USABILITY EVALUATION OF QUERYLENS: IMPLICATIONS FOR CONTEXT-AWARE INFORMATION SHARING USING RFID

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Abstract
RFID Technology allows us to easily capture and access information anywhere at anytime. However, RFID-based information sharing systems will likely fail if they cannot provide the “right” information in the “right” way. This paper describes design and usability evaluations of QueryLens, a system that accumulates queries and answers in relation to RFID-tagged physical objects and discusses the implications of our in-depth usability analysis for RFID-based context-aware information sharing in general.

Key Words
Context awareness, ubiquitous computing, information sharing, RFID, usability evaluation

1.  Introduction

Our everyday environment is increasingly being populated with various ubiquitous computing devices. For example, RFID technology is already being put into applications in the retail arena. RFID tags are also used to track down shipments and improve supply chain operations. The cost of RFID tags for item-level tagging is gradually dropping and, in some cases, already economically feasible to use high-priced sales items such as pharmaceutical products, electronic appliances, jewellery, and designer clothes and shoes.

Item-level tagging creates opportunities to design applications for so-called “Internet of things,” where, in its ultimate form, everything in the physical world is connected to digital information spaces. One can envision a “smart shopping” application for a retail store where RFID tags are embedded in all sales items. Consumers could use mobile devices with integrated RFID readers to access all kinds of information that may improve their shopping experiences as well as contribute information (e.g., customer can review and answer other customers’ questions). Information sharing that is contextualized by identification markers such as RFID tags and barcodes is referred to as ID-based information sharing.

Despite these advantages, ID-based context-aware information sharing systems have made a small impact in most fields. For the most part, this lack of acceptance can be explained by two factors. First, there has been a general lack of understanding or attention to issues of designing ID-based information sharing environments. It is not a trivial task to develop an ID-based information sharing system that can provide the “right” information in the “right” way, thereby, truly support users’ activities with no distraction. Second, little attention has bee paid to evaluate the overall quality of the systems, while identifying usability problems that may be experienced in a real context. As with other ubiquitous computing systems, context-aware information sharing systems pose challenges for usability evaluations. These systems provide diverse users with continuously ongoing access to information resources at many different locations. However, such a continuously ongoing interaction between the user and system has not been addressed by traditional usability studies [1]. In addition, there is a lack of empirical evidence on the usability and performance of ID-based context-aware information sharing systems.

Thus, this study was conducted to systematically evaluate the overall quality of an ID-based context-aware information sharing system. QueryLens [2], in order to obtain usability and performance data, and to develop design guidelines for the development of ID-based context-aware information sharing systems using RFID. QueryLens is a RFID-based context-aware information sharing system that accumulates queries and answers in relation to RFID-tagged physical objects. User and system requirements that should be considered in designing and evaluating the systems will also be specified.

2.  ID-Based Information Sharing System

In this section, properties of the ID-based information sharing systems will be overviewed as an effort to specify user and system requirements for the development of ID-based context-aware information sharing systems.
2.1 Related Work

Context-awareness [3, 4, 5] and personalization technologies [6] are keys to the next steps for many ubiquitous computing applications such as location-based [7, 8] and ID-based [9, 10] information services.

ID-based information access has been studied in the WebStickers system [11] and in the CoolTown project [12]. In these efforts, Web pages are associated with physical entities by using sensors and computing devices. For example, the CoolTown project proposes the notion of Web presence, which is the representation of people, places, and things on the Web. The infrastructure for Web presence includes the mechanism in which a handheld device recognizes an ID of a physical entity, obtains a corresponding URL via a resolver, and displays the URL, which allows for ID-based information access. However, the approach of the QueryLens system to an ID-based information environment maintains that information contributions are also equally important as information access, while addressing some of the challenges of “ubiquitous contributions” by exploiting user profiles and shared persistent queries.

