Leveraging RFID Data Analytics for the Design of an Automated Checkout System

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Abstract. Traditional checkout systems are labor-intensive and can be a source of great frustration for customers having to wait in line. In contrast, automated checkout systems seamlessly scan, total and charge a customer's purchase to a registered payment account while they are simply leaving the store. We focus on the main challenge of automatically detecting customer purchases. To this end, we develop a checkout system that leverages data mining techniques to (i) reliably and timely detect items leaving the shopping floor area and (ii) assign them to individual customers. We demonstrate the system's feasibility using a large data set collected in the laboratory under real-world conditions.

Keywords: Data Analytics, RFID, Internet of Things, Automated Checkout

1 Introduction

While RFID solutions are commonly used in retail supply chains for automatic detection of logistical units in upstream and backroom processes, front store customer-facing applications have not progressed beyond pilot trials. RFID solutions for this "last mile" of the supply chain are especially challenging because of the sheer number and variety of simultaneously moving objects. Complexity is further increased by the manner in which objects are transported (stacked, in bags, etc.), unpredictable customer behavior, and suboptimal store layouts. Against this backdrop, we consider RFID-based automated checkout systems, which promise great value potential for the retail industry [1]. Our research objective is to decompose the challenge of such systems into tractable sub problems and demonstrate the feasibility of a pilot implementation.

2 Automated Checkout System Requirements

Traditional checkout systems are labor-intensive and can be a great source of frustration for customers when having to wait in line. To reduce costs retailers have started adopting self-service systems which enable shoppers to scan, bag and pay for their purchases with little or no help from store personnel [2, 3]. These systems, however, offer hardly any improvements over traditional checkout with respect to the customer

13th International Conference on Wirtschaftsinformatik,
February 12-15, 2017, St. Gallen, Switzerland

Hauser, M.; Günther, S.; Flath, C.; Thiesse, F. (2017): Leveraging RFID Data Analytics for the Design of an Automated Checkout System, in Leimeister, J.M.; Brenner, W. (Hrsg.): Proceedings der 13. Internationalen Tagung Wirtschaftsinformatik (WI 2017), St. Gallen, S. 1201-1204

experience, potentially offering an even worse experience. In contrast, automated checkout systems scan, total and charge a customer's purchases to a registered payments account while they are simply leaving the store.

In our research, we focus on the main challenge of automatically detecting customer purchases. Here, we must cope with two problems: The system (i) has to reliably detect all purchased products and (ii) assign these to individual customers. Undetected products cause direct losses to the retailer and inventory inaccuracy resulting in out-of-stock situations [4]. Incorrectly assigning items to a customer, on the other hand, may lead to customer dissatisfaction and interruptions of in-store operations [5].

Academic literature on automated checkout systems is sparse. To the best of our knowledge, only one group of researchers have developed a system ("MyGrocer") that addresses the previously mentioned challenges [6, 7]. This solution relies on shopping carts equipped with RFID readers that detect objects placed in the carts. Similar to this approach, we also rely on RFID for the detection of products. In contrast to optical barcodes, RFID allows identification of products at the item level. In addition, identification does not require a direct line of sight between the tag and the reader device, which allows for simultaneous bulk detection of multiple objects. In contrast to the previous studies, we decided against RFID-equipped carts for several reasons: First, shopping carts are not used in all types of retail stores (e.g., fashion retail stores) which limits the generalizability. Second, the costs for equipping shopping cart with RFID readers are very high [7]. In addition, there are high operating costs for regular service of the carts. Instead, we propose an automated checkout system that is implemented at the exits of retail stores and does not require customers to use specific devices. This system facilitates the detection of items in carts and items carried by customers.

The MyGrocer carts only need to detect items within them. In this case, sufficient data quality can be achieved by selecting RFID antennas with read ranges of only 20cm. In our case, the antennas need to detect items that leave a store through an exit gate, which requires antennas with large read range and high power. Unfortunately, this in turn leads to the detection of RFID tags carried nearby by the gate instead of through the gate. Secondly, assigning items to customers can hardly be realized with hardware-based approaches. Customers would have to wait in line and pass the gate one after the other to avoid purchases of different customers being read at the same time.

