The Smart Box Concept for Ubiquitous Computing Environments

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Abstract

In everyday life we are often faced with the need to monitor the contents of some kind of container e.g. the contents of a medicine cabinet or a tool box. In this paper we show that this entire class of scenarios has similar features and properties. To remove the annoyance associated by the user with this monitoring task we propose a smart box concept. In this concept the monitoring is facilitated by any automatic identification technology. RFID technology proved to be a suitable means to invisibly monitor the contents of the box without requiring the user to adapt the way he interacts with the smart objects. We describe the characteristics of the smart box concept and then demonstrate the usability of the smart box concept with three applications: the smart toolbox, the smart medicine cabinet and the smart surgical kit.

1. Introduction

Mark Weiser's vision was that embedded technology would calm our lives by removing the annoyances [1]. Based on this vision we witnessed the development of smart objects such as the Media Cup [2] or the Internet fridge in recent years that addressed some of the annoyances people faced when interacting with those real-world objects in their daily life.

Most of the Ubicomp gadgets we have seen so far collect data only to infer the user's context and then based on the analysis of those data provide additional services to the user. Examples include monitoring noise levels and the number of people present to detect that a user is in a meeting. This context information is then used to switch the mobile phone into silent mode [3]. In this example the automatic data collection carried out by the mobile phone did not replace any manual intensive monitoring, since it is a trivial task for the user to detect that he is a meeting.

In this paper we describe smart object applications that show how ”everyday” annoyances associated with monitoring can be removed without changing the way the users interact with the smart objects. All applications have in common that the annoyance is caused by the need to manually monitor the contents of some kind of a ”box”. The content checking is required to take the appropriate action in case of an abnormality.

To relieve the user from the monitoring task with the help of some smart technology, the last thing the smart technology should do is to create additional irritations by changing the way we deal with those everyday objects made smart. As shown by Want [4] RFID technology represents a suitable means to bridge the physical and virtual world in an invisible or at least unobtrusive manner. The sample applications we developed to demonstrate the smart box concept use RFID technology to sense the contents of the box.

The remainder of this paper is structured as follows. Section 1 presents the properties and features of the smart box concept. The subsequent section describes sample applications which implement the smart box concept. Section 4 details the technical aspects and Section 5 draws a conclusion.

2. The smart box concept

2.1. Common properties of ”box monitoring” scenarios

In daily life we are often faced with the need to check the content of some kind of container or box. Examples include making sure that a toolbox or a first aid kit is complete or checking the contents of a medicine cabinet. All of those examples have in common that we often experience this checking task as cumbersome and annoying, since we are required to check many times more frequently than we actually detect any ”abnormalities”.

As mentioned earlier we believe that the above scenarios belong to a specific class of scenarios. The following properties characterize this class of scenarios:

- Knowing the current content of the box is essential e.g. what is inside in the box and what is not.
- The existence of a desired content configuration. This configuration is either static (e.g. defined by the type of box itself) or dynamic.
- Identifying the person that is interacting with the box is benefitial, e.g. the mechanic adding and removing tools to and from a tool box.

The box can typically be in two states: (1) in an ”optimum” state which is reached when the desired configuration is sensed and (2) in an ”adverse” state when this desired configuration is not achieved. Whenever it is in the latter state appropriate actions need to be taken by the user to remedy the situation.

2.2. Required functionality

To automate the contents checking task we propose the concept of a smart box (see Figure 1). The smart box has to provide at least the functionality offered by the ”manual” alternative:

- it needs to monitor the content of the box unobtrusively
- it needs to know about the desired configuration and ideally indicate any discrepancy

If the above core functionality is realized with some smart technology, the following additional service can be realized with little additional effort:

- providing additional information about the objects e.g. expiry dates and recall status

