Abstraction of Process Relevant Information from Geotechnical Standards and Regulations

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Summary

The paper presents the abstraction of process relevant information in order to enable the workflow management based on semantic data. It is shown for three examples, how the standards define the information needed to perform a certain planning activity. Abstraction of process relevant information is discussed for different granularities of the underlying process-model. As one possible application ProMiSE is introduced, which uses process relevant data in individual tokens in a petri-net based process-model.

1 Introduction

Planning and realisation of a construction require intensive exchange of information between all planning participants. From the first idea of a project to the takeover of the building by the owner a large amount of documents of all kinds are generated, representing the exchanged information. With respect to the efforts to improve the process of planning and realisation by means of a process model based cooperation in heterogeneous computer networks, it seems essential to have sufficient knowledge about the information being exchanged. In this paper the authors contribute to this aspect, concentrating on geotechnical information. Additionally an implementation approach based on the Petri-net theory for a process-model-based cooperation system is presented.

2 Information Exchange in Structural and Geotechnical Engineering

Planning and building of a project is a distributed process of co-operation. The planning participants and building contractors usually act in economically and juridically separate organisations and are connected to the team work by contracts either with the building owner or as a sub-contractor to the general contractor. For legal reasons information is exchanged in a document-based manner. With the development of web-based project management tools the use of digital documents (as hpgl-plots and dxf-files) becomes more and more widespread and documents are still the official media for the exchange of information.

Legal documents can be generally categorized as follows:

- contracts including bill of quantities
- statical calculations
- cost calculations
- plans
- expertises
- general correspondence

- reports / protocols
- project management documents

The documents contain information in textual, numerical and graphical form. Due to the lack of semantic structures and conventions the information is usually comprehensible only to the human reader of the document. In order to characterize the content of the documents, the file servers of the web-based project management systems often set up naming conventions, containing, e.g., the type of the document, the planning phase, the scale, and the structural elements. In general, the semantic information is not readable by the computer.

The type and the amount of documents varies with the progressing project. In the early planning phases the number of participants is typically small and increases gradually. During the construction the number of participants increases significantly and so does the number of documents. The analysis of the log-file of a web-based project-management-system of a 140 m high building in Frankfurt / Main (Germany) showed the following distribution of documents over time, that had been exchanged in the project (Figure 1):

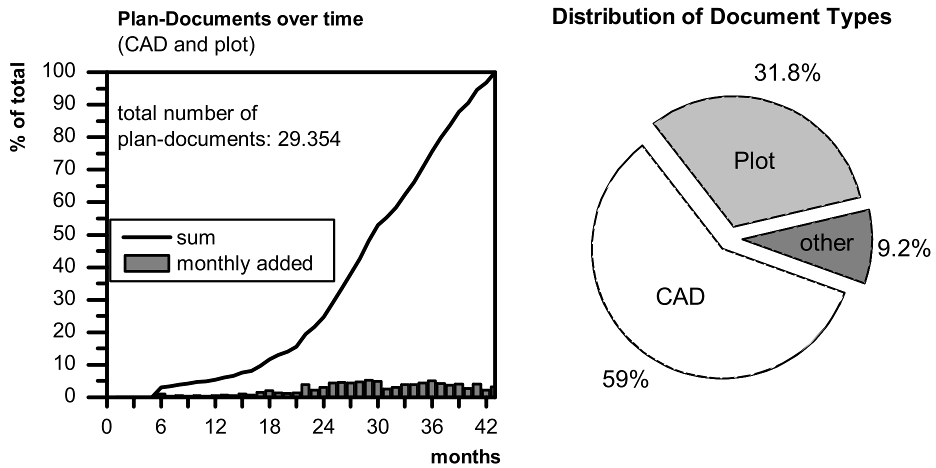

Figure 1:

Documents in the Project-Management-System

Of all exchanged documents approx. 90 % were CAD-related documents (CAD and plot). The number of participants in the project summed up to approx. 100, of which 70% were contractors and 30% were involved in planning.

2.1 Information Exchange in Geotechnical Engineering

Geotechnical engineering is typically involved in the following different phases of the planning and construction:

- Geotechnical investigations
- Specialised structural engineering tasks (foundation engineering, excavation pit, earth works)
- Specialised construction supervision (either for the contractor or for the owner)

Each of these fields is connected to a typical information exchange, which has been well-documented in the German standards and which will be taken as a basis to characterize the information in geotechnical engineering. In the following sections the exchanged information for these three examples and their characteristics are presented.

2.1.1 Soil Explorations

In the soil exploration all properties of the soil as construction material and as subsoil have to be determined including subsurface constructions and obstacles. The result is the basis for all other geotechnical planning and calculations. Soil exploration includes the exploration of all relevant soil layers and of the groundwater by direct and indirect exploration techniques. The extent of the soil exploration programme is determined by the complexity of the structure and the subsoil and by constraints concerning the allowed vertical and horizontal movements. Soil exploration includes also the evaluation of existing boring-profiles, geological maps, data and experiences gained from previous projects. As a result of the exploration possible foundation techniques, techniques to deal with the groundwater or hints concerning the construction of building elements may be recommended.

All results of the soil exploration are documented in the soil expertise. In the german national standard for soil exploration DIN 4020 a general setup of the document is prescribed and a list of the required information in the document is provided. According to the standard the soil expertise is divided in the following three parts:

1. Results of the geotechnical site investigation programme,
2. Evaluation of the results,
3. Conclusions, recommendations and hints.

The documents are human readable, the main information is textual; especially in the first part though, the results of the geotechnical investigations are documented in graphical and numerical form, e.g., as site plan, laboratory reports, graphics of the boring profiles and graphical representations of numerical data like hydrograph curves. These documents are attached as the information basis to the soil expertise.

In the second part the results of the first part have to be evaluated and discussed by engineering judgement and a soil model is proposed. Apart from the important textual information, this part contains also the numerical data of the soil properties, the simplified soil model as a geotechnical profile (numerical/graphical data). Table 1 gives an overview of what is proposed by the German standard as content of this part and the corresponding type of information representation.

Table 1: Information in soil expertise

(DIN 4020:1990-10, translated into English)	Information Representation [1)]
Critical evaluation of all results of the geotechnical investigation presented in section 1.	T
Tabular and graphical representation of the field- and laboratory-tests including – if necessary – the determination of scattering, deviation, error and fractiles according to error theory	T/N/G
Specification of the relevant groundwater table in consideration of seasonal and long-term variability of the groundwater table	T/N
Profile of strata according to DIN 4023 summarizing similar soils and rocks to homogeneous strata	G/T
Textual description of the found soils and rock referring to their physical properties, their deformability (...), their mechanical strength (...)	T
Hints at limited inclusions, voids, sinkholes and other singularities	T
Summary of the determined or estimated properties of each stratum including the scattering	T
Assessment of the results of the investigation from soil, groundwater and ground air concerning contamination	T

[1)] T: Textual – N: Numerical – G: Graphical

The textual information in the last part gives a series of hints and recommendations concerning the construction. One important numerical information is the geotechnical category of the building, which reflects upon the overall geotechnical complexity of the construction and the soil. The categorization (1-3) greatly influences the further proceeding, as it may lead to the necessity of further investigation and / or monitoring during construction. The very important information in soil expertises is generally not readable to the computer. Process relevant information has to be abstracted from the textually, numerically and graphically represented information by specialists in order to enable a workflow management, e.g. based on Petri-nets.

2.1.2 Specialized Structural Engineering

As an example for specialized structural engineering the calculation of slope-failure is presented which is coded in the German standard DIN 4084: 1981-07. Calculating the safety against slope-failure is one important part of geotechnical constructions like retaining walls and an essential for the design. The standard explicitly defines the necessary information as input to the safety analyses.

