Multilevel information management in geotechnical engineering

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ABSTRACT: A generalized approach is described aiming at the integrated management of heterogeneous information in geotechnical engineering. The generalized architecture of a possible hybrid management system joins two approaches operating on different levels of information integration. This paper analyzes both kinds of systems. In particular notice will be given to the components of a strictly integrated management system for geotechnical engineering, following the demands of time-critical information management. Elements supporting presentation of all kinds of information as well as tools supporting net-based cooperation will be considered. The aspect of demands and potential for ICT support in construction engineering is briefly touched.

1 INTRODUCTION

Geotechnical engineering like other engineering disciplines can be seen as an information driven discipline. The need of information recurs throughout all stages of construction, ranging from design, planning and execution to the use of the building. However, throughout its lifecycle different demands on the management of information and different levels of integration can be identified.

Information in construction engineering is in general very heterogeneous. Typical types of information are: CAD drawings and plans, sketches, rough calculations from the early design phases, detailed calculations from blueprint and implementation planning, dimensioning of construction members, contracts, construction logs, cost estimations and accounting, schedules for planning and execution, and so on. Traditionally working small and medium construction companies have a working environment which consists of a heterogeneous collection of engineering software applications and ‘standard software’ including office software for processing this information. However, ICT support is not yet as sophisticated as in other engineering industries (Jung et al. 2004); quite some information processing is still handled ‘manually’ (handwritten). The application of ICT becomes profitable with a certain complexity of tasks. Big companies only apply heavyweight integrated software solutions which support the information processing throughout all phases of a construction project including project communication, workflow functionality, documentation and financial issues (like AEC/community, baulogis, BuildOnline and others).

To support particularly small and medium construction companies the following approach of a multilevel information management is proposed. The information management system combines two approaches operating on different levels of information integration.

The first approach is to manage information resources in a distributed project environment applying web-based technologies. Each single document as a container of heterogeneous information is managed by a semantically describing database. The information resources themselves remain physically at their point of origin in the responsibility of their authors. By application of web-based technologies the documents can be shared among the partners; they are available any place any time. The organization of the documents, however, goes beyond the scope of file system structures. No special software is needed on the client side.

However, for a comprehensive information management a simple document management does not appear to be sufficient. Therefore the second approach is to integrate information that is contained in the aforementioned information resources into a system that supports the finding of information and raises the transparency. Moreover, frequently accessed information shall be provided to the engineer in a suitable manner without the obligation to access and open the documents containing it. This demands for the abstraction of typical engineering information. Engineering processes and flow of information have been analyzed to identify ‘key information’ as an abstraction of detailed information. An information model for geotechnical engineering has been developed on this level and complemented with an appropriate user interface.

The combination of the resource management system operating on the level of documents and data files with the model-based information management system operating on the level of key information results in a multilevel information management applicable in geotechnical engineering. The generalized design of the information model allows for the adaptation for other engineering disciplines.

2 RESOURCE-BASED INFORMATION MANAGEMENT

One part of the multilevel information management system is provided by a web-based resource management system (Hildebrandt 2004, Holz et al. 2003). It was developed to support the sharing of heterogeneous information resources in distributed project environments by a common information base on a semantic level. This approach is closely related to the traditional working processes which base on the exchange of information, mostly contained in documents. However, the major drawback of information exchange is the lack of topicality due to different copies and versions of circulating information. This is overcome by the information sharing mechanisms supported by the web-based resource management system.

Typical information resources in engineering are all kinds of (traditional) engineering documents (plans, drawings, calculations, schedules, contracts, construction logs, codes), data files (monitoring data), charts, pictures and video files (observation and documentation). The management of these information resources demands for the explication of its implicit and hidden information. To overcome the problem of semantic heterogeneity a single domain ontology is the base for the semantic markup of the information resources with descriptors (Fig. 1). The ontology is flexibly adaptable for each project depending on special glossaries of the respective discipline and companies and the demands of involved partners.

The format of an information resource is indicated by its MIME type.