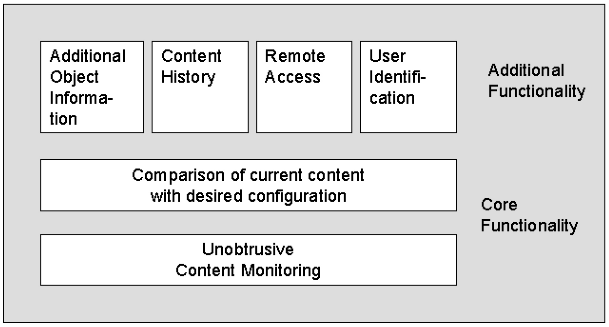

Figure 1: *Functionality associated with a smart box.*

- keeping a history of the object inside the box e.g. showing for how long a certain object has been inside the box
- making the current contents of the box available for remote access
- identifying who has been interacting with the smart box

To realize the unobtrusive monitoring a low cost automatic identification technology is essential. We decided to use RFID technology for our prototype implementations of the smart box scenarios, since RFID technology does not require any support from the user and monitors the content invisibly and reliably. Tagging the objects in the box and integrating an antenna and reader into the box allows us to realize Mark Weiser's vision of a world in which UbiComp technologies "weave themselve into the fabric of everyday life" [1].

2.3. User interface

In the most simplistic case any implementation of the smart box could just have an indicator such as a green and red LED to indicate the state of the smart box (complete or not complete). However, a screen that provides the user with more detailed information about the box is usually helpful. This screen can also be used to provide additional services based on the data collected such as history of the objects and additional product information. In the sample application shown in the subsequent section an LCD screen is used as the user interface, but other display technologies such as PDAs are of course also feasible.

One of the distinguishing features of the smart box user interface is that all interaction with the application takes place via the smart objects themselves e.g. additional information about a recalled pack of medicine is requested by adding and removing the pack of medicine from the medicine cabinet rather than by selection with the keyboard and mouse.

To support visually impaired people in particular, a voice output can also be integrated into the smart box user interface.

3. Sample smart box applications

The three sample applications described in this section illustrate the smart box concept discussed previously. When developing these applications, we have focused on identifying typical annoyances associated with content monitoring.

3.1. The Smart Toolbox

The smart toolbox is an application that was designed to support mechanics in the aircraft maintenance. It improves the verification of the content of the toolboxes.

Figure 2: *Setup of the Smart Toolbox Application.*

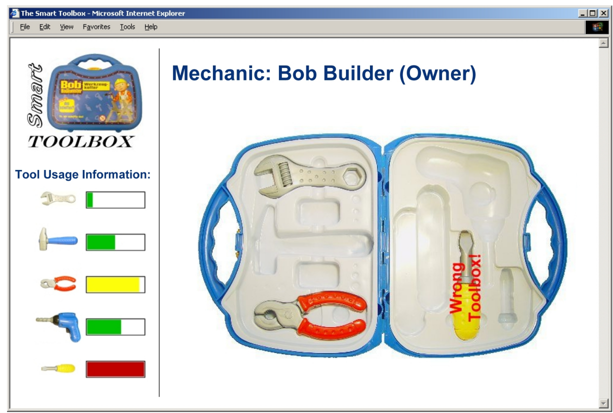

Figure 3: *Screenshot of the Smart Toolbox Application.*

The need for the smart toolbox resulted from the fact that mechanics in the aircraft maintenance have their personal toolboxes with marked tools and that they are required to check the content of their toolboxes after a finished maintenance task. Additional checks are required at the end of the day and double checks each month. These checks are important since a mechanic is personally liable for any damages that are caused by a tool he forgot in an airplane after a maintenance task.

We implemented the smart toolbox prototype (Fig. 2) to automatically monitor the content of the toolbox using RFID technology, i.e. RFID tags are attached to all tools and the boxes are equipped with RFID readers and antennas (see Section 4). The smart toolbox checks if the state corresponds with the desired configuration. The desired configuration of the toolbox is reached if two conditions are fulfilled: (a) The toolbox is complete, i.e. there are no empty spaces in the toolbox, and (b) if the content is correct, i.e. all the tools present in the toolbox actually belong to the toolbox. The state of the toolbox is visualized (Fig. 3) in two ways corresponding to the two conditions: (a) Missing tools are shown by empty spaces, and (b) tools that belong to a different toolbox are highlighted with a special indicator. The mechanic easily recognizes if a tool was forgotten in an airplane or if tools were mixed up between different mechanics. He can take the appropriate actions right after he finishes a maintenance task.

