TECHNISCHE UNIVERSITÄT DRESDEN
INSTITUT FÜR BAUINFORMATIK
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RESEARCH AND LECTURE ACTIVITIES IN 2016

December 2015

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 2016. 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. Most of the topics have been accumulating in our ongoing common development “An 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.

2015 was a year of consolidation and of successfully exploiting the results of our first two research projects on energy efficiency, HESMOS and ISES, moreover migrating the results to the current 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 *http://openeebim.bau.tu-dresden.de/software/ivel.zip*. 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.

The institute strongly promotes ICT in research and industry. Prof. Scherer is chairman of the European Association of Product and Process Modelling, which will hold its 11th ECPPM conference in Limassol, Cyprus, on 9th-11th September 2016 (*http://www.ecppm.org*). The ECPPM started in 1994 and is the oldest BIM conference. The preceding one in Vienna in 2014 was a very successful one with over 150 participants and over 120 papers. In conjunction with the 10th ECPPM, the 5th Workshop on ee-Building Data models was held, which underpins the importance of BIM methods for energy-efficient design and maintenance of buildings.

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/)*. In November 2015, the institute organized the 6th conference “Bauinformatik – Baupraxis” (construction informatics – construction practice) in Dresden, supported by the Saxon chamber of architects, the chamber of engineers and the “Dresdner Bauinformatik-Gesprächskreis” (Dresden Construction Informatics Roundtable) on the topics ongoing regulations – guidelines – standardization for BIM, which provided an overview of the VDI work.

E-learning results of the project eWorkBau with focus on the interfaces for BIM access and a domain BIM query language are both available as freeware BIMcraft on the openeeBIM website and embedded in e-learning courses. The European online Master course “IT in Construction”, coordinated by the University of Maribor, Slovenia, is now in its 12th academic year and students can enrol at 7 European universities.

In early 2015, Ksenia Roos submitted her PhD thesis and left the institute. In July, Sebastian Fuchs successfully defended his PhD thesis on multimodels. In July and September, Eko Nityantoro and Mario Gürtler left the institute for interesting positions in industry. Helga Tauscher submitted her PhD thesis in late 2015 and will pursue her carrier in industry. In December, Al-Hakam Hamdan and Ngoc Trung Luu defended their diploma theses and join the institute as researchers in January 2016. Alexander Benevolenskiy will have his PhD defence in December and then continue his research carrier at the institute.

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, Russia, Syria and Turkey.

Collaborative research has successfully been continued in 2015. Dr. Sylvain Robert from the CEA, France, together with two students, Bastien Guillon and Robin Delgado from the Université Paris Sud, had a 2-month stay for in-depth research at our institute in July and August.

Several members of the institute have received awards. Ronny Windisch and Alexander Wülfing have got the second prize in the category construction management and Ken Baumgärtel has got the third prize in the category civil engineering, both for best annual ICT software in construction informatics from the German ministry of construction and infrastructures at the annual construction fair.

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

Dresden, in December 2015 Raimar J. Scherer

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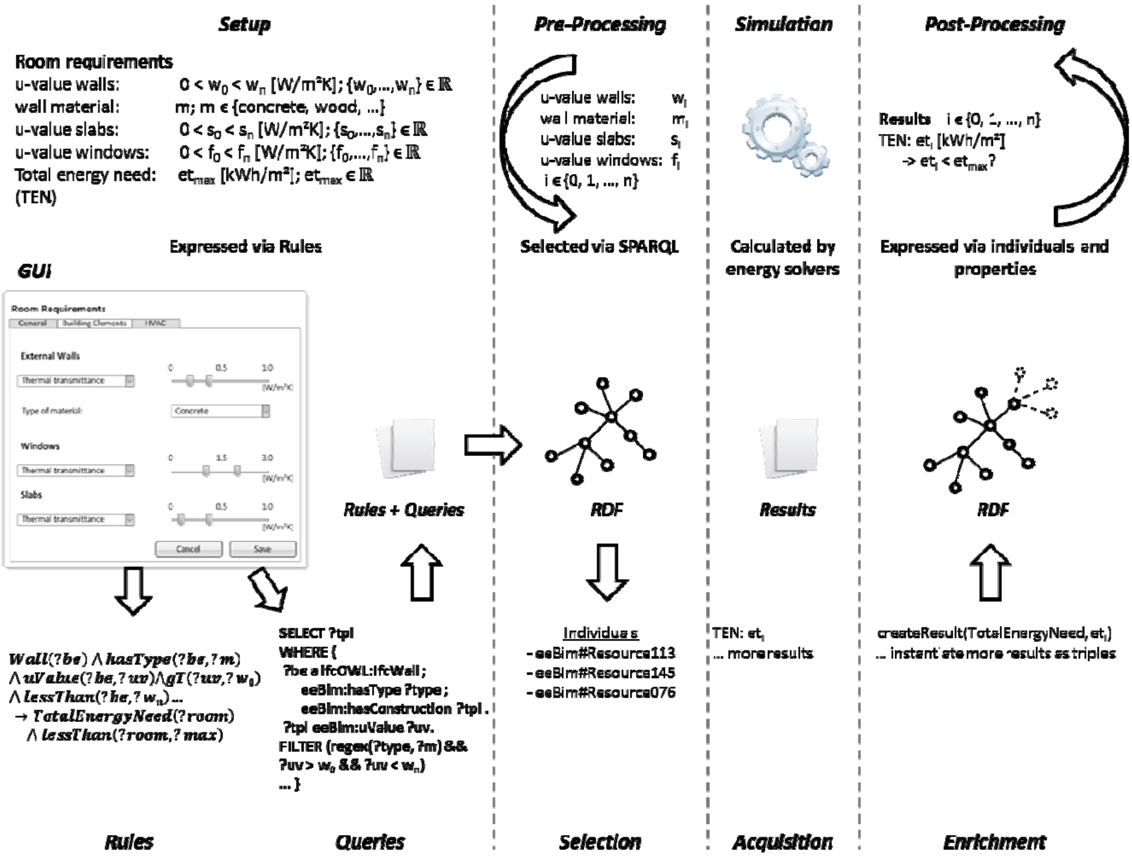
Overall the employees at the institute cover a broad range of expert domains as well as languages with researchers from Bulgaria, France, Iran, Russia, Syria, and Turkey.

Ontology-controlled Energy Simulation Workflow

Ken Baumgärtel

Objectives

A green building design consists of strategies that conserve resources, reduce waste, minimize life cycle costs, and create healthy environment for people to live and work. Especially in the conceptual stage, decisions have considerable impacts on the building performance, for example the right shape and the correct building orientation can reduce energy consumption by 30-40%. Unfortunately, the iterative trial-and-error process of searching for a better design solution is time-consuming and ineffective because of the inherent difficulty in exploring a large design space. Therefore, an intelligent sensitivity analysis with automatic selection of parameters can help to find out optimized green building designs.



Ontology controlled simulation cycles

Approach

The simulation-based target values and green building design requirements are set up by the user and stored in the ontology together with rules and SPARQL queries for configuring and validating simulations later on. The simulation resource selection in the pre-processing phase is done in the following way: if there are assignments which are of cardinality 1:1 they will be static in the whole sensitivity analysis and used for every simulation run. For example, the user defined that all windows are triple-glazed and have a specific glass and frame fraction. If the user specifies value ranges, for example for the thermal transmittance value, then this are dynamic resources and there will be a cardinality of 1:n, so that in each simulation this value will be replaced by a new value within the defined range. In each simulation run one resource will change regarding the required parameters until the first solution was found which fulfil all required key performance indicators (KPIs) or, if the user wants to have the best solution, until all acceptable resources were taken. The energy simulation solver consumes the selected static and dynamic resources and computes the results in multiple files like estimated room temperatures for the whole year based on the used weather data, heating energy, cooling energy etc. In the post-processing phase these results were used to compare the KPI as-is with the KPI to-be. The computed KPIs are instantiated as individuals in an RDF graph so that the generated rules and constraints of the setup phase can be applied. If the simulation results show that there is a variant with defined thermal transmittance values and a total energy not higher than the predefined target value then this is added to the design candidate list. This research is part of the eeEmbedded project.

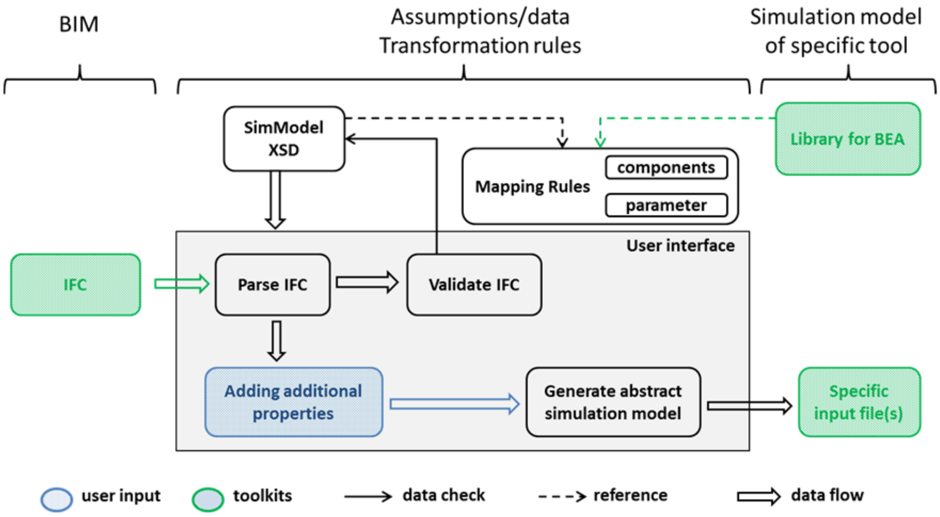
From BIM to Building Performance Analysis

Frank Noack

Objectives

Translating from a Building Information Model (BIM) to a Building Performance Analysis Model (BPA) has historically been an error-prone and time-consuming process. To set up an energy-performance analysis, specialist engineers gather and combine 2-D or 3-D drawings, material data and other information to construct the simulation model in the respective software. There are different paths between BIM and BPA. But no matter what tools are used, getting a valid BPA for whole building energy analysis is a vitally important step.

The Green Building XML schema (gbXML) was developed to capture the appropriate information to enable interoperability between building design models and a wide variety of engineering analysis tools and has become a defacto industry standard schema. The disadvantage of gbXML is that it comprises only part of a building information model, necessitating conversion to and from other models like IFC. There is already an IFC Model View Definition for building energy performance analysis (MVD-BEA). The MVD-BEA specifies the different IFC components required for energy analysis. Nevertheless, some information is still not provided by MVD-BEA or even IFC. Furthermore none of the commercially available tools for energy BPA supports seamless input from the IFC format.



Workflow for model transformation. The building model can be stored as an IFC (ifcXML) file, the transformed simulation model is stored as output of the system.

Approach

Modelling, simulation and analysis of heavy heterogeneous systems which involve multiple domains, such as thermodynamics, fluid dynamics, heat and mass transfer, electrical systems and control systems requires a higher level of abstraction and modularisation to manage the complexity compared to established building simulation processes. It requires a separation of the particular simulation model in the simulation framework - bound to the special software as input specification - from a more generalized simulation information model.

The whole purpose of this abstract simulation information model is to provide the modelling and simulation environment representing knowledge about the physical system in a way that is usable for different simulation tasks. The simulation information model represents the user interface and does not depend on how it is going to be used by the simulation program. This separation is an essential principle for a future modelling and simulation environment which does not depend on particular tools for simulation of building systems or BPA respectively.

From the abstract model, a simulation model for a specific tool can be generated by using symbolic manipulations to sort or invert equations and replace derivative operators with numerical discretisation schemes. The generation of the simulation can be done manually by a programmer, as it is the current practice in most cases or alternatively it can be semi-automated or even automated, as done in equation-based modelling environments for component-oriented, multi-domain modelling of dynamic systems.

This research work is part of the projects eeEmbedded, Design4Energy and HOLISTEEC.

Stochastic Analysis Workflow for Building Design under Uncertainty

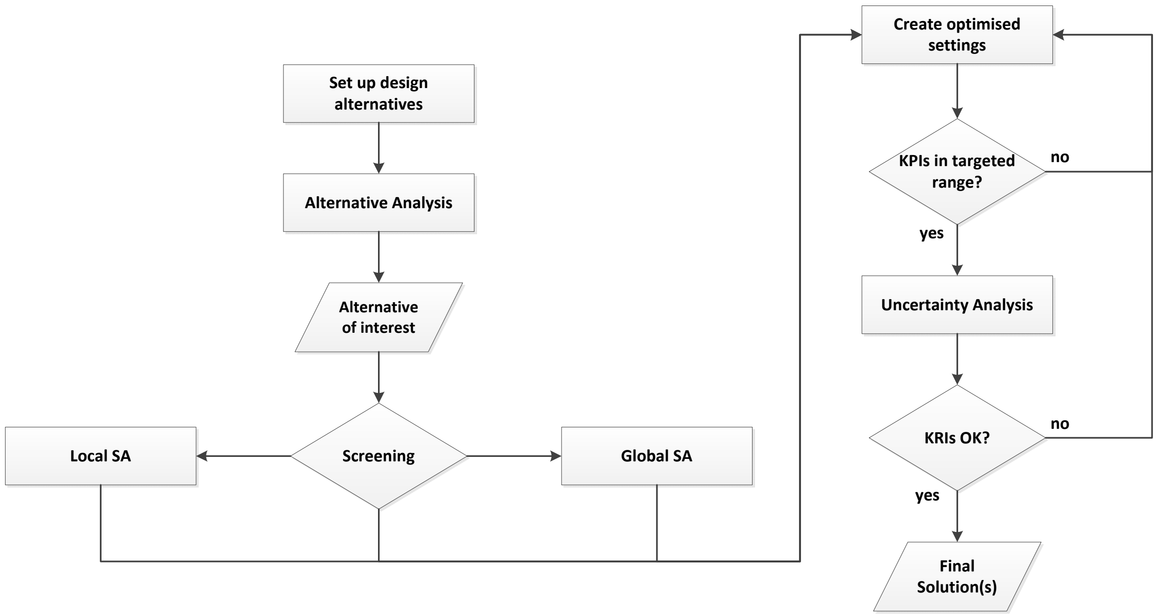
Tom Grille

Objectives

A modern building design has to meet several conflicting demands, like safety, cost and environmental considerations. When trying to quantify the fulfilment of these goals by a specific design, several sources of uncertainty have to be considered. Here the focus lies on uncertainties that are inherent in the future usage of the building and influence the energy balance of the building. For example typical uncertainties reside in weather conditions and building occupancy.

