
DESIGN AND ASSESSMENT OF PROSPECTIVE MOBILE SERVICES FOR CONSTRUCTION

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ABSTRACT

Mobile applications become more and more used in both private and professional activities. Innovation through mobile services specification and prototyping becomes a major trend in construction sector research. The project presented in this paper aims both at demonstrating the interest of mobile technologies for assisting building construction coordination and to elicitate the most interesting and common requirements of construction practitioners for this type of application. Then the paper focuses on the method used for specifying basic requirements and the experimental protocol setup for assessing the developed prototype. The main outputs are a set of specifications and a prototype of mobile application as well as a method for defining experimental protocols in a context of service-based innovation. The prospects envisage considering context-aware mechanisms for the recommendation of mobile services to construction practitioners.

Keywords: Construction management, Mobile computing, Mobile service prototyping, Experiment protocol.

1. INTRODUCTION

Mobile computing has become an important challenge for the construction industry in the recent years. While technology and standards evolve, editors provide hardware and software solutions for construction practitioners. It could be noticed that most of the existing solutions are dedicated to particular construction fields such as enterprise resource management (e.g. allocation of workers, tracking of vehicles...), stock management (i.e. contractors material stock) or labour tracking (e.g. time spent, work done...) (Bowden 2005). In parallel, the development of communication networks, mobile operating systems and touch-based smartphones and tablets are increasing, and especially target general consumer markets. These mobile systems provide functions that could be useful for construction practitioners' every day work. *However these functions are scattered into multiple applications, e.g. photo snapshot, note taking and mail applications.*

A main factor of construction project success is the quality of cooperation processes and information exchange between practitioners. Until now, the project management web platforms dedicated to construction projects were generally designed for office-located use, on usual laptops or workstations computers (i.e. desktop versions). Some of them provide mobile access through mobile browsers or dedicated applications (i.e. mobile version). *However their functions are more or less derived from the desktop-versions' ones and do not benefit from the user's context to enhance information delivery (Aziz et al. 2009).* It is well known that the usability of innovative IT-based systems is a key factor of their success. But designing Human-Computer Interaction for mobile applications is not trivial.

Indeed the development methods of mobile applications should take into account utility and usability of services in the early design and prototyping stages. However ergonomic assessment methods are just emerging in the field of mobile development. They face many issues, such as the limitations of classic in-lab tests, which do not take into account the mobile user context (Nielsen et al. 2006). *Then user testing methods should be dedicated to mobile services experiments.*

This article describes the MoBuild project, which focuses on mobile computing in the construction sector. Firstly, the specification method and the first result of this research project will be presented. Then, the experiment stage and user's feedback will be described. Finally, prospects will be considered to improve the MoBuild application considering context-aware perspectives.

2. MOBUILD PROJECT

2.1 Mobile computing in construction

The application domain targeted in this article is the Architecture, Engineering and Construction (AEC) sector. Every AEC project is a prototype as well as its organization. Indeed actors are heterogeneous and vary from one project to another, their tasks are not repeatable and the construction site context remains unpredictable due to various environmental conditions (e.g. weather forecast, sub-contracting or external providing of materials). Despite the fact that cooperation is usually structured and that plans or norms are used in construction projects, the everyday practitioners' working practices usually try to fit the characteristics of each cooperative situation by strengthening informal exchanges and mutual adjustment. When considering construction site related activities, this statement leads to two types of activities (Kubicki et al. 2006): 1) the highly-structured ones where information exchanges are planned and problems are explicitly addressed (e.g. weekly site meeting) and 2) the adhocratic ones (Toffler 1970) consisting in informal ad-hoc meetings required to solve unexpected problems. Considering both of these two situations, capturing the events occurring on construction sites is of paramount importance such as treating them, and especially diffusing information to the person who can make use of it.

In the AEC cooperative contexts, mobile situations of work are numerous for most of the actors of a project: construction site, visit to a partner, material provider office, industrial production plant or architectural visit. However, despite of the wider possibilities of accessing Web applications from mobile devices, there are not many solutions dedicated to the distant access to project information. As the business needs seem obvious, one has to consider the real mobile usages in order to design HCI that limit the amount of information, and adapt the interaction to this new kind of devices, taking into account users context.

