

Unobtrusive User Profiling: The Use of RFID to Create a Smart Wardrobe

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Abstract. Many profiling systems rely on the user interactions directly with the systems to gather their raw data. We present a profiling system based on RFIDs. Unlike many profiling systems, the proposed profiling system is unobtrusive because it does not interact directly with a mobile device or computer systems. As proof of concept, we illustrate the idea by developing a Smart Wardrobe system which creates the profile by observing the movement of clothing items that have been tagged by RFID, in or out of the wardrobe. Based on the observations, the fashion profile of the user is generated. The prototype shows that meaningful profile can be created and can be used to feed other applications, such as shopping assistant or recommender systems.

1 Introduction

One major role that a computer plays in the modern society is providing convenience to the users. The convenience is achieved by alienating mundane tasks from human activities or by offering personalized services. The proliferations of smart devices and information services together with the imposing 'fast' pace of modern society places the need to provide users with the right information in a timely manner and be delivered in a way that conveniences the users. In the early development of computer systems, it is common that the systems dictate the way a user would use the systems. This phenomenon has changed rapidly in the last decade. Many computer systems provide personalized services to the user. Hence, it is the user who dictates how the system should behave. One major area of interest of many researchers in providing personalized and convenience services to human is in the area of pervasive computing, specifically in the investigation and development of smart home.

In a smart home environment, it is perceived that the electrical appliances can be programmed to be aware of the user's need and therefore are able to provide a personalized service to improve the user's quality of life [7]. These appliances usually refer to the traditional electrical appliances such as fridge, TV, washing machine, dishwasher, music player and so on. In this paper, we present a system that allows non-electrical item in the house to be equipped as a smart device. We propose the use of RFID to create a smart wardrobe system. The RFID based system is used to build the user's fashion profile. The fashion profile, in turn, can be used to build recom-

mender system. In this paper, we present how the user's dressing behaviour and fashion sense can be observed and learned to create a fashion profile.

The paper is organised as followed. Section 2 presents the overview of other researches that are related to our work. In Section 3, the architecture of the smart wardrobe, the algorithms designed for creating the fashion profiles and the underlying data model used are presented. Sample scenario of the proposed system is discussed in section 5. We conclude our discussion in Section 6.

2 Related Work

Radio Frequency Identification (RFID) has been around since World War II. It was used to help soldiers identify fighter planes as friend or foe [2]. Its usage in modern era is also for identification purpose. As stated by Vogt [10], "Identification is a central concept in user-oriented and ubiquitous computing". RFID is used to identify real objects such as humans, books, as well as movement of these objects. There has been research on ubiquitous ("being or seeming to be everywhere at the same time" [12], computing, which utilises RFID system architecture to pursue the seamless integration of technology and human environment [11]. The same research objective was also undertaken [4], which presented the idea of having services provided by virtual worlds such as computers to assist users in their daily tasks.

Want, et al. [11] states that the RFID technology has been used for sometime. However, only simple prototypes were developed in many cases. This is due to the relatively high cost of implementation in the past. Recent development allows the reduction of the implementation cost of RFID systems which results in the emergence of many smart and useful applications. These applications include:

- **Tagged Business card:** The application involves automatic detection of a person through the embedded RFID in the business card. When a reader senses the business card, it will trigger the user's computer to open the home page of the person represented in the business card [11].
- **Tagged Printed Documents:** In this system, printed documents are tagged such that a document can be linked to its electronic copy for an up to date version so that readers are always aware of the version of the document [11].
- **Tagged Dictionary:** Once reader senses the tag, the system will perform a language translation of the document displayed [11].
- **Smart Toolbox.** There are laws in aircraft maintenance business that requires continuous checking and monitoring of tools used in the maintenance process to ensure quality and safety of aeroplanes. To date, these routines are done manually and thus time consuming and prone to human errors. Smart toolbox is proposed to automatically detect missing tools [5].
- **Smart Medicine Cabinet [3]:** This system is designed to provide visual representation of RFID tracked medicine in the cabinet. The visual representation can be adjusted for visually impaired users.
- **Smart Surgical Kit [3].** Often doctors forget to remove some swabs and bandages that have been used in surgical operations. This prototype is proposed to continuously track and monitor how many RFID-tagged swabs and bandages

have been used and whether all have been returned or disposed. Otherwise it will send out an alarm signal to doctors.

