic mathematics and numeric computations together with the real-time simulation capabilities of EuroSim. In this way, the typical way control engineers like to work – executing feasibility studies before going to actual source code – can be maintained whilst ensuring that intermediate products can be used later on in EuroSim.

4 Computer Aided Control Engineering applications

NLR has built up expertise in modelling and simulation of interacting dynamical systems, like a robotic arm that captures a satellite and planetary rovers interacting with the terrain. ISMuS contains this enterprise knowledge in the area of CACE, preserved in s/w models, documents and data.

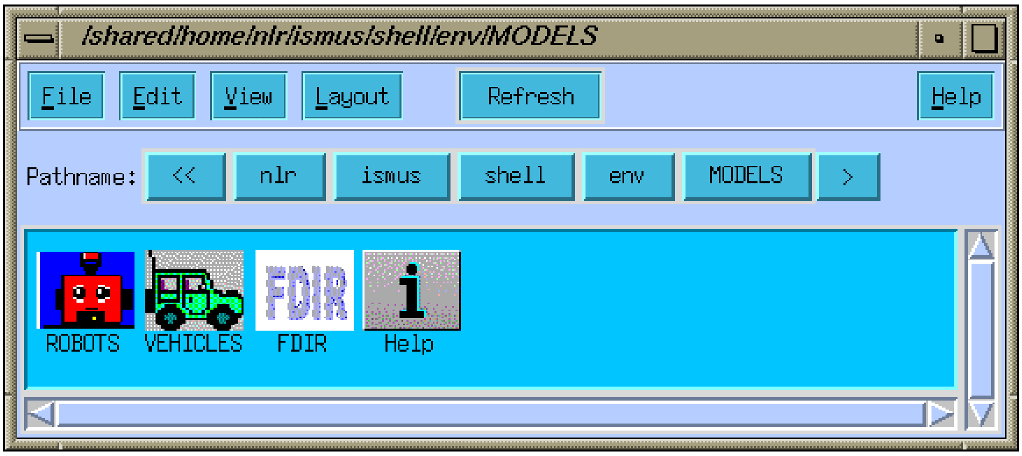

Fig. 6 Screen dump of the model selection window in ISMuS.

FDIR capabilities, competence of robotic applications, and knowledge of modelling and control of vehicles is part of NLR's expertise in aerospace application and is present in ISMuS. In the remainder of this section we will briefly discuss two projects, TRaCE and Simultaan to illustrate CACE competence management.

For over a decade NLR has worked on modelling, control and simulation of a robotic manipulator that interacts with its environment [6]. Whenever a space-borne manipulator comes in contact with its environment, e.g. a satellite or the space station, it may not damage the environment. This leads to stringent requirements on control of a robotic arm, e.g. low contact force levels and smooth controlled contact [7].

NLR has accumulated and exploited knowledge using ISMuS. TRaCE is one of the robotic simulators available in ISMuS. TRaCE is a 2-D MATLAB based robotic simulator for control design and numerical research made by NLR. Another robotic simulator is ESF: a EuroSim based space-borne robotics simulation tool developed by Fokker Space. NLR contributed in the development of ESF.

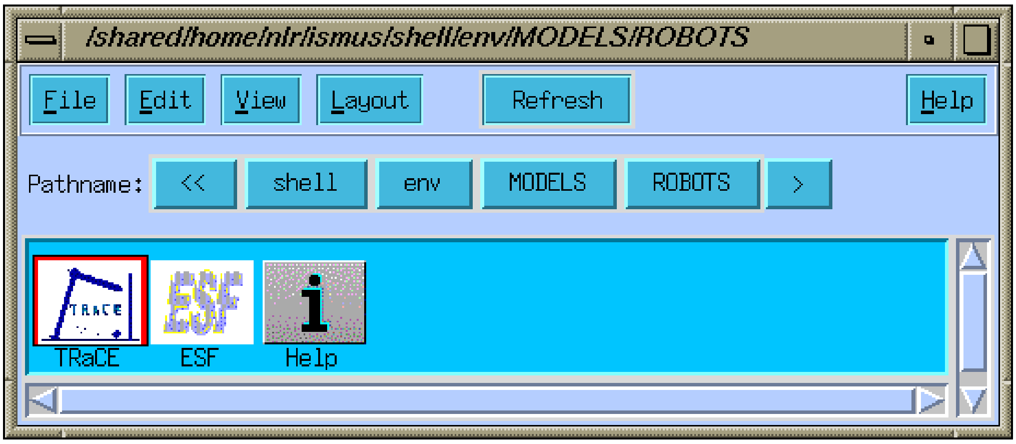

Fig. 7 Screen dump of the Robot Model selection Window in ISMuS.

From the mid-eighties onward the combination of force and position control of robotic manipulators attracted academic interest. Nowadays, many scientists study compliant motion issues for robotic manipulators. As a knowledge institute, NLR plays a key role in making scientific knowledge suitable for use in industrial applications. From the start of the simulation environment TRaCE it was clear that both experienced users and inexperienced users would use the facility. In particular, NLR employees use TRaCE to execute feasibility studies on CACE topics that are identified both at NLR and in industry, whereas for instance master degree students from universities examine novel approaches on their merits via simulation studies.

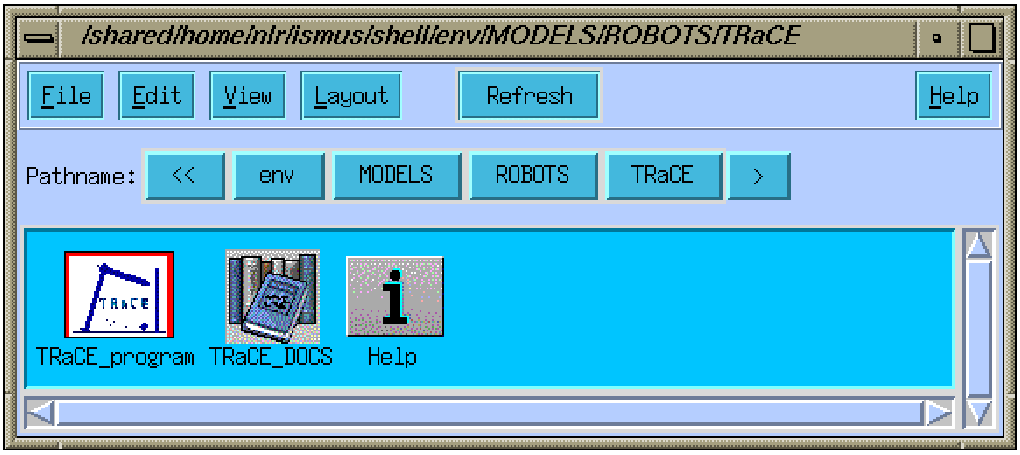

Fig. 8 Screen dump of the TRaCE simulation facility window in ISMuS

Knowledge on successful controller paradigms as well as knowledge on controllers that was found to be not suitable for a specific task is preserved in ISMuS. Usually students who work at

NLR are experts on for example controller design, but are less experienced in executing simulation studies in the filed of robotics. It has been experienced at NLR that the presence of a CACE working environment leads to very short periods of familiarisation with the subject at hand. Since students are typically working for short periods of time at NLR it is clear that shorter familiarisation periods in turn leads to efficient usage of academic expertise. An example of a TRaCE simulation study is depicted in figure 9.

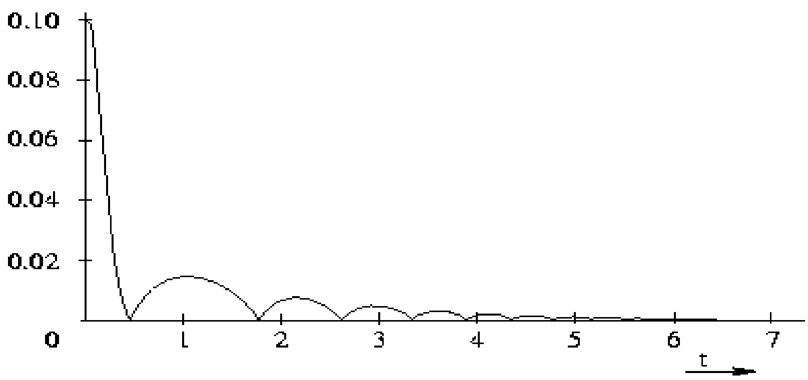

Fig. 9 Screen dump of a simulation result using TRaCE: a potentially damaging contact between the end-effector of a rigid 2-D robotic manipulator and a rigid surface.

