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RFID Context-aware Systems

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Korea

1. Introduction

For several decades, RFID technology has been advancing and widening its application fields by penetrating into the traditional industries with the benefits of efficiency, costs saving, and fast processing. As the result, nowadays it is widely used in logistics, inventory, security, supply-chain, manufacturing, and retail industries. For example, Wal-Mart required its top 100 suppliers to attach RFID tags to their goods [1], and logistics and manufacturing companies including Siemens have been adopting RFID rapidly [2]. Experts expect that it will widen faster its application fields thanks to low tag cost, advance in network technology, and various trials of combining ICT (information and communication technologies). With ICT, RFID systems are providing users with smarter services such as world-wide object identification, and world-wide monitoring and tracking objects.

In the ubiquitous computing, context-awareness is one of the hottest issues in the academia and the industries. The basic idea of context-awareness is that the systems are able to recognize not only environmental condition and events but also internal system status, and provide users with smart services that fit on users’ intention and their current situation. We call these external and internal conditions and events as context. Therefore, context-aware systems usually have sensing sub-systems that recognize the environmental condition and events and a smart module that determines the current context and the services according to the context. For sensing sub-system, they adopt camera, temperature sensor, GPS, motion sensor, and other sensors. As you might expect, RFID’s identification facility is also an important source of sensing the external condition and events. In fact, there have been a myriad of works that apply RFID to context-aware systems. Some read user data from tag to provide smart services according to user’s role [3], and another identify user location by reading tags attached to fixed objects to provide services related to the location [4,5]. Still another recognizes user’s intention by reading object identifiers and provide services about the objects [6]. These RFID-based context-aware systems are very diverse and the number of these systems is increasing.

Though RFID has been gaining interests in context-aware systems, little attention has been paid to studies on survey of existing systems or studies on context-awareness in RFID systems in detail. These studies are needed to help system stakeholders understand RFID-based context-aware systems. Therefore, we survey the existing systems and introduce our RFID context-aware system in detail. We have two purposes for this article. The first one is to survey and classify existing RFID context-aware systems. By surveying the existing applications, we identify what kinds of context are used, what kind of context-aware services they provide. We group these applications into five categories according to the data
type of tag value: user identifier, location, object, neighborhood, and behavior. We also group context-aware services into five categories: branch, trigger, resource scanning, follow-me, and context recording. The classification of tag value types and context-aware services can help stakeholders to understand the RFID-based context-aware systems. Specially, these are helpful to analysts and designer with understanding and modeling context and services. After survey, we define some concepts on context-awareness including context attribute, context, and other concepts in measurable terms, and we also introduce some designing issues on context-aware system.

The second purpose is to show how we apply RFID to our museum exhibition guide system, named MyGuide. This system is able to provide user specific information on the exhibit to users. For example, when a user does not have knowledge about the exhibit and he/she speaks Korean, it explains the exhibit with plain Korean. It can also provide multimedia data to help the user to understand the exhibit when he/she has a multimedia-enabled device. For this context-aware service, it adopts four context information: location, background knowledge level, device facility, and language. RFID is used to locate users in the museum, and the system gets other information from user registration on the web. After considering context modeling issues such as context extensibility, inference, simplicity, and implementation, we draw two contexts - TEXT and MULTIMEDIA - from four context attributes. For software architecture, we adopt ECAM (event-context-action-model) architecture. The architecture is suitable for RFID context-aware systems, because it supports event-drivenness and context-awareness. MyGuide prototype system is implemented in Win32 platform with Java language, 13.56 MHz RFID readers, card type tags, Oracle DBMS, and Apple’s Darwin Streaming Server. MyGuide shows how to model context from multiple context information including RFID and how to provide user-specific contents according to the context.

This article consists of five sections. In Section 2, we describe about RFID system: its elements and various existing systems. After this, we define some concepts on context-awareness such as context attribute and context and explain context-aware features in RFID systems in Section 3. In Section 4, we introduce our RFID system, MyGuide, which provides exhibition guide according to user’s location and other user’s information and preference. Finally, we reveal our conclusions in Section 5.

