# Context in Collaborative Mobile Scenarios

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**Abstract.** Groupware systems support users performing a collaborative task. Designers of such systems may consider the deployment of mobile devices in many cases apparently taking advantage of the good features of these devices. However, mobile gadgets are not always suitable. We develop a framework of contextual elements to be considered when a collaborative application for mobile scenarios is being designed. These contextual elements have been identified based on the authors experience on collaborative applications in such scenarios. The use of this framework is illustrated analyzing three examples of collaborative situations.

**Keywords:** Contextual framework, Groupware applications design.

## 1. Introduction

Groupware technology supports work groups by creating a virtual shared environment where group members can share software artifacts, objects and self-representations. As a consequence, group members may be able to work asynchronously and geographically distributed across several countries, following many regulations and belonging to various time zones. Workers may be physically close; e.g., they may be part of a building construction project where engineers, architects, stakeholders and builder staff are located in many places in the same city or country. Moreover, the distance can be variable if work group members move from place to place or even if they change location within several offices in the same building: *nomadic* workers.

Groupware technology has also attempted to follow the evolution of user needs, by moving from complex and heavy software tying users to fixed computers (Luff and Heath 1998) to light clients downloadable from internet or Web portals. In the latter case, the software is accessible from everywhere at anytime. Following this trend and the current evolution of communication technologies, portable and smaller devices such as laptops, PDAs, handhelds, RFID tags and cellular telephones have been considered to be integrated in collaborative scenarios (Antunes and Costa 2002; Kirda et al. 2002; Myers 2001). These effects are seen in diverse areas such as the professional world, the education arena or the so called extreme environments, e.g., disaster management systems.

On the other hand, it is long recognized that successful group work is not simply the union of individual tasks but an organized set of coherent activities with good strategies of communication, cooperation and coordination among group members. However, groupware has had unexpected successes and failures. Several authors have attempted to shed light into the possible causes for failure. For instance, Grudin (1994) identifies 8 challenges for developers; one of them recognizes the importance of

designing groupware taking into account not only technological issues but also the complex social dynamics within which group activity occurs, e.g., social, motivational, political and economic factors. He recommends a sophisticated understanding of the prospective users' workplace. Ljungberg and Holm (1996) analyze conversational systems such as the Coordinator (Winograd and Flores 1986) and found it drastically decontextualized, that is, it does not consider the wide social context where interaction actually occurs, assuming a stable and immutable role structure. Bardram concludes the same while analyzing a groupware system to support health-care workers (Bardram 1997). As stressed by these authors, the problem is that groupware does not acknowledge the context where the group activity takes place and it may be mainly concerned with technological issues and hopefully with the collaborative task to be developed.

For the case of groupware using mobile devices, the problem may be even more complex. Stanton and Neale (2002) found that subtle changes in the way mobile devices were used by children in three experimental situations led to different types of collaborative behaviors. They found more convenient the provision of occasional well-structured information rather than a continuous flow of information, and favor loosely coupled interaction. Luff and Heath (1998) developed a system for supporting workers who constantly move around a fairly large domain, however in this case technology actually hampered people work, and they concluded there must be serious attention to the ways in which personnel interact with colleagues rather than merely replace traditional technology with mobile devices. Furthermore, they stress the need of considering not simply the character of tasks and responsibilities but most importantly, how the access to such information requires and engenders collaboration. Besides, the researchers highlight the task-dependant nature of their insights.

That is, mobile groupware systems design must take into account the diverse factors that are involved in a particular implementation and such factors go beyond purely technical and social concerns. Portable devices differ not only in their physical properties but also in the kind of interactions they can support, the physical environment where such interactions take place (Brown and O'Hara 2002), and the time or collaborative process phase where such interaction belongs. Mobile devices possess also some inherent restrictions that could make them not well suited for supporting group work *successfully in every* working scenario, e.g., limited screen size, available memory, input facilities, processor speed, bandwidth, battery capacity, and communication intermittence (Tauber and Kaashoek 1997; Guerrero et al. 2005), and finally the current context where such devices are used changes constantly.