The management of the resources is handled by resource entries stored in a meta-database. They contain the semantic markup, the format information and information about the physical location of the resource (URL). Only the resource entries are stored in a meta-database. The resources themselves remain physically at their origin on any server worldwide in the responsibility of their authors. The resource management system is implemented as a web application (Java Servlets) running the database and handling the requests of the users.

The system is accessed from the client side by the web browser. No special software is needed. Any equipment such as PC, PDA or even mobile phone (limited) can be used. As these instruments are mobile, access to the system exists at any time from any place. Basic functionalities include search mechanisms (according to the semantic markup), resource browsing (by tree structure), resource editing, integrated resource visualization (provided by special customizable applets, e.g. visualization of time series from data files), personal workspaces for registered authors and bulletin board communication.

This architecture has the advantage that the responsibility towards content and topicality remains with the provider of the resource. Furthermore it has the advantage that the presentation of the resource on the client side follows the MIME type supporting tools and thus is always familiar to the engineer. The users have an always up-to-date common information base.

3 MODEL-BASED INFORMATION MANAGEMENT

Building is contracted to consortia operating as closed systems not open to the public. Between the partners, however, information about the contracted

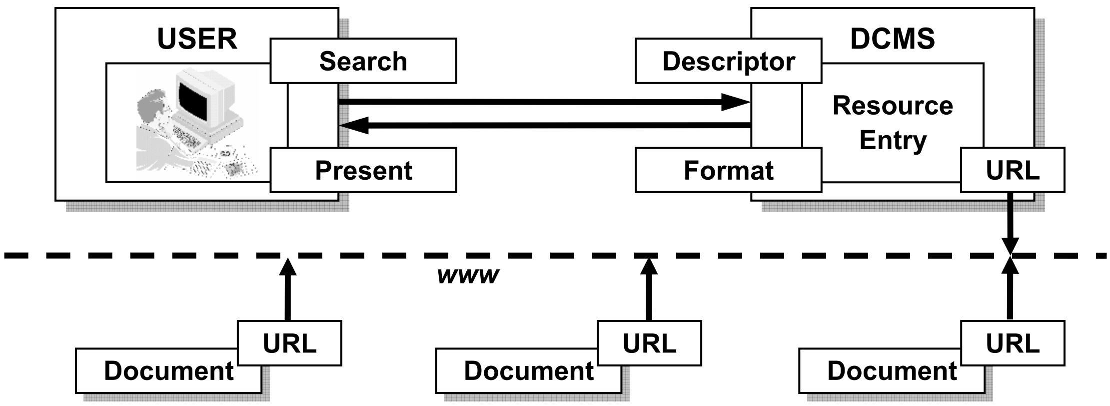

Figure 1. Web-based resource management system.

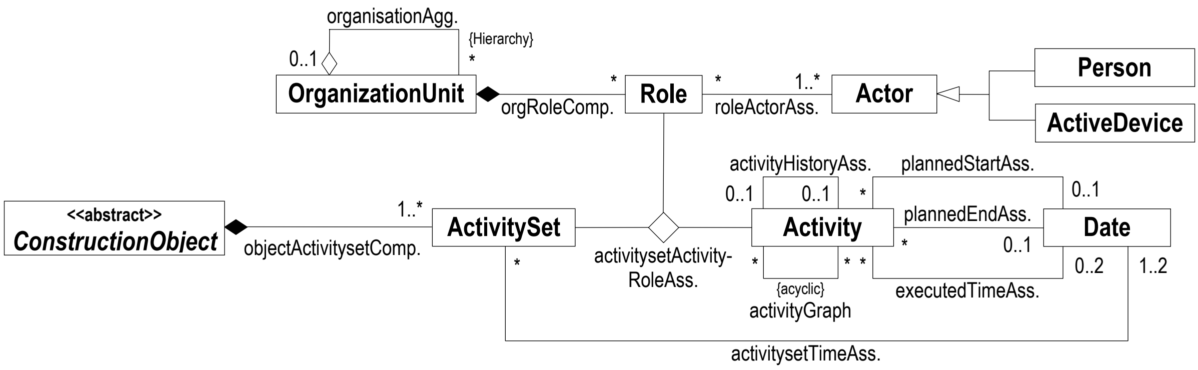

Figure 2. Excerpt from the construction site information model.

construction and operation of the building site is commonly shared. Providing just this information within a password protected resource management system as described might well be used in this environment.