2.2 Prospective approach towards requirements elicitation

The MoBuild project aims to identify the interest of mobile computing for the AEC professionals. In this context, a prospective prototype has been developed. By "prospective prototype", we mean a prototype of application which anticipates the users' needs and which provides functionalities responding to their future needs, not explicitly formulated at this time, but already identified.

It was important to rapidly define the sector's needs in order to adapt the application proposals. The building site is an activity largely mobile by nature. Based on the literature (Magdič et al. 2004; Menzel et al. 2004; Bowden 2005; Löfgren 2005; Anumba et al. 2006; Aziz 2009; Lee et al. 2009) and on a brainstorming where architects and computer scientists were presents, business practices in mobile situation were identified. Then a second brainstorming allowed us to identify the smartphone features and their technical possibilities. Finally the results of these two brainstormings were reconciliated by business experts (see Table 1). It was decided to focus the objective on the "picture as support for the building site monitoring". The requirements selected by the business experts were the following: 1) Taking photos and videos. 2) Associating textual comments to photos or videos. 3) Graphically commenting the pictures. 4) Geolocalize photos and videos. 5) Send information by e-mail. These requirements have been implemented in the MoBuild prototype.

Table 1. Business practices and smartphones features

		Smartphone features								
		GSM	Camera	Microphone	Speaker/headphone	Vibrator	GPS	Internet connection	Bluetooth	Others
Smartphone feature / business practices		Call	Photo	Voice recording	Sound/music	Alarm/reminder	Location	Xeb	Found devices	Input text
		SMS	Video recording	Speech input	Alarm/reminder	Tactile feedback	Itinerary	E-mail	Exchange files	Digital compass
				Voice recognition			Geotagging		Audio equipment	Noise detection
							Speed			Proximity sensor
										Gestual interaction
										Light sensor
										Calendar
Business practices	Schedule an appointment									●
	Track a malfunction		●							●
	Contact a project stakeholder	●								
	Check calendar									●
	Monitor progress of tasks execution									●
	Identify new tasks									●
	Draw a construction detail									●
	Write observation/comments		●	●						●
	Transmit a document							●	●	
	Validate material delivery									●
	Send a reminder				●	●				
	Identify risks on construction site									●
	Send/share a given document (e.g. photo)		●				●	●	●	
Manage "daily" photos		●				●			●	
...										

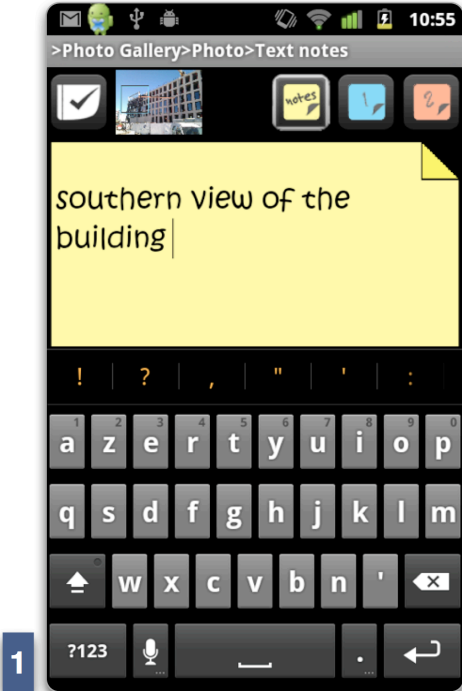
2.3 MoBuild application

This section describes the implementation of the prototype and its functionalities. Based on the fact that architects (or more largely other AEC professionals such as construction managers) want to capture information on site to more rapidly write reports or improve communication, the MoBuild prototype has been developed in order to associate picture (related to construction site activity) with vocal, textual or graphical annotations. So the user can take a photography with his smartphone and then complete the picture with annotation. He can use the microphone to associate an audio recording or the keyboard for textual comment. If the comment concerns some areas on the picture, he can use graphical forms (i.e. arrow or rectangle) to highlight the area on the picture (e.g. a malfunction). Finally the user can send the set (i.e. picture and annotations) by email in order to inform a project stakeholder that there is a dysfunction on site, or to his own email box for constituting a set of information as basis for writing the construction report.

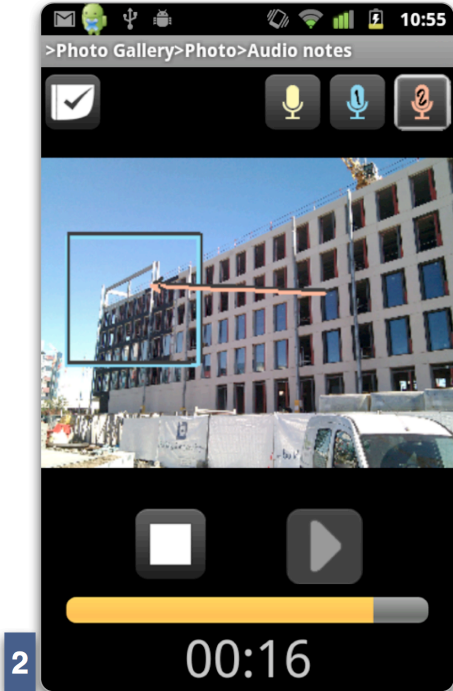
The MoBuild prototype enables managing a large amount of pictures. Then two modes are available for consulting the pictures: the pictures can be accessed from the photo gallery or thanks to both their location and related calendar event. The user can consequently consult all the pictures related to one of his building sites or one of the meetings he has been involved in.

Figure 1 shows some screenshots of the MoBuild prototype developed for the Android platform. The screenshot 1 shows the interface enabling the user to annotate a photo thanks to textual annotation. Up to 3 annotations can be added to the photo description. The screenshot 2 shows the controls for audio annotation of an image. 3 audio annotations can be added. One can notice the blue square and red arrow, which are the graphical annotation that can be used to highlight particular items inside photos. The colors correspond to the second and third possible text or audio annotations (possibility to add text/audio corresponding to the graphical annotations). Then the screenshot 3 shows the "Google© Maps" view, above which construction sites and photos are shown. Users can add construction sites by placing a pin on the map. They also have to define the radius within which photos will be "incorporated" to the site. Other photos are shown separately. Finally the fourth screenshot shows the interface presenting the photos' miniatures filtered by the construction site they belong to. The user

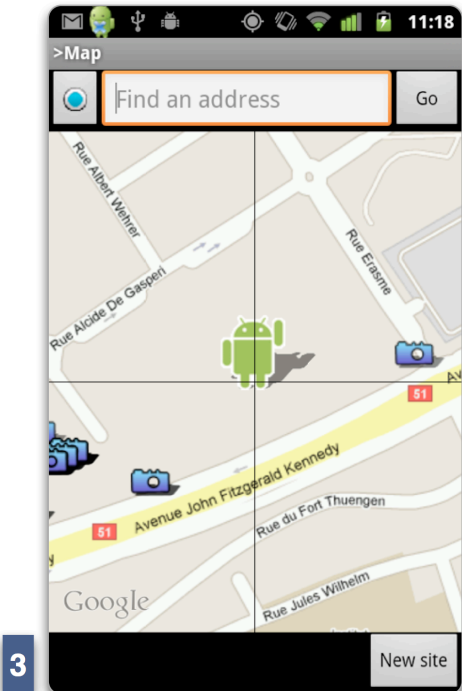
can then open the gallery of photos filtered by the construction site, and start reading or adding annotations.



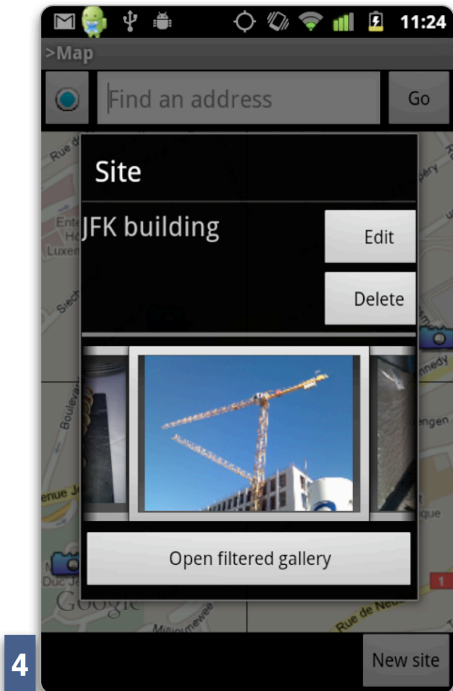
Textual comment on a picture



Audio comment on a picture and graphical highlights



Selection of pictures by localization
View of the map



Selection of pictures by localization
Preview of the picture and site information

Figure 1. Screenshots of the MoBuild application

3. EXPERIMENTS AND USERS FEEDBACK

The process of designing prospective services such as the one described above has to rely on methodological foundations in order to lead the research team to qualitative project results. Indeed in most of the cases such research projects do not focus on the prototype applications by themselves, but rather on the demonstration that prototyped services have a value in a given business context. Experimental levels were previously defined in (Guerriero et al. 2009) depending on the research context and the obtained/developed results. Both the protocol of MoBuild experiment and the results are described in the following sections.

3.1 Definition of the experimental protocol

The figure 2 shows the main characteristics of the experimental protocol both for the first validation stage (red continued line) and the expected one (green discontinued line, experimental protocol for future version).

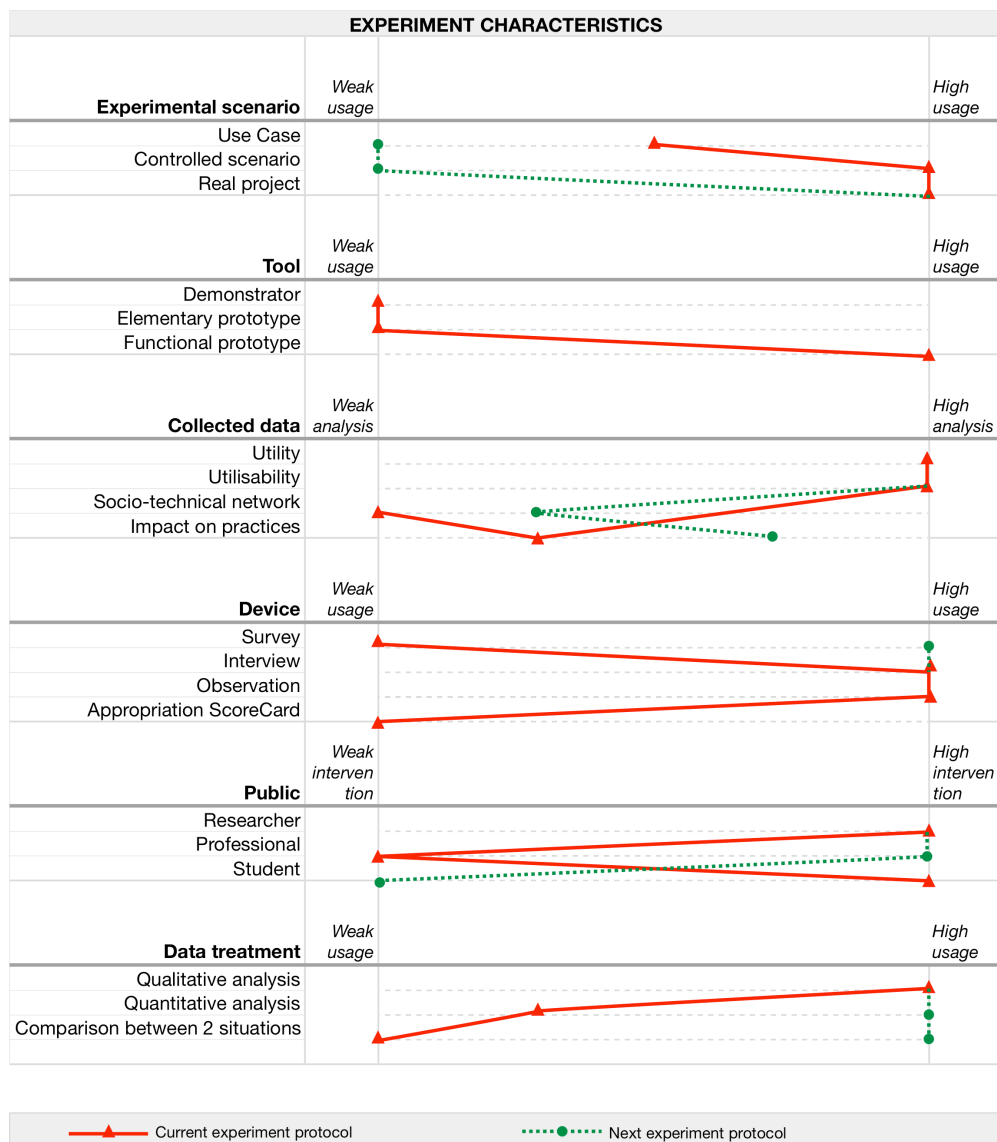


Figure 2. Experimental protocol

For setting up the experiments we considered that the “support”, i.e. the prototyped service, will be functional. This means that experimenters will have the possibility to use the final application on the mobile device, with all the functionalities available.

The experimental scenario consisted in several use cases, used during the design time, in order to ensure possible scenario were associated with the application requirements. These scenarios were especially validated with “business experts” (i.e. researchers in the AEC field). The experiment with real users consisted both in the definition of “controlled scenarios” (for in-lab tests) and of a “real project” where the application was used.

Concerning the data to be collected during the experiments, the main focus was to gather information about utility of the developed application, but also about its usability (considering that such mobile application have to be intuitive enough, but also simply to use and touch-based). The usability is an important concern also because it is a kind of constraints on the utility: a low-usable prototype could perhaps lead to the misunderstanding of some of its functionalities. However, the socio-technical network was not a focus of the experiment. We also did not focus on the impact on business practices of such a tool considering that its aim was to discover new usages and practices of mobile technologies.

The main devices used for experimenting the prototype were both interviews and observations: the goal was to gather the impression of users after testing the application through interviews, and observations enabled to observe usability issues concerning the interface.

Final the targeted public was researchers and students, the majority of these experimenters having skills in AEC, for efficiency reasons: it was simpler to contact such experimenters. Considering the highly innovative aspect of the project, and our aim to discover new usages, this was not blocking. However for the next experiment period we aim at testing the application with practitioners.

Finally the treatment of collected data was largely qualitative, consisting especially in interest of experimenters for such mobile services and of new ideas for improving the prototype. Quantitative data were also analyzed for the usability concerns, on the basis of standard questionnaires.

3.2 Experiment results

The development method including domain experts as “fictive client” for application is a first point to obtain an application corresponding to the needs of the construction domain. Nevertheless, it is important to validate the prototype in situation with final user. Consequently, the experiment was divided into two steps following the characteristics expected in the experimental protocol definition (see above).

Firstly, a user has used the prospective prototype on site in a pedagogical context: “Les défis du bois 2010/ Wood challenges 2010” where students have to perform a wooden construction project. This event is organized each year both by the Epinal university and Nancy Architecture School in France. The prototype has been used during one week for the monitoring of these projects. Then the user has been interviewed to identify the different problems on site and to complete a survey for satisfaction assessment (SUS – System Usability Scale). The feedback was very positive, especially about the interest of the system to provide a unique application where photos are stored, as well as the user’s annotations. It confirmed the main usage that was envisaged by the research team: the tracking of problems and the sending of information by email should enable easier reporting of construction activity (e.g. writing of construction reports). Some issues regarding contextual usability were also highlighted thanks to this test in real situation. Especially the contrast and screen luminosity was a problem for using the tool outdoor when the sun was shining. This part of the experiment was very useful to assess the utility of the prototype, however we noticed that the usability of such mobile, touch-based applications was hard to finely assess in the framework of “on-site” conditions (i.e. outdoor, under fluctuant weather conditions etc.).