In the Simultaan project (see [8]), the focus is on distributed training simulators. An important part of a real-time training or engineering simulator of a vehicle is realistic behaviour model of that vehicle. The mathematical model, implemented in code, must run in real-time to provide motion cues to a driver. In the past this meant that a trade-off had to be made between computation-time and model complexity. This trade-off often implied a reduction of model complexity. Nowadays, behavioural and performance requirements are such that this may not acceptable. To arrive at realistic simulations, the mathematical model must be structured to facilitate high performance.

In the Simultaan project NLR is responsible for the making of a generic behaviour model of a large class of road vehicles. Simultaan fits NLR's long term policy in the area of modelling and control of complex dynamical systems. The Simultaan project has a duration of 2,5 years and is partially funded by the HPCN foundation in the Netherlands HPCN programme [8].

The approach taken by NLR is to apply existing knowledge, preserved and available via ISMuS, to the case of behaviour models of vehicles. One key issue is to model and simulate contact between two or more subsystems [6,7]. Obviously, the contact modelling, control and simulation issues that arise in the case of road vehicles are similar to the ones that occur in the case of robotic manipulators (i.e. TRaCE) of which extensive knowledge is available within NLR. Feasibility studies have been performed by students on caterpillar tracked vehicles and on a Marshokod like rover. These results, together with experience preserved in TRaCE have been used a starting point in Simultaan.

Within Simultaan, an object-oriented approach is taken to model vehicles that contain rigid as well as flexible parts and that are moving on several types of terrain. This will lead to generic (sub)models that can be used to construct in an easy manner behaviour models of, for instance planetary rovers, trucks and cars, tractors, and caterpillar tracked vehicles. The behaviour model collection of Simultaan will exist of a collection of realistic and validated mathematical models of vehicles and aerospace systems suited for real-time simulation in a distributed simulation environment. High-level descriptions of the features of the models are included. This facilitates selection of the appropriate model including all relevant data and documents. The relation between s/w, data and documents is safeguarded in the CACE working environment ISMuS. The latter is important especially since a large number of people are involved: mathematicians, physicists, engineers and computer science experts. It is concluded that CACE competence management is necessary.

5 Concluding remarks

Sharing of know-how and know-why in a CACE working environment can contribute significantly to cost reduction. First it is experienced that a reduction in start-up time is achieved. Second, the sharing of information can be mentioned, e.g. via licenses for commercial software packages. Furthermore, enterprise knowledge is not lost but preserved and reused instead. Moreover, the "first time right" principle is also supported. The required number of simulation runs to answer a specific question can be minimised. This requires know-why and the ability to apply know-how. Working environments provide the framework for competence management.

The success of a working environment like ISMuS is significantly based on the assumption of a certain drive and willingness of people to include and share know-how and facilities in ISMuS, to share the use of this know-how and these facilities, and to collaborate and use know-how developed elsewhere. Drive and willingness are essential to be present in engineers and managers. Since engineers and managers often have quite different objectives, it is considered to be essential that a sufficient degree of commitment shall be present of top management to use advanced techniques such as ICT in the engineering process. In this context, budget and time constraints are considered as short term guidelines only.

It is experienced that willingness to use working environments is improved by incorporating the 'right' tools in the proper way. The incorporation of EuroSim in ISMuS proved to be important, with the positive side-effect of enhancing EuroSim capabilities as real-time simulation tool by the very present of complementary CACE tools. The benefits of EuroSim in a CACE working environment are experienced daily.

NLR’s ICT knowledge is successfully applied to facilitate CACE competence management in the computer based working environment ISMuS. ISMuS provides a way of working towards accumulation and reuse of knowledge.

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