Technologies for assisting shoppers are explored in research and “real” business settings using computer-equipped shopping carts [13], PDAs [14, 8, 15] and mobile phones [16]. Few of these technologies have not been rigorously evaluated. One exception is the work by Newcomb et al. [14] in which people’s grocery shopping habits were analyzed and a prototype application was qualitatively evaluated. However, their work focused only on features such as shopping lists and store maps without exploring the potential of ID-based information sharing.

2.2 Requirements Specification for ID-Based Information Sharing System

Based on extensive research of existing commercial and research systems, informal interviews with several potential users, and small field research at a few retail stores we identified the following three issues that should be considered in designing ID-based information sharing environments. Here we discuss the issues in the light of existing related conceptual frameworks.

Universal Usability and Personalization: Many of the existing and envisioned ID-based information services, such as food traceability information services and “Store of the Future” [13], need to be designed for a diverse user population. Ideally, ID-based information sharing systems should be usable regardless of age, gender, experience, physical and cognitive abilities, etc. When considering diverse user populations and use settings, it is also desirable that systems support various types of media and interaction modalities in order to support the “right” people in the “right” way.

Personalization is also a useful approach to building systems that are usable by a wide range of users. If ID-based information sharing systems exploit user profiles to adapt their user interfaces and contents, selection and application of user profiles should be quick and easy. In addition, personalization technologies generally need to be designed for shared understanding. This imposes a unique challenge in design as well.

“Invisible” User Interface: In general, ID-based information sharing environments require users to present identification markers such as RFID tags or barcodes to the system. Then, relevant information can be accessed or contributed using graphical user interfaces or other user interface technologies. One of the goals in supporting these basic tasks is to help users accomplish their important activities without distractions from unexpected system behaviours that interfere with their “primary” activities. This suggests the need for systems that reliably recognize identification markers and retrieve pertinent information quickly and easily. Also desirable is a usable and useful data entry mechanism. User interface metaphors can be useful for better anticipating users’ expectations on system behaviours. If such a metaphor is exploited, all system mechanisms should consistently support it.

Support for Social Interactions: Success of information sharing systems largely depends on the value of the content the system provides. This suggests the need for user interfaces that support social interactions, thereby, facilitate and encourage contributions from end-users. Mechanisms for supporting users’ social interactions also play an important role in facilitating the evolution of shared content.

3. The QueryLens System

QueryLens is an ID-based information sharing environment that allows users to share and accumulate queries and answers in relation to RFID-tagged physical objects [see 8 for more details]. It uses a metaphor of a lens through which users can view and manipulate information that is associated with a physical object.

The QueryLens system (Figure 1) was implemented by using a Palm OS® PDA, an RFID reader (Inside Technologies HandIT) and a barcode reader (Symbol® CSM 150).

Figure 1: Using the QueryLens system
A mobile database system is used to manage the information space. A database server (Sybase® Adaptive Server Anywhere) running on a PC and mobile databases (Sybase® UltraLite) running on PDAs synchronize with each other through a wired or wireless connection. A bi-directional synchronization mechanism is realized by using a database synchronization tool (Sybase® MobiLink). The RFID tags (Inside Technologies PicoTag™) operate at 13.56MHz and their communication range is about several centimeters.

Figure 2 shows a user interface for interacting with queries and answers. A user can browse queries by using a page-turn gesture on the touch screen, and obtain answers of a query by pressing the 'ASK’ button.

Figure 2: Graphical user interface of QueryLens

The same gesture can be used to browse answers. In addition, queries and answers can be displayed in a list view. The ‘NEW’ button on each screen brings up a window to enter a new query (or a new answer), while the ‘EDIT’ button allows users to modify the current query (or answer) and store it as a new query (or a new answer). The existence of ‘Q’ mark at the top of the screen (Figure 2a) indicates that there is an SQL query associated with this query. Selecting the ‘Q’ mark brings up a window to view, modify, and execute the SQL query. The information generated by the query execution is added as an answer to this query. The existence of the ‘i’ mark at the top of the screen (Figure 2b) indicates that there is some additional information related to this answer. Selecting the ‘i’ mark brings up a window with a list of URLs, multimedia files, etc. When users want to simply view and attach annotations to a physical object, they can switch the software to the “info mode” in which users can use QueryLens as a sort of a digital version of PostIt® Notes. The information space of the “info mode” is a subset of the information space of the regular “Q&A mode.”

