Understanding the Relationship between Requirements and Context Elements in Mobile Collaboration

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Abstract. The development of mobile collaborative applications involves several challenges, and one of the most important is to deal with the always changing work context. This paper describes the relationship between these applications requirements and the typically context elements that are present in mobile collaborative work. This article presents a house of quality which illustrates this relationship and shows the trade-off involved in several design decisions.

Keywords: Context Elements, Software Requirement, Mobile Collaboration, House of Quality.

1 Introduction

One of the most challenging activities when developing software applications is to understand how user needs are satisfied by the application's functionality. Groupware applications are not an exception, and although determining groupware users' needs in advance and creating the correspondent software may seem uncomplicated, the experience proves that it is not the case and that groupware users will refuse to use collaborative systems that do not support their needs in a wider context [Gru94; Luf00; Orl92; Suc83].

In addition, typical groupware applications have been criticized for being decontextualized, they do not consider the complex conditions (e.g., social, motivational, political or economic factors), where software will be executed causing users to reject the system [Gru94, Lju96, Bar97]. The problem is that most groupware developers usually focus almost exclusively on the analysis and specification of functional requirements neglecting the non-functional ones. Furthermore, users may be unaware of their needs in a wider context (e.g. social, physical, etc.), so that, by simply asking them to identify their requirements, software developers may not obtain the appropriate information [Ack00].

User's needs are translated into functional requirements and some functions are implemented to satisfy such requirements. However, the appropriateness of such functionality is mostly evaluated later, when the software has been built. Misconceptions at that

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point in the software life cycle are costly, which adds to the costs of groupware testing. Hence, new techniques are required in order to understand in advance the impact of the intended functionality on user's needs in a wider context.

One of such techniques is the Software Quality Function Deployment (QFD). QFD can be considered as a set of methods that allows contrasting the customer requirements with the product functionality and can be applied at each product development stage [Cha03, Haa96]. QFD aims to understand how users' needs are intended to be satisfied; it is a consumer-driven process. Typically, QFD is applied in four stages: product planning, parts deployment, process and control planning and production planning. Each step produces a matrix that serves as an input to the subsequent steps. Due to its shape, the matrix is called a House of Quality (HOQ) [Kus99].

A HOQ relates *customer requirements* with *technical descriptions* of the product, including design activities. That is to say, the HOQ captures the essentially non-linear relationships between functions offered by the system and customers needs. Conflictive features become apparent and trade-offs are identified early in the design process. QFD has been used successfully for identifying customers and their needs [Mar98] considering user satisfaction as a measure of product quality.

The use of formal tools that accompanies software development has been proven to be significant in various industries and some researches had accounted the usefulness of QFD for the design of groupware applications [Ant05, Gle04]. However, due to the complexity of groupware design, we believe that technical descriptions are not enough for analyzing whether user's requirements are met or not. As stated by Grudin [Gru94] and Ackerman [Ack00], among others, groupware users needs go beyond technical functionality and involves various contexts of analysis, such as social, technological, and physical context.

Based on a framework for contextual design derived by the authors [Ala06], the QFD technique and the authors' experience, we present a correspondence matrix that shows the relationship between typical mobile groupware requirements and context elements inclusion. The analysis shows that trade-offs appear early during design, and some context have up to 9 relationships. Our aim is to provide groupware developers with formal software techniques that help them to reduce software costs while enriching its quality. We believe that such quality is strongly related with the contextualization degree of the application.

Section 2 presents the context elements that typically are involved in mobile groupware applications. Section 3 describes the groupware requirements involved in the development of these tools. Section 4 presents the derived HOQ as well as an analysis of the relationships between user's requirements and context elements. Finally, section 5 presents the conclusions and future work.

2 Context Elements

The authors defined a set of context elements that are briefly explained below. Context elements should be considered during the development of collaborative mobile applications and are represented in the columns of the HOQ shown in figure 1.

Readiness to use IT. This context element allows determining the group members' preparation for using Information Technology tools. Users' experience, readiness to use technology and learning will influence the kind of interaction dialogues, interfaces, protocol design options and even the project feasibility.

Previous formal context (e.g., rules and regulations). This context element assists on characterizing users' information needs, as well as the actions the group should perform in order to conform to such regulations.

Previous informal context (e.g., social conventions and protocols). Unlike formal contexts, social conventions naturally emerge during everyday users' interactions. They cannot be imposed and they constitute a frame for understanding each other behavior and purposes.

Work practice tools. Every work practice community usually develops its own tools. These tools are not necessarily supported by technology. Provided they mediate social interactions, they can assist the analyst to understand the current underlying workflow.

Group members interaction. This context element helps identify general interaction scenarios among group members in order to determine which of them require mobile support. Such interaction must consider users' communication needs for data and/or voice transfer.

Mobility Type: mobile coupled. This context element represents a type of mobility that can be present in a collaboration scenario. Group members performing mobile collaboration activities in a synchronous way are considered as carrying out mobile coupled activities.

Mobility Type: mobile uncoupled. This context element represents to the asynchronous work carried out by mobile workers during a collaboration process.

Communication requirements. Communication can be direct or mediated; public, private or a mixture; broadcast or multicast. This context element represents the communication requirements of a mobile collaboration activity. Communication strategies constrain the coordination strategies that can be applied.

Coordination requirements. Coordination elements and policies are contextual element that needs to be identified. Some of these elements are: support for session management; floor control administration; user roles support; shared information handling.

Activity criticality. It is important to determine the urgency of achieving the activity goals and the activity importance for the user. These criteria may influence the choice of communication and coordination strategies.

Activity duration. Except for the case of mobile phones, activity duration in mobile collaboration based on PDAs, notebooks or Tablet PCs can be critical as it could be restricted by battery life. This context element identifies the activity duration and the requirement of power supply.

Organizational structure (rigid/flexible). The organizational structure will influence the group needs for coordination and control policies. A rigid organization requires formal coordination with strict control, but flexible organizations must quickly react to environmental changes. This context element represents the type structure of the organization that host mobile workers.

Collaboration policies/rules/norms/conventions. Every organization develops a series of social protocols, policies, rules and norms that regulate its workflow. It is important to identify which are the social rules that may be relevant for the intended collaborative application.

Group size. Group size matters. Research in groupware has pointed out the importance of group size for the success of the coordination, communication and collaboration strategies. Most groupware design elements will be affected by the group size.

Roles. An appropriate identification of roles will help developers to design useful applications. Otherwise, the collaborative mediation process could not be well supported. Clearly it may have a meaningful impact on the group performance.

Group structure. The relationships among roles will define the group structure. An understanding of the group structure and the relationship between it and the organizational structure could be useful to design the interaction policies to support collaboration.

Demographics. It is also important to take into account the users' characteristics, e.g., their age, gender, race, and language may influence the application design. Usability of the application will probably be improved when considering this context element.

Physical space. This element represents the available space for deploying and operating the collaborative mobile application. The smaller/less comfortable/less stable the physical available space is, the less likely is to use large or heavy computing devices.

Adverse environmental conditions. This context element represents physical conditions such as noise, light, number of people around and distracting factors. These factors impose restrictions over the type of user interface to be used for interacting with the collaborative application.

Safety and privacy. These are two important context elements to consider during the application design in case of mobile applications being used in public spaces. Handheld devices are especially appropriate for use in public spaces.

User location (positioning). Traditionally in groupware, it refers to users' location within the virtual environment and is known as location awareness. Current technology lets users locate the partners in the physical world.

Power supply. The activity duration is in direct relation with this context element. The analysis of this element helps developers to identify if the power autonomy of the selected mobile device is enough to support each activity.

Communication capability. This context element represents the availability of networking infrastructure in the work scenario. This element also includes the communication bandwidth that is possible to get in the physical scenario for supporting the mobile collaboration activity.

Uptime effort. A mobile device may need short start-up time, e.g., when users have little time periods to carry out work or when quick reactions are required. This element represents the effort to leave available the mobile application.

Transportability. It is important to identify those activities requiring mobility and to estimate the effort the users are able to spend while transporting the devices.

Computing power. This element represents the processing and storage capacities required for a mobile computing device. Based on that, more than one device type can be selected to support activities with different requirements.

3 Computer Supported Mobile Collaboration Requirements

Based on a literature review and the authors' experience, this section describes general requirements of collaborative mobile solutions. These issues will be useful to help understand the type of applications and capabilities required to work in a specific scenario. Next, a brief explanation of each requirement is presented.

Interoperability. The interoperability of a collaborative mobile application has two faces: communication capability and interaction services of the mobile units. Communication capability involves the threshold, protocols and infrastructure used to support the communication process among mobile units [Ald06, Kor01, Tsc03]. The structure and meaning of all information shared among the applications should be standardized in order to support any kind of interoperability.