However, when contracts with consortia are established, they contain precise information of partners, objectives, tasks, finances, responsibilities, time-frame and organizational structure. This information permits the design of information models on a densely integrating level for rapid construction follow-up and fast reaction in emergency situations. An information model for geotechnical engineering has been developed integrating construction elements, building processes, monitoring, actors and organizational structure (Schley et al. 2004). The main objective for this information model lies in the support of handling emergency situations in geotechnical engineering. It is designed to contain key information only, since only few technical details about construction members and their states are needed for emergency handling. However, it has shown that this information model is applicable for the information management throughout the entire construction process.

The information model and its corresponding model editors are not intended to replace existing software packages and tools the engineers are using at their regular work. It is rather intended to be a supplementary instrument that fits into the engineer's working environment and provides a central point of reference concerning information management. A corresponding mechanism for interfacing with other sources of information is presented.

3.1 *Construction site information model*

The information model (Fig. 2) follows an object oriented approach and is described by the unified modeling language (UML). The abstract generalized model consists of three components. They represent the construction objects of the building, the construction process and the organizational structure.

Construction objects are structure components (members), measuring devices, construction equipment, site facilities and machines of the construction project as well as objects interfering directly or indirectly with the project like neighboring buildings or soil and groundwater bodies. An extendable class hierarchy has been created to model typical geotechnical engineering construction objects like excavation, sealing slab, slotted wall, anchor, gauge and pump. The construction object's properties are modeled separately with specialized property classes. They contain the actual key information. The integrity of the model is ensured by the definition of mandatory properties for certain construction object types. Other properties are optional and can be combined freely.

Construction processes are mapped with activities and relations between them. An activity graph maps the work schedule with its planned and actual times of execution as well as completion. It allows for a complete control and survey of the construction process. Changes of the work schedule are documented in the information model for later evaluation and assessment of critical emergency situations. Property objects provide information about the planning, execution and finish state of construction objects. Predefined construction sequences can be integrated.

The organizational structure model component is rather independent from the other ones. It is capable of mapping the prevalent organizational and responsibility structures of building sites. The hierarchic structures, as determined by contracts, are represented with organization units. They can be real (company, division, department …) as well as virtual units (joint venture …). For one building project there can be mapped several organization hierarchies (subcontractors).

3.2 *Interfacing with external models*

Major problems in model-based information systems are the integrity and the consistency of the information model. Many software products are available for all the different engineering tasks covering the whole construction and building process providing their own underlying models. For persistent storage and exchange of information proprietary formats are established. However, integrated solutions are feasible with the development of common product models, like IFC (IAI 2004) for civil and building engineering. But the implementation and support of common product models in commercial products is not yet as satisfactory as necessary.

The described information model for geotechnical engineering was designed for quick access to key information only. The key information considered is usually contained in other resources available to the engineers, sometimes ‘hidden’ or implicit. However, tough competition does not permit to spend extra effort, costs and manpower on condensation and integration into the information model. Besides this the problem of undesired redundancies arises from the concurrent provision of information from both the information model and the original information sources (e.g. proprietary storage within the information generating software products).

The following approach of a collection based core model has been developed to overcome both problems (Brüggemann & Liang 2004). It defines selected proprietary formats as persistent core together with providing a collection based generalized interfacing methodology. The described information model is integrated part of the persistent core. Interfacing is done with reader and writer components implemented specifically for the proprietary formats. The readers and writers are interconnected with trasformer components. Readers, writers and transformers operate with basic set operations on a transient collection based model consisting of objects, collections and relations only. The collection based model is a very high level of abstraction of the information to be interfaced. No further semantics is contained.

As a side effect the inevitable redundancy is managed by the collection core approach. Information is marked as original and dependant information, thus allowing for consistency checks if parts of the (whole, distributed) model change.