It is important to emphasize that the way the mechanic handles the tools and the toolbox does not change by introducing the smart toolbox application. The automatic monitoring happens unobtrusively relieving the mechanic of annoying check-

Figure 4: *Setup of the Smart Medicine Cabinet Application.*

Figure 5: *Setup of the Smart OP Box Application.*

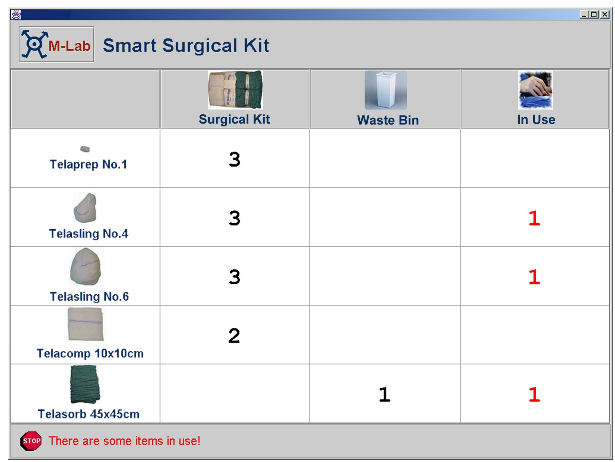

Figure 6: *Screenshot of the Smart OP Box Application.*

ing procedures.

In addition, the smart toolbox identifies the mechanic who interacts with the box by detecting the RFID badge of the mechanic. If he is not the owner of the box a warning will be displayed to help avoid mixing up of tools in advance. Another additional benefit is the usage history of the tools that is inferred by keeping the times a mechanic takes out a tool and puts it back in. The time until the next maintenance or exchange of a tool can be visualized by combining the usage history with the expected life time or maintenance frequency of a tool.

3.2. The Smart Medicine Cabinet

The medicine cabinet monitors the medication it contains and shows a virtual representation of the tracked objects on the user interface. The main motivation for the contents checking is to make sure that the prescribed medication is contained in the medicine cabinet. The motivation for additional services depends on the target group: (1) For visually impaired people who have difficulty reading the small writing on the medication packaging, the smart medicine cabinet shows the name of the medication enlarged on the screen and provides a voice output. (2) For general ”maintenance” purposes in a home and hospital environment, the smart medicine cabinet avoids the cumbersome process of checking the expiry date on each folding box by listing the expiry dates comprehensively. It also indicates which drugs have been recalled. (3) For mobile patients with chronic diseases the smart medicine cabinet is supposed to improve the medication compliance by programming reminders into the user's mobile phones. It also gives them remote access to the contents of the medicine cabinet with their mobile phone. More details about the technical realization of this scenario are presented in [5].

The unobtrusive content monitoring, a characteristic of the proposed smart box concept, is implemented by integrating an RFID antenna into the medical cabinet. As shown in Figure 4 this was done in such a way that the appearance of the medicine cabinet remains unchanged. Each medication pack was then equipped with a passive RFID tag (more details on the technical realization of the prototypes are given in Section 4).

The desired configuration of this smart box is the set of medications that have been prescribed to the doctor. With the proliferation of e-prescriptions the prescriptions made by the doctor can be directly linked to the desired configuration of the smart medicine box. The dynamic update requires the smart box to have access to an Internet-based backend infrastructure.

The additional service for the three different target groups rely on the box content identification. They are typical examples of the additional services mentioned when we described the characteristics of the smart box concept earlier (see Fig. 1 for details). The service for the visual impaired people is an example of the smart box user interface targeted to special needs. The expiry date and recall check functionality are an illustration of providing additional information about the individual smart object itself and the product type. The scenario that allows young patients to check the contents with their mobile phone is an example of providing remote access to the contents of the smart box.

The concept of a medicine cabinet augmented by information technology has been demonstrated previously by Wan [6]. The focus of the implementation by Wan has been to create a ”situated healthcare portal” in the bathroom. In contrast to Wan the focus of the medical cabinet presented in this paper has been to demonstrate the smart box concept.