2. RFID system overview

2.1 RFID system elements

RFID is an identifying technology that uses wireless radio frequency, and it is widely used in various fields because of its merits: efficiency, costs saving, fast recognition, multiple recognition, and long recognition distance. In general, an RFID system is basically made up of three elements as shown in table 1: readers, tags, and servers. Table 1 shows the three elements and their classification.

Tags keep a small amount of data such as identifier in their internal memory, and they are classified according to their memory types: read-only and read-write. Most of tags have mobility because they can be carried with users; however, some others are immovable because they are attached to fixed objects. Mobile tags have close relationship with users because they move with users, but immovable tags are related with fixed objects or locations.
### Table 1. RFID Elements Classification

<table>
<thead>
<tr>
<th>Elements</th>
<th>Criteria</th>
<th>Classification</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tag</td>
<td>Power Source</td>
<td>Active</td>
<td>Long recognition distance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Passive</td>
<td>Short recognition distance</td>
</tr>
<tr>
<td></td>
<td>Memory</td>
<td>Read Only</td>
<td>Unchangeable value (ex. Identifier)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Read/Write</td>
<td>Changeable value (ex. State, money)</td>
</tr>
<tr>
<td>Reader</td>
<td>Mobility</td>
<td>Stationary</td>
<td>Attached to fixed location</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mobile mRFID</td>
<td>Connected to wireless network, PDA type</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mobile</td>
<td>Connected to CDMA or GSM, Cell phone type</td>
</tr>
<tr>
<td>Server</td>
<td>Service</td>
<td>Primary</td>
<td>Primary server for the services</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Secondary</td>
<td>Auxiliary server</td>
</tr>
</tbody>
</table>

RFID readers read data from tags and pass the data to the primary server. They can be classified into two groups: mRFID [8,9] and stationary RFID according to whether they are connected to a mobile communication network including CDMA and GSM. The former is connected to mobile communication networks, and the later is connected to wire-networks. The mobile RFID has two advantages: mobility and connectivity with the network. It is mobile because it is attached to a user’s hand-held device such as a PDA or mobile phone. It is connected to the network anytime and anywhere because it uses CDMA or GSM network. Therefore, users can use it any places.

There are two kinds of servers: primary server and secondary server. The primary server is the server that receives the data passed from readers and processes it according to its business logic to meet users’ requests. In stationary RFID systems, computer systems usually play the role of the primary server. However, in mobile RFID systems, hand-held devices usually play the role of the primary server. The secondary server is the server that helps the primary server by processing requests from it. ONS (Object Naming Server) in EPC (Electronic Product Code) systems [10] is one example of a secondary server. As RFID systems are getting complicated, the importance of the secondary servers increases. In addition, a variety of secondary servers come out. In mobile RFID systems, a service broker [8] is also an example of the secondary servers.

Typical RFID systems are connected to each of three elements shown in Fig. 1. In the figure, $T_1$ and $T_2$ mean RFID tags, and $R$ represents RFID readers: fixed reader or mobile reader. $P$ is a primary server and $S$ is secondary servers for the system services.

![Fig. 1. RFID System Model](www.intechopen.com)
As illustrated in Fig. 1, tags have mobility in stationary RFID systems; however, readers have mobility in mobile RFID systems. In both cases, readers can access the tag data within the distance $d_1$. When readers recognize the tag data $i_1$, they transmit the data to the primary server $P$ over the network. Then primary server $P$ configures the services, and if it needs support from the secondary servers $S_1$ and $S_2$, it transmits the requests to them. Finally, the primary server $P$ processes the data and provides the services to the users. In some cases, tags are writable, and readers may write data $i_2$ into tags. Furthermore, some applications, such as smart box [7], use several tags at the same time, and they should stay within a constant distance $d_2$.

### 2.2 Various RFID systems

We survey the existing RFID systems, and identify various types of them. During the survey, we find out that most of tags keep identifier values, but the meaning of them are all different. Therefore, we classify the tag values into five groups according to their meaning or types: user, object, location, neighborhood, and behavior. Table 2 shows the five types of tag values, their meaning, and their usage patterns in the RFID systems.

<table>
<thead>
<tr>
<th>Tag value</th>
<th>Meaning</th>
<th>Usages Patterns</th>
</tr>
</thead>
<tbody>
<tr>
<td>User</td>
<td>A person who owns the tag</td>
<td>User’s ID, role, preference, etc</td>
</tr>
<tr>
<td>Object</td>
<td>An object that a tag is attached</td>
<td>Object ID, object $=$ action[28], monitoring</td>
</tr>
<tr>
<td>Location</td>
<td>The location where a tag or a reader is</td>
<td>Location based services, Follow-me, etc</td>
</tr>
<tr>
<td>Neighborhood</td>
<td>The relationship among the objects to which tags are attached</td>
<td>Cooperation among objects, Relationship among objects, monitoring, etc</td>
</tr>
<tr>
<td>Behavior</td>
<td>User’s behavior or intention</td>
<td>Monitoring</td>
</tr>
</tbody>
</table>

Table 2. Tag values in RFID Systems

#### 2.2.1 User

One of the most popular areas of RFID applications is identifying users. These systems identify users for their own purposes; access control, security, payment, and managing people. With these systems, users keep their own tags and there are stationary readers at some location such as gates, doors, or other places. The systems identify users by reading the values stored in the tags and matching them to their databases. Fig. 2 shows a user identifying system. By approaching the user’s tag to the reader, the reader scan the value in the tag and the system determine who the user is or whether to allow him/her to access to the cetificate data or places.

User information in the tag can be combined with other data in the server system and provide more sophisticated services. RFID applications considering user’s preference or tastes usually use this information plus his/her preference information together for determining user specific services. Another example is the role-based services, in which user information is used to determine the role of the system. This kind of applications are closely related to the security, authorization, and authentication. However, other areas can also
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... apply this role based service to their services. For example, Bravo [3] adopted two types of roles - student and teacher - in his application. If a teacher approaches, the system shows the lecture notes. However, if a student approaches, it shows his/her homework.

Fig. 2. User Identification

2.2.2 Object
A RFID tag may contain information - usually identifier - about an object which it is attached to. By reading the information, RFID applications can identify objects, get information about the objects, and keep track of them. These applications are used for logistics, inventory, and retail. In logistics, applications classify and deliver goods using RFID tags attached to them, and monitor to keep track of the goods while delivery. In inventory, they use tags to check which goods are stocked in and which items are out of stocks. In retail, companies can figure out which goods are sold. Retail industries enjoy the benefits of fast processing and preventing shoplifting.

Object identifiers in tags are the gateway which connects the physical world and the virtual world. Users can get information about the object and control the object from the virtual world. The EPC(Electronic Product Code) is the standardized object code developed by EPCglobal [10]. Using EPC, RFID applications send requests to EPCIS(EPC Information Service) which manages the information about objects and provides the services for the inquiries. ONS(Object Name Service) provide the location of data about the object which is indentified by the object identifier. EPC Discovery Service is the search service for the data location for the objects.

We find that some interesting researches which treat the object as the users’ intention. It means that reading object identifier triggers an action which is closely related to the object with users’ intention. For example, during shopping a shopper lifts an item, it means that he/she has interests on the item. Therefore, the shopping assistant application may show information about the item or suggest another items that match the picked item. Fig. 3 shows the Smart Shopping Assistant system researched by Michael Schneider [11].

Another example is Trevor Pering [6]’s Elope system. The system identifies objects and provides a services which are related to the purpose of the objects. For example, users scan the tag on the remote controller for presentation, and the system allows users to use presentation. Fig. 4 shows the architecture of Elope system. These RFID systems consider objects as the user intention, and this view changes the user interface in the computing environment from WIMP(Windows, Icons, Menu, and Pointing device) to object = action paradigm. Ailisto [12] argues that object=action paradigm can...
change user interface paradigm of desktop computer by touching objects with mobile RFID readers. The typical example is the business card with RFID tag [13]. When a user touches the card with his/her cell phone equipped with RFID reader, the phone calls the person automatically.

2.2.3 Location
In context-aware systems, location is very important context information. Location based services (known as LBS) are good examples of context-aware services using location as context information. Searching for nearest restaurant from the user’s location and weather service according to users’ location are typical examples of LBS. There are two types for location system: one for absolute location with latitude and longitude and the other for symbolic location with relative location to the base location. There are several technologies for determining location including GPS, RF signal length, triangulation, and RFID. RFID is good for determining indoor location because it is easy to implement. Lionel’s [14] does researches on determining a user’s location and movement in the building. Lionel uses active tags and determines a user’s location by calculating users’ location with reference tags and a tracking tag.
• (F1): register user information. This information is used to determine user-customized
guide information.
• (F2): provide a user with information about the exhibition next to the user in user-
customized format and with user-customized contents considering user’s background
knowledge of the exhibition.

Besides the two basic functional requirements, there are at least six non-functional
requirements as follows. Most of these requirements are related to the usability issues, but
we exclude performance, throughput, and security requirements because we intend to focus
into RFID and context-awareness in our system.
• (R1) Customized Services: Existing guide systems provide the same services to all
visitors without considering the visitors’ background knowledge or age. This can feel
unsatisfactory to the visitors. Children and beginners don’t understand the explanation
with jargon, and experts are not satisfactory with an explanation that contains only
general information. Therefore, our system considers the visitors’ background and
provides appropriate information according to their profiles.
• (R2) Easy Use: The end-system or terminal should be easy to use, and the visitors
should feel comfortable using the technology.
• (R3) Personal Usage: The visitor should be able to get and control the services at any
time when he/she wants in the museum.
• (R4) Multimedia Services: Our system should be able to deliver multimedia data to the
visitors. Multimedia content is very effective to explain information to a visitor whether
he/she is a child or an adult, or a beginner or an expert. On the other hand, if the terminal
does not support multimedia service, it should be able to provide text data at least.
• (R5) Less Cost: Our system should be implemented with the least costs and efforts
because of limited budgets. Therefore, we prefer to use the existing technologies
without developing new technologies.
• (R6) Multiple Languages: One of the interesting requirements from stakeholders is for
the system to support multiple languages as the number of visitors from other countries
increases. Therefore, our system should support guide contents in multiple languages.

In order to meet the basic requirements, we have to determine our fundamental platform
and technologies. Since there are several alternative platforms and technologies, we have to
evaluate them and choose one of them. Table 4 shows the alternative technologies and the
evaluation result.

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Technologies</th>
<th>Location</th>
<th>Mobile Device</th>
<th>Messaging Protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RFID</td>
<td>mRFID</td>
<td>Triangulation</td>
<td>Cell Phone</td>
</tr>
<tr>
<td>F2</td>
<td>●</td>
<td>●</td>
<td>○</td>
<td>●</td>
</tr>
<tr>
<td>R1</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>○</td>
</tr>
<tr>
<td>R2</td>
<td>●</td>
<td>●</td>
<td>○</td>
<td>●</td>
</tr>
<tr>
<td>R3</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>R4</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>●</td>
</tr>
<tr>
<td>R5</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>●</td>
</tr>
<tr>
<td>R6</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>●</td>
</tr>
</tbody>
</table>

Table 4. Evaluation of Possible Technologies
After the evaluation, we choose three basic technologies: RFID, mobile phone, and context-awareness. There are several reasons why we choose these technologies as follows:

- **RFID**: An RF tag is small enough to carry with the visitor and it is natural and easy to use. It is a stable technology because it has been used in various fields for a long time. Furthermore, there are ample system components and software modules for RFID systems, so we can reduce costs and efforts by using the existing components instead of developing them from the scratch.

- **Cell Phone**: In order to support mobility, we need mobile devices including PDA, cell phone, and other dedicated mobile terminals. From several kinds of devices, we choose mobile phone based on the following merits. First, most of the new products support multimedia display, and even older ones support at least a text message service without adding any hardware components or installing any software modules. Second, we can save cost and effort in developing end-systems for providing guide service. Third, the mobile phones are easy to carry and people tend to keep their phones with them. Fourth, they are user friendly. It is their own phone, and they use it every day. Fifth, a mobile phone is always connected to a CDMA or GSM network at any place. We don’t need to consider a situation in which the end-system is disconnected.

### 4.2 Context modeling

In the usage scenario of MyGuide, we assume two things. First, the system database has a table that maps the exhibit and the RFID reader’s identifiers. Therefore, we can get the visitor’s location when a reader reads his/her RF tag. Second, the visitor registers his/her information with an RF tag value.

There are countless environmental elements around the context-aware system. However we cannot consider every contextual element, so that we limit the number of contextual elements in our system to the information that is necessary to meet the requirements. We identify four kinds of context attributes that affects the service of our system.

- The visitor’s location
- The visitor’s background knowledge
- The facilities of the visitor’s mobile phone
- The visitor’s preferred language

For each context attribute, it has its own value set. The visitor’s location is a primary context attribute. The system can determine which exhibit draws a visitor’s attention according to his/her location. We use RF tags and RFID readers to identify the visitor’s location. When the visitor with an RF tag approaches to an exhibit, the reader attached to the exhibit identifies his/her tag value. In the perspective of guide information, the location determines the subject of data to be served.

Considering the visitor's background knowledge is the most valuable feature of our system. The more we divide the level of the background knowledge, the more the service will be satisfactory. However, we should consider development costs and the maintenance problem of contents, so that we group the background knowledge into three levels.

- **Beginning**: basic information for children and those unfamiliar with the subject
- **Normal**: general information for ordinary adults and middle/high-school students
- **Advanced**: advanced information for experts or college students

The facilities of the visitor’s mobile phone determine the media type of information. Some phones support multimedia data display, but others may have the only minimum functions...
for mobile phone. Therefore our system should consider the facilities of the visitor’s mobile phone. We therefore categorize mobile phones into two types: Text or Multimedia.

The visitor’s preferred language is also an important context attribute to be considered. As the world becomes smaller, we need to serve the visitors from other countries in museum.

We consider total three languages: Korean, English, and Chinese.

MyGuide adopts four context attributes for its services. The notable feature of them is that they are orthogonal and independent of each other. For example, the visitor’s location has nothing to do with his/her preferred language, and the subject and the language of the contents have nothing in common. The four types of context information can be represented orthogonally in the four-dimensional coordinate as shown in Fig. 15.

Fig. 15. Context Information Space of MyGuide System

According to our definition, a context may be represented as a dot in the coordinate system in Fig. 15. However, in MyGuide system, we have too many contexts. Let C be the set of all possible contexts in MyGuide system. Then a context c ∈ C can be represented as a tuple: c = <loc, level, dev, lang>, where loc ∈ Loc, level ∈ Level, dev ∈ Dev, and lang ∈ Lang. We can imagine that Loc = {x | x is an exhibit.}, Dev = {multimedia, text}, Lang = {Korean, English, Chinese}, and Level = {beginning, normal, advanced}. Then we can calculate the number of contexts in MyGuide as follows:

\[ | C | = | Loc | x | Dev | x | Lang | x | Level | \]

If we define context as the tuple of context attribute values, this system has too many contexts. Therefore, we need to categorize them according to commonality and variability. In MyGuide system, media type determines the metadata and service server, so we categorize context information according to media type. Furthermore, we choose closed context model because we will not extends our context model later. Considering these issues, we model context as shown in Fig. 16. The notation used in the figure follows our prior studies [20]. The notation is similar to class diagram. According to this notation, a context may be implemented in multiple ways, so that it is represented as an interface. Similar contexts have common features, and the common features can be generated as context type. MyGuide has two contexts: Multimedia and Text and four context attribute type: location, background knowledge level, mobile phone type, and language.

The system maps the four context attributes to one of the two contexts after the following context reduce algorithm. In the algorithm, retrieve(T, s, v) means that it retrieves data from the database meeting the condition. As you see the algorithm, you will notice that the media type determines the context.
Algorithm. Determine_context (TagId, ReaderId)

\[ v = \text{retrieve (Tag, tagID == TagId, "visitorID")} \]
\[ (pnum, mcode) = \text{retrieve (Phone, visitorID == v, "phononenumber, mcode")} \]
\[ \text{type = retrieve (MediaType, mcode == mcode, "desc")} \]

if (type == MULTIMEDIA)
    new MultimediaContext
else if (type == TEXT)
    new TextContext
end-if

4.3 Implementation of prototype system

We implemented MyGuide prototype system on the Microsoft Window platform. We chose the Java language for software implementation, and MIDP [25] for mobile phone programming. We used 13.56 MHz RFID readers and card-type RF tags. We used GNU java serial communication library [26] to connect to the RFID readers. For multimedia service, we adopted Darwin Streaming Server from Apple [27]. We managed the context information and the guide data on the exhibits in Oracle 10g DBMS. Fig. 17 shows the architecture of the prototype system and its components.

MyGuide starts services on READ event from RFID reader. The visitor’s profile and his/her mobile phone information are stored in DBMS. Fig. 18 shows the E-R diagram of the prototype system. Contents entity means the guide data for an exhibit. For an exhibit, there are several Contents records to provide visitors with suitable data. Visit entity means the trace data of a visitor’s access to the exhibits.

The class diagram of MyGuide is shown in Fig. 19. TagManager gets the values stored in the RF tag and the reader’s identifier, and generates READ event. On the event, the Controller takes the control and coordinates the cooperation between CntxtReducer and MsgSender. CntxtReducer infers the current context from the values of contextual elements. It uses DbFacade for retrieving contextual data stored in DBMS. Controller determines the contents of service using the context, and asks MsgSender to generate Msg for the service and send it to the visitor. Msg consists of the explanation of the exhibit and the metadata.
Fig. 17. Architecture of MyGuide Prototype System

Fig. 18. ER Diagram for MyGuide Prototype System
Fig. 19. Class Diagram of MyGuide Prototype System

Fig. 20 show the running examples of MyGuide prototype system. Fig. 20 (a) shows the text service at beginning level in Korean. Fig. 20 (b) shows the multimedia service at beginning level in Korean.

5. Conclusions

There have been many attempts to adapt RFID technology to context-aware applications. However, until now they have paid little attention to survey of existing systems and to analyze them. In this article, we surveyed the existing context-aware RFID systems, and identified interesting issues: the meaning of tag values, their usage patterns, and context-aware services.

We also introduced a mobile guide system for exhibitions and museums. It considers four kinds of context information: location, background knowledge, media type, and language.
Based on the context information, the system provides the most suitable services to the visitor. For example, when a Korean visitor is an expert on the exhibit, and he/she has a mobile phone that supports multimedia, the system provides the multimedia type expert information in Korean. Furthermore, we introduced some interesting issues when developing context-aware systems: system requirements, context information, context modeling, software architecture, and its prototype system. We drew system requirements from stakeholders during the informal interview. From the requirements, we chose three basic technologies for the system: RFID, mobile phone, and context-awareness. We also found out the four types of context information. Because the context data are independent each other, there are too many possible contexts. Therefore, we model context from context information and determine two kinds of contexts. We chose ECAM architecture pattern for our system because it is event-driven and it can handle multiple kinds of context information. Our prototype system is implemented with 13.56MHz RFID reader, Darwin Streaming server, and MIDP APIs.

6. References


Radio frequency identification (RFID) is a fascinating, fast developing and multidisciplinary domain with emerging technologies and applications. It is characterized by a variety of research topics, analytical methods, models, protocols, design principles and processing software. With a relatively large range of applications, RFID enjoys extensive investor confidence and is poised for growth. A number of RFID applications proposed or already used in technical and scientific fields are described in this book. Sustainable Radio Frequency Identification Solutions comprises 19 chapters written by RFID experts from all over the world. In investigating RFID solutions experts reveal some of the real-life issues and challenges in implementing RFID.

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