SENIORPROFESSUR BAUINFORMATIK
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TECHNISCHE UNIVERSITÄT DRESDEN

RESEARCH AND LECTURE ACTIVITIES IN 2019

December 2018

Research at the "Senior Professorship 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 2019, when new chances and new challenges will come up. Since 1st of April 2018 the institute of construction informatics has a new head, Prof. Karsten Menzel. He has been already active in our research area 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 got the position of a Senior Professor for Research, continuing with research as usual and with enthusiasm. This report covers only the research activities of the Senior Professorship to inform the interested community following our research developments since 1997. In that sense, it is only a subpart of the research report of the Institute of Construction Informatics established for our long term friends.

In 2018 our research topics have undergone a shift from energy-efficient building design to system and damage identification and hazard simulation as the main application areas. However, the underlying informatics baseline has remained principally the same, namely the Virtual Engineering Lab extended to cyber-physical systems, which is the core methodology of our research. It is based on the research methods regarding building information modelling, multimodels, interoperability, model filters, filter languages, MVDxml filter specifications, ontologies, description logic, intelligent construction management, virtual organizations including collaboration, project risk management, dynamic process modelling, simulation, ICT-supported computational engineering for building performance studies, grid/cloud computing and stochastics. Most of the topics have been accumulating in our ongoing common development "intelligent semantic Virtual Engineering Lab" (isVEL), which highly automated connects the BIM and the computational engineering world, smartly providing simulation power to planners to revolutionize architectural and engineering design and construction, meanwhile extended to BIMification.

One new project has been acquired in 2018, strengthening our isVEL developments. BIM-SIS is focused on intelligently complementing identified damages from various observations using a knowledge system of damages from re-engineered structures. Hence, it presents a specific aspect of system identification. The BIM-SIS system will be dynamic, modelled as a multimodel system and including damage management and stochastic variations. It is grounded on the method of simulation-based system identification, where a plethora of possible states of the examined system is setup, simulated and the simulation results are compared to monitored data in order to identify the most feasible possible state, which is complemented by knowledge-based completion of observations. This needs a highly automated isVEL, i.e. advanced BIM, filtering, BIM2SIM, HPC, Response Surface fitting combined with Data Mining methods, as well as precise nonlinear material laws, computational methods and sensor systems to detect small changes in time and distinguish them from noise. The simulation-based method needs good starting values, i.e. a starting model obtained with the help of the knowledge-based damage completion approach.

Standardization is well advancing and the newly established ISO 21597, Information Container for Data Drop, which was started in February 2017 at Barcelona is in the final phase and will appear in mid 2019 as a new ISO standard. The MultiModel (MM) method will be a merged part of ISO 21597 in particular recognizable in Part 1 of the standard. The developed bifunctional XML to RDF converter will be fully compatible with the MMC of buildingSMART (see GitHub) and the German MM application for tendering and cost management.

The ECPPM 2018 was successfully held in Copenhagen from 12th to 14th September 2018 organized by our colleague Jan Karlshøj (*https://www.ecppm2018.org*). It was decided to hold the next ECPPM 2020 in Moscow, organized by our colleague Vitaly Smirnov, in order to set signs of research collaboration beyond the EU. For 2022 there is already a proposal from Trondheim, Norway from our colleague Eilif.

In FIEC, the European Association of the Construction Industry, the BIM working group changed to the working group Industry 4.0 focusing the scope to BIM for production methods and broadening to robotics and cyber-physical production systems. A new chairperson Prof. Ziga Turk was elected, whereby the old chairperson Mr. Kjetil Tonning became president of FIEC in April 2018.

Regarding the research staff, in year 2018 we had only one change. Mr. Yaseen Srewil left the institute to take a new research position at the University of Applied Science at Dresden to develop further the interoperability between GIS and BIM. He was replaced by Mr. Mushtak Seeaed, an Iraqi rooted civil engineer.

In 2018, Ken Baumgärtel received his PhD and Xenia Roos already submitted their thesis. The group of co-workers at the Senior Professorship keeps a broad international background and covers a broad range of expert domains, like civil engineering, ICT and mathematics.

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

Dresden, in December 2018 Raimar J. Scherer

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Stochastic Aspects of Simulation-based System Identification of Bridges

Tom Grille

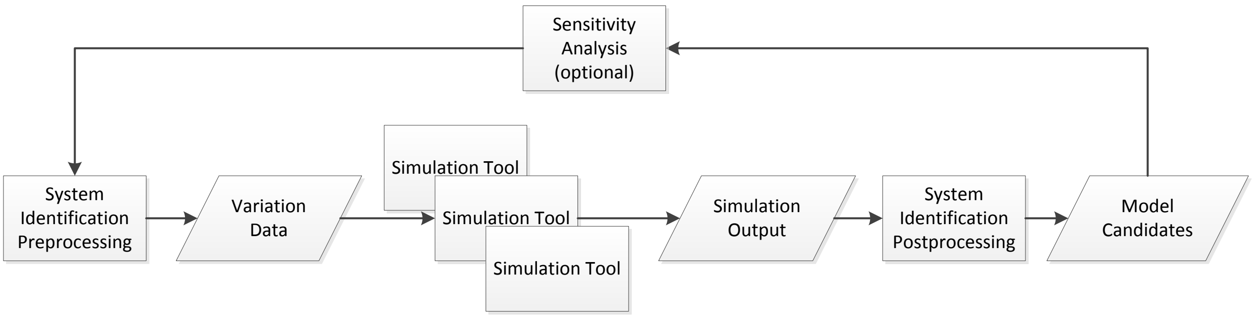
Objectives

A new system identification process for bridge damage assessment is proposed. While common frequency based approaches are suited to examine the global behaviour of a system, the new method is based on combining finite element analysis and mass simulation to spot local irregularities that point towards structural damages. The four main examined models are the building model, the damage model, the traffic load model and the sensor data model.

To achieve a high degree of automation, a combination of knowledge-based methods, Sensitivity Analysis and System Identification is envisioned. The stochastic questions arising in this framework can be separated into the following categories:

1) High uncertainty, stemming from model and measurement errors
2) Dependence of simulation outputs at a single location
3) Dependence of System Identification results at different times

The goal of this work is to formulate a consistent workflow handling these issues at the highest degree of automation possible.



System Identification Workflow Overview

Approach

The model is first set up using a knowledge database. While this kind of precalibration of the simulation model is useful, it also introduces a new source of errors. In addition, too detailed information can hinder the approach of variants space exploration.

The System Identification operates under different kinds of uncertainties. To take into account the model error in particular, a model falsification approach is proposed. The goal hereby is not to find the best fitting model but to dismiss models that lie outside a variants subspace. To define the boundaries of this subspace by a significance level like proposed in (Goulet & Smith, 2013), estimations of model errors and measurement errors are required. An alternative approach, requiring less prior knowledge but resulting in slower rejection rates is a conservatively fixed deviation level at every measurement node, taking into account the empirical covariance of the simulation outputs. These approaches are not powerful when used on a single measurement but win strength over time, when repeated measurements, applying different load scenarios are performed and model candidates are repeatedly revaluated.

Additional Sensitivity Analysis loops can help to reduce the number of variated parameters and thus reduce the number of simulation runs in each cycle. A further application of Sensitivity Analysis results is their highlighting of regions of high importance in the variants subspace, which can guide a task-oriented customisation of the model. Furthermore, Sensitivity Analysis can be used to find unrealised optimisation potential in the sensor and monitoring system setting.

Source:

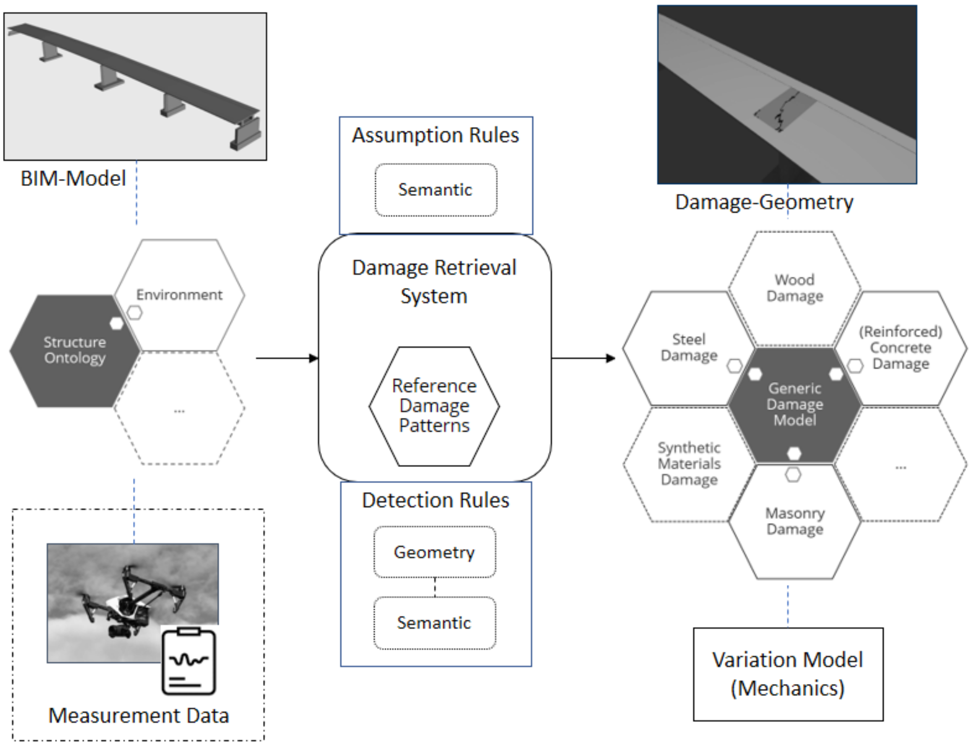
Goulet, J. A., & Smith, I. F. (2013). Structural identification with systematic errors and unknown uncertainty dependencies. *Computers & structures*, *128*, 251-258.

Ontology-based Reasoning of Structural Damage

Al-Hakam Hamdan

Objectives

Advancements in the field of photogrammetry enable the detection of anomalies in surveyed structures. By using unmanned aircraft systems, the identification and localization of structural damages and defects can be processed automatically. However, the classification of these anomalies and the reasoning of undetected damages (overseen, unreachable ones) must be performed manually by an expert. Therefore, to enhance the assessment process of existing structures and to automatize the damage classification, a damage configuration system is currently under development. In order to assume undetected damages, the system uses the data from an ontology, which describes the topology of the damaged structure, additional semantic data as well as predefined assumption rules. Additionally, the ontology is linked with a BIM model by utilizing the Multimodel approach to assess the component's geometrical data. For classification of anomalies, detected from imported measured data, additional detection rules are used. As result, a damage model is generated, that is also serialized as an ontology. Each damage individual is linked with a geometric and variation dataset for mechanical parameters as well as the BIM model and the structure ontology.



Imported and exported data objects of the damage configuration system.

Approach

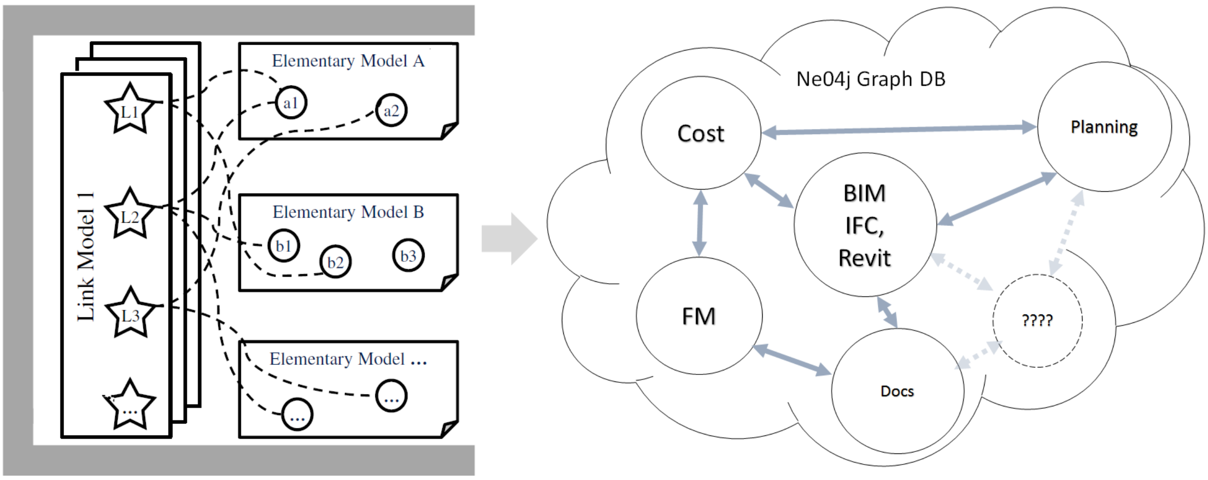
The configuration of damage model is performed on two levels. On the first level, the damage is only assumed based on the design model and knowledge about the structure and its environment, so that no inspection needs to be performed. Therefore, only the structure ontology and predefined assumption rules are used for reasoning. On the second level, a damage inspection is performed and anomalies are detected. Based on the geometric characteristics of these anomalies and the information of the structure, the damages can be classified by using detection rules. For generating the objects in the damage model, the retrieval system has access to a collection of templates, called reference damage patterns. Since the presumed structural damage is only a prognosis, a variation model is attached to each object, defining the possible range of the damage parameters affecting structural capability. The same variation model is used for detecting damages, since some parameters, such as the depth of cracks, cannot be measured accurately by image processing methods. The damage model and the related variation model are the prerequisite for a simulation based system identification that is developed in the projects wiSIB and cyberBridge.

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

Ali Ismail

Objectives

Construction project are getting bigger and more complex and during the planning and construction phases a lot of information from different sources are generated and should kept updated and linked together. This information and the relationships between different models could remain inaccessible due to the absent of suitable data management tools. Connecting those models in a single graph-based dynamic connected Common Data Environment (CDE) has a big potential for a better way to manage the whole project data as one 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 AEC data models and connect them through a labelled property graph-based model and developing suitable tools for project data management. Ideally these connected data models will be bundled together as a Multimodel container according to the Information container for data drop (ICDD) ISO 21597 part 1 or using RDF-links based on ontology dynamic semantics ISO/DIS 21597- part 2 specifications . The transformation process focuses on 3D BIM models in IFC 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.



Multimodel Container (XML or RDF based) CDE for Connected Project information

Approach

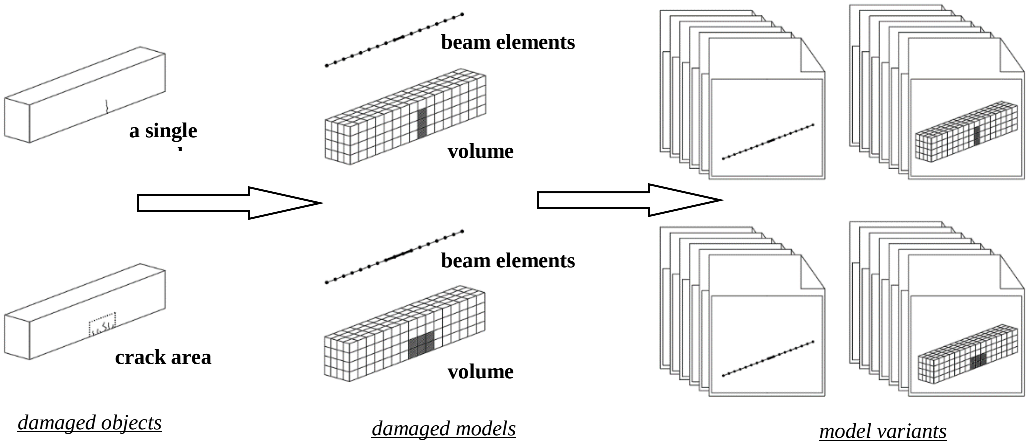
Each data model inside the Multimodel container will be converted into Neo4j labeled graph database or imported from RDF-store if a Multimodel according to ISO 21597-2 is available. The conversation process of IFC models will be done in 3 steps, at first all IFC entities will be automatically converted 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 BIM graph database will be extended and connected with other data models like planning and cost information. For text-based data models a special parser will be developed to convert them into graphs and assign nodes with further information. In the final step the links between different models will be converted into relationships connecting nodes from different graph models together. The access to the graph database will be achieved through a user-friendly web based application. A set of graph queries will be predefined for most of common data exchange tasks and filter operations, for example to generate 4D models or cost estimations. Another set of queries will be prepared for automatic generation of dynamic links 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.

Finite Element Analysis Based Bridge Damage Modeling for Monitoring and System Identification

Fangzheng Lin

Objectives

Based on the report from the German Federal Ministry of Transport and Digital Infrastructure in the year of 2016, there are about 39,440 bridges locating in the net of federal highways in Germany. Among these highway bridges, approx. 70% are erected of prestressed concrete and ca. 15% of them are in a critical situation in the past decade. Hence, the damage in bridges, which has such large hazard-potential, is supposed to be of concern. With the application of grid/cloud computing, a novel approach of bridge system identification will be developed based on Finite Element Analysis (FEA) with a massive amount of construction model variants. As a component of this novel process of system identification, bridge damage is mapped into input models of FEA Software, and the model variants are generated automatically before the parallel execution of simulation in grid or on cloud. This research work aims at realizing a generic and comprehensive mapping of bridge damage data into FEA, so that as many types of bridge damage as possible can be reflected in input models of FE-Simulation Software for further research.



The automatic workflow of damage mapping and generation of model variants

Approach

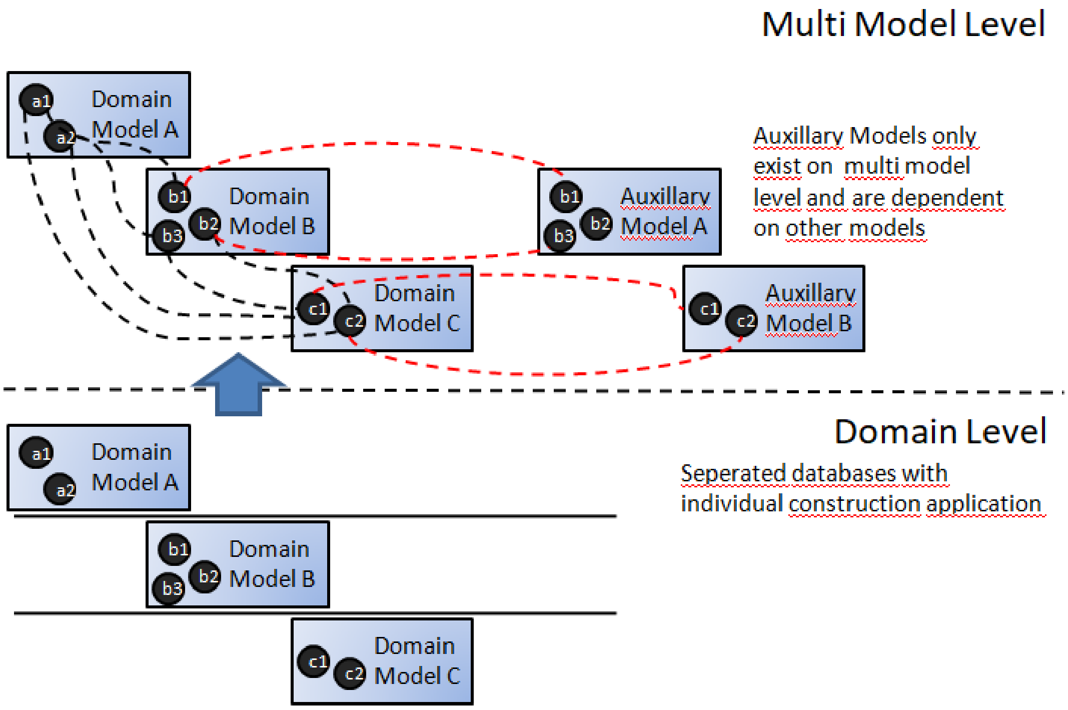
FEA-software SOFiSTiK and ATENA are used to implement the methodology in this research work. While SOFiSTiK is usually applied to analyze bridge structure with finite beam elements, civil engineers solve the similar problems in ATEAN through finite volume elements. Therefore, according to the different modeling philosophies in these two applications, the file formats of input bridge models meshed beam and volume elements are both studied, as well as the description of each part in a bridge in the input files, such as cross sections, material, geometry of reinforcements and tendons, load cases, support types, elements and their nodes, etc. Next, a corresponding parser will be developed to convent the original unstructured data into a manipulatable structured database storing the information of the above-mentioned construction parameters, so that the input bridge models can be modified. Subsequently, an available data file, where the data of bridge damage are semantically modeled, is interpreted. The essential information filtered out from the damage data file should involve data of concrete cracks, data of damaged reinforcement bars and tendons. The data of concrete cracks contain the location of single cracks or crack areas; the data of reinforcements and tendons includes the identifications of damaged reinforcements or damaged tendons. Based on these data, the corresponding parameters of input files are altered. In order to complete the massive simulation in grid/could computing for system identification, a large number of damaged bridge models are created, which serve as the input models with changed parameters referring to the real damage in bridge. For this reason, the process to generate damaged models needs to be automated and to become efficient. Considering the engineering practices, the research of crack modeling is emphasized. Both open cracks and breathing cracks coupled with loads will be simultaneous taken into account. This work is supported by the research projects cyberBridge and wiSIB.

Towards a Framework for the Conception and Creation of Multimodel in the AEC Industry

Ngoc Trung Luu

Objectives

With the increasing digitalization in the construction industry through Building Information Modelling (BIM) combining a variety of information models represented in different data models and formats like IFC, GAEB or GIS, the demand for interoperability is increasing as well. The multi model method allows the linking and combination of different data models to solve holistically interdisciplinary tasks. The linked models offer an increased information value compared to the individual models. Recently, the method has become more and more in the focus of the construction industry, for example DIN SPEC 91350 for the definition of AVA-BIM multi-models or the emerging Information Container for Data Drop (ICDD) standardized in the ongoing ISO 21597. While the added value of multimodels has already been proven, the conception and creation of multi-models for explicit application is still a major problem.



Concept of Auxillary Models on a Multi Model Context

Approach

For the development of suitable methods and processes for the creation of multimodels, different application cases for multimodels were investigated. It has shown that the original definition of the multimodel consisting of a container, one or several domain model and link model is not sufficient.

The introduction of auxiliary models can further simplify work with multimodels. In contrast to the independent domain models, which usually also have their own software for processing, auxiliary models are always dependent on other models and therefore only exist in the context of the multimodel. Two types could be elaborated: (1) annotation models and (2) variation models. The first allows the extension by data in the multimodel context which are not covered by a domain model. An example is material data or energy data. The second is used as template for mass simulation in recurring engineer task, e.g. bridge dimensioning, in which the Variation Model can be used to generate simulation models with different combinations of material parameters to find the most efficient solution. In further steps other auxiliary models can be developed for other general use cases.

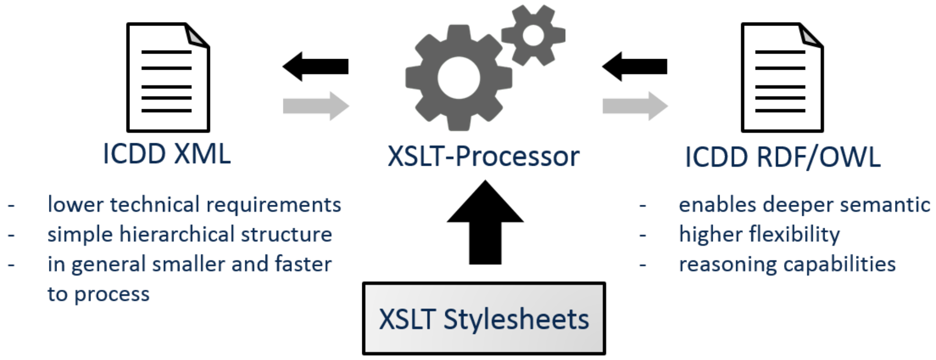
An Alternative ICDD XML Specification

Ngoc Trung Luu

Objectives

The upcoming ISO 21597 describes an Information Container for Data Drop (ICDD), which mainly combines two functional approaches: (1) multimodel method and (2) linked data approach. The first enables structures and methods for interlinkage of heterogenic data and their exchange between different applications as a closed solution of an engineering problem. The second enables an environment for integration of, and reasoning on, data on the web as well as dynamic semantic through Open World Assumption. Both approaches have their specific application field in the AEC industry. The ICDD uses Semantic Web technologies (RDF, OWL, etc.), as it is the higher requirement for the combination of both approaches, thereby users, who only want to use the multimodel capability of the ICDD, are forced to meet higher technical requirements than necessary.

In the following a method is described which bypasses this problem and is conform to the ISO 21597 at the same time.



Advantages of the two Serializations and Transformation between them

Approach

An alternative serialization to the RDF/OWL representation of the ICDD is developed, based on the XML Schema specification of the W3C. This serialization is called ICDD XML and is a more streamlined version for the multimodel-only application. As a result, it is generally smaller and can be processed faster; it is better supported through multiple tools and frameworks, due to xml approach, which is closer to the industry. This goes in favor of the ability, which is encompassed through linked data.

Persons and organizations may choose ICDD XML for implementation, because they do not have sufficient expertise in the use of semantic web technologies and would thus prefer a less complex, easier to understand and process XML-based specification. It may also be used in closed project environments where robustness and simplicity are preferred over the deeper semantics, the higher flexibility, dynamicity, and the reasoning capabilities offered by the RDF/OWL specification. In addition, the ICDD XML provides for better compatibility to the MMC 2.0 specification of buildingSMART and the existing German standard DIN Spec 91350, which is already supported by a number of software vendors.

To achieve the conformity to the ICDD standard a converter is created which enables the full transformation between the ICDD XML and the ICDD RDF serialization. The converter consist of four XSLT stylesheets, one for every file (container, link model) and direction. Those stylesheets can be interpreted by a XSLT processor and create the file in the desired format from an outgoing file.

Towards a generic workflow engine for the performance analysis and simulation of the build environment on Grid / Cloud

Michael Polter

Objectives

Various domains of civil engineering are characterized by repetitive workflows. Thus, for example, in fluid dynamics, structural analysis and energy simulation, the tasks to be solved are largely the same in information structure and differ only in concrete forms, e.g. the software used and related numerical engine and the model to be simulated. Most of the steps are still performed manually, since most of the time different software tools are needed, which in most cases cannot be coupled directly to each other due to the lack of interoperability and appropriate interfaces. Therefore a generic domain specific framework will be developed for these numerical BIM tasks. Individual platforms populated on the basis of this BIMgrid framework should be able to integrate the software of different vendors and thus allow automation by automatically calling the respective tools according to the task currently being performed. For this and recurring tasks, workflows must be established and stored in the system that describe the individual workflow steps, the necessary software and the data artefacts consumed or produced.

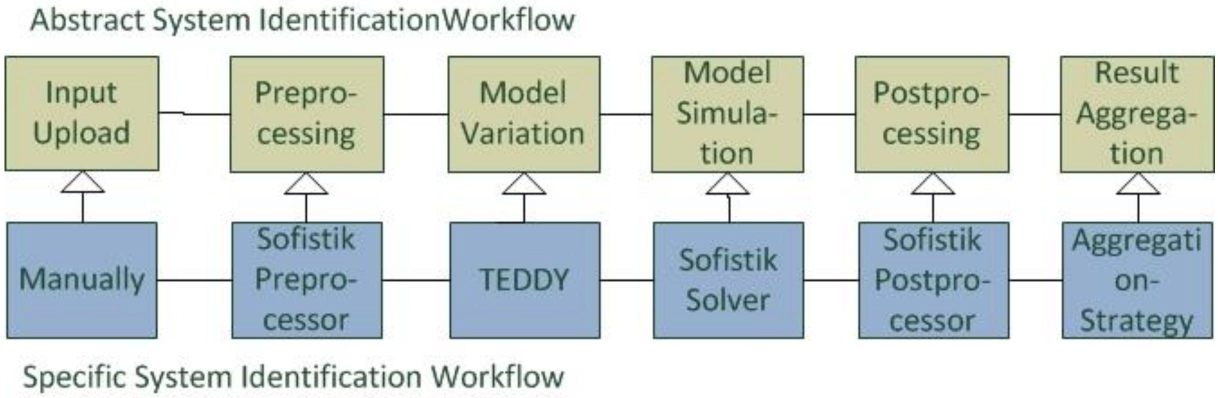


Fig. 1: Abstract and instantiated system identification workflow

Approach

The BIMgrid framework is a blueprint for the development of customized software applications, based on already existing tools and integrating distributed hardware resources. The goal is the development of a generic workflow engine for the BIMgrid system, which provides various customizable workflows based on workflow templates and enables the largely automated execution of engineering workflows using the platform features, provided by the BIMgrid. Users should not only have the opportunity to choose from existing concrete workflows, but also to be able to adapt them, for example, by using a different than the default software, provided that it is integrated into the system.

For this purpose, a workflow representation will first be created with an abstract description of the individual steps of various tasks. These workflow steps can then be instantiated either by the user himself with appropriate software, or directly selected and used as a ready sample implementation. The individual steps can also be marked as "manual", which signals the system a necessary user interaction and interrupts the automatic workflow processing.

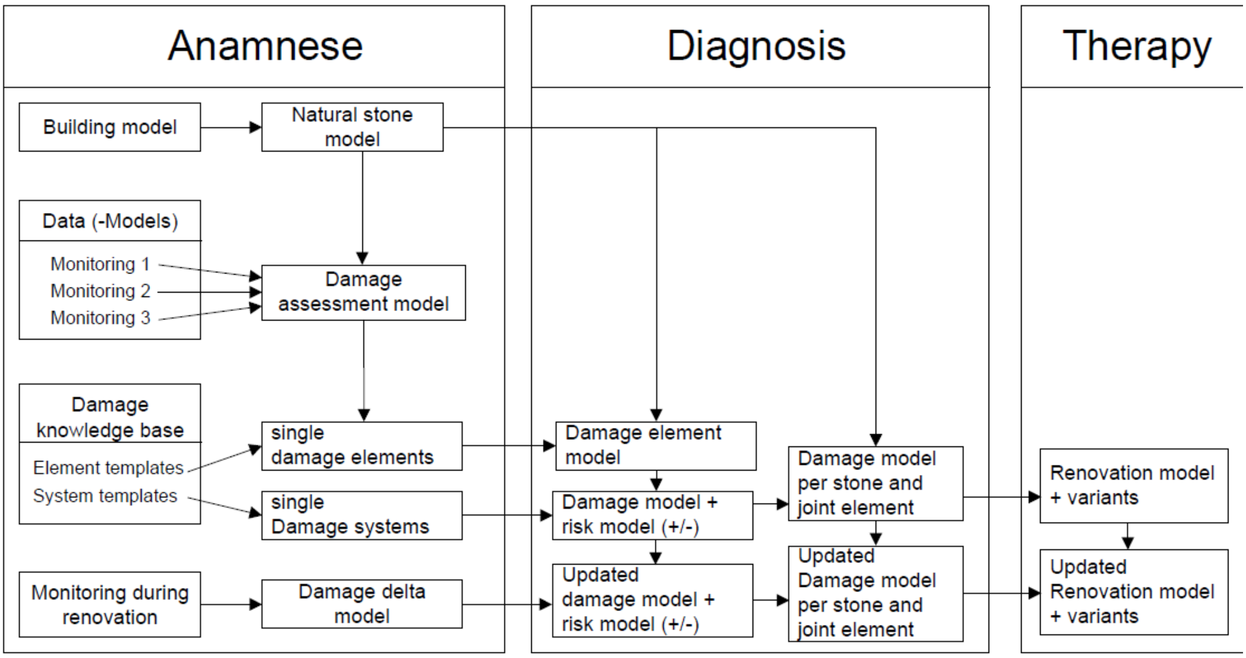
Furthermore, the potential to optimize concrete workflows by the engine automatically based on the possibilities of BIMgrid will be investigated. For example, by parallel processing of workflow steps that have no dependencies on each other. Another possibility is the distribution of interdependent tasks on the same hardware node to avoid expensive data transfer between steps.

Stone damage identification method for BIM operation

Mushtak K. Seeaed

Objectives

Development of a novel integrated damage identification system for stone materials (natural stone, artificial stone, plaster and concrete). The aim is to create a highly automated information system that allows to virtually merging various damages, recorded in different information systems and with different procedures, in a damage model in order to assess them integratively as well as in detail and material supported by knowledge based methods to develop high-quality, uniform and cost-effective and cost-effective restructuring strategy. The damage and the digital damage model must be dynamically expandable and revisable in order to record the increase in knowledge during the renovation work, to present it objectively and to work in partnership with the client on increases and reductions in the remediation work, i. to negotiate on a transparent, objective basis of information. The latter is to be supported by means of realistic virtual BIM models and augmented reality on site at the construction site.



Process flow with the specialized models up to the renovation model

Approach

From this damage baseline model, it is then possible to derive reorganization concept models, cost models and supplementary models via interoperable information flows and knowledge-based support, which can be flexibly adapted to the current and dynamically changing context. Methods of technical virtual and augmented reality are important in order to penetrate the complex information of damage, dismantling, renovation and new construction with required high accuracy and aesthetics as well as the cost transparency between contractor and client and to detect dependencies BIM- damage identification system should not be developed fundamentally new methods of VR and AR, but it should be examined and implemented, which information, especially technical, in which representation of the large information pool to be filtered out and represented in VR and AR to the technical Transparency and understanding in the conflict situation, in which contractors and clients are in the process of supplements, should be significantly improved.

Applicability of parametric model definitions and geometric feature extraction to remodel existing infrastructure

Andreas Ellinger

Objectives

Semantic 3D-Models play an increasingly large role in structuring and managing information regarding existing infrastructure. These models are one of the major pillars of the so called "digital twin", a machine-readable, idealized representation of the real-world project environment. Since creating such models manually is time-consuming and cost-intensive, ways to automate this process are of interest for many sectors of the industry. While similar tools already exist for other domains (e.g. to remodel pipes in plant engineering) they are usually specialized to fit a specific use case. Out-of-the-box-solutions that could provide the same functionality to reverse-engineer existing infrastructure are yet to be developed. This work focuses on researching a process-pipeline, that combines existing tools and algorithm-libraries to achieve this goal.

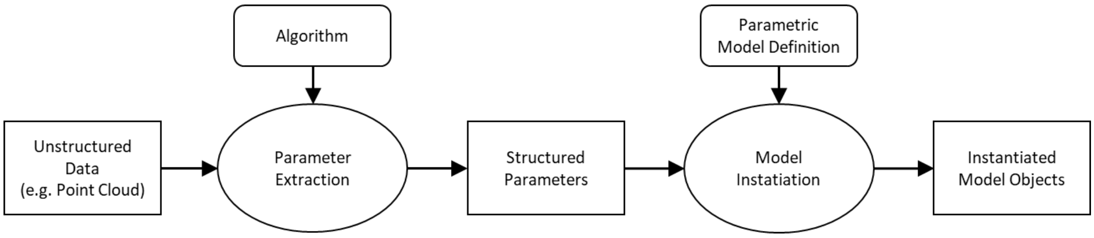


Figure 1: Data-flow in the projected process-pipeline (conceptual)

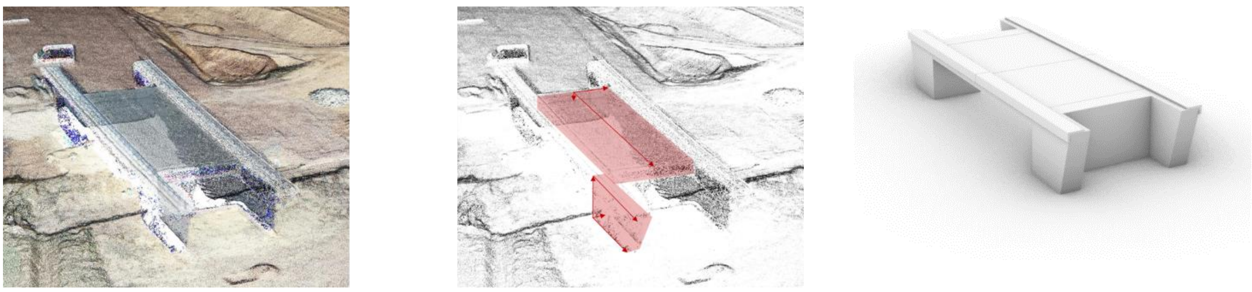


Figure 2: Illustration (schematically)

Approach

So far, two major steps are identified: 1. Creating a parametric model-definition of the desired CAD-object and 2. acquiring the parameters needed to instantiate a specific object by means of extracting them from a set of "unorganized" measurement data, e.g. a point cloud.
Step one is in other domains already state-of-the-art, since it is common practice during the design phase in product design and construction. The primary question here is to what extent such parametric models can be used to minimize redundant work steps when remodelling existing structures. Key points here seem to be the desired level of detail and geometric accuracy on the one hand and the variety of shapes a certain kind of object or structure can take on the other.
Any real-world infrastructure site contains many objects and structures, and most of them need many geometric parameters to be fitted by a sufficiently realistic parametric model definition. Therefore, the problem of how to effectively obtain those parameters arises. Step two researches ways to automatically extract these parameters from "raw" measurement data such as point clouds. A first approach focusses on deploying algorithms from the point cloud library (PCL).
Figure 1 shows a top-level diagram describing the data-flow in the intended process-pipeline, figure 2 illustrates an idealised sample use case.

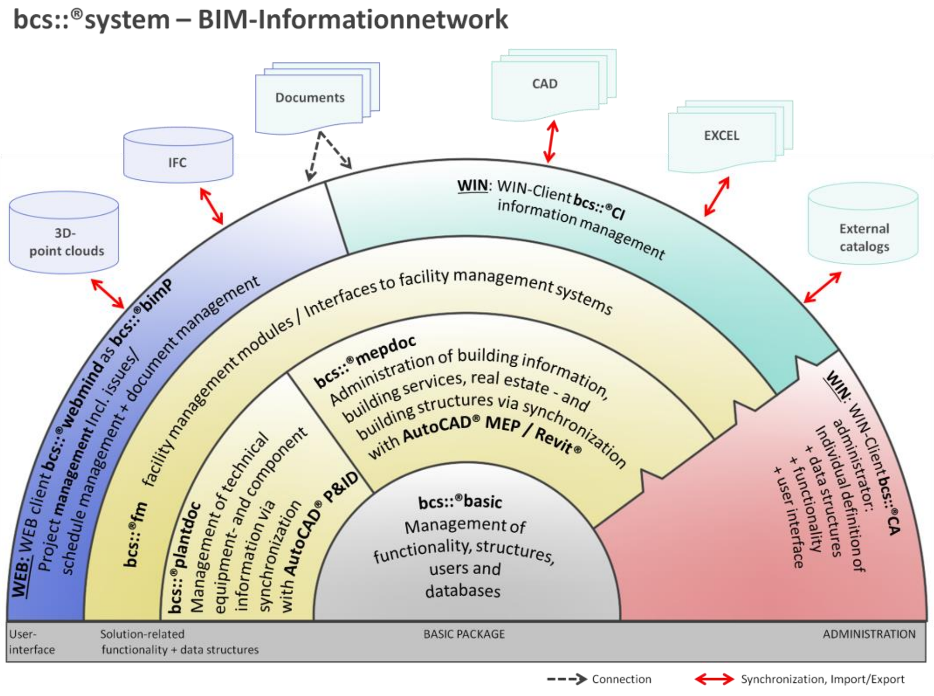
Development of a BIM compliant WEB and CAD based information system

Eugenie Hilger

Objectives

Collaboration with various companies has shown that especially the subject **BIM information network** is an important issue. The network aims to facilitate the coordination of BIM projects throughout the lifecycle of a building. A smart project space that can manage the large amounts of data in a central location that can be retrieved across devices and location-independent incl. BIM tools must be developed accordingly. A shared database that is BIM compliant does not lose information and keeps incomplete or unlinked data to a minimum. The multiple input of information is avoided, saving time and money. The research work focuses on the development of such a system.

The **BUILDING CONTENT SYSTEM bcs :: ®system** forms the basis for the BIM information network solution, which intelligently interconnects each BIM data source, manages the BIM data in a vendor-neutral BIM database, and operates both on the company's LAN / WLAN as well as WEB-based. It is also operable on the secured virtual infrastructure in the **bcs :: ®webmind**.



BIM components and product structure of the **BUILDING CONTENT SYSTEM bcs :: ®system**

Approach

The complex example of Vetter Pharma GmbH & Co. KG shows how BIM prevails despite all opposition and what effects can be achieved when using BIM information networks. It also clarifies how components can be intelligently handed over via IFC and how existing documents can be efficiently integrated in a variety of forms (3D / 2D plans, 3D point clouds, etc.). The cooperation of the planners and operators, and their access to the BIM model from different perspectives, and the neutral provision of the models as openBIM compliant IFC models, is in the foreground.

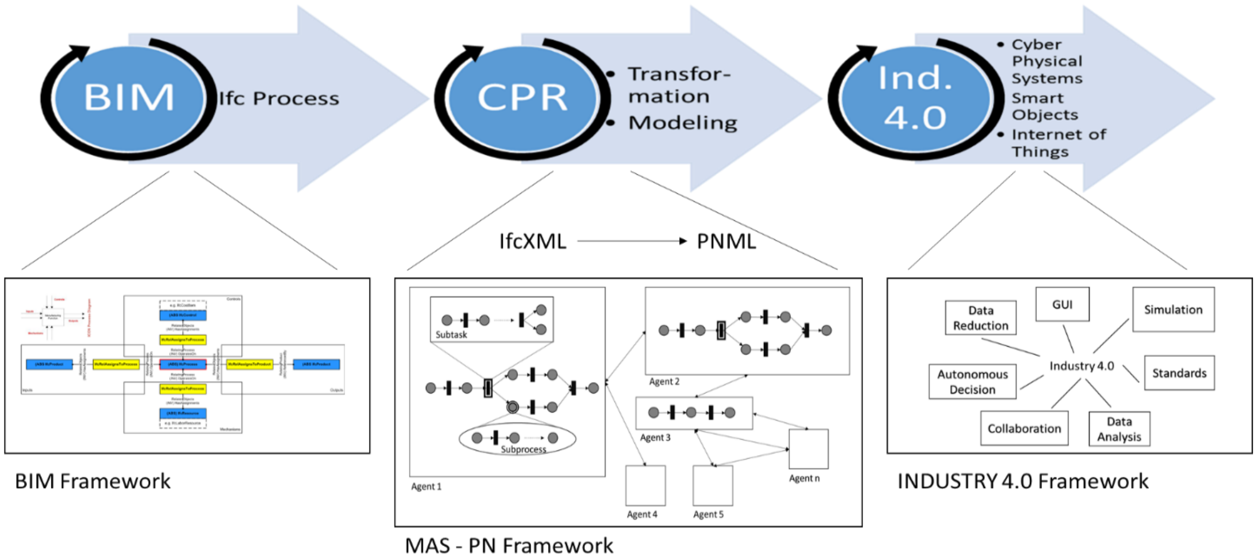
For efficient inventory data acquisition, documentation and administration, 3D laser scanning technology was integrated with the WEB-based NavVis Viewer. For OPEN BIM-compliant device data management and archiving, the WEB-based IFCwebserver.org is used.

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.

Exploration of the Multimodel Information Space

Hervé Pruvost

Objectives

As building design is tackled as an optimization problem involving multiple performance criteria, one designer need is to rapidly evaluate and compare many different design options already in early stages. Such an evaluation relies on complex analyses which like by building energy analysis (BEA) require multidisciplinary information as input for detailed results (e.g. geometry, materials, energy source, climate, occupant use). Even if the open BIM standard IFC provides for a comprehensive multidisciplinary vocabulary, it is still not sufficient to provide in a single data model the full amount of cross-domain information most analysis applications require. These necessitate additional data from other models and formats. Moreover, the reliability of such an evaluation is always a critical point because of uncertainty associated with the building design. Such uncertainty is for a part induced by the stochastic nature of the building usage (occupancy, climatic conditions, system failures, etc.). In view of that, this research work presents an innovative modeling approach that supports and fastens complex analysis of numerous building design options and life cycle scenarios on the basis of multimodel data.

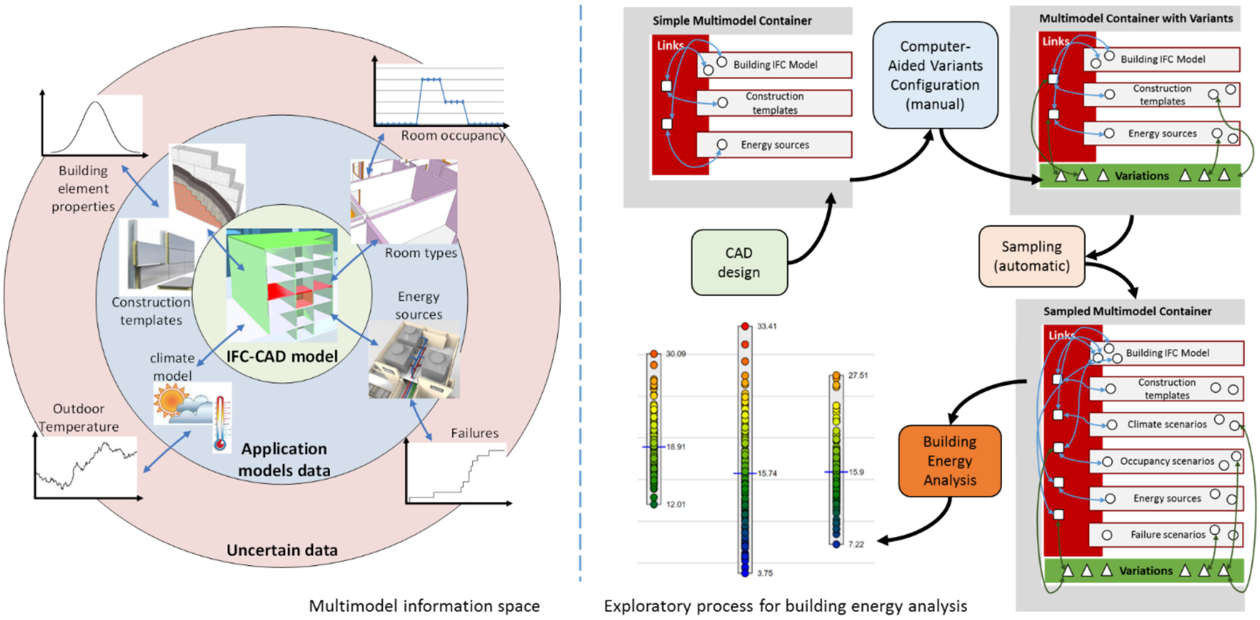


Illustration of the multimodel information space (left) and the process for analysing its subsets (right)

Approach

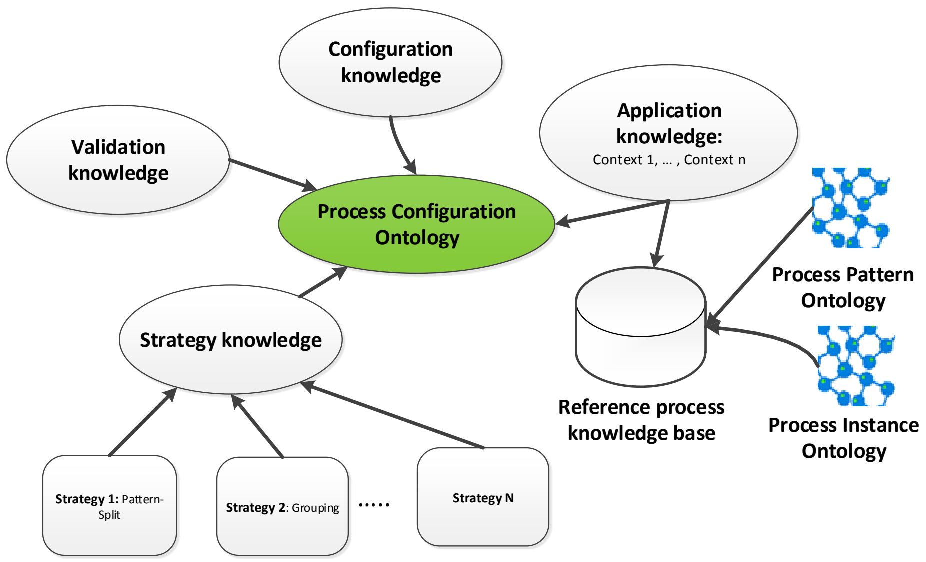
The multimodel method enables interlinking heterogeneous data from different application models into a consistent data resource called multimodel container (MMC). For that purpose, it introduces explicit links that describe the semantic connections between objects from application models. The method is extended so that one single MMC represents not only one but numerous building designs as well as usage scenarios. In that context, a new metadata model is introduced for describing variations of data from any application model while avoiding information redundancy and serving also as an analysis protocol. The model does not include domain-specific vocabulary and can describe variations of all type of data at attribute, object, file or resource level. This modeling approach eases exploration of the multimodel information space (left figure) and has been exemplary implemented in a four steps process (right figure). The IFC CAD building model is used as central model and can be manually interlinked through a dedicated user interface (MM navigator) with other application models. Within this task, several variants can be defined thus configuring e.g. other types of windows or energy sources. As next, a sampling service generates for each variant several scenarios (e.g. climate conditions, occupancy and failure schedules) on the basis of stochastic models. Finally, all information is processed in BEA software providing several results as means of comparison between the variants. The example in the figure gives the yearly energy demand by 3 design variants and 50 scenarios each. This research was inspired from a former approach developed in the project ISES which has been fully redesigned for multimodel support and universality within the projects HOLISTEEC and eeEmbedded.

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:

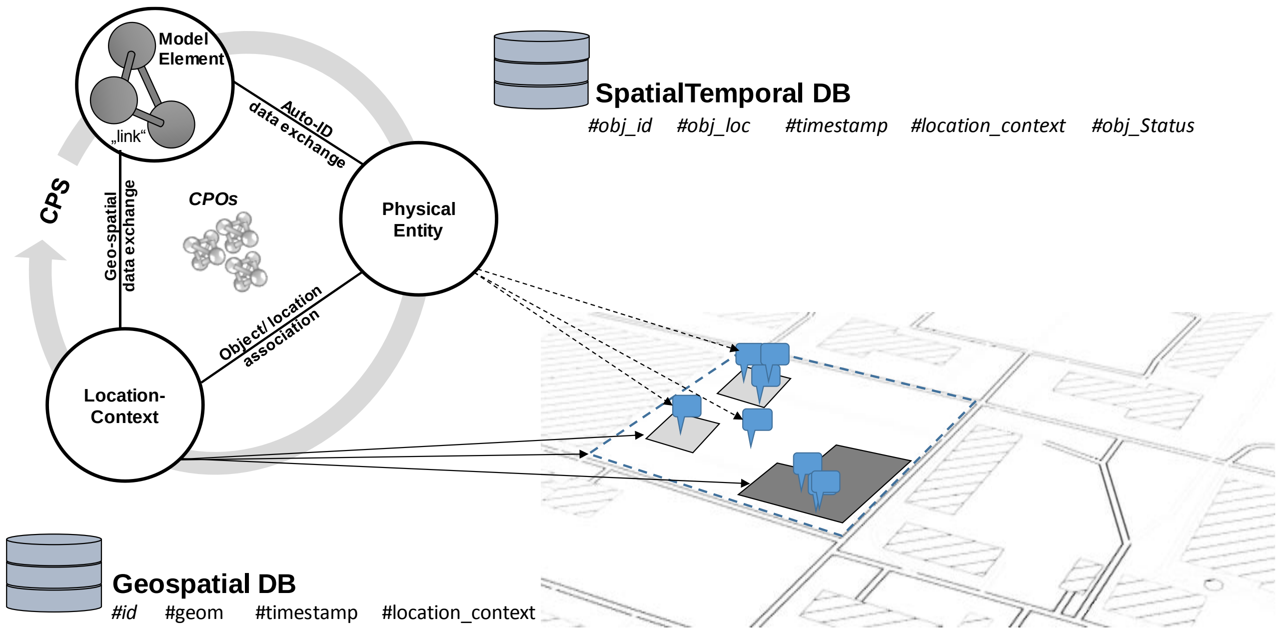
- *Application knowledge*. This knowledge describes the application conditions of the process patterns, for example as keywords searching criteria for a certain pattern
- *Strategic knowledge*. This knowledge describes different building strategies. Strategy can be defined as procedural methods/plan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

Geo-referencing for Supporting the Situational Awareness of Objects on Construction Site

Yaseen Srewil

Objectives

The path toward smart construction has recently addressed because of the evolving of the ICT and BIM technology in the construction industry. The combination of digital models and physical construction entities using sensing technologies supports making immediate and accurate decisions directly affects the entire jobsite. The cyber-physical interaction between the BIM models, spatial information and physical entity based on connectivity is shifting the construction site into a smart production environment. The collaboration of GIS data and BIM models supports the identification of the site-layout model and improves the content of the field-captured data. Linking the physical entities, digital models and geospatial information is establishing situational objects (i.e. cyber-physical objects CPOs). They provide the cyber-physical systems (as operators) with relevant and enough information about the construction site activities without being distraction in order to enable smooth operations. Here, the geo-referencing is fundamental in order to align the construction site layout model with real-world position datasets.



Spatial-temporal database supporting situational awareness on construction site

Approach

The analysis of the construction site requirements, conditions and constraints are fundamental to enable a situational awareness system in which each entity is timely tractable. Although the recent IFC Standard (IFC4) provides geo-referencing in multiple ways, the practical applications have shown that the model geo-referencing data are often poorly or completely not filled in the results project's models. To add geo-referencing attributes to BIM models a geospatial database for construction site will be prepared.

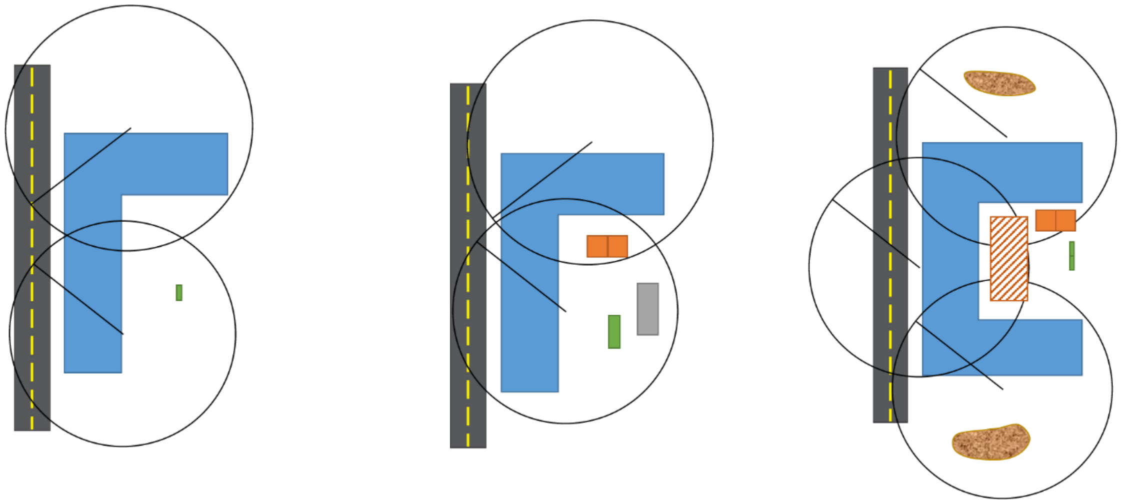
Breaking down the construction site into functional oriented work areas taking into account the site schedule provides a necessary context for the geolocation. Thereby, the geometry of the work zones is stored in a geospatial database. The 2D footprints are partly derived from the BIM models and will transform to the correct geolocation. In this geo-site model, the production locations are semantic enrichment representing the functions of the site's areas over a specific period. Among others, the asset tracking solutions on site will benefit from this proposed site model. The status of an identified physical entity can be continuously acquired by the mapping of objects location to the current functional work zone. The changes in an object's status release a specific event based on predefined rules, in which start and end of an activity are traceable or even exceptions can be early anticipated.

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.

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
Tech. Manager: Dr.-Ing. Peter Katranuschkov

Financial Support: BMBF (German Federal Ministry of Education and Research), Research Program IKT 2020

Budget/Funding: 1.20 million Euro / 0.80 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 combines 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 of fire and toxic gas expansion in buildings;
(2) Development of a crowd simulation tool with dedicated behavioural patterns for fire and hazardous context
(3) Coupling of CFD and crowd 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;
(4) Embedding the simulation system into a BIM-based virtual 3D Lab for building design and evaluation of existing building stock;
(5) Development of an application program interface (API) for modular integration of the simulation services in a compute cloud environment for fast online response.

The CFD system is based on an existing software application for the simulation of fire in tunnels. It is 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. Crowd flow simulation is based on the AnyLogic agent system, extended by a database for human behaviour patterns that combines physical and psychological models and considers CFD and building element interactions. Building modelling is based on the multi-model method developed by CIB. It enables 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 training of 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, Munich – **Coordinator**
SimPlan AG, Hanau
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 Federal Ministry of Education and Research), Research Program IKT 2020
Budget/Funding:	1.20 million Euro / 0.80 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 local damages (cracks) as well as their development over time (damage migration). This provides 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 arises from the following 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 to years to complete. Hence, there is strong need for a 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 potentially dangerous damages due to considerable noise in the measured values. Taking that into account, wiSIB develops local system identification methods that combine structural analysis methods, including the examination of nonlinear and transient behaviour with regard to stress, strain and deformations with sensitivity analysis and mathematical optimization methods. The focus of the research work is on the comparative evaluation of sensor data against the predicted bridge behaviour and on the strategic sensitivity and model variation studies aiming at the achievement of improved system identification. It encompasses the development of (1) a BIM-based multi-model framework for bridge structures using standardised BIM/IFC modelling and the Multimodel approach developed at TU Dresden, (2) a knowledge-based classification system for bridge model types and related damages, applying a newly developed damage ontology, (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 is implemented as a BIM-based platform using the virtual laboratory approach developed at TU Dresden as baseline. It will be tested on a real bridge structure in Germany.

Partners:

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

Title:	**cyberBridge – BIM-based Cyber-Physical System for Bridge Assessment**
Project Leader:	Prof. Dr.-Ing. R. J. Scherer Tech. Manager: Al-Hakam Hamdan
Financial Support:	EU – Eurostars Program
Budget/Funding:	1.34 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, a new **cyber-physical bridge assessment system** is developed 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 is 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 patented monitoring and vehicle identification method of Dr. 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 system identification of global and local structural behaviour using massive Grid/Cloud enabled simulations
(2) Load monitoring method for identification of individual vehicles and their synchronisation with the monitored bridge behaviour values
(3) Reliable and accurate prediction of the remaining lifespan and planning of efficient retrofit measures on the basis of the identified system
(4) 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
(5) Improved sensor layout and tuning method based on multiple virtual scenario simulations and the Multimodel information management approach
(6) Improved sensor network with max 1 ms delay.

Advanced BIM technology and the new multimodel method of TU Dresden are utilized to create a semantic 3D model of the bridge, explicitly interlinked with mass stored monitoring information, deterioration data, sensor data and probabilistic models. Reactions are measured at predefined locations equipped with sensors, whereby the related load values are typically not directly measurable but can be derived on vehicle basis using the new iBWIM method of partner PSP.