After the specification of target values, one can monitor there fulfilment using a Key Performance Indicator (KPI) framework. A KPI is a numerical value mostly gained through simulation that represents a decision relevant characteristic of the design at hand. Simple examples for KPIs are “energy consumption per year”, “CO_2 emission per year” or “maintenance costs per year”.

Sensitivity Analysis and Uncertainty Analysis are used to specify the impact design decisions (represented by design variables) have on the KPIs and to examine the effects of the considered uncertainties.



Sensitivity and Design Optimisation Workflow

Approach

To verify and optimise a building design, three different kinds of analyses are combined: Alternative Analysis (AA), Sensitivity Analysis (SA) and Uncertainty Analysis (UA).

AA is a comparison between different possible solutions and serves as a starting point for further examination. When one design is elected for in depth analysis, a specific set of SA techniques is applied. First a screening, e.g. the Morris’ Method gives a rough ranking of the importance and the kind of impact of the different design variables. By identifying neglectable variables, the amount of variables under consideration can be reduced and thus the computational time of the following examinations can be lowered considerably. Now a combination of local and global SA techniques, e.g. differential analysis and the Fourier Amplitude Sensitivity Test, is applied to gain detailed insides into the interactions between the different design variables and their impact on the KPIs of interest. After possible changes of the design and repetitions of the SA steps, finally the uncertainties, also called stochastic regressors, are considered. To do so each uncertainty is modelled separately and the design under consideration is simulated repeatedly with random samples from the stochastic regressors. This procedure yields the probability distributions of the KPIs when uncertainties are considered. From these distributions, so-called Key Risk Indicators (KRIs) can be derived which are used for the final validation of the design.

This research work is part of the eeEmbedded project.

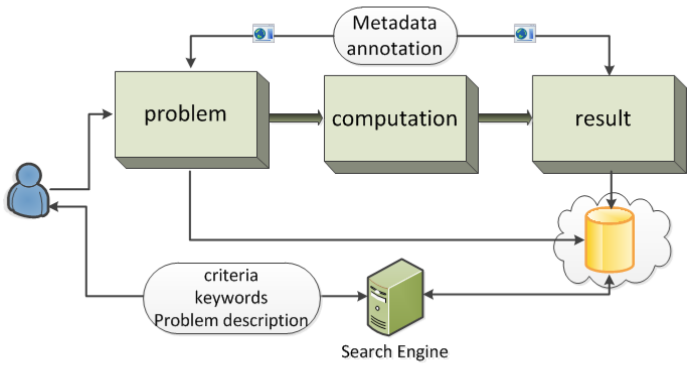
Model Generation and Storage Optimization for Mass Computing Applications in Civil Engineering

Michael Polter

Objectives

Parametric studies demand the creation of a huge number of building models. Currently an EXPRESS schema for the definition of parameter variations directly in the IFC file is developed. However the single values still have to be determined manually which can be very elaborate for a huge number of model parameters. The goal is to enhance our *integrated Virtual Engineering Laboratory* (iVEL) with a component for the generation of parameter values for different simulation tasks.

Another area of interest is the efficient storage and retrieval of computation results. Though the result files can reach sizes up to 5 GB, the technological progress in the area of memory allows long time archiving of nearly all generated artifacts at relative low cost. However the storage of huge amounts of data only makes sense if the cost for the retrieval of specific information is kept low as well. Therefore efficient data management methods, customized for the civil engineering domain, are indispensable.



Intelligent storage and retrieval of problems and computation results

Approach

When it comes to the generation of parameter values, the following three aspects have to be considered: 1) the development of generation rules, 2) the reuse of already determined values for similar problems and 3) the exclusion of invalid values through the definition of constraints which have to be complied with. Therefore different applications of parametric studies and possibilities for problem grouping have to be investigated. This will help us to determine adequate, problem and parameter specific generation formulas as well as possible relations between the current task, the investigated structure and the computed parameter value. The definition of constraints for the exclusion of values or value combinations is essential to reduce the amount of models which have to be computed and hence to keep the demand for computing resources as low as possible.

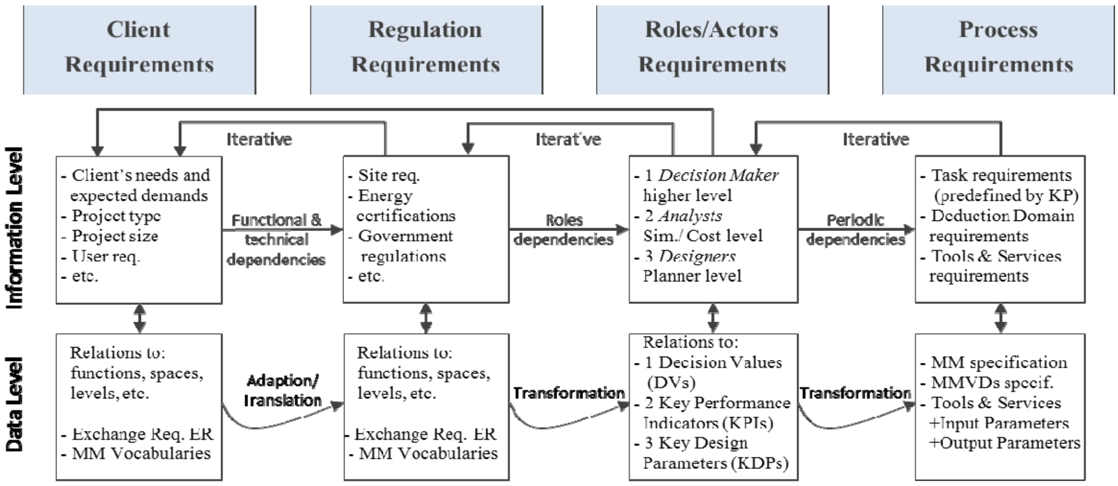
Furthermore our research is focused on the storage of results, especially in mass computing applications like parametric studies. The motivation is to find the optimal and hence most cost effective utilization of resources. Therefore common civil engineering problems have to be investigated regarding to the resources needed for their computation and the resources needed for the storage of the results. Then it has to be determined if it is more effective to store the computation results or to simply store the problem description and to recalculate it on demand. In both cases the semi-automatic annotation with suitable metadata would support the quick recovery of information or even the deduction of implicit information with data mining strategies (Figure 1). Regarding to the storage of data itself we look for the best way of distributing it across the local computation grid or even the cloud under consideration of the locality principle to reduce the network traffic to the lowest possible amount. This research work is part of the *SE-Lab* and *eeEmbedded* projects.

Integration, Management & Assessment Framework for Building Requirements

Romy Guruz

Objectives

A construction project is a complex task of closely interwoven subtasks and many-sided interests. The goals of planning are basically determined by the previously defined requirements and are thus essentially depending on whose accuracy, intelligibility and targeted placement. Supporting tools for managing client and functional requirements as well as government regulations before and during building design are barely or not available. This lack causes among management gaps and also an inadequate verifiability of design requirements. The Key Point design methodology is an approach to verify requirements during the interdisciplinary building design processes. Key Points are defined as *e.g. energy related* verifiable design check points, expressed in Decision Values (DVs), Key Performance Indicators (KPIs) and Key Design Parameters (KDPs), which are providing domain related requirements in form of target values, which can be checked after common design steps. Concepts and procedures for the practice verifiable Key Points during the design process are already developed. This research aims the development of an integration, management & assessment framework to adapt and transform client and regulation requirements on data level in a generic, repeatable way. Benefits are the synthesis between structured requirements (non-geometric data) and later established design results represented by e.g. geometric models, enhanced possibilities in allocation of templates and in the provision of consistent data already at the beginning of the design processes as basis for an automation of supported process steps.



Adoption and transformation from the left: "what" to achieve, to the domain on its right: how to fulfil "what"

Approach

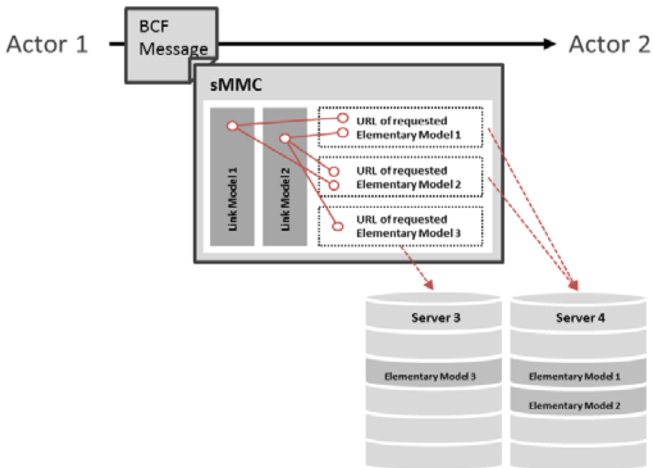
The client domain considers the needs and aspects that the client is looking for in building, technical system, materials and/or process etc. In the regulation domain, the former collected needs are specified in alignment to the regulations. This step is needed to be repeated during the whole planning process. In order to fulfil the fully specified requirements, the Key Points are defined and allocated to the individual performer in the roles' domain. As a result, the Key Points are structuring the design phases and sub-phases which are characterized by variables in the process domain. To enable a gapless integration of requirements, with regard to the full deployment in the participating domains, the following technique is suggested: in the first step, the client needs and qualities are collected and structured, then adapted for, translated in and extended with regulatory requirements. Client requirements are not always unambiguous and thus vulnerable to incorrect interpretation. Hence, the requirements are specified in depth and checked after each main planning step for consistency. The second step describes the transformation of the most significant requirements into domain related Key Points. This transformation step is typically a one-to-many process which means, for a given requirement several Key Points can be influenced. The suggested hierarchy in role requirements allows discovering the correct responsibility. Finally, the design processes that are characterized by Key Points can be developed with the last transformation. This research work is part of the on-going EU project *ee*Embedded.

Utilizing the Lean Multi Model Container Approach to Encounter Collaboration Obstacles

Marc Mosch

Objectives

During planning and construction of a building, companies from different domains have to cooperate to reach a common goal. Yet at the same time each company pursues targets of their own agenda. The individual goals are likely to interfere with other companies' goals, leading to competition situations where it is desirable to provide as much information as possible and at the same time as little as necessary. In those situations it becomes beneficial to be able to hide certain information from others to retain privacy of information, which is an important aspect of entrepreneurship. The Multimodel approach proposed as a solution is typically intended to support collaboration and data exchange and not so much as a means to ensure privacy. This approach involves a Multimodel Container which combines different Domain Models by linking individual elements to each other or to other models via Links, which are organised separately in Link Models. This concept makes no strict provisions on where the Models have to be located. Therefore it is possible to store and transport the models inside the container, but it is also possible that the Multimodel Container only stores links to the corresponding Domain Servers and Link Models. Besides the collaboration benefits, this *Lean Multimodel Container* to be investigated in depth in the eeEmbedded project, offers another advantage which is beneficial in the field of tension between the benefits and risks of cooperation in general and in the building industry in particular.



Lean Multimodel Container approach

Approach

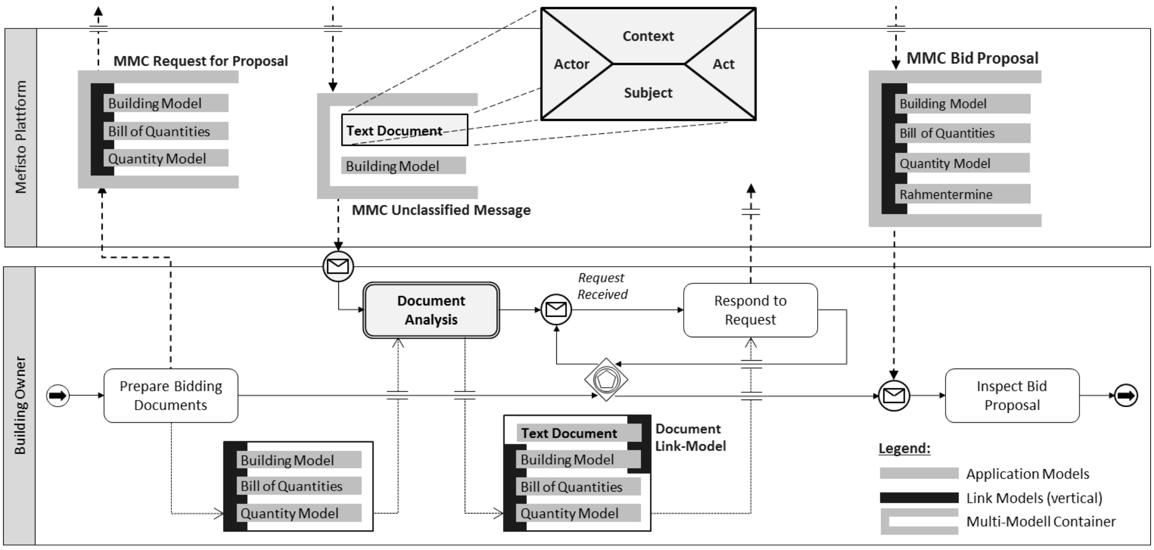
The concept of Lean MMCs seems to be an appropriate measure to address the above mentioned challenge. By referring to models or to parts of them instead of transmitting whole models directly, it is possible to restrict access. In an ideal case, the owner of the model is the owner of the storage location and is thereby able to restrict access to particular model segments that are worth protecting. It is furthermore possible to define who is granted access to which parts of the model as well as to monitor this access. The research efforts will be focused on the tweaking of the Lean MMC architecture characteristics and their effects on the settlement of the given challenge to find a balance between cooperation and the protection of legitimate interests. This research work is part of the projects eeEmbedded.

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

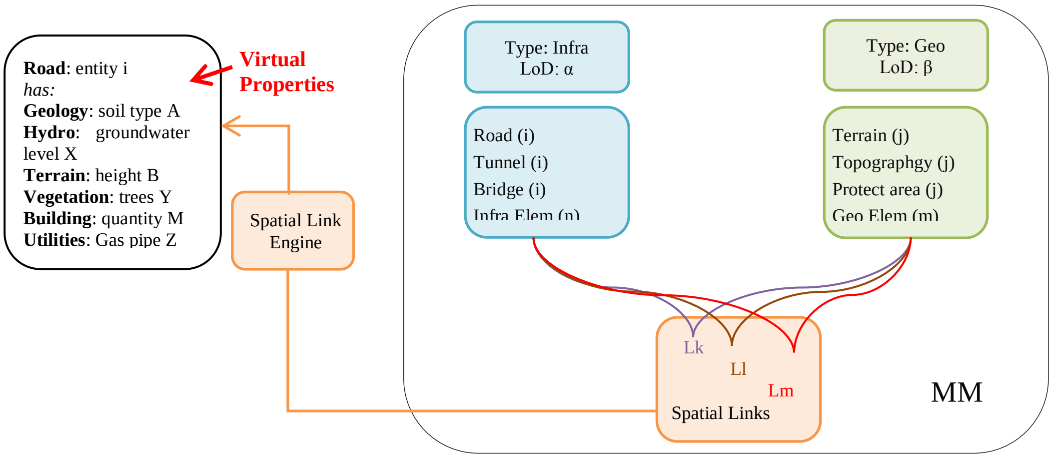
The figure above illustrates the analysis of a text document within the context of a Multi-Model Workflow for construction bidding. While predetermined formal MMCs can be used for the request and the submission of bidding information by/to the owner, intermediate requests and notifications may comprise 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.

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

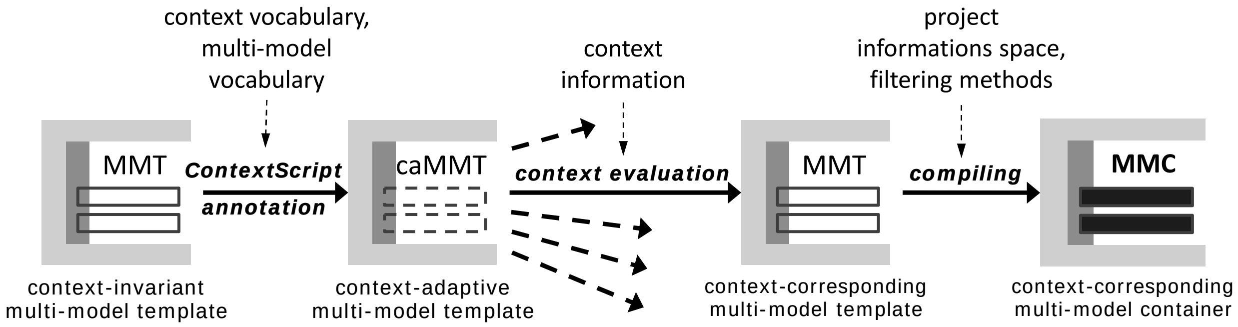
Multi Model (MM) is a method where heterogeneous data models from various domains are bundled together into a container keeping their original format. In separate Link Models the elements of the data models will be linked together. Yet the multi model and the generated links have no inherent domain semantic. 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.

Context-Aware Information Spaces in Construction

Frank Hilbert

Objectives

The planning and creating of structures and buildings are based on interdisciplinary construction information processes. The information supply thereby is characterized by a decentralized exchange of heterogeneous domain models. Several model elements are often interdependent. Such a collection of models and its dependencies form so-called information spaces. With such an information space, the need for information of an information process can be satisfied. In the future, a steady increase of the information volume can be expected. Therefore, the possible information spaces are becoming larger and more complex, although no one needs all the available information at the same time. Thus, an effective situation-adapted supply of information will become increasingly important. Looking at the information needs of construction information processes a context dependency can be established, because the compilation of the required information space is influenced by different aspects of the process situation (the user role, technical possibilities, project phase, etc.). With knowledge of these aspects, context-dependent information needs can be anticipated and a context-oriented information supply of construction information processes can be realized. A prerequisite for such an intensive use of contextual information is a methodology that enables to formally depict dependencies between contextual information and information space elements.



Context-compliant multi-model container by using context-adaptive templates

Approach

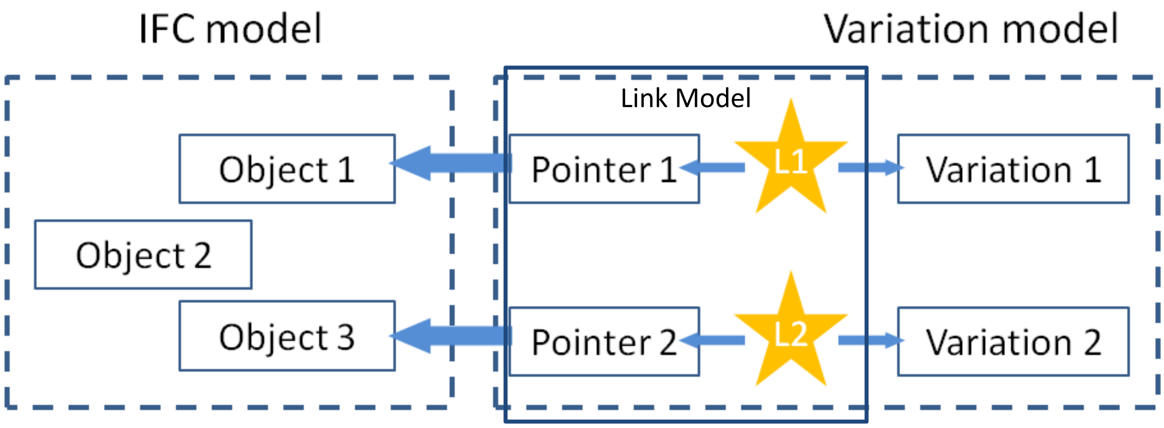
One implementation of the informational space concept is the multi-model methodology. A special feature is the possibility of describing needed multi-models by so-called multi-model templates. Based on these templates an approach was developed to formalize the context dependencies of the information needs. Originally, the structure of these templates is static and for each processing situation, a new custom template needs to be created. In order to make the templates adaptable, the ContextScript approach has been developed. Through ContextScript a mapping between acting contextual factors and affected information space parameters in multi-model templates can be represented. For this, a ContextScript rule is annotated directly in the multi-model template instead of a static attribute value. Such an annotated multi-model template can be persisted as a so-called context-adaptive multi-model template along with an associated reference process. At the time of use appropriate situational information requirements can be derived based on the situational context. Finally, these requirements support the generation of corresponding context-oriented information spaces. Thus, the presented approach allows for the realization of a context-oriented information supply that makes it possible to anticipate context-based information needs and to generate a corresponding situational information space. This approach may be the basis for a context-sensitive information logistics, which accurately provides the information spaces for the project partners in the construction industry, which are needed in an actual work situation. The research described here was enabled by the financial and technical support of the Mefisto project partners and the German Ministry of Education and Research (BMBF).

A Concept for the External Definition of Building Model Variants

Ngoc Trung Luu

Objectives

During the planning process structure usually undergo a large number of different building model variants which have to be exchanged between several designers which use different software. For example non-linear structural analysis requires a variety of separate analysis from building model variants for each load combination. Another example are design variants of constructions, which have to be considered separately. The application from one to another construction software requires the time and cost consuming transformation of the models into the software-specific data format. The Industrial Foundation Classes (IFC) as standard for the exchange and sharing of virtual building models allows a barrier-free model exchange between construction software, but yet does not possess a concept for transferring data efficiently for similar model variants. Currently the exchange of model variants is realized costly with multiple IFC building models.



Conceptual structure of the variation model

Approach

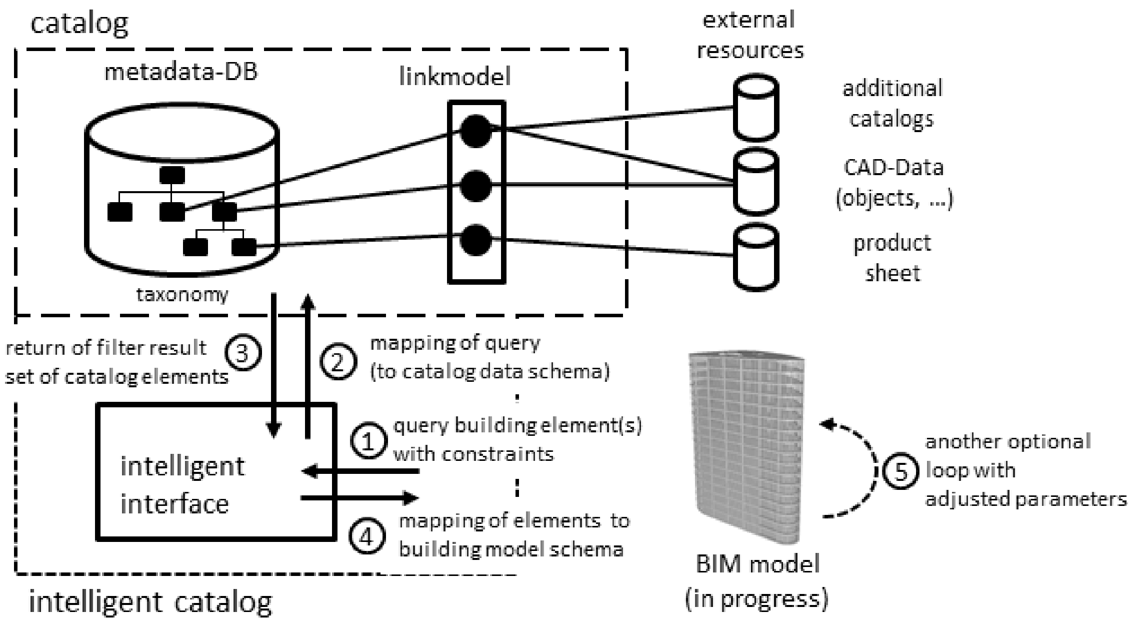
The concept of a separate variation model eases the exchange of building model variants. It allows the description of multiple model variants in a variation model. The variants are expressed there as a specific set of parameter variations, which differ from the basic IFC building model. Therefore only the variation model with its link model and the basic building model have to be shared between the stakeholders, instead of exchanging a complete IFC building model for each model variant. For validation a prototype is implemented, which generates the model variants as IFC building models from the basic and the variation model. The data structure of the variation model is formalized by a variation scheme in the description language EXPRESS. A parameter variation in the variation model consists of the parameter values and a link which references the related parameter in the origin building model. This structure is chosen, whereby variation models can be reused for different building models by replacing the pointer for the new parameters of a different model. The parameter values can be stored in a list or be represented by a result of Boolean operations and lists. Furthermore the scheme offers operations to connect the particular parameter variations into model variations. This allows the definition of complex model variants with multiple parameters which distinguish from the basic model. This research work is a part of the on-going EU-projects SE-Lab and BridgeCloud.

A Multimodel Approach for Intelligent BIM Product Catalogs

Frank Opitz

Objectives

In spite of the BIM based working paradigm many design decisions and various design activities are carried out simultaneous or in parallel. With various performance analysis, such as structural analysis, energy simulation and design changes during the design phase information overflow may easily happen and will prolong the design processes. Parameterized and prefabricated building objects can strongly reduce modelling costs and cut the total project time. Especially in the early stage of a project the use of information of objects from manufacturer catalogs provides advantage about generic building objects which can be updated later in the process, with the correct fixtures and fittings. The risk there is that these generic objects will get forgotten and left in place or are only corrected in some written specification. Nowadays different catalogs by different manufacturers are available. In addition, the major companies offer multiple catalogs for different building trades. This again increase complexity and ask for a intelligent information management system.



Workflow of a request to an intelligent BIM catalog

Approach

The suggested methodology aims to extend existing catalogs with an intelligent overarching interface. A catalog or a product catalog is defined as a systematically ordered collection of information on products or services. The list of these products or services usually takes place according to specific classifications and groupings after one or a few identical characteristics. The information don’t have to be stored directly in the catalog, references in different formats can be supported as well as links to elements in other catalogs. During admission of a product in the catalog metadata is automatically generated. The metadata taxonomy can be either stored in database or in an ontology where additional relationships between the elements can be defined creating a generalized knowledge-based information space.

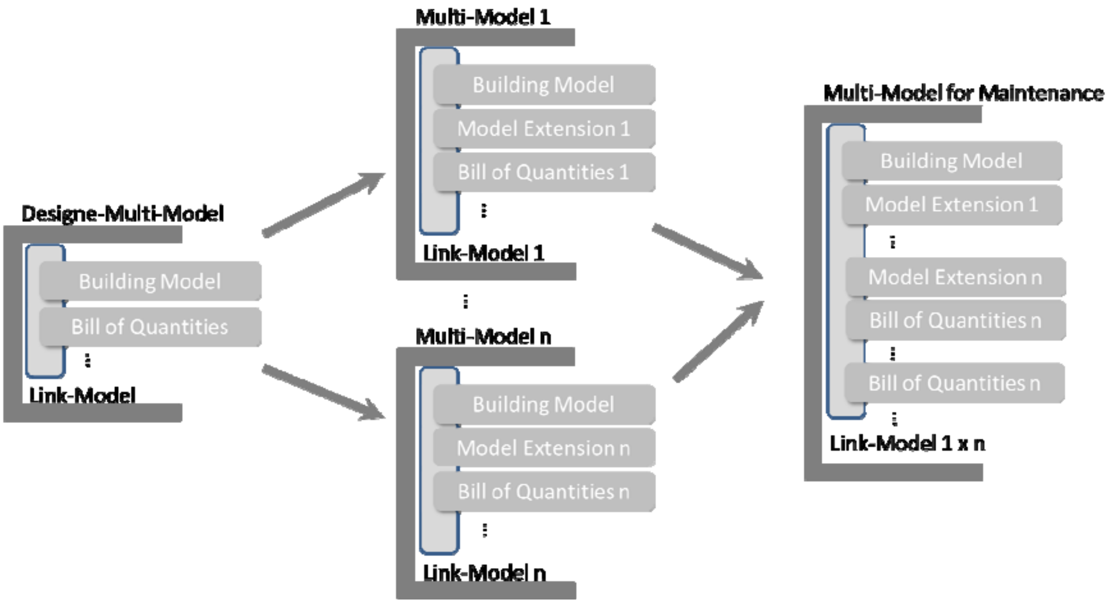
Starting with a user request the aim is to retrieve a building element or a variation of elements and to integrate these elements in an existing building model with a given data format. The request is mapped by a parser which is part of the intelligent interface. As a result of the query one or more elements of the catalog are selected. The resulting set is mapped to the building model schema. For the element request three different options are conceivable: The search for an element with specific parameters, undetermined parameters or with a specified range of values. The last step is to validate the generated list of elements by the user and selecting one or more elements or even a set of variants if a variation or sensitivity study is requested. If the validation fails, the user has to adjust the parameters of the request. This research work is part of the eeEmbedded project.

Multimodel Containers for a BIM-based Facility Management

Robert Kreil

Objectives

Since every construction building is a unique project there is the requirement that every building consortium, consisting of planners, executors, facility managers, users and owners, is able to match different tasks and organise their cooperation and collaboration. Since up to 90% of the life-cycle costs of a building occur after construction, the facility management is an important factor and needs special attention. To be able to perform the facility management at peek efficiency a detailed building documentation is necessary. However, the classical construction documentation is in paper form and generally fills many ring binders, which results in a major problem: the huge amount of paper is hard to access and nearly impossible to analyse. Moreover the documentation is hard to update and updates often further increase the complexity of the paper work.
A more efficient way of documentation would be a BIM-based documentation, which could replace the ring binders by an electronic documentation. This documentation could be a 3d model of the building, which contains links to all necessary documentation and product sheets, making all related and required information accessible over the model.



Schematic description of the multi model container showing the links between domain models

Approach

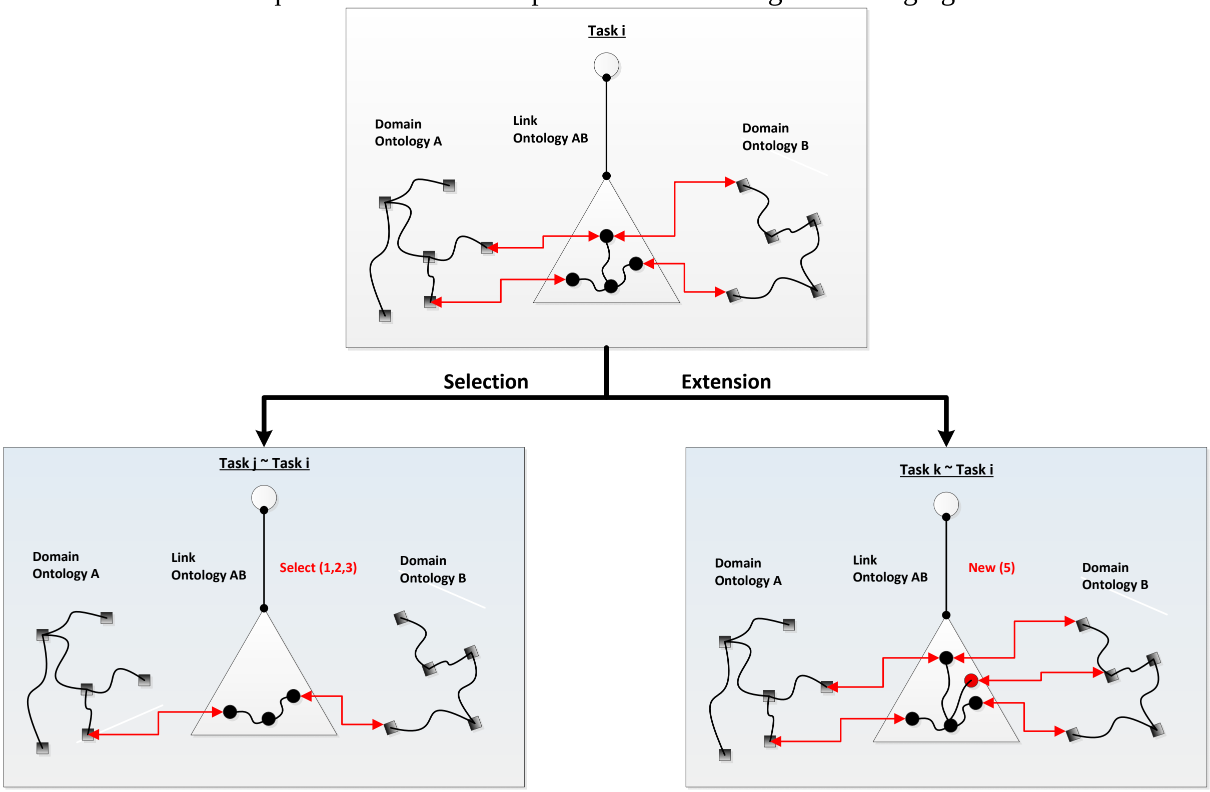
Therefore, a catalogue of all necessary information that is used during the building life cycle is proposed. The Multimodel Concept has been developed in the last few years to interlink different domain models and to enrich a model with additional information. It allows to the tender, bidding and also the accounting for construction projects. For the purpose of using the Multimodel Containers (MMC) in the billing-process of multiple construction disciplines, which generally means different companies, the MM has to be separated in different models for each single craft. This way it can be guaranteed that each company only gets access to their necessary information and also is able to add further information as well as make changes to the model for i.e. supplements. These single Multimodel Containers already contain a huge amount of information for each single construction craft. This information will be enriched with additional documentation like protocols, manuals, etc. during the construction process. Then the enriched, single Multimodels have to be extracted, reduced and combined to one model, which contains all up-to-date information but discards all redundancies. This task is especially important for the link models as the interdependencies between the different Multimodels need to be identified and taken into account when producing the final Multimodel.

Ontology-based Managing of Task Specific Cross Domain Links

Mathias Kadolsky

Objectives

Specific engineering tasks like the analysis of the energy demand of a building require next to the building model additional information like climate information as input. This additional information has to be linked with the building information in a meaningful manner resulting in a multimodel. For saving work and time it is a certain issue to reuse the linking information and the resulting link model in different projects. Linking is task dependent and in this sense link models could be stored by relating them to a certain task. Thereby, the question arises how theses link models should be represented: Each link model represented as separate explicit link model? The goal of this research work is to answer this question and to develop a method of storing and managing link models.



Ontology-based Selection and Extension of Cross Domain Links

Approach

Link models can be described by an explicit model or by a functional model. Using an explicit model the links are already created before the runtime. However, using a functional approach, the links will be generated during the runtime. On the one hand it doesn't make sense to store an explicit link model for each task, on the other hand it is not efficient to generate each link model reiteratively during runtime. The envisaged approach is based on an ontology framework, which opens up the possibility to (de)select links and reducing the link model as well as extending the link model by using deriving rules. In this sense the ontology approach follows the idea of identifying similar tasks, which could be grouped and whose link models can be developed by selection and extension based on an explicit link model as starting point. So, the implementation result for such task groups is a core link model explicitly represented and selection queries and deriving rules attached to this core model and related to the corresponding tasks. A further challenge will be the identification of an overall context function, so that based on the kind of the task changes within such a task group are defined the kind of selection queries and deriving rules can be derived. The elaboration of this approach is part of the research work in the eeEmbedded project.

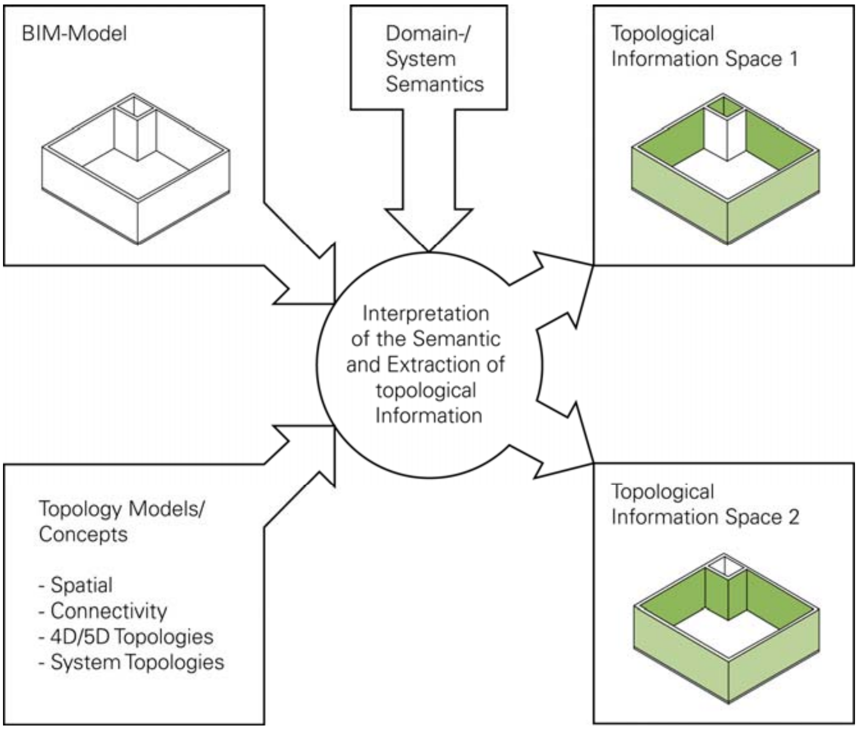
Spanning Domain-specific Topological Information Spaces

Robert Schülbe

Objectives

With the Building Information Modelling (BIM) working method digital building models have become increasingly complex and filled with information. Different domains of the architecture, engineering and construction (AEC) industry have different demands on a building model and more often than not they only need a portion of the complete building model. To share information more efficiently and to reduce the amount of unnecessary information the Model View Definition (MVD) approach has been devised. In short, this approach extracts a subset of the complete building model and thus enables a more focused and domain-oriented view on the building, while at the same time reducing storage and transmission effort.

As with the complete model there are topological information hidden within the data of the smaller, specialized MVD-model. However how certain information should be interpreted can change dramatically from one domain to the next, as it can be seen on the example of spaces. When doing an occupancy analysis, virtual walls as borders would be considered for spaces. Then again they may be ignored in the course of a climate analysis. This differentiation reduces unnecessary information and will speed up the simulations as well as it will lead to more precise domain-specific filtering and results.



Obtaining different topological Information Spaces through the application of semantics.

Approach

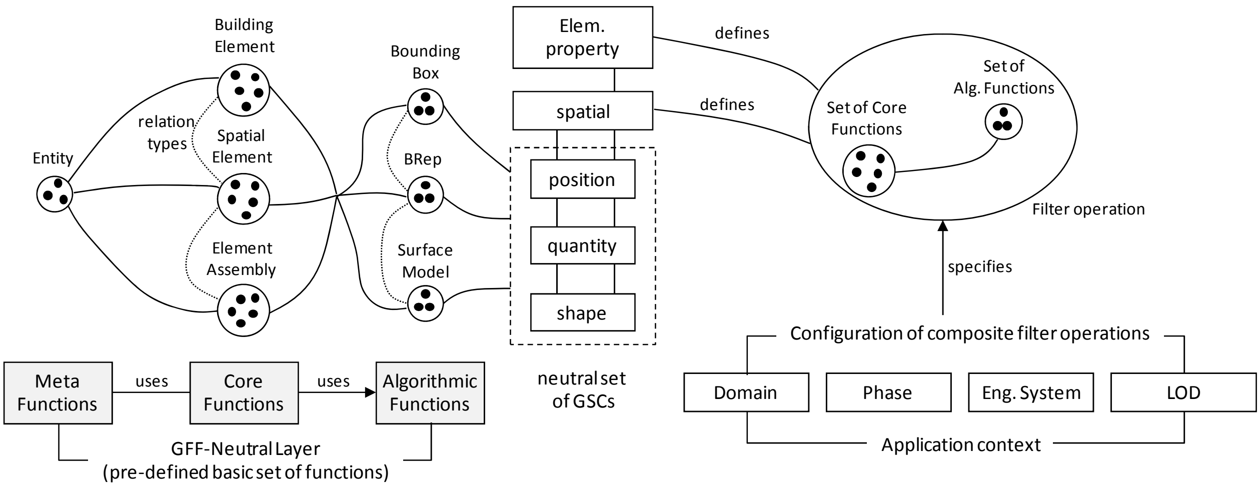
Therefore a system of basic topologies combined with semantics is proposed to extract fine-tuned topological information. The semantic will be domain specific and customizable to allow tweaking results and the resulting views. Firstly this requires a set of clear and fundamental topology models which are flexible enough to be altered in their decision-making to extract the various information (e.g. spatial- as well as time-adjacency, connectivity, spatial positioning). And secondly the semantics need an easy to use interface to be applied to the topologies. This will be achieved by tweaking key numbers and functions of the basic topologies, which as stated above, have been devised to support such interfaces. Through this system it will be possible to interpret topological concepts and models in ways that are specially tailored to the need of a certain domain or system. In short through the combination of basic topological concepts with a domain- or system-specific semantic it will be possible to generate different topological information spaces.

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.

Configurable nD-visualization for Building information models

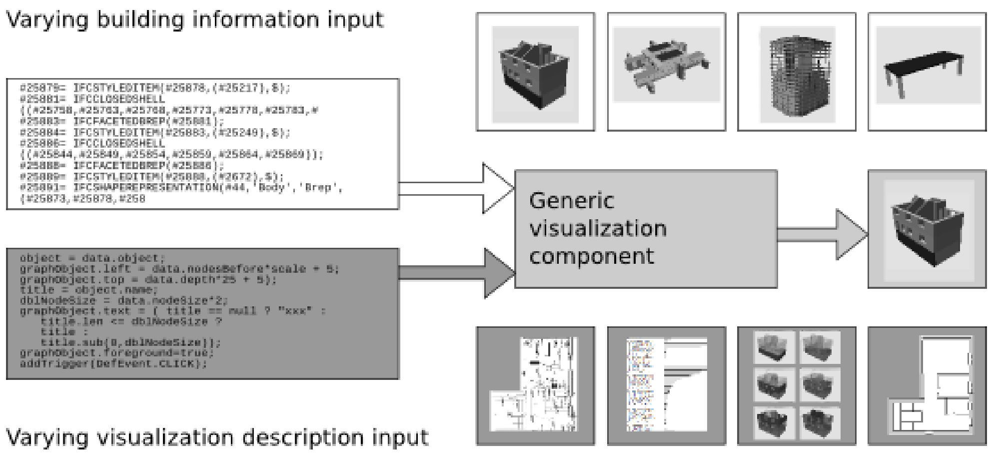
Helga Tauscher

Objectives

With the ongoing development of Building Information Modelling (BIM) towards a comprehensive coverage of all building information in a semantically explicit way, visual representations became decoupled from the building information. While traditional construction drawings implicitly contained the representation besides the building information, nowadays they are generated on the fly, hardcoded in software applications dedicated to other tasks such as analysis, simulation, structural design or communication.

Due to the abstract nature of information models and the increasing amount of digital information captured during construction projects, visual representations are essential for humans in order to access the information, to understand it, and to engage with it. At the same time digital media open up the new field of interactive visualizations.

The full potential of BIM can only be unlocked with customized task-specific visualizations, with engineers and architects actively involved in the design and development process of these visualizations. The visualizations must be reusable and reliably reproducible during communication processes. Further, to support creative problem solving, it must be possible to modify and refine them.



Generation of visualizations from building information and visualization description input

Approach

The research aims at reconnecting building information models and their visual representations on a theoretic level, on the level of methods and in terms of tool support.

First, the research seeks to improve the knowledge about visualization generation in conjunction with current BIM developments such as the multimodel. The approach is based on the reference of the visualization pipeline and addresses structural as well as quantitative aspects of the visualization generation.

Second, based on the theoretic foundation, a method is derived to construct visual representations based on given visualization specifications. To this end, the idea of a Domain Specific Languages (DSL) is employed.

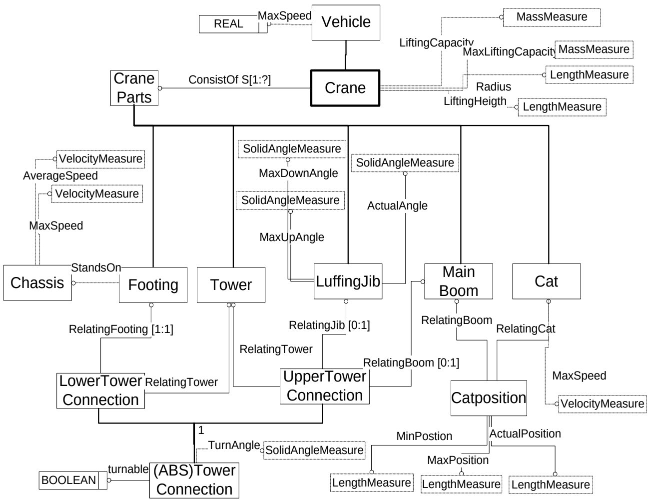
Finally, a software prototype proves the concept. Using the visualization toolkit, visual representations are generated from a specific building information model and a specific visualization description. This way, different visualizations for the same building model can be created, and visualizations can be reused for different building models.

4D Construction Site Viewer Based on a Hierarchical IFC conform Model

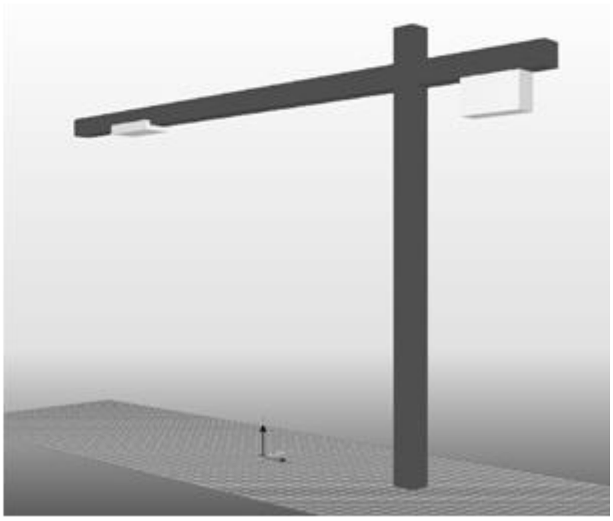
Ulf Wagner

Objectives

To enable integrated IT-supported planning and realization of construction projects, it is necessary to design construction sites at the computer and exchange the resulting information models in digital way. Today, there are several software tools available for construction site modelling. However, often they do not integrate well with common 3D CAD programs and they do not provide for a qualified data exchange with other tools. Most often the existing construction site modellers support the 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 processes, e.g. checking possible collisions of cranes, supply chain bottlenecks, storage area availability etc. The objective of this research is to develop a 4D construction site viewer that allows for the visualization of predefined animation paths as well as interactive animations. The animation paths will be preferential for workflow and production simulation proofing. With the help of user-interactive animations collision checks can be done. The viewer shall be available to normal end-users without special simulation training.



IFC-based Construction Site Model



Context sensitive Visualization

Construction Site Equipment Model Viewer

Approach

The IFC model is a common data standard that is supported by most CAD programs for the exchange and sharing of building models. In our research the IFC schema is extended to also represent construction site elements such as construction equipment and materials. Moreover, site infrastructure elements such as roads, gateways, utilities and pipes are considered. Overall, the IFC construction site model is kept as simple as possible, complementing available IFC geometrical representations with only a few essential classes and attributes. To support more complex planning tasks such as animations, simulations and collision checks an additional library of detailed equipment models is developed. Within that library the IFC model data are complemented with more detailed geometrical information, kinematic and performance descriptions as well as respective cost data. The realization of the 4D construction site viewer is based on three essentials aspects:

(1) The description of construction site models in correspondence to the IFC standard, so that the construction site elements can be visualized and utilized within different viewers and CAD programs;
(2) The description of the animation paths separately from the IFC construction site model (thus, the construction site models remain static models that only hold the positions of construction site elements at a certain point in time while their movements are captured within external XML-based time diagrams or tables);
(3) 4D IFC viewer with an integrated animation component developed on the basis of the available open source viewer provided by the Open IFC Tools.

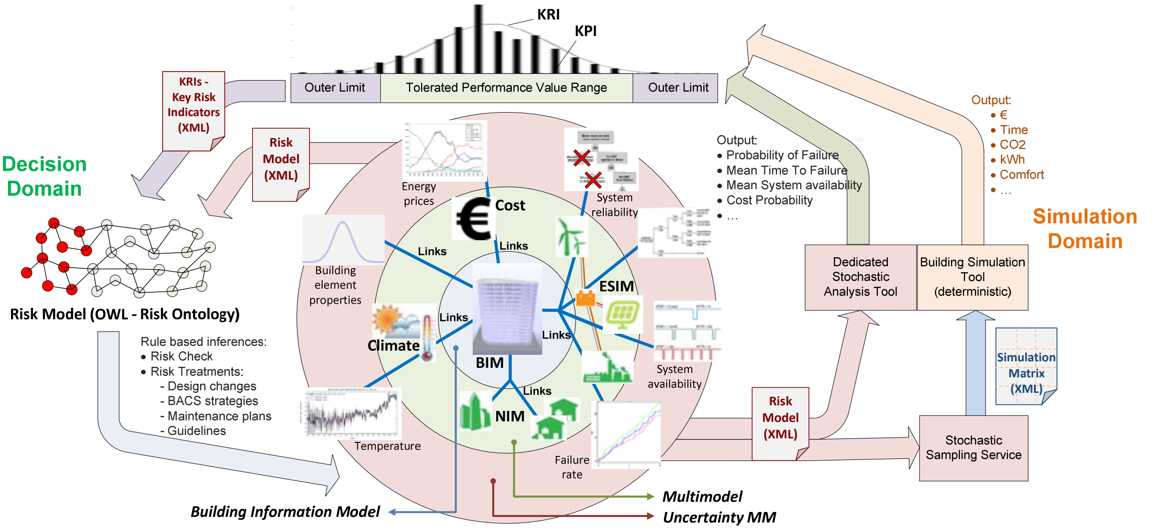
This research work is part of the German *mefisto* project.

Performance-Driven Management of Uncertainty in BIM on the Basis of Key Risk Indicators

Hervé Pruvost

Objectives

Because of its stochastic nature every building project is affected by uncertainties that can result at some point in the future in building performance deviations. In order to avoid or at least minimise that unwanted effect, uncertainty should be taken into consideration as early as possible, specifically during the design phase of a building. In order to analyse and keep a certain control over uncertainty several techniques and standards have emerged in the field of risk management. Unfortunately the AEC industry still makes poor use of such techniques. Indeed risk analysis is often done manually and sporadically by putting stochastic parameters in one proprietary data format, e.g. xls. Moreover, often only one specific category of uncertainty is focused on, e.g. cost risk. Nevertheless risk can have effect on all building performances. In order to close those gaps this research proposes an approach that relies on IT-methods for systematising and automating risk management in building design as much as possible and for providing a holistic view of risk within the building lifecycle.



Approach

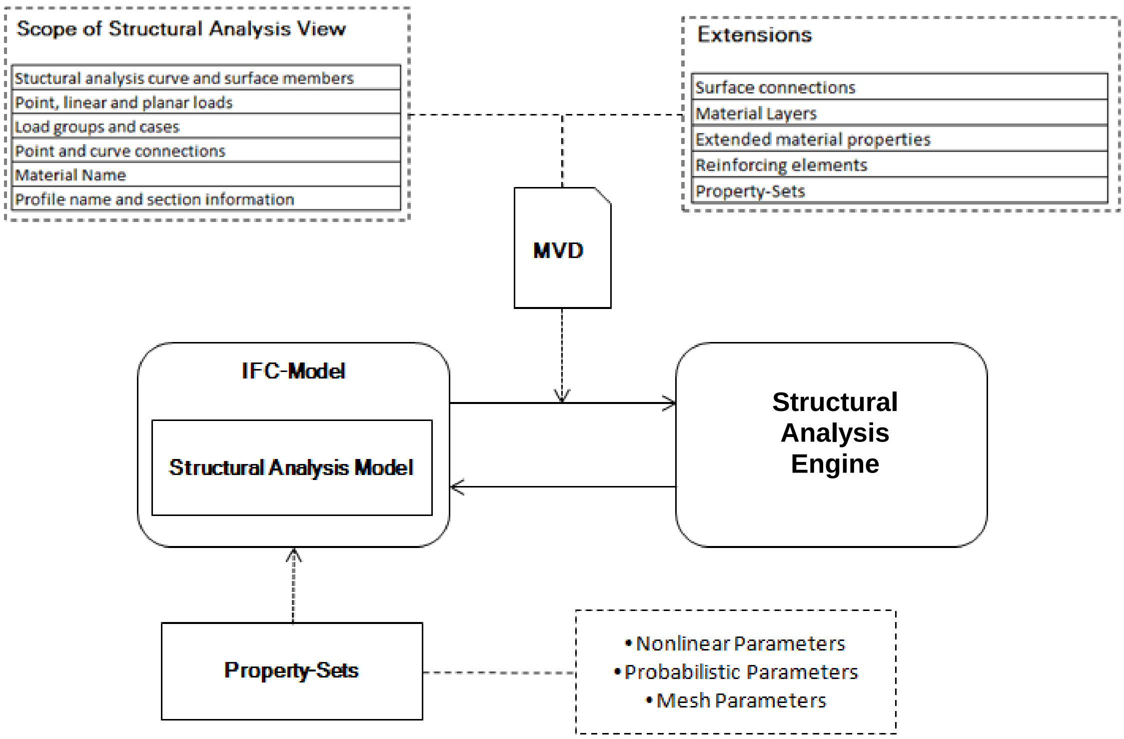
In order to provide a holistic view of risk and thus a good decision basis for a designer, a set of Key Risk Indicators (KRI), a few to by need hundreds, is predefined as part of a common risk model. Per definition a KRI is a metric that helps an organisation identifying and quantifying a certain risk. In the context of building performance KRIs are introduced to quantify the level of uncertainty in the performances of an actual building design. Such risk can be expressed in terms of cost but also among others in terms of energy demand or energy system reliability. As examples KRIs can be defined as a variance of certain Key Performance Indicators (KPIs), as a probability of failure or of crossing a certain KPI value limit. To compute KRIs existing tools can be used in combination with stochastic methods. In this context two possibilities exist: 1) the tool can process stochastic variables like many statistic software (e.g. "R", "@Risk"…); 2) the tool cannot process stochastic variables directly because its purpose is deterministic building performance simulation (e.g. TRNSYS, EnergyPlus…). In the second case a pre-processing is required consisting of a stochastic sampling and a samples storage in a simulation data model named simulation matrix. Like the KRIs the stochastic variables specified in the project are part of the risk model. Following a BIM approach the risk model is interlinked with the Building Information Model as well as with other related data models from a Multimodel e.g. cost model and energy system information model (ESIM). The links specify to which object uncertainty applies and can for example link a probability distribution to a cost item, a failure rate to an energy system component or a KRI to a building. For supporting risk treatment decisions the risk model is mapped into a risk ontology that contains risk tolerances predefined by the decision maker. Ontology is then used to check the compliance of KRIs with tolerated risk ranges and to infer, on the basis of rules, risk reducing design alternatives or investment recommendations from a knowledge base. This research work is part of the eeEmbedded and HOLISTEEC projects.

Information Exchange between BIM and Structural Analysis Based on IFC and the MVD Method

Al-Hakam Hamdan

Objectives

The Structural Analysis Model (ST-4) is an extension of the Industry Foundation Classes (IFC). Although it has been implemented in the IFC specification since the Version IFC2x Edition 2, there still exist some problems that prevent the usage of ST-4 in any structural analysis software. One main problem of ST-4 is the lack of several parameters that are needed for a non-linear and probabilistic structural analysis. Mesh-parameters for the finite elements method (FEM) cannot be defined in an IFC-model either. To solve the problem of missing parameters, property-sets can be used, which act as a container class in IFC. Another problem is that the data exchange between IFC/ST-4 and the structural analysis software is not properly defined. This is necessary, because not every entity of the IFC-model is needed for a structural analysis. In consequence it is advised to create a sub-model as part of the data-exchange-process. There a Model View Definition (MVD) can be used, that declares which entities should be implemented in a subset.



Data exchange between an IFC-model and ATENA using a MVD and property sets

Approach

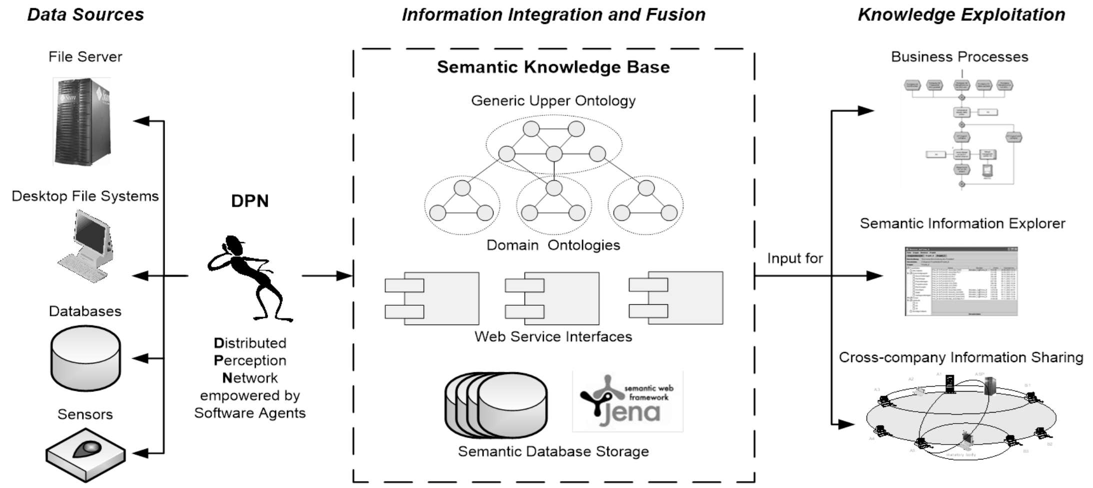
Because every program has different numerical approaches and parameters for the input, the prototype of MVD and property-set extensions are specific for ATENA (Červenka, Praha, CZ) as a representative for non-linear structural analysis software. In ATENA non-linear attributes can be defined through different material parameters. Therefore property-sets have been developed, that contain information about these material types. For a support of different mesh-element types, property-sets for global and local meshing can be used. Furthermore property-sets for different probability-distributions have been developed. These can be assigned to different entities, to describe a probabilistic behavior. There already exists in the MVD "Structural Analysis View" which defines the entities of a sub model for structural analysis purposes. This MVD has been extended with some new concepts that support several aspects of the structural analysis, like reinforcing elements or material layers. The MVD is created in the standardized format mvdXML. This research work is part of the project HOLISTEEC:

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.