When a query is contributed, its answers may not exist in the information space yet. The QueryLens system collects answers using the following three methods:

1. **Making queries accessible to other users**: The query is displayed when other users scan the same physical object.

2. **Active querying**: A user can specify recipients (individuals or groups) of her query using a pop-up selection list. When the recipients scan the corresponding physical object, the query is brought up in a pop-up window asking for an answer. In addition, users can subscribe to a physical object (Subscribing a physical object sends users the relevant queries by email.).

3. **Searching existing information resources**: The system can associate SQL database queries with corresponding natural language queries and use them to automatically fetch answers from existing databases. For example, using this feature, a query about a book’s publication date can be retrieved from an existing bibliographic database.

4. Usability Evaluation

A lab-based user experiment was designed to systematically evaluate the overall quality of the ID-based information sharing system, QueryLens, in order to obtain usability and performance data, and to develop design guidelines for the development of ID-based context-aware information sharing systems using RFID.

In particular, this study employed two groups of participants (the younger vs. the elderly) to assess the requirements for ID-based information sharing systems mentioned in the section 2.2 (i.e., universal usability and personalization, invisible user interface, and support for social interactions). That is, the QueryLens system was tested whether it effectively supported social interactions of diverse user groups without distraction. Thus, it was hypothesized in the study that the QueryLens system would be usable for both age groups, showing no significant differences in task performance, user satisfaction, and perceived workload.

4.1 Method

4.1.1 Participants

Twenty participants who volunteered to be in the study were compensated for their time. Students at the University of Arkansas and individuals from the general community participated in the study. In the younger age group there were four females and six males whose mean age was 21.20 (SD = 0.92). The older age group consisted of 10 participants (six females and four males), whose mean age was 57.30 (SD = 3.27).

4.1.2 Materials and Equipment

**Task Scenario**: To evaluate the main functions of the system, we developed eight task scenarios representing user’s most common tasks on the QueryLens system. Table 1 is a summary of task scenarios and their main testing objectives.
Participants were asked to perform these task scenarios with the QueryLens system. One example of the task scenarios (Find Related Information) is as follows:

In this scenario, you will browse the information about a product and find additional information you are looking for. You are planning on buying the Pink Floyd CD “Wish You Were Here.” You want to know more about the CD before you made the purchase. Look and see what the most popular song on the album is. Please find additional information associated with the most popular song on the album.

**Questionnaire:** A Likert-type rating scale was used to rate users’ satisfaction. The questionnaire contains six items measuring task completion, predictability of system behavior, usefulness, awareness of system capability, simplicity/ease of use, information match (Figure 3). All items were rated on a 6-point scale. The questionnaire also included open-ended questions to obtain users’ preferences and recommendations.

Indicate how easy it was to complete this task

1  2  3  4  5  6
Very Difficult  Very Easy

Figure 3. An example of the rating scale used to obtain users’ satisfaction (simplicity/ease of use)

The NASA Task Load Index (TLX) was also used to measure the workload that participants experienced. The NASA TLX contains six subscales measuring mental demands, physical demands, temporal demands, own performance, effort, and frustration. All items were rated on a 10-point scale.

