Poster: Evaluating RFID for Automatic Checkout in Smart Retail

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Abstract

We explore the potential of an RFID gate for a *just walk out* Smart Micro Market, offering valuable data for sensor fusion with additional system technologies.

1 Introduction

You're thirsty and see a small shop nearby. You scan a QR code at the entrance, walk in and pick up a bottle of water. Some local products catch your eye, so you place a couple in your bag then walk out. You didn't interact with an attendant, didn't scan the items you selected, and yet you are accurately charged. This is the concept of the "Smart Micro Market" of the EU project MIMEX (`https://www.mimex.shopping/`) - a *just walk out* experience that balances customer needs with cost-effective, high-performance technologies. Data from sensors, ranging from smart shelves that detect when an item is picked up to video cameras that monitor hand movements, are combined to produce an accurate, reliable, and easy experience.

Recently, the revenue potential of *smart retail* has attracted both research and industry [2], e.g., the Amazon Go platform [1] is based on high-quality, high-performing cameras feeding deep neural networks (DNN) for object and user recognition and tracking. As it is both expensive and the accuracy depends on the quality and quantity of training data, many efforts study lower cost technologies, e.g., RFID to tag products, shelves and carts [4, 5, 3]. The MIMEX shop is small, does not provide carts, and cannot rely on shop technology being collect at the exit. This article focuses on the utility of RFID at the exit to increase the accuracy of the virtual shopping cart whose items are charged to the customer.

2 RFID in the Smart Shop

The MIMEX RFID sub-system uses standard passive RFID tags attached to each item and a commercial reader with up to four antennae. The antennae are strategically

Figure 1: Inside the Smart Micro Market. The exit corridor. Exit showing six possible RFID antenna positions.

placed at the exit and hidden behind the walls and false floor/ceiling. Figure 1 shows (left) an individual in the store, (center) leaving the store, and (right) a close-up of the exit corridor showing the six possible RFID antenna locations.

The single UHF Reader ($860-960$MHz) [FEIG ISC.LRU1002] is connected to a standard PC via Ethernet. The four antennae [ISC.ANT.U270/270] are directional along a $65^\circ \times 65^\circ$ cone and present a 9dB gain in the normal direction of the patch antenna with variable output power. The RFID tags are UHF On-Metal printable 60×24 mm tags, a choice that allows us to affix them to metallic items.

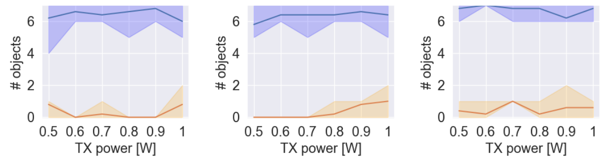
To focus the antenna reading area on the exit, we explored the use of shielding, specifically the 33403 WE-FAS RFID Flexible Absorber Sheet. We cut panels and attached them to the store-side of the antennae.

3 Evaluation

Our goal was to evaluate the ability RFID to offer useful information for fusion with other technological elements of MIMEX. Perfect accuracy of the shopping bag contents was not our objective. To this end, we identified four configurations; numbers refer to antenna positions in Figure 1:

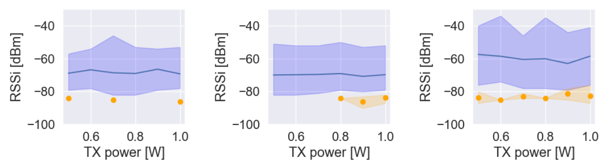
- WALLS(1,2,3,4), WALLS+SHIELD(1,2,3,4): Two antennae at shoulder height and two at knee height, with and without shielding.
- FLOOR (2,3,5), CEILING (2,3,6)): Two shoulder height antennae with shielding, plus one antenna on the floor or ceiling.

When testing each configuration, the RFID reader is continually active. At steady state, due to the antennae orientation toward the exit door, no tags are detected; however, when the user passes through the exit hallway, the reader begins to register tags. The virtual shopping cart is filled with all IDs from the moment that the first item is detected un-



(a) WALLS. (b) WALLS+SHIELD. (c) FLOOR.

Figure 2: Count of objects detected.



(a) WALLS. (b) WALLS+SHIELD. (c) FLOOR.

Figure 3: Average RSSI of detected objects.

til the exit door closes. For each test, the user carried a bag with 7 tagged items such as cans, soap, etc. We varied the output power, had the user pass through the exit 5 times at each power level, and shifted the items inside the bag each time to avoid bias from item shielding inside the bag.

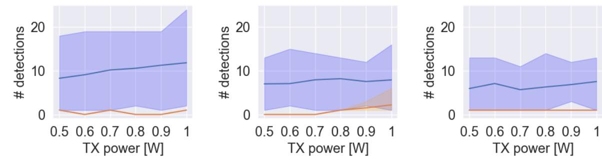
In the following, we report only the first three configurations as the CEILING configuration gave very poor results as the three antennae were far from the bag making it difficult to distinguish bag items from shelf items.

3.1 Count of Objects Detected

We begin our analysis by observing the number of objects detected, separating them according to whether they were in the shopping bag (blue) or still on the shelves (orange). Figure 2 reports the average number of items of each category (dots/solid line) as well as the minimum and maximum (with bands) of the 5 trials. Unfortunately, most experiments detect a few items from the shelves, