TECHNISCHE UNIVERSITÄT DRESDEN
INSTITUT FÜR BAUINFORMATIK
PROF. RAIMAR J. SCHERER
JAHRESAUSBLICK

RESEARCH AND LECTURE ACTIVITIES IN 2017

December 2016

Research at the "Institute of Construction Informatics – Bauinformatik" (CiB) is in two directions:

Applied Informatics and ***Applied Uncertainty Methods***

The view of the brochure is directed to the future – to the new ideas and plans for 2017. Research topics are: building information modelling, multimodels, interoperability, generic model filters, intelligent construction management, virtual organizations, project risk management, dynamic process modelling, simulation, ICT-supported energy efficient buildings and system identification. Most of the topics have been accumulating in our ongoing common development the intelligent Virtual Engineering Lab (iVEL), which bridges the BIM world with the computational engineering world, smartly providing simulation power to planners, designers and operators. Underlying basic methods and technologies are: object-oriented modelling, process modelling, ontologies, description logic, service-oriented architectures, grid and cloud computing, stochastics and vulnerability.

2016 was a year of acquiring new projects in civil engineering, namely iSiGG on fire and toxic gases in buildings and persons' behaviour and wiSIB on system identification of monitored bridges, and of successfully exploiting the results of our currently three main research projects on energy efficiency, the EU IP projects eeEmbedded, Design4Energy and HOLISTEEC. The intelligent Virtual Energy Lab yielding from these projects is a great success and has been made available as freeware for non-commercial purposes at https://openeebim.org. Other multimodel BIM tools are already online and can be reached at *http://mefisto-bau.de/resources/resources_software.html*, namely the filter toolbox BIMfit, now also with a mvdXML interface, the multimodel container viewer and manager M2A2, the construction simulation toolkit CST, the multimedia visualizer Billie, and the information access tool BIMcraft. The multimodel container method and the lean IDM interoperability method have been adapted by buildingSMART for recommendation and standardization and the first MMC group of buildingSMART has finalized the first recommendation document on the multimodel container MMC v2.0. Together with COINS and LinkData a common ISO standardization group for multi and distributed data is envisaged.

The institute strongly promotes ICT in research and industry. Prof. Scherer is chairman of the European Association of Product and Process Modelling, which held its 11th ECPPM conference with over 120 participants and over 80 papers in Limassol, Cyprus, on 9th-11th September 2016 (*http://www.ecppm.org*). The ECPPM started in 1994 and is the oldest BIM conference. The 12th ECPPM will be held in Copenhagen in September 2018.

Know how transfer to the industry has a high priority for the institute to facilitate practical exploitation of the innovative ICT solutions developed. For the industry CiB is a contact point in BIM and construction ICT. It is active in international and national standardization bodies. In October 2014, the VDI work group for BIM guidelines was founded and meanwhile has 8 working groups (*http://www.vdi.de/technik/fachthemen/bauen-und-gebaeudetechnik/querschnittsthemen-der-vdi-gbg/koordinierungskreis-bim/*). One of them, Qualification is headed by Prof. Scherer. Also FIEC, the European association of the construction industry has inaugurated a BIM working group last summer, in which Prof. Scherer is member.

E-learning results of the project eWorkBau with focus on the interfaces for BIM access and a domain BIM query language are both available on the openeeBIM website and offered as BIM courses by ZWH Düsseldorf. The European online Master course "IT in Construction", coordinated by the University of Maribor, Slovenia, is now in its 13th academic year and offered at 7 European universities.

Since January and February, Al-Hakam Hamdan and Ngoc Trung Luu, resp. have been researchers at the institute and in September Fangzheng Lin joined the team. In July Alexander Benevolenskiy left the institute after finishing his PhD to take on a position in industry. In February Frank Hilbert successfully defended his PhD, and Helga Tauscher in October as well. Both left the institute in the preceding year to go ahead with their academic carrier at other places.

All in all, the employees at the institute cover a broad range of expert domains as well as languages with researchers from Bulgaria, France, Iran, Syria, Turkey and China.

Collaborative research has successfully been continued in 2016. Prof. Scherer spent a 1-week stay at the University of Cyprus.

Some further information can be found at our web pages *http://tu-dresden.de/biw/cib*

Dresden, in December 2016 Raimar J. Scherer

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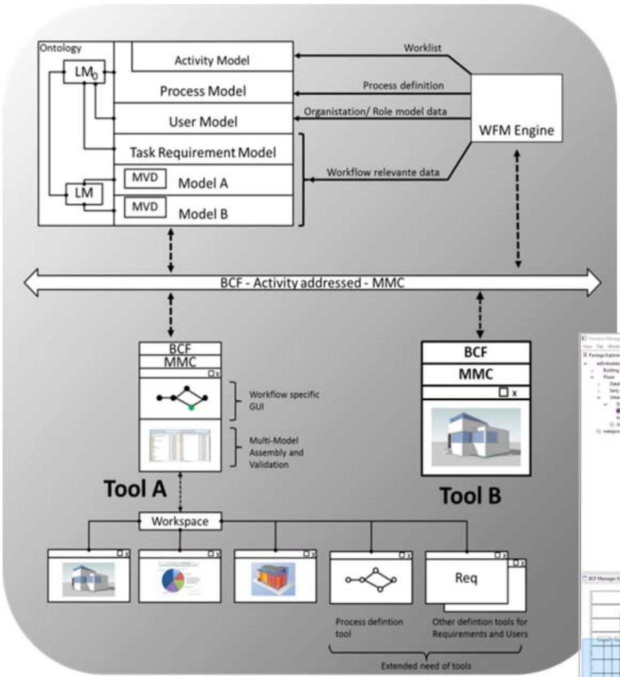
Overall the employees at the institute cover a broad range of expert domains as well as languages with researchers from Bulgaria, France, Iran, Russia, Syria, and Turkey.

Managing Building Design Processes using BIM- and BPMN-based Collaboration

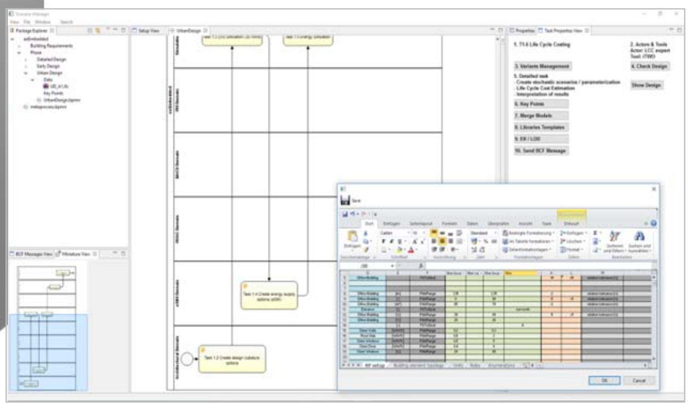
Ken Baumgärtel

Objectives

The Building Information Modeling (BIM) stages consist of many different domains. Each domain has its own users, data models and software applications. The aim is to simplify and to improve collaboration between all users. This includes software interoperability and data exchange. The Information Delivery Manual (IDM) method guarantees a structured way to let users specify data and requirements and to find a way that software can help them to optimize processes. Therefore, process maps are created to specify process participants, dates, content and exchange formats in BPMN diagrams. However, until now BPMN diagrams are only used to document processes in the construction domain. The research work focusses on the usage of such process models to automatically control and validate BIM data of all participating users in design processes.



High-level view of the workflow-driven multi-model BIM collaboration platform (left) and example screen-shot of the implementation (right)



Approach

The improvement of process collaboration is reached by the implementation of a BIM collaboration platform that includes a tool called Scenario Manager (ScM) that is used by each design team member. It provides functionality of project and process management and covers the whole IDM aspects. Its core consists of a workflow management (WFM) engine and a workspace for storing all relevant BIM information. The ScM (left figure, Tool A & Tool B) interact with each other to send data between users and synchronize their workspaces. At the beginning, a BIM manager specifies project requirements and project workflows with a BPMN editor (right figure). The manager then assigns actual team members and requirements to tasks. After starting the process, the WFM engine controls the project collaboration by evaluating the defined BPMN diagram.

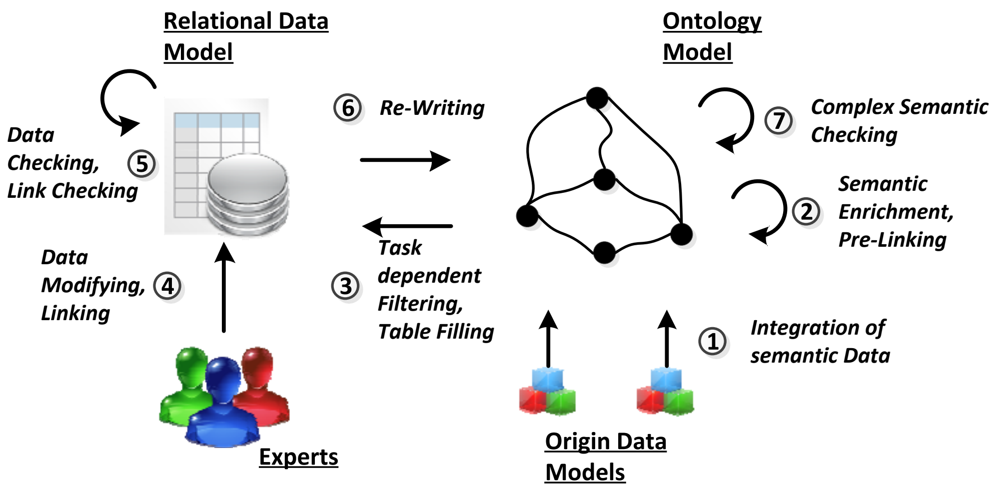
Data sharing is done using Multimodels encapsulated in BIM Collaboration Format (BCF) messages. Multimodels can be used to inter-link many different domain models and to provide them in a Multimodel container (MMC). BCF, developed in a working group by buildingSMART, supports the communication through multiple BIM software applications. Each MMC includes a process model (the BPMN diagram) and the current state with the data shared by the user task. The WFM engine automatically checks provided task data with an ontology system by validating assigned task requirements. If the check succeeds, ScM informs the next team member and all needed data is provided in the target workspace. If the check fails, the users have to rework the data until all exchange requirements are fulfilled. This research is part of the EU project eeEmbedded.

Combining Relational Data Models with Ontology Models for Improving Design Interoperability

Mathias Kadolsky

Objectives

The complexity of engineering design issues leads to the necessity of integrating different domain models and data sources. For example, for analyzing the energy efficiency of building designs the BIM model has to be linked with non-BIM models for creating an overall information basis and providing the input information for simulation tasks. Thereby, two kinds of integration methods can be distinguished, (1) tool-to-tool integration, and (2) meta-model integration. Tool-to-tool integration is aimed to put together all data for a certain tool application. Here, all data including all geometric data will be integrated into one application model. However, for creating an information basis not all this information is necessary. Only the semantically rich data are important to identify gaps and errors and allow predictions and semi-automatic corrections. This requires a semantically enriched data model but has the disadvantage that such models are not efficient for practical use. Hence, the goal of this research is to develop a better understandable and easy to use approach, at the same time avoiding the drawbacks of the tool-to-tool approach.



Combined information model approach

Approach

Linking of data is a procedure of generating relations. Thus, linking can be also realized using relational databases. The concept of relational databases is easy to understand and its use is in line with actual practice. From this point of view, it makes sense to combine the relational data model with the semantically rich, integrating ontology model. Consequently, the relational data model and its tables will form the practical part and the application layer and the ontology will form the strongly networked complex part and the information layer. This includes the following steps:

1 Integration of Semantic Data: Only the data, which are relevant for linking are integrated in the ontology. These data are semantic data, which means that geometry data will be largely excluded.
2 Semantic Enrichment and Pre-Linking: The data coming from the original models are first harmonized; in a second step, enrichment rules are applied to derive additional information.
3 Task dependent Filtering and Table Filling: Regarding the planned task, the data within the ontology model are filtered and mapped into the relational data models.
4 Data Modifying and Data Linking: The mapped data are modified regarding the upcoming task; so, data values could be adapted.
5 Data Checking and Link Checking: The entered data are checked against ranges defined in type tables.
6 Re-Writing Data and Links: The adapted data and defined links are mapped back into the ontology.
7 Complex Semantic Checking: Complex checks, which are not based on a simple comparison of values, are realized within the ontology like transitivity checks.

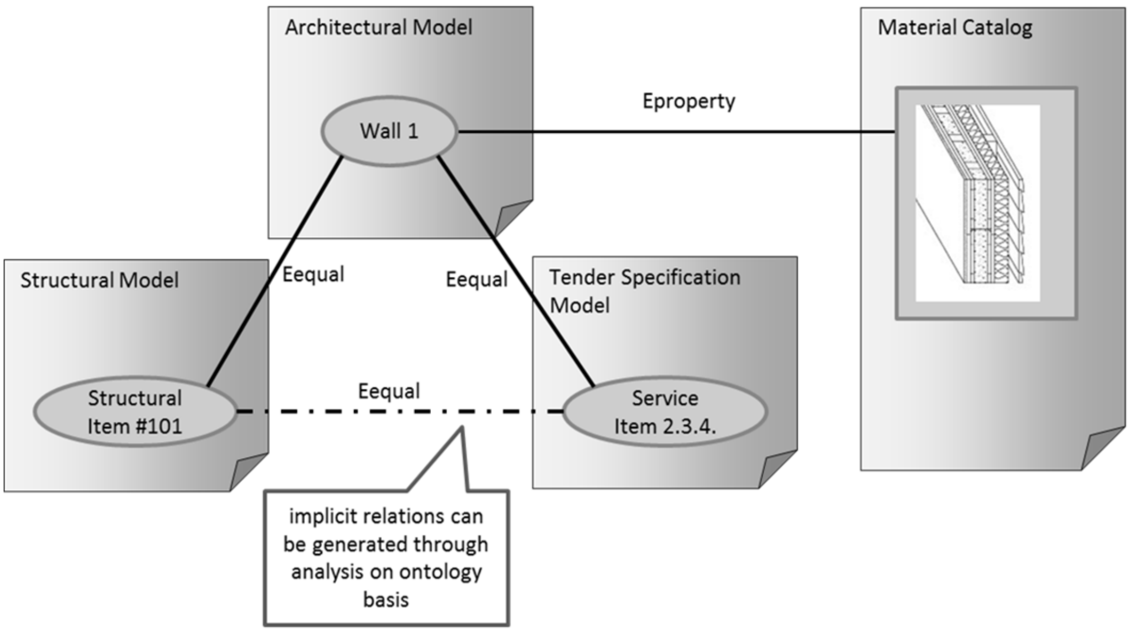
This research is part of the EU project eeEmbedded.

Semantically Enhanced Links for Multimodels

Ngoc Trung Luu

Objectives

The Multimodel approach provides new opportunities for the interoperability between the models used in the building process. This interoperability is achieved due to links, which connect objects or entities of different models by referencing them via ID´s, creating a cross-domain information space.
Links represent relations between the linked objects, though the specific form of the relation is not represented. Therefore, links are grouped in Link Models, giving them a context through the meta information of their Link Model. This allows the Multimodel approach to be on a high abstraction level and thus generic in its application. However, the meta information describing the meaning of the links is only interpretable by the user. Multimodel software cannot exploit this information, giving up on a high information potential. By implying additional semantic into the Multimodel on a still generic base, this potential can be accessed. Therefore, the goal of this research is to investigate the implementation of semantically enhanced links into the Multimodel approach.



Example for semantically enhanced links
(using links of the "Eequal" type to connect 3 elements from different models, as well as attaching information from an external supplier catalog via the "Eproperty" link)

Approach

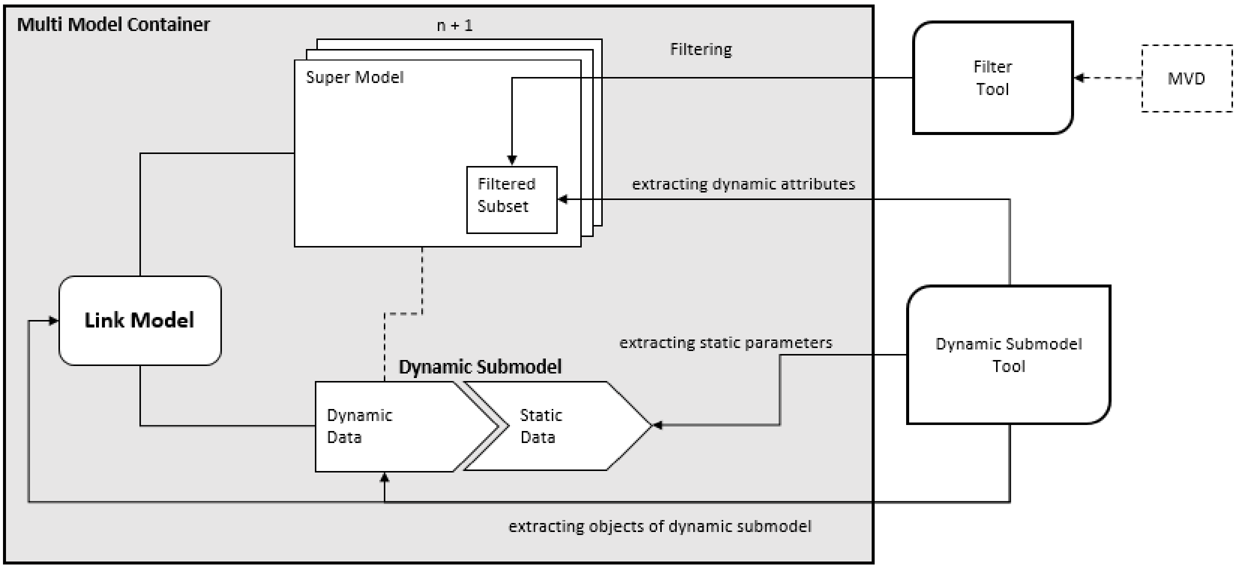
Links are bidirectional relations between two or more elements with little semantic. By introducing link types instead of the existing generic link concept, the Link Model can be enriched with deeper semantic, creating a low-level ontology. The link types can specify the kind of relation between the linked elements. For example elements, which represent the same objects in different models can be connected by the link type 'Eequal', whereas additional properties can be added to other elements or the whole model as global properties with the types 'Eproperty' and 'Mproperty'. Another link type is 'Einteract', which is used to connect models by their elements as interface. This approach allows new methods of link evaluation and link creation on logical basis, as well as new filter opportunities. It shall expand the current Multimodel implementation but still maintain the previous functionality. For that purpose, the new link types are developed as specialisation of the generic link concept, and can also be transformed back into it. This research is conducted as part of the German iSiGG project.

Dynamic Submodels – A Concept for Enhanced Filtering in BIM

Al-Hakam Hamdan

Objectives

In the common building design process several collaborators of different fields work together to develop an executable model of the relevant building. By using Building Information Modelling (BIM), the actors aim to cooperate mainly on one central BIM model. Nevertheless, only a subset of information from the BIM model is needed for those, who work on specific fields. Therefore, filters are applied, so that efficient submodels can be generated. However, these sub-models are static and they are detached from the original supermodel. Hence, future interaction between them is difficult. Currently it is impossible to update changes in the submodel that were made in the supermodel without generating the whole submodel repeatedly through filters. Consequently, data that were created in the submodel are lost. To overcome the problems of deleting data through working with filtered models, this research aims at developing an approach for dynamic submodels that refer through links to the original supermodel. By using such submodels, the user can declare static values that will not be overwritten, while the dynamic values change constantly without using a filter method.



Structure of the dynamic submodel and usage of the dynamic submodel tool

Approach

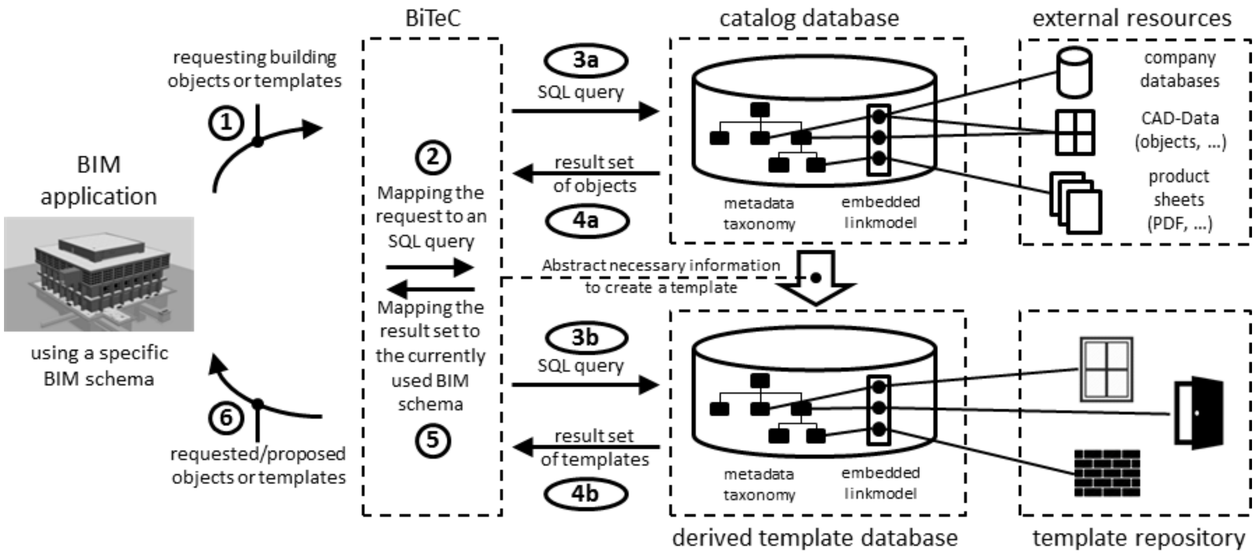
To connect the supermodel with a generated submodel, the Multimodel Method developed in previous research work is used. According to that, the models are linked through Link Models and are saved in Multi Model Containers (MMC) for data exchanges. A dynamic submodel will thereby consist of dynamic values, which refer to the filtered objects of its supermodel. Similar to IFC, the dynamic submodel uses STEP for the declaration of implemented objects, with the difference that *placeholder objects* will represent the objects in their original state. Consequently, the data values will be only in the supermodel to which the submodel is linked. In this way, the values in the supermodel can be modified and will also be changed analogically in the dynamic submodel. Thus, the dynamic submodels are always subordinated to the supermodel, which means that editing the submodels will have no influence on the supermodel. Additionally, the placeholders can be transformed into static values, which do not apply the changes from the supermodel. In this process, it is possible to update the model consequently with new data from the supermodel without losing user defined information from the submodel. Thus, although submodels do not influence their linked supermodels, it is possible to overwrite the supermodel data with data from the submodel. Here it has to be taken into account that the supermodel data are lost in this process. Therefore, such data exchanges must be organised and controlled in appropriate way. To make use of the dynamic submodel format, a dedicated software tool will be developed, which can read the references from the submodel and extract the relevant data from the supermodels through the Link Model. The research started in earlier projects of the institute will continue in the frames of the German BMBF project wiSIB.

Template-based Repository for Catalog Objects Integrated in an Intelligent BIM Element Management System

Frank Opitz

Objectives

Due to the move of the construction industry to the new BIM paradigm modeling activities have become more than ever important in all stages of a construction project. Specifically, in the early design phase the main task of the architect is to create the virtual building. However, in that phase he has to rely on minimal and constantly changing information. Therefore, one major goal is to provide for pre-parameterized building objects that can strongly reduce modelling time and cut the total project costs. Here it must also be considered that especially in the early stage of a project, the information for objects from manufacturer catalogs can be of advantage for the use of generic building objects, which can be updated later in the process, with their correct fixtures and fittings. Nowadays different catalogs by different manufacturers are available. Moreover, all major companies offer multiple catalogs for different building trades. This again increases complexity and asks for an intelligent information management system. Therefore, a second goal is to make use of automatically generated building elements based on stored templates in order to circumvent disturbing details in the specifications of the manufacturers.



Concept of the intelligent BIM element management system with suggested workflow

Approach

The suggested approach aims to combine the above two objectives. To reduce the modeling effort, an intelligent interface, called BiTeC (BIM template and catalog element API), is provided to the modeler. BiTeC is an interface between a BIM application (typically a CAD system) and one or more databases with information about catalog objects and building element templates. A product catalog is thereby defined as a systematically ordered collection of information on products or services. The catalog database references existing catalogs with the support of different data formats (CAD data, PDF documents etc.). During admission of a product in the catalog database metadata is automatically generated. In contrast, a template is a pattern to create user-selected or context-sensitive building objects. Alternatively, the metadata taxonomy of both element types can be stored in an ontology where additional relationships between the elements can be defined creating a generalized knowledge-based information space. Starting with a user request the aim is to retrieve a building element or a variation of elements and to integrate these elements in an existing building model with a given data schema. In steps three and four, a distinction is made between catalog elements and object templates, depending on the user request.

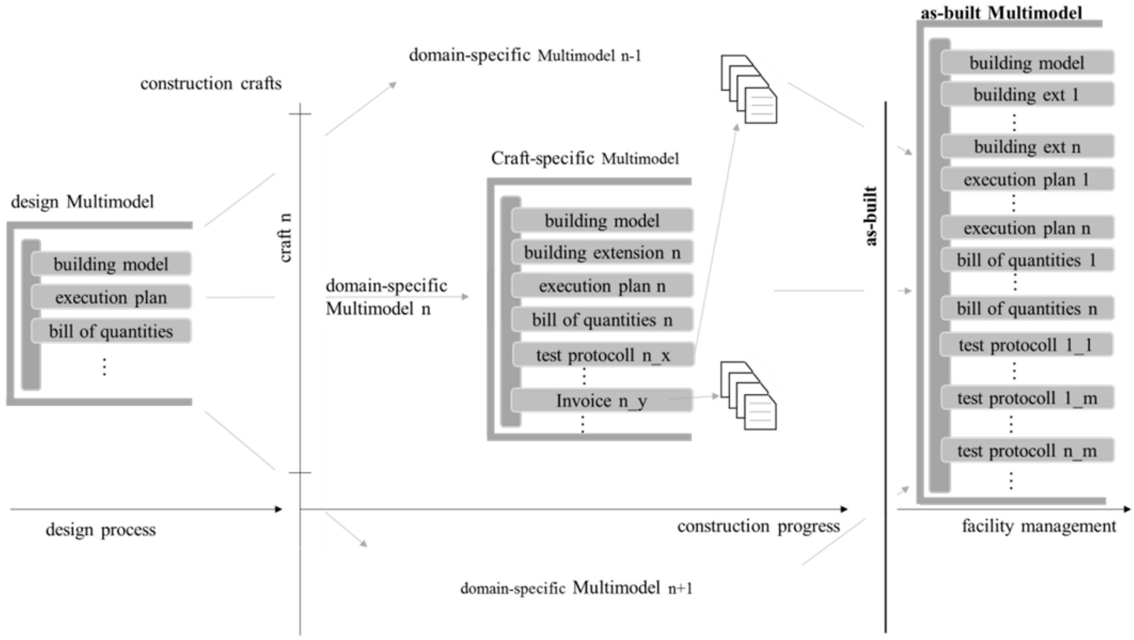
The fundamental idea of BiTeC is the (semi) automatic generation of templates by using the catalog database as a blueprint stack. This means templates are construed from catalog elements and stored as derived elements. To generate a template element, the necessary information is abstracted from the catalog taxonomy. Consequently, the main focus is to develop a coherent taxonomy schema to ensure that the catalog objects are derivation-processable by the API.

Multimodel for As Built Documentation

Robert Kreil

Objectives

Since up to ninety percent of the life cycle costs of a building arise after the construction has been finished the as built documentation of a construction deserves utmost attention. However, today as built documentation is still in paper form and fills a huge amount of file folders for every single construction craft. Hence, several problems arise: The huge amount of paper is hard to access and maintain and nearly impossible to overlook by people who were not involved in the construction process, like for example the building's facility managers. The documentation of extension or reconstruction processes further increases the extent and complexity of the documentation. In addition, the German VOB/C determines that for public buildings a complete documentation is obligatory. In contrast to the enormous paper-based documentation with a huge amount of duplicated cross-referenced data sheets, a digital documentation would save a lot of time and effort. The aim of this research is to develop an approach for BIM-based as built building documentation, which could be of great benefit for the facility management.



Schematic description of timeline of the generation of the as-built Multimodel

Approach

The suggested approach is based on the generation of Multimodels, which takes place in parallel to the construction process. Each construction trade has its own Multimodel containing a common 3D building model, the execution plan, the bill of quantities, etc. During the construction progress, these domain-specific Multimodels are enriched with additional information, like material documentations, test protocols, invoices and other trade-dependent data. By this procedure, the Multimodel gathers all information needed for the later documentation for each single craft. To increase the practicability of the method and to enhance the data exchange the approach will be implemented in a cloud-based environment. In that cloud environment, each construction participant is assigned a distinct role to be able to control the access of the single domain-specific multi-models and their information. In this way, it will be guaranteed that confidential information (like invoicing documents) is kept secret. To gather the final overall Multimodel of all domains, all single domain-specific Multimodels have to be merged. During this process all redundant information has to be identified and removed. This is considerably easier and unambiguous than in the design phases where numerous changes done in parallel have to be considered.

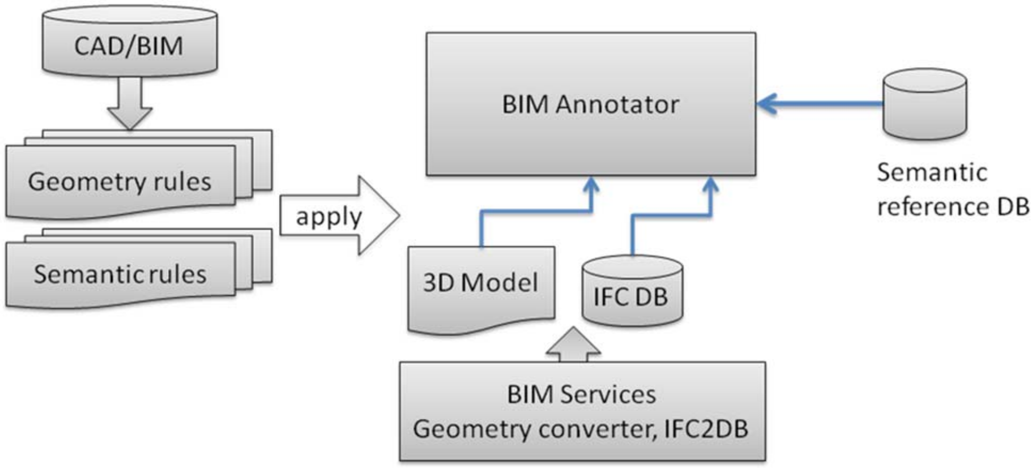
Providing a methodology for BIM-based as built documentation using the multi-model approach will not only give a better way to create that documentation, it also offers better usability and accessibility. Moreover, it can be used as basis for further extensions or reconstructions of the building.

Smart Annotation and Classification of 3D and BIM Models Using a Rule System and Semantic Reference Database

Ali Ismail

Objectives

One of the major promises of the BIM method is improving the collaboration and efficient information exchange between different stockholders through the construction project life cycle. However, the support of semantic information enrichment in most BIM authoring tools is limited to the design phase. For real collaboration before or beyond the design phase (e.g. laser scan of existing building, construction and operation phases) there is a need to adopt a smart and collaborative solution, which allows stakeholders to update and exchange domain specific information based on BIM models. Our ongoing research aims to develop an online BIM annotation tool in order to support post classification and information enrichment of 3D and BIM models based on the IFC standard and a sematic reference database. The implementation for manual semantic enrichment is already finished; the planed work aims to adopt a smart geometry and semantic rule system for semi-automatic identification, classification and annotation workflow.



Rule based annotation and classification system for BIM models

Approach

BIM Annotator is implemented as a web-based online viewer to visualize 3D and BIM models. The approach of semi-automatic annotation and classification of BIM models thereby helps to reduce the annotation time dramatically and improve the quality of BIM models. The suggested rule system comprises rules that can be classified into two kinds: (1) geometry-based rules, (2) semantic-based rules. For the geometry-based rules, a set of geometry recognition algorithms will be developed in order to classify the objects based on their 3D shape, for example recognizing columns and slabs based on their dimension ratios. The sematic-based rules analyze the available information of model elements in order to exclude non-related attributes or to generate new properties automatically, e.g. by filtering property sets templates based on the material type (concrete, steel, precast) of the element, or the mass assignment of names based on a specific property value.

The system architecture diagram shown above illustrates the components and data flow. The BIM-Annotator will be also extended to allow the user to filter and extract sub-models easily. The current work focuses on using the BIM annotator to improve the semantic quality of bridge models. The IFC-Bridge extension will be analyzed and a special data based for classes, properties and enumerations will be included in the semantic reference database. The extended semantic data model will be saved externally and linked with the BIM model through special link models, following the multi-model data exchange approach.

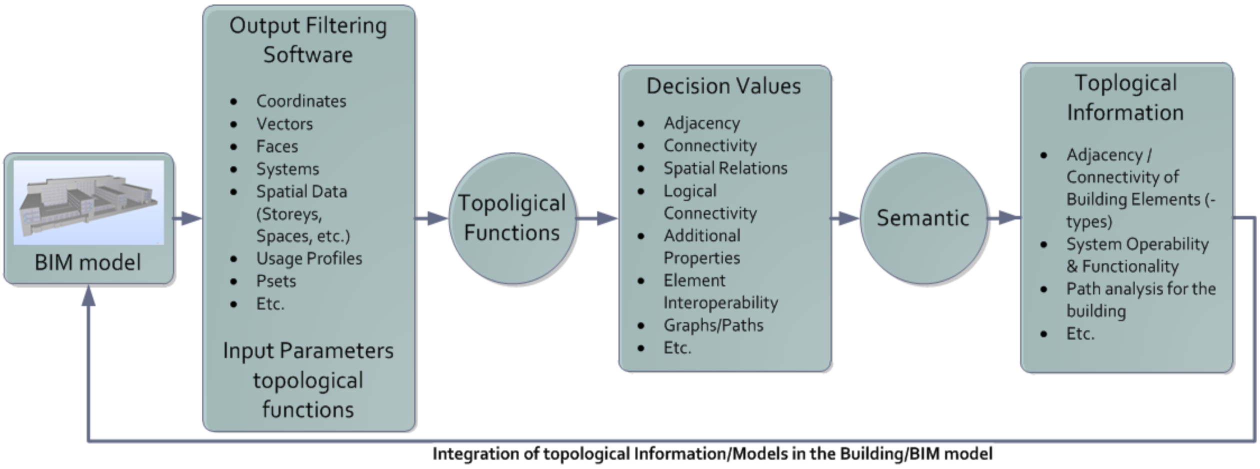
The research work was started as part of the recently finished EU project BridgeCloud and is currently continued in the frames of the German BMBF project wiSIB.

A Framework for Generating and Extracting Meta-Information from Building Models

Robert Schülbe

Objectives

Within a building model, there are various data originating from relationships and dependencies between the building elements. Typical examples for such meta-information include adjacency and connectivity information, spatial information, but also logical information, e.g. logical system connectivity and operability. Most often, this information is not expressed explicitly and may vary depending on the user and his employed reasoning logic. However, the meta-information can be of great value for a wide variety of applications, e.g. for planning or for simulations, or simply to highlight dependencies. Plenty of algorithms exist to extract such information, but they are tailored to calculate the information in a specific, rigid way and are mostly part of larger proprietary CAD software in which case they function as a black box. This leads to the problem that the user often has only limited knowledge on the process of obtaining the meta-information (e.g. used input variables, algorithms and logic) and even if he has access to said knowledge he has no way of altering any of it. For example, depending on the actual system or domain the user may want to employ different metrics or regulations to calculate distances. On the other hand, it is difficult for non-experts to understand or even to conceptualize how to extract and reason for that meta-information. To address these issues we will develop a modular meta-information framework, which aims to provide an environment for the generation of any desired meta-information of a building model, while maintaining high user adaptability, accessibility and flexibility. The proposed concept will enable users to extract meta-information that suits their specific needs without the demand to employ any specific filtering and calculation software.



Simplified Workflow for generating topological Information

Approach

The core of the framework will consist of a library of topological functions, which derive Decision Values out of given models (e.g. distance between walls), and a semantic, which will check and process the Decision Values to create the meta-information (e.g. connectivity of walls). The library is envisioned to be accessible to the user for requirement-based fine-tuning of the functions for each task. The semantic is meant to be adjustable with regard to thresholds for Decision Values and reasoning patterns. The topological function will use basic and explicitly input parameters, which can be extracted by any filtering tool and which only requires an appropriate mapping between the output from the filter software and the required input for the topological functions. Through this modular design, the framework can be easily enhanced and/or expanded on demand. The actual implementation work has started by in-depth study and development of categorisation and classification methods for the meta-information as well as the corresponding Decision Values, reasoning and calculation algorithms. The topological functions of the framework will be implemented according to the results from this research.

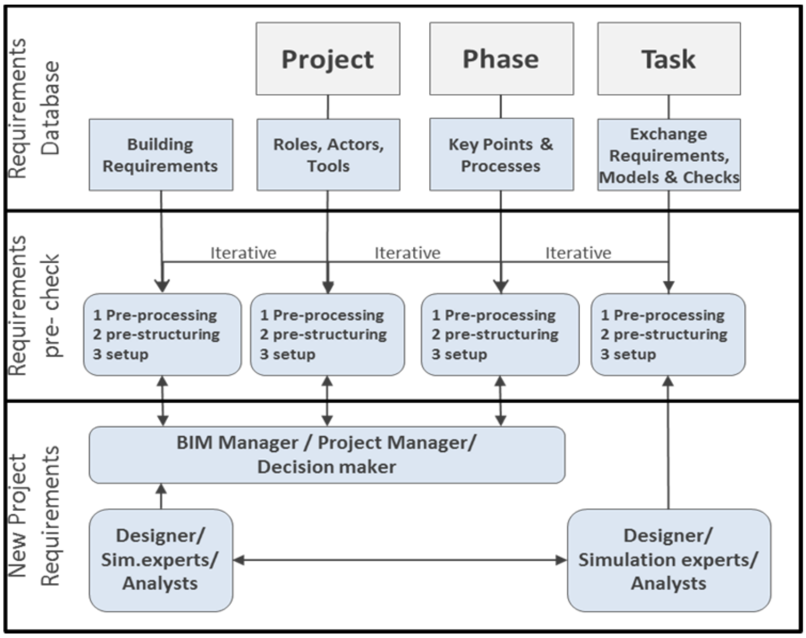
The research work is performed as part of the EU project eeEmbedded and is intended to be continued in the frames of the German iSiGG project.

Parametrical Requirements Management for BIM Collaboration

Romy Guruz

Objectives

The planning and preparation of large BIM projects is very demanding and time-consuming. Major challenges in the BIM planning processes still lie in the setup of efficient planning processes and a frictionless data exchange between the participating partners and tools, as well as in the smart realization of their domain-specific requirements in view of the overall design focus. The methodology of Information Delivery Manual (IDM) was developed to define the "who" and "when" by means of a general process map as well as the "what" in form of required data as exchange requirements listed in tabular form. Based on the IDM steps, a BIM collaboration platform called Scenario Manager (ScM) was conceptualized and is now prototypically implemented. This fully automated setup process includes in addition to the IDM the possibility of building requirements (BR) aggregation into verifiable design check points, so called Key Points (KPs), which are used for the task and process setup, they describe verifiable milestones within the design phases. This research aims to outline a method that enables pre-structuring setups on project, process and task level though parametrical building requirements management. This will result in a faster setup of large BIM projects and will allow also revealing the effects of building requirements on the planning processes.



Process Model: Parametrical Management of Building, Project and Process Requirements

Approach

The BRs provide the framework for the parametrical requirements management. They enable in the very beginning the setting of the major goals and the necessary measures. Based on them, in a first step on project level a structured project setup including roles, software decisions and exchange rules is done. In the second steps, the ScM provides a matrix where the manager can enter verifiable design targets and their upper and lower bound based on the BRs. Using these target values on phase level, the users will build up her/his processes and workflows. This step also includes the setup of task related information. On task level, each user opens their own Scenario Manager and is able to track the progress, to send and receive data and messages with all other participants. To compensate possible changes of the BRs during the processes, the parametric definition of BRs is suggested. A parametrically defined BR consists, for example of a value-range and of a standardized unit, which is summarized an information entity type. Using the information of former successful projects in terms of knowledge templates and the examination of the interdependencies of building requirements on processes and milestones in the way described above, enables a semi-automatic BIM project setup. This research is part of the EU project eeEmbedded.

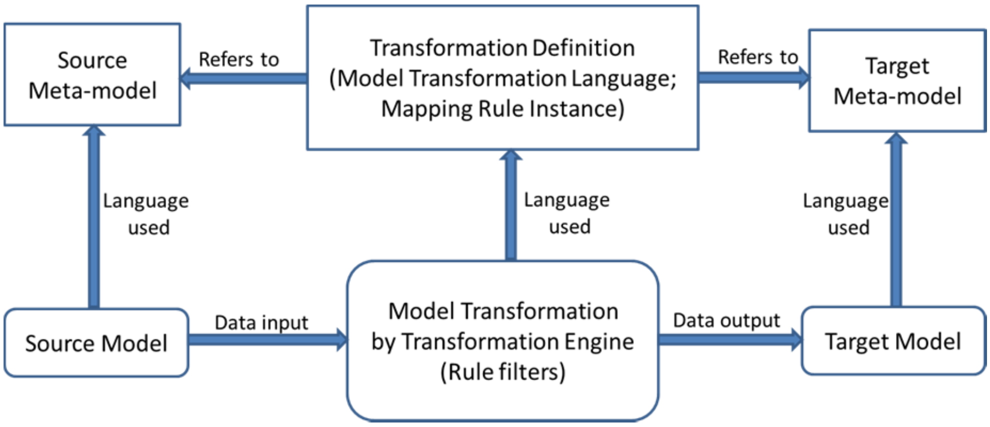
Model Transformations for BIM-based Analyses and Simulations

Frank Noack

Objectives

As more architects and engineering consultants adopt BIM-CAD systems that are based on intelligent objects and are compliant with emerging standards for software interoperability (such as the IFC), the ability to simulate and visualize all aspects of a building's behaviour will become increasingly accessible in everyday practice. That will result in safer, more efficient and more comfortable buildings.

With the current state of the art, various types of simulations and visualizations like energy-efficiency, structural capacity, light, sound, cost factors, spreading of smoke and fire or means of escape etc. must each be run separately by (partially) incompatible software, typically operating on separate instances of the CAD building model. Moreover, data attributes attached to drawing or model features also vary from model to model and from tool to tool. This process imposes a heavy burden of computational overhead on large scale building projects, which can involve a dozen or more separate computer simulation models-all derived from the architect's underlying CAD model, yet each optimized for its own special flavour of energy, CFD, FEA, or other simulation tool. In each case, even though the model represents the same building, it may be altered to suit the input requirements of a specific suite of analytic software. Automated reuse of data from Building Information Models by an adequate model transformation approach is therefore needed to improve the interoperability and avoid manual data input.



Basic concepts of model transformation

Approach

A model is an abstract representation of a system defined in a modelling language. A modelling language consists of the abstract syntax, concrete syntax and semantics. Metamodeling is the process of complete and precise specification of a domain-specific modelling language, which in turn can be used to define models of that domain. A transformation engine transfers the source model data into the target programming language model. Hence, what is needed are (1) the meta-models for the source model, (2) the target programming language, and (3) the transformation defined with respect to the meta-models. A meta-model describes the type of model and typically defines the abstract syntax of a modelling notation (semantics information of the data model). The transformation is an instance of the mapping rule schema used by the transformation engine translating the model data. The transformation engine contains a set of different mapping rule filters that correspond to the different mapping rules developed in the mapping rule schema. The overall filtering process determines the model transformation strategy. Users are only concerned with providing the mapping rules. If the source and target Meta-models are identical, the transformation is endogenous. Otherwise, it is exogenous. If the level of abstraction does not change, the transformation is referred to as horizontal transformation. If the level of abstraction does change, the transformation is referred to as vertical transformation.

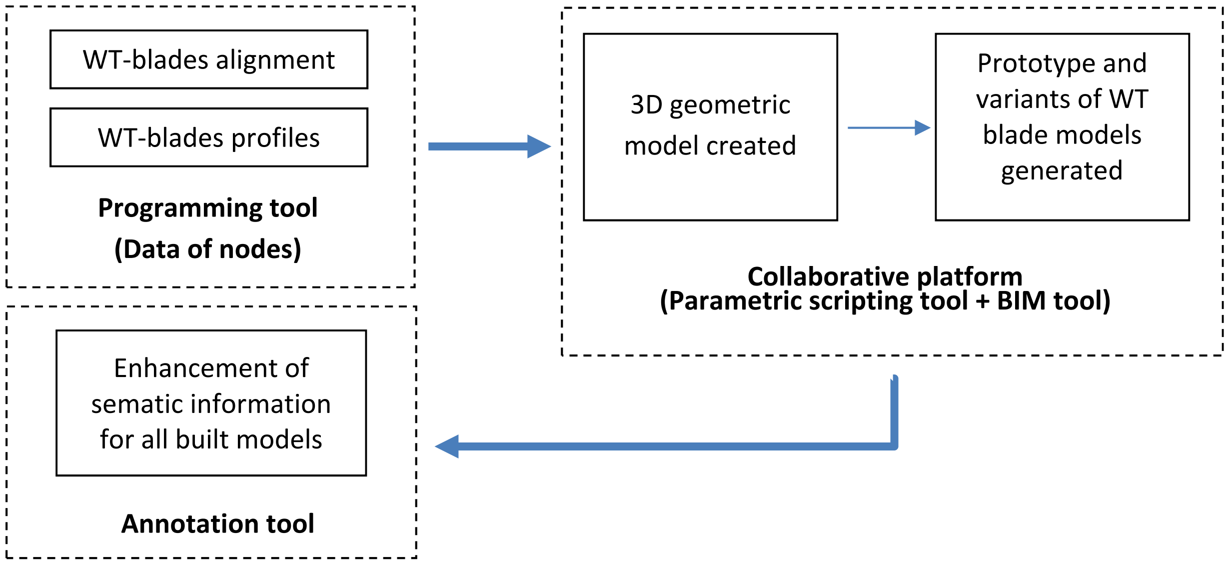
A first implementation of the transformation from an architectural model to an energy specific simulation model representing the described generic approach is developed within the Design4Energy project.

Parametric Modelling of Wind Turbine Blades via Visual Programming Language

Fangzheng Lin

Objectives

Visual Programming Language (VPL) is a tool, with which users are enabled to construct programmatic relationships using a graphical user interfaces. That leads to more efficient geometric design of complex structures. For example, in the development of wind turbines (WTs), researches about computational fluid dynamics (CFD) of WT-blades have become popular. However, it is always a tough step to build a geometric model of the irregular WT-blade shape for the following meshing and computation operations, especially to model a series of WT-blade variants. On the other hand, according to the structural analysis view of the IFC standard, the geometric information is exchangeable from structural design models to structural analysis models. Therefore, the purpose of this research work is to solve the geometric design problem for objects with complex geometry using VPL, so that BIM tools contribute to structural computational analysis at least on the level of geometry. Not limiting the overall conceptual approach, the selected application case will be focused on wind turbine analysis.



Principal design process in the development of wind turbines

Approach

Aiming at structural analysis and obeying the IFC structural extension, the geometric information has the primary interest. Besides, other exchangeable information including material names and structural loads is also worth to be considered. The data files of the WT-blade alignment and various typical WT-blade profiles composed of corresponding node coordinates should be firstly imported into a parametric scripting tool, where 3D-visible geometric models are created by the imported information. Due to VPL this offers designers an approach to assemble custom relationships by connecting pre-packaged nodes together to make a custom geometric WT-blade model without writing code. For that purpose, *Dynamo*, serving as efficient component software for *Autodesk Revit*, can be used. Both software tools collaborate together, hence groups of elements with a common set of parameters, and a related graphical representation in a BIM tool can be applied (such as the *family* concept in *Autodesk Revit*). The built WT geometric models could be one or several series of model variants, whose shapes are controlled by a branch of parameters. Thus, new 3D geometric models of WT-blades can be easily generated. Subsequently, the resulting models with comprehensive geometric representation will be enhanced with semantic information by annotation and can then be used in comprehensive CFD analysis tasks. This research work is inspired by a Master Thesis supervised at the institute and is intended to continue in the frames of the German WiSiB project.

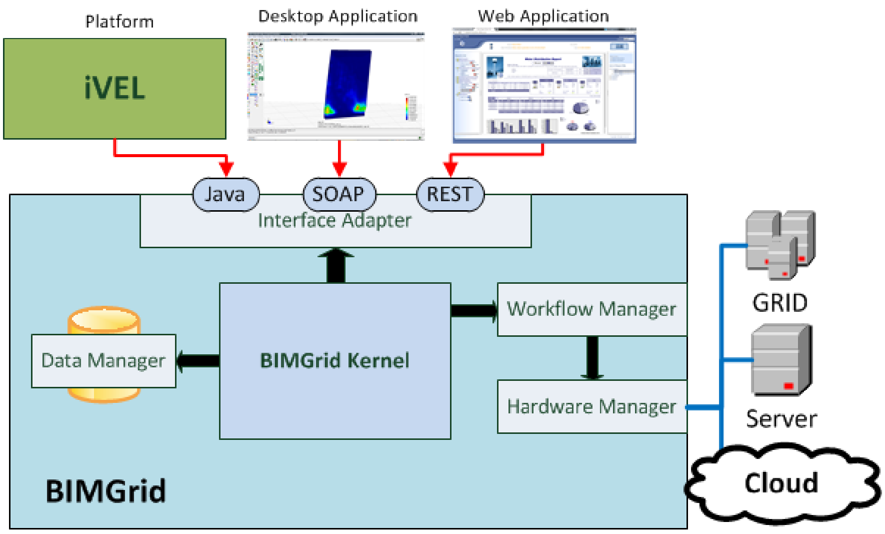
BIMgrid – Intelligent Distributed Computing for Civil Engineering Applications

Michael Polter

Objectives

Today civil engineering SMEs own powerful hardware resources in the form of desktop PCs or even small-scaled servers, which are usually not used to their capacity. Current developments of civil engineering software vendors trend to the outsourcing of the whole engineer's workstation to the cloud. For SMEs this change would mean the dissipation of so far made investments in hard- and software. In addition, various security and confidentiality concerns have also to be resolved. However, although some middleware solutions like UNICORE, Globus or gLite for the efficient combination of hardware already exist, they are mostly based on UNIX operating systems and further demand advanced technological knowledge to implement. There are no solutions to integrate local hard- and software resources with cloud resources efficiently and demand-oriented.

The intended BIMgrid will be a framework, which provides web based platforms as well as desktop applications with combined computing power of distributed resources and efficient data management methods over standardized interfaces.



Schematic illustration of the BIMgrid top level architecture

Approach

With the development of the BIMgrid we pursue several specific goals which will be reflected in the features of the system. An adaptive infrastructure represents one of the biggest benefits by integrating cloud resources automatically on demand and thus in cost-efficient way. For this infrastructure a new scheduling algorithm will be developed to achieve optimal resource utilization at lowest possible cost. Distributed computations result in huge amounts of distributed data which have to be managed and transferred in a smart way. Federated database systems will be investigated and, if needed, extended for this purpose. Another crucial aspect is the development of interfaces based on well-established standards and technologies like SOAP, REST or Java to seamlessly connect the BIMgrid with legacy systems such as existing desktop applications or web-based platforms.

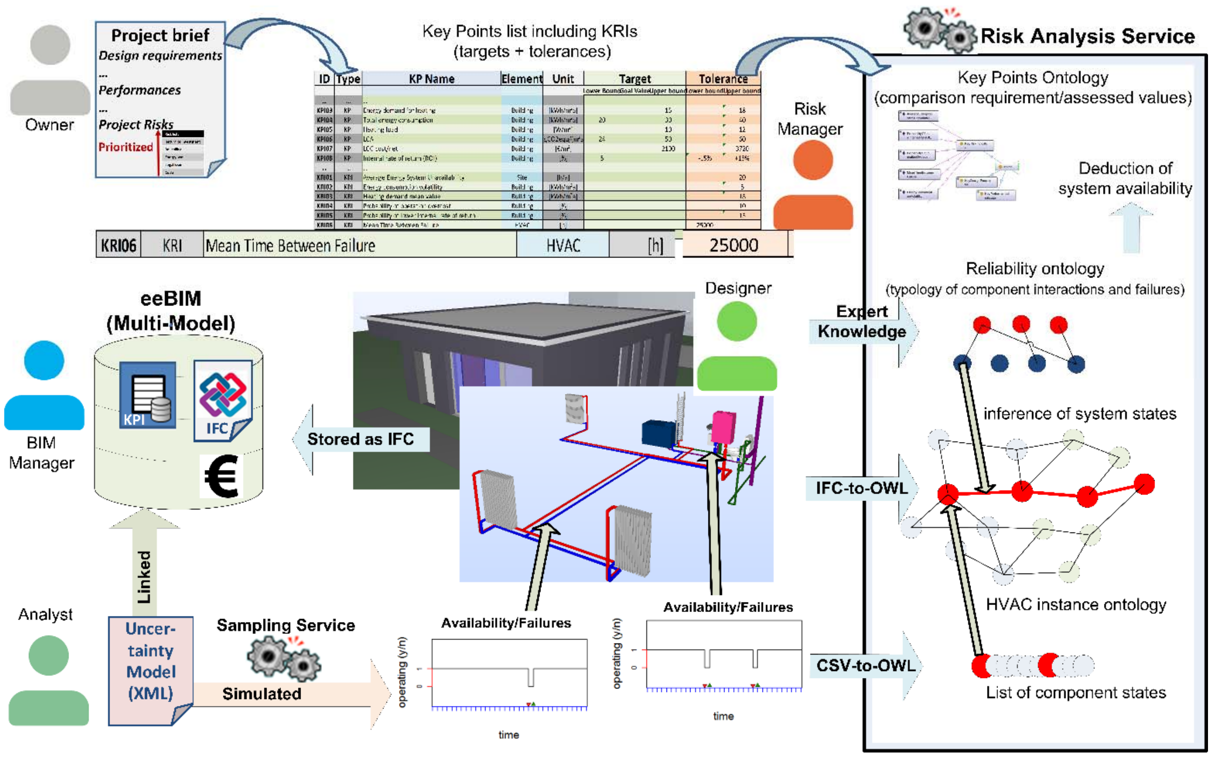
The BIMgrid will not be an end-user tool for engineers and hence it will not provide graphical user interfaces. Instead, it represents a powerful framework for application developers to overcome the resource limitations of single computers. During the conception an increase in efficiency of established workflows as well as high acceptance of potential end users is emphasized. The developments will be tested with the integrated *Virtual Engineering Laboratory* (iVEL), a BIM-based engineering platform developed at our institute. As application domains, the simulation of pollutant gas spread and thermal energy analyses are envisaged. This research work is part of the German iSiGG project.

Integration of Uncertainty and Reliability Analysis in a BIM Design Process

Hervé Pruvost

Objectives

Building Information Modelling (BIM) is used in the building industry as an innovative method that supports the integration of many different data related to a building. A major part of this data concerns strategic key values in terms of cost, energy consumption and many other performance values that project stakeholders try to optimize. Many of these values are thereby computed by analysis software that reuses a subpart of the BIM data as input. Nevertheless, this actual usage of BIM focuses more on providing a better view of building performances but less on the threats and unwished situations that can occur in the building life cycle. This research aims at closing this gap by integrating different sources of uncertainty into the BIM data space. Those uncertainties induce at some point in the project some risk of not fulfilling performance targets and even worsening key building characteristics. In the presented use case the focus is set on the reliability of building technical systems. A specific method for coupling HVAC system, uncertainty analysis and expert knowledge is introduced as part of a holistic risk-aware collaborative methodology.



Different steps of a collaborative BIM workflow by reliability analysis

Approach

As in every building project, the first preliminary step to building design is to collect the requirements of the owner. This happens in the project brief, which contains requirements in terms of design, performance and risk, including the required level of service for the energy system. It is then up to the risk manager to translate these requirements into a list of relevant metrics such as Key Risk Indicators (KRIs). Each KRI refers to an appropriate assessment method and input factors that have to be used to compute it. For example, to assess the Mean Time Between Failure (MTBF) associated to the HVAC system, an analyst shall define reliability properties for each component of the system. This can be done with the help of stochastic models. Related parameters are then included in an uncertainty model that is interlinked with the BIM HVAC model. Through simulation, it is then possible to generate for each system component availability/failure schedules expressed as binary time series. To deduce failure occurrences of the whole system, it is furthermore necessary to describe the interactions between its components. For that purpose, an ontological representation is provided, composed at instance level of the HVAC model converted into ifcOWL, and at an abstract level of a reliability model that describes known failure dependencies according to component interaction types. This research work is done in the frames of the EU projects eeEmbedded and HOLISTEEC.

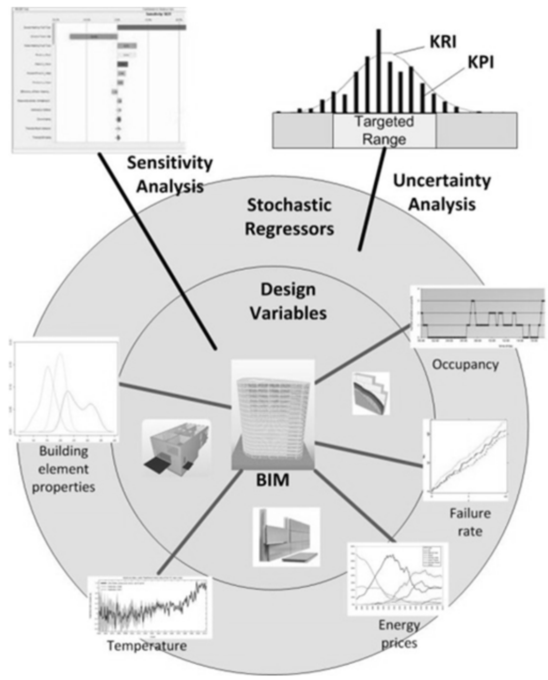
Integration of Uncertainty Analysis into Sensitivity Analysis for the Support of Decision Making in Building Design

Tom Grille

Objectives

When sensitivity analysis and uncertainty analysis are used to guide building design decisions in practice, most often both analyses are processed separately. The main reason is the assurance of acceptable computing time and easy to interpret sensitivity indices. However, in spite of these conveniences, it is undeniable that the same uncertainties whose impact on e.g. key performance indicators is analyzed by uncertainty analysis also affect the outcome of sensitivity analysis. Therefore, ways to integrate both types of analyses with a focus of introducing the effects of uncertainty into sensitivity analysis are to be investigated. Hereby three main problems have to be addressed:

1) Most of the common sensitivity analysis methods are by design not able to process pre-sampled values (e.g. the Fourier Amplitude Sensitivity Test)
2) Coupling two computational heavy methods results in a drastic increase of computing time
3) Interpretability of sensitivity indices gets complicated, when they reflect two separate effects, i.e. sensitivity and uncertainty



Sensitivity and Uncertainty Analysis Overview

Approach

We investigate and compare three approaches for the solution of the above problems.

In the first approach, the effects of uncertainty are externally added to the calculation of the sensitivity indices. This results in “sensitivity indices under uncertainty”. While computationally most efficient, the information value of these indices is questionable, as the impact of uncertainty cannot be assessed after calculation.

In the second approach, a new variance-based measure is developed. Doing so, in addition to the computation of the ordinary correlation ratio, a variation in the sensitivity indices caused by the considered uncertainties is studied. Then the new measure is derived, combining this variation information with the original index value. While being the most flexible, this also seems to be the computationally heaviest approach.

The third approach incorporates the uncertain inputs into the sampling plan. Seemingly intuitive, this approach is hindered by the fact that some of the stochastic regressors are represented by multivariate stochastic processes. An extension of sensitivity computing methods will be needed for this inclusion.

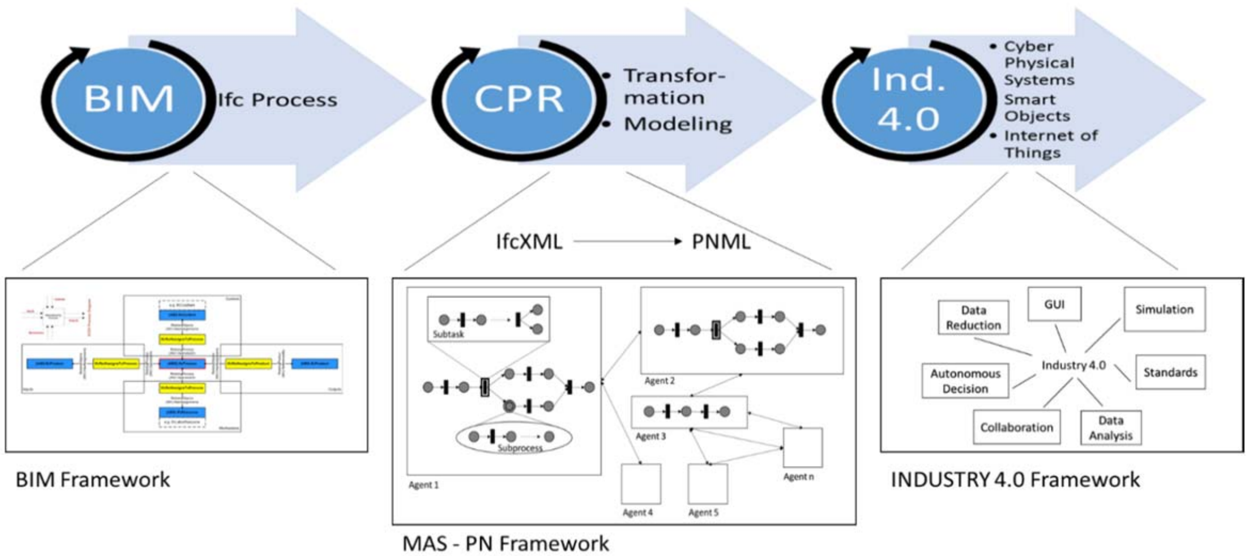
This research work is part of the EU project eeEmbedded.

Design of a Multi-Agent System for Construction Process Reengineering in the Context of Industry 4.0

Faikcan Koğ

Objectives

Industry 4.0 is the high-tech intersection of production, information and communication systems and technologies, which opens a gateway to the next industrial revolution. Industry 4.0 provides an environment for the needs of modern production systems such as productivity, flexibility, sustainability, security, safety, etc. including reconfiguration and technological advances related to cyber-physical and cloud computing systems. Despite the great opportunities and potential advantages of this new paradigm, there are still challenges of reconfigurability, optimization, human interaction, etc. in complex business processes such as construction processes. Building Information Modeling (BIM), which is defined as a digital representation of physical and functional characteristics of a facility, is a state of the art technology to improve construction productivity in the AEC Industry. IFC, which is an open object-oriented data model that covers the whole building life cycle, has been intended for the computerized process and information interoperability as a BIM standard. However, production systems in the AEC industry need more sophisticated and complicated approaches in order to deal with big data and to support decision making. In addition, construction projects require more flexible and dynamic object oriented workflows and processes for effective project deliveries. Therefore, BIM based processes have to be innovative, adaptable and extensible in order to provide intelligent and automated solutions. The objectives of this research are (1) the transformation of BIM based construction processes into useful intelligent information and process models and (2) the proposal of autonomous environment for BIM, which is integrated with cyber physical systems and smart services.



Reengineering Approach of the BIM-based Construction Process for Industry 4.0

Approach

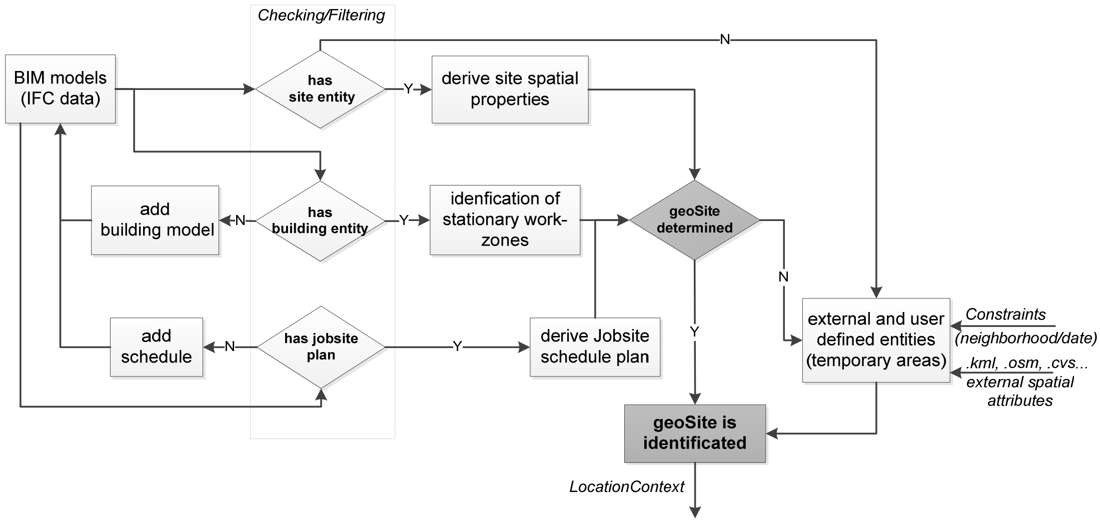
Reengineering is the selected technique to support integration of BIM-based construction process approaches within an Industry 4.0 environment. A multi-agent system is used for both the reengineering base and for smart objects. The autonomous agent decisions and the distributed cooperation between the agents lead to high flexibility and sustainability. Besides, the learning ability of the agents offers opportunities of productivity and competitiveness. Moreover, decentralized agents leverage the necessary information to achieve high efficiency. Petri Nets (PN) are thereby used to formalize agents' structures and protocols. The literature indicates that PN have unique advantages and are more suitable than other methods to simulate the production systems in Industry 4.0. Therefore, it is also aimed to use hybrid Petri Nets in the simulation of construction processes in the context of Industry 4.0. BIM processes will be handled in the MAS – PN Framework and a PV Tool (from previous researches) will be adapted to perform and to visualize the approach. As a further step of the research, Industry 4.0 compatible intelligent BIM-based construction process framework will be proposed.

Semantic Construction Site Spaces for Supporting Virtual Built Environments

Yaseen Srewil

Objectives

The construction site is beyond the location where most construction processes take place, acting as an interface among all project parties. Contrary to production space in manufacturing, the construction site areas like temporary facility places, storages, gates and streets are complex and change greatly in the course of the production process. Therefore, upgrading a traditional construction site is necessary to create a virtual environment that describes the functions, features and the continual interaction between diverse real site components (i.e. spatial, construction elements, personnel, machines, etc.). This requires a method that (1) considers the space attributes of the jobsite where elements are processed, (2) leverages asset tracking using sensing technologies and (3) enhances the content of collected data by adding semantics to physical locations of assets. Here, the space context is fundamental for the identification of the items' state in a specific area on the site. Pairing site semantics spaces and raw data, we aim to discover continually the progress of all site activities based on resource state. The objective is to enable construction site spatial semantics to support digitisation and integration of onsite logistics and allow better process planning.



Flowchart for construction site identification and extracting location context data

Approach

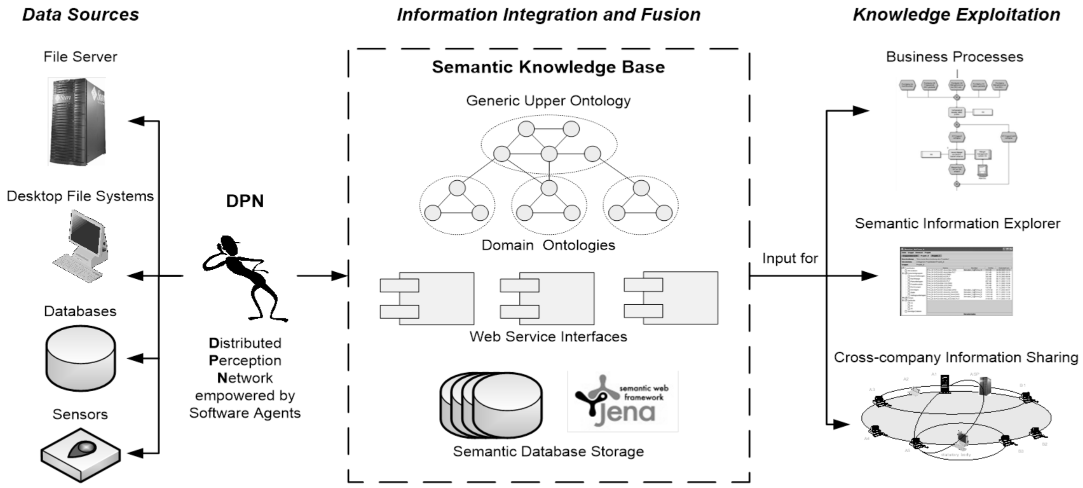
The construction site is a temporary limited manufacturing place for the related buildings. Hence, a complete virtual built environment including integration of all physical site processes is vital for successful project delivery. The envisaged digitalisation approach requires first a site layout planning concept, named "geoSite", in which the site is broken down into functional work areas that provide a necessary semantic for each work zone. Secondly, a data collection system associates physical construction elements and BIM models. The geoSite concept distinguishes two types of work areas, namely (1) stationary work zones donating the facility places where the production processes are taking place, and (2) temporary zones referring to all temporary facilities that support the construction activities e.g. laydown areas, gates, streets etc. The geoSite is established basically by extracting the site spatial attributes from BIM models such as IfcSite, IfcBuilding, IfcSpace and extending them as necessary by topographic site and user-defined data to cover all work areas that are needed to facilitate the entire construction/logistics processes identification. The dynamic changes and complexity of construction site conditions will be considered through linking the site schedule plan and constraints to geoSite. There are four main attributes that formulate site semantic locations. These are *LocationContext*, *TempWorkZone*, *Building* and *ConstructionSite*. For instance, *LocationContext* provides a semantic category for physical locations, which refers implicitly to the function of this location (storage → components being stored). The proposed approach helps inferring action/behaviour information of the elements onsite. Therefore, it will facilitate understanding and structuring of events attributes of related site activities (e.g. moving a precast column out of a storage area into a facility place would automate changing of element's status from "stored" to "installed").

Gathering and Fusion of Distributed Heterogeneous Information Using Semantic Web Ontologies and Agent Technology

Alexander Gehre[1]

Objectives

A prerequisite for efficient process-centred work is an adequate accessibility of relevant and up-to-date information. Integration of all information will only be successful if it can be treated in a coherent way that allows referencing and accessing it in a single efficient methodology. However, most information in current IT environments is dispersed spatially, accessible by heterogeneous interfaces and coded with task-specific formats. In order to provide for overall information awareness an integrated approach for proficient information gathering and sound information fusion is needed. For the achievement of a maximum of general applicability the approach has to respect a broad set of different information types from simple but dispersed and partially offline sensor data to standard data in files and databases to complex information in multifaceted data models and knowledge bases. In addition, it has to respect that completely centralised data management is not achievable in modern infrastructures with a huge amount of heterogeneous information. To some extent information has to remain on dedicated distributed systems, while a central meta-data management system just maintains significant expressive information about available and even currently unavailable resources. A framework that meets these objectives can provide Business Process Management with a powerful and flexible uniform technique for information integration.



Information Gathering and Fusion Using Semantic Web Ontologies and Software Agents

Approach

A hierarchical model of general and domain specific semantic web ontologies is applied constituting the semantic knowledge base of the environment. An upper model describes general concepts and specifies modelling principles and constraints. Domain specific models are plugged to the general model, extending it as necessary with specialised concepts and expert knowledge. The complete set of models is dedicated to capture heterogeneous information. If enterprise information resources cannot be integrated directly, only rich metadata are stored. At runtime the model is used to establish a semantic (virtual) enterprise knowledge base (concepts and runtime assertions). The information and metadata themselves are provided by a Software-Agent empowered *Distributed Perception Network* (DPN). It is composed of active and passive modules responsible to extract information from all data sources of the enterprise systems participating in the enterprise knowledge base. Usually, participating systems integrate a single DPN module directly; alternatively an autonomous software agent can take responsibility in observation, information extraction, analysis, condensation and integration. DPN nodes can be manifold, from simple sensors observed by agents, to local file systems of employees, to complex databases. For stored metadata, a generic yet flexible methodology for accessing the underlying information resource is an essential part of the system. As all knowledge is captured using one shared ontological system, hidden knowledge can be revealed based on defined rules and automatic reasoners. Information and knowledge contained in the system can be exploited straightforward by business process models that apply the concept definitions in their own model and use the runtime knowledge base during business process execution, e.g. for management of cross-company information and decision making.

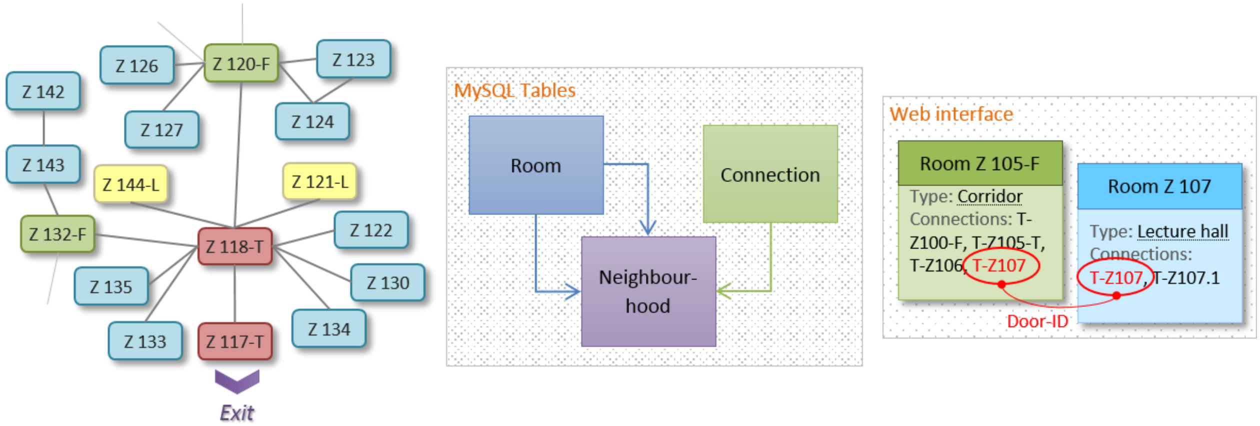
[1] Currently founding a spin-off company in construction informatics

Graph-Based Navigation in a 3D Campus Infrastructure Model

Hermin Kantardshieffa

Objectives

Modern navigation systems based on LBS (Location Based Services) and GIS (Geographic Information Systems) provide an individual with information on position and aid with guidance. From a functional point of view, navigation includes two separate tasks: localization and guidance. The localization is a method to obtain the position of an object in a defined referential area. The guidance is used for real-time interactions with the drivers of a vehicle (boat, car, and airplane) or with a pedestrian via voice, maps or symbolic representation. It includes the computation of the shortest or fastest way to go from the current point to the desired one and the communication to a person. An infrastructure model represents the virtual and interactive 3D visualization of a set of associated buildings that exist in the real world such as university campuses. The virtual three-dimensional model of a complex campus infrastructure allows various navigational methods. The most important aim of a virtual navigation for the user is the Indoor (or In-Building) navigation. The goal of the proposed graph-based navigation within the scope of a research project ISCID[1] is the development of efficient methods for the calculation of the shortest and optimum path between two topological spaces as rooms in a three-dimensional building infrastructure model.



A coloured graph of a campus building and a MySQL database are required for a web-based campus navigation

Approach

The navigational tasks of routing (i.e., route planning) and guidance are theoretically based on graph theory rules. In order to describe the matter of Indoor navigation visually a graph model is used. Each campus building is represented as a non-directional connected graph $G = (V, E)$ with $V = \{ v_1, v_2, v_3, \ldots, v_k \}$ as a vertex set representing the rooms and $E = \{ e_1, e_2, e_3, \ldots, e_n \}$ as an edge set representing the doors, where k is the total number of the rooms and n is the total number of the doors. The vertex set V consists of four different vertex classes that form the graph G as a coloured graph with $S = \{$ blue, green, red, yellow $\}$ as a colour set. All structural components of the building graph – the vertices and the edges – are stored as unique data sets in a relational MySQL database. Since rooms are connected to their neighbour-rooms via unique door connections, a double one-to-many-relationship between tables is used. The degree of each vertex describes the maximum amount of possible connections for a specific room to other neighbour-rooms. Since $V \leq E$ and each room has at least one door connection, it is essential to consider the correlation $\frac{E}{V} \geq 1$ in order to precisely calculate the shortest paths between given start and end positions within a building. The two-way routing paths are obtained by using a shortest-path algorithm such as Dijkstra's. The routing decisions are based on topology information (i.e., neighbouring nodes). A web-based navigational method "Connection Search" is used to calculate the nearest connection (i.e. entrance) to the next adjacent room. Some rooms like foyers, corridors and stairways have more than one connection. On the web interface and according to the floor plan, each room-to-neighbour-room-connection is represented as a PHP-generated link labelled with the corresponding door identification.

[1] ISCID (**I**nformation **S**ystem for **C**ampus **I**nfrastructure **D**ata) – http://www.htw-dresden.de/~v3cim – supported by the Saxon State Ministry of Sciences and Arts.

Complexity reduction of imprecise structural systems based on the probability box concept

Jamshid Karami

Objectives

Nondeterministic Finite Element Methods (FEM) including Interval, Fuzzy and Probability Bounds Analysis gained increased attention in recent years. Among them, the Probability Bounds Analysis (PBA) incorporates both imprecision and probabilistic characterizations by expressing interval bounds on the cumulative probability distribution function of a random variable. Quasi Monte Carlo simulation (QMCs) with deterministic low-discrepancy sequences is a new approach to Finite Element Analysis (FEA) with imprecise variables. It results in more efficient interval samples, which leads to interval FEA (IFEA). Consequently, the lower and upper bounds on probability of failure in each simulation can be computed.

Although such new procedures offer a more realistic approach for analysis, their utilization in practical applications remains limited due to the lesser attention to develop the necessary IT tools and the computational efforts that are much more than for deterministic analysis. Thus, performing reliability analysis leads to impractical computational costs. There are many limitations in current methods, they do not guarantee to bound the true response ranges and the results tend to be excessively conservative with the increase of problem complexity. Therefore, there is a need for a computationally efficient method that is capable of accounting for uncertain parameters and yielding rigorous and sharp bounds on the ranges of the structural responses with limited samples.

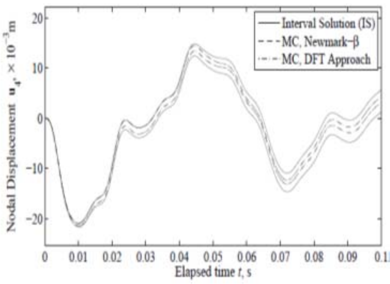
$$A_e = \begin{Bmatrix} 1 & 0 & 0 \\ 0 & 0 & 2 \\ 0 & 1 & L \\ -1 & 0 & 0 \\ 0 & 0 & -2 \\ 0 & -1 & L \end{Bmatrix}, \Lambda_e = \begin{Bmatrix} \frac{2}{L} & 0 \\ 0 & \frac{2}{L^3} \\ 0 & \frac{3}{L^3} \end{Bmatrix}, \boldsymbol{\alpha}_e = \begin{Bmatrix} \mathbf{EA} \\ \mathbf{EI} \end{Bmatrix}$$

$$\mathrm{K}_e = A_e \mathrm{diag}(\Lambda_e \boldsymbol{\alpha}_e) A_e^T,$$

$$\left(-\omega_j^2 M + i\omega_j C + K\right) \mathcal{F}_t(u)_j = \mathcal{F}_t(f)_j,$$

$$\begin{Bmatrix} \mathrm{K}_{\mathrm{eff},j} & C^T \\ C & 0 \end{Bmatrix} \begin{Bmatrix} \mathcal{F}_t(\mathbf{u})_j \\ \mathcal{F}_t(\boldsymbol{\lambda})_j \end{Bmatrix} = \begin{Bmatrix} \mathcal{F}_t(\mathbf{f})_j \\ 0 \end{Bmatrix}$$

$$\mathrm{K}_{\mathrm{eff},j} = \begin{cases} -\omega_j^2 \mathrm{M} + i\omega_j \mathrm{C} + \mathrm{K}, & 0 \le j < N/2; \\ \text{conjugate of } \mathrm{K}_{\mathrm{eff},N-j}, & N/2 \le j < N, \end{cases}$$



Approach

Developing an efficient procedure for sampling is one of the most important parts of this research. The goal is to reduce the number of Finite Element Analyses to reach a reasonable accuracy. Therefore, the samples are generated based on low-discrepancy sequences. Definition of a suitable measure for describing damage and limit state function comprises the next phase of the work. However, the definition of an efficient Interval FE procedure for frame structures under dynamic loads remains the most important part of the research. To obtain a tight enclosure and reduce the overestimation due to interval dependency, which is the main challenge in any interval computations, decomposition strategies are used to the nodal equivalent load vector and the stiffness matrix. The goal is to reduce the multiple occurrences of the same interval variable to the minimum. Numerical integration methods are not applicable for IFEA under dynamic loads, because overestimation due to interval dependency accumulates, and the yielded interval enclosure quickly becomes excessively wide and practically useless after a few iterations in time. Alternatively, the transformation approach can be used. In the proposed method, the Discrete Fourier Transform (DFT) approach will be adopted and the structure is studied in the frequency domain; then the results will be transferred to the time domain.

Another significant effort is to handle the overestimation of the derived quantities. The core idea is to integrate all variables of interest into one single system via Lagrangian multipliers, and solve all of them simultaneously. As a result, both primary quantities, such as displacement, and derived quantities, such as internal forces, are obtained with sharp bounds.

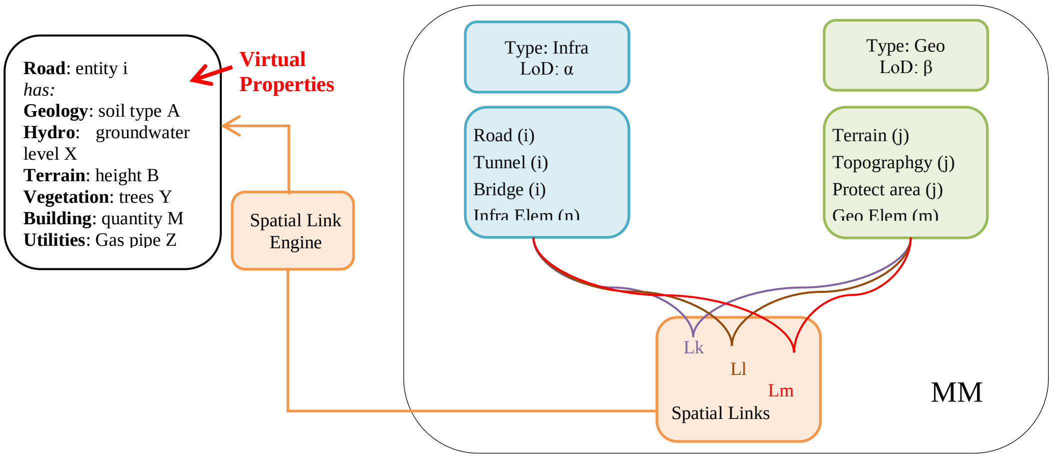
Then by means of case studies, the efficiency of the proposed method will be verified. Numerical analyses will be performed using the developed IFEA code. For this purpose, Steel Moment Frames as the target group of structures will be used. In this phase, the results of previous stages of current research will be used as a guideline to select the appropriate input parameters. Based on the results, a methodology will be proposed for reduction of the complexity of IFEA of structural systems under dynamic loads.

Interoperability of Infrastructure Planning and Geo-Information Systems

Nazereh Nejatbakhsh Esfahani

Objectives

Building Information Modelling or Model-Based Design facilitates to investigate multiple solutions in the infrastructure planning process early enough to help better decision making. The most important reason for implementing model-based design is to help designers and to increase communication between different design parties. It improves team collaboration and facilitates faster and lossless project data exchange and management across extended teams and external partners in project lifecycle. High level infrastructure suits mostly facilitate to analyze the infrastructure design based on the international or user defined standards. Called rule-based design, this minimizes errors, reduces costly design conflicts, increases time savings and provides consistent project quality. Yet design packages either don't consider GIS domains such as energy and environmental impacts or consider their own data domains like materials and land which might not meet the requirement of the other project members. Besides infrastructure projects demand a lot of decision makings in governmental as well as Private Public Partnership (PPP) level considering different data models. Therefore lossless flow of project data as well as regulations across project team, stakeholders, and governmental and PPP is highly important. Therefore because of the lack of or poor integration between different data models involved in infrastructure projects, a new method of BIM for infrastructure projects has been investigated.



Spatial Links of Infrastructure and Geospatial Data Models and obtaining Virtual Properties in an MM

Approach

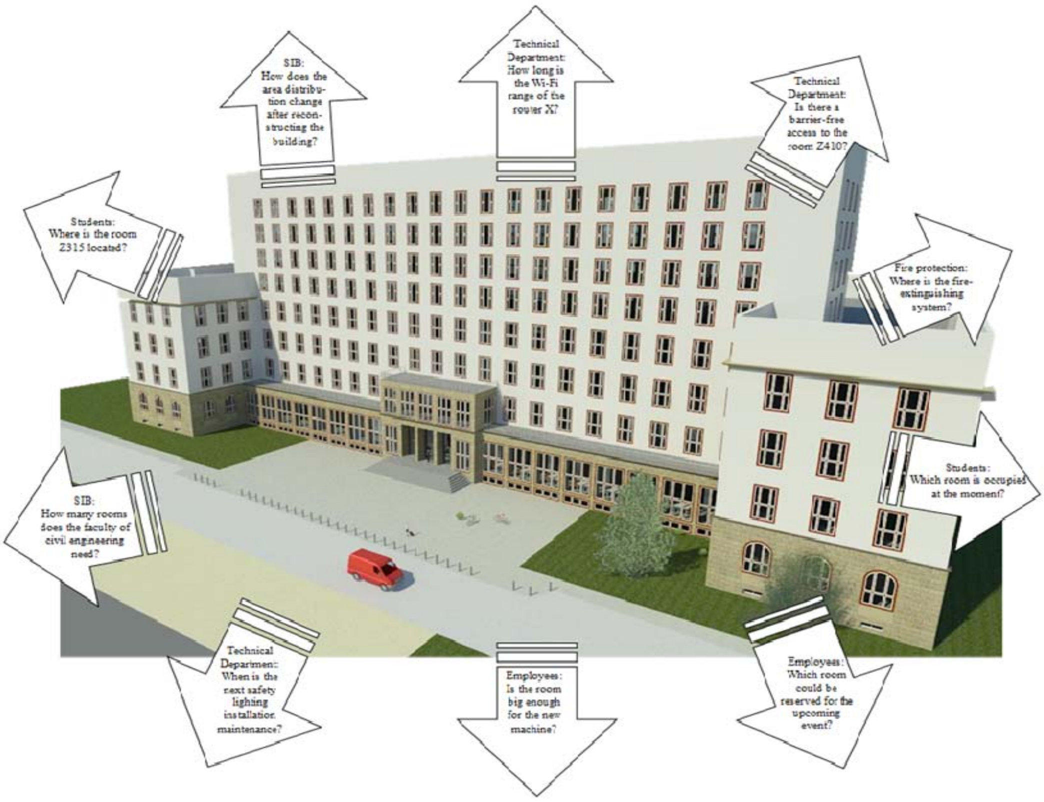
Multi Model (MM) is a method where heterogeneous data models from various domains are bundled together into a container keeping their original format. In separate Link Models the elements of the data models will be linked together. Yet the multi model and the generated links have no inherent domain semantic. In infrastructure information processes, there is a need for semantic linking of different data models, because it is not known which domain models might be integrated in future tasks. Therefore a method is needed which allows for definition of semantic links or an adequate rule based filtering through topological queries. The most important unification of data models involved in infrastructure projects is the spatial property of them. Spatial identification joins such data models in a semantic way. Therefore the promising approach for the interoperation of Infrastructure and Geospatial Domains is to generate interlinks through spatial identity of entities. Called Spatial Links, these match the geometry of infrastructure data with the geospatial information in accordance to the location of the elements. Each infrastructure entity receives the spatial information which is stored at the location of entity or is related to the targeted entity due to sharing the equivalent spatial index. Thus, the geometrical entity which is devoid of spatial intelligence gets through this approach all information related to the entity. This information will be virtual properties for the object. Nearest Neighborhood algorithms are applied for spatial match finding and a filtering and refining approach is performed in accordance to the LoD and product model being observed.

Development of a Knowledge Base for Campus Infrastructure Models

Eugenie Pflaum[1]

Objectives

The aim is to standardize and to simplify administration as well as business processes with software products. In this way a higher data consistency can be realized. The focus is to connect the system with CAD whereby information from building information models will be transferred into the databases. Based on this, an efficient, sustainable and flexible rule based information management system will be developed. This will be assembled under consideration of German building standards, regularities and rules for campus-infrastructure domains. The figure below shows some typical queries to the knowledge-based system.



Exemplary retrieval on the knowledge-based system

Approach

On one hand a system should be provided, which is able to capture all campus building related data in various places, and which allows managing and updating data centrally. On the other hand the system should be able to analyze, evaluate data and automatize work routine by the integration of various processes and data stocks. The result will be an optimized process. There will be an additional option allowing to take information directly from CAD models and to integrate them into fm-projects. Special attention will be paid onto 3d-models as they already include all relevant geometrical information without any additional step of work; further attributes like maintenance of schedules, user groups, etc. can also be integrated and included into the model. Evaluations are based on simple and modifiable rule packages instead of difficult and complex source codes. Thus, it is easily possible for users to adapt rules according to current building codes and standards without programming knowledge’s.

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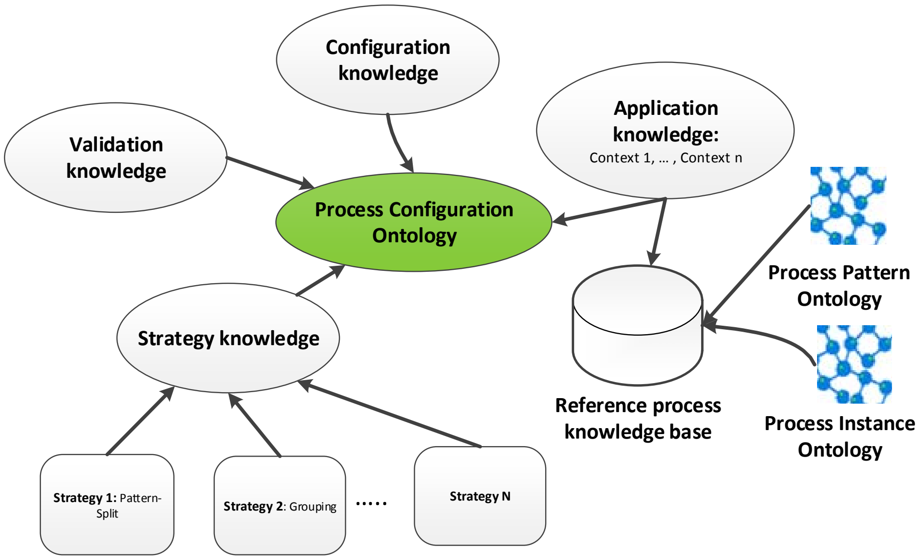
[1] This is a cooperative PhD thesis with the University of Applied Science Dresden.

Knowledge-based Process Configuration in Construction

Ksenia Roos

Objectives

The essential characteristics of the construction processes are the continuous flow of information and close communication between the participants involved in the construction project. In a significantly large project, where the construction site extends to thousands of hectares and many construction companies, each with different software, are involved, different data models, various standards, the coordination and effective exchange of information can lead to difficulties in quick process configuration or reconfiguration. Therefore, a higher-level structure, which would encapsulate the heterogeneity of the distributed environment by providing of common-shared ontological definitions, plays an important role. So the ontology-based approach benefits in consideration of the existing problems. The configuration flexibility is supported by the rule-based applications. In addition, intelligent solutions can be obtained by applying of different building strategies that can optimize the process flow. The processes, ontologies and rules can be presented as different types of knowledge enabling as a combination an efficient knowledge-based process configuration.



Approach

The Process Configuration Ontology for storing strategies, user-defined constraints and configuration steps is modelled within this approach. Four types of knowledge influence the development of the Configuration Ontology:

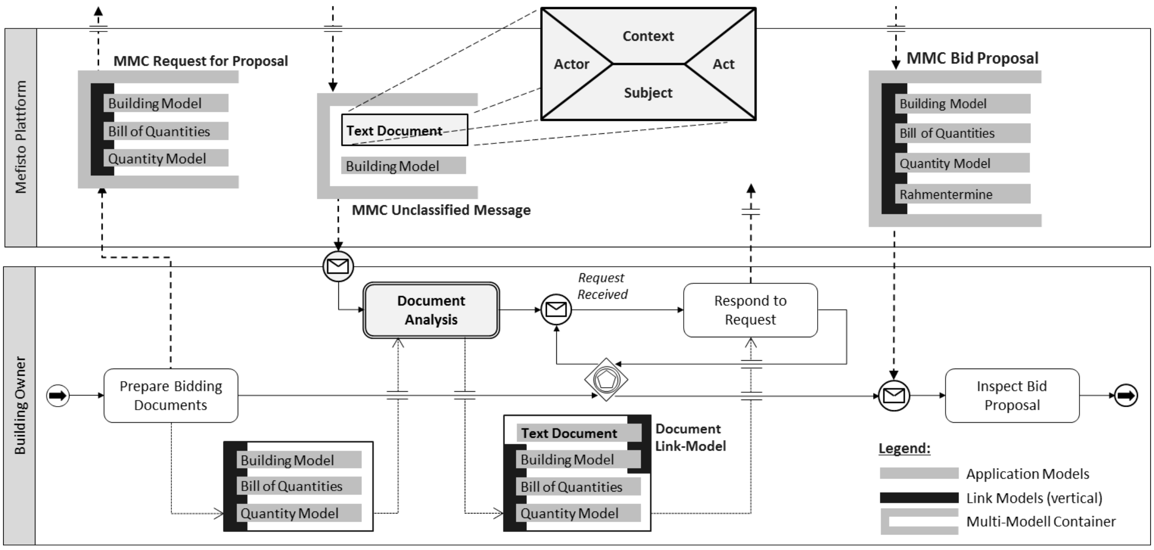
- *Application knowledge*. This knowledge describes the application conditions of the process patterns, for example as keywords searching criteria for a certain pattern
- *Strategic knowledge*. This knowledge describes different building strategies. Strategy can be defined as procedural methods/plan to achieve the target configuration. In construction numerous strategies can be specified. An example of a proven strategy is "thoroughfare areas in high-rise buildings (hallways, stairways) should be completed downwards".
- *Configuration knowledge*. This knowledge consists of the objects of a specific domain (construction processes) and the relationships between these objects. It includes also the knowledge of the procedural construction methods used during the configuration.
- *Validation knowledge*. This knowledge includes rules and algorithms that are used to check the configuration of the entire process for syntactic and semantic correctness.

Integrating Text Documents in Multi-Model Collaboration Processes

Sven-Eric Schapke

Objectives

With the increasing utilisation of model-based planning and controlling information there is a need to integrate heterogeneous resources of project information. In the research project Mefisto novel software technologies were developed to interlink different types of application models such as building information models, bill of quantities and project schedules and combine them in so called multi-models. The multi-model provides synchronised project information for subsequent planning, controlling and analysis applications. It can be exchanged using a neutral Multi-Model Container (MMC) format. To coordinate the creation and use of multi-models throughout a project, workflows can be applied that specify the input and output information for each task by Multi-Model Templates (MMT). The objective of this research is to extend these methods for multi-model-based collaboration to also allow for integrating text documents. For that purpose, text documents are considered a new type of application model that first of all contains unstructured project information. Using semantic annotations the content of the document and the document as a whole can be classified and interlinked with related application models.



Analyses and integration of a text document received in the process of construction bidding

Approach

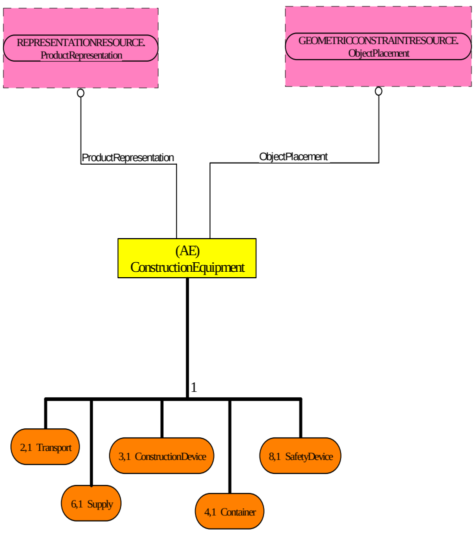
The figure above illustrates the analysis of a text document within the context of a Multi-Model Workflow for construction bidding. While predetermined formal MMCs can be used for the request and the submission of bidding information by/to the owner, intermediate requests and notifications may comprise unstructured, semi-structured as well as fully structured content as indicated by the unclassified message container. To integrate the text information from these messages with the owner's information base, text technologies can be applied to semi-automatically identify, extract and classify important text elements. In the analyses factual, contextual and intentional matters of the message have to be considered in contrast to regular engineering and management reports that often resemble to application models and comprise factual self-contained representations of the building product and its production processes. Hence, four types of message statements are distinguished that are concerned with (1) the sender (Actor) and (2) his/her intention to send the message (Act) as well as (3) the products and production processes (Subject) and the corresponding workflow tasks he/she refers to (Context). Identifying all four statements provides for interlinking the message to the respective project models representing the project organisation (Actor), the building products, specifications and processes (Subject) as well as the respective project workflow (Context) and its current status (Act). In turn, these models and their data specifications also provide the necessary vocabularies and domain knowledge to support the analyses. The figure illustrates the anticipated analysis results, triggering a request event in the bidding workflow and interlinking the text document (e.g. a request for information on certain concrete columns) with the respective building elements.

IFC Conform Construction Site Model Taxonomy

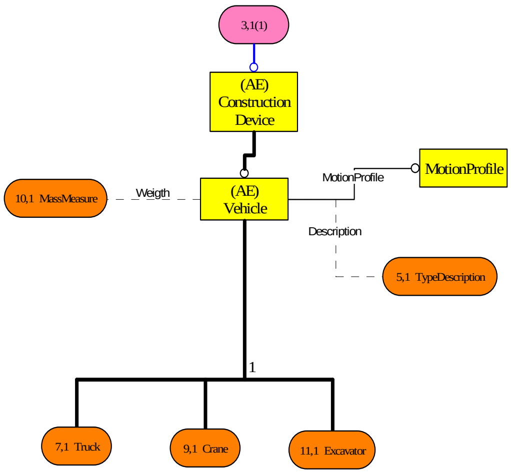
Ulf Wagner

Objectives

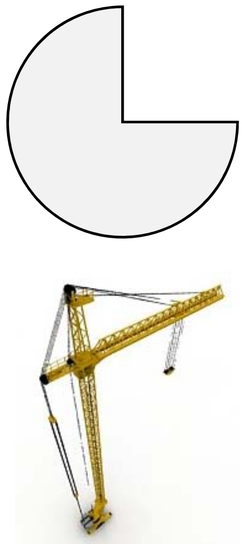
For better-integrated building project planning and realization, it is necessary to be able to design a construction site using IT. Moreover, it is necessary to be able to interchange construction site information digitally, in a qualified information model enabling 3D, and not only as plain 2D files. Today, there are several software tools available for construction site modelling. However, they are not well integrated with common 3D CAD programs and they do not provide for qualified data exchange with other related tools. Most often, the existing construction site modelers support visualization of the construction site equipment but they offer little functionalities to simulate the construction site processes and to prove the practicability of the planned construction activities, e.g. checking possible collisions of cranes, supply chain bottlenecks, storage area availability etc. The objective of this research is to design an IFC conform construction site model taxonomy that can provide standardized information basis for a number of IT tools in the domain.



Construction Equipment Integration in IFC Model



Inheritance from Vehicle



Crane in different Levels of Detail (2D top view and 3D view)

Approach

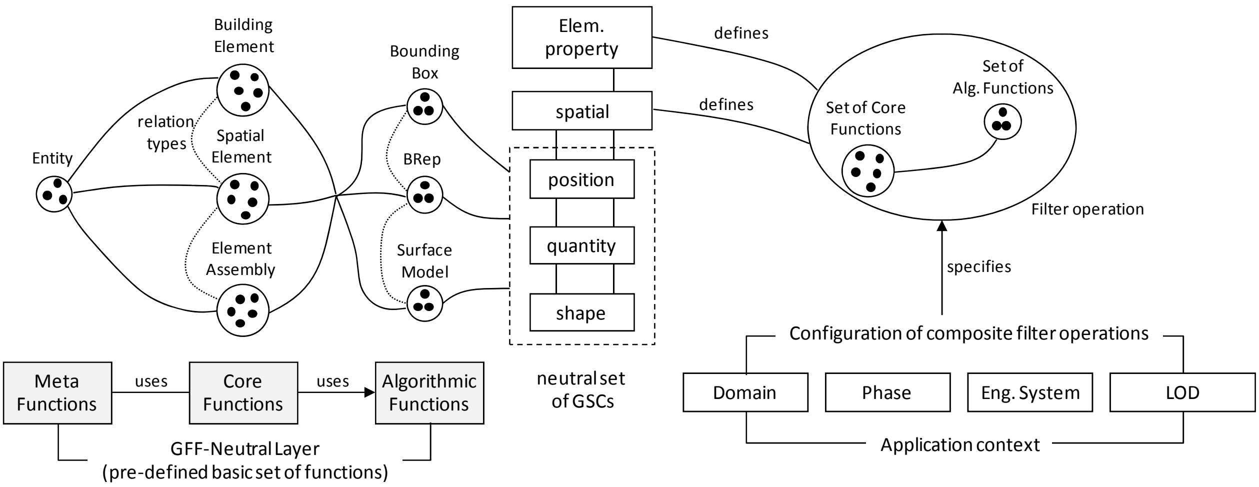
The elements inside a construction site model require structuring and sorting. Modelling of unsorted sets of components gives more freedom, but wastes a lot of optimization potential because attributes and relations to other objects have to be modelled individually for every single object type. To order the elements of the construction site, they have to be analyzed taxonomically. A taxonomy or classification schema is a consistent model, which classifies objects by defined criteria. This means, it orders them in hierarchical categories or classes whereby the choice of the classification criteria is of highest importance. Miscellaneous aspects have to be considered for that purpose, such as type, usage, performance, costs, operating expenses (compose, moving, decompose), versatile/not versatile etc. Of these aspects, type and usage describe the most common way of ordering. Besides this, the use of multiple inheritance is worth investigating. The model can be slimmer if multiple inheritance is used because various attributes will not be duplicated thereby minimizing data redundancy. However, it has to be considered that in some cases the uniqueness may get lost. For example, a truck-mounted crane can be a child class of vehicle and chain host at the same time. Both, the car and the chain host will have velocity as attribute but by the car it is the driving speed and by the chain host the up and down speed. This leads to the so-called diamond problem. It is not clear which velocity is meant in the truck-mounted crane class. Therefore, multiple inheritance is used with special care in our modelling approach. Furthermore, as not all information can be stored in one model, additional libraries and component ontologies are applied where auxiliary information can be stored.

Geometrical and Spatial Constraints in BIM-based Information Filtering

Ronny Windisch

Objectives

It is obvious that geometrical and spatial information about abstract and physical building elements as well as the building itself in various application contexts plays an important role in all phases of the building lifecycle, e.g. for design validation like clash-detection or code-checking, automated information pre-processing for downstream applications like computational structural analysis, quantity take-off or construction resource planning. Thus, in the frames of a BIM-based project environment, information filtering comprises various use cases applying geometrical and spatial constraints (GSC) in order to enable seamless information exchange and delivery thereby providing application and task specific information subsets derived from a commonly shared project information space, e.g. represented by a building information model. Information filtering processes like ad-hoc model querying or static and dynamic model view generation may apply GSCs in terms of predicates or information requirements represented by derived, calculated or aggregated object sets or values according to user-defined element types, properties or geometrical and spatial relations between different elements with respect to the given application context at hand. Since the application context specifies the information needs of a particular actor and may vary regarding engineering domain and system, project phase and level of development (LOD) numerous types of GSCs, i.e. types of geometrical and spatial representations of building elements, their parts and relationships, have to be supported based on a commonly used, neutral data model (e.g. IFC). The outlined research work aims to develop a geometrical information filtering framework that provides for the application of GSCs in various use cases with respect to the variety of the actors information needs occurring in BIM-based information management processes.



Composition of geometrical-spatial-constraints based on a generic filter framework

Approach

The capabilities for applying geometrical and spatial constraints in information filtering processes shall be embedded into the Generic Filter Framework (GFF) recently developed at our Institute. The GFF concept is based on a breakdown of single application specific filter operations into several reusable and configurable filter functions encapsulating a particular piece of operational logic. Each filter function is assigned to one of three different levels of abstraction which together establish the Neutral Layer of the GFF. Each layer implements the operational mapping to the concepts of the upper layer since each function is specified by using functions of the layers below. This approach allows for providing filter functionality tailored for a considerable amount of different application contexts based on a finite set of pre-defined filter functions. However, the amount of relevant, domain-independent geometrical information considered in the approach can be divided into three main categories: (1) quantity, (2) shape and (3) position, and two sub-categories related to the geometric reference for each of them: (a) self-referred (element properties) or (b) relative (to other elements or a certain spatial reference). The GFF will be extended to integrate the according stringent geometrical concepts with information derived from engineering knowledge in order to define GSCs related to a particular application context.

Research Contracts

Title: **eeEmbedded – Collaborative Holistic Design Laboratory and Methodology for Energy-efficient Embedded Buildings**
http://eeEmbedded.eu

Project Leader: Prof. Dr.-Ing. R. J. Scherer
Operative manager: Dipl.-Ing. (Arch.) Romy Guruz
Technical manager: Dr.-Ing. P. Katranuschkov

Financial Support: EU – EC FP7 Integrated Project No. 609349
(EeB.NMP.2013-5 Optimised design methodologies for energy-efficient buildings integrated in the neighbourhood energy systems)

Budget/Funding: 11.10 million Euro / 7.65 million Euro (total), 1.26 million Euro (CIB)

Duration: 4 years, since 10/2013

Approach: **eeEmbedded** develops an open BIM-based holistic collaborative design and simulation platform, a related holistic design methodology, an energy system information model and an integrated information management framework for designing energy-efficient buildings and their optimal energetic embedding in the neighbourhood of surrounding buildings and energy systems. A new design control and monitoring system based on hierarchical *key performance indicators* (KPI) is established to support the complex design collaboration process. The developed knowledge-based detailing templates allow energy simulations already in the early design phase, and BIM-enabled interoperability grounded on a novel system ontology provides for a seamless holistic design process with distributed experts, and a seamless integration of simulations of various performance issues, thus extending the system to a real *Virtual Engineering Lab*. A test period of 12 project months, overlapping the first 42 development months of the project, will provide for real pre-market validation.

The approach is based on 2 business models – the business model of the owners (and hence the equipment providers), and the business model of construction and design companies. The applications and services of the eeEmbedded platform build upon a set of ISO and industry standard data structures such as IFC, STEP, RDF and OWL to enable greatest commonality and inter-company operability of the developed ICT solutions. A new ontology-based Link Model, aligned with the broad Linked Data initiative, provides the bridge between the multiple physical and mathematical models involved in the eeBuilding domain, thereby warranting the desired data and services interoperability. In addition, a general-purpose energy simulation model (ESIM) will provide the prerequisite to plug in different computational tools on the platform, such as the energy analysis tools NANDRAD and TRNSYS-TUD of the TU Dresden, EnergyPlus, CFD analysis tools of SOFiSTiK, Greece, as well as tools based on Modelica. Baseline for all ICT services is the developed methodology for BIM and KPI-based eeDesign and the related overall ICT framework of the Virtual Engineering Lab, which is elaborated in four application domains: (1) building thermal design, (2) building energy embedding design based on ESIM, (3) building sensor and control system design, and (4) eeConstruction planning and embodied energy design. On that basis, new ways of facility management will be suggested and forwarded to AEC/FM practice.

Partners: TU Dresden, Institute of Construction Informatics – **Coordinator**, and Institute of Power Engineering (Germany), Fraunhofer Gesellschaft – Institute IIS/EAS (Germany) Nemetschek Allplan Slovensko (Slovakia), Data Design Systems ASA (Norway), RIB Information Technologies AG (Germany), Jotne EPM Technology AS (Norway), Granlund Oy (Finland), SOFiSTiK Hellas AE (Greece), iabi – Institute for Applied Building Informatics (Germany), Fr. Sauter AG (Switzerland), CEMOSA (Spain), Obermeyer Planen + Beraten GmbH (Germany), STRABAG AG (Austria), Royal BAM Group nv, AZ (The Netherlands)

Title:	**HOLISTEEC – Holistic and Optimized Life-cycle Integrated Support for Energy-Efficient Building Design and Construction**
Project Leader:	Prof. Dr.-Ing. R. J. Scherer Co-leader: Dipl. Ing. Hervé Pruvost
Financial Support:	EU – EC FP7 Collaborative Project No. 609138 (EeB.NMP.2013-5 Optimised design methodologies for energy-efficient buildings integrated in the neighbourhood energy systems)
Budget/Funding::	9.7 million Euro / 6.5 million Euro (Total), 0.45 million Euro (CIB)
Duration:	4 years, since 10/2013
Approach:	The main objective of HOLISTEEC is to design, develop, and demonstrate a BIM-based, on-the-cloud, collaborative building design software platform, featuring advanced design support for multi-criteria building optimization. Such a platform can help to improve the current state-of-the-art, which still features many limitations with regard to the complexity and variability of building life cycles, end user awareness and participation, use of new business models and interoperability of the ICT support. The HOLISTEEC platform accounts for all physical phenomena at the building-level while also taking into account external, neighbourhood-level influences. The design of the platform relies on actual, field feedback and related business models and processes. Hence, it will enable building design and construction practitioners to take their practices a step forward, for enhanced flexibility, effectiveness, and competitiveness. HOLISTEEC main assets are (1) an innovative feedback / loop design workflow, (2) a multi-physical, multi-scale simulation engine; (3) a unified data model for Building and Neighbourhood Digital Modelling, (4) a full-fledged open software infrastructure for building design tools interoperability leveraging available standards, and (5) innovative and flexible user interfaces. HOLISTEEC is expected to have a direct impact at macro level on the construction sector as a whole, through the following aspects: improved overall process efficiency, improved stakeholders collaboration and conflict resolution, lifecycle cost reduction, reduction of errors and reworks. These impacts will be quantitatively evaluated during the demonstration and validation phase of the project, where the proposed design methodology and tools will be extensively applied to real construction projects, in parallel to standard design approaches.
Partners:	D'Appolonia S.p.A. – **Coordinator** and S.T.I. Engineering S.r.l. (Italy); Technische Universitaet Dresden, iabi - Institute For Applied Building Informatics and G.E.M. Team Solutions Gdbr (Germany); Gdf Suez, Centre Scientifique et Technique Du Batiment, Geomod S.a.r.l. and Commissariat A L'Energie Atomique Et Aux Energies Alternatives (France); Acciona Infraestructuras S.A., Cype Soft S.L., Pich-Aguilera Arquitectos S.L.P. and Fundacion Tecnalia Research and Innovation (Spain); Senaatti-Kiinteistöt and Teknologian Tutkimuskeskus VTT (Finland); Nemetschek Slovensko S.R.O. (Slovakia); Koninklijke Bam Groep Nv (Netherlands); Bergamo Tecnologie Sp Zoo (Poland); National Taiwan University Of Science And Technology (Taiwan)

Title: **Design4Energy** – **Building Life-cycle Evolutionary Design Methodology Able to Create Energy-efficient Buildings Flexibly Connected with the Neighbourhood Energy System.**

Project Leader: Prof. Dr.-Ing. R. J. Scherer
Co-leader: Dipl.-Inf. Dipl.-Ing. Mathias Kadolsky
Technical manager: Dr.-Ing. Peter Katranuschkov

Financial Support: EU – EC FP7 Integrated Project No. 609380
(EeB.NMP.2013-5 Optimised design methodologies for energy-efficient buildings integrated in the neighbourhood energy systems)

Budget/Funding: 6.5 million Euro / 4.9 million Euro (total), 0.40 million Euro (CIB)

Duration: 4 years, since 10/2013

Approach: **Design4energy** develops an innovative Integrated Evolutionary Design Methodology that will allow the stakeholders to predict the current and future energy efficiency of buildings (both at individual level and neighbourhood level) and make better informed decision in optimising the energy performance at building life cycle level, including operation and maintenance.

Visualizing the life cycle performance will allow to design energy efficient building not only for the present but also for the future building stock. Design4energy takes this in consideration and develops tools and methodologies that can help designing energy efficient buildings by regarding both short-term performance as well as future scenarios, including important factors such as deterioration curves, technology evolution, climate change effect, energy neighbourhood configuration and continuous commissioning alternatives while evaluating their impact in the building energy performance. The continuous commissioning will include strategies as preventive maintenance, renovation of energy systems technologies (HVAC, RES, etc.), including deep retrofitting strategies.

The proposed methodology is based on a sophisticated technology platform, that will make use of energy attributes of building components, deterioration of building components and systems, neighbourhood energy systems, energy related parameters, energy simulation tools and current usage parameters of the tenants, derived from maintenance and operation data. The technology platform developed within the project will allow the stakeholders to explore various design options and make validated and qualified choices as early as possible.

Partners: SOLINTEL M&P SL – **Coordinator**, Gaspar Sanchez Moro Arquitectos S.L.P., SISTEMAS Y MONTAJES ELECTRICOS SL, ANCODARQ S. L. and Assignia Infraestructuras SA. (Spain);
University of Salford - School of the Built Environment and Loughborough University - Construction Informatics (UK);
TU Dresden - Institute of Construction Informatics, 3L-Plan Lenze-Luig-Walter GbR and Fraunhofer Gesellschaft - Institute IAO (Germany);
Teknologian tutkimuskeskus VTT (Finland);
IZNAB Sp. z o.o. and TPF Sp. Z o.o. (Poland);
UNINOVA (Portugal);
Corio nv (Netherlands);
Metropolitan Research Institute Ltd. (Hungary);
CADCAMation KMR SA. (Switzerland)

Title:	**iSiGG – A Dynamic Interactive Simulation System for Fire, Smoke and Pollutant Gas Spreading in Buildings Taking into Account the Interaction with People**
Project Leader:	Prof. Dr.-Ing. R. J. Scherer
Financial Support:	BMBF (German Ministry of Education and Research)
Budget/Funding:	1.2 million Euro / 0.8 million Euro (total), 0,29 million Euro (CIB)
Duration:	3 years, since 07/2016
Approach:	iSiGG will develop an interactive integrated cyber-physical simulator for fire, smoke and pollutant gas spread in buildings in cases of fire, chemical, biological and radiological incidents and terrorist attacks. It will combine computational fluid dynamics (CFD) methods with methods for numerical simulation of people flow based on a semantic building model that is capable to support non-stationary changes of the model status such as opening/closing of doors and windows, state changes in the HVAC and the fire protection systems, damages due to blasts or people actions etc. The research work encompasses: (1) Development of a CFD simulation software specifically optimized for the targeted application domain; (2) Coupling of CFD and people flow simulations to an integrated co-simulation using the Functional Mock-Up Approach as baseline and enabling interaction with the building and dynamic state changes of the building model; (3) Embedding the simulation system into a BIM-based virtual 3D Lab for building design and evaluation of existing building stock; (4) Development of an API for modular integration of the simulation services in a compute cloud environment for achievement of fast online response. The Simulator will be of benefit for a number of different actors in the construction process such as designers, facility managers, owners, security personnel, public authorities and insurances, especially with regard to the planning of safety measures, the evaluation of existing buildings and the development of training scenarios for rescue and security teams. The integrated BIM functionality will enable easy to use visual examination of evacuation plans and virtual team training thereby helping to improve the overall quality of the design process regarding high-rise buildings, shopping malls, railway stations and airport terminals.
Partners:	FIDES DV-Partner Beratungs- und Vertrieb GmbH – **Coordinator** SimPlan AG TU Dresden, Institute of Construction Informatics

Title:	**wiSIB – A Simulation and Knowledge-Based System Identification Approach for Bridge Structures**
Project Leader:	Prof. Dr.-Ing. R. J. Scherer Co-Leader: Dr.-Ing. Peter Katranuschkov
Financial Support:	BMBF (German Ministry of Education and Research)
Budget/Funding:	1.2 million Euro / 0.8 million Euro (total), 0,37 million Euro (CIB)
Duration:	3 years, since 01/2017

Approach:

wiSIB develops an IT-supported system for the identification of the structural behavior of bridges for the purposes of bridge monitoring, life cycle forecasting and retrofitting. The need for such a system is raised by the following three major challenges:

(1) Bridges are an essential part of the infrastructure of each country. Their aging and the related deterioration of their structural capacity are critical issues for the planning and financing of appropriate monitoring and retrofitting measures. However, current state-of-the-art methods cannot predict damages in the early phase and are therefore insufficient to provide for reliable life cycle prognosis.

(2) The structural response of bridges is difficult to identify from local sensor measurements. Damages occur in millimeter ranges and this means a scale of 1:1,000,000 with regard to the overall bridge structure. Hence, 100s or even 1000s of sensors are needed to assess the bridge response, which increases enormously the complexity of the system identification task.

(3) Bridge retrofitting is an expensive measure that takes months or even years to accomplish. Consequently, there is strong need of an accurate and reliable forecasting system as to when and in what scope such measures should be undertaken.

Today's methods of system identification based on dynamic eigenfrequency analysis are only helpful for already occurring strong damages but cannot help in the estimation of the effect of smaller or local damages due to considerable noise in the measured values. Therefore, wiSIB will develop local system identification methods that will combine dynamic analysis with holistic structural analysis methods, including the examination of nonlinear and transient behavior with regard to stress, strain, eigenfrequencies and deformations. The focus of the research work is on the comparative mass evaluation of sensor data and on strategic sensitivity and model variation studies aiming at the achievement of fundamentally improved system identification. It encompasses the development of (1) a BIM-based multi-model framework for bridge structures based on standard BIM, (2) a knowledge-based classification system for bridge model variants and bridge damages, (3) cloud-based mass simulation for the system identification, and (4) strategies and methods for reduction of the damage model variants and for the identification of model states and state changes. The whole system will be implemented as a BIM-based SaaS Platform and tested on real pilots, for which an agreement with the motorway authority of north Bavaria (Autobahndirektion Nordbayern) exists.

Partners:

Leonhardt, Andrä und Partner VBI AG – **Coordinator**
TU Dresden, Institut für Bauinformatik
FIDES DV-Partner Beratungs- und Vertrieb GmbH

Title: **Campus-Navigator – The Guidance System of the TU Dresden**

Project Leader: Dr.-Ing. habil. Uwe Reuter

Financial Support: TU Dresden

Duration: Since 2001

Approach: Room-related digital data of buildings belonging to the TU Dresden campus are collected by the university administration. **Campus Navigator** summarizes these data as an externally working system and provides employees, students and visitors these data in a textual and graphical way on an interactive web site. All relevant information stored in the university's CAFM system KOPERNIKUS, using an ORACLE database, can be accessed that way. The software visualizes floor and orientation plans in real time out of the stored data by transforming them into vector graphics in the SVG format, which finally can be displayed in web browsers, for instance via the ADOBE SVG plug-in. Linking and visualizing of the graphical and textual data is based on XML. Via a self-managed ORACLE database, specifically created HTML pages for disabled persons are integrated. Besides the automatic synchronization with the administration databases the content of the curriculum timetables is also provided. With special attention to disabled or mobility restricted persons a routing system (routing through the campus) based on the A-star-algorithm has been developed, which is supported by a parsing process that augments the existing CAD-data with the necessary semantics. The benefits of the system include the collection of information from a diversity of data sources, their transformation, graphical rendering and especially the deployment in existing and established networks and end-user environments.

The system is continuously developed and enhanced with user-friendly functionality and information access features. Information resources are thereby added and updated on regular basis.

Lecture Activities

Since 2006 the students can choose construction informatics as a competence subject in their curriculum. This means that in the 4-semester Diploma course (equivalent Master Courses), starting with two preparatory lectures two semesters before, students can choose construction informatics as a second subject. As the main subject, Diploma courses are offered for (1) structural engineering, (2) construction management, (3) urban engineering, infrastructure and transportation engineering, (4) hydraulic and environmental engineering and (5) computational engineering. Studies in the Diploma course are organized in modules of 6 hours a week yielding in 5 credit points. The 4 semesters include a project work in the 3rd semester and the Diploma thesis in the 4th semester. Both can be done in construction informatics. As construction informatics has to be a complementary subject a pool of 5 modules is offered to the students in order to allow them complementing their basic studies in an optimal and individual way. One of the 5 modules is recommended as the starting module, namely BIW3-13 “Construction Informatics – Fundamentals”, whereas the other one can be chosen out of the remaining four (BIW4-XX). Each of the 4 modules is preferably aligned to one of the Diploma courses, which is indicated by intended audience of the course.

Structogram on Construction Informatics (CI) in the Civil Engineering Curriculum

BIW1-07 *obligatory*	1st + 2nd semester		
BIW2-09 *obligatory*	5th + 6th semester	BIW2-15 *obligatory*	6th semester *One of both depending on the track chosen*

Diploma/Master Course if Construction Informatics Competence is Chosen

Structural engineering	Construction management	Urban and infrastructure engineering	Hydraulic and environmental engineering	Computational engineering	
BIW3-13	BIW3-13	BIW3-13	BIW3-13	BIW3-13 *recomm.*	5th + 6th semester
BIW4-22 *suggested*	BIW4-33 *suggested*	BIW4-60 *suggested*	BIW4-60 *suggested*	BIW4-69 *suggested*	7th + 8th semester

Module BIW1-07: Construction Informatics Fundamentals

Intended Audience: Main courses of civil engineering (1st and 2nd semester)
Duration: 2 semesters
Lectures and Tutorials: Scherer/Kreil

Subjects: This module, comprising two courses, provides basic knowledge about algorithms and data structures as well as their modular implementation in an integrated software system. The relational and the object-oriented modelling and programming approaches and the definition and generation of specific views (such as geometrical, topological and graphical representations) are explained on the basis of real AEC objects. The students obtain the ability to think ‘object-oriented’ in order to structure complex problems modularly and develop generalised modular solutions using algorithms and data structures adequately, with due consideration of their dual and complementary nature. They acquire the capability to formally specify and perform selective, focused modifications as well as further extensions to existing software systems using available software libraries. The module is as preparatory module and introduction module to Building Information Modelling (BIM) and is configured as an e-learning module with object-oriented e-learning tools.

Module BIW2-09: Information Management and Numerical Mathematics

Intended Audience: Main courses of civil engineering (5th and 6th semester)
Duration: 2 semesters
Lectures and Tutorials: Scherer, Reuter/Opitz, Luu

Subjects: The two courses of this module enable the acquisition of knowledge about the basic methods and procedures from the domains of numerical mathematics and information management that are used for the solution of engineering and economic problems in AEC. The students obtain knowledge about principal solution algorithms for linear equation systems and skills in the handling of matrix methods as well as approximation and interpolation techniques, especially using Spline Methods. They learn the fundamentals of Building Information Modelling (BIM) and their object-oriented representation which is especially useful for tackling the complexity and heterogeneity of the information resources in construction, the resulting distributed modular data structuring and the related interoperability methods. Basic techniques for the structuring and the formalisation of complex engineering information are presented that empower the students to handle the complex information used in AEC software in such way that it can be efficiently communicated within cooperative design and project management processes.

Module BIW2-15: System and Information Modelling

Intended Audience: Main courses of civil engineering (6th semester)
Duration: 1 semester
Lectures and Tutorials: Scherer/Opitz

Subjects: The module introduces into system modelling holistic views and BIM with focus on the information flow and information logistics. Basic modelling languages like IDEF0 and EXPRESS are shown. The focus is put on the modelling of sub-systems, on aggregation and on complex relationships of the sub-systems. The students should acquire competence to model the complex energy system of buildings on different levels of granularity as well as in separate sub-systems, and synthesize these to a total system, thereby properly describing the building and the energy system both as a whole and as their parts like the solar sub-system, the building envelop, the sensor system, the building usage or the user profiles in the frame of the overall building life-cycle.

Module BIW3-13: Construction Informatics – Advanced Fundamentals

Intended Audience: All master courses in civil engineering (selectable obligatory module) Obligatory module for the master courses in Computational Engineering
Duration: 2 semesters (from 5th semester up)
Lectures and Tutorials: Scherer/Opitz, Hamdan, Ismail

Subjects: The module comprises courses on the topics ‘System Theory and Logic’ and ‘Graph Theory’. It introduces the fundamental principles of Mathematical Logic and provides an overview of the basic rules of 1st and 2nd Order Predicate Logic thereby enabling the acquisition of basic knowledge in conceptual modelling, logical reasoning and consistency checking of complex systems. The fundamentals of Relational Algebra are presented and on that basis the classification of Graphs (as e.g. simple, bipartite, multi- and hyper-graphs) together with their specific properties are explained. Furthermore, the fundamentals of graph based Network Planning are presented including topics like 'paths in networks', ‘path algebra', 'flows in networks' etc. Basic knowledge about Petri Nets is also provided to enable the students to (1) develop, (2) formally describe and (3) check in terms of consistency various functions of static and dynamic systems such as the force flows in structural systems, the transportation flow (logistics) in urban planning and construction project management and the overall information and work flows in construction projects (information logistics). The students acquire relevant system-theoretical knowledge and learn composition and representation methods that will enable them to distinguish between various formalisation possibilities such as state-space-based, event-based or activity-based modelling.

Module BIW4-22: Cooperative Design Work and Numerical Methods

Intended Audience: Master programme in structural and computational engineering (selectable obligatory module)
Duration: 2 semesters (from 7th semester up)
Lectures and Tutorials: Scherer, Reuter/Katranuschkov

Subject: This module comprises two courses on the topics 'Numerical Engineering Methods and Visualisation' and Methods for Collaborative Work'. The first course imparts basic knowledge about the numerical algorithms for (1) function approximation, differentiation and integration, (2) the solution of non-linear systems of equations, (3) boundary problems in ordinary differential equations of first and higher order, (4) partial differential equations and (5) eigenvalue problems, as well as knowledge about the stability and decidedness of numerical solutions. It provides also principal knowledge about the visualisation of multidimensional variables thereby generating skills to use graphical methods for the visualisation of engineering values and entities in goal-oriented manner, in order to correctly determine system behaviour. The second course imparts basic knowledge with regard to (1) distributed information management with long engineering transactions, (2) cooperative work methods, (3) workflow methods and (4) data security. On the basis of this module the mathematical and information technology prerequisites for efficient practicing of networked cooperative design work are acquired.

Module BIW4-33: Software Systems

Intended Audience: Master programme in construction management (selectable oblig. module)
Duration: 2 semesters (from 7th semester up)
Lectures and Tutorials: Scherer/Katranuschkov, Ismail

Subjects: The module comprises courses on the topics 'System Development' and 'System Integration'. It imparts capabilities (1) to conceptualise an integrated information system that satisfies the requirements of a construction project, and (2) to use efficiently proprietary software programmes applying as much as possible commonly known, typical tools and standardised data structures. The focus of the acquired knowledge is on practice relevant methods of system development, database design, structuring and application, and the conceptualisation of appropriate interfaces. The knowledge acquired in the area of System Development, includes the preparation and use of requirements analyses, the formalisation of the information process and the information flows, the development of system architectures and of meta data structures, and the definition of programming specifications. The knowledge acquired in the area of System Integration addresses the capabilities to develop the structure of a database using a typical database management system (DBMS), create the database itself using standard software tools, conceptualise appropriate interfaces, and integrate data converter, filter and external web-based services.

Module BIW4-69: Simulation and Monitoring of Engineering Systems

Intended Audience: Master programme in hydraulic and environmental engineering (selectable obligatory module)
Duration: 2 semesters (from 7th semester up)
Lectures and Tutorials: Scherer/Katranuschkov, Hamdan

Subjects: This module comprises courses on the topics 'System Simulation' and 'Data and Information Analysis'. It enables the acquisition of skills for multidisciplinary conceptualisation, control and monitoring of dynamic processes in engineering systems, as well as for their modelling and simulation and the definition of appropriate interfaces for their modularisation. The students acquire the necessary knowledge about numerical and computational methods for the simulation of dynamic systems and about various approaches for the application of distributed computing. Furthermore, they acquire knowledge of the basic methods for data analysis and data reduction as well as Fourier, principal axis and wavelet analysis. The module imparts fundamental knowledge on Information and Data Mining Methods that will enable the students to correctly interpret the behaviour of an engineering system in order to identify damage and complex damage inter-relationships, system malfunctioning and system gaps, and establish appropriate risk management procedures.

Module BIW4-70: Model-based Working, BIM

Intended Audience: Master programme in construction management (selectable oblig. module)
Duration: 2 semesters (from 7^{th} semester up)
Lectures and Tutorials: Scherer/Hamdan, Luu

Subject: Through the two courses of this module the students acquire basic and advanced BIM capabilities to structure and formalise complex construction projects in order to handle their information logistics and internal relationships efficiently. This enables them to design an appropriate organisational and processing structure, determine the respective information management methods and procedures and develop appropriate risk management plans. The module imparts knowledge about (1) contemporary modelling methods, (2) object-oriented data structures and the conceptualisation of meta schemas and hierarchical schemas, and (3) interoperability approaches based on methods for model mapping, matching and merging. In the first course detailed knowledge is provided with regard to methods for formal object-oriented system description, the formation of subsystems and consistency checking, and their realisation on the basis of numerical and logical algorithms. In the second course detailed knowledge is provided about the modelling of project processes and process flows, including the complementary information processes and their formal representation.

Module: Information Systems (read in English)

Intended Audience: ACCESS Master programme, European Master programme IT in construction
Duration: 2 semesters
Lectures and Tutorials: Scherer/Opitz

Subjects: This module is comprised of three parallel courses: (1) Management Information Systems, (2) Information Mining, and (3) GIS for Infrastructure Systems.

The first course introduces the methods for object-oriented modelling of complex engineering systems. Further course material focuses on communication methods and the formal representation of communication goals which allow the efficient application of automatic evaluation and decision support methods and algorithms. A third part of the course is specifically dedicated to the use of control methods and the development of a methodology for performance measurement.

The second course introduces methods for data analysis and data mining, such as correlation and regression, classification, decision trees and clustering, whose practical application aims at the early detection of damages and faulty system behaviour. In conjunction with that the scope of application and how the methods are complemented are discussed. Part of the course is specifically dedicated to data pre-processing since the efficiency of the methods strongly depends on the modelled data.

The third course provides an introduction into graph theory, by which the partitioning and the formal area-related variables dependencies can be described. The mapping from object-oriented data models to area-related representations and the generation of area boundaries by means of data mining methods are discussed. Different ways of graphical representation for complex, multi-layered information in terms of area magnitude are introduced. The lectures and tutorials provide insight into preferred modelling and data analysis techniques for corresponding graphical representation methods.

Module BIWO-04: Software Engineering

Intended Audience: Master programme in Advanced Computational and Civil Engineering Structural Studies
Duration: 1 semester
Lectures and Tutorials: Scherer/Reuter

Subject: This module aims at providing students with knowledge of the basics in software engineering for computational engineering, in particular complex software system design, data structures and numerical algorithms for continuous mathematics. The module is divided into two parts. The part software systems covers system capturing and system architecture, formal representation of systems, relational and object-oriented data structures, object-oriented modelling of complex engineering systems, communication and data exchange, user interfaces, and application for integrated engineering systems for monitoring and control. The part numerical methods covers the construction and analysis of algorithms to solve continuous mathematical problems, direct methods to compute the exact solution to a problem in a finite number of steps at unlimited computer precision, iterative methods to compute approximations that converge to the exact solution, solution of linear and non-linear equations, systems of equations and eigenvalue problems, numerical integration and interpolation, and implementation of the algorithms in software applications.

Publications in 2016

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[2] BAUMGÄRTEL K., PIRNBAUM S. & SCHERER R. J.: Automatische Prüfung und Filterung in BIM mit Model View Definitions, In: Proc. 28th Forum Bauinformatik, Hannover, Deutschland, September 2016.

[3] BAUMGÄRTEL K., PIRNBAUM S., PRUVOST H. & SCHERER R.J.: Automatic BIM filtering using Model View Definitions, In Proc. 33rd CIB W78 conference, Brisbane, Australia, November 2016.

[4] BENEVOLENSKIY A.: Ontology-based Modeling and Configuration of Construction Processes Using Process Patterns (Ontologie-basierte Modellierung und Konfiguration der Bauprozesse mit Hilfe von Prozessvorlagen, Dissertation). ISBN: 978-3-86780-477-6. Serial publications of the Institute of Construction Informatics at TU Dresden, Volume 12. February 2016.

[5] CALLEJA G., GURUZ R., GEIßLER M.C., STEINMANN R., LINHARD K. & DANGL G.: Collaboration requirements and interoperability fundamentals in BIM based multi-disciplinary building design processes. In: Proc. eWork and eBusiness in Architecture, Engineering and Construction: ECPPM 2016, Limassol, Cyprus, September 2016.

[6] FUCHS, S.: Access of Cross-domain Information Spaces Using Multi-models (Erschließung domänenübergreifender Informationsräume mit Multimodellen, Dissertation), Technische Universität Dresden, Fakultät Bauingenieurwesen, 2015, ISBN: 978-3-86780-451-6, http://nbn-resolving.de/urn:nbn:de:bsz:14-qucosa-182126

[7] GRILLE T., PRUVOST H. & SCHERER R.J.: Stochastic Analysis for Design Space Exploration and Building Performance Optimisation, In Proc. Central European Symposium on Building Physics 2016/BauSIM 2016, Dresden, Germany, September 2016.

[8] GURUZ R., KATRANUSCHKOV P., SCHERER R.J.: eeBIM LAB – Towards a coherent green building design process. In: Proc. CESBP Central European Symposium on Building Physics / BauSIM 2016, Dresden, Germany, 14-16 Sept 2016.

[9] HILBERT F.: Context Adaptive Information Spaces - Support of Interdisciplinary Information Processes through a Context-aware Information Logistics (Kontextadaptive Informationsräume: Unterstützung interdisziplinärer Bauinformationsprozesse durch eine kontextbewusste Informationslogistik, Dissertation). ISBN: 978-3-86780-482-0. Serial publications of the Institute of Construction Informatics at TU Dresden, Volume 13. March 2016.

[10] ISMAIL A., SREWIL Y., SCHERER R.J & MANSPERGER T.: Semantic Enrichment and Multimodel Data Exchange Approach for CFD Analysis of Bridges, In: Proc. European

Group for Intelligent Computing in Engineering: EG-IC 2016, Krakow, Poland, 29th Jun. 1st Jul. 2016.

[11] ISMAIL A., SREWIL Y. & ABEDIN S.: Applying visual programming methods for parametric bridge modeling and generation of model variations, In: Proc. 28th Forum Bauinformatik, Hannover, Deutschland, September 2016.

[12] KADOLSKY M., SCHERER R.J.: Task-Specific Linking for Generating an eeBIM Model based on an Ontology Framework, In Proc. eWork and eBusiness in Architecture, Engineering and Construction: ECPPM 2016, Limassol, Cyprus, September 2016.

[13] KATRANUSCHKOV P., SCHERER R. J., BALARAS C.: BIM-based multi-model framework for energy efficient design. In: Proc. 41st IAHS World Congress "Sustainability and Innovation for the Future", 13-16 September 2016, Albufeira, Portugal, Paper ID 218

[14] KATRANUSCHKOV P., SCHERER R. J., HOCH R.: Optimizing energy efficient building design using BIM. In Proc. ICCCBE 2016, 5-8 July 2016, Osaka, Japan, Paper ID 113.

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[16] POLTER, M., SCHERER, R. J., ISMAIL, A., GRILLE, T., HAMDAN, A., LUU, N. T.: Schlussbericht zum Vorhaben "Virtuelles Ingenieurlabor – SOA-basiertes Informationssystem zur Integration von Grid-/Cloud Rechenleistung und BIM Informationsmanagement", Report, Technische Informationsbibliothek Hannover, Oktober 2016.

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Positions in Editorial Boards of Journals

Automation in Construction	Elsevier Publishers	The Netherlands
Information Technology in Construction (electronic journal)	Intl. Council for Research and Innovation in Building and Construction (CiB)	The Netherlands
Construction Innovation	Emerald Group Publishing	UK
Design Sciences and Technology	European Productions	France

Membership in Standardization Groups

DIN NA 152-06-05	Standardization committee for technical product documentation	Member
DIN NAM 96.4.1-3	Product data exchange in civil engineering	Member
ISO 10303/BC	Standard Exchange of Product Data, work group Building Construction	Member
buildingSMART	Building SMART International Alliance for Interoperability, German Council (product modelling in AEC/FM)	Member of the Multi-Model group
VDI 2552	Guidelines for BIM	Chairperson of working group #8 Qualifications