We began to analyze which were the favorable cases or scenarios for the use of PDAs in collaborative work in a previous paper (Guerrero et al. 2005). Now, we go further in this aim and we distinguish six contexts that must be taken into account when designing collaborative mobile applications. Some of them had been identified in various areas of research and some neglected. In this paper we present a design framework based on such contexts: physical scenario, social context, computational context, interaction, technology support, task at hand. In addition, we analyze and discuss three collaborative mobile applications with the framework.

The paper is organized as follows: section 2 presents our understanding of the *context* concept, section 3 presents the context-based framework for designing collaborative mobile applications, section 4 analyzes the application of the framework for three cases, and section 5 presents some conclusions.

## 2. Understanding Context

There is no consensual definition about what is context or what it comprises. Context has been described, e.g., as a set of preferences/beliefs, a set of objects in a graphical interface that belongs to a certain region or window where the user's action takes place, a set of attributes, a set of characteristics of the situation at hand and the knowledge use goals, a set of knowledge pieces related to a particular activity or situation (Brezillon 1999a). In a broader sense, context can be understood as "the interrelated conditions in which an event, action or situation takes place"[1]. Other definitions follow that direction: context can be seen as "a complex description of shared knowledge within which an action or event occurs" (Rittenbruch 2002), or as "whatever does not intervene explicitly in a problem solving but constrains it" (Brezillon et al. 2004).

Although dissimilar, the research in the "context" topic seems to agree in two aspects: First, context is regarded as whatever that surrounds something, e.g., situation, an activity, an idea, but is not the thing itself. There is a differentiation between the action currently taking place and the *elements* – circumstances, conditions or whatever – that are related – surrounding or associated – to it. For instance, in the area of context-aware computing, user context is described as the *conditions associated to* the user's current location, such as, social aspects or physical properties (Chen and Kotz 2000). In AI, context is used for interpreting the meaning of a sentence. For instance, if a friend asks us to "close the window", in a cold, windy day we may understand that s/he refers to a physical window instead of a window on a computer graphical interface. In this case, the environmental conditions where the situation has taken place are *the conditions associated with* the question. In HCI, Bannon (1991) proposes that even artifacts have no meaning in isolation: their meaning depends on the context of use of the object, i.e., *the interrelated conditions in which* an individual interacts purposefully with such object. In groupware, contextual information is provided to group members so they can understand how their actions fit into the group goals, which are the *conditions closely related to* their current activity and how the actions of their team mates change such conditions. With this understanding, group members can choose the appropriate response from a set of possibilities (Gutwin and Greenberg 2002).

Second, context comprises a set of interrelated elements that keep a coherence relationship, where such relationship brings a particular meaning to *the thing*, e.g., situation, an activity, an idea. For instance, we can analyze a software product *in the context of* its technical capabilities finding its successes and failures; if somebody criticizes the product by arguing that it may change the political order in an organization, we may say that such argument is *out of context* or that it corresponds to a *broader context*. This way, context also defines a semantic relationship among context elements, e.g., circumstances, conditions. Naturally, an activity or thing can be interpreted in many types of contexts at a time, but some of them will be more or less

[1] Excerpt from Merriam Webster On Line at http: // www.m-w.com

relevant. Put it in another way, conditions are semantically related with the current action; furthermore, some conditions are closely related with the current action while others are subsidiary or distant, and such "closeness" changes dynamically.

Several attempts have been made to identify different general types of context. Brezillon (1999b) and Brezillon et al. (2004) distinguish three main parts of context which can be understood as three major scopes or ranges using the "closeness" metaphor: *external knowledge* – knowledge not relevant to the situation at hand but shared for group members –, *contextual knowledge* – knowledge relevant to the situation at hand – and *proceduralized context* – concerned with the dynamic aspects of context. Chen and Kotz (2000), distinguish four types of context: *physical* – lightning, noise level, traffic conditions, temperature –, *computing* – network connectivity, communication cost, bandwidth and nearby resources –, *time* – time or day, season – and *user context* – users' profile, location, people nearby and social situation. Brezillon et al. (2004) distinguish group, project and individual contexts. However, these classifications of context are too general and since we are concerned with groupware design, our interest focuses on the types of context which must be considered at least for this kind of design.

Several experiences in the use of groupware applications have shown the lack of flexibility of these tools to support collaboration in various scenarios (Bardram 1997; Grudin 1994). The main reason is the lack of importance given by groupware designers and developers to context elements that characterize the collaborative activity, the users and the collaborative activity. Typically, the physical context that describes the physical characteristics of the collaboration scenario and the social context that describe the particularities of the users and the interactions among users, are not considered during the design of a groupware application.

The design process of a groupware application should be context centered in order to ensure the tool will be useful to support the collaborative activity it was intended for. In addition, this process should identify favorable tendencies and coherence relationships among the elements that characterize the collaborative activity. In summary, the influence of the context elements over the groupware application design is so important that it is really difficult to develop a successful tool without considering these contextual elements.

## 3. A Framework of Contextual Elements

Collaborative mobile applications are different from those designed for fixed scenarios. The main difference is caused by the computing and interaction restrictions of mobile devices, the capability of being portable as well as the lack of a stable service for data access and communication. These differences are added to the requirements for designing groupware applications, including social context. Based on our experience on developing fixed and mobile collaborative applications, we have designed a framework for designing collaborative mobile applications in the form of six types of context realms.

We do not claim these are the unique contexts in which collaborative activity can be understood, but based on our experience, we believe these categories cover the most

relevant contexts to be considered at design time. Contexts are presented in Fig. 1 and are ordered according to the typical development process: first, the collaborative task is designed, then its groupware support, the interaction, the computational support, the social context where the application will be immersed and the main prospective physical scenario where the activity will take place.

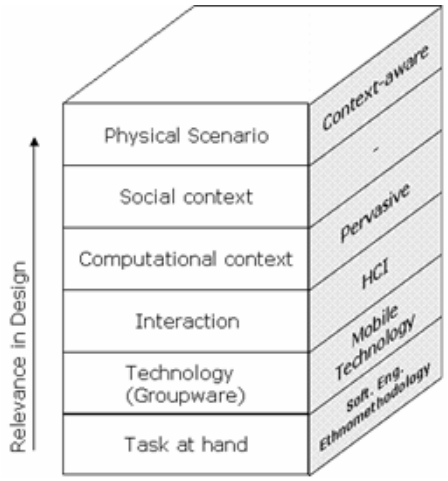


**Fig.1.** Design context for collaborative mobile applications

Some of these issues are also studied in other disciplines. Thus, physical scenario is being researched mostly in context-aware computing, while computational support has become the major focus in pervasive computing. The context categories are discussed below.

### 3.1. Task Context

In the context of the task at hand we are mainly concerned with the design of the collaborative task. Some issues are typically addressed at this point, for instance:

- The set of *Activities* that must be carried out. The collaborative process can usually be divided into several sub-activities. Some sub-activities could require mobile support, while others could be fixed or located. In addition, group members could execute activities in a coupled – joint – or uncoupled – independent, parallel – modes. By considering both categories, sub-activities can be characterized as mobile/coupled, mobile/uncoupled, located/coupled and located/uncoupled. The identification of these sub-activities helps designers to identify the most appropriate type of device for supporting them.

- *Communication.* Communication is a very important issue in groupware applications. However, for the case of collaborative mobile groupware, it will depend on the degree of tasks parallelism.

- *Coordination* and *Negotiation.* Again, these very important issues will depend on the activity needs. Activities with a high degree of parallelism will require strong coordination mechanism whereas in joint activities, coordination could be subtle. Negotiation in mobile environments could be demanding due to device restrictions.