<table>
<thead>
<tr>
<th>Task Scenario</th>
<th>Testing Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Find an Answer</td>
<td>To assess if browsing information about a product and finding the answer is looking for is clear</td>
</tr>
<tr>
<td>Create a New Question</td>
<td>To verify that creating a new question about the product is clear</td>
</tr>
<tr>
<td>Answer to a Question</td>
<td>To test if answering a question that has been previously asked by someone about the product is clear</td>
</tr>
<tr>
<td>Find Related Information</td>
<td>To assess if the way to find additional information the users are looking for is clear and usable</td>
</tr>
<tr>
<td>Modify Related Information</td>
<td>To verify that changing current information about the product is clear</td>
</tr>
<tr>
<td>Create New Related Information</td>
<td>To test if adding new related information about a product is clear</td>
</tr>
<tr>
<td>Enter New Information</td>
<td>To assess that entering new information about a product is clear</td>
</tr>
<tr>
<td>Modify Information</td>
<td>To verify that changing some of the information about a product is clear</td>
</tr>
</tbody>
</table>

4.1.3 Procedure

At the beginning of the experiment, participants were informed of their rights as participants and asked to read and sign Informed consent form. They then provided demographic information. Participants also performed a short training exercise designed to familiarize them with the QueryLens system.

Participants performed eight task scenarios representing user’s key tasks on the QueryLens system. These tasks were presented to the participants in a random order. Participants were asked to hold the QueryLens within 5cm of a product, scan the item, and press one of the hardware buttons in the middle to complete the scan. Information and queries related to the product will then be shown on the screen (see Figure 1). After performing each task, participants were asked to complete a questionnaire designed to identify their satisfaction with the use of the system as well as a NASA Task Load Index (TLX) questionnaire that measures participants’ overall workload. At the end of the experiment, participants completed a demographic questionnaire and were debriefed.

4.2 Results

Both quantitative (e.g., percent of tasks completed, task time, user satisfaction, and perceived workload) and qualitative (e.g., critical incidents, usage problems, and user comments) data were obtained from the user experiment. A series of independent-samples t tests were conducted to determine differences between the two age groups on task performance and user satisfaction. An analysis of variance was conducted to investigate users’ perceived workload.

4.2.1. Percent of Tasks Completed and Task Time

The percent of tasks completed was computed as the ratio of completed tasks to total tasks. This measurement reflects the overall task performance. Results showed that participants completed most of the tasks successfully (100% for younger group; 97.5% for older group).

As expected, older participants ($M = 163.90$ seconds, $SD = 34.5$) spent a longer time completing tasks than younger participants ($M = 103.33$ seconds, $SD = 16.68$), $t(18) = 5.0$, $P < .0001$.

4.2.2 User Satisfaction

The reliability of the rating scale was first assessed by calculating Cronbach’s coefficient alpha [17]. The standardized alpha of rating scales showed acceptable reliability ($\alpha = .77$), with coefficient greater than the suggested value of .70 [18].
Task completion: Response to “Indicate how easy it was to complete this task.” The mean ratings of task completion were higher in younger participants (M = 5.24, SD = 0.48) than in older participants (M = 4.75, SD = 1.02). However, there was no significant difference in mean ratings between the two age groups for task completion, t(18) = 1.36, P = .1891.

Predictability of system behavior: Younger participants (M = 5.16, SD = 0.54) were given higher mean ratings compared to older participants (M = 4.78, SD = 0.73). However, no significant difference was found between the two age groups for predictability of system behavior, t(18) = 1.35, P = .1943.

Usefulness: The mean ratings of usefulness were higher in younger participants (M = 4.79, SD = 0.78) than in older participants (M = 4.64, SD = 0.86). However, there was no significant difference in mean ratings between the two age groups for usefulness, t(18) = 0.41, P = .6867.

Awareness of system capability: Younger participants (M = 5.01, SD = 0.56) were given higher mean ratings compared to older participants (M = 4.78, SD = 0.61). However, no significant difference was found between the two age groups for awareness of system capability, t(18) = 0.91, P = .3773.

Simplicity/ease of use: The mean ratings of simplicity/ease of use were higher in younger participants (M = 5.33, SD = 0.58) than in older participants (M = 4.65, SD = 0.84). However, there was no significant difference in mean ratings between the two age groups, t(18) = 2.10, P = .0502.

Information match: Younger participants (M = 4.63, SD = 0.61) were given higher mean ratings for information match compared to older participants (M = 4.84, SD = 4.63). However, no significant difference was found between the two age groups for information match, t(18) = 0.84, P = .4093.

4.2.3 Perceived Workload

The overall workload ratings on the NASA TLX subjective workload index were very low (M = 3.0, SD = 0.8). An analysis of variance was also carried out with age group (young versus old) as between-subjects variable, and task scenario (eight different tasks) as within-subjects variables. First, the main effect of age group was not significant, F1,18 = 1.18, p > .2922. Mean workload was not significantly higher in older participants (M = 3.11, SD = 0.98) than in younger participants (M = 2.81, SD = 0.37). Workload was rated differently with respect to the task scenarios, F7,128 = 5.29, p < .0001. Workload was rated the lowest for the task 4 (M = 2.63, SD = 0.88) - Find Related Information, and the highest for the task 6 (M = 3.26, SD = 0.78) – Create New Related Information. No interaction effect was found.

5. Discussion and Conclusions

The primary purpose of the study was to systematically evaluate the overall quality of an ID-based information sharing system, QueryLens, in order to obtain usability and performance data, and to develop design guidelines for the development of ID-based context-aware information sharing systems using RFID.

The results of the study showed that the QueryLens system effectively supported social interactions for diverse user groups without distraction. That is, the QueryLens system was usable for both age groups, showing no significant differences in task performance, user satisfaction, and perceived workload. There are several implications for ID-based information sharing design, which will be discussed in relation to requirements specification for ID-based information sharing system described in Section 2.2.

Universal Usability and Personalization: ID-based information sharing systems should be usable regardless of age, gender, experiences, physical and cognitive abilities, etc. This study showed that the QueryLens system could effectively support social interactions for the two different age groups without distraction. When considering diverse user populations and use settings, ID-based information sharing systems should also support various types of media and interaction modalities in order to support the “right” people in the “right” way.

"Invisible" User Interface: Eliminating distractions requires more than just avoiding system breakdowns; it also requires the realization of what Weiser and Brown [19] called Calm Technology, which provides the “right” information in the “right” way by engaging both the center and the periphery of our attention, and moving back and forth between the two. This has many implications on the design of mobile user interfaces as well as off-the-desktop interaction methods involved in the uses of ID-based information sharing systems. For example, some types of information can be “pushed” to users while other types of information made available to be “pulled” by users. Some can be presented as an alarm sound or an icon on the screen, while others can be presented as text, audio, or video with brief summaries or full detail. Also, systems may need to provide users with opportunities to contribute information they want.

Support for Social Interactions: There are certain unique aspects that need to be considered in designing ID-based information sharing systems. First, design and management of IDs affect how users are connected, as well as how relevant information is accessed and contributed. For example, if one has two CDs that have the same barcode number, they are
equivalent but not identical; they contain the same songs recorded by the same artist and marketed by the same record company. However, they are two different physical entities. RFID typically uses 64–256 bit IDs that are long enough for distinguishing equivalent, but non-identical items. Users may or may not expect that all equivalent CDs bring up the same information.

Second, using mobile devices, users may communicate in a succinct manner depending largely on context. In such cases, difficulty arises in communication when users do not share necessary context. For example, if a person on a train receives a question such as “where was this picture taken?” from a consumer in a music CD store, the query may not make sense without contextual information (e.g., the picture, the title of the CD, etc.). There are cases that it is too restrictive to limit information access to people who share the same context (e.g., customers who come to the music CD store).

In this study age group was only considered to evaluate the overall quality of an ID-based information sharing system. Further research should include other individual differences such as gender, experiences, physical and cognitive abilities in order to investigate how effectively the system can support such diverse user groups. Finally, it should be mentioned that privacy around item-level tagging is an important area of research that is complementary to this stream of our work [20].

References:


