STORE VIEW: Pervasive RFID & Indoor Navigation based Retail Inventory Management

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Abstract
Today's retail consumers' general behavior consists of doing the research for products preferably online while purchasing them offline. Users would like to access stores' inventories before going to the shop. This paper first identifies the challenges that need to be addressed to navigate within a store and its inventory anytime and anywhere without being physically there. Then, it analyzes the existing approaches for inventory management based on Radio Frequency Identification (RFID). And finally, it proposes a solution based on robots. We believe that this proposal is an important contribution to fill the gap between online and offline worlds in the context of retail.

ACM Classification Keywords
H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous.

Author Keywords
Inventory management; store view; user browsing; robot; Radio Frequency Identification (RFID)

Introduction
Would you like to search for a garment online anytime, anywhere and receive the exact location/s where you could find it? At present, when we look for a restaurant, shop, monument, etc, Google Maps and similar

applications are there to help us. They save us a lot of time, and probably this is why they are considered some of the most popular applications for smartphones. But why is this service not yet extended to indoor spaces? In this paper, we first outline the challenges that need to be addressed in order to allow users to navigate inside a store without being physically there. Then, we analyze the existing approaches for inventory management based on Radio Frequency Identification (RFID). Moreover, we propose a solution based on a robot. In the last section we outline the impact of this proposal and future issues that should be considered.

Google Maps for indoor

Indeed, Google is working on the extension of their Google Maps to indoor spaces [2]. But it seems they are facing too many difficulties. First, Google Maps for Business [1] detected that most of the inventories from retailers were not up-to-date, and thus, the service would fail too often. Second, Google Indoor pretends to create "store views" based on the pictures that retailers will upload [2]. It is obvious that it is not a scalable solution as in many stores the organization of shelves changes frequently and taking all the necessary pictures is hard work if needs to be done manually. And third, the location of items is not available because Global Positioning System (GPS) technologies do not perform well indoor. Furthermore, we cannot count on shop floor plans because they are not always available and, when they are, usually are not in a usable form. In conclusion, we need a solution that: a) guarantees that inventories are up-to-date, b) creates a "store view" automatically and easily updatable, c) integrates the location of garments within the "store view", and d) includes a web-based Graphical User Interface. This paper focuses mainly in a) and also, in b) and c).

Inventory based on RFID

RFID is a technology that provides unique identification and location of items [10]. It has already been already identified as a suitable technology for enriching retail among the research community [12, 7]. We can distinguish four main approaches when applying RFID technology to inventory management, understanding inventory as the identification and location of garments.

- The **use of robots** integrated with RFID readers is one of the most efficient approaches in terms of space resolution. It guarantees to read a complete indoor space but may take a long time depending on the area and items to inventory.
- On the other hand, placing **antennas in the ceiling** offers great results in terms of time resolution (real-time inventory) but sometimes fails in reading a complete indoor space.
- The third approach is to use **phased arrays**, which are groups of antennas that allow the electronic steering of the beam. Thus, this approach is better in terms of space resolution than the simple antennas in the ceiling, but needs a little bit more of time to perform a complete inventory.
- Finally, the most recent approach is the use of **smart shelves**. Not only they perform well in terms of time and space resolution because they concentrate many antennas in a relatively small space, but also they are currently used for detecting and enriching consumer interaction.

Figure 1 shows a graphical representation of the four approaches in terms of time resolution versus space resolution.

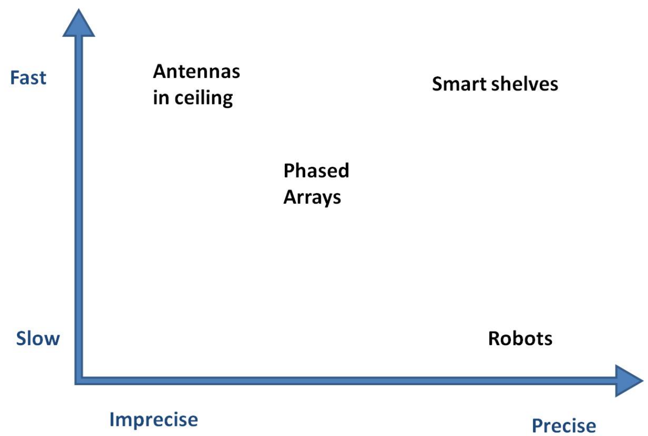

Figure 1: Time resolution versus Space resolution graphical representation of RFID-based inventory approaches.

In our work we need to identify all the items within the store. It would be a big fail if we could not detect all the garments available. Furthermore, we need to locate a garment within the "store view" quite precisely. Thus, space resolution needs to be as high as possible. Indeed, robots and smarts shelves are the approaches under our consideration. As shown in Figure 1, smart shelves may perform as well as robots in terms of space resolution while being much faster. But before making a choice, another important factor needs to be considered: scalability. For a big store or retail chain it may be worth it to install RFID infrastructures, but probably not for a medium or small one. Furthermore, we need to consider the changing distribution of shelves within stores, and the variety of existing types of shelves. In overall, we believe that the use of robots is the most suitable approach for our objective as it guarantees scalability and high spatial resolution.

"Store view" proposal

Our proposal is based in a robot that incorporates a camera and RFID readers, as well as all the necessary sensors required for its autonomous navigation within a store. Furthermore, we will need basic image processing for stitching all the photos taken by the robot along its path into a 360 panoramic view, and synthetic vision techniques in order to integrate RFID information onto the 360 store view. Robot navigation is also an important area of research which has already shown a number of interesting results [6]. Among many robot navigation approaches, Simultaneous Localization and Mapping (SLAM) [13], and its variants, FastSLAM [9] and Visual SLAM [8, 11], is suitable for unknown environment as well as for known or structured environment of robot navigation. In order to locate garments we will combine information from the RFID reader and from the robot navigation system. And in the same way, to locate the pictures within a store we will combine information from the camera and also from the navigation system. Thus, it will be essential to understand how it works perfectly.

Figure 2 shows a picture of our current robot. The robot base is from PAL Robotics [4] and the integration of RFID readers has been done at KEONN Technologies [3]. It was presented at the RFID Journal Live! Conference 2013 and won the Coolest Demo Contest [5]. Nevertheless, at present it includes neither the autonomous navigation system, nor the camera, and thus a lot of work still needs to be done. Our next steps consist of: first, evaluating the RFID-based inventory performed by the robot, second, integrating the camera in the robot in order to create a visual model of the store and finally integrate the inventory information in the "store view". The autonomous navigation system will probably be developed by a third party.

Figure 2: Robot integrated with RFID readers.

Conclusions

The integration of offline and online commerce is, currently, the major concern among retailers. Up-to-date inventories accessible anytime anywhere by users would certainly fill the gap between these two complementary ways of shopping. In this paper, we propose a solution based on state-of-the-art technologies that would allow users to navigate within a store and browse garments without being physically there. Of course, after finishing this ambitious project many more issues will need to be addressed. Probably the most interesting one will be how to integrate smart-shelves, which have been identified as the most efficient approach in terms of Time and Space resolution, in our "store view" system in order to improve inventorys time resolution. But also a cost analysis of the different approaches identified in this paper would be of utmost interest.

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