- *User Location*. In groupware, one of the most claimed needs from groups is the provision of location awareness, but traditionally, it refers to users' location within the virtual environment. As the technology presents the possibility of recognizing the user actual location, privacy issues arise. Again, whether the provision of user's location information is important or not will depend on the nature of the activity. For the case of mobile/coupled applications, it could be important for group members to know the location of each other in order to make a decision. In applications where parallelism prevails, users may want to know each other location for planning encounters.

### 3.2. Technology Context: Groupware Support

In the context of enabling technologies, groupware comprehends a large bundle of research. Most studies have been done in this context both in the fields of CSCW and CSCL. For this reason, we will only enumerate some of the elements that comprise groupware technology, since they are well known: Awareness, notification mechanisms, privacy policies, perception techniques, group memory, and architectural design. In fact, we may argue the strong focus of research in this context alone has caused the groupware problems mentioned in the introduction: groupware does not consider other contexts.

### 3.3. Human Factors Context: Interfaces and Cognition

As technology evolves with time, its impact and demands on user cognition increase. Thus, portable devices restrictions must be taken into account for designing an effective user/device interaction. Specific restrictions are briefly described below.

- *Visualization.* Since a portable device screen size is typically small, its graphical capabilities, resolution and colors gain importance. In some situations, user interfaces convey complex information while people are engaged in several activities at the same time, while in other ones, a small text message will be enough.

- *Data Input*. This element represents type and rate of data input required by the collaborative application. Some of the typical data input devices are: keyboard, handwriting devices, pointing devices, microphone, video-camera. The data input rate and the type of data input involved in the collaborative process help designers to identify the best computing devices to support each collaboration activity.

- *Multimedia capabilities*. This element represents the data format to be considered. It includes input, output and management.

- *Multitasking*. People's ability to perform more than one task simultaneously. For example, talk and use the collaborative system at the same time.

### 3.4. Computational Context

- *Power Supply*. Electric power availability allowing the application to function in a continuous way.

- *Compatibility*. Capability of a device to communicate with other devices using a specific communication protocol – IEEE 802.11x or Bluetooth –. This is a specific issue for mobile scenarios.

- *Off-line Support*. Capability of the collaborative application for off-line work. It involves specific mechanisms to synchronize events and actions from the collaborators.

- *Communication bandwidth*. Relevance of communication bandwidth for the continuous operation of the collaborative application.

- *Security*. Transactions security can be an important issue to consider because any unauthorized device may be able to access a MANET. Encryption and message delivery based on roles can be used to improve security.

- *Information Privacy*. This is related to the information that is migrating from one machine to another. The information may be distributed in many machines instead of using a central server to store and manage data access. Moreover, if information is actually stored in a central repository, it could be accessed at a later time by people not necessarily authorized by the information generator (Guerrero and Pino 2001).

- *Deployment capability*. The mobile devices supporting the collaborative activity need to be deployed in the working scenario. Mobile devices are usually easier to deploy than desktop PCs or other devices designed for stable settings.

- *User mobility.* Requirements on user mobility according to the case. The relevant mobility concerns cases in which people need to work with the device to interact with the collaborative application.

- *Network availability*. This context element represents the availability of networking services in the collaboration scenario. Networks do not need to be always available and yet, it is possible to have mobile devices for collaboration, since people interact asynchronously until an active network service point is reached.

- *Memory requirements*. This element concerns the non-volatile memory requirements. Typical applications requiring large memories use multimedia data. Even if the memory is expanded, care should be taken with the input/output performance while retrieving/storing data.

### 3.5. Social Context

Social context has become relevant in recent years. However, it is hard if not impossible to say what comprises and what not, because all human actions are ultimately rooted in the social context. For the sake of practicality, we consider some aspects that had been proved to be important in groupware design: *organizational structure* – roles, conventions and norms and control hierarchies –, *demographics* – age, gender, race, and language –, *familiarity with IT*, *cultural heterogeneity*, *readiness*

*to use the application*, *politics supporting system implementation*, *previous formal context* – law and rules.

### 3.6. Physical Context

- *Space*. This element represents the availability of a physical space large enough to deploy a computing device and operate the collaborative application. The smaller the physical space available, the less likely is to use large or heavy computing devices.

- *Physical Conditions*. Physical conditions such as noise, light, temperature, pollution and distracting factors also impose restrictions over the type of computing devices to be used for interacting with the collaborative application.

- *Safety*. The safety level of the scenario provides a guideline to find the best computing device to be used during the collaboration process.

- *Privacy*. This is a context element to consider during the application design because mobile applications are probably going to be used in public spaces.

## 4. Applying the Framework

This section presents the application of the framework as a tool to help identifying favorable collaborative scenarios to use PDAs as supporting devices. First, the next three sub-sections briefly present previously developed collaborative applications supported by mobile devices. Then, these applications and their collaboration scenarios will be analyzed in section 4.4 using the framework of context elements.

### 4.1. Text Co-Authoring

MoSCoW – Mobile Support for Collaborative Writing – (Guerrero et al. 2005) is a collaborative text editor using mobile devices. MoSCoW is a Web-based system, but it has a module allowing downloading documents to a PDA, updating them, and then, synchronize them with the Web versions. Therefore, the editor has two modules with similar functionality: one of them to be used in the Web environment, and the other one, on the PDA. This project started as a simple collaborative editor to be used by professors in our Dept. to co-author scientific papers. A second phase of the project attempted to support the same type of work, but performed from mobile devices, with the obvious restrictions due to the PDA features: small screen size, slow data input, etc. The goal of the new software module was to enlarge the editor use context, i.e., to allow co-authors to continue working papers when being out of their offices, e.g., when going home by subway. No attempt was made to replace the functionality of the Web editor. The idea was not to create a new PDA editor either, but to continue working in the same task in another context. Thus, a co-author may choose the tool – Web or PDA – best suited to her current work environment.

### 4.2. Dramatic Production Support

Making television series is a complex process which can be modeled as the transformation of written text – scripts – into audiovisual products. Several professional groups participate in the recording process. They are responsible for specialized technical components such as set decoration, set assemblies, makeup and costume. Each group has specific functions within the whole process. For instance, the costume group has different responsibilities than the set decoration group.

Furthermore, several scenes for a series need to be recorded on the open field in real environments – outside the studio –, and thus, wireless devices are required. An application supporting dramatic production was developed (Calderon 2004). It used a point-to-point network with a Wi-Fi notebook as a server and PDAs with digital cameras as clients. The PDAs let to take snapshots from the set and to make annotations. This guarantees a later process of organizing scenes in the right sequence, since they are recorded in another sequence, determined by availability of the set, availability of actors, etc. Several people may input information on the scene being recorded, e.g., place, time, clothing, as well as snapshots. The Director and people in charge of costumes and set use this information to prepare work for the next recording session.

### 4.3. Disaster Relief

Activities to resist and recover from natural, hazardous and intentional *extreme events*, such as terrorist attacks, chemical spills, hurricanes and earthquakes, demand effective collaboration among a broad range of organizations, agencies and entities. This collaboration is needed because each entity is specialized to solve a part of the problem and the mitigation process requires more than the addition of the parts. Every disaster scenario is new; therefore the collaboration scenario also changes; however they share a chaotic, unstable, stressful and dangerous environment.

Typically, mitigation efforts involve participants with three different roles: *disaster managers* – e.g., experts or government authorities –, *first responders* – e.g., police, firefighters and medical personnel –, and *supporting organizations* – e.g., hospitals, civil organizations and meteorological centers –. The collaboration scenario and the task assigned to each type of participant are different; thus the support they need to work together is specific.

