INSTITUT FÜR BAUINFORMATIK
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TECHNISCHE UNIVERSITÄT DRESDEN

RESEARCH AND LECTURE ACTIVITIES IN 2018

December 2017

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

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

The view of this brochure is directed to the future and more precisely to 2018, when new chances and new challenges will come up. The institute will have a new head from the 1st of April, right after Eastern. On that date I will hand over all my obligations and commitments to Prof. Karsten Menzel. He has been already active in our research domain as Professor for Construction Informatics at the University College Cork for more than a decade and may be quite well known to most of you. I will get the position of a Senior Professor for Research, continuing with research as usual and with enthusiasm. I already do have officially the position of a Senior Professor for Vacancy since my formal retirement on October 1st, 2017.

Thus, the following reflections about the future of the institute are somewhat constrained regarding the new head of the institute, Prof. Karsten Menzel. He will and should give the institute a new research and lecturing scope. Such things need time and we both agreed that 2018 should be a transition period to pave the new way of the institute for the future intertwining new and old research topics to the best benefit of the institute.

Research topics have undergone already in 2017 a smooth shift from energy-efficient building design application to system identification as the main application areas (3 out of 4 new projects). However, the underlying informatics methods have remained the same, namely the Virtual Engineering Lab, the heart methodology of our research. It is based on the research methods about building information modelling, multimodels, interoperability, model filters, MVDxml filter specifications, filter languages, ontologies, description logic, intelligent construction management, virtual organizations including collaboration, project risk management, dynamic process modelling, simulation, ICI-supported computational engineering for building performance studies, grid and cloud computing, stochastics and vulnerability. Most of the topics have been accumulating in our ongoing common development "An intelligent semantic Virtual Engineering Lab" (isVEL), which bridges the BIM i.e. the informatics world and the computational engineering world, smartly providing simulation power to planners to revolutionize architectural and engineering design and construction.

In 2017 two new projects have been acquired strengthening on isVEL development. CyberBridge is focused on new material laws and mass parallel simulations for the system identification of aged bridges. GeoProduction4.0 is focused on the system identification of the geological ground and the geotechnical structure during the production of deep excavations and the feedback on the production process, thereby constituting a cyber-physical production system. System identification is based on the method of simulation-based system identification, where a plethora of possible states of the system is setup, simulated and the simulation results are compared to monitored data in order to identify the most feasible possible state. This needs a highly automated isVEL, i.e. advanced BIM, filtering, BIM2SIM, HPC, Response Surface fitting combined with Data Mining methods, as well as high precision nonlinear material laws and computational methods and sensor systems in order to detect small changes in time and distinguish them from noise.

Standardization is well advancing and together with the COINS and the Linked Data Group we established a new ISO standardization group ISO-NP 21597, Information Container for Data Drop, which was constituted in February 2017 at Barcelona. We contributed our MultiModel (MM) method, and are actively involved to reflect in the best possible way all three developments: COINS, MM and Linked Data. In addition, the BCF collaboration method should be included in 2018 for which already a part is reserved. As a kind of forerunner in Germany the MM for the tendering face is already standardized as DIN SPEC 91350.

We are already in preparation of the next ECPPM. It will be held at Copenhagen from 12th to 14th of September 2018 (*https://www.ecppm2018.org*) and organized there by our colleague Jan Karlshøj. We would be happy to see many of you at this event, where often valuable decisions concerning BIM definitions and standardization have been trigged. So, at the last ECPPM 2016 at Limassol, Cyprus the coming together of the competitive groups for ISO/NP 21595 has been paved.

FIEC, the European Association of the Construction Industry, finalized their white paper (called Manifesto) on BIM and launched it successfully at the commission. The BIM working group was reconstituted in their last meeting in 2017 in the working group Industry 4.0 focusing their scope to BIM for production methods, broadening to robotics and cyber-physical production systems.

E-Learning was focused during the last years on BIM education for craftsman which was very successful and a new project may arise in this context in 2018. The European online Master course “IT in Construction” coordinated by the university of Maribor, Slovenia and University College Cork, Ireland, will enjoy much more activity from TU Dresden in n2018, due to Prof. Menzel’s move to Dresden.

Concerning the research staff, the year 2017 was directed to decreasing the number of employees to the size of a Senior Professor’s research team and providing a new starting condition, i.e. employing new co-workers according to the views and ideas Prof. Karsten Menzel with regard to lecturing and research support. Accordingly, the institute will announce in January and February 2018 a fulltime position for a senior researcher (equivalent to assistant professor) and two for assistants for lecture doing research for PhD.

In 2017 between July and December Ken Baumgärtel, Romy Guruz, Mathias Kadolsky, Faikcan Kog, Frank Noack, Frank Opitz, Hervé Pruvost and Robert Schülbe left the institute. Nearly all of them submitted their PhD thesis or will do so in the next 6 months.

Nevertheless, the remaining group of co-workers at the institute still has a broad international background and covers a broad range of expert domains, like civil engineering, informatics and mathematics.

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

Dresden, in December 2017 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.

[1] until 30th March 2018
[2] from 1st April 2018

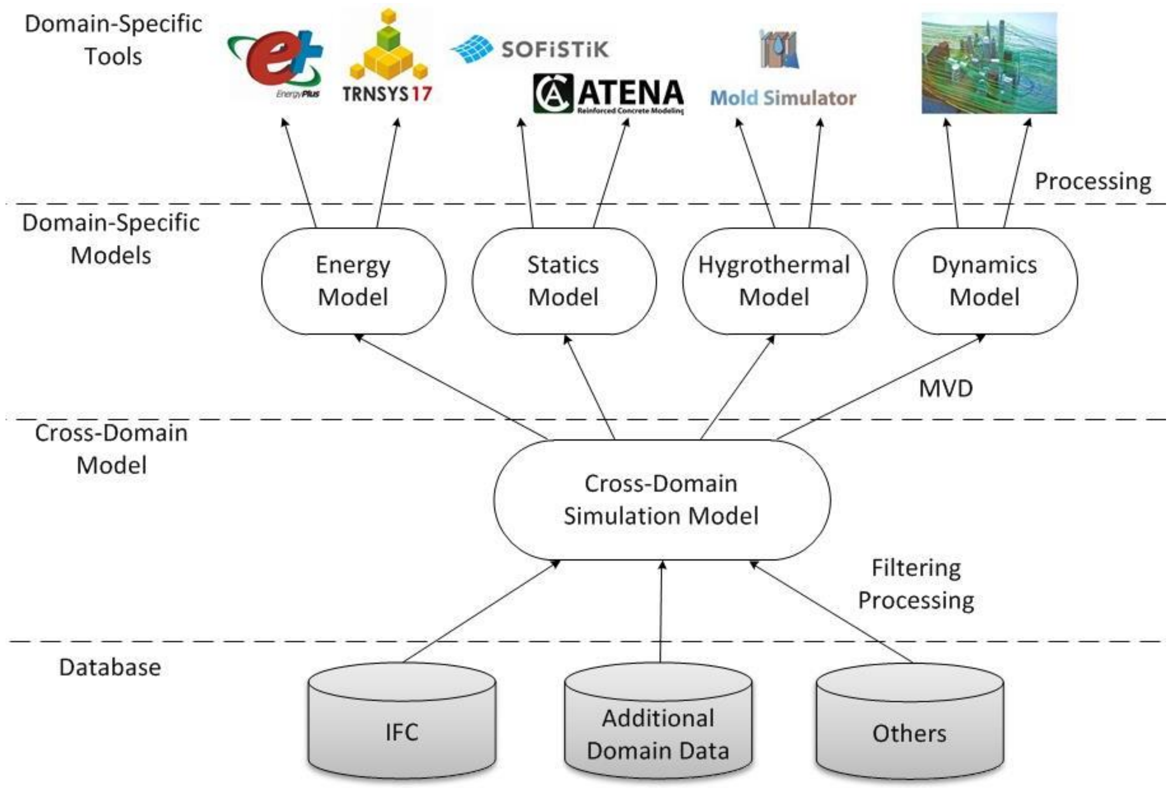
Requirements for a Simulation-Ready BIM for Cross-Domain Building Simulation

Tom Grille

Objectives

The planning of a building design or retrofitting is a complex task, since it is necessary to pursue a multitude of contradictory objectives. There is a variety of building simulations tools that can support decision makers in this process. The most important domains are statics, energy, dynamics (CFD) and hygrothermals. All these domains have different model and data requirements.

The goal of this research is the definition of BIM requirements for a model that can be evaluated with tools of all domains. To achieve this cross-domain interoperability, an intermediate model is defined which combines the necessary information from the BIM and processes it to make it usable by the various simulation tools.



From Simulation-Ready BIM to Domain-Specific Application

Approach

A four-step approach is envisioned.

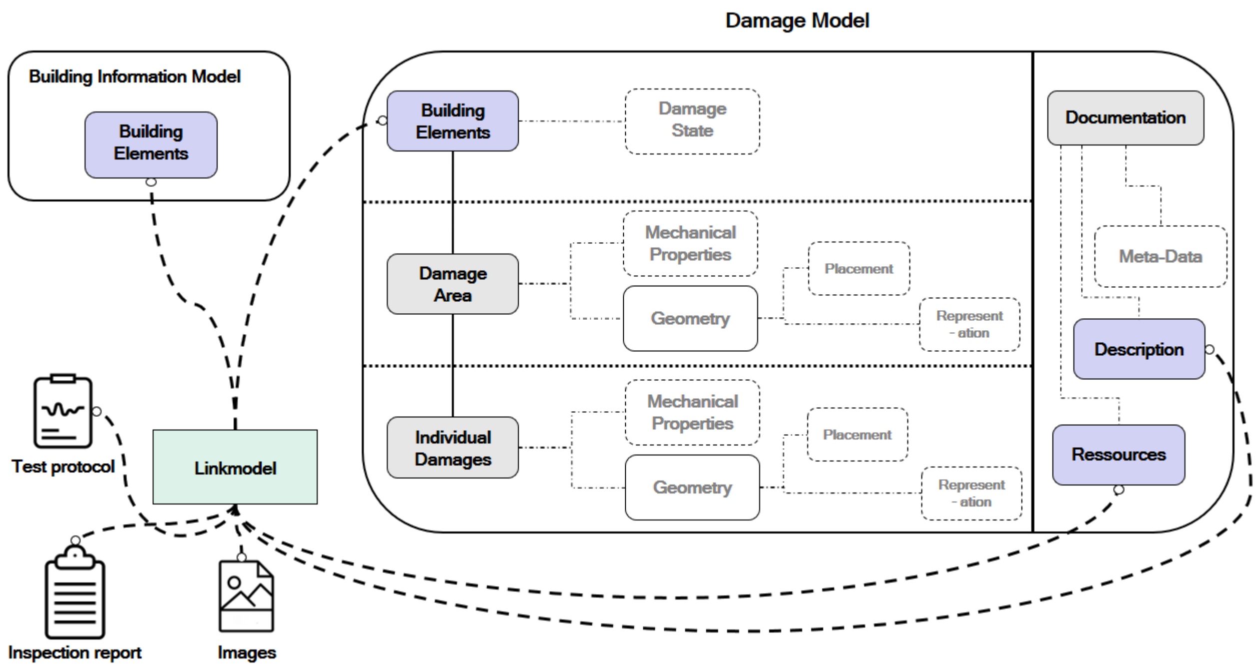
1) Starting from the different tool input requirements, common domain specific simulation requirements will be derived and independent data models for each simulation domain will be defined. The question of tool dependent formats arises but is not the focus of attention.
2) These models will be analysed to find common variables as well as capabilities to define common variables by constructing derivations or abstractions of existing ones. Here special attention to geometry and topology and their mapping to a finite element model has to be paid.
3) This set of common variables form a cross-domain simulation model. This model's purpose is twofold: On the one hand, it is responsible for filtering and processing the data basis. On the other hand, it forwards this information to the domain-specific models using MVDs.
4) The requirements of the cross-domain simulation model define the minimum requirements of a simulation-ready BIM. Here different ways of adding external information to IFC, e.g. defining proxies or using external links in a multimodel approach, have to be evaluated.

Digitalization of Structural Damage in BIM

Al-Hakam Hamdan

Objectives

Despite the possibilities of registering damage, such as material cracks, electronically through sensors or advanced measuring instruments, the methods how these data are stored are still limited to graphical representations of the structural damage or sets of measuring data, which have no context to the building model. Due to this, the damage of buildings must be evaluated and categorized manually by experts. The possibilities of a computer-aided analysis, where tools for filtering or reasoning could be executed, are restricted because of a missing object oriented data model for structural damage. For this reason, a model for digitalizing damage in buildings and infrastructure will be developed, which will be linked with the corresponding BIM-Model by using the Multi Model approach. The linked models are then read in by appropriate software and prepared for evaluation operations. The use of a model to record structural damage opens up new opportunities in the field of building maintenance. In this way, it would be possible to filter damages recorded in the data model according to various criteria and the temporal course of the damage could be analyzed with more ease.



Structure of the Damage Model with related external elements referenced in a Link Model

Approach

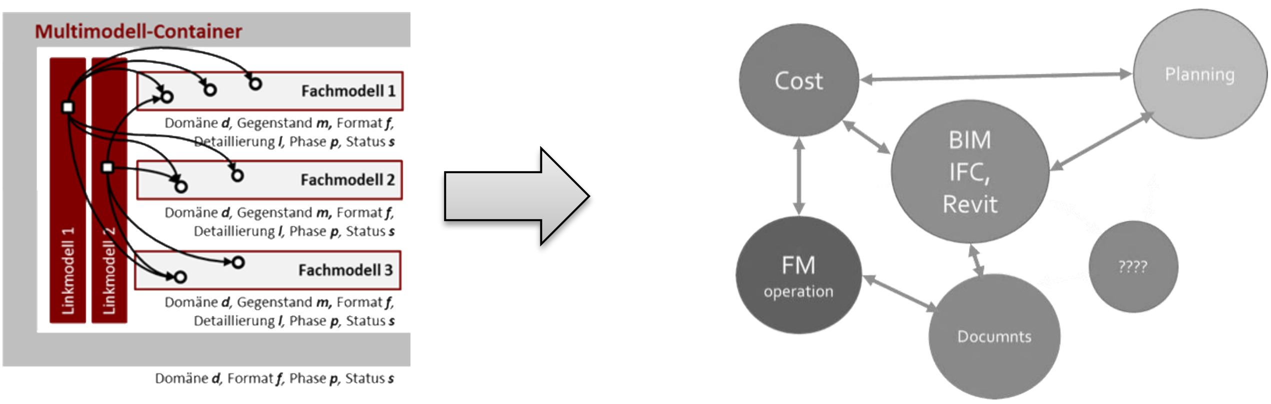
The Damage Model under development uses three levels of detail to describe the registered damage. The damaged building element is represented at the top level. If this concerns a damage that covers the entire component, a corresponding definition within this representation is possible. Besides a global unique identifier and values regarding the damage, no further information for the component such as geometry or relations between other elements exist in this model. Therefore, the data from other linked models must be taken by using the Multi Model approach. The subordinate level describes damaged areas within the affected component where generally mechanical changes are applied. For example, in the case of cracked areas within a concrete component, the smeared crack concept can be used and a stiffness matrix including reduction factors is defined. At the lowest level of detail, individual damage components such as single cracks or corrosion spots are described as realistically as possible with consideration to their geometry. Additionally, they can be combined and grouped together. Using this method, allows the modelling of complex crack patterns. Furthermore, documentation data such as inspection reports or photos of individual damage can be linked with specific documentation elements, which are related to other objects in the Damage Model.

Graph Database Approach for Managing AEC Connected Data Models Based on Multimodel Data Exchange Method

Ali Ismail

Objectives

Construction project are getting bigger and complexer. During the planning and construction phases a lot of information from different sources are generated and should be updated with time. This information and the relationships between them could remain inaccessible due to the absent of suitable data management tools. Connecting those models in single dynamic connected Common Data Environment (CDE) has a big potential for a better way to manage the whole project data and to be the source of truth which can be accessed and updated by all project actors. Graph databases have shown great capabilities in understanding and accessing rich complex datasets in different domains. Graph models are extremely useful for representation and description of the complex relationships. This research aims to develop a workflow for automatic transformation of most important data models and connect them through a labelled property graph-based model and developing suitable tools for project data management. Ideally these data models will be bundled together as a Multimodel container. The transformation process focuses on 3D BIM models in IFC standard format, 4D planning data like project scheduling, 5D cost calculations and project documents. The CDE should enable checking BIM model's quality based on predefined rules and carrying out advanced query and topology analysis of BIM models, visualize and analyze the relationships between all project data sets.



Approach

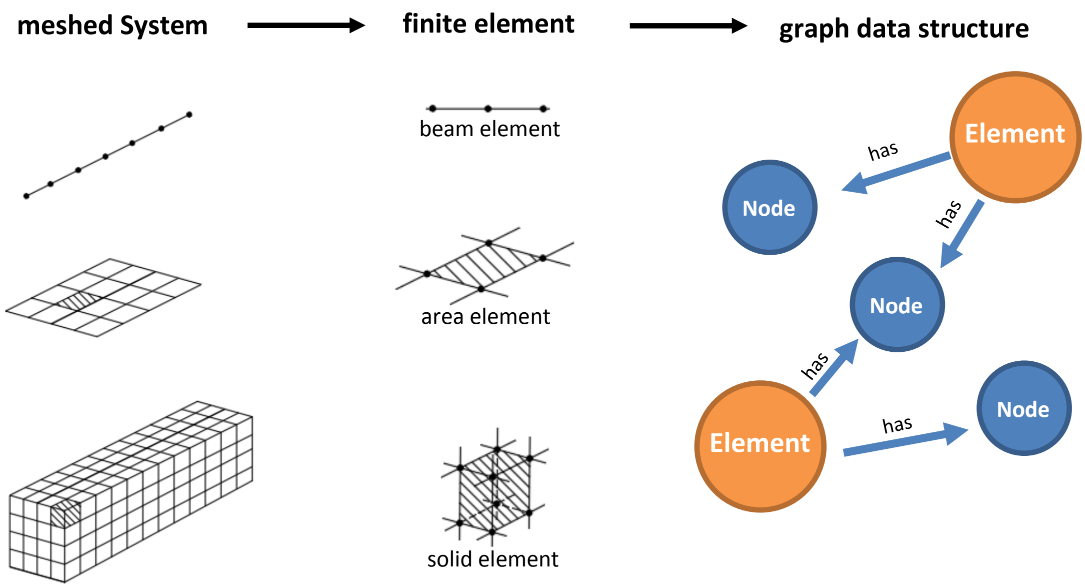
Each data model inside the Multimodel container will be converted into Neo4j labeled graph database. The conversation process of IFC models will be done in 3 steps, at first all IFC entities will be converted into nodes where each node will have a set of properties of the entity basic attributes, in the next step all relationships between entities will be converted into graph relationships. In the last step, the non-direct relationships will be simplified and all redundant nodes and relationships will be deleted. The conversation process will use the IFC data model server IFCWebServer.org. The BIM graph database can be extended and connected with other data models like planning and cost information. For text-based data model a special parser will be developed to convert them into graphs and assign nodes with further information. In the final step the links models will be converted into relationships connecting elements from different data models together. The access to the graph database will be achieved through a user-friendly web based application and an online BIM viewer with an API interface. A set of graph queries will be predefined for most of common data exchange tasks and filter operations. Another set of queries will be prepared for automatic generation of links between graph database entities based on rules. The graph-based CDE will allows users not only to access the connected information of Multimodels but also to edit them and add more connections to other data sources.

A Graph Database of Finite Elements for Structural Analysis

Fangzheng Lin

Objectives

The Building Information Modeling (BIM) technology has shown its possibilities in the entire lifecycle of a building project in many ways. However, the development of BIM in the domain of structural analysis is limited. The current so-called combination of BIM and Finite Element Method (FEM) still floats on the surface of geometric data exchange, such as the data mapping from an IFC model to a specific file, which is executed by a certain kind of FEM-Software. The general relation of BIM and finite elements has been not much investigated so far. This research work aims at building a graph database of finite elements to store the information of each node and element, and to represent the relation between these adjacent nodes and elements in one system, so that finite elements are informationized for the further requirements from the combination with BIM.



The architecture of a graph data base of finite elements

Approach

First off, a graph database needs to be built for the information of finite elements. One finite element is composed of several nodes, and one node could be the component of two or more elements, which depends on the types of finite elements and the system geometry. In this way, the entire meshed system can be imaged as a local social network. Each node is regards as an account having “personal information” like location, forces, displacements, etc. A finite element works as a social group with properties, which contains a few accounts. Meanwhile, there are also connection among these accounts. Actually, finite elements are represented with the combination of nodes and borders, which is the relations of nodes. Therefore, the most essential point of building a database for finite elements is the relation between nodes. In term of dealing with the relations in data, graph database have more advantages than relational databases. As next step, this graph database ought to be applied to modify or manipulate the finite elements based on the needs, to visualize the meshed system, and to map the data to the FEM-Software.

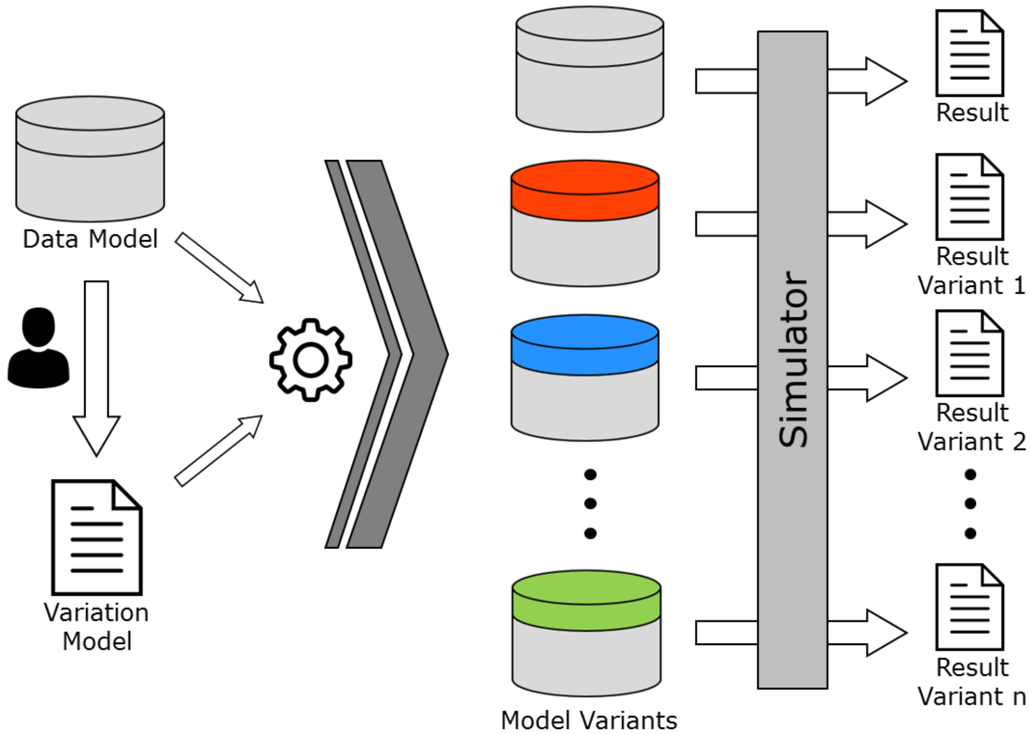
A meshed system exists not only in the domain of structural analysis. A plenty of possibilities wait to be discovered. The database will be more generalized, its implementation would also be expanded to strengthen the functionality of this graph database.

A Concept of a Variation Model for Mass Simulation Approaches in Structural Engineering

Ngoc Trung Luu

Objectives

With the increasing complexity and requirements of buildings and other structures, computer-aided analyses tools are more and more required for design, construction and maintenance. Simulation is a popular approach for the building structure domain, e.g. energy simulation, construction process simulation etc. A single simulation can only investigate one model state at a time. For tasks like building component dimensioning, it is necessary to simulate/calculate multiple models which do not differ much from one another in mass simulations. Therefore, the simulation experts to create input models for mass simulations manually by hand, which is costly and time consuming. The approach of a Variation Model will be investigated to remedy this problematic.



Concept of a Variant Creation through Variation Model

Approach

By defining a variation of model data in a separate model, the creation of input models for mass simulations or other system analysis approaches with a model-based input to reaches a higher degree of automation. The method also enables the use of the Variation Model as template for recurring engineer tasks, e.g. bridge dimensioning, in which the Variation Model can be used for multiple bridge data models to generate simulation models with different combinations of material parameters to find the most efficient solution. The Variation Model defines single variations of other data model parameters on a generic base and combines them to model variations, which represent the entirety of data models with the different manifestation of the varied parameters. Model-spanning links connect the parameter variations with their parameters, so this approach can be embedded into the Multi Model method as an annotating model. With the Variation Model, the models for the mass simulation can be generated through an external solver or directly consign to the simulator by interpreting the Variation Model during pre-processing through an interface.

Management of heterogeneous Computation Infrastructures

Michael Polter

Objectives

Nowadays, engineers are faced with a large number of different computation and collaboration tools as well as database implementations, which have to be utilized in combination to solve complex, cross-domain tasks. Existing solutions at best allow the link-up of applications of a vendor. But if one of these tools is missing a particular functionality, the tool chain is interrupted and automation is impossible. Furthermore, these "Suite" products are generally either bound to the resources of a workstation or completely hosted in the cloud. In this case, an additional cloud license has to be acquired for already purchased applications. The aim of the BIMgrid is to provide a framework for the efficient link-up of applications from different vendors while primarily utilizing the local company hardware that can be extended by cloud resources on demand. We use the UNICORE grid middleware to manage the heterogeneous infrastructure, consisting of local workstations and virtual cloud resources (see Fig. 1). The adapter concept of the framework allows the combination of various software in automated workflows. In order to exploit the infrastructure as best as possible, a suitable workflow engine for the distribution of jobs has to be identified and adapted to consider specific characteristics of physical and virtual nodes.

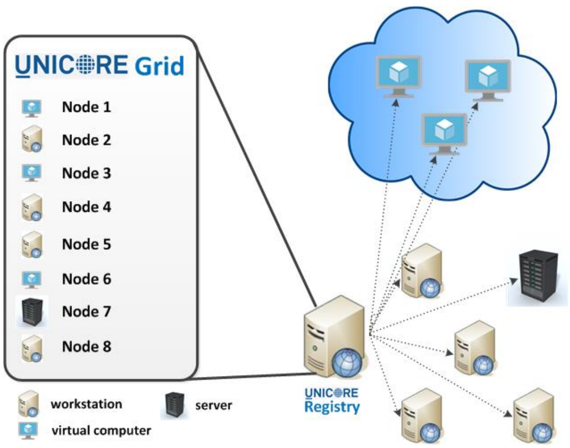


Figure 1: Mixed Infrastructure Management

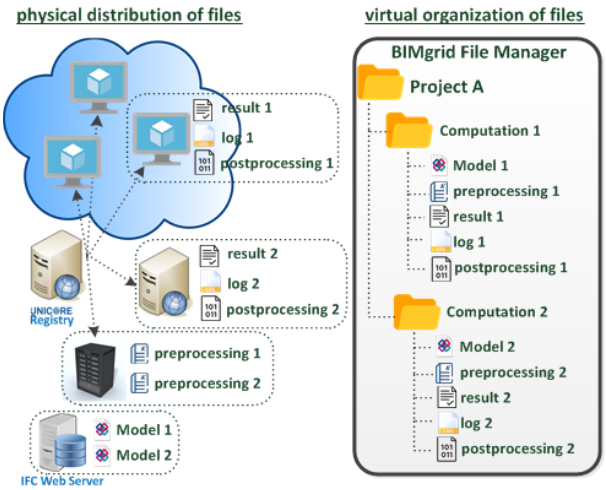


Figure 2: Distributed Data Management

Approach

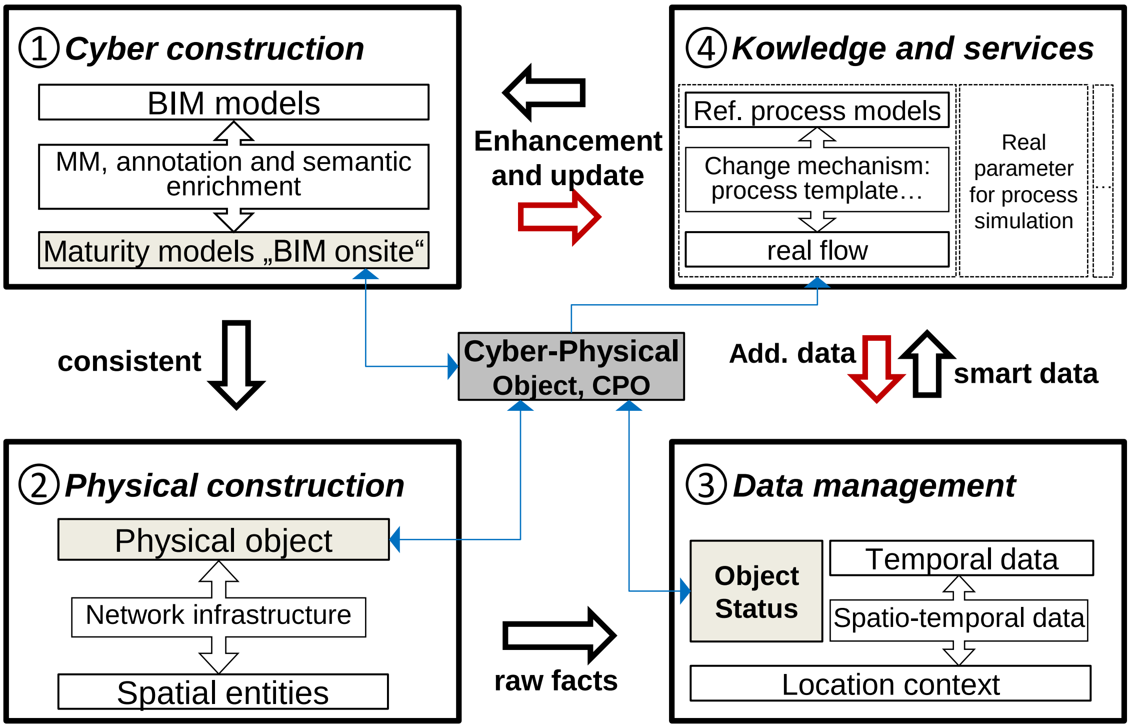
The UNICORE middleware has originally been designed for the management of local computer grids. To apply it on a mixed infrastructure, consisting of physical and virtual resources, it has to be extended with particular functionality like, for example, the assignment of costs to cloud resources. Users have to be provided with a location independent view of data artifacts, which are distributed amongst the computation nodes (see Fig. 2). Therefore methods and technologies for the integration of virtual file systems have to be reviewed. This allows a decentralized data storage and reduces the network load significantly. Suitable redundancy mechanisms have to be applied to prevent bottlenecks at unreliable network parts and to guarantee data availability. The link-up of heterogeneous applications is also a challenge for workflow management and job scheduling. Computation nodes have to be compared with regard to reachability, which is more reliable on local resources, and availability, which is more reliable on virtual resources that can be completely dedicated to a job. These are just two of the criteria which have to be considered to meet the user's preferences. BIMgrid implementations should be able to integrate capabilities of external systems on a service level. For example, the IFC Web Server could be used to manage building models. Therefore the BIMgrid has to be extended with appropriate web service interfaces. As application domains, mass simulations for bridge monitoring and bridge assessment are envisaged.

A framework to embed construction objects for establishing CPS in construction

Yaseen Srewil

Objectives

The Cyber-Physical Systems (CPS) is about conjunction between the physical world of objects and digital "cyber" world of software and computing. Similar to the pioneer role of CPS in industry 4.0 initiatives, CPS approach can be seen as a promising paradigm for digitally driven technological fusion in construction sector. Thereby the objects and processes of site operations tied directly to the digital building models using automated data capture techniques. This research proposes a framework establishing CPS in construction domain. The designed framework is to close the information loop between the digital models and physical construction. According, the physical entities and information are inextricably linked in Cyber-Physical Objects (CPOs). Hence, there are no longer differences between information and physical items especially in the context of flow. CPOs have a centric role in the framework, in which objects and construction processes are mutually-influencing. In this manner process and objects will be inseparable, i.e. physical things become part of the processes. The CPOs in the framework are distinct by identity, status, behaviour and/or action derived based on a mathematical algorithm and logic.



Framework embeds construction objects to enable CPS in construction

Approach

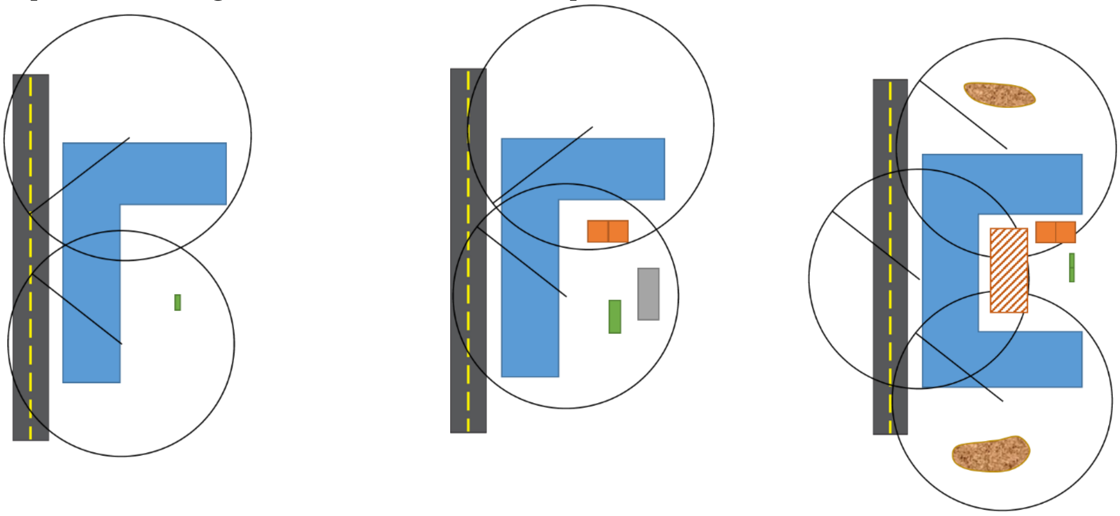
Designing a spatialized system such as CPS in construction needs a solution bundles various facets of constructions into a generic framework. The framework offers information interoperability and interaction among all sub-systems. Thus, the individual entities of different parts work together toward a scalable system with new capabilities. Abstractly, the framework comprises: (1) a cyber construction represents the maturity of the digital models realizing the BIM models onsite. Semantic enrichment, annotation and /or multimodel approaches can be used to enrich BIM models beyond the design phase ensured a tight connectivity of models to the real physical entities. (2) Physical construction includes the construction site, where the physical entities are processed, and resources which are mainly the engineered materials (prefabricated components, modular elements, etc.), equipment, machine and even personnel onsite. (3) Data management part is necssary to handle and filter field raw fact shifting these data into meaningful information and in advance into „smart data“ which are designed to play an actuation role within the system. (4) Knowledge and services are an access point to deal with real-world problems and making decisions. Thereby the bi-directional coordination between the real world and digital models are accomplished by a continuous monitoring (physical→cyber) and control (cyber→physical).

Ad hoc Modelling of Construction Sites

Ulf Wagner

Objectives

Construction site design is an iterative process. During the planning phase of a constructions site the level of detail increases and design changes of the site and as well of the building or trail are possible. So maybe the building owner decides that he needs one more stairway for security reasons in his building. This has impact to the ground plan and finally a rearrangement of the construction site is necessary. Therefor other cranes are essential and this require other constructions techniques. This shows that that current and consistent information must be provided automatically for each development process step as far as possible. Due to the large amount of data accumulated during construction site design, efficient information logistics are indispensable. An engineer should only get the data he needs directly for the task, so as not to sink into a flood of unnecessary data. In this way can it be ensured that he can work quickly and productively. It also makes it easier to implement security aspects, especially when working with external partners, and the technical provision of large volumes of data in a development network.



first draft *intermediate stage* *final plan*

Approach

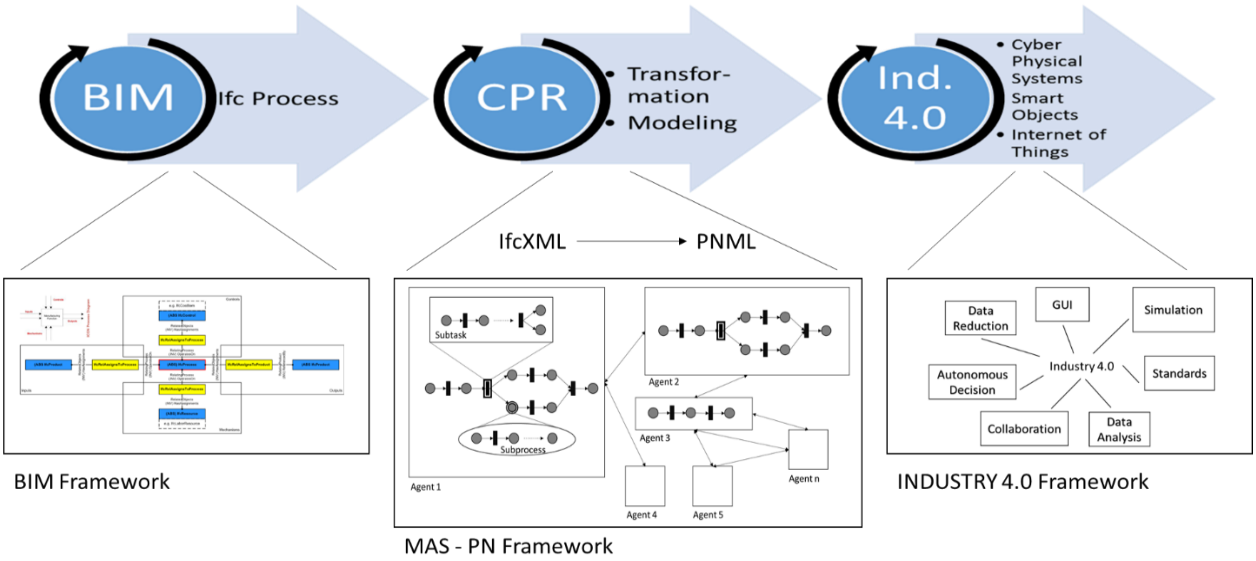
In order to provide the engineer with the information required for the current process step, data modelling within a workflow must determine the degree of accuracy. On the one hand, it has to be modelled which minimum and maximum data quality an input parameter of a process step needs so that it can be processed in a meaningful way. On the other hand, it must also be defined in which quality levels a process step will deliver preliminary and final output data. Due to the provisional nature of the data, additional rules must be observed when modelling the dataflow between the process steps. Otherwise, maybe that process step cannot be processed because, although all input parameters are supplied with type-conforming current data, but are not available in the correct quality. However, not only the construction process is in focus, but also spatial conditions such as ranges and collision problems must be checked. Different levels of detail of the constructions site model are required. Depending on the domain for which an object model is to be designed for the construction site, the required attributes and the categorization of the elements differ. The computer-aided construction site equipment focuses on the spatial dimensions of objects and the possible uses of equipment. For the simulation of construction site processes, the main focus is on performance and availability. In the 4D simulation, construction processes are subdivided into sub-processes and tested for their feasibility with regard to spatial conditions. For the cost calculation, a distinction is made by once, repeatedly and continuously costs. These must be mapped in the modeling and different cost models used for this. For each level is to choose which attributes are available in this level. This is mapped in the model for each element and can be retrieved or filled by a view accordingly.

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

Faikcan Koğ

Objectives

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



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

Approach

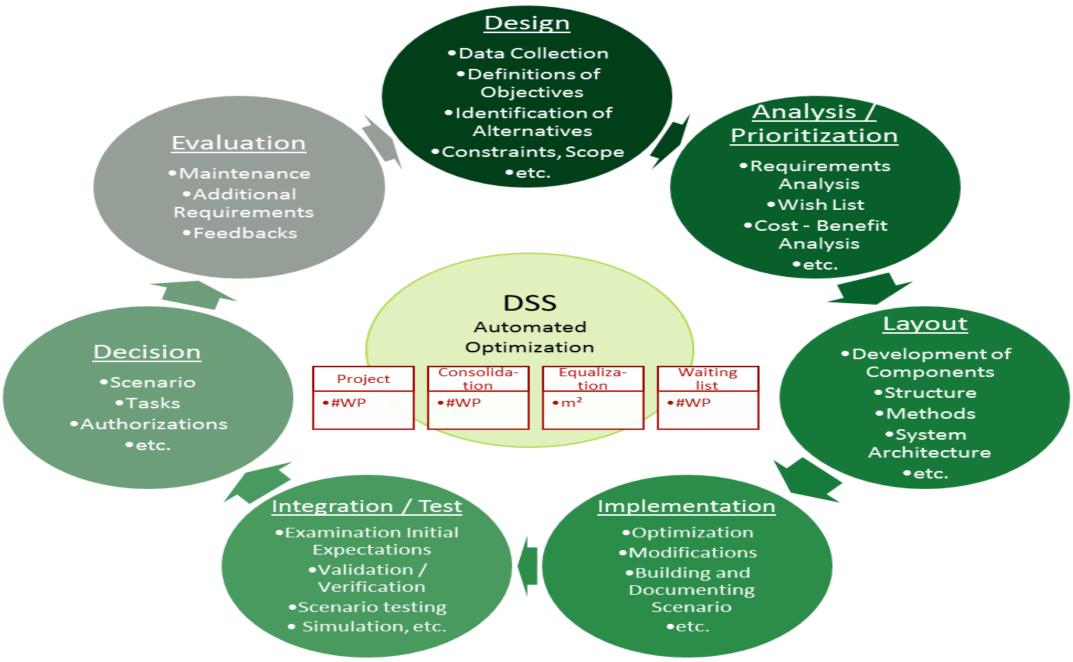
Reengineering is the selected technique to support integration of BIM-based construction process approaches within an Industry 4.0 environment. A multi-agent system is used for both the reengineering base and for smart objects. The autonomous agent decisions and the distributed cooperation between the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

Automated Optimization of Multiple Objective Office Space Re-Allocation for CREM

Faikcan Koğ, Safak Ebesek (ITU)

Objectives

Corporate real estate management (CREM), which is an operational and strategic management level for organizations, consist of facility management, project management, transaction management and space management. In recent year, due to the strategic importance to the property assets of companies, CREM became a core business with its complex challenges. Office space allocation (OSA) is one of most important challenge that every corporate real estate managers must be faced. It focuses to reduce the misusage of space meanwhile to increase the efficient use of the space, which is one of the most expensive resources in a typical organisation. It contains many conflicting objectives, constraints and regulations. The designed allocation during the construction or movement phases could not satisfy the needs of organization in time. Moreover, reconstruction or renovation may not be an efficient solution for the space utilization because of the possible high costs and time loss. Therefore, OSA should be handled as a continuous process, and in order to resilience constant changes such as personnel movements, maintenance / renovation of existing spaces and reallocations, there is a need of easy and fast adaptive solution system. The objectives of this research are (1) the examination of multiple objectives of OSA and re-allocation and (2) the proposal of automated optimization method which consist of consolidation, adjacency and requests of units, utilization and equalization of spaces.



System Development Lifecycle of an Automated Optimization of Office Space Re-Allocation

Approach

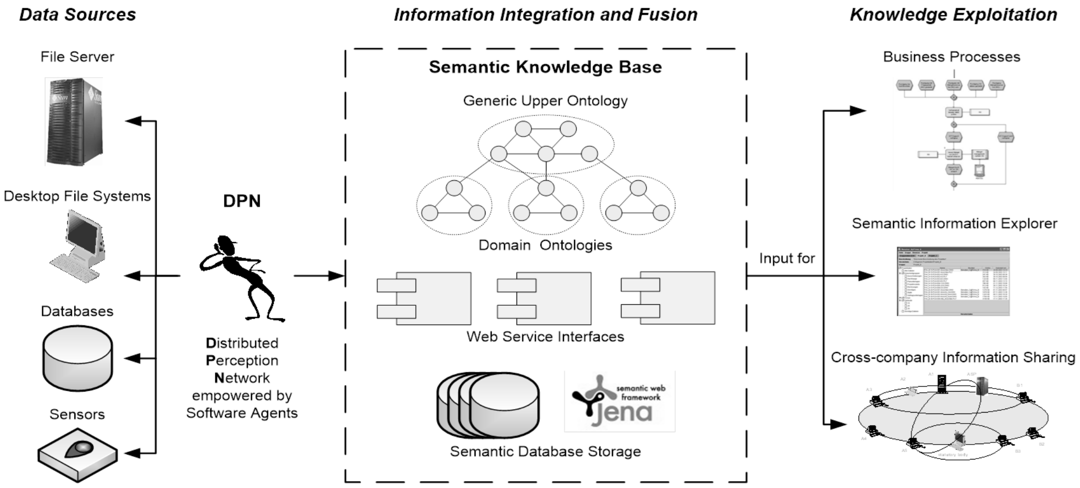
Optimization is the selected technique to meet the demand of OSA problem within a system development as a decision support system (DSS). However, instead of classical human based optimization approach, an automated optimization technique and a hybrid system, which is based on Particle Swarm Optimization (PSO) and linear programming was selected to provide optimized solutions. In addition, it deals with the complexity and large size of the problem with multiple objectives and constraints. The system development lifecycle of an automated optimization of OSA is based on the four objectives, which are project, consolidation, equalization and waiting list. In three of them the number of workplaces are main parameters, whereas the size of space in equalization. These are the core purposes of system and they generate a goal function for the mathematical algorithm. Lifecycle consists of seven phases such as design, analysis, layout, implementation, testing, decision and evaluation. Automated optimization is executed according to this sequence. Matlab and Java are selected tools to perform and visualize the approach. Real cases from industry will be used to indicate results of the model. The study will be enlarged with the integration of BIM based platforms.

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

Alexander Gehre[1]

Objectives

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



Information Gathering and Fusion Using Semantic Web Ontologies and Software Agents

Approach

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

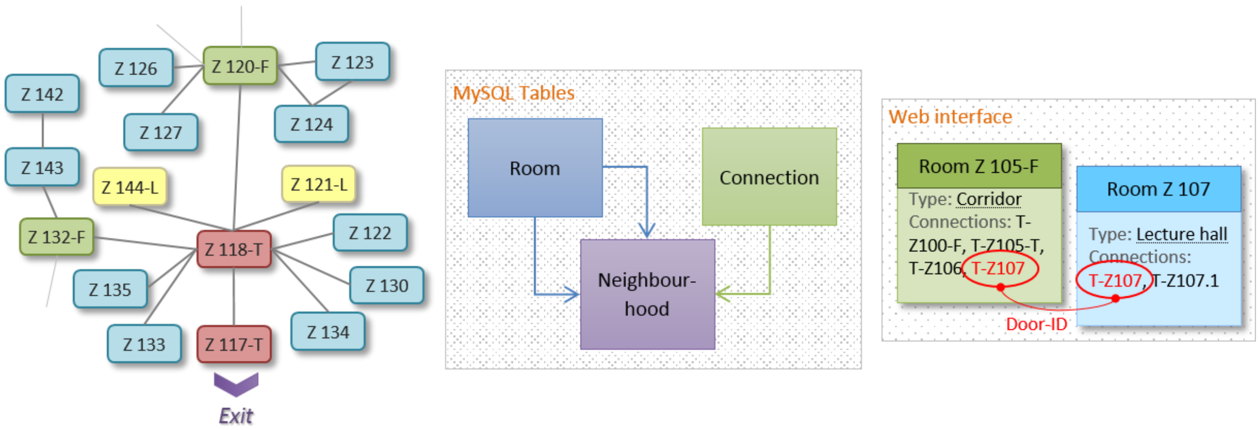
[1] Currently founding a spin-off company in construction informatics

Graph-Based Navigation in a 3D Campus Infrastructure Model

Hermin Kantardshieffa

Objectives

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



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

Approach

The navigational tasks of routing (i.e., route planning) and guidance are theoretically based on graph theory rules. In order to describe the matter of Indoor navigation visually a graph model is used. Each campus building is represented as a non-directional connected graph $G = (V, E)$ with $V = \{ v_1, v_2, v_3, \dots, v_k \}$ 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.

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

Jamshid Karami

Objectives

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

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

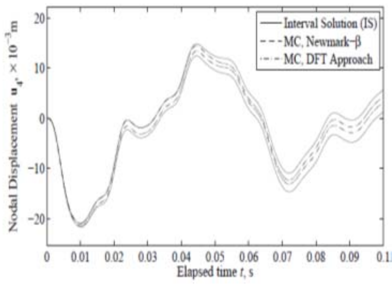
$$A_e = \begin{Bmatrix} 1 & 0 & 0 \\ 0 & 0 & 2 \\ 0 & 1 & L \\ -1 & 0 & 0 \\ 0 & 0 & -2 \\ 0 & -1 & L \end{Bmatrix}, \Lambda_e = \begin{Bmatrix} \frac{2}{L} & 0 \\ 0 & \frac{2}{L^3} \\ 0 & \frac{3}{L^3} \end{Bmatrix}, \boldsymbol{\alpha}_e = \begin{Bmatrix} \mathbf{EA} \\ \mathbf{EI} \end{Bmatrix}$$

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

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

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

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



Approach

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

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

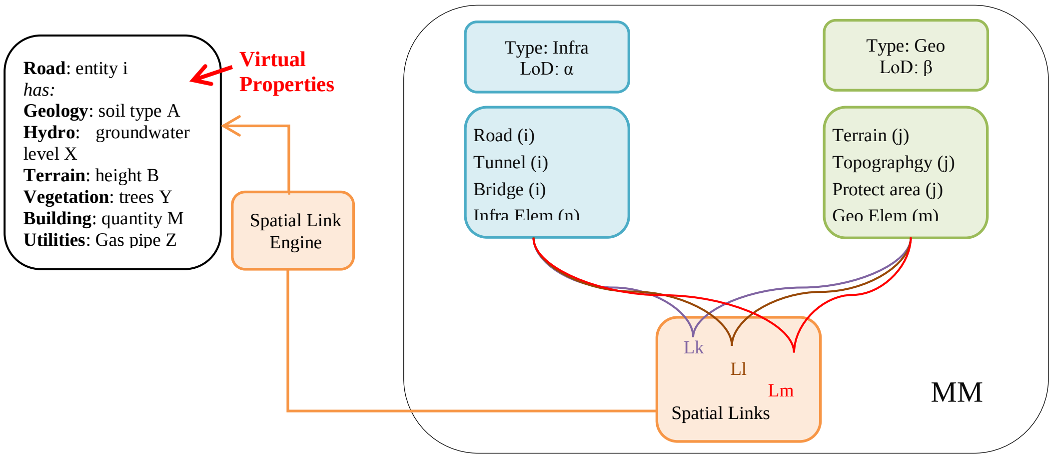
Then by means of case studies, the efficiency of the proposed method will be verified. Numerical analyses will be performed using the developed IFEA code. For this purpose, Steel Moment Frames as the target group of structures will be used. In this phase, the results of previous stages of current research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

Interoperability of Infrastructure Planning and Geo-Information Systems

Nazereh Nejatbakhsh Esfahani

Objectives

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



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

Approach

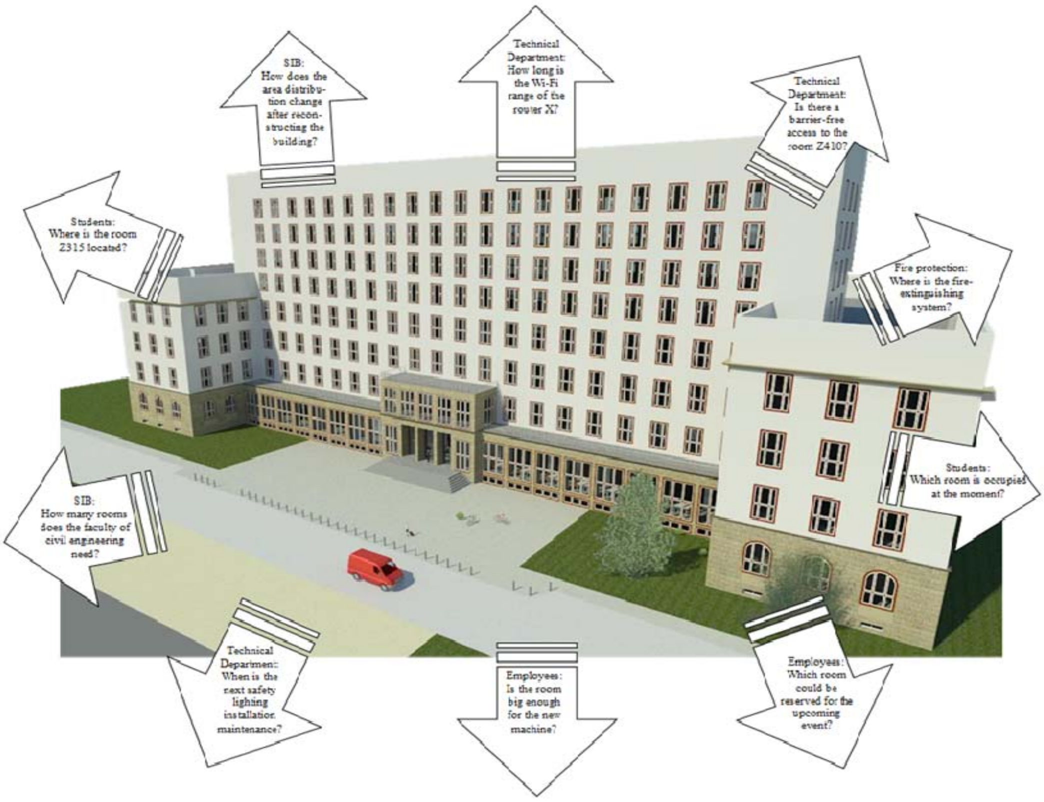
Multi Model (MM) is a method where heterogeneous data models from various domains are bundled together into a container keeping their original format. In separate Link Models the elements of the data models will be linked together. Yet the multi model and the generated links have no inherent domain semantic.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

Development of a Knowledge Base for Campus Infrastructure Models

Eugenie Pflaum[1]

Objectives

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



Exemplary retrieval on the knowledge-based system

Approach

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

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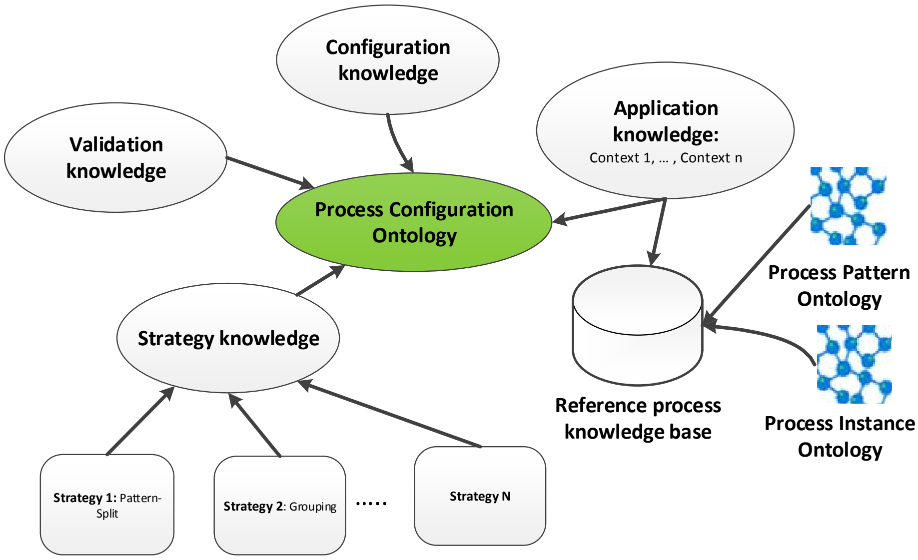
[1] This is a cooperative PhD thesis with the University of Applied Science Dresden.

Knowledge-based Process Configuration in Construction

Ksenia Roos

Objectives

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



Approach

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

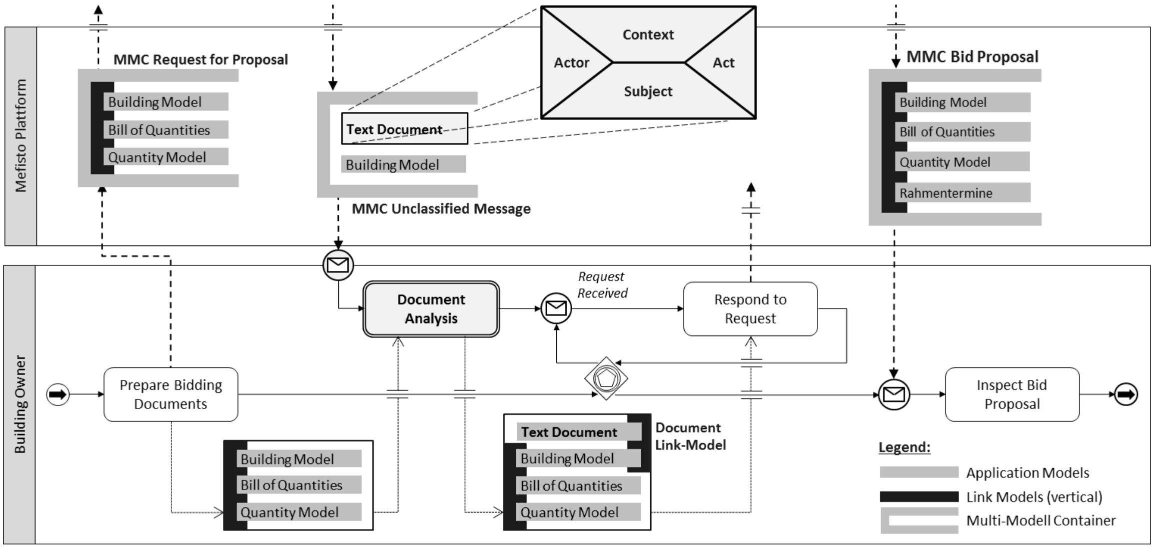
- *Application knowledge*. This knowledge describes the application conditions of the process patterns, for example as keywords searching criteria for a certain pattern
- *Strategic knowledge*. This knowledge describes different building strategies. Strategy can be defined as procedural methods/plan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

Integrating Text Documents in Multi-Model Collaboration Processes

Sven-Eric Schapke

Objectives

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



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

Approach

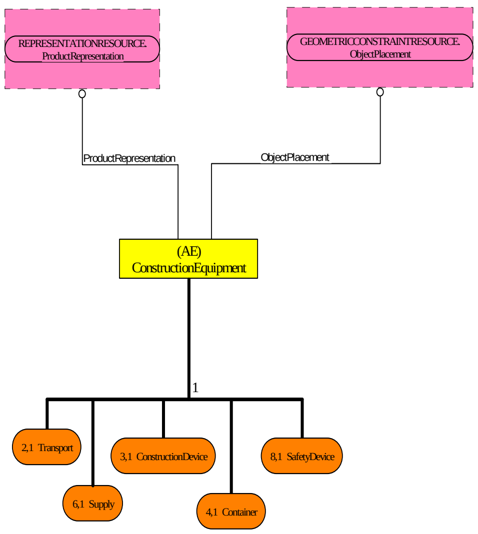
The figure above illustrates the analysis of a text document within the context of a Multi-Model Workflow for construction bidding. While predetermined formal MMCs can be used for the request and the submission of bidding information by/to the owner, intermediate requests and notifications may comprise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

IFC Conform Construction Site Model Taxonomy

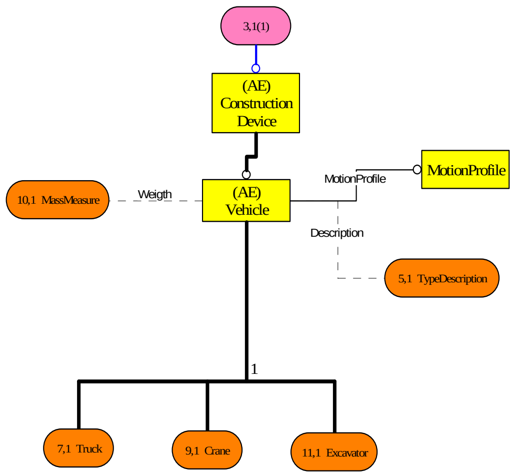
Ulf Wagner

Objectives

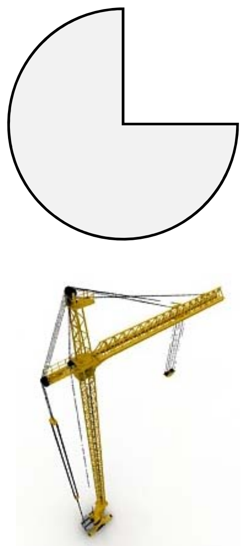
For better-integrated building project planning and realization, it is necessary to be able to design a construction site using IT. Moreover, it is necessary to be able to interchange construction site information digitally, in a qualified information model enabling 3D, and not only as plain 2D files.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



Construction Equipment Integration in IFC Model



Inheritance from Vehicle



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

Approach

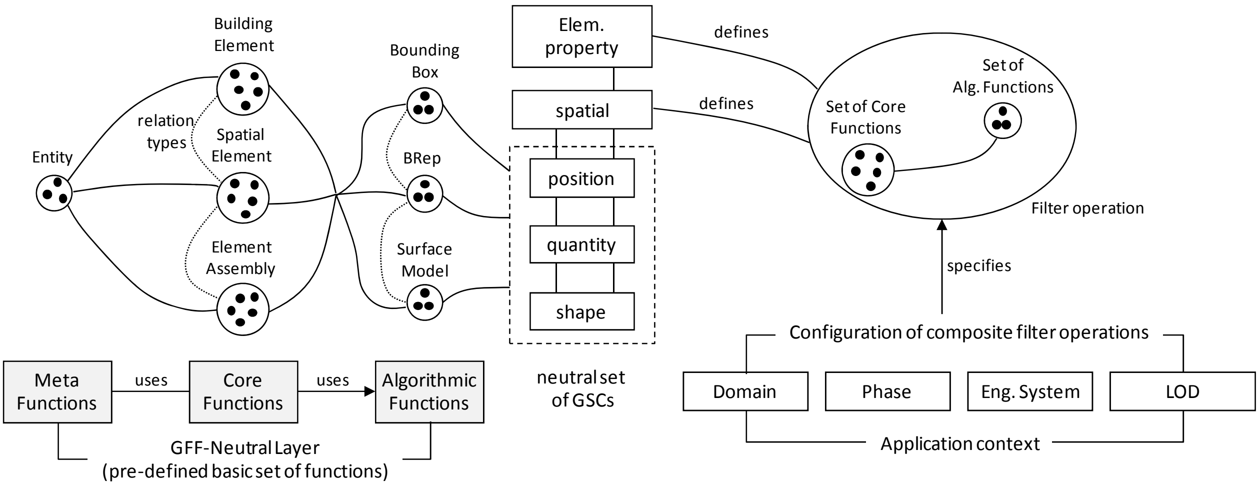
The elements inside a construction site model require structuring and sorting. Modelling of unsorted sets of components gives more freedom, but wastes a lot of optimization potential because attributes and relations to other objects have to be modelled individually for every single object type. To order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

Geometrical and Spatial Constraints in BIM-based Information Filtering

Ronny Windisch

Objectives

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



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

Approach

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

Research Contracts

Title:	**iSiGG – A Dynamic Interactive Simulation System for Fire, Smoke and Pollutant Gas Spread in Buildings Taking into Account the Interaction with People**
Project Leader:	Prof. Dr.-Ing. R. J. Scherer
Financial Support:	BMBF (German Ministry of Education and Research), Research Program IKT 2020
Budget/Funding:	1.2 million Euro / 0.8 million Euro (total), 0.29 million Euro (CIB)
Duration:	3 years, since 07/2016

Approach:

iSiGG develops an interactive integrated cyber-physical simulation system for fire, smoke and pollutant gas spread in buildings in cases of fire, chemical, biological and radiological incidents and terrorist attacks. It will combine computational fluid dynamics (CFD) methods with methods for numerical simulation of people flow based on a semantic building model that is capable to support non-stationary changes of the model status such as opening/closing of doors and windows, state changes in the HVAC and the fire protection systems, damages due to blasts or people actions etc.

The research work encompasses:

(1) Development of a CFD simulation software specifically optimized for the targeted application domain;
(2) Coupling of CFD and people flow simulations to an integrated co-simulation using the Functional Mock-Up approach as baseline and enabling interaction with the building and dynamic state changes of the building model;
(3) Embedding the simulation system into a BIM-based virtual 3D Lab for building design and evaluation of existing building stock;
(4) Development of an application program interface (API) for modular integration of the simulation services in a compute cloud environment for achievement of fast online response.

The CFD system will be based on an existing software application for the simulation of fire in tunnels. It will be extended by an open library of building materials including functions for material heat release rates, consideration of HVAC equipment, coupling of the mass transport and the Navier-Stokes equations and combination of fire and smoke spread models with a radiological model. The people flow simulation will be based on the AnyLogic agent system, extended by a database for human behaviour patterns combining physical and psychological models and considering CFD and building element interactions. Building modelling will be based on the multi-model method developed by CIB. It will enable the dynamic linking of the three modelling subdomains (building, CFD, people flow) and the use of rule-based methods for automated derivation of model change states.

The developed simulation system will be of benefit for a number of different actors in the construction process such as designers, facility managers, owners, security personnel, public authorities and insurances, especially with regard to the planning of safety measures, the evaluation of existing buildings and the development of training scenarios for rescue and security teams. The integrated BIM functionality will enable easy to use visual examination of evacuation plans and virtual team training thereby helping to improve the overall quality of the design process regarding high-rise buildings, shopping malls, railway stations and airport terminals.

Partners:

FIDES DV-Partner Beratungs- und Vertrieb GmbH – **Coordinator**
SimPlan AG
TU Dresden, Institute of Construction Informatics (CIB)

Title:	**wiSIB – A Simulation and Knowledge-Based System Identification Approach for Bridge Structures**
Project Leader:	Prof. Dr.-Ing. R. J. Scherer Tech. Manager: Dr.-Ing. Peter Katranuschkov
Financial Support:	BMBF (German Ministry of Education and Research), Research Program IKT 2020
Budget/Funding:	1.2 million Euro / 0.8 million Euro (total), 0.37 million Euro (CIB)
Duration:	3 years, since 02/2017

Approach:

wiSIB develops an IT-supported system that will allow accurate identification of the structural behavior of a bridge subject to structural deterioration. Continuous automated evaluation of sensor data coupled with automated variation of the system's model based on goal-oriented convergence control parameters will enable the identification of both local damages (cracks) as well as their development over time (damage migration). This will provide the necessary prerequisites for informed decision-making with regard to the expected residual life span of the bridge and the related retrofitting measures.

The need for such a system is raised by the following three major challenges:

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

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

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

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

Partners:

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

Title:	**cyberBridge – BIM-based Cyber-Physical System for Bridge Assessment**
Project Leader:	Prof. Dr.-Ing. R. J. Scherer
Financial Support:	EU – Eurostars Program
Budget/Funding:	1.32 million Euro / 0.85 million Euro (total), 0.42 million Euro (CIB)
Duration:	3 years, since 05/2017

Approach:

Motivated by the growing demand for better assessment of bridge health under increased traffic loads, the project develops a new **cyber-physical bridge assessment system** that will allow at low cost continuous online monitoring and system identification beyond modal analysis on the level of crack propagation. The system will be delivered both as a product and as a service. Besides selling the system, continuous support and training, partial and complete bridge monitoring services and life cycle prognosis will be offered.

The research and development work will be grounded on standard BIM, the Multimodel approach of CIB, the algorithm for structural bridge analysis of Cervenka Consulting taking into account nonlinear behaviour and crack propagation, the advanced monitoring and vehicle identification method of Petschacher and the bridge design know-how of Leonhardt, Andrä und Partner. The system will be capable of continuously detecting micro cracks and the deterioration state of a concrete bridge at more precise and higher confidence level than today's monitoring systems at about the same costs. This will be achieved through the use of several new developments:

(1) Continuous simulation-based identification method for global and local behaviour identification using massive Grid/Cloud computational resources
(2) Load monitoring method for identification of individual vehicles and their synchronisation with the monitored bridge behaviour values
(3) Evaluation method for Best Fit of time instant and trend considering one monitoring phase at a certain time point and deducing the set of best fitting structural mechanics models, the changing of the bridge response due to the deterioration over a larger time interval, and the changes of certain physical parameters over that time interval to identify newly emerging cracks
(4) Prediction method for the remaining life span on the basis of the identified system and massive Grid/Cloud sensitivity simulations and probabilistic methods
(5) BIM, Multimodel and ontology-based information management and visualisation methods providing for flexible combination of the various needed data sources and models, improved result evaluation and reliable decision-making
(6) Improved sensor layout and tuning method based on multiple virtual scenario simulations and the Multimodel information management
(7) Improved sensor network with max 1 ms delay.

The developed cyber-physical system will be of benefit for three kinds of end-users: (1) Bridge Owners using the complete system (including installing the software and the equipment, training, consultancy on demand and helpdesk support) or dedicated consultancy for individual bridge assessment, (2) Monitoring and Assessment companies, and (3) Design consultants, subcontracting specific parts of the IT platform. The system will be tested with realistic usage scenarios on two pilot projects in Austria (Railroad bridge "8134 Draubrücke" near Föderlach - a box girder steel bridge with a span of 140 m, and Road bridge "Friedensbrücke G.A.V. near Villach - a steel arch construction with a span of 110 m) and one pilot project in the Czech Republic (Road bridge "Pavel Wonka" in Pardubice – prestressed concrete bridge with a span of 170 m). All pilots will be digitally modelled using standard BIM/CAD, parametric modelling with Dynamo and the Multimodel approach of CIB.

Partners:

Cervenka Consulting s.r.o. (Czech Republic) – **Coordinator**
Petschacher Software und Projektentwicklungs GmbH (Austria)
Leonhardt, Andrä und Partner VBI AG (Germany)
TU Dresden, Institut für Bauinformatik (CIB)

Title: **GeoProduction 4.0– Cyber-Physically Controlled Production of Underground Structures**

Project Leader: Prof. Dr.-Ing. R. J. Scherer

Co-Leader: Dipl.-Ing. Ali Ismail MSc.

Financial Support: BMBF (German Ministry of Education and Research)

Budget/Funding: 1.36 million Euro / 0.94 million Euro (total), 0,272 million Euro (CIB)

Duration: 2 years, start 01/2018

Approach: GeoProduction 4.0 as an industry 4.0 engineering and production system will revolutionize the current geotechnical production process through a cyber-physical system approach encompassing the components of online monitoring, online simulation-based geo-structure identification (i.e. soil, rock and building structures) with advanced related non-linear mechanical models, high-performance computing, online risk management and warning, in-time adjusting of the construction process through simulation of production alternatives and the re-dimensioning of underground structural elements like the retaining elements of the geotechnical structures using most modern BIM technology.

The project will develop a simulation-guided engineering and construction process for underground structures that will radically improve the production process, the safety, the reliability and leads to an optimization of underground construction through: (1) a new high-precision simulation-based system identification method for geo structures based on dynamic multi-model and ontology control framework, (2) an improved deformation monitoring method synchronized with the simulation identification cycles and the construction process, (3) an improved non-linear numerical modelling and numerical simulation of the complex geotechnical structural system,(4) integrated model variation management and high-performance Grid/Cloud computing, (5) knowledge-based matching of simulation and observation, (6) a 5D BIM-based construction, progress and prognosis visualization and warning system, (7) knowledge production simulation-based decision support for construction adjustment measures and semi-automated adjustment of the construction process, and (8) BIM-based sustainable long-term archiving of information for management and control of the construction site as well as for the life cycle and related maintenance activities

In this project, the Institute of Construction Informatics will provide: (1) a BIM extension based on the standard IFC data model for the modelling of geotechnical structures, sensor networks, sensor data and probabilistic models as well as the extension of the Multimodel Framework with filtering capabilities. (2) ontology system for the BIM-based Multimodel and the ontology based rule system for generation of geotechnical models with different failure events, different material laws and different related parameter values, (3) BIM-Grid platform for mass computing of simulation models and finally (4) a BIM annotation tool.

GeoProduction 4.0 will lead to reduce the structural safety factors of geo-engineering structures resulting in cost savings of the product and maintenance and retrofitting costs of about 20-40 % because of the exactly mirrored reality in the virtual model.

Partners: ZPP Ingenieure AG-(Germany)-**Coordinator**
Cervenka Consulting s.r.o. (Czech Republic)
Intermetric GmbH (Germany)
SAFIBRA s.r.o.,(Czech Republic)
TU Dresden, Institut für Bauinformatik (CIB)

Lecture Activities

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

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

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

Diploma/Master Course if Construction Informatics Competence is Chosen

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

Module BIW1-07: Construction Informatics Fundamentals

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

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

Module BIW2-09: Information Management and Numerical Mathematics

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

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

Module BIW2-15: System and Information Modelling

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

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/Kreil/Hamdan

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

Module BIW4-22: Cooperative Design Work and Numerical Methods

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

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

Module BIW4-33: Software Systems

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

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

Module BIW4-69: Simulation and Monitoring of Engineering Systems

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

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

Module BIW4-70: Model-based Working, BIM

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

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

Module: Information Systems (read in English)

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

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

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

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

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

Module BIWO-04: Software Engineering

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

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

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Positions in Editorial Boards of Journals

Automation in Construction	Elsevier Publishers	The Netherlands
Advanced Engineering Informatics	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

Membership in Standardization Groups

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