- **RFID Chef** [6]. This prototype illustrates how an RFID mechanism can be incorporated into smart home. Apart from providing the users with easy access to information on cooking recipes based on RFID-tagged grocery items, it also explores the idea of context awareness. An advancement of the RFID chef's capability has been mentioned in Römer et al. [8]. In this system, a user preference is added to the selection of recipes, eg vegetarian or Asian dishes. A similar idea is also proposed by Schneider [9] where an application called Smart Shopping Assistant is designed to help the shopper by displaying information regarding products in a display unit. The shelves and the products are equipped with RFID reader and tags respectively so that the application can identify which product information to display.
- **Flytrap** [1] is a smart system that will play appropriate songs based on the music preferences of occupants in a room. It has the knowledge of the occupants' musical tastes and will construct a play list of songs that will please everyone in the room. The system will construct each of the user's songs preferences by monitoring what music each individual person plays on his/her own computer. This system is a good example of how a system can be built for a truly ubiquitous environment. The presence of the system is seamless in the room but it is useful for everyone

From these examples of prototypes and applications of RFID, it is evident that RFID technology is a simple, unobtrusive identification tool that can be used to track and monitor real objects. One area that has not been addressed by the sample prototypes is the utilisation of RFID to build personal profile. Personalisation of services is crucial for pursuing ubiquitous computing. In many cases, the collection of data to build user profile is done through WWW interactions. Example of such system is amazon.com. In this type of profiling system, the data collected is owned by the organisation that owns the server. It is not possible for individual to get the data for their personal use. RFID provides an alternative to the way data can be collected. It shifts the data collection process from the organisation to the individual, hence will shift the ownership of the data to the individual and enhanced privacy. In this research, we illustrate how and RFID system can be used to create individual-owned profile. We use the scenario of fashion profile which is created based on observing the users daily clothing choices.

3 Smart Wardrobe Architecture

We envisage that the user profile generated by observing the behaviour of the user can be used to help user understand his/her fashion preferences and be familiar with the content of his/her wardrobe. This information can be used to help user make decision when purchasing fashion items in the future. For example, knowing that one hardly uses bright colour clothes to work, he/she may not want to buy bright colour jacket during a shopping trip. There are several interesting fashion profiles that can be collected. In this research, we consider the following profile items as interesting:

- Most and least frequently worn item.
- Most and least frequently worn brand.

- Most and least frequently worn colour.
- Most and least frequently worn pattern (eg. floral, plain).
- Most frequently worn combination of items;
 - During the daytime.
 - During the evening.
 - During the weekend.

The profile items presented above are used as illustration of the types of profile items that can be generated. The list is not considered exhaustive. New profile item can be added to the system.

The smart wardrobe uses observation of events to build the above profile items. The following events are being observed by the system:

- A clothing item is in or outside the wardrobe.
- A clothing item is being worn. It is possible that an item is taken out of the wardrobe for a few minutes but not actually being worn.
- Two or more clothing items are being worn together.

The architecture consists of three major components as shown in Figure 1. An RFID reader is used to detect the presence or absence of clothing items inside the wardrobe. Therefore, each clothing item that the user has must be tagged with an RFID tag. Each of these tags has a unique id, so that the application is able to differentiate one item from other items. In addition, the RFID reader is designed to periodically read all tags attached to clothing items inside the wardrobe. Then, signals can be sent to the smart wardrobe application regarding which items are present, i.e., which items are available inside the wardrobe.

This application also utilises a database. The database consists of several tables; one table that stores information about the inventory of the wardrobe, another table records the data regarding the user dressing activities.

Based on the information on what the user has in the wardrobe as well as the usage of these clothing items, the Smart Wardrobe application will then generate a user fashion profile that reflects the user's dressing preferences.

3.1 Data Model

The smart wardrobe keeps the information regarding the inventory of the wardrobe and the events generated due to the wardrobe activities in a database. For the wardrobe inventory, the system keeps the information on the type of clothing, colour, brand, material, pattern and category. Examples of category instances are formal, evening and casual. Formal refers to the clothes that are considered business-like, eg suits.

A second table in the database is used to record the "in" and "out" of the clothing item of the wardrobe. This table is updated periodically in a given read cycle. The reading of the complete cycle is compared with the reading of the previous cycle to identify any missing tag id. Any missing tag-id will be considered as item-out-of-wardrobe. If a tag-id is still missing after a number of cycles, the item is considered a worn-item. The data in the event tables is used by three different algorithms in the system to determine three different events.

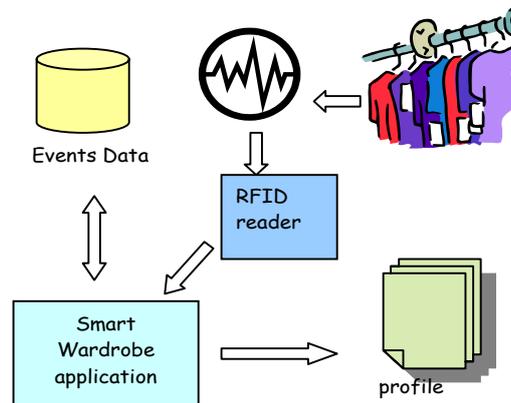


Fig. 1: System Architecture.

3.2 Event Detection Algorithms

There are three types of event that the system needs to detect as explained in section 3.1.

Algorithm 1. Detecting the IN and OUT of item.

At the start of the application, the application initialises the data storage that is used to store the tag ids read by the reader. At each polling, every tag id that is read by the reader will be added to a list. The list of tag ids that are read during current polling are compared with the list from previous polling. If the id is present during reading, it will be concluded as being inside the wardrobe. However, when a tag is not present during the current reading, but was available in a previous polling, the application will conclude that the corresponding item has been taken out of the wardrobe.

The application will continuously execute these steps for the duration of the application runs. However, when an item is concluded as being taken out, it does not mean the user is wearing it. Consider the scenario where the user takes an item out of the wardrobe but decides not to wear it and puts it back into wardrobe within a certain time frame; the application should be able to differentiate this event from other events when the user actually decides to wear the item he/she takes out. In order to accomplish this, our proposed model has designed a second algorithm to detect whether an item is being worn by the user.

Algorithm 2. Detecting whether item is being WORN.

The algorithm calculates the number of consecutive pollings allowed for an item to be absent before it is concluded as being worn. If it first encounters that the tag status is not present, it will check through the subsequent values from the following polling. If the tag is still not present during these pollings, then it will be concluded as being worn and then added to the list of worn items. This information is recorded as it is important for the application to discover which of the items are worn together as a pair in the next algorithm.

Algorithm 3. Detecting a pair of items worn together.

Using the result from the previous phase, this algorithm checks if at least two items have been concluded as being worn, resulting from Algorithm 2. For the first item that is concluded as worn, the application will try to find the partner for this item by checking the polling period in which the partner is taken out. In this context, assumption is made that at any one time, the user wears only two items, top and bottom items. If the application can find another item that meets the criteria, i.e. also taken out during the time allowed, then this pair will be added to a list as a pair of clothing items that are worn together. Then, these items are removed from the list of single items.

Following these steps, the application will then make database entries into a table with information about items that are worn together as well as the time of usage, i.e., the day and the time of the day.

With respect to the time of usage, in the prototype, we have two time periods: MORNING and EVENING. Every dressing event that occurs between 6am to 5pm will be recorded as the MORNING event. If it occurs between 5pm and 6am, it is categorized as an EVENING event. This categorization is important since most of the time there is a distinct difference between a morning outfit and an evening outfit. For example, a working professional can be assumed to be wearing business wear in the morning and casual wear in the evening.

3.3 User Profile Generation

There are two main sources of data to be used in generating user fashion profiles. The first is the inventory data and the second is the usage data.

The inventory data contains information regarding the user's current clothing collections in the wardrobe. As mentioned earlier, the application database stores information regarding each item's attributes, such as the colour, brand, pattern and material. From this information, the application is able to analyse and generate this part of the user's "potential" favourite attributes in his/her fashion profile simply using SQL queries.

The second part of the user fashion profile is generated based on the usage of the clothing. The information used to generate this profile is those that are recorded by the application based on the events data collected by RFID reader discussed previously. It is important to analyse this record because at times what user has in the wardrobe does not necessarily illustrate what he/she likes to wear. Thus, it is worthwhile to design this application to generate the profile from two different perspectives: the favourites based on usage statistics as well as the favourites based on wardrobe content.

Finally, usage patterns are derived. This information is useful as patterns can be found from the way the user dresses such as the colour combination, pattern combination, and type combination. These combinations suggest the way the user matches his/her top item with his/her bottom item. An example is shown below in Figure 2.

<p>Colour:</p> <ol style="list-style-type: none"> 1. white and black 2. blue and black 3. pink and blue <p>Pattern:</p> <ol style="list-style-type: none"> 1. plain and plain 2. stripes and plain 3. stripes and stripes <p>Types:</p> <ol style="list-style-type: none"> 1. shirt and pants 2. t-shirt and jeans 3. shirt and skirt

Fig. 2. User Dressing Combinations.

This example above shows the three most often combinations from each category. The most often colour combination is white top and black bottom; the most often pattern combination is plain top and bottom; and the most often type combination is to wear shirt and pants.

This information is derived by applying the standard data mining algorithm to usage data. In this instance, we use association rules to capture patterns. The result is useful as the application can use the knowledge to make recommendations to the user. For example, when a user has selected a shirt, it will recommend wearing pants with it since from the pattern found from the usage data, the user is very often wearing shirt with pants (rather than jeans, for example).

4 Physical Design Considerations

In our proposed model, as described in previous sections, all clothing items must be uniquely tagged. The RFID can be installed on each clothing item or attached to the clothes hanger. The second option is less reliable because it requires user to ensure that the clothes are placed with the correct clothes hangers. Having each clothing item tagged with an RFID may not be far from reality as retailers have started demanding manufactures to tag all their products with RFID [2].

Besides installing the RFID on the item, an RFID reader is also required to be installed inside the wardrobe. The reader may be installed near the wardrobe door or in a place where the reader will be able to detect the tags inside the wardrobe. An ideal option is to install an RFID reader that can read multiple tags so the polling can be done almost instantaneously.

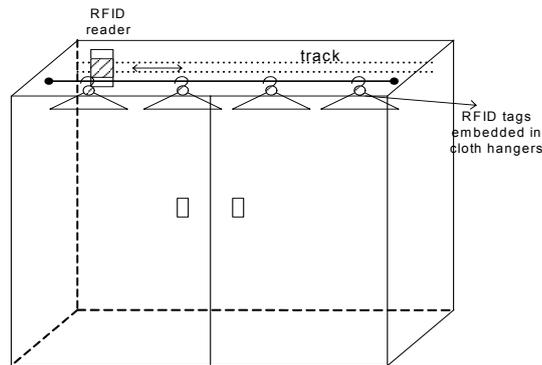


Fig. 3. RFID technology installation in wardrobe.

For the case of an RFID reader that is able to read only one tag at a time, the wardrobe needs to be equipped with a motor and reel installed along the length of the wardrobe; the RFID reader, then, should be positioned on top of the motor such that the reader is able to move along the reel to read the tags inside the wardrobe one by one.

Figure 3 illustrates the wardrobe set up of the RFID reader that is only able to read one single tag at a time. This setting does not show the installation of the motor. However, the RFID reader should move along the wardrobe track to read the tag one at a time. In this example, we assume the RFID tags are embedded in cloth hangers. In the future, clothing labels will be made of RFID labels so that we do not need to embed the RFID tags in cloth hangers.

Once the reader is installed, it needs to be started such that the reader will start to travel along the reel to read tags inside the wardrobe, i.e. polling for data, one tag at a time. This polling can be scheduled to happen periodically. For example, every 2 minutes, the reader will be activated to start polling i.e. reading radio frequency signal that is reflected back from the tag within the range. This reader signals and notifies the application with information of which tags have been successfully read. This information consists of the unique id numbers of the RFID tags. From this unique id number, the application is able to cross match the read id with the corresponding clothing item. Therefore, it is able to identify which items are currently in the wardrobe. This process of reading tags will be done periodically within the time periods set by the user.

5 Prototype Evaluation

As proof of concept, a prototype of the Smart Wardrobe Application has been built. Random generated data were populated into the events data storage. We created simulation data from two different types of user, a working professional and a student. These two categories are chosen because these types of users may be considered to be different in the way they dress. Therefore, we like to test whether the application can appropriately generate the profile.