[DIN 4084: 1981-07, page 2]:

"Section 5: Information:

a) *information on the general configuration and dimensions of the supporting structure or of the slope, the least favourable water levels and the values of the loads required for calculation the various loading cases.*
b) *subsoil exploration (...)*
c) *the soil mechanical parameters of the subsoil, especially the force per volume of the individual soil layers and the shear parameters (φ', c') of the types of soil present in the vicinity of the sliding surface which, in the case of cohesive soils, must be determined for the consolidated state – final stability – and, if required, for the unconsolidated state – initial stability (φ_u, c_u).(...)"*

The information necessary can be categorized as follows:

Table 2: Necessary information for slope-stability analysis

	Information Representation [1)]
1. Information about the general design and the dimensions of the structure	T/N/G
2. Information about groundwater-levels and soil including soil properties	T/N/G
3. Dimension and characteristics of the loads	T/N
4. Hints concerning possible construction techniques and other constraints	T

[1)] T: Textual – N: Numerical – G: Graphical

The required information matches the information in the soil expertise. In addition the information contained in plans of the architect and in plans of the structural engineer concerning the required loads.

2.1.3 Construction

In geotechnical engineering the design is closely related to the construction and often both are performed by the contractor. A lot of decisions are made by contractors up to specific proposals for the construction which includes partially or totally a new design phase.

The main difference in construction between structural engineering and geotechnical engineering is the necessity of controls; firstly because the components cannot be checked easily in the ground, and secondly to verify the results of the soil exploration. Depending on the geotechnical category, supervision can be obligatory, furthermore the observational method could be necessary. The supervision is used to detect discrepancies of the construction from the planned design for quality management and for constantly checking the statical bases. The observational method is needed, when the soil exploration and the calculation is not sufficient to explain the soil behaviour. The new German standard DIN 1054 2003-01 gives defaults for the supervision, the observational method and the therefore needed measures and measurements during the construction phase.

As an example the construction of cast-in-situ concrete slurry walls, e.g. as retaining walls of an excavation pit, is presented and we therefore focus on the German national standard DIN 4126: 1986-08 and the European standard DIN EN 1538: 2000-07.

The DIN EN 1538 contains the following information:

1. definitions
2. necessary documents for the execution
3. necessary soil investigations, also during the execution
4. permitted materials, their requirements and experiments for the proof
5. criteria for most execution phases
6. execution steps with appropriated defaults and details
7. construction supervision and controls: Spreadsheet containing measurement categories for construction phases and current objects like groundwater or reinforcement cage; there are several spreadsheets for different types of slurry walls.
8. for information: Preprints of Construction documents for different types of slurry walls

DIN 4126 contains information to the same topics for only cast-in-situ concrete slurry walls, but not so detailed in some points, i.e., the controls during the execution. But information for the calculation is included, as mentioned above.

For construction in geotechnical projects information is needed for planning the construction and for the regular process (not time-critical) and for instant reactions after detecting discre-pancies, or - in the case execptions occur - (time-critical), e.g., water leakage during or after the dewatering of the pit. In addition to construction planning information primary from 1.-6. of DIN EN 1538 process relevant information (see section 3) can be abstracted for the construction process and 7.-8. are additionally needed during the construction if planning changes or fast reactions based on supervision information are made. For technical reasons the contractors are particularly in need of the information for construction planning shown in Table 3.

Table 3: Information for planning execution

		Information Representation [1)]
1.	Position and geometry of structural components	T/G
2.	Sequence of structural components if statically necessary	T/G
3.	Dimensions of the building	T/N
4.	statical dimensions and materials of structural components (profiles, strength of concrete, reinforcements,...)	T/G/N
5.	Information about soil and groundwater (soil expertise, see 2.1.1)	T/G/N
6.	Survey information (land borders, adjacent buildings,..)	T/G
7.	Bill of quantities (defaults to vibration protection, side facilities,...)	T/N
8.	Location and dimension of utitlity lines	T/G

[1)] T: Textual – N: Numerical – G: Graphical

For time-critical reaction but also for regular construction a co-operation platform has been developed which is based on a generalized information model mapping key information. A great part of the key information is rendered during the construction phase and necessary for exeption handling, and therefore contains also process relevant information. The co-operation platform and the information model has been developed at the Institute of Geotechnical Engineering, Technical University Berlin, and at the Institut Bauinformatik, Brandenburg University of Technology at Cottbus [Schley et. al. 2004].

3 Abstraction of Process Relevant Information

Information is process relevant if it enables decisions in workflows and thus determines further planning activities.

Within this framework we understand the process as the sequence of all activities with well-defined states at their beginnings and ends. This process can be represented mathematically as a graph where different forms are usual. Resources and actors linked to the states and activities are also an essential part of the process models (see section 4). Most important for the workflow is also the flow of information or materials through the system and the logical decisions for its distribution.

The idea to abstract process relevant data from other data in the planning process is due to the idea to improve the planning process and the interactions between all participants by providing a consistent underlying model. At decision nodes in that model, at least references are needed which refers to the actual planning but might not be the planning data itself.

One example is the existence of a groundwater table above the lowest point of the building pit, which requires planning activities to either design a waterproofed excavation or lower the water table below the sole of the pit. Furthermore this might imply activities to get the necessary approvals by the authorities in charge to install the dewatering, maybe even connected to measures of decontamination. The total number of sheetpiles used for the retaining wall however is not process relevant in the way that the kind of activities to be carried out after the number has been determined remains the same. The fact that sheet piles are used as retaining wall is itself linked to the question of driving them either by vibrating or by ramming. Chosing the appropriate driving method is itself based on geotechnical information about the mechanical properties of the soil, on constraints on the allowable dynamic acceleration in the ground and the allowable sound emission and of course on economic calculations.

Process relevant data is connected to the granularity of process modelling and thus the granularity of activities and decisions being modelled. The following two modelling granularities can be distinguished:

- As to model the interaction of planning participants it is sufficient to represent the designing and dimensioning of one structural element or one group of structural elements as one activity (e.g., planning of footings), provided the activity does not require any interaction with other planning participants. Process relevant information derives mainly from the necessity to design specific structural elements. For example the necessity to design water-proof retaining walls due to a high groundwater-table is process relevant in this case. The structure of the data is mainly textual, describing existence or necessity (e.g., foundation: piles, groundwater above sole of pit: true).

- To model activities carried out within one planning domain (e.g., structural engineering) further discretization is necessary, so i.e. the algorithm of dimensioning a slab or a pile can be modelled as a process. Process relevant information in this case represents mainly numerical data like dimensions and forces.

Abstraction of the process relevant information requires structuring which is adequate to the process-model being used. One example of process modelling is the use of Petri-nets with individual tokens. The definition of one adequate formalization of process relevant information is given in section 4.2. From the human-readable information, which is exchanged in documents, the process relevant information is abstracted to a computer-readable and processable form.

4 Workflow control based on process relevant data

To adequately support the management and the control of planning processes an appropriate process modelling method and elaborate workflow control software has to be developed. Both, the modelling method and the control software closely rely on the existence of significant process relevant data. In the following, the requirements of a workflow management system and the idea of process relevant data according to the WfMC is illustrated. Furthermore, an implementation approach based on the Petri-net theory [Petri 1962] for a process-model-based cooperation-system is presented.

4.1 Requirements according to WfMC

The Workflow Management Coalition (WfMC) defines the general requirements of a software tool for the management and the control of workflows in [WfMC 1995]. Essentially, these requirements are

- process design, definition as well as analysis at build time, and
- process instantiation, control and user/software interaction at run time.

These characteristics and the dependencies between the build time phase and the run time phase are illustrated in Figure 2.

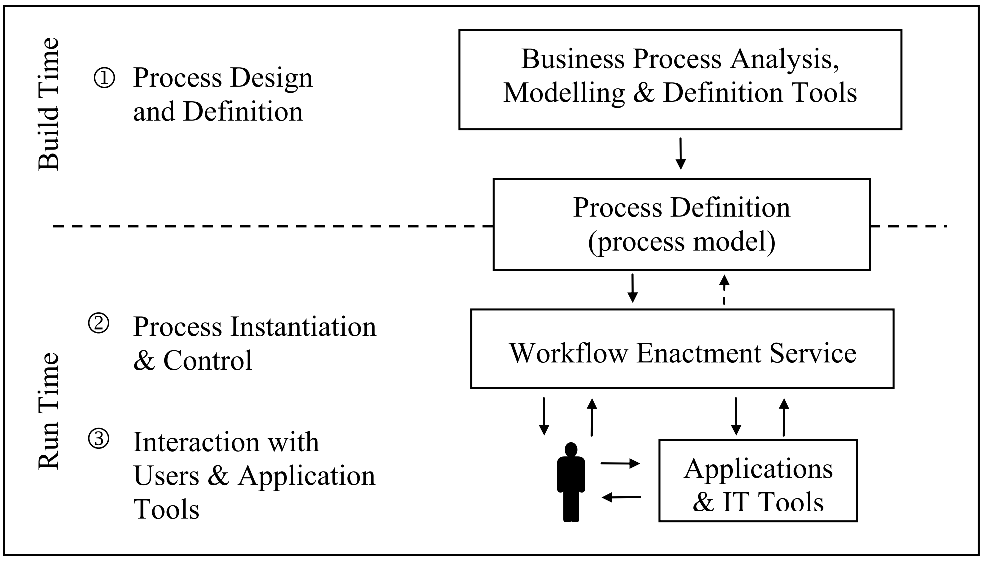

Figure 2:

Workflow System Characteristics [WFMC 1995]

Concerning the process modelling, the process control, the interaction and finally the process relevant data document [WfMC 1995] states the following characteristics in more detail:

- During the build time phase, business or engineering processes are abstracted from the real world into a formal, computer processable process model. Based on the chosen modelling technique different analysis possiblities are available to analyze and verify the process model.

According to [WfMC 1995] a process model comprises a number of discrete activities with associated computer and/or human resources and rules governing the progression of the process through the various activity steps.

- At run time the process model is interpreted by a software tool, often referred to as workflow engine, in order to manage and control the various activities within the process and to invoke humans and IT application resources. The software has to provide appropriate network communication mechanisms to cope with activities distributed across a heterogeneous computer environment.
- Also at run time the individual activities within the process model are carried out by humans and/or software tools. Interaction with the process control software is necessary to transfer control data between activities, to monitor (and control) the progression of the process, to notify humans or to invoke application tools and to pass the appropriate data, etc. In order to realize this interaction a standardized framework with consistent interfaces is necessary.
- To enable process navigation decisions, or other control operations within the process control software, specific data generated or updated by technical application programs has to be accessible to the process control software. According to [WfMC 1995] this kind of data is termed "process relevant data" in contrast to "application data" and it is the only data accessible to the process control software.

Based on these requirements defined by the WfMC [WfMC 1995] there exist many different possibilities to build up a network enabled workflow management system. For the modelling and the management of civil engineering workflows additional requirements were defined and illustrated, e.g., in Meissner et al. 2003 and Rueppel et al. 2003: in addition to the modelling of workflow activities with sequential, concurrent, iterative and synchronizing routing blocks, the explicit modelling of states has to be supported by the modelling method. Furthermore, a unique formal semantic is important in order to enable the analysis and control of processes. Finally, the workflow management system has to support the modelling of logical expressions based on engineering knowledge at process decision nodes and the flow of information or materials through the system.

In this contribution the management of engineering processes in heterogeneous computer networks is realized with a network enabled software tool called ProMiSE. ProMiSE was developed at the Institute for Numerical Methods and Informatics in Civil Engineering in close co-operation with the Institute of Geotechnics at the Darmstadt University of Technology. ProMiSE is based on Petri Nets with individual tokens to represent and evaluate process relevant data, introduced in sections 2 and 3, in order to support process navigation decisions and thus enable the management and control of engineering processes.

4.2 Petri Nets with Individual Tokens for Modelling Process Relevant Data

The network enbaled workflow control software ProMiSE and its appropriate client applications for run time interaction introduced in this contribution implement the requirements of the WfMC as follows:

- The workflow control software provides Petri Nets as a formal modelling method with various analysis possibilities (e.g. [Aalst 1998], [Baumgarten 1990]).
- The workflow control software provides Petri Nets (with individual tokens) to enable the definition of rules governing the progression of the workflow (e.g. [Jensen, 1996]).
- The workflow control software provides network interaction mechanisms based on WebServices, the HTTP-, SMTP- and SOAP-protokol, which are all standard protocols

[Chappell 2002][Englander 2002][Harold 2000]. A web application based on the Java-Servlet-API and a SOAP client based on the Apache Axis implementation serve as a consistent interaction interface for the human workflow participants. Thus, everyone with a simple (standard) web-browser on his computer can interact with the workflow control software.

- The workflow control software can process "process relevant data" (section 3). The meta-information is generated by client applications or humans, is submitted to the workflow control software via the web interface and is represented as coloured tokens in the underlying Petri Net. Combined with firing rules of the Petri Net's transitions the meta-information is used for process navigation decisions and process control.

ProMiSE provides means for modelling processes based on Petri Nets with individual tokens, i.e. the process modelling engineer can specify states and transitions representing planning states and planning activities. Furthermore, the engineer can model process navigation nodes, often referred to as OR-split, with a place and subsequent transition where each transition is associated with a specific firing condition. Based on the Petri Net's individual token value, only one of these transition can fire and thus can initiate subsequent planning processes.

Figure 3 shows a typical process navigation node, by example of the "geotechnical category" (GC) defined in DIN 4020 [DIN4020]: during the preceeding planning processes the geotechnical engineer evaluates various information, designs the foundation, and determines the process relevant information. At the process navigation node this information is evaluated and based on the geotechnical cateogry value 1, 2 or 3, subsequent planning processes will be initiated.

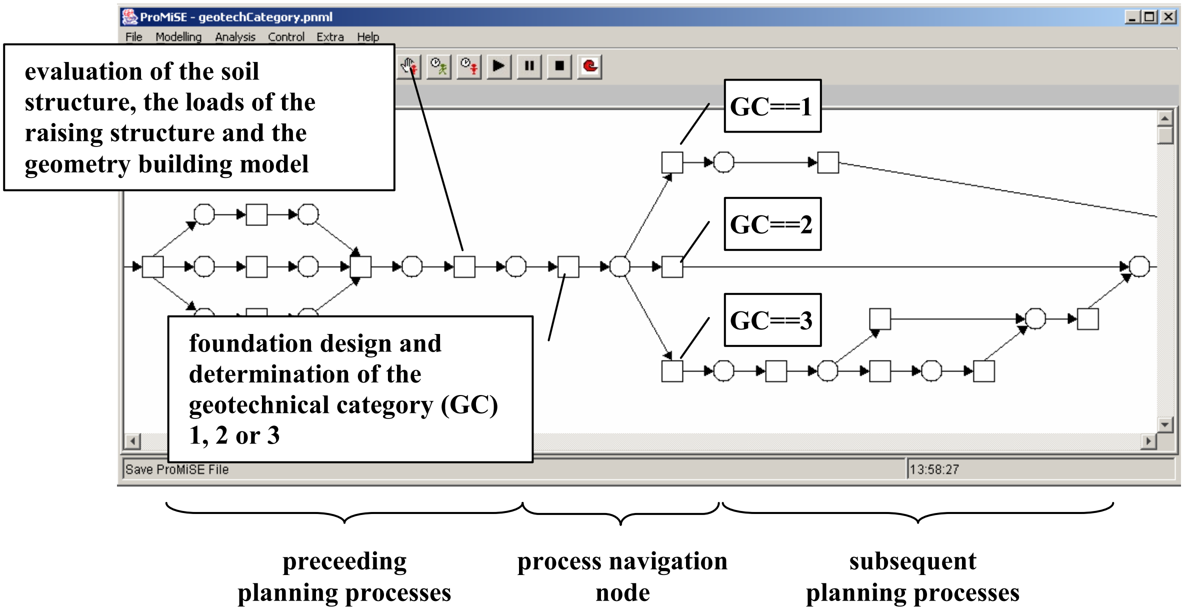

Figure 3:

Process Navigation Node (XOR-Split) Base on the "Geotechnical Category" (GC)

In the ProMiSE environment the geotechnical engineer can use GAPP, the "Geotechnical Application for Product- and Processmodelling", in order to generate a 3D geometry model for a foundation and a retaining wall. Additionally, he can specify process relevant information as a list of 3-tuples [Katzenbach and Giere 2004], where each tuple consists of

- the name for the process relevant information as `String` data type,
- the corresponding value of this information either as `String`, `Integer` or `Double` data type, and
- the index as a history indicator as `Integer` data type.

Figure 4 illustrates the 3D-geometry modelling and the association with process relevant information, in GAPP.

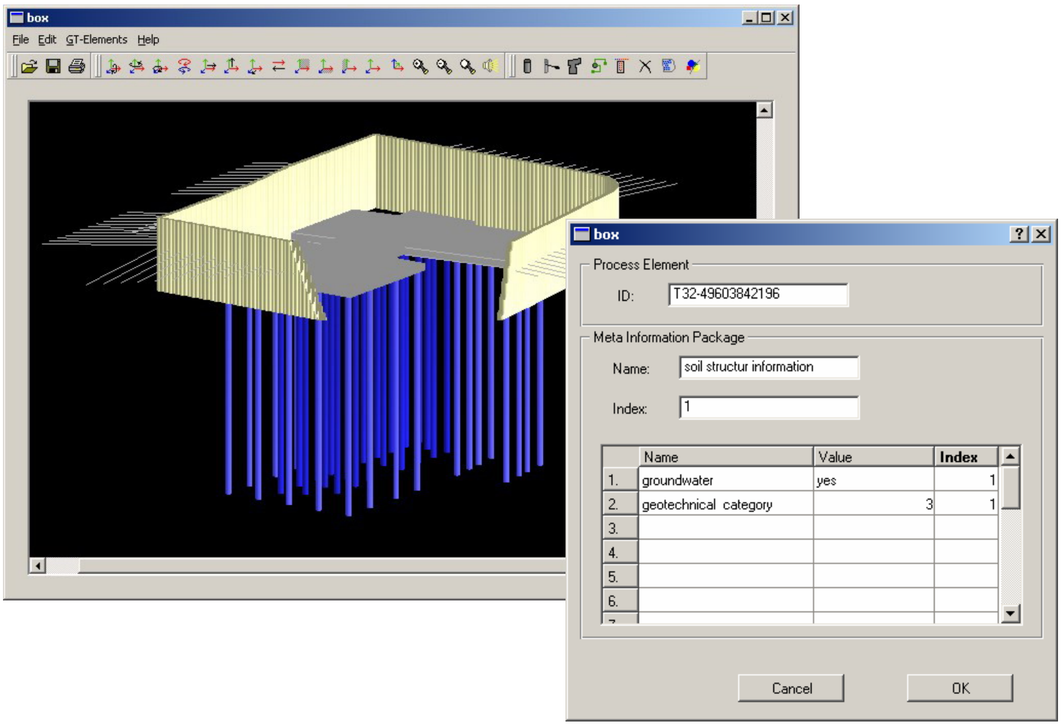

Figure 4:

3D-Geometry Modelling of a Foundation and Association of Process Relevant Information in GAPP

GAPP was developed in C++ at the Institute for Numerical Methods and Informatics in Civil Engineering based on the OpenGL graphics library and the Qt window toolkit.

The network communication between the client application GAPP and the ProMiSE Petri Net server is realised with XML/SOAP messages and WebServices (Figure 5). The XML message comprises geometry model information (GMI) and process relevant information (PRI). A SOAP Client wraps the pure XML information as SOAP package, and sends it to the XML Filter WebServices. This service separates the geometry model information and the process relevant information. The former is stored to the local file system and a corresponding reference is inserted in the RDBMS. The process relevant information is being sent to ProMiSE, there it is represented as an individual token (IT) in the Petri Net based process model, and evaluated on a appropriate process navigation node like, e.g., the one illustrated in Figure 3. Depending on the token's value, different process paths will be executed and thus different planning participants will be involved in the planning process specifically. For invocation purpose different approaches are possible. One common approach implemented in ProMiSE is to send an e-mail to the concerned planning participant in order to provide instructs for a specific planning task.