Multimedia support. If the application requires capturing, managing and/or transmitting heavyweight data types, such as image, video or audio, smaller the device size more limited will be the solution. The features of each device limit the quality and quantity of data that is able to capture, store and transmit.

All road. Typically the nomadic work makes the work context changes periodically, therefore the groupware application has to be context-aware, and also it has to consider as much work scenarios as possible.

Robustness. Nomadic work requires an important effort of the persons that use the computer-based applications. Several distracting events and interruptions are happening around them. Therefore, if the mobile groupware application is not robust and able to consider these distracting factors, then the users could not utilize the application to support the nomadic work.

Autonomy. Typically, the nomadic workers carry out loosely-coupled work. It means they work autonomously and collaborate on-demand. Such autonomy must be provided by the software tool; therefore it must avoid using centralized resources.

Usable or usefulness. The functionality provided by the tool, the design of the user's interfaces, and mobile computing device utilized to perform a mobile collaborative activity, influence the usability of the solution in the work field. These three elements must be considered during the application design in order to improve the impact of the solution.

Synchronous/asynchronous work. Mobile collaborative applications require synchronous/asynchronous communication capabilities depending on the type of activity to be supported (synchronous or asynchronous). If asynchronous communication is required, every mobile computing machine is able to provide such support based on minimal network availability. On the other hand, if synchronous communications is required, a permanent and stable communication service should be provided independently of the environment the user is located [Sar03]. Mobile phones supported by cellular networks are typically the best option for synchronous communication provided their large coverage range and good signal stability [Mal02]. However, these networks have a limited bandwidth. Another option is to provide synchronous communication capabilities to mobile applications using a Wi-Fi communication infrastructure [Rot01, Kor01]. Although the bandwidth is better than cellular networks, Wi-Fi signal stability depends on the physical environment where it is deployed [Ald06]. Furthermore, this type of networks has a limited coverage range [Mal02].

Portability (transportability). If the application requires to be used on the move, transportability is a strong requirement. Typically, the way to address this issue is through the mobile computing device chose to support the collaborative work. Smaller the device size the more transportable is the device. However, the device size reduction implies restrictions at least on the screen size and input capability [Kor01].

Privacy. If the privacy is an important requirement, mobile computing devices usually have small screens, and thus, they provide better privacy protection than notebooks and tablet PCs if data displayed on screen needs to be hidden from other people in public spaces. Furthermore, the physical distance between the user and the handheld device during the interactions is shorter than the distance between a user and his/her notebook or tablet PC. Another privacy consideration in mobile collaboration is the visibility of the users and users' actions in MANETs or public networks [Kor01]. Ensuring accuracy of location information and users' identities, and establishing private communication could be a critical issue in some cases [Che00].

Long time support (battery life). Activity duration in mobile collaboration provide a strong requirement on the type of device can be used to support it. Many researchers have identified the battery life as critical to support mobile collaboration [Kor01, Gue06]. However, the use of context-information provides a way to optimize the use of power supply resulting in a longer lasting battery life [Che00, Hak05]. On the other hand, it is always possible to carry extra batteries when PDAs, notebooks or Tablet PCs are used. Activity duration is not so critical in the case of mobile phones because these devices are able to work for many hours without being re-charged [Hak05].

Capability to be deployed. Handheld devices are easy to deploy and carry, and also they require low user's attention and have short start-up time. These features allow fast reaction from the users; such speed could be critically needed in these physical environments.

Mobility. Users' mobility on a physical environment depends on the features of the physical environment where the users are located and the current environmental conditions. A user equipped with a mobile computing device can be *traveling*, *wandering* and *visiting* [Kri00]. Traveling is defined as the process of going from one place to another in a vehicle. Wandering, in turn, refers to a form of extensive local mobility where an individual may spend considerable time walking around. Finally, visiting refers to stopping at some location and spending time there, before moving on to another location. Sarker and Wells report that "the optimal size of a device associated with wandering was necessarily lower than an acceptable device size when visiting or traveling" [Sar03].

Performance. The processing power needed for certain mobile applications can exceed what handheld devices can currently offer [Kor01, Gue06]. However, in case of PDAs, it is possible to find commercial devices with CPU speeds higher than 500 Mhz. The processing power limitation of these devices becomes visible, e.g., while processing multimedia information. Although every mobile computing device is able to address basic multimedia needs, just notebooks and tablet PCs are able to handle strong multimedia requirements, such as support for 3D games.

Storage. Storage restrictions have been reported in the literature, especially related to handheld devices [Kor01]. However, these devices keep improving their storage and memory capacities. Last versions of these devices allow mobile applications to manage and store complex data types, even simple multimedia information.

Data input. A possible requirement for a mobile collaborative application is the need for massive data entry. Typically, the mobile computing device used to support the solution will play a key role. PDAs and mobile phones use pen-based data input, which is slow, but also useful to support short annotations [Buy00, Sar03]. On the other hand, notebooks and tablet PCs are the most appropriate devices to support data intensive processes using the keyboard.

4 House of Quality

The correspondence matrix, also called House of Quality (HOQ), has typically three parts (Fig. 1): customer requirements (leftmost rectangle), technical descriptions (upper rectangle), and relationships between customer requirements and technical descriptions (centered rectangle). In addition, the grey line shows the direction in which each relationship should be enhanced in order to improve the application's capability to support the mobile work.

	Social				Ta	Activity						Org.		Group			Physical					Technological				
	Readiness to use IT	Previous Formal Context	Previous Informal Context	Work Practice Tools	Group Members Interactions	Mobility Type: Mobile Coupled	Mobility Type: Mobile Uncoupled	Communication	Coordination	Activity Criticality	Activity Duration	Organizational Structure	Collab. Policies/Conventions	Group Size	Roles	Demographics	Physical Space	Adverse Env. Conditions	Safety	Privacy	User Location	Power Supply	Communication Capability	Uptime Effort	Transportability	Computing Power
Direction of Improvement	↓	--	--	↑	--	↑	↑	↑	↑	↓	↓	--	↑	↓	--	↑	--	↓	↓	↓	↑	↓	↑	↓	↑	↑
Interoperability		O		X				▽	▽														▽			
Multimedia Support					▽													▽	▽		▽					●
All road	▽			▽	O	X	●	O	▽		▽		▽	▽		▽		▽	▽			O	●	▽	●	
Robustness				X		X	O		O		▽			O		●		▽				▽	▽			▽
Autonomy	▽		▽			#	O		▽		O											●	▽		▽	
Usable	●			O	▽	X	▽		●				O		▽	●	●		▽	▽	O		▽	▽	O	▽
Synchronous					O	●		●	O		▽										O		O	▽		
Asynchronous					O		●	O	O														O			
Portability(transportability)		O	▽													▽									●	
Privacy		O	▽					X	▽			●	O	▽	●		●			O	X					
Long Time Support (battery)						X	▽	X			●										X	●	X			X
Deployable	O																●	O	O					●	O	
Mobility						X	●										O	O	O	▽			▽		●	
Performance (bandwidth)				X		X	O	X						▽							X		O			●
Storage						X	X	X	X																	
Data Input	▽			▽			▽									●	O	O	▽	▽					X	

● : Strong Positive
O : Positive
▽ : Weak
X : Negative
: Strong Negative

Fig. 1. House of Quality

Analyzing the matrix it is possible to see that around a 30% of the intersections between rows and columns have some kind of relationship. It means each design decisions should be made carefully. The positive relationships must be increased and enhanced, and the negative ones should be minimized and neutralized. In addition, applications with high degree of interoperability among various software tools as well as coupled interaction pose the major challenges as they consume several resources (storage, bandwidth, battery) and may compromise application's robustness, mobility, and performance.

Authors expect this matrix helps developers to make fast and accurate decisions during the development process. When a design decision has to be made, the designer will evaluate their alternatives, against the HOQ, in order to determine which is the most appropriate. Therefore, the proposed tool not only systematizes and facilitates the decision making process, but also it makes it cheaper and expedite.

5 Conclusions and Future Work

The article presents the typical users' requirements and work contexts that are present in the development of mobile groupware applications. The paper also presents and analyzes the relationship among these two set of components.

The analysis shows that trade-offs appear early during the application design. In addition, such analysis allows designers to easily identify the context variables that should be monitored in order to detect a work context change, or improve the users' interaction paradigm. Our aim was to provide a tool (the HOQ) that allows mobile groupware developers to improve software quality, in term of usability and effectiveness, through the improvement of the decision making process at the design time. We believe that product's quality is strongly related with the contextualization degree of the mobile application.

As a next step, we are analyzing in detail three mobile groupware applications, in order to show how the HOQ can be used to support particular design decisions, and also to show the impact these decisions have in the products' usefulness. If the authors assumptions becomes true, this proposal could have an important impact in the development of mobile groupware applications.

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