EFFECTIVE SEMANTIC WEB-BASED SOLUTIONS FOR CIVIL ENGINEERING

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ABSTRACT

The World Wide Web (the Web) has become widely recognized as the primary channel of communication and dissemination of information in industry. It has made immense amounts of information available and has been gradually accepted by users who now readily incorporate it into their daily lives. In civil engineering, despite the wide use of the Web, its use is still limited by the users' willingness and ability to share their knowledge. The Semantic Web challenges this problem as it adds meaningful descriptions to information in a manner that facilitates automated analysis and extraction by computer systems. While many scholars in the field realize the importance of using such technologies to promote collaboration with various parties including the general public, research that is conducted on the Semantic Web and similar technologies is often disconnected from its application. Nevertheless, there is general consent that this collaboration is essential for the creation of sustainable solutions in civil engineering. This paper reviews and analyzes current research being conducted on this area in Europe and North America. We also propose methods that involve the Semantic Web to improve usability and effective information flow in city-scale projects.

KEYWORDS

Civil Engineering, Semantic Web, Sustainable Engineering, Project Collaboration, Information Flow, Information Technology and Usability

1. INTRODUCTION

The field of civil engineering has been revolutionized by the introduction of different forms of technology and specially automation through computers. However, these computer-based automation technologies were adopted by civil engineers at different stages. Furthermore, the way these different technologies were integrated varies from one user to another. This variance is partly due to a disparity in skills and, sometimes, level of comfort and willingness to change. These factors present a recurrent problem in civil engineering where a technology lag has been created due to slow user acceptance. In addition to acceptance, issues like security and confidentiality come into focus with technologies that are based on the Internet. Communication over the Internet is one the most important components of most current automated systems in which the Web is used as the platform for document exchange.

The World Wide Web (the Web) has become widely recognized as the primary channel of communication and dissemination of information in industry. The Web is the current platform for most communication and involves over one billion fixed Internet users and billions of documents and pages. These figures exclude the number of mobile users that access the Web. In general, it has made immense amounts of resources instantly available across the globe and has been gradually accepted by users who now readily incorporate it into their daily lives. However, this incorporation, as mentioned above, is not expressed by all users in the civil engineering industry as some still prefer tangible means of communication like paper design documents and facsimiles. In civil engineering, despite the wide use of the Web, its utilization is still limited by the users' willingness and the experts' ability to share their knowledge. Naeve (2005) elaborates on how the Semantic Web handles this problem by adding meaningful descriptions to information in a manner that facilitates automated analysis and extraction by computer systems. Integration of the Semantic Web is already under way in several fields in which taxonomies and relationships are being standardized (Sheth et al. 2007).

Efficient collaboration has been the focus of our research since we identified these problems, especially in city-scale projects. Most of the problems faced in city-scale projects arise due to the need for concurrent coordination with more than one party. These parties include the public, government bodies and other construction entities. Once this coordination has been achieved, city-scale models can easily be extended to span projects that involve international collaboration. While many scholars in the field realize the importance of using such technologies to promote collaboration with various parties (El-Diraby and Gill 2006), research that is conducted on the Semantic Web and similar technologies is often disconnected from its application (Robertson et al. 2007). In addition, despite the prevalence of technology as a means of improving construction processes, steps need to be taken to promote further integration through coordinating with users and facilitating active participation of the public.

Nevertheless, many scholars agree that this collaboration is essential for the creation of sustainable solutions in civil engineering (Barrett 2008; Robertson et al. 2007). This paper reviews and analyzes current research being conducted in the area of collaboration in Europe and North America. Although several other regions are already leading a technologically-advanced and prospering construction industry, this review will limit the context of comparison and research scope by excluding regions other than those mentioned above. In order to identify the deficiencies within this scope, a review of current automation technologies is necessary. This paper will review current technologies before describing state-of-the-art approaches involving the Semantic Web. We also recommend improvements in areas that would help speed up the integration process.

2. CURRENT AUTOMATION TECHNOLOGIES

The field of civil engineering has seen the successful integration of technologies such as computational intelligence, modeling and simulations and finally the Web. The integration of technology was brought about by a growth in the industry, and the technology, in turn, promoted further growth. This growth is evident in several fields of civil engineering. Project management, for instance, currently involves extensive use of communication and automation technologies.

Unfortunately, this automation is being utilized within a generally fragmented industry. This fragmentation is a problem due to the large size of the civil engineering industry, and is hindering further growth foreseen by researchers. The size of the construction industry, as one aspect of civil engineering, in the UK alone represents 9.9% of its GDP which makes it one of the largest industries in the UK (Barrett 2008). With an industry that shows such diversity, great inconsistencies arise in various processes. These inconsistencies in processes as well as data can be directly translated to significant losses in funds and time. Barrett (2008) suggests that rather than considering this fragmentation a problem, researchers should look at it as an attribute of the industry. This approach helps in dealing with the fragmented nature more positively and perhaps justifies why the integration process has been a hard one all along.