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

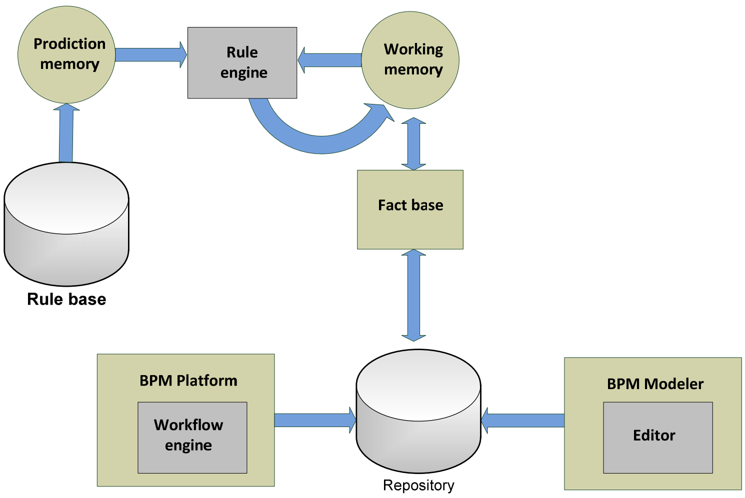
Configuring Design Processes with Business Process Templates and Production Rules

Alexander Benevolenskiy

Objectives

Planning and designing of energy-efficient buildings and their optimal energetic embedding in the neighborhood of surrounding buildings and energy systems is a complex design collaboration process, which needs always a new individual configuration. Configurable design process templates support standardization and reuse of proven design practices and can be configured to meet the specific project requirements, depending on the actual project conditions, available resources or changing constraints. Different dimensions of variability can be considered in this design process templates: activity level variability, decision level variability or reordering of processes. Various levels of variability mean that some of the design processes may be performed by using alternative options or that different criteria or rules can be used for the same decisions in the design templates. Furthermore, similar recurring subprocesses for the verification of the Key Design Parameters (KDP) or validation of Key Performance Indicators (KPI) in that design processes can be also modelled as configurable templates.

The objective of this work is to analyse and develop and approach for the modelling of configurable design processes by using a business process management platform combined with the rule management system. Some of the ideas of this work are partially based on the methodology and concepts proposed and developed in some of the previous works about the ontology-based configuration of production processes, but in this approach the main focus is on the modelling of design process templates in the Business Process Modelling Notation (BPMN) and a possibility of their dynamic configuration.



Integration of Business Process Management Platform and Production Rule System

Approach

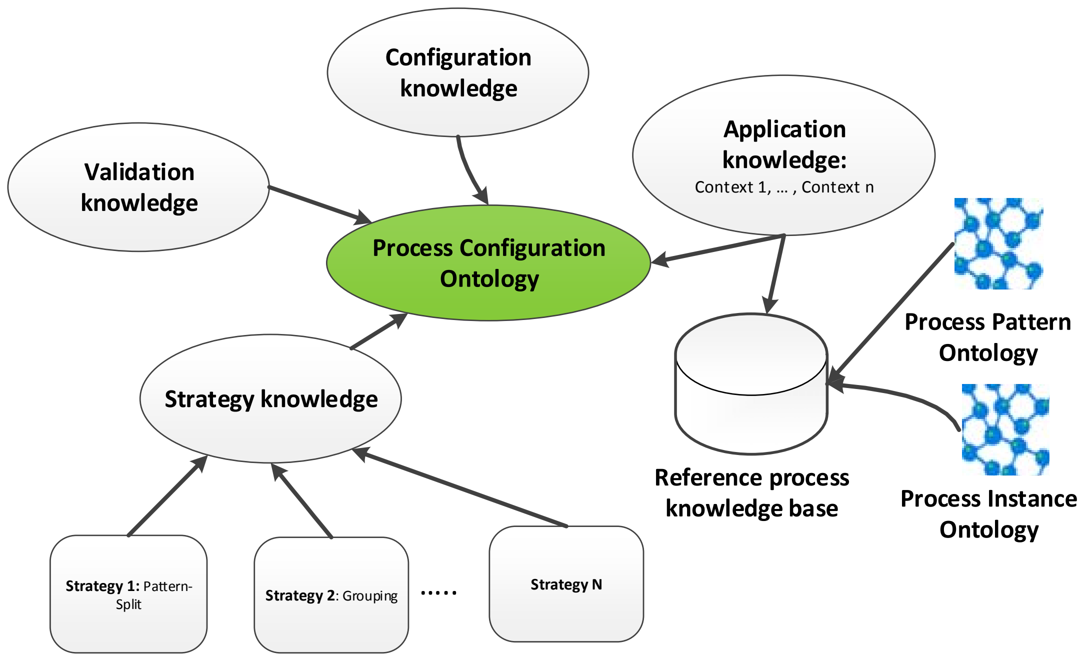
The usage of an open-source business rule management system can add flexibility to the design process and make it easily adaptable to different design cases. Business rule management systems are systems that use rules to derive conclusions from premises. A rule-base together with an inference engine and a working memory are the main components of a rule-based system. One of the main applications of rule-based systems can be found in the area of artificial intelligence where they are used in expert systems, which are computer systems emulating the decision-making process of a human expert. In the current work a rule-based system is combined together with business process management system in order to provide business rules for the design templates. The proposed approach of using the business rule management systems together with business process management platform has the advantage that the design process templates can be configured and modified dynamically depending on different project conditions. This research work is part of the EU project *ee*Embedded.

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:

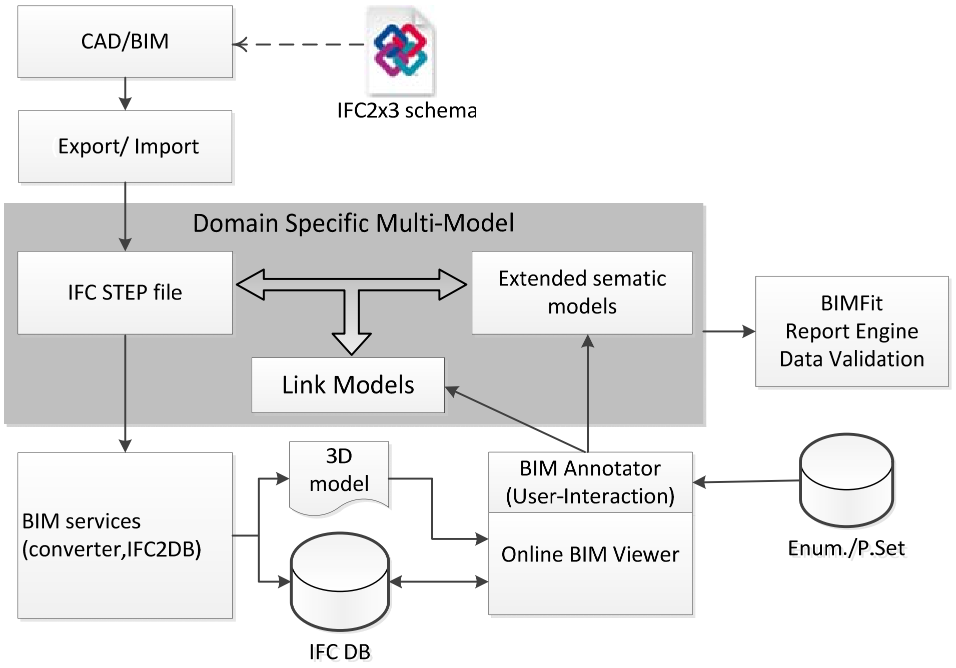
- *Application knowledge.* This knowledge describes the application conditions of the process patterns, for example as a keywords searching criteria for a certain pattern
- *Strategic knowledge.* This knowledge describes different building strategies. Strategy can be defined as procedural methods/plan 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.

Enhancing the Quality of Bridge and Infrastructure IFC Proxy Models through Annotation and Classification

Ali Ismail

Objectives

The Industry Foundation Classes (IFC) is the ISO standard format of BIM models for exchanging and sharing project-related data between several disciplines and applications. Ongoing research works in civil infrastructure (roads, tunnels and bridges) aims to extend the IFC data model. However, the standardization and the subsequent implementation process of the new extended IFC schema in common BIM authoring software will take a long time to complete. Our research aims to develop a user friendly BIM annotation tool in order to support post classification and data enrichment of BIM models based on the current IFC schema IFC2x3. The objective here is to develop a friendly user web-based annotation tool "BIM Annotator" that enables users to work collaboratively in order to improve the semantic data quality of IFC models through classification of elements, adding/editing element properties and create groups of objects and link them with new domain- specific properties e.g. wind-analysis of bridges. The extended sematic model data can be saved externally and linked with the BIM model through special link models, following the multi-model approach which is developed in the Mefisto project (http://mefisto-bau.de/)



BIM Annotator system architecture

Approach

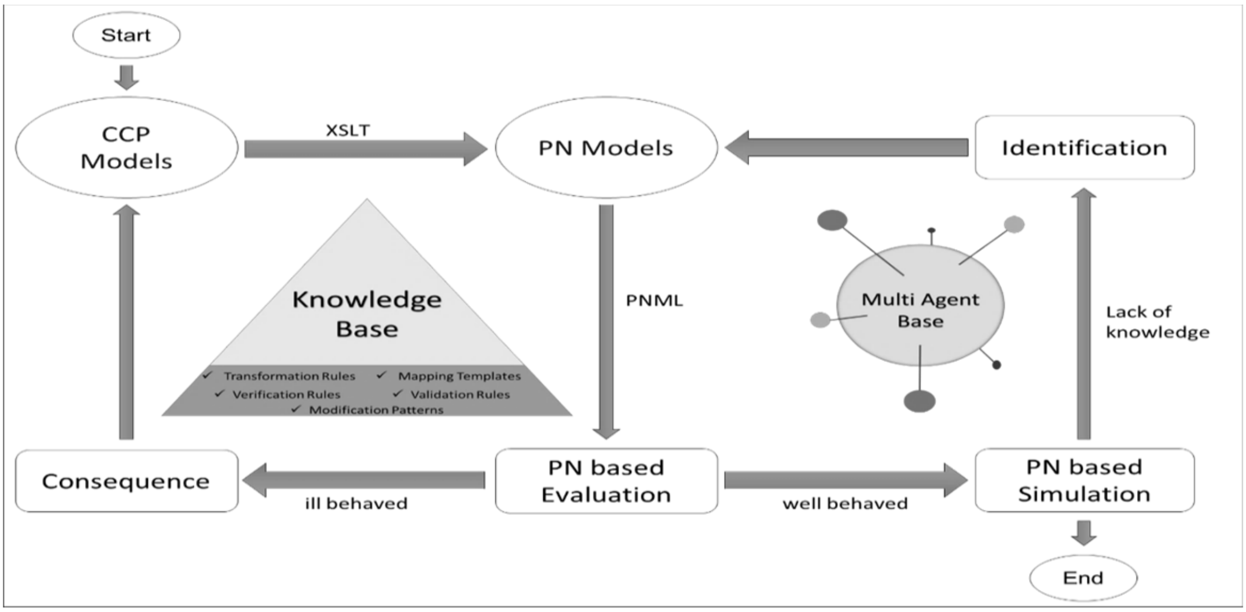
BIM Annotator is based on a web-based online viewer to visualize IFC models. It allows the user to set/change the class of any element and to add meta- information in form of standard or user-defined property sets. The system architecture diagram illustrates the components and data flow. IFC models exported from CAD/BIM software will be converted to a web compatible 3D format based on an open source IFC geometry engine (www.ifcopenshell.org) and the sematic data will be extracted and saved inside a data base (IFC DB) using an IFC parser and transformation tool. A user interaction layer, which is built on top of the online viewer, will offer several annotation functions, for example changing IFC classes of elements, adding and editing property values, delete existing properties and defining new group of elements. 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 quality of IFC bridge models, therefore the IFC-Bridge extension will be analyzed and a special data based for classes, properties and enumerations will be developed. This research work is a part of the on-going EU-project BridgeCloud.

Validation and Simulation Approach of Configured Construction Processes

Faikcan Koğ

Objectives

Process configuration is a method to integrate various business process variants into a single model in order to eliminate redundant process parts and to bring flexibility to the modeled business process. However construction projects consist of very complex and detailed processes, which are not easy to model or to integrate with each other and to evaluate mathematically and graphically. Moreover construction sector needs more sophisticated facilities to design and to control inherent uncertainties of their production systems due to the one of kind product, production and project organization, due to the high complexity of the projects and due to the short lead time. Therefore, process configuration should support not only process sequence variants, but should also support ad hoc changes in the construction process at all stages. In addition, configured construction processes (CCP) should be supported by verification and validation in order to identify and to avoid system errors like deadlocks, infinite loops, logical errors, etc. and to determine the model coherence according to the real world. The objectives of this research are (1) complementing the existing modeling methods and tools for verification and validation of construction process models according to the behavioral and structural properties and (2) integrating the construction process simulation into the framework of the process evaluation system.



Petri Net based Configured Construction Process Validation and Simulation Approach

Approach

The main focus of this research is integrating the Petri Nets based simulation method to the knowledge base supported verification and validation approach of semi-automatic configured construction processes. The simulation model provides an appropriate insight to understand how projected operational scenarios are impacting the projects plan and design as well as appropriate capability evaluation for target requirements. Knowledge base consists of mapping templates, transformation rules, verification rules, validation rules and modification patterns. Petri Nets method, which is already selected for the evaluation and modification purpose, is also used to create event based simulation models. A Java based process evaluation tool is designed in order to support automated XSLT transformation between BPMN and PN models, to validate and verify the initial models and to figure out the evaluation outputs in case of an ill-behaved model. In this research well behaved models are handed over to the PN based Simulation tool. Resource allocation and scheduling are selected process levels in order to optimize the instance CCP models in process evaluation system. The research will be extended with the identification of model gaps in case of incomplete knowledge on structure, parameters or the algorithms of the system. Agent based systems are proposed to deal with this kind of unexpected behavioral or knowledge problems in simulation phase.

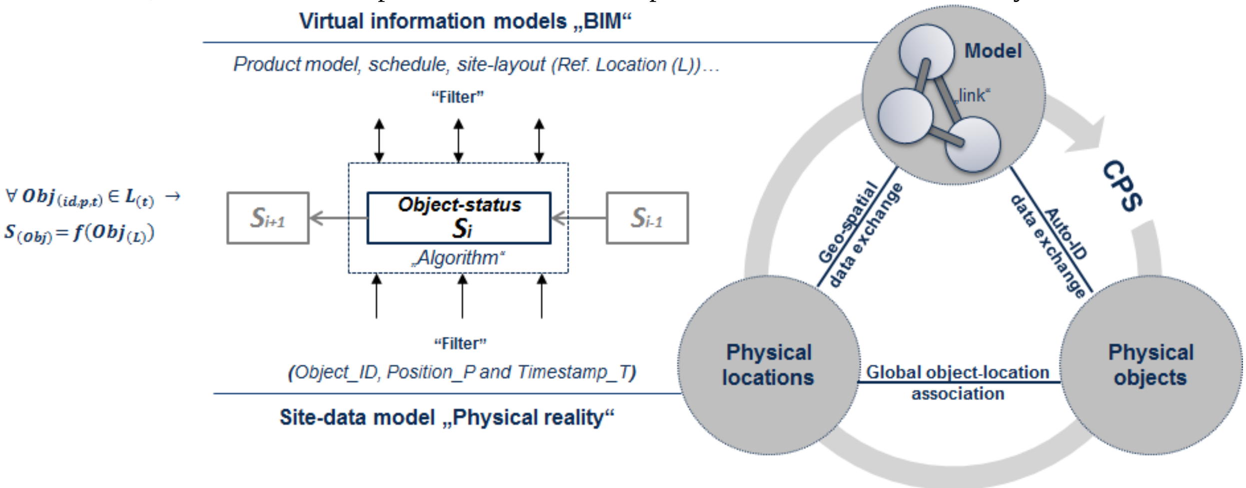
Construction Digitalization Approach based CPS Principle

Yaseen Srewil

Objectives

Building and infrastructure industry is a very local, conservative and fragmented business. Currently, the gap between physical construction reality and their digital instances is hindering timely feedback with predictable recycle flows. Moreover, BIM and ICT technologies have to reach to a high level of maturity which allows full digital construction process. The advances in automatic data Acquisition technologies tackle these challenges and open the opportunities to achieve a “near” real time bi-directional coordination between virtual information models and physical fields. Similarly to industry 4.0, Cyber-physical system (CPS) approach ensures a tight conjoining of virtual building information models “BIM” and physical construction to enable data bi-directional integration, coordination and control using Auto-ID and positioning system as sophisticated coupling tools. Generally, the physical construction entities have cyber capabilities. However, developing a hybrid system based on CPS principles needs formalism with emphasis on spatial-temporal behaviour. This work proposes a solution with two levels of integration:

- Linking construction objects “horizontally” to their physical locations; A RFID system is proposed to identify the physical elements and associate them to their temporal location. The system can be extended to handle machine-to-machine M2M, machine-to-object M2O and Human-machine (HMI) problems.
- Vertically, the information models will be coupled into physical objects. This needs a method to create a digital link between BIM model and the physical components by means of RFID technology. Furthermore, the identified components associate with pre-defined construction site layout data.



Data exchange between digital models and the physical construction to derive “near” real time construction processes in framework of CPS principles

Approach

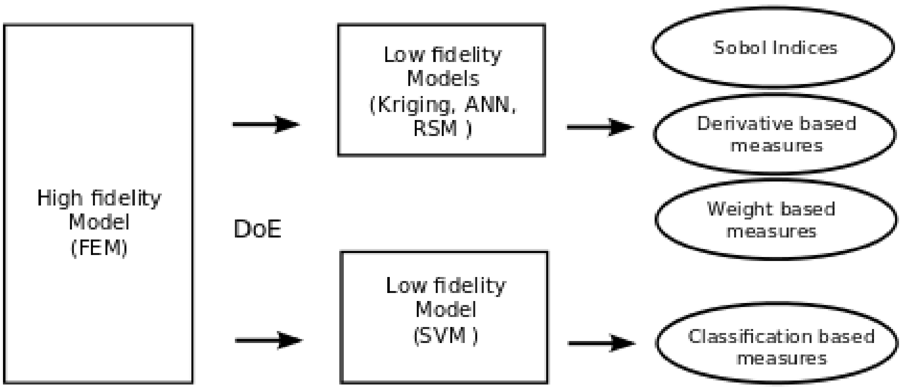
The bi-directional and interactions between the virtual construction models and physical construction field can be characterized by three main tasks: *(1) Cyber-physical products link establish:* it links the physical building elements to their virtual instances in BIM model. This work suggests using a passive RFID system to identify construction physical objects and track them during project execution. The current IFC data model supports creating a link using globally unique identifier (GUID) as interfaces with RFID tags. *(2) Geospatial site data integration (i.e. the site factory);* it is to improve interoperability between geospatial construction site data and IFC. The IFC spatial entities (*IfcSite, IfcBuilding, IfcSpace*) can be used with extended “external” spatial information (like *work-zones; facility places laydown-areas, gate…)* to describe roughly the construction site layout model. Here, construction site layout model is a spatial, functional, semantic structure and is used to formalize the structure of job site. *(3) Object- global location association;* this kind of association is necessary to link the physical construction elements to their temporary global locations. Hence, the location of each tracked element on site is approximately identified. These valuable data are aggregated, validated and stored to a well-structured database. Whereby, the relevant data are configured on the virtual construction “BIM”. This solution allows deriving the real construction processes by inferring information about physical objects, their locations at specific time frame and the work zones to which they belong. Also, it enables a “semi“- real time simulation for process optimization.

Non-linear Global Sensitivity Measures for an Efficient Optimization of Structures

Zeeshan Mehmood, Uwe Reuter

Objectives

An optimal design of structure requires a computationally expensive optimization process. The structural response is often dependent on a number of design parameters, so as the optimization process. The complexity of the optimization problem can be reduced if the relationship between the design parameters and the model response is effectively identified with the help of the methods of sensitivity analysis and only sensitive parameters are then considered for optimization process. Methods of Global Sensitivity Analysis (GSA) helps in identifying the most significant model parameters affecting a specific model response. These methods are also applied by engineers for structural design problems for extracting the sensitivities of the structural response but these methods demonstrate certain limitations based on certain assumptions. Since the design of structures involves high-dimensional and computationally expensive physics based models, the classic methods of Global Sensitivity Analysis can only be applied using low-fidelity models because they require frequent calls to the underlying model of interest for their realization. For practical reasons, meta-models are then used with few sample points for calculating sensitivity measures. Thus, the accuracy of meta-models and the underlying theoretical basis of the classical GSA methods come into effect for problems related to structural design. The objective of this research is to evaluate and develop efficient methods for global sensitivity analysis of non-linear models in order to facilitate the optimization of a structural design.



Global Sensitivity Analyis using meta-models

Approach

The practical implementation of already existing variance based, weight based and derivative based sensitivity measures requires meta-model based approximation of the structural response for the given structural data. These sophisticated sensitivity approaches provide results in a computationally expensive manner. In this research, the meta-model based approximation process is reduced to classification of the structural data at certain levels of the structural response and classification based sensitivity measures are sought. Thus, the requirements for a full approximation of the model response for calculating sensitivity measures are dealt with. The sensitivity is assessed by means of change in classification level in structural response. Classification based sensitivity analysis can be performed using Support Vector Machines (SVMs). Nonlinear SVMs perform classification by transforming the input space in a higher dimension space using kernel functions. In addition to change in class level, properties of the kernel functions and the discriminating hyperplanes in the higher dimension can also be exploited for calculating sensitivity information. Sensitivity analysis with classification models is likely to be less computationally expensive and can be easily applied to the relevant industry problems.

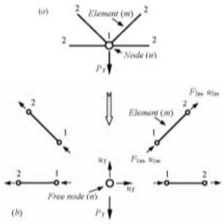
Complexity Reduction of Imprecise Structural Systems Based on Probability Box Concept

Jamshid Karami

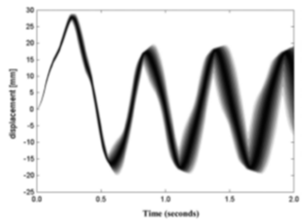
Objectives

Nondeterministic Finite Element Methods (FEM) including Interval, Fuzzy and Probability Bounds Analysis gained more 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 completely new approach to Finite Element Analysis (FEA) with imprecise variables. It results in more efficient interval samples that lead to interval FEA (IFEA). Finally the lower and upper bounds on probability of failure in each simulation and then the P-Box of failure can be computed.

Although such new procedures offer much more realistic approach for analysis, the utilization of these methods in practical applications remains limited due to less attention to develop necessary tools for analysis and the computational efforts that are much more than deterministic analysis. Thus, performing reliability analysis, leads to impractical computational costs especially for complex structural systems. There are many limitations in current methods, they do not guarantee to bounds 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.



$$\begin{bmatrix} \mathbf{K} & C^T & B^T & 0 \\ C & 0 & 0 & 0 \\ B & 0 & 0 & -I \\ 0 & 0 & -I & 0 \end{bmatrix} \begin{Bmatrix} \mathbf{u} \\ \boldsymbol{\mu} \\ \boldsymbol{\lambda} \\ \boldsymbol{\gamma} \end{Bmatrix} = \begin{Bmatrix} \mathbf{f} \\ \mathbf{0} \\ \mathbf{0} \\ \mathbf{0} \end{Bmatrix}$$



Approach

Developing an efficient procedure for sampling is one of the most important parts of research. The goal is to reduce the number of FEA to reach a reasonable accuracy. Therefore the samples are generated based on low-discrepancy sequences. Defining a suitable measure for describing damage or a suitable limit state function is the next phase of the work. Representing an efficient procedure to reliability analysis under imprecise seismic loads presented by P-Boxes is another main step of the research.

Definition a new IFEM for frame structures under dynamic seismic loads is the most important part of the research. The aim is to further reduce overestimation due to dependency, transformation and calculation of primary and derived quantities of proposed method. The effort to handle the overestimation is concentrated on using the iterative enclosure method which generates a nested sequence and provides rigorous bounds on the solution. 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, all variables, both primary quantities such as displacement and derived quantities such as internal forces and strains, are obtained with sharp bounds. A FE code will be developed to perform PBA and reliability analysis and a methodology will be proposed to reduce the complexity of IFEA of structural systems under seismic excitation..

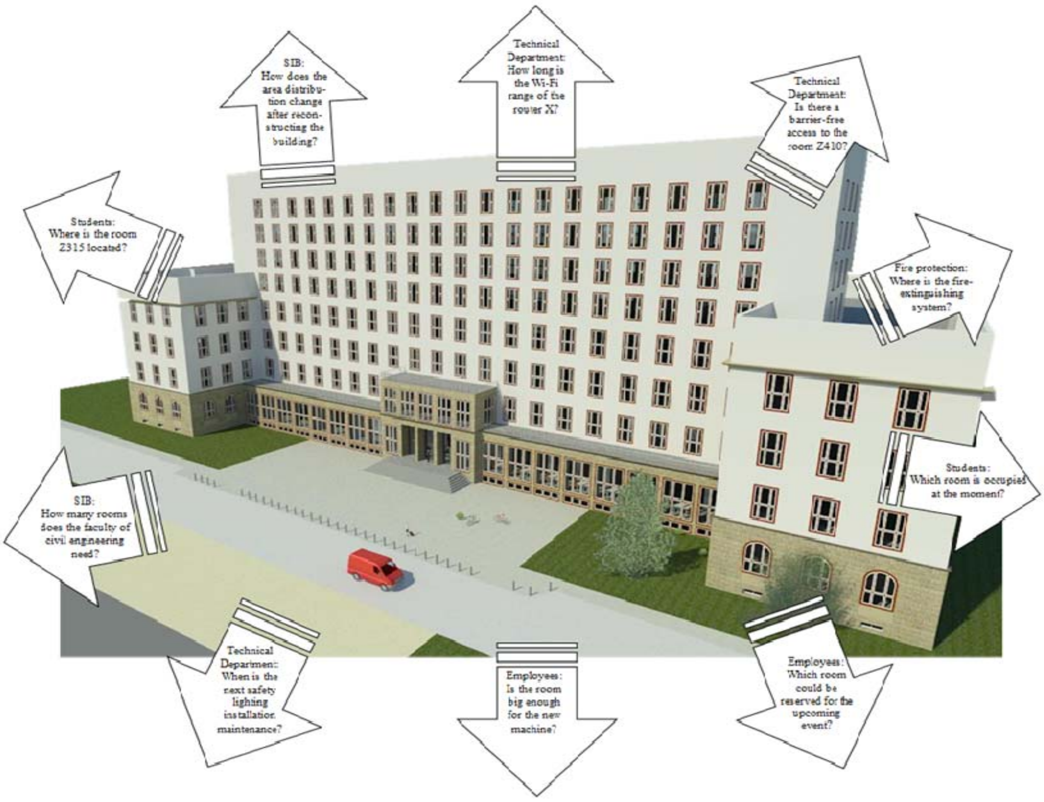
Then by means of case studies the efficiency of proposed method will be verified. Numerical analyses will be performed using developed IFEA code. For this purpose Steel Moment Frames as the target group of structures, with P-Box representation of material properties and seismic loads will be used.

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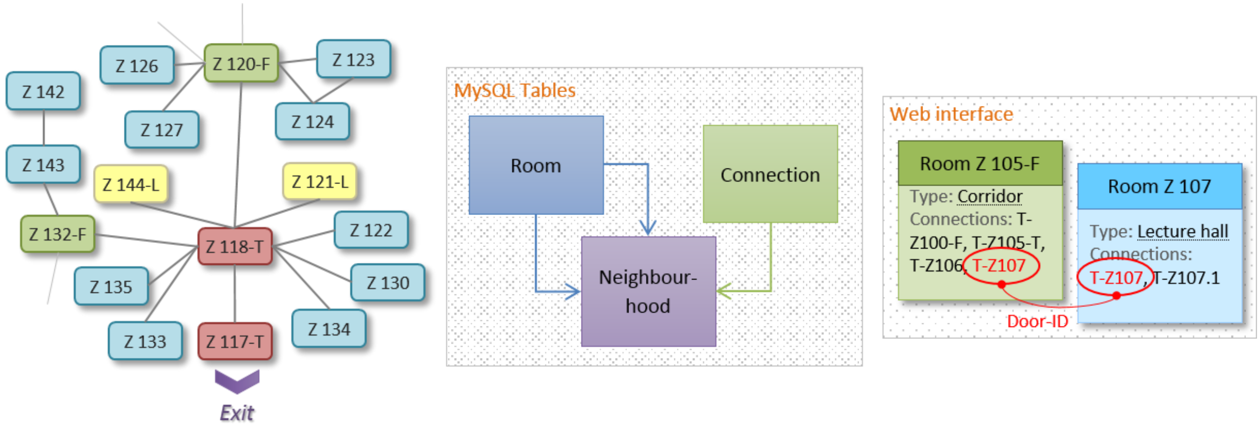
[1] This is a cooperative PhD thesis with the University of Applied Science Dresden.

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 $V = \{ v_1, v_2, v_3, \dots, v_k \}$ as a vertex set representing the rooms and $E = \{ e_1, e_2, e_3, \dots, e_n \}$ 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.

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** will provide 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) will be developed to support the complex design collaboration process. Knowledge-based detailing templates will allow energy simulations already in the early design phase, and BIM-enabled interoperability grounded on a novel system ontology will provide for a seamless holistic design process with distributed experts, and a seamless integration of simulations of various performance issues, thus extending it 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 development work will be 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. Applications and services of the eeEmbedded platform will built upon a set of ISO and industry standard data structures such as IFC, STEP, CityGML, RDF and OWL to enable greatest commonality and inter-company operability of the developed ICT solutions. A new ontology-based Link Model, will provide 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 necessary prerequisite to plug in different computational tools on the platform, such as the energy analysis tools NANDRAD and TRNSYS-TUD of the TU Dresden or EnergyPlus, CFD analysis tool of SOFiSTiK, Greece, and tools based on Modelica, etc. Baseline for all ICT services will be the developed methodology for BIM and KPI-based eeeDesign and the related overall ICT framework of the Virtual Engineering Lab, which will be 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:	Despite recent evolutions of tools/practices in the Architecture Engineering, Construction and Facility Management have already resulted in considerable advances, some limitations remain, related to the complexity and variability of building life cycles, addressing building end user awareness and participation, lack of new business models, life cycle fragmentation, limited interoperability of the ICT supports. The main objective of HOLISTEEC is thus 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. This platform will account for all physical phenomena at the building-level, while also taking into account external, neighbourhood-level influences. The design of this platform will rely on actual, field feedback and related business models / processes, while enabling building design & construction practitioners to take their practices one step forward, for enhanced flexibility, effectiveness, and competitiveness. HOLISTEEC main assets are: (i) an innovative feedback /loop design workflow (ii) a multi-physical, multi-scale simulation engine; (iii) A unified data model for Building and Neighbourhood Digital Modelling (iv) a full-fledged open software infrastructure for building design tools interoperability leveraging available standards; (v) innovative and flexible user interfaces. HOLISTEEC is expected to have a direct impact at a 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 four real construction projects, in parallel to standard design approaches.
Partners:	D'Appolonia S.p.A.(Italy) – Coordinator, and Koninklijke Bam Groep Nv (Netherlands), Acciona Infraestructuras S.A. (Spain), Nemetschek Slovensko S.R.O. (Slovakia), Senaatti-Kiinteistöt (Finland), Gdf Suez (France), S.T.I. Engineering S.r.l. (Italy), Bergamo Tecnologie Sp Zoo (Poland), Cype Soft S.l. (Spain), G.E.M. Team Solutions Gdbr (Germany), Geomod S.a.r.l. (France), Pich-Aguilera Arquitectos S.L.P (Spain), Centre Scientifique et Technique Du Batiment (France), Commissariat A L'Energie Atomique Et Aux Energies Alternatives (France), Fundacion Tecnalia Research and Innovation (Spain), Technische Universitaet Dresden (Germany), Teknologian Tutkimuskeskus Vtt (Finland), Institut Für Angewandte Bauinformatik (Institute For Applied Building Informatics) (Germany), 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
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), 0.4 million Euro (CIB)
Duration:	4 years, since 10/2013
Approach:	**Design4energy** will develop an innovative Integrated Evolutionary Design Methodology that can 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 future will provide to design energy efficient building not only for the present but also for the future, ensuring an Energy Efficient Life Cycle of the building. The Design4energy project will take this into consideration and will develop tools and methodologies, that can help designing energy efficient buildings, that can consider both short term performance as well as future scenarios, considering important factors such as deterioration curves, technology evolution, climate change effect, users, energy neighbourhood configuration, continuous commissioning alternatives while evaluating their impact in the Building Life 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 will be 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 Design4energy 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 (Spain) – **Coordinator**, TU Dresden - Institute of Construction Informatics (Germany), Teknologian tutkimuskeskus VTT (Finland), 3L-Plan Lenze-Luig-Walter GbR (Germany), Loughborough University - Construction Informatics (UK), Fraunhofer Gesellschaft - Institute IAO (Germany), UNINOVA (Portugal), Corio nv (Netherlands), University of Salford - School of the Built Environment (UK), SISTEMAS Y MONTAJES ELECTRICOS SL (Spain); IZNAB Sp. z o.o (Poland), Gaspar Sanchez Moro Arquitectos S.L.P. (Spain), Metropolitan Research Institute Ltd. (Hungary), ANCODARQ S. L. (Spain), CADCAMation KMR SA. (Switzerland), TPF Sp. z o.o. (Poland), Assignia Infraestructuras SA. (Spain)

Title:	**BridgeCloud – Model-based Aeroelastic Analysis of Long-span Bridges on the HPC Cloud**
Project Leader:	Prof. Dr.-Ing. R. J. Scherer Co-leader: Dipl. Ing. Ali Ismail
Financial Support:	EU– Eurostars Nr. E! 7987; BMBF (German Ministry of Education and Research)
Budget/Funding:	2.6 million Euro/1.8 million Euro (total), 0.30 million Euro (CIB)
Duration:	3 years, since 07/2013

Approach:

BridgeCloud aims to develop a bridge-wind interaction virtual design lab for the combined Fluid-Structure interaction analysis of aeroelasticity phenomena in long/medium span bridges, that integrates semi-automatic modelling on a BIM basis, numerical wind-bridge interaction analysis and cloud computing power, providing for an easy-to-use sophisticated design tool to bridge design through SMEs. The virtual design lab will enhance the design by shifting the experimental phase (virtual wind tunnel tests) towards the early stages of the whole design procedure, thus facilitating testing and comparison of alternative bridge typologies, and optimizing bridge design in all design stages. By performing all necessary design tasks in-house, structural design office productivity will be improved, and by optimizing the structural system and bridge cross-sections, the overall construction cost will be reduced. The interaction between the fluid flow and an embedded elastic body is extremely complex. The aeroelastic instability includes phenomena like vertical due to vortex shedding phenomenon induced by the flow over bluff bodies, torsional, and coupling of vertical and torsional instability, called flutter. If the wind speed is greater than the critical wind speed the aerodynamic instability develops, which leads to failure.

Aerodynamic aspects will become a major design factor in bridge engineering. As the design of long-span bridges, and other slender structures, becomes ever more ambitious, each new design challenges further the available technology. The most important factor in the performance of such structures is their tendency to move under the influence of aerodynamic forces in a way governed by a complex interaction of wind and structure. Wind tunnel testing is the standard procedure for the assessment of the aerodynamic behaviour of bridge decks, but numerical methods will offer detailed insight into the flow properties.

BridgeCloud aims to revolutionize everyday bridge design by developing a methodology and producing a corresponding software product for (i) obtaining wind pressure distributions in space and time accounting for fluid (wind) – structure (bridge) interaction, (ii) automatically incorporating them into the structural design process, and (iii) capturing and avoiding eventual aerodynamic instability effects that may endanger long-span bridges.

Partners:

FIDES DV-Partner Beratungs- und Vertriebs-GmbH, (Germany) – **Coordinator**

TU Dresden, Institut für Bauinformatik

Wacker Bauwerksaerodynamik GmbH, (Germany)

DENCO Development and Engineering Consultants S.A,(Greece)

Institute of Bioorganic Chemistry Polish Academy of Science-Poznan Supercomputing and Networking Center, (Poland)

Title:	**SE-Lab - A Cloud-/Grid-Based Virtual Laboratory for Non-linear Probabilistic Structural Analysis**
	http://www.selab.eu
Project Leader:	Prof. Dr.-Ing. R. J. Scherer Co-leader: Dipl.-Ing. Ronny Windisch
Financial Support:	EU – Eurostars Nr. E!7521; BMBF (German Ministry of Education and Research)
Budget/Funding:	1.2 million Euro / 0.8 million Euro (total), 0.46 million Euro (CIB)
Duration:	3 years, since 12/2012

Approach:

SE-Lab is an innovative combination of (1) sophisticated mathematical methods from computational mechanical and probabilistic engineering (2) computer science methods from public cloud and private grid and web service technologies, and (3) construction informatics methods related to Building Information Modelling (BIM), in particular engineering information management, filtering, interoperability, model mapping and model change propagation.

More slender structures, new architectural design paradigms, retrofitting of cultural heritage, life-cycle consideration of civil engineering structures and an increased demand for safety in the society require broader application of advanced non-linear mechanical modelling and probabilistic safety concepts for structural design. This, in turn, calls for advanced information management and automation of the mass of simulations needed for well-grounded design variations and probabilistic evaluation, and hence for much more computer power. The partial safety factor approach that is commonly used today cannot be applied in combination with structural non-linear analysis and has to be replaced by the full probabilistic approach. In addition, for non-linear structural analysis the linear superposition principle is not valid, which means that for multitudes of load combinations separate non-linear analyses must be carried out. The use of currently available tools for such purposes exceeds the labour resources and the computer power of SMEs in the construction domain. Therefore new integrated methods are needed.

SE-Lab is developing an IT environment, which is fully BIM-integrated with the architectural CAD design systems. It will allow carrying out the huge amount of structural analysis tasks required for the realisation of the outlined full probabilistic non-linear approach without significant additional efforts of the designers. Moreover, it will offer the possibility to inspect any individual analysis run in 3D on demand, to study crack and failure mode propagation and hence to obtain in-depth understanding of the structural behaviour in order to find the optimal structural design.

The developed platform will be applicable to all engineering structures, like steel, re-enforced concrete, composite, geotechnical and glass structures and components. It will be an information management platform on web service basis where all computational and graphical tools are plugged in via web-service wrappers. No specific tool will be preferred, each will be exchangeable and there will be no tools to which SE-Lab is limited. The stochastic developments will be based on the newly proposed international probabilistic safety standard, the fib model code 2010 to achieve maximum international acceptance. Various specific national guidelines can later be added on demand due to the flexible SOA structure of the SE-Lab platform.

Partners:

Cervenka Consulting, s.r.o., (Czech Republic) – **Coordinator**

Leonhardt, Andrä und Partner, Beratende Ingenieure, VBI, GmbH, (Germany)

TU Dresden, Institut für Bauinformatik

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

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

Financial Support: TU Dresden

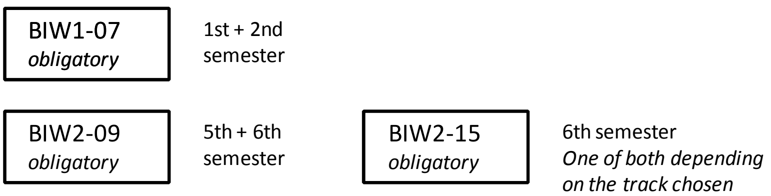
Duration: Since 2001

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.

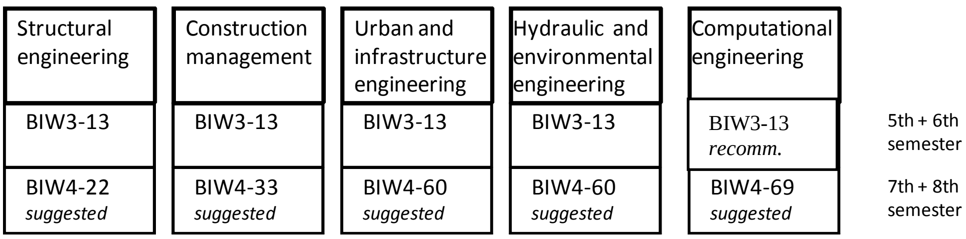
Lecture Activities

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



Diploma/Master Course if Construction Informatics Competence is Chosen



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, Reuter

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

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 7^{th} 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 7^{th} semester up)
Lectures and Tutorials: Scherer/Katranuschkov, Luu

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 7^{th} 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

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

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.

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[5] ISMAIL A., SCHERER R. J.: An Integrated process-based simulation platform for construction project planning. In: Proc. 5th International/11th Construction Specialty Conference, 8-10 June 2015, Vancouver, British Columbia.

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[11] SCHERER R. J., KATRANUSCHKOV P.: BIM-Labore der Zukunft. In: Scherer R. J., Katranuschkov P., Opitz F.: Bauinformatik – Baupraxis; Leitlinien – Richtlinien – Normen – Ergebnisse aus dem VDI-Koordinierungskreis BIM. ISBN 978-3-86780-458-5. Dresden, November 2015.

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[13] TAUSCHER H., HOFFMANN S., KURZROCK B.M. (2015): Integrating foreign studies within the constraints of European harmonisation: A BIM e-learning course. In: 3rd Annual SEFI (European Society for Engineering Education) Conference, Orléans, France, June 2015.

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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. Vice chairperson of the ST-4 Structural Model group.
VDI 2552	Guidelines for BIM	Chairperson of working group #8 Qualifications