The collaboration scenario for the disaster managers and supporting organizations is usually safer and more comfortable than the collaboration scenario for people doing fieldwork – first responders –. In addition, the mobility of these people is low or null and the probability to have communication infrastructure is high. However, the collaboration scenario for first responders is unstable and dangerous, and the nature of the task they should carry out, e.g., search and rescue, requires high mobility. Therefore, a mix of collaboration scenarios was considered in the design of this application. Some of them were supported by PDAs and others by PCs or Notebooks.

### 4.4. Analysis Using the Framework

The three previous applications present various situations for which groupware applications were designed incorporating mobile devices. Table 1 shows the degree of importance of each of the context elements of our framework – Sect. 3 – for each of the applications. The table includes three categories according to the impact in design for each application: very relevant, relevant, little relevance.

It is interesting to note the disaster relief application is very dependent on wireless devices, since that type of work could not be done without them. Moreover, the critical nature of this task makes many of the context elements very relevant for design.

By contrast, the text editor has low dependence on mobile devices, since the corresponding work can always be done without them. Furthermore, a device failure is not too severe, since the system can easily recover without much information loss. Mobile devices are then a complement to the work being done. This contrast between the two applications can be easily observed in Table 1.

The dramatic production application requires "coordinated" rather than "collaborative" work. Interaction among users is small and PDAs are used mostly for capturing and transmitting snapshots.

## 5. Conclusions

Collaborative activities usually involve people playing different roles, interacting at different times and at various physical scenarios. The design of a groupware application so general that can be used by any people, at any time and scenario, is almost impossible to be built. We recommend dividing the collaboration process in phases or activities according to the collaboration scenarios to be supported. These activities are equivalent to the "use cases" in Software Engineering development processes. Every scenario should be characterized by its context, and the solutions proposed to support collaboration in each scenario should consider such characteristics and restrictions.

PDAs, SmartPhones and TabletPCs are some of the appealing devices to support collaboration in mobile scenarios. The cost and functionalities of those devices make them an exciting option. However developing software applications to support collaboration using these mobile devices could represent a major challenge if the software architects do not know the main issues to be considered when designing the collaborative solution. For that reason this paper proposes a framework of context elements that should be considered when designing collaborative applications for mobile scenarios. The framework is based on the authors' experience as developers of this type of applications. As a way to evaluate the framework, three complex tools developed for mobile scenarios were analyzed and discussed.

In addition, it is possible to use the framework as a diagnosis instrument when we are analyzing technological devices to support various parts of the collaborations process. Every early good decision can help developers to reduce the development effort and increase the impact the solution has over the collaborative process.

| Context Element | Relevance (Design Concern) | | |
|---|---|---|---|
| | Case 1: Text Co-Authoring | Case 2: Dramatic Production | Case 3: Disaster Relief |
| **Physical context** | | | |
| Space | | | |
| Physical Conditions | | | |
| Safety | | | |
| Privacy | | | |
| **Social Context** | | | |
| Organizational structure (rigid/flexible) | | | |
| Demographics (are they significant?) | | | |
| Readiness to use TIs | | | |
| Politics for system implementation | | | |
| Previous formal context | | | |
| **Computational** | | | |
| Power Supply | | | |
| Compatibility | | | |
| Off-Line Support | | | |
| Communication Bandwidth | | | |
| Information Privacy | | | |
| Deployment Capability | | | |
| Transportability | | | |
| Security | | | |
| Network Availability | | | |
| Memory Requirement | | | |
| **Interaction** | | | |
| Visualization | | | |
| Data Input | | | |
| Multimedia Capabilities | | | |
| Usability | | | |
| Multitasking | | | |
| **Group Technology Support** | | | |
| **Collaboration Work** | | | |
| Activities (complexity/number?) | | | |
| Mobile/coupled | | | |
| Mobile/uncoupled | | | |
| Located/coupled | | | |
| Located/uncoupled | | | |
| Coordination | | | |
| Communication | | | |
| Negotiation | | | |
| User Location | | | |


**Table 1.** Level of impact for each context element in each application

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