An integrated platform for collaborative performance - efficient building design: the case of HOLISTEEC project

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Abstract

HOLISTEEC is a EU FP7 project which objective is to design, develop, and demonstrate a collaborative building design software platform, featuring advanced support for multi-criteria building optimization. Conceptual phases of the design process are the ones addressed, taking into account external and neighbourhood-level influences. The platform offers, among other services, a unified IFC-compliant data model for BIM, a set of multi-physical simulation engines to evaluate the performances of the designed building at the different steps of the conceptual phases, and an open infrastructure for building design interoperability based on available standards. The design of this platform has relied and still relies on feedbacks by domain experts and on the currently adopted business models, while enabling at the same time a renewed and enhanced design process, to take current practices one step forward for an improved flexibility, effectiveness, and competitiveness.
This article presents the state of the works of the HOLISTEEC project to day as well as the functional and technical details about the features offered by the platform.

Keywords

BIM, IFC, Holistic design platform, Simulations, Cloud, Collaborative design

Introduction

HOLISTEEC is a EU FP7 project started in October 2013 with the objective of designing, developing, and demonstrating a collaborative building design software platform featuring advanced support for multi-criteria optimization of design choices. HOLISTEEC tools will therefore focus on multi-criteria performance assessment during the design phases. Thanks to a qualified validation process, relying on a set of selected real case studied, the platform is expected to bring valuable experience on workflows and on performance assessment activities based on the *Building Information Modeling (BIM)* process, yet tackled in very limited way in current practices, according to surveyed business conduct and literature.

This article presents the state of the works to day as well as the functional and technical details about the features offered by the platform. The idea is to present here an overview of the results obtained till now by a research project which is expected to have a direct impact at a macro level and on the construction sector as a whole.

User needs and objectives of the work

The study of the state of the art related to current design practices (Delponte et al, 2014) has shown how the increasing of complexity, multidisciplinary targets, and tools to be taken into account in the design process are requiring deep changes in the building industry. The HOLISTEEC project has identified the main critical issues of current design process, and a new methodology for building design has been proposed (Delponte et al, 2014). Its main features are:

a performance-based approach to requirements' setting;

a collaborative (i.e. integrated) approach to design in order to involve all the strategic stakeholders in the decision-making process;

a BIM-based design and evaluation process throughout design.

In order to support those features, better tools than the ones currently available are needed as well. HOLISTEEC platform is therefore meant to integrate the existing tools and to provide new ones to fill the identified gaps, to support the proposed enhanced methodology.

Related works

A literature review has been made to determine the state-of-the-art for collaborative multi-user platforms. According to Charalambous et al. (2012), the potential of BIM in combination with online collaboration platforms provides an opportunity for addressing many building industry obstacles (such as fragmentation, low innovation, and adversarial relationships). Different kinds of recent surveys, case studies and analyses consistently reported that BIM improves visualization, coordination of documents, communication, and that it can bring advantages such as cost savings, profitability, and time reduction (e.g. Kreider et al, 2010; Malleson, 2014; Finne et al, 2013; Bryde et al, 2013; Saini and Mhaske, 2013). However, much less information is available in literature about the degree of usefulness of BIM to improve the quality of the designed buildings thanks to the support of the management of performance aspects along the building lifecycle.

A literature review of software tools and research works allowing multiple stakeholders in design process shows that available market and research tools are mainly focused on sharing model-based data and information: main functionalities relate to design coordination among players and model data storage.

Only a limited number of tools are designed for project evaluation purposes: simulation capabilities or analysis features are not integrated in collaboration tools; performance evaluation tools currently exist but are mostly self-standing tools and are integrated -to some extent- into authoring software through data exchange mechanisms based on the *Industry Foundation Classes (IFC)* standard. Energy performance and thermal comfort have anyway gained significant relevance in the process of evaluation of the quality of the building design, thus currently playing a key role in the design process.

These needs and drawbacks are the ones the HOLISTEEC project wants to address and overcome.

Collaboration tools

Charalambous et al (2012) performed a study on short term opportunities for (UK) collaboration platforms to offer greater value under existing working practices. The work presents a reference list of functionalities that different studies have reported to exist or to be nice-to-have. Recently developed functionalities include workflow management, reporting tools, measuring tools, management of meeting minutes, e-bidding and e-procurement. Features labelled as nice-to-have are related to design process visualisation, social data integration, geospatial visualisation, clash detection, design and procurement integration and mobile applications.

Singh et al (2011) conducted a study about BIM-based collaboration platforms in Australia in 2007-2009 to explore theoretical requirements for multi-disciplinary collaboration platforms. The work summarises the technical requirements for BIM servers: a) model management requirements, b) design review requirements, c) data security requirements, and d) BIM server set up and using assisting requirements.

Design evaluation approaches

Aouad et al (2005) present a prototype of a *n*-D modelling tool aimed to aid in integrated, concurrent design, primarily in the design phase. The tool would encourage and support the project team to consider all elements of the product life cycle. The tool enables to systematically assess and compare the strengths and weaknesses of different design scenarios. Such *n*-D modelling aims to integrate number of design dimensions into a holistic model that studies knowledge capture, utilisation, and transfer without data loss. The focus of this work was rather put on collaborative design and project information management, but discarded performance evaluation and simulation issues, as HOLISTEEC wants to do.

From the user point of view, an assessment tool for assistive design must be easy to use, able to provide feedback in a quick way, and allow rapid comparison of design alternatives (Urban, 2007). Most existing tools, and even the one of Aouad et al (2005), do not meet these needs, usually because they were only intended for building modelling. User interfaces are often complex, simulations can take hours or days to prepare, run, and interpret results. Such tools are too sophisticated to use for design purposes, while designers mainly need something simple to use and that could address the open issues related to collaborative and integrated design and to performances evaluation.

Architecture of the platform

The following picture reflects the architecture of the platform, which has been designed by combining stakeholders' requirements, HOLISTEEC partners' technological background and already available commercial and research solutions.

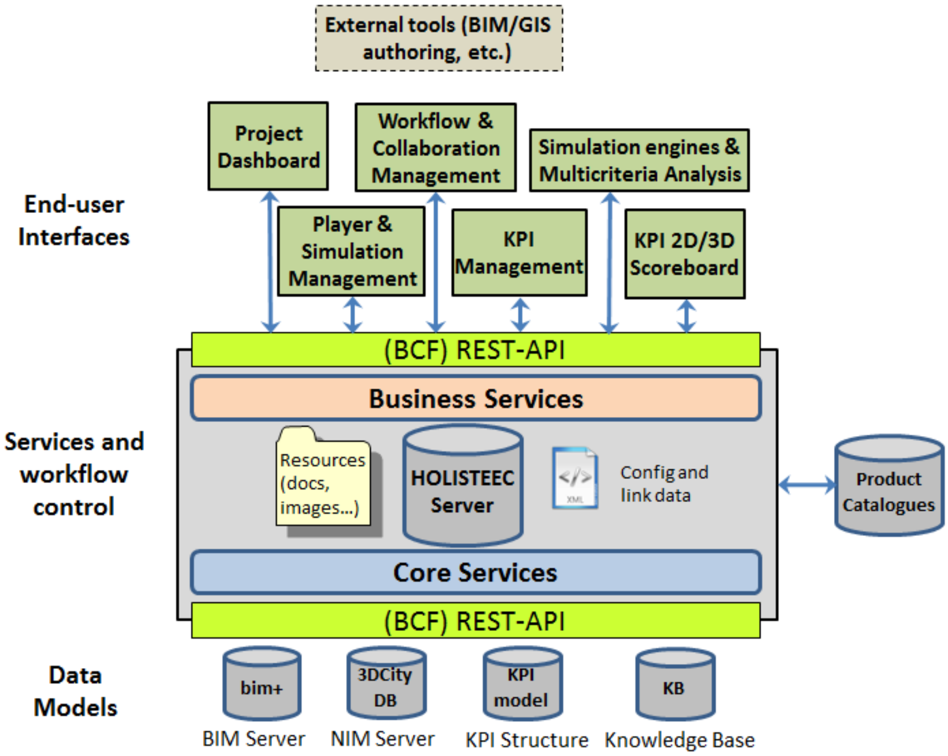

Figure 1: Architecture of the platform

The HOLISTEEC platform (Figure 1) is devised as a cloud-based infrastructure accessible through web services, which makes the different users involved in the design process interact by supporting the workflow defined in the newly-defined design methodology. Service layers are specified by following public standards, like RESTful[16] Application Programming Interface (API) and *BIM Collaboration Format (BCF)* REST API for supporting collaboration.

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[16] *Representational State Transfer (REST)* is a software architecture style for building scalable web services. More details can be found here: www.restdoc.org/spec.html

This approach allows a flexible and customizable evolution of the platform through pluggable and replaceable components, both on end-user and model storage side, the only condition for integration being the compliance with the platform REST APIs specification. From the business perspective it opens the way to third parties to enhance and enrich the platform with additional functionalities not currently offered.

The main HOLISTEEC server will be in charge of the workflow orchestration, project management and repository, tracking of the different projects' versions and variants, and the smooth connection to different storage models. A neutral layer of core services will enable the basic operations (create, read, filter, update and delete) for the different stored models, like:

- *Building Information Models (BIMs)* database, containing data about the designed building;
- *Neighboring Information Models (NIMs)* database, containing data about the surrounding environment where the building is supposed to be located;
- *Key Performance Indicators (KPIs)* database, containing the definition of the metrics to be used for the evaluation of design choices and relevant aspects;
- Knowledge Base (KB), containting the specification of domain and expert knowledge for design choices' evaluation and the generation of recommendations for design improvement;
- Product Catalogues contain the technical data related to commercial solutions or widely used products, to be used for building design.

Platform Services

The platform offers a collection of business services through REST API. Building model authoring is supposed to be performed outside the platform, through external BIM or *Geographic Information System (GIS)* tools. Platform aim is indeed to efficiently and effectively support data exchanges and make the required data available at the right time to the right person, for a faster design and simulation loop. Handling and comparing different variants in parallel is part of the offered functionalities. In order to reach the above-mentioned objectives, services include intelligent model transformation processes, which automate some manual tasks, e.g. the generation of different simulation alternatives. A list of offered service categories is presented in the following, with brief examples of the allowed activities; the platform provides tailored UI for most services, some developed from scratch while others adapted from solutions provided by project partners.

- **Project dashboard**: overview of the project, users, targets, project and document management.
- **Workflow and collaboration management**: exchanging requests, issues and feedback and project timelines.
- **KPI management**: KPIs configuration and status, calculation and target achievement (e.g. building energy consumption, acoustic isolation, etc.).

- **Player & simulation management**: generation and execution of different simulation variants.
- **Simulation engines**: performances evaluation w.r.t. domain: thermal (heat and energy consumption), acoustic (noise comfort), lighting (power consumption) and environment (pollution and environmental impact). Different level of granularity (from room (finest) to neighbourhood) according to the domain interest.
- **Multicriteria analysis (MCA) tool**: analysis of the data of the platform (BIM data, simulation outcomes) in order to give appropriate feedbacks to end-users such as risk detection, compliance checking or improvement suggestions.
- **Scoreboard**: data visualization, comparison of different design variants in terms of performance, visualization of MCA feedbacks and link with 2D/3D model visualizations.

BCF layer for service integration and extensibility

BIM Collaboration Format (BCF) REST APIs are designed to be an easy-to-implement way of exchanging BIM data between clients and servers. RESTfulness allows the APIs to rely on standard HTTP communications and on the *JavaScript Object Notation (JSON)* technology to describe and exchange BIM data. The communication flow is similar to that of email exchanges, with central servers acting as hubs for the communication between the parties: clients connect then to a server to create and retrieve BCF messages. Specification of the BCF REST API can be found here: https://github.com/BuildingSMART/BCF-API

BCF REST API is the way in which the different components of HOLISTEEC platform are integrated and exchange information. This modality allows to rely on a BIM-based data exchange standard (BCF is a standard adopted by the BuildingSmart Consortium, which is responsible also for the specification of IFC), and to extend platform services or tools through BCF-compliance as unique requirement. Indeed, most cases a BCF plugin for an already existing tool can be easily developed and implemented thanks to the BCF underlying standard technologies (HTTP and JSON).

Usage and workflow

Through Project Dashboard the project manager can setup the environment and control the different aspects related to the workflow of a project. It gives an overview of the involved stakeholders and of the status of tasks, design contents, building project objectives, model versions and variants and performances evaluation. The design phase-oriented workflow management helps the user to organize resources and items, to make efficient model assessment through the integrated simulation management and to focus on model variants' flaws and benefits by evaluating and comparing them through the scoreboard.

A typical scenario for model assessment would consist of a user selecting the performance criteria to consider for one or more building variants given the project design phase and model maturity. These criteria would then be automatically translated into a list of KPIs directly processable by the suitable simulation engines.

BIM models are then transformed (automatically, or with the intervention of simulation expert where needed) into an abstract *SImulation Model (SIM)* format representing the base input for all HOLISTEEC simulation processes. BIM data are "normalized" to adapt to simulation requirements (e.g., geometry, building elements representation and classification property are adapted), missing but simulation-relevant information are added (e.g. space boundaries, thermal bridges, etc.) and parameters for the domain-specific simulation engine are set.

Different drafts of building models stemming from the original BIM can then be created just-in-time, thanks to the paramters' setting features allowed by the Player-Simulation loop. Player allows the user to select the models he wants to "play" with and to assign products and the related physical attributes to a selected set of elements in the simulation model (e.g. choose facade glazing products for the northern facade of the building). Since Player SIM models are ready to be inputted to simulation engines and do not need further intervention by users or experts, the Player can feed the simulation services with a vector of temporary models to be evaluated in a row; this ease the task of evaluating different solutions where product permutations occur and these solutions can be explored over night and in parallel, if technological resources allow it.

Performances of different variants can then be quickly viewed in the Player and compared through the Scoreboard. If required targets are not met, the implementation of further products or solutions can be evaluated.

The MCA tool will alert the user of potential risks (e.g; design choices leading to comfort reduction, high energy consumption, conflicts with the current national/local regulations, etc.) and guide him through the selection of the best building elements and products according to the required criteria. Once the best solution configuration has been determined, it will be transformed back to the building model and made available to the user as part of final simulation results.

Once such an assessment is performed, the calculated KPIs result values will be available and can be visualized anytime within the Scoreboard. This allows the support of the decision-making process through the elimination of variants or the re-modelling of the bad performing parts of the building.

Conclusion

The platform here presented allows the design and performance evaluation of buildings during the early phases of the design process. Offered services are: a unified IFC-compliant data model for BIM process, a set of multi-physical simulation engines to evaluate the performances of the designed building at the different steps of the conceptual phases, a multicriteria analysis tool to assist the user during the process and, globally, an open infrastructure for the interoperability of building design tools leveraging on available standards.

The design of this platform has relied and still relies on feedbacks by experts of the fields and on the related business models. Further tests for evaluating utility and helpfulness of the proposed platform on real case studies provided by the industrial partners of the project Consortium are going to be conducted in the rest of the HOLISTEEC project (4-year duration, scheduled end September 2017).

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