3.3. The Smart Surgical Kit

During surgery the surgeon sometimes forgets to remove some of the swabs and bandages used to stop an internal bleeding. Currently this problem is addressed by integrating a thin thread into swabs and bandages, which shows up in a post-surgery x-ray. The downside of this approach is the compulsory x-ray to detect swabs left inside the body and the inconvenience associated with opening the wound to potentially remove a swab.

To reduce the chance of leaving a swab inside the body in the first place and to remove the annoyance of keeping track of the swabs used, the smart box concept provides a suitable solution. For this ”smart surgical kit” prototype we rely on the fact that today’s swabs and bandages come in pre-configured arrangements that are tailored to the specific type of surgery performed (see Fig. 5).

By equipping the swabs with RFID tags we can automatically detect the individual items (see Fig. 5 and Fig. 6) and facilitate the automatic content monitoring characteristic for the smart box concept we propose. Since it is difficult to detect tags on swabs that are in use in the wound, the application needs to monitor both the contents of the surgical kit and the bin into which the swabs are placed after use. Any items that are not in either of the two locations are believed to be in use.

The desired configuration e.g. the number of swabs in a certain surgical kit type is determined by detecting the RFID tag on the surgical kit and looking up the appropriate product configuration. Knowing the desired configuration of the box and comparing it to the items that have been detected either in the kit itself or in the bin, the application can now inform the surgery team on the number of tags still in use (see Fig. 6). Before closing the wound this figure should of course be down to zero.

Additional services such as using the content history to determine the most heavily used type of swabs and deciding whether a particular configuration is appropriate for an operation are straightforward to provide.

4. Implementation

The RFID system integrated into our smart box applications is the Philips I-CODE system. The Philips I-CODE system operates at a frequency of 13.56 MHz, i.e. it uses inductive coupling to transmit power and information between the RFID reader and the RFID tags, and it employs a stochastic anti-collision protocol to detect multiple tags at once in its read range [7].

RFID tags in the form of flexible RFID labels, which are available in different sizes are attached to the physical objects in order to identify the smart objects. The unique 64-bit ID that is stored on the RFID tag is used as the ID to map between the physical objects and their virtual information.

We encapsulated the software part dealing with the identification of the smart objects using RFID in a lightweight component, which acts as a layer between the RFID hardware and the smart box application. The application is notified of the detection of smart objects via an event mechanism by the RFID component. To support multiple boxes and RFID readers a more complex smart object infrastructure is needed. First ideas have been presented in [8].

The advantages of using passive RFID as the identification technology for our applications are:

- Passive RFID tags are inexpensive which makes them affordable to tag inexpensive objects.
- Passive RFID tags do not have an on-board power supply which avoids the need to replace dead batteries.
- The size of the RFID tags is small enough to tag objects for most smart box applications unobtrusively.
- No line of sight is required compared to other identification technologies such as bar code or infrared technology.

The technical challenges we encountered implementing the smart box applications are:

(a) Due to collisions occurring on the air interface in the tag reading process it is possible to receive false negative readings of RFID tags. To minimize the false negative readings we traded some of the response time of the system for increased accuracy in the object detection process by introducing a time filter .

(b) Metal or liquids in the RFID antenna environment have a negative effect on the ability to detect an RFID tag. In a real-world implementation of the smart tool box the antenna design needs to be adapted to a potential tool box made out of metal and special ferrite coated RFID tags need to be placed on metal tools to reduce the shielding effect of the metal.

(c) The RFID reader and display of the smart box applications consume considerable power. This makes a truly mobile scenario difficult if not unfeasible. The use of the smart box concept with passive RFID technology is most suitable for ”fixed” boxes or mobile boxes that return regularly to the same location.

5. Conclusion

The smart box concept presented in this paper is based on automatic and unobtrusive content monitoring and the comparison of the actual content to a desired configuration. Built upon this core functionality of any smart box we identified four different types of additional services. The illustration of the smart box concept with three sample applications underlined that the smart box concept applies to many ”box monitoring” scenarios.

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