Then, a usability test with direct observation has been deployed with eight experimenters. Six of them were architects. The test suggested six scenarios of use. At the end of the prototype manipulation, the user was interviewed and the SUS survey was filled in (see results in Figure 3). This second part of the experimental process aimed at achieving the assessment of usability, but was also easier to manage and enabled interviewing more experimenters than during the first step. The results of this test highlighted usability issues (place of buttons or chosen icons, not enough guidance, photo deletion not intuitive) and some lack of features (mainly the possibility to upload all photos of the day on a collaboration platform or on a PC once back at the office). If usability has been finely assessed, one

should mention that lab-based tests of a mobile application does not lead to the assessment of the use of the application in real conditions, because such applications are designed for outdoor use.

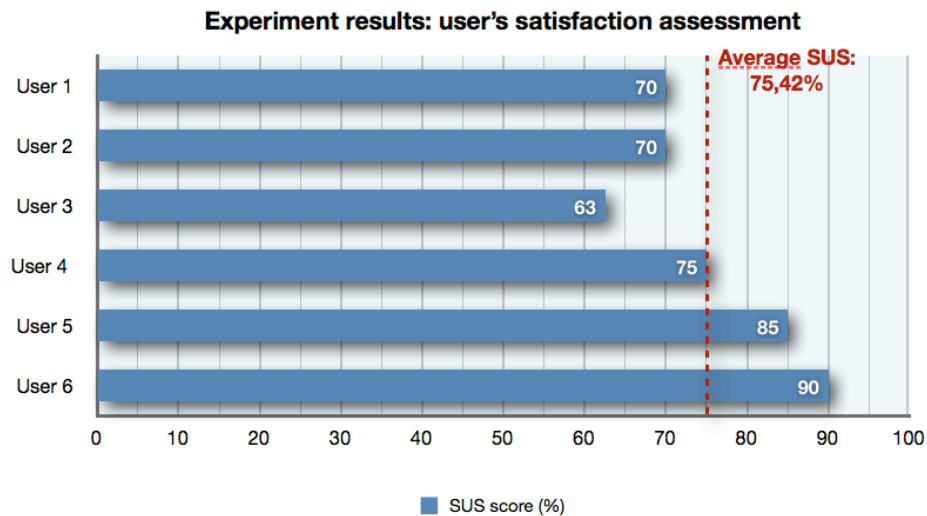


Figure 3. Experiment results (only for “architect” experimenter profile)

4. PROSPECTS

At this time, we consider that integrating theoretical approaches coming from the context aware computing could adapt the characteristics of the application according to the characteristics of the context.

In context-aware computing, the notion of context is defined as “*any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves*” (Abowd et al. 1999). Based on these authors’ works, (Chen et al. 2000) consider four categories of information characterizing context:

- “*Computing context*” concerns information related to the network connectivity or the characteristics of the device.
- “*User context*” specifies the user’s profile, preferences and situation.
- “*Physical context*” is linked to the environment, and consider information related to the light, the noise, the temperature, etc.
- “*Time context*” consider information such as time of a day, week, season, etc.

Concretely, we imagine that these contexts could be considered as theoretical framework for contributing to context-aware recommendation, i.e. improving the services suggested to the user according to the context. “*Context-aware recommendation aims to provide a given user with personal recommendations by reasoning the user’s static and/or contextual profile, which is acquired by context-aware computing technology, at a certain situation.*”(Kim et al. 2007). The work of G. Adomavicius and A. Tuzhilin suggests integrating additional contextual information such as time, location, company of other people, etc. (e.g. case of watching movie) (Adomavicius et al. 2011).

In our case, we have already developed some features taking into account some context elements to improve photo retrieval: automated location tagging, link with time (i.e. calendar event). In the prototype, the four types of context could enable the recommendation of services. We suggest that the MoBuild application could be adjusted considering the parameters of the building site such as noise (e.g. in case of high level of noise, the prototype does not propose the use of the microphone), when other project stakeholders are present, the application could suggest to send information (i.e. pictures, annotations, etc.) to them, and finally, the user’s profile could be used to recommend new services (e.g. connexion with other services where the user can have an account (CRTI-weB project management platform (Kubicki et al. 2009)).