4 MULTILEVEL INFORMATION MANAGEMENT

The proposed multilevel information management system combines both aforementioned approaches. The resource-based approach provides the management of all kinds of traditional documents usually shared during construction processes. Moreover it can handle heterogeneous information resources that change dynamically during their life time like all kinds of data files providing for instance measured data. The web-based resource management system also allocates communication and collaboration tools and makes it part of a web-based cooperation platform. The model-based approach provides the access to and the management of distinctive information, topological correlations and dependent information which cannot be recognized out of documents. However, the underlying information model cannot give and is not designed to provide whole coverage of all information for construction management. Only key information is provided. The link between both approaches is managed by the information model. Special properties of construction objects, activities or organization objects contain links to resources, pre-formulated queries or dynamically formulated queries for the search mechanisms of the resource management system.

Navigation through information to access key information is crucial for decision making processes and crisis management. To support these needs a graphical navigator has been set up (Fig. 3). It serves as central information editor for the entire information model presenting the construction project with its construction objects in a schematic generalized form by appropriate tools and editors. This allows for quick information retrieval and the recognition of spatial and temporal bearings to the engineer. The temporal context, provided by the process compo-

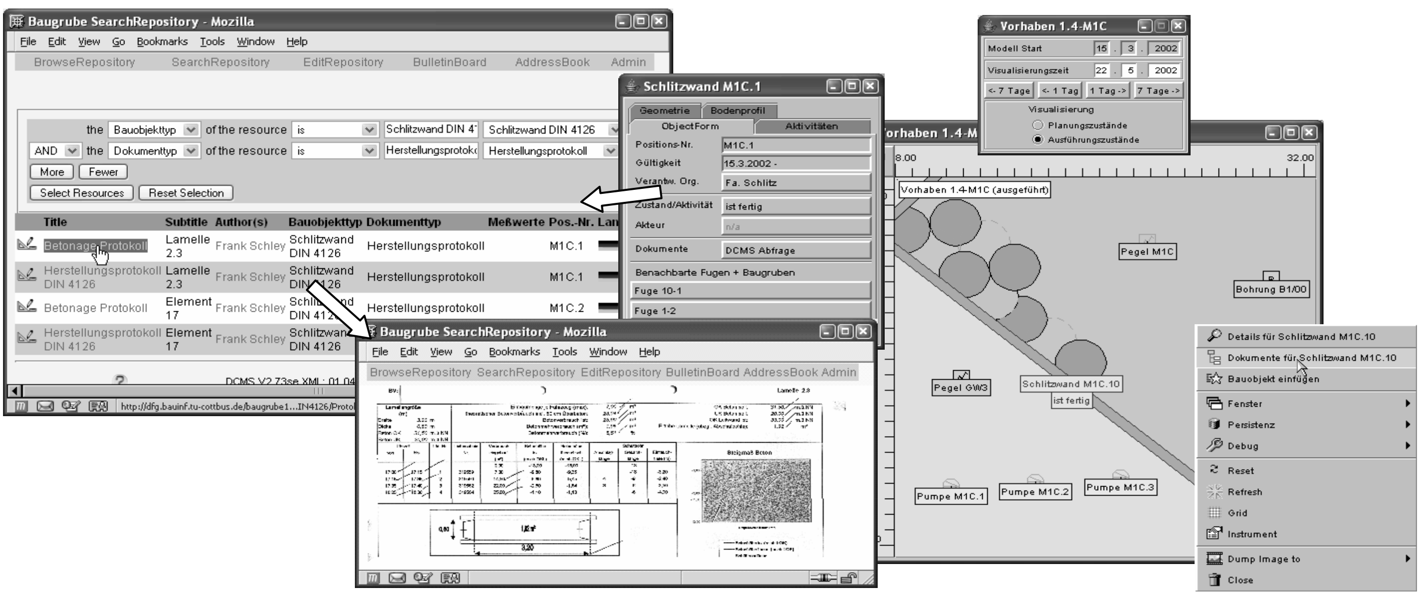

Figure 3. Graphical information navigator and some model editors.

nent of the model, displays the status of the building process at any time level of construction work. It also allows for comparisons of both the as-built and the as-planned states. Accessibility to information about the project status at current and any previous time supports decision makers to understand possible interactions between building, soil, water and activities as well as the development of failures and their reasons.

