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Formalisation and implementation of collaborative material research process

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Abstract

This paper describes concepts used in formalising the research processes in order to integrate them into a technical information system (TIS) supporting the collaborative material research. The present modelling approach is based on three requirements: (1) persistent recording of the process, (2) need for a local notification mechanism and (3) straight forward transformation of formalised processes into process classes within the TIS. We shortly review the techniques available for process modelling and discuss their applicability for the present domain of application. The utilisation of the modelling techniques is shown on the system application for research on textile reinforced concrete (TRC). Two real-world examples and applications from the TRC research are presented: (1) scheduling and coordination of tests on new material components spanning several users and experimental set-ups and (2) generic specification of automated calibration procedure to identify material parameters. The paper also discusses the applicability of the formulated concepts and of the developed system in interdisciplinary projects on other composite materials. The user's perspective and interaction with the system has been described in more detail in the companion paper.

Keywords: Material research; Process modelling; Object-oriented modelling; Software engineering; Technical information system

1. Introduction

This paper focuses on improving the support for information sharing and exchange in the area of material research. Even though there is a number of effective software tools supporting the simulation and evaluation tasks of material science, they are mostly applied as islands of automation. The practical experience still shows that material research is carried out with a lot of redundancies and informational bias induced by the incompleteness of the experimental data and missing validation of material models. Thus, there is a strong need for systematic evaluation of the experimental and numerical data, going beyond the traditional reviews of scientific papers and conference discussions. Furthermore, research tasks are often carried out in a rush without documenting their complete environment. This lack of information prevents others from reproducing the results. But the reproducibility of results is one of the most crucial requirements for any kind of reputable research. Improving the completeness and quality of the process documentation is a crucial goal that requires tool support.

The intended application domain of the formulated process model is indicated in Fig. 1 emphasising the iterative nature of data accumulation within the research process. Ideally, the data should be recorded for several types of research tasks running in parallel at different levels of material structure and with different focus of investigation. The aim of the formulation is to capture the dependencies and structural relationships in processes involving experiments, simulations and their interactions. In contrast to the

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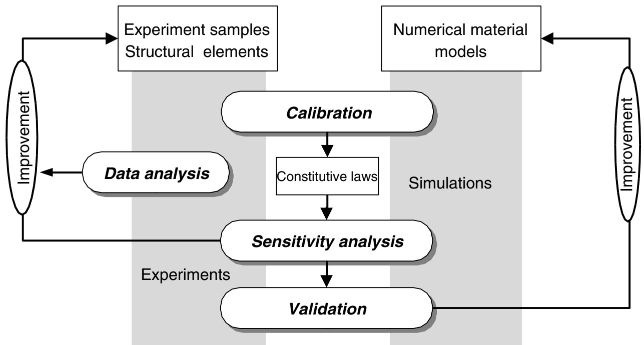

Fig. 1. Overall process of material research and development.

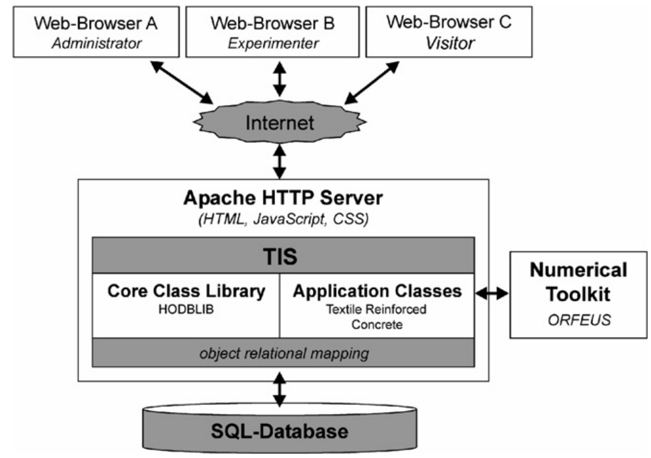

Fig. 2. Architecture of the Technical Information System (TIS).

companion paper [1] dealing with the user's perspective here we focus on the formal aspects of the design. The particular ambition of this work is to formulate processes in a compact way so that it is possible to extract the dependencies between the process state and the state of the meta-data prescribing the instantaneous structure of involved data. The design exploits the subordinate nature of the data structures with respect to the evolving processes. As a result of the approach, the actual process enactments can be made persistent and complete with regard to their input and output parameters.

It should be noted that it is not the goal of the present paper to extend the formal tools of process modelling. Rather than this we combine and adapt existing methods within an underrepresented but very important application domain.

The organisation of the paper is as follows: The technical realisation of the process model is based on the previous development of the TIS-TRC presented in [2]. In order to make the paper self-contained we shortly review the major features of the system and of its object model in Section 2. After that, we summarise major requirements on the process model in Section 3. The relevant formal tools available for process specification are discussed in Section 4 and the chosen formal framework for the present application is explained in Section 5. Finally, two examples of process formulations picked up from the area of material research on textile reinforced concrete realised within the TIS-TRC are presented in Section 6.

2. Realisation framework

At the technical level the system is realised as a database-powered Intra- and Internet server by employing the LAMP architecture and object relational mapping technique [3] (Fig. 2). Users (including researchers, administrators and visitors) access the system with standard web browsers via HTTP.

The system is designed using three layers of classes as shown in Fig. 3: (1) a set of core classes defining the object model, (2) an application independent, partly generic class library and (3) application specific classes (in the present application – classes representing entities of textile reinforced concrete research).

2.1. Object model

The core classes defining the object model comprise

- the abstract base class `HYObject`,
- attribute classes derived from `HYAttribute` (like `HYFloat`, `HYFile` or `HYRef`) and
- the meta-class `HYClass`.

Instances of the meta-class `HYClass` define the application classes. Every application class is directly or indirectly derived from the abstract base class `HYObject` which collaborates with the attribute classes in order to provide the following functionality:

- Class & Object concept, object identity, complex objects, object methods.
- Access control governed by class-, object-, attribute- and method-specific rules defining the required level of permission to be possessed by the user for the basic operations (view, edit and delete).
- Complex editable queries spanning over several classes.
- Visualisation and editing through HTML pages.
- Transparent mapping into and from a relational database.

The fact that object-relational mapping has been applied to realise the object model is not of primary importance. As shall be documented in the sequel, the constructed database object model is sufficiently rich to provide the required object-oriented concepts and offers a suitable framework for formulating, realising and testing the product and process model that is capable to capture the structure and behaviour of objects and processes involved in material research.