Fig. 4. Clothes items being worn.

When creating this simulation data, some assumptions are made. They are:

- The inventory generator creates woman's clothing items. We choose to generate woman data because there is a broader range of woman clothing items compared to menswear.
- All clothing items inside a single wardrobe belong to a single user.
- All clothing items inside the wardrobe are tagged with RFID tags.
- When one decides not to wear the item, one will always put the item back into the wardrobe. Therefore, application can be certain that the user wears clothing items that have been taken out of the wardrobe for a long time period.

Based on the simulated data, the system generates profile of the inventory statistics, usage statistics and usage pattern. To generate the usage pattern, the system employs association rules algorithm. Figure 4 shows the interfaces of the system. Figure 5 depicts the content of a simulated wardrobe of a working professional.

From the generated inventory data, the events of wearing any of these items as pairs in a given time of the day are generated. And the user profile is generated. An example of the profile is the information about the combination of items worn. The information is generated using the association rules algorithm. An example of this type of profile is shown in Figure 6.

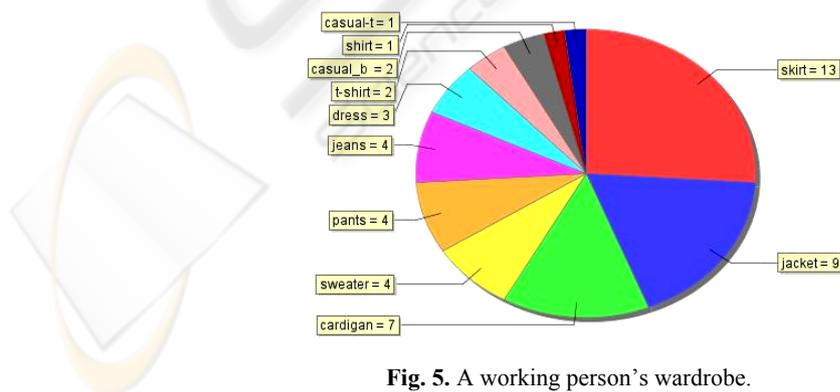


Fig. 5. A working person's wardrobe.

The discovered pattern shows that a working professional is likely to match his/her jacket with pants. Using this information, when the user picks a top item, the application will then be able to make appropriate suggestions of which item to match with the selected top.

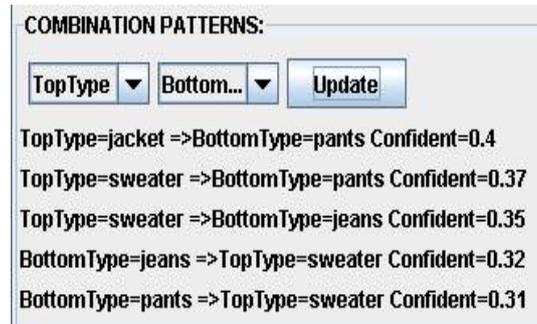


Fig. 6. Association of clothing items generated.

6 Conclusion

We have illustrated the use of RFID for creating individual profile. The profile is generated based on the observation of the user's daily activities. In this particular system, we observe the fashion activities of the user. The SmartWardrobe system shows that creating individual and private profile is possible without having the user interact directly with a computer panel, which many of the current profiling systems rely upon. The prototype has shown that some useful profile can be generated regarding the user's fashion profile, such as inventory statistics, commonly used brand, commonly used fabric and commonly used combination of clothing items. This information can be consumed by other applications, such as shopping assistant or recommender systems. The profile can be loaded into a PDA or mobile phone and assist the user in choosing appropriate clothing item during a shopping trip. For example, the user may not buy a clothing item with the colour that does not match with any item in the wardrobe. Additional functionality to generate the profile can also be added to the system in order to enrich the profile. For example, associating the clothing items with the season and the time of the day.

The idea can certainly be extended to other containers (not just wardrobes) such as a laundry basket, a bin, a shopping trolley etc. They can contain similar kind of instrumentation and tagged items for the same purpose. Certainly, such a system needs to be tested in longer term scenarios – an avenue for future work on our anecdotal experiments and prototype demonstration. Long term learning is conceivable as we envisage our techniques can be easily extended to such learning.

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