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 and one pilot project in the Czech Republic. 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, Institute of Construction Informatics (CIB), Germany

Title:	**GeoProduction 4.0 – Cyber-Physically Controlled Production of Underground Structures**
Project Leader:	Prof. Dr.-Ing. R. J. Scherer Tech. Manager: Ali Ismail
Financial Support:	German-Czech Research Program in the topic area Industry 4.0
Budget/Funding:	1.36 million Euro / 0.94 million Euro (total), 0.27 million Euro (CIB)
Duration:	2 years, since 01/2018

Approach:

GeoProduction 4.0 develops a simulation-guided cyber-physical environment that will radically improve the engineering processes, the safety and the reliability of underground structures to provide for optimized geo-engineering construction. The research aims are:

(1) Achievement of an integrated information management system for dynamic modelling, performance analysis and simulation-based system identification along with high-precision control and feedback for production adaptation
(2) Improvement of the preciseness in data monitoring with new sensors and optimized sensor systems
(3) Improvement of the preciseness in computational structural dynamics simulations using non-linear numerical material laws.

Today continuous model adaptation to the information gained from continuous monitoring of the construction site is missing, which is due to the related inverse problem requiring huge computational power. It needs very precise measurements and cannot be solved analytically but only numerically, through simulation-based system identification with a mass of simulation variations. Therefore model adaptation is done by engineering judgement, offline and based on only a few simulations.

GeoProduction 4.0 will improve the current geotechnical production process through a cyber-physical system approach encompassing the components of online monitoring and online simulation-based geo-structure identification using advanced non-linear mechanical models, high performance computing, online risk management and awareness, just-in-time adjustment of the construction process through simulation of production alternatives and re-dimensioning of underground structural elements like the retaining elements of the geotechnical structures using modern BIM technology.

The approach of GeoProduction 4.0 is based on a precise system identification method, which requires a highly automated IT system of observation and online noise analysis, model variation and simulation, model response evaluation and matching against observations, as well as cloud/grid computing to achieve adequate online response for the system identification task. The data complexity is managed by applying multi-model and ontology methods for the geo-engineering domain including semiautomatic steering via a knowledge assistant system. This involves:

(1) An improved deformation monitoring method synchronized with the simulation identification cycles and the construction process
(2) Mass simulation control, mass results management and pre-evaluation and a construction site production simulation system for geo-structures
(3) Dashboard with 5D BIM graphical representation
(4) A construction site production simulation system for verification of the construction process in terms of resources and time.

Partners:

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

Title:	**BIM-SIS – Adaptive Knowledge-Based Identification of Damages for the Renovations of Stone Facades with Feedback to Tendering and Subsequent Event Management in BIM-based Work Environments**
Project Leader:	Prof. Dr.-Ing. R. J. Scherer Tech. Manager: Dr.-Ing. Peter Katranuschkov
Financial Support:	BMBF (German Federal Ministry of Education and Research), Research Program "KMU Innovativ" (Innovative SME Research)
Budget/Funding:	1.10 million Euro / 0.77 million Euro (total), 0.22 million Euro (CIB)
Duration:	3 years, since 09/2018

Approach:

BIM-SIS develops a new knowledge-based approach for the identification of the actual damage state of stone facades and the planning and execution of respective renovation measures that builds upon the novel BIMification concept suggested by the TU Dresden. It encompasses the phases Anamnesis, Diagnosis and Therapy and will be complemented by an ontology-based method for the estimation of stone damages that can only insufficiently be deduced by currently practiced optical and non-disruptive measurement procedures. For damages that can only be recognized after the start of the actual renovation process a new management system for tender revision will be introduced that will implement a dynamic extension of the Multimodel framework developed at TU Dresden.

The research is motivated by the large amount of existing natural and artificial stone facades in the historical and modern building stock in Germany. This includes not only regular residential buildings but also many representative and cultural heritage buildings and infrastructure facilities. The renovation techniques depend on the type of stones used, their petrographic characteristics and the actual damages. The accurate knowledge about the specific properties of the damaged stone material is thereby considered of growing importance for the development of reliable and efficient renovation plans. Hence, there is a strong need for methods that can enable more accurate identification of damages at poorly accessible or even inaccessible places and can correctly anticipate the impact of such damages and the related consequences of the possible deviations in the damage recording process. This is an essential prerequisite for the development of efficient renovation concepts and the related cost estimation as well as for the decision making regarding the tendering and the later possible tender revisions.

Taking that into account, the project work is specifically focused on the following Industry 4.0 related key points:

- IT system for online coupling of site measurements and damage analysis
- Knowledge-based damage identification and classification
- Ontology-based development of renovation concepts and alternatives
- Transparent and reliable damage visualization and quantity take-off
- Simple and easy to apply risk assessment
- Structured representation of dynamically accumulated model data through a framework of linked domain models
- Virtual and augmented reality presentation of the damaged construction to support the dynamic management of tendering and tender revision processes.

The overall system will be implemented as a BIM-enabled platform that can be used by all involved stakeholders (architects, building owners, cultural heritage protection authorities, construction companies, craftsmen). It will be exploited via software licensing, as a SaaS platform or as part of renovation services.

Partners:

TragWerk Software Döking+Purtak GbR, Dresden – **Coordinator**
3L Architekten + Industriedesigner, Menden
Institut für Diagnostik und Konservierung an Denkmalen in Sachsen und Sachsen-Anhalt e. V., Dresden
TU Dresden, Institute of Construction Informatics (CIB), Dresden

Publications in 2018

[1] ELLINGER A.: Ansätze zur halbautomatischen Bestandsbrückenmodellierung. In: 30th Forum Bauinformatik, 19 - 20 Sept. 2018, Weimar, Germany

[2] HAMDAN A., SCHERER R. J.: Modular Concatenation of Reference Damage Patterns, Proc. 2018 European Conference on Product and Process Modelling, 12 - 14 Sept. 2018, Copenhagen, Denmark

[3] HAMDAN A.: Generierung eines Tragwerkmodells basierend auf IFC-Daten für geschädigte Brücken, Proc. 2018 Forum Bauinformatik, 19 - 21 Sept., Weimar, Germany

[4] HAMDAN A., SCHERER R. J.: A Generic Model for the Digitalization of Structural Damage, Proc. 2018 International Symposium on Life-Cycle Civil Engineering, 28 -31 Oct., Ghent, Belgium

[5] ISMAIL A., SCHERER R. J.: A graph-based approach for management and linking of BIM models with further AEC domain models, eWork and eBusiness in Architecture, Engineering and Construction- Karlshoej & Scherer (Eds). Proc. European Conference on Product and Process Modelling – (ECPPM 2018), 12 - 14 Sept. 2018, Copenhagen , Denmark. Taylor & Francis Group, London, ISBN 978-1-138-58413-6

[6] ISMAIL A., STRUNG B., SLUSARCZYK G.: Building Knowledge Extraction from BIM/IFC Data for Analysis in Graph Databases; Proc. 17th International Conference on Artificial Intelligence and Soft Computing (ICAISC 2018), 3 - 7 June 2018, Zakopane, Poland. pp. 652–664 https://doi.org/10.1007/978-3-319-91262-2_57

[7] LIN F., LUU N. T.: An Algorithm to Generate and Process the Variation Model for Mass Simulation. In: 30th Forum Bauinformatik, 19 - 20 Sept. 2018, Weimar, Germany

[8] LUU N. T., HAMDAN A., POLTER M., MANSPERGER T., SCHERER R. J.: A Variation Model Method for Real Time System Identification in Bridge Health Monitoring, In: Proceedings of the IABSE 2018 Copenhagen, 25 - 27 June 2018, Copenhagen, Denmark.

[9] POLTER M., SCHERER R. J.: Towards the application of the BIMgrid Framework for Aged Bridge Behavior Identification, In: Proceedings of the 12th European Conference on Product & Process Modelling (ECPPM 2018), 12 - 14 Sept, 2018, Copenhagen, Denmark.

[10] SCHERER R. J., KATRANUSCHKOV P.: BIMification: How to create and use BIM for retrofitting, Advanced Engineering Informatics 38 (2018), 54–66, https://doi.org/10.1016/j.aei.2018.05.007

[11] SCHERER R. J., LUU N. T., et. al.: Towards a Multimodel Approach for Simulation of Crowd Behaviour under Fire and Toxic Gas Expansion in Buildings; Proceedings of the 2018 Winter Simulation Conference, 9 - 12 Dec. 2018, Gothenburg, Sweden

[12] SREWIL Y., SCHERER R. J.: Cyber-Physical Systems Framework for Smart Built-Environments. In Technological Developments in Industry 4.0 for Business Applications, ed. Luis Ferreira, Nuno Lopes, Joaquim Silva, Goran D. Putnik, Maria Manuela Cruz-Cunha and Paulo Silva Ávila, 129-148, 2018, doi:10.4018/978-1-5225-4936-9.ch006.

Positions in Editorial Boards of Journals

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

Membership in Standardization Groups

DIN NA 005-01-39-02	Data Exchange	Member
ISO 21597	Information Container for Data Drop	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