5. CONCLUSION

The work presented in this article consists in the elicitation of prospective requirements for mobile services in AEC projects, followed by the development of a prototype and its experiment with future users. The research especially focuses on the methods that are useful for researchers in the various related innovation activities: elicitation of requirements without any real “client”, controlled experiment of the prototyped services. The result itself, in terms of specification and prototype, are now reused in a new project following this one.

Our prospects are to improve the existing prototype through the development of new functionalities related to building construction management, as well as a general improvement on the basis of context-aware mechanisms (described in the prospects section). The resulting new prototype (MoBuild v0.2) will be assessed in a closer way to construction practitioners (as it is envisioned in the Figure 2) in order to better evaluate its business interest and its potential commercial transfer.

ACKNOWLEDGMENTS

The authors thank the other members of the project team (Fabrice Absil and Charles Gilbertz), and the team of the CRAI laboratory who participated in the experiments.

REFERENCES

- Abowd, G., Dey, A., Brown, P., Davies, N., Smith, M. and Steggles, P. 1999. Towards a better understanding of context and context-awareness. In *Handheld and Ubiquitous Computing*, Springer, 304-307.
- Adomavicius, G. and Tuzhilin, A. 2011. Context-Aware Recommender Systems. In *Recommender systems handbook*, Ed. Francesco Ricci, Lior Rokach, Bracha Shapira et Paul B. Kantor, Milton Keynes, UK, Springer, 217-253.
- Anumba, C. and Aziz, Z. 2006. Case Studies of Intelligent Context-Aware Services Delivery in AEC/FM. In *Intelligent Computing in Engineering and Architecture*, Springer, 23-31.
- Aziz, Z., Anumba, C. and Pena-Mora, F. 2009. A road-map to personalized context-aware services delivery in construction. *Journal of Information Technology in Construction*, 14: 461-472.
- Bowden, S. L. 2005. *Application of mobile IT in construction*. Engineering Doctorate (EngD) degree. Loughborough University, Centre for Innovative and Collaborative Engineering (CICE), Department of Civil & Building Engineering, Loughborough, 171 pp.
- Chen, G. and Kotz, D. 2000. A survey of context-aware mobile computing research. Technical Report TR2000-381. Dartmouth College, Hanover, NH, USA.
- Guerriero, A., Johannsen, L. and Kubicki, S. 2009. Designing IT services for the Construction Industry. Lessons learnt for Selection of Validation Techniques. *26th CIB-W78 Conference. "Managing IT in Construction"* October 1st-3rd, 2009, Istanbul, Turkey.
- Kim, S. and Kwon, J. 2007. Effective Context-aware Recommendation on the Semantic Web. *IJCSNS International Journal of Computer Science and Network Security*, 78(8): 154-159.
- Kubicki, S., Bignon, J. C., Halin, G. and Humbert, P. 2006. Assistance to building construction coordination. Towards a multi-view cooperative platform. *ITcon Electronic Journal of Information Technology in Construction*, 11(Special Issue "Process Modelling, Process Management and Collaboration" edited by P. Katranuschkov): 565-586.
- Kubicki, S., Guerriero, A. and Johannsen, L. 2009. A service-based innovation process for improving cooperative practices in AEC. *ITcon Electronic Journal of Information Technology in Construction*, 14, Special Issue Building Information Modeling Applications, Challenges and Future Directions: 654-673.
- Lee, U.-K., Kim, J.-H., Cho, H. and Kang, K.-I. 2009. Development of a mobile safety monitoring system for construction sites. *Automation in Construction*, 18(3): 258-264.
- Löfgren, A. 2005. Socio-technical management of collaborative mobile computing in construction. *CIB W78 Conference*, Institute for Construction Informatics, Technische Universität Dresden, July, 19-21, Dresden, Germany.

- Magdič, A., Rebolj, D. and Šuman, N. A. 2004. Effective control of unanticipated on-site events: a pragmatic, human-oriented problem solving approach. *ITcon Electronic Journal of Information Technology in Construction*.
- Menzel, K., Keller, M. and Eisenblätter, K. 2004. Context sensitive mobile devices in Architecture, Engineering and Construction. *ITcon Electronic Journal of Information Technology in Construction*, 9: 389-407.
- Toffler, A. 1970. *Future Shock*, Ed. Random House, New York, Bantam Books.