MAKING A SMUDGE ON COLLECTIVE (UN)CONSCIOUS: DESIGNING COLLABORATIVE PLATFORMS FOR CONSTRUCTION

Anastasiya Yurchyshyna, PhD / Research Consultant, Anastasiya.Yurchyshyna@unige.ch
Michel Léonard, Prof. PhD / Director of HEC, Michel.Leonard@unige.ch
Institute of Service Sciences, University of Geneva, Switzerland

ABSTRACT

Collaboration and collaborative environments have been playing an increasingly important role in the construction domain. Designing and process modeling, knowledge management and dissemination, communities of practice – this is just an initial list of the building-related activities that benefit from collaboration- and services approaches characterizing the construction industry.

In this paper, we discuss the phenomenon of collaboration in construction, study the existing collaborative platforms that are used (or might be applicable) for different building-related activities and identify the main challenges that are currently not addressed in the current researches. We furthermore underline the role of services-oriented technologies for modeling industry- and business-related processes, and show how they have been *de facto* implemented for the construction industry.

Despite a large number of different fit-for-purpose collaborative platforms for construction, we nevertheless underline the necessity of a semantically rich collaborative environment for heterogeneous construction experts that would allow them to keep their own terminology and working practices, but to acquire a shared understanding of a common task without losing its integrity.

In order to do so, we introduce our services-based approach for actionalizing the expert knowledge and developing an information kernel of a discussed task. This approach forms a theoretical foundation for developing a collaborative platform, the Cross-Pollination Space, the semantics of which is dynamically modeled by ontologies and the related interactions are enabled by services. We show how this framework allows enriching the collaborative environment during its functioning and supports expert collaboration without imposing an artificial platform-specific terminology and/or collaboration patterns.

Finally, we canvas the ongoing and future works related to this research and discuss the particularities of their contextualization for the construction industry.

Keywords: Collaboration in Construction, Shared semantics, Expert knowledge, Collaborative platforms, Service approach in Construction.

1. INTRODUCTION

The general interest to innovation and creation has recently arisen in the construction domain where an increasingly important role of collaboration and collaborative environments starts defining the main vector of the sector development. Designing and process modeling, knowledge management and dissemination, communities of practice – this is just an initial list of the building-related activities that benefit from collaboration- and services approaches characterizing the construction industry.

Based on the requirements of *rich understanding* of the environment to be modeled and the usage of ontology-based approaches to do so, as well as the necessity of a *dynamic and adaptable environment* for different contexts, conditions and usages, our society is characterized by the *knowledge* as its main factor, which creation, dissemination and usage are seen to benefit from *collaborative idea creation* processes and *usage-based experiences* enabled by *services*.

This paper discusses the phenomenon of collaboration in construction and identifies its main risks and challenges. By underlining the role of knowledge actionalizing (Argyris 1996) during the process of creation, we introduce our services-based approach for developing collaborative platforms and briefly discuss the main concepts of the CPS platform, the ongoing project aiming to illustrate the feasibility of this conceptual contribution. We discuss how the CPS framework allows supporting the process of creative collaboration without imposing a unique terminology. Finally, we outdraw the perspectives of this research for the benefits of the construction domain.

2. PHENOMENON OF COLLABORATION: GENESIS AND DISCUSSION

In this paper, we discuss the phenomenon of collaboration in construction, study the existing collaborative platforms that are used (or might be applicable) for different building-related activities and identify the main challenges that are currently not addressed in the current researches. We furthermore underline the role of services-oriented technologies for modeling industry- and business-related processes, and show how they have been *de facto* implemented for the construction industry.

2.1 Creativity as new "must" for collaboration within the knowledge society

In the context of our society when knowledge is becoming one of the main factors of its development, the phenomenon of creativity is taking a new dimension. Indeed, by offering new conceptual and practical instruments for production, development and management, ICT and Internet technologies, in particular, contribute to developing an environment for knowledge creation, dissemination and capitalization.

From a different viewpoint, our society has also gained the characteristics of being services-oriented allowing the actors of collaboration being both providers and consumers of different types of knowledge and services, by keeping their own languages, ways of thinking and/or working. Service orientation and services support make it possible to respect daily working practices of actors, enable and simplify the exchange between them and increase the effectiveness of their main activities.

Collaboration between various actors always requires a certain level of collective intelligence, i.e. the ability to learn, understand and reason exercised by a group of individuals acting collectively, and collaborative maturity (Guangbin and Dongping 2010), i.e. the measurement of willingness, ability and competence of individuals/companies working together. They are particularly useful for addressing new or trying situations, which require the initial knowledge to adapt to a changing environment.

2.2 Trans-disciplinary collaboration

Generally, collaborative innovation is seen as trans-disciplinary, since it is based on the idea that the knowledge origin goes *within* and *beyond* the scientific disciplines, and involves arts, culture, etc. In our research, we refer to trans-disciplinarity as a capacity of building knowledge, methods and tools for creating a new service discipline. This development relies on the intertwinement of several existing disciplines and domains, which are, in their turn, enriched either automatically in the process of creating or manually by users of a new service.

Such diversity is intrinsic for the society, since it concerns a large amount of human activities, the multitude of actors involved in creating, consuming and capitalising information and knowledge, the trans-disciplinarity of topics and situations of innovation, the cultural and geographical diversity, etc. This leads to enforcing the role of collaboration as a basis for bringing together the knowledge, experience and skills of multiple team members to contribute to the development of a new product/service more effectively than individual team members, each of them a professional in her highly specified domain.

3. RISKS AND CHALLENGES OF COLLABORATIVE ENVIRONMENTS

Working in collaborative environments has now become one of the main standards of contemporary business and academic world. By combining organisational, technical, technological and social aspects, these environments support collective knowledge-related activities and allow various experts to benefit from ICT, online communities, communities of practice, etc. for achieving their common goal. It is crucial that the members of collaborative working environments accept online-oriented changes in traditional project management tools (Froese 2010), share the principles of open innovation and have a certain level of collaborative maturity (Guangbin and Dongping 2010).

3.1 Collaborative working environments for construction

Despite a large number of different fit-for-purpose collaborative platforms for construction, we nevertheless underline the necessity of a semantically rich collaborative environment for heterogeneous construction experts that would allow them to keep their own terminology and working practices, but to acquire a shared understanding of a common task without losing its integrity.

In the context of this paper, we do not aim at offering an exhaustive review of construction-oriented collaborative platforms, but schematically sketch some main types of existing ones, in order to identify their characteristics and possible gaps to be addressed.

Generally speaking, the choice of a platform can be based on the strategic decision of the company's management (e.g. only open source software), the type of construction-related activities (e.g. document exchange within a certain tape of construction projects), the phase of project development (e.g. design with the help of CAD tools), the personal preferences of involved actors (e.g. SAGE platform), to mention but a few.

First, it is important to note that multiple types of general collaborative group- and software (e.g. Collaba, Adobe Connect, different IBM and Microsoft products supporting collaboration) can be used for construction-related activities, especially for tasks of reviewing, scheduling, document management, business intelligence and social networking.

As for group- and software, which is specifically oriented construction, one can note those supporting BIM: e.g. Collaborative Construction Resource System (http://collaborativeconstruction.com/), NEC3 from 4Projects (http://www.4projects.com/), those addressing different aspects of the complex construction domain: e.g. a range of SAGE products (http://www.sageforconstruction.co.uk/), CMiC software (http://www.cmic.ca/), EADOC solutions (http://www.eadocsoftware.com), as well as collaboration and teamwork components of the "architectural musts": e.g. ArchiCAD (http://www.graphisoft.com/products/archicad/teamwork.html).

Alternatively, there are a number of academic contributions offering strategies for achieving more effective implementation of distributed object modeling (van Leeuwen and Fridqvist 2006), web-based collaboration platforms in the construction sector (Stewart et al. 2005), (Nikas and Poulymenakou 2006), as well as exploring the interoperability between BIM software applications in conjunction with collaborative delivery of projects by interdisciplinary teams within the AEC industry and (Pniewski 2011).

3.2 Risks of creative collaboration

While analysing the risks of creative collaboration in different application domains (Yurchyshyna et al. 2011), we have identified several groups that are to be addressed when developing construction-oriented collaborative platforms.

- Cognitive limits of decision-making.

As an "old" industry, the construction industry has been successfully developing its "know-how" and expert practices. In many cases, current decision-making processes are reduced to a choice between several previously identified and (partially) formalized alternatives, as well as collaborative discussions are focused around choosing a (partially) pre-defined solution, but not really constructing a new solution.

Whilst saving an effort at dealing with repeated issues, such decision making risks being rather limited and not using advantages of multi-disciplinarity of the knowledge bases of involved actors. It is thus necessary to restructure decision making processes in the way that they would allow constructing a decision during – and not before – discussions.

- Risks of group thinking

Groupthink refers to any type of thought within a deeply cohesive in-group whose members try to minimize conflict and reach consensus without critically testing, analyzing, and evaluating ideas. This might be a case for highly heterogeneous expert groups working on complex construction-related issues. Resulting different reasons (Rittgen 2009): (i) illusions of invulnerability encouraging risk taking; (ii) direct individual pressure that might challenge the group's assumptions; (iii) excessive presence of mind guards within a group; (iv) conformism of participants due to their anonymity; (v) lack of motivation or willingness to participate, to mention but a few; groupthink might lead to defective decision making and disables almost any types of decision constructing.

- Influence of propaganda and spam on collaborative decision

Related to the previous risk concerning the search of *a right collaborative decision*, the phenomena of propaganda and spamming are mostly typical for Web environments and online communities. Ii is explained by introducing additional information and its emotional evaluation by some actors of communities might lead to propagating the unreliable information and to increasing the general distrust in collaborative decision making processes. Several general techniques (Metaxas 2009) for preventing spamming in Web and online environments and for increasing the quality of the exchanged information have been recently developed. However, the risks of semantic noise in collaborative environments still represent an important challenge for construction-oriented online communities.

- Risks of cognitive and professional security

The resistance of domain experts to change their work routine is typical for "old" industries. Many architects of an old "pencil-and-paper" school are willing to integrate new knowledge and ways of doing in their current work only if they are described in their own terminology and do not require an effort from their part. We call this type of risks of cognitive and professional security: new ideas proposed by some domain professionals can be hardly understood by experts from different domains and as such, the corresponding innovations might face some cognitive resistance of decision-making actors. Thus arises the necessity of allowing and supporting "native" terminologies, to allow jargon-free discussion around new ideas.

- Conservation of traditional roles of providers and consumers of information and knowledge

According to the principles of collaborative environments, all actors can be both providers and consumers of different types of knowledge and services. The risk of conserving their roles might however be present in construction-oriented platforms, which sometimes position the role of initiator or domain expert as a solo producer of knowledge (especially if it is connected with a corresponding CAD software, which is based on a predefined range of roles). Alternatively, by allowing the dynamic enrichment of domain ontologies, it is possible to decrease this type of risk.

- Risk of model limitations, for example ontological modelling, for knowledge formalization and usage in collaboration processes

The diversity and complexity of different types of construction-related knowledge (which in many cases is non-formalized, tacit and even non-identified) requires implementing powerful approaches that are able to support the semantics of this knowledge and to make it (partially) formalized and processable. A good example for such a mechanism is ontological modelling that allows a high level of semantic consistency for representing domain knowledge. The risk here is not to aim at the only unique and absolute approach for knowledge formalization, and neither to identify a definite answer applicable in all domains and contexts. Ontology-enabled modeling could be effective only thanks to the constant dynamic integration of new knowledge related to specific construction domains, usage-based practices and feedback from implementation in different construction contexts.

- Private and public data in the context of open environments

Collaborative open environments motivate their members to create, link and share knowledge, and consequently face the dilemma of balancing public and private data: it either should be available for large communities or protected for the specified usage. To our best knowledge, there is no unique solution for solving this dilemma: in different cases, collaborative environments apply various techniques – from developing for example so-called platforms of liberation and platforms of control (Vitalari 2009) to defining cyber-infrastructure principles for research and scientific collaboration (David 2006).

- Paradoxes of innovation in collaboration

This group of risks reflects the dualistic nature of innovation and creativity that should be at the same time generally scientifically exploratory and concretised effectively problem-oriented. In other words, collaborative platforms should offer a certain balance for: (i) goal-oriented and exploratory idea constructing; (ii) general common sense and specific expert and domain knowledge; (iii) participants personal motivation and a common goal of collaborative activities. This group of risks requires thus creating a structured approach for a priori unstructured innovative ideas.

4. SERVICES-BASED APPROACH FOR ACTIONALIZING EXPERT KNOWLEDGE

In order to address the requirements of the knowledge society by taking into consideration the identified risks of creative collaboration, we aim at developing a generic approach for developing collaborative platforms.

One of the starting points for this study is to develop an approach allowing a *hidden* simplicity – to benefit from rich knowledge bases of involved experts and corresponding domains, based on ontological knowledge modeling, from one side, and services enabling smooth exchange and system update, from the other side.

4.1 Services and knowledge creation

Recently, services can be considered as the most growing sector of the world economy thanks to their role in organization, deployment, maintenance and operation in business activities and ICT-based complex systems. Indeed, they have evolved into an interdisciplinary approach to the systematic innovation in service systems, integrating management, social, legal and engineering aspects (Demirkan et al. 2008).

Our scientific vision shares a belief that current services-oriented trends might significantly increase the effectiveness of modeling business processes, since they allow the integration of scientific knowledge and practical intelligence retrieved from different domains into the domain ontologies, and as such contribute to their interoperability.

In Construction, as well as in different sectors, the most added values from collaboration can be expected in the field of developing new innovative ideas aiming to create a new product, offer a new service or increase the effectiveness of business practices. To facilitate this, we introduce our services-based approach for supporting innovation processes by actionalizing the related expert knowledge and developing an information kernel of an innovation target.

Innovation targets are the objects of the decision constructing. They can take several forms:

- "request for discussion": a tacit need and not yet defined problem, but an intuition of experts that the proposed target might lead to an innovative solution (e.g. new principles of constructing new nuclear power plants);
- "request for solution": a defined problem or area of intervention without a proposed solution (e.g. standardizing the procedures for dealing with unforeseen conditions in construction agreements);
- "direct proposition of action": a problem with a possible solution to be discussed and validated (e.g. a new approach for earth-quake resistant construction in Malta).

4.2 When knowledge starts working

This approach forms a theoretical foundation for developing a collaborative platform, the Cross-Pollination Space, the semantics of which is dynamically modeled by ontologies and the related interactions are enabled by services. We show how this framework allows enriching the collaborative environment during its functioning and supports expert collaboration without imposing an artificial platform-specific terminology and/or collaboration patterns.

Actionalizing of the knowledge of a target is done during its discussion. It starts with the occurrence of an event (catalyzing this target) or of a requirement (why this target is launched). Initially, a target is launched by an initiator who owns the initiative and offers it for discussions. To make it understandable by other actors, the semantics of this target should be actionalized: the knowledge describing it is formalized, modeled and published on a collaborative platform.

After launching the target, its semantics is analyzed and the target is positioned in one (or more) activity domains (e.g. thermal requirements for construction) through the repository of ontologies. The repository of ontologies combine different types of knowledge related to this target: from specific expert knowledge to regulatory databases.

Such a positioning, allows opening a call for participating around this target by addressing it to the experts who might be interested in discussions. These processes are also enabled by services that monitor target's lifecycle and identify the addressees.

The discussions around this target are enabled by services and rely on ontologies for extracting the main concepts of the target, defining the semantic relationships with other related domains, and finally identifying the main concepts and relationships of the target that create its information kernel. Various comments around this target represent the knowledge to be actionalized during the discussion, and as a result to be: (i) integrated into knowledge bases; (ii) identified inconsistent and ignore it; (iii) validated by other experts to be added into the information kernel; (iv) represented to experts with respect to their professional jargon and level of required detail.
Finally, when the consensus is found, the information kernel of the resolved target is formalized and transmitted for development of a new service.
As an example, the target of "a new approach for earth-quake resistant construction in Malta" is discussed, adapted and finalized as the information kernel represented with the help of an OWL-Lite ontology. This information kernel is then used at the phase of service creation to first extract the procedure for constructing earth-quake resistant buildings, formulate it in the form of regulation texts and rules, and then disseminate this procedure between the stakeholders in the form of an electronic document.

5. CROSS-POLLINATION SPACE: ANOTHER VISION TO COLLABORATIVE ENVIRONMENTS

The cross-pollination space, CPS, is designed as a platform for enabling the creation of new domain services and aims at creating a collaborative environment that brings together experts and non professional users from different domains that work together on the co-creation process.

5.1 CPS as an environment for decision constructing

In its conceptual design, CPS addresses the general goals to support collective, trans-disciplinary and co-creative activities for the generation of ideas, which are common for many collaborative platforms. However, there are two main characteristics that allow us to differentiate the CPS platform from most of them.
First, collaborative decision constructing supported by CPS is particularly oriented to the innovation phases of a service lifecycle based on knowledge. In other words, our decision constructing process leads not only to identifying a new innovative idea, but also to developing a service (or services) to enable the implementation of this idea, as well as update of the initial knowledge bases by the knowledge acquired during this decision-making process.
Second, CPS allows us to address the dualistic nature of innovation in services via the interdependence of its static and dynamic characteristics. Indeed, traditionally, many collaborative platforms are focused on modeling (relatively) static characteristics (e.g. actors, roles, etc.) and their discrete exchanges (e.g. via emails, blogs, etc.), while enriching them by some relationship-oriented concepts (e.g. role in information system, concepts describing the mission/intention of decision-making). However, despite their diversity and business success, there have been relatively rare attempts to model the decision-constructing process in its complexity: when its main concepts and ontologies are dynamically enriched *during* the process according to the current situation and *ongoing* results of decision-constructing, as well as the *intentions* are also concretized and/or modified during this process.
The CPS platform is based thus on a complex model for collaborative environment that allows defining its main characteristics *during* decision constructing and is based on the experience-based ontological knowledge. In other words, our approach is not oriented on context-independent modeling the decision process itself, but on defining the principles of the development of the *environment of decision-constructing activities* that includes the actors, formal and tacit knowledge, the situations of usage, different contexts, related ontologies, etc., and is characterized by a variety of static and dynamic characteristics.

5.2 Towards answering the challenges of creative collaboration

The CPS environment empowered by the knowledge actionalizing process allows us to offer possible answers to certain identified risks of creative collaboration. We note that we do not claim their uniqueness and optimality, but underline a possibility to address some of them, which were previously left open questions.

- Thanks to dynamic constructing of the information kernel during the process of knowledge actionalizing, it is now possible to extend the *cognitive limits of decision-making*, while taking into consideration the environment of collaboration as well as the usage and practices. Indeed, since the identification of possible choices of decision is done *in parallel* with discussions, the initial possible solutions can be dynamically enriched with new ideas expressed during the discussions.
- The difficulty in addressing the risks of *groupthink* is not only their diversity, but also the origin, i.e. social and psychological aspects of collaboration. For this reason in this study, we do not aim at answering this issue in its complexity, but propose a number of solutions to be implemented in the corresponding framework, which combination will positively influence on group thinking: (i) ICT and services allow certain anonymity within online communities, which weakens the direct pressure to certain members of real-time offline decision processes; (ii) the ontological background provides the technical solutions necessary for actors to be understood without changing their terminology, and as such the knowledge is disseminated easier and can be used more effectively; (iii) CPS platform offers a system of roles and develops the principles of open publishing that aim to motivate actors' participation.
- The process of decision constructing is naturally characterized by the *risks of cognitive and professional security*: new ideas proposed by some domain professionals can be hardly understood by experts from different domains and as such, the corresponding innovations might face some cognitive resistance of decision-making actors. However, by emphasizing the importance of allowing "domain" terminologies and by supporting them by ontologies, we allow jargon-free discussion around new ideas, which are constructed in multi-domain collaboration.
- Following the spirit of services society, it is crucial to allow the actors of collaboration to be both *providers and consumers* of different types of knowledge and services. By putting our prior attention to this requirement, our approach is designed as services-oriented: we promote the initiator's role-taking, the capitalization of knowledge created as a result of collaboration and develop a concept of *open papers* for authors' motivation and recognition.
- The risk of the *limitations of ontological modeling* is not addressed on the conceptual level. We reserve it to be addressed on the implementation level, according to the concrete use case.
- Our answer to the dilemma on the balance between *private and public data in open environments* is based on offering a system of dynamic roles for collaborative decision constructing. Initially, the access to data is defined in the scope of different roles, which might dynamically adapt according to the activity of actors during collaborative discussions, the coherence and non-contradiction of the exchanged and created knowledge. Technically, such an adaptation is enabled by services and semantically described by ontologies related to the process of decision constructing.

Our approach for knowledge actionalizing and its implementation as the CPS platform are helpful for addressing some identified risks of creative collaboration, whilst other ones offer a wider field for research. For example, the evaluation of different collaboration techniques for effective innovation processes might significantly improve our model, as well as monitoring the level of semantic noise from cognitive propaganda and spam could be useful for the validation of consistency of related ontologies. These are among our future works.

5.3 CPS: main keystones

The CPS framework (cf. Figure 1) is defined by 5 "static" and 4 "dynamic" characteristics (in this context, we use the terms of static and dynamic in a weak meaning: they refer to the ability of concepts of the CPS environment to update their semantics during the process of decision constructing). The static ones are as follows: (i) Actor; (ii) Role; (iii) Concept; (iv) Organization; (v) Initiative (or target for decision constructing). The dynamic characteristics are defined by: (i) Situation; (ii) Intention; (iii) Ontology; (iv) Information system and/or services.

The CPS conceptual framework is based on the services approach: services are dynamically used for capturing main concepts of each domain, elaborating the cognitive information, capitalizing the results of its implementation and usage, as well as assisting the process of negotiation and collaboration corresponding to identifying the semantics of knowledge used by different experts.

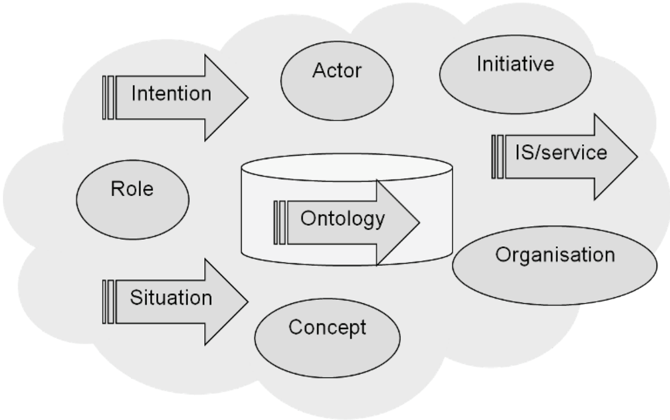

Figure 1: CPS concepts.

In the context of this paper, we will not focus on the technical side of the CPS implementation: an initial framework was presented at (Yurchyshyna and Leonard 2010) and a boundary model was detailed at (Yurchyshyna et al. 2011). It this scope, we are intended to show how this framework allows enriching the collaborative environment during its functioning and supports expert collaboration without imposing an artificial platform-specific terminology and/or collaboration patterns.

5.4 Making a smudge on collective (un)conscious

Let us refer to an example discussed in Section 4.2 concerning the target "a new approach for earth-quake resistant construction in Malta", which is to be solved with the help of the CPS platform.

Initially, CPS relies on the corresponding data- and knowledge bases, documents, regulations, ontologies that define the principles of earth-quake resistant construction, academic foundings in the domain, etc., which are *formally represented*. In order to be processed, the target should also be formalized (in our approach thanks to ontological modeling) and then communicated to other CPS participants. We believe that such a formal ontological representation and usage of ontology facets allows different level on detail and terminology for different types of actors: starting from a trivial language difference, via a rather detailed *natural language* description for non-resistance-construction experts, to a *model-based technical documentation* for resistance-construction professionals.

During the discussions, some new knowledge representing actors' points of view is created and/or shared, which might be also *capitalized by ontological representation* (e.g. "in USA some principles of earth-quake resistant construction are described in Document A"). Once acquired and validated, this coherent knowledge describing existing practices can be automatically *integrated onto the initial ontologies*, since it is already accepted by the CPS participants, and further used in CPS discussions.

As the result, such knowledge acquisition might be seen as unconscious by non-professionals who simply agree that the proposed practice sounds reasonable (and do not need to learn professional jargon for comprehending its details). From a different point of view, once the target of creating a procedure for constructing earth-quake resistant buildings is resolved, this knowledge is becoming not only conscious and explicit for professionals, but also a *formally defined* by regulation texts and rules, to be finally *actionalized by a service* generating an electronic document.

6. CONCLUSION

This paper is devoted to the phenomenon of collaborative decision constructing and discusses the challenges of developing collaborative environments. By analyzing the existing challenges of our society and by underlying the role of ICT and Internet technologies in collaboration, we identified the main risks related to creative collaboration. With respect to the multitude of different scientific approaches and business-oriented platforms supporting collaboration in construction, we underlined the necessity of creating a semantically rich collaborative environment that dynamically evolves during its functioning without imposing an artificial platform-specific terminology and/or collaboration patterns. To answer this challenge, we introduced our services-oriented approach for knowledge actionalizing on the conceptual level and described some practical issues of its implementation as the CPS platform.

Being developed as a generic environment, the CPS platform addresses several issues of collaboration characterizing complex environments in general, which are – between others – identified as crucial for the construction domain, in particular, e.g. multitude of actors, resistance to new technologies, conservation of practices, necessity of semantically rich exchange, etc. However, some construction-only issues still offer a wide field of research, which implementation would significantly contribute to the practicality of CPS, as well as to standardization of construction-related working practices. They are seen as perspectives of this research.

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