The graphical navigator provides the following groups of tools and information editors:

– Tools and editors for construction object information. They handle the type specific properties of construction objects and their topologic dependencies. These tools provide continuous comparison of target and actual values on construction object base. A modular structure of these tools allows for an easy combination of desired tools and implementation for other type specific properties.
– Tools and editors for process information. This group of tools is designed for tracing, control and editing of construction process information.
– Tools and editors for organization information. They visualize organization hierarchies and make them editable easily. The definition and assignment of roles to their organization units as well as roles to actors and activities is provided. Contact information assigned to organization units, roles and actors (persons) can be edited and instantly applied for the establishment of communication channels (e-mail, SMS, net-based telephony). Links to construction object and process information are navigable.

Furthermore the graphical navigator is interlinked with tools that according to type of critical development propose engineers immediate prevention measures according to predefined scenarios and collaboration schemes. This supports remembering and considering alternatives which might be difficult during alert times.

All of the abovementioned tools contain links to the resource management system for further information not provided by the corresponding part of the information model.

An alternative approach for an efficient information access in less time critical situations through a navigational model is given by Reinhardt et al. (2004).

5 CONCLUSION

The approach to manage heterogeneous information in geotechnical engineering with a multilevel management system has been outlined. Wide use of web technology has been made. The first level is used for loosely integrated information in document and data file based information resources. This level follows closely the traditional document based working processes taking advantage of ICT for information sharing instead of information exchange. The second level is the level of key information mapped in an information model. Both the information model and the resource management system are integrated in a web-based cooperation platform.

The general approach taken supports ‘virtual’ collaboration ‘any time – any place’. Furthermore the model driven approach extends this working paradigm towards the information retrieval paradigm ‘right time – right place’. It seems that this dimension is not yet familiar to practice in this environment and will need some more preparedness.

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REFERENCES

Brüggemann, B.M. & Liang, S.-J. 2004. Virtual Hydroinformatics Laboratories: Providing and Interconnecting Resources and Tools with Web-Services. In Liong, S.Y. et al. (eds), *Proceedings of the 6th International Conference on Hydroinformatics, Singapore, 21-24 June 2004*. Singapore: World Scientific Publishing.

Hildebrandt, G. 2004. *Web-based Resource Management & Collaboration Platform “DCMS”*. Brandenburg University of Technology at Cottbus. http://dcms.bauinf.tu-cottbus.de/ (Apr. 20, 2005).

Holz, K.-P. et al. 2003. Virtual Laboratories for Projects in Environment Water. *17th International Conference Informatics for Environmental Protection, The Information Society and Enlargement of the European Union, Cottbus, 24-26 September 2003*. Marburg: Metropolis.

International Alliance for Interoperability (IAI) 2004. *IFC/ifcXML Specifications*. http://www.iai-international.org/Model/IFC(ifcXML)Specs.html (Apr. 25, 2005)

Jung, Youngsoo et al. 2004. Informatization Index for the Construction Industry. *Journal of Computing in Civil Engineering* 18(3): 267-276.

Meißner, U. & Rüppel, U. 2000. *DFG-Schwerpunktprogramm 1103: Vernetzt-kooperative Planungsprozesse im Konstruktiven Ingenieurbau*. University of Technology at Darmstadt. http://www.iib.bauing.tu-darmstadt.de/dfg-spp1103/ (Apr. 6, 2005).

Reinhardt, J. et al. 2004. Navigational Models for Computer Supported Project Management Tasks on Construction Sites. *Journal of Computing in Civil Engineering* 18(4): 281-290.

Schley, F. et al. 2004. Network-based Co-operation Platform for Geotechnical Engineering. In Beucke, K. et al. (eds), *Proceedings of the Xth International Conference on Computing in Civil and Building engineering, Weimar, 2-4 June 2004*. Weimar: Universitätsverlag Bauhaus-Universität Weimar.