3 Description of the Automated Checkout Artifact

We pursue a design-oriented research approach to create an automated checkout artifact that (i) reliably and timely detects items leaving a store and (ii) correctly assigns them to individual customer. The architecture combines hardware components and software components. The hardware component consists of two RFID reader installations, a ceiling-mounted system which tracks items in the store and a gate-mounted system that helps to detect items that are leaving the store (see Figure 1). This infrastructure collects low-level RFID data that is then processed by the software components.

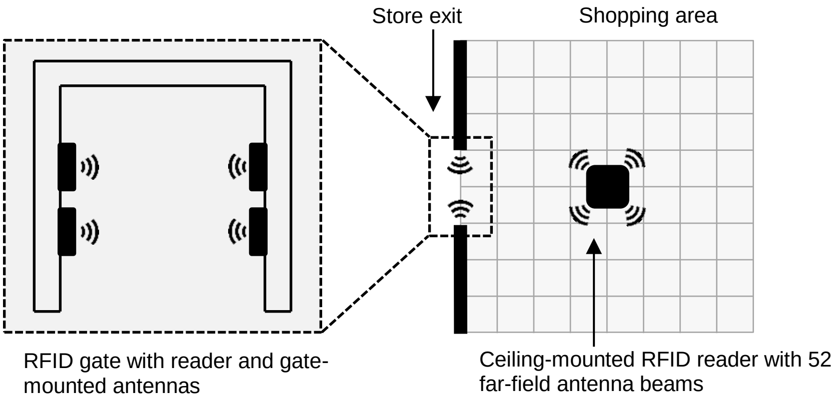

Figure 1. Hardware infrastructure with two distinct RFID reader installations

There are two distinct software functionalities. The *first* software component uses data mining techniques to reliably and timely detect items that are leaving the store. To this end, we extract features from the low-level RFID data, which contain information regarding observed real world events. One simple example is the maximum received signal strength value measured in a series of detections of a particular tag within a certain time interval. With these features we train classification models that are able to distinguish between items that leave the store through the exit gate and others. We follow the conceptual approach described in Hauser et al. [8]. However, we go beyond the state-of-the-art by considering run fragments in real-time instead of evaluating completed paths ex-post. The *second* software component assigns items leaving the store (identified by the first component) to individual customers. To this end, we infer item paths in the shopping area and then apply cluster analysis to group them. The procedure rests on the assumption that the paths of items purchased by one customer are more similar to each other than to paths of other items.

4 Expected Contribution and Future Work

We use a large data set collected in a laboratory environment for instantiation and evaluation of the artifact. Our experimental setup takes into account the limited process control in retail stores by considering multiple walking paths, varying numbers of persons and items as well as different movement speeds. Our experimental design includes 18 different tests. We repeated each of the tests 50 times. We then perform 5-fold validation to ensure representative results. We found that the artifact reliably and timely detects all shopping baskets carried out of the shopping floor area. On average, the baskets were detected 0.41 seconds before customers stepped out of the sales floor area. In addition, 94% of the shopping baskets assigned by the artifact contained the correct items.

These misclassifications arise in two particularly challenging test scenarios where multiple customers approach the exit gate simultaneously on very similar (almost identical) movement paths. In practice such a situation could easily arise when friends are shopping together which highlights the limitations of the pilot implementation. Nonetheless, our initial study demonstrates the fundamental feasibility of RFID-based automated checkout. Going forward, we want to evaluate our artifact in different test environments to evaluate its generalizability. In addition, we want to include additional, richer test settings (e.g., scenarios in which customers take objects from shelves that are placed near the exits). Our ultimate objective is to ensure feasibility under real-world conditions.

5 Acknowledgement

This research was carried out under the Research Project SERAMIS (Sensor-Enabled Real-World Awareness for Management Information Systems), funded by the EU under the VII Framework Research Program.

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