Other than fragmentation, and despite evident automation, the second important deficiency is the difficulty of acquisition of knowledge. For example, a case study from Greece shows that determining the failure reasons in waste management could be a very hard task due to the parties not cooperating (Dokas and Panagiotakopoulos 2006). In this case, an expert system was successfully used to enhance the knowledge acquisition process. Nevertheless, little thought was given to global application and if, in fact, it could be communicated globally.

Expert systems are also used in the infrastructure industry in the U.S. which has the largest highway system in the world. Within this complex system, engineers use expert systems to automate the process of evaluating existing bridge systems to prevent future disasters (Issa et al. 1995). However, despite the significance of this system as a rating model, its effectiveness and field of application could be reduced by lack of transferability across different bridge systems. A simple discrepancy such as incompatible rating units could act as a barrier against seamlessly communicating data on an international level.
As can be seen in the previous examples, the general trend revolves around problems that are based on lack of cooperation and difficulty of data acquisition. As a remedy to these problems, while keeping the advantages

of an automated system, applications involving the Semantic Web have been proposed. Despite being a relatively new concept, some of these applications are already in operation.

3. THE SEMANTIC APPROACH

The Semantic Web comes as a natural evolution of the Web. It adds a semantic aspect to the current syntactic Web that is based on resources, mostly in the form of documents. In the context of the Semantic Web, these documents can be described and then easily analyzed using technologies based on the Extensible Markup Language (XML). The main advantage of this approach is that a user would be able to receive relevant data and trends without manually carrying out any comprehensive identification. In turn, this saves human resources and time, which both translate to a reduced cost.

One important point to note is that the aforementioned data inconsistencies that arise are a consequence of changes in data trends as well and not just underperformance on part of the users. We are subjected to immense amounts of information that becomes overwhelming even for adept managers. Naeve (2005) describes how the Semantic Web makes information suitable for identification and machine processing. This facilitation is achieved by relating the descriptions of different sets of information. In other words, the Semantic Web automates the fetching of information. This taxonomic automation of the search and analysis processes was the missing link in most of the applications mentioned above. Taking the case from the previous section as an example, the waste management fault expert system in Greece could be an area where the Semantic Web would be used in the integration and deployment of the expert system. This integration is especially useful in developing countries where expert knowledge may be lacking or not immediately available.

It is increasingly demonstrated that the applications of the Semantic Web have seen a boost over the past two years. This boost was accompanied by standardization of many of the concepts involved in the Semantic Web, hence, the technology became more usable. Following are case studies that deal with some of these applications. These cases give an idea of the general trend, our current ability to identify and deal with the deficiencies and level of progress. The main areas covered by the following cases are related to virtual organizations and risk assessment in construction.

Virtual Organization (VO) is a term that generally describes collaboration between companies within the context of a specific project. The term can also be used more specifically to describe business collaboration or the exchange of skills between companies (Gehre et al. 2007). The InteliGrid platform is a European Union project that uses research aimed at establishing a grid-based VO environment. Dolenc et al. (2007) explain how this project uses grid technology and semantic interoperability to provide a prototype that can be used by the engineering industries. This line of research represents a powerful integration approach in which the computing power of grids is used to collaborate between higher-level business processes. Gehre et al. (2007) further discuss the management of VO processes using Semantic Web concepts. Their research effectively brings the user into context by designing end-user applications with graphical user interfaces to facilitate testing. Their model provided a proof of concept and also indicated that more "flexible semantic human-computer interaction" needs to be developed.

Another area that could make great use of the Semantic Web is privatized infrastructure finance where private-public interaction occurs. El-Diraby and Gill (2006) extend the application of the Semantic Web to this area where construction meets external disciplines like finance. The collaboration with different disciplines requires bridging through a transfer of knowledge. The main aim of this knowledge transfer is to assess and communicate the risks in an efficient way. For instance, the taxonomy developed by El-Diraby and Gill (2006) would enable a construction company to communicate the evaluated risks to financial institutions efficiently. In addition to the assessment of risk, the suggested tool also provides the user with the possibility of documenting best practices. These documented results can later be analyzed by the system to detect certain patterns and create appendices accordingly. El-Diraby and Gill (2006) acknowledge the limitations of the proposed taxonomy as it is difficult for a single ontology to cover a full domain. The taxonomy, however, represents a successful attempt at connecting the financial and construction industries. Dealing with such gaps between industries typically provides significant challenges when applying the Semantic Web due to the complexities of creating common ontologies or integrating them.

The cases described above showed the diversity of applications the Semantic Web can be involved in. They also offer proof that integration on a large scale is facilitated by these technologies. In brief, the technology is available and the need for such technology has been established. The problem that is seldom tackled is obviously the user acceptance and promotion. A major question is why Semantic Web technologies do not appear to be catching up with other automation technologies. In the next section we discuss ways of promoting Semantic Web technologies and enhancing their usability.