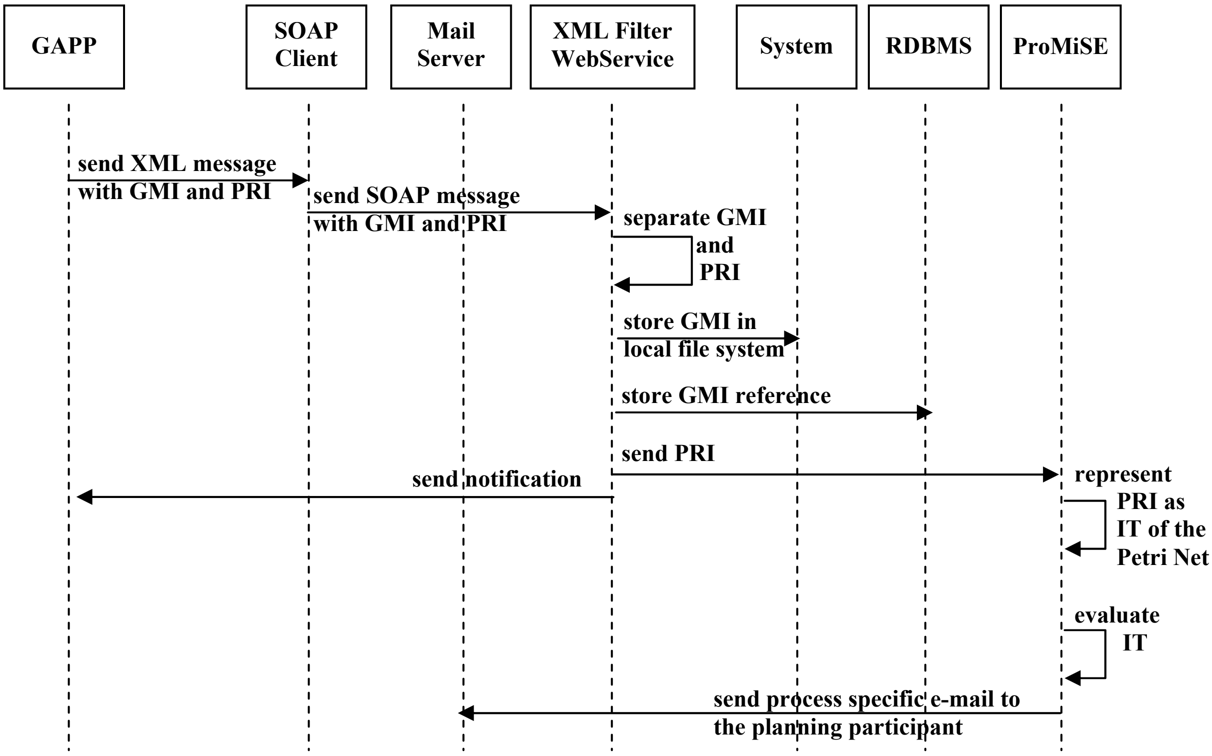

Figure 5:

Network Communication Between the Client Application GAPP and the ProMiSE Petri Net Server Realised with XML/SOAP Messages and WebServices

5 Conclusions

The enormous complexity of co-operation and co-ordination processes is characterised by the huge amount of produced and exchanged information along with the large number of planning participants within big projects. The presented approach to facilitate the coordination uses process relevant information, which is abstracted from the underlying exchanged data. It is shown, how in three typical phases, in which geotechnical engineers participate in the planning and construction progress, process relevant information can be derived from national standards as an approach to the problem.

With regard to the requirements of workflow modelling and control software, defined by the WfMC, the design of ProMiSE was illustrated. ProMiSE is a network enabled Petri Net-based software for the modelling and the control of planning processes in Structural Engineering. The use of process relevant information, abstracted from geotechnical standards, for process control was explained. By example of the ProMiSE server, the GAPP client application and appropriate communiaction software the specification, the network based exchange and the evaluation of process relevant data was explained.

6 References

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