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Intensified construction process control using information integration

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ABSTRACT

In this research, novel information technology and advances in communication and machine control systems were combined into a method intensifying construction control. Changes in the operation environment of constructors have revealed a clear need for more efficient process management. The objective of this research was to improve process management through more effective information integration, processing, and exploitation, leading to an intensified infrastructure building process with more effective process control and reaction to process status changes. Based on requirements gathered through interviews with domain professionals, the developed method exploits ontology-based information formulation to integrate design and as-build data with the help of advanced communication and machine control applications. In addition to actual construction process control, the use of the developed method potentially intensifies operations before and after the project, enhancing process efficiency, cost-effectiveness, and eco-efficiency. The results of the presented development phase will be verified in the following practical implementation phase.

1. Introduction

The infrastructure building companies among other industries are facing huge pressure to strengthen and intensify all the processes due to hard competition, new regulations and public demand for more environmental friendly processes. Talking about the larger scale infrastructure building projects they are less organized and formalized due to more badly measured process parameters, low technical status of participants in the process and sometimes quite complicated subcontractor and system chains. The technology variety and technology knowledge level of different subcontractors in the same construction site may cause difficulties to project management to integrate and exploit relevant process data. The information needed may be scattered in several information systems which are at different technology stages. The project management requires combined information for efficient decision-making. Usually an infrastructure building project consists several parallel processes where machine break down or other kind of interruption may cause delays and unplanned costs. A random interruption in the process containing several parallel sub-processes may cause large-scale problems. These interruptions should be handled immediately and preferably automatically as fast as possible. However, in many cases in the infrastructure building field, process data is handled slowly and manually by error-prone human operators without knowledge from every affecting process parameter. The implication of the aforementioned is that in infrastructure building process, the process control is very challenging. Difficulties in control lead to the situations where the status of the sub-processes is worse known, which makes the overall process control and dynamic reaction to the changes impossible and therefore processes are inefficient, hazardous, expensive and slow. To summarize, in order to be efficient in process management, one has to have the most recent and refined process information that is not nowadays possible due to heterogeneous and incompatible information systems of different counterparts. In a way of development of improving systems are at least mentioned highly varying technology awareness of different counterparts, closed systems of different machine and software provider systems and lack of standards in data formats etc.

According to the description above, there is a clear need in the infrastructure building industry for the deployment of more intelligent methods to manage projects. These methods should concern both the information of the original plan and the dynamically changing construction time process data. The research problem was to develop suitable method to enhance the process management by providing more extensive information accessible from one place. The developed method should enable an integration of the most important subcontractor process information to intensify the infrastructure building process by enabling more efficient process control and reaction to the changes in the field. The method should take advantage of the current innovations to be advanced. The utilized integration method should not only be conventional data format based point-to-point integration but also take into account novel methods enabling advanced utilization of the integrated data. The implemented integration method should be general purpose in nature to ensure maximal applicability. The main benefits of the method should be more efficient, cost-effective, more environmentally friendly and safer infrastructure building projects through the improved project data

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exploitability. The most important facilitators of the developed method are novel technologies in the areas of the machine control systems, data formats, location systems, information management technologies and finally general web technologies. Fig. 1 illustrates the basement of the developed method, the utilization of common ontology format that enables intelligent access to the integrated project data. The method is based on material gathered from the companies operating mostly in Scandinavian area and results are therefore biased to follow in Scandinavian culture of project management and work in road construction.

This paper presents an advanced method for intensified infrastructure building process. By improving process management the infrastructure building process is accelerated and rationalized. The intensification here refers to more cost-effective, quicker, and safer process management when the current and forecasted process status is better known to the process management personnel. The significance and the level of the intensification of the method will be measured in the sub-sequent research where two similar projects will be managed and compared with and without the utilization of the developed method. The novelty of the developed process control method lies on combining recently developed technologies with new ways and offering an effective and modern tool for infrastructure building site management. In the method, the management of the design data, automatic dynamically changing and manually added process data is formalized in a way that it could be easily integrated as a whole and also exploited efficiently by using automated data fetching and inferring.

2. Novel technologies and research methods

2.1. Infrastructure construction process management in academia

In the academia, the infrastructure building topics as well as system integration are vastly researched areas. Boddy et al. [1] have made an interesting review from the point of view of computer integrated construction, and Shen et al. [2] have made an excellent review on system integration in the field of AEC/FM (architecture, engineering, construction and facilities management). In the following some examples of integration research in the area of infrastructure building are gathered.

In the mid-1990s Navon et al. [3] begun to research construction industry management. Industry related state-of-the-art research has been conducted in Israel [3]. Navon and his colleagues focused in their researches on automated productivity measurements using GPS-data and the concept of work envelopes [3,4]. In the same time Navon stated that in the beginning of the 2000 century the background for the construction process control was thin and all the actions were done by manually made calculations [3].

Later on two German research projects have started to study the ways to improve construction processes and management. Researched focus areas were e.g. improving the total construction process and optimizing the workflow with the help of machine control, logistics planning, virtual phase visualization, documentation, and data management. State-of-the-art technology like PDM-systems and close range identification was used to help in reaching the targets [5–9].

Several academic researchers have also researched lately the potentials of ICT-related construction management [10–12]. The common factor of this ICT-related researched mentioned above is the use of novel ICT technology for process measurement and follow-up.

Kosovac (2007) [13] proposes a framework for information use and management in AEC/FM. The prerequisite for meeting requirements of information management of complex domain is the efficient communication between parties, both humans and machines. The framework identifies three basic types of assertions (senses, relationships, information) and their two properties (category, scope) which are used to relate all kinds of semantic resources and information management approaches. In the pilot implementation numerous and diverse components share their content via Web Services using the proposed framework.

El-Diraby et al. (2005) [14] present a domain taxonomy for construction. The taxonomy is based on IFC (Industry Foundation Classes) and several other classification systems. It uses seven major domains to classify construction concepts: Process, Product, Project, Actor, Resource, Technical Topics, and Systems. The major ontological model is process-oriented and can be summarized as follows: construction knowledge is encapsulated in several overlapping systems, where a set of Actors use a set of Resources to produce a set of Products following certain Processes that are part of a Project according to boundary conditions and within the confines of the work environment (Technical Topics) [14]. The operation of developed domain ontology was evaluated during e-COGNOS project [15] as a part of web based knowledge management software, which connected various systems using Web Service technology. The development of ontology architecture was continued by adding more knowledge levels (application knowledge, user knowledge) to domain ontology [16].

The study presented in this paper has the same kind of ideas of using ontologies for system integration and information management during infrastructure construction process as in previously presented researches. However, the focus of the study is on how to use developed information integration method and other mentioned novel technologies

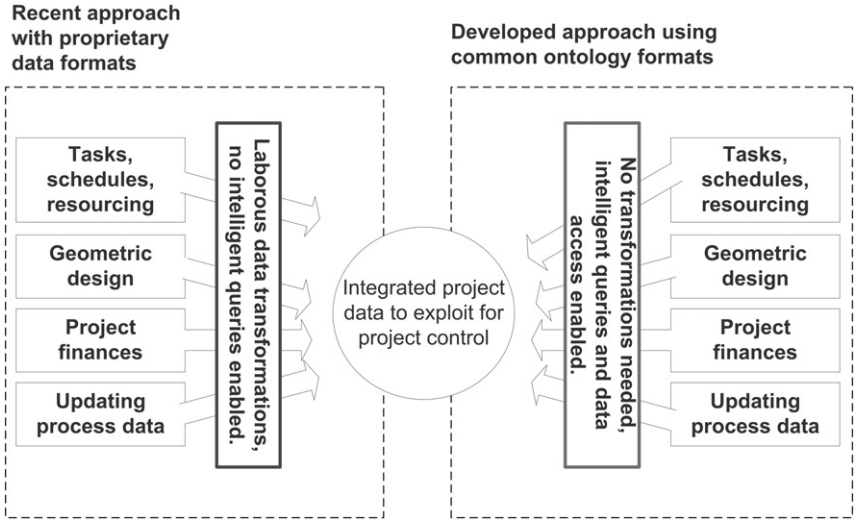

Fig. 1. Introduced process management method brings advances through easier data integration and more versatile and efficient utilization of integrated data.