4. PROPOSED SOLUTIONS

Many civil engineers, specifically construction engineers, have been using computer software as a major component of the design and cost estimation process. Although other forms of technology may not have been received in the same manner, this existing familiarity with the use of software as a design tool should facilitate the promotion of new technologies. Yet, as mentioned earlier, this familiarity is not expressed by all engineers and a few steps need to be taken to introduce the Semantic Web effectively. The first and most important step is to guarantee access to communication technologies. Unfortunately, the communication infrastructure problem is not a problem that is limited to developing countries. One would find it hard to believe that a developed country like Spain would be falling behind in the availability of communication links. However, one of the recent projects in Andalucia, Spain dealt with the issue of installing fiber-optic cables for better connectivity to smaller regions in the country (Cortes et al. 2006). The issue of stable connectivity is a possible problem in most rural and remote areas around the world. With the continuous development in the construction industry, these remote areas could host several construction projects and even company branches. Therefore, investment in communication technologies in these areas is recommended on the long run for full automation of information flow. If permanent communication lines are not possible, although this is highly unlikely in the presence of satellite communication, offline data repositories should be synchronized frequently. In general, good communication lines promote the use of Semantic technologies as they offer a more stable system.

Besides communication, Semantic Web applications need direct marketing. The public and practitioners alike have to be widely aware of its possible applications so they can relate it to the problems they face and how it would help alleviate some of these problems. They also need to be assured that they can trust this technology and that it would actually promote better performance and lower costs on the short or long-run. Outsourcing the technology aspects of construction project is a very effective approach that provides this trust. Outsourcing companies also provide the required marketing through proven track history as the same technology could be transferred from one project to another upon proven success. The idea of outsourcing all information technology aspects of a project to a specialized company is not a new one and has proven to be very effective. Lin and Harding (2007) explain how outsourcing enables companies to focus on their core competencies. Among the advantages of outsourcing, the civil industry can make use of best practices and case studies that are gained by experts in outsourcing. Outsourcing companies also provide the best available technologies as they frequently update their services and security standards.

Whether a civil engineering company opts for outsourcing or develops its own in-house system, the first stages involved in the introduction of the new system are very important and could determine the overall success of the process. Contingency plans should be created with a design that accounts for some manual processes in case of unforeseen failure. Moreover, a modular structure is essential to achieve some independence among the processes. A modular approach would also mimic the fragmented nature of most projects as noted earlier. These modules would then be easily integrated in a process that follows careful and planned differentiation (Barrett 2008). Many companies start using a pilot approach in which the introduction of the Semantic Web is carried out as a pilot project until the documentation is carried out and the proof of concept is completed. This procedure also gives the users enough time to acclimatize and promotes efficient use of the system.

Thirdly, the role of regulatory authorities and governments is indispensable in introducing Semantic Web technologies in cases where it is perceived useful within their vision for the industry. Barrett (2008) points out that the role of a knowledgeable government is as important as the role of the users. This significant role is especially evident in construction education. Moreover, through the integration of the Semantic Web technologies and knowledge management systems, these governing bodies can design plans to bring the industry up to their anticipated level of collaboration. These authorities should also provide recommendations and guidelines that fit the direction they want to drive the industry. On the long run, the collaboration systems would also provide them with better means to coordinate with other entities in the civil industry. In Europe, the aim is that by 2030, a more competitive and sustainable construction sector would be achieved through the Strategic Research Agenda (Robertson et al. 2007). On the other hand, it appears that there is little evidence of similar initiatives in North America. Whether the application will catch up with these research plans within the given time-frame will remain subject to uncertainty.

Finally, it is essential to acknowledge that while the semantic automation process needs an investment of time and funds, its gains can be soon realized through collaborative action across the industry. For this reason, planning should take the education of young engineers into consideration to allow for a directed rather than forced evolution of the technologies.

5. CONCLUSION

In this paper, we have presented the prevailing trend in today’s construction industry. It can be seen that there is a sufficient amount of research being conducted that is, unfortunately, lacking application. It was also shown that more research needs to be directed towards involving the users. Current research has been concentrating on different automation technologies. While automation has been successfully achieved in most realms of the industry, inconveniences due to fragmentation constantly surface. This fragmented structure arises due to the large number of companies that can be involved in one construction project. Research that tried to tackle this fragmentation as a problem was focused on eliminating fragmentation which proved quite challenging. As a result, it has been proposed that this fragmentation should be dealt with as an attribute, rather than a problem, of such an expanding industry that is built on large-scale projects. Alternatively, some research implemented methods that educated users on ways to look for information. While these methods are on the right track, they still do not make full use of the available technological resources.

The Semantic Web is an easily accessible technology that has been emphasized in this paper. It addresses the fragmented nature of the industry, yet applications of the Semantic Web have to overcome the difficulty of integrating different ontologies in a relatively seamless and consistent manner. The current literature provides effective ways of utilizing the Semantic Web in engineering to make processes more efficient in addition to providing value to society. Currently, there is evidence of more resources being employed into developing good communication pathways: both physically and through software.

It is known with certainty that expert knowledge is indispensable, but also of less value if not communicated across the industry. For such communication, the technology is available and under constant improvement. We believe that the future is in the integration of the Semantic Web. This integration will help users confidently catch up to the technology and effectively utilize it. It is not surprising that a lot of the current research deals with the education for engineers and the general public as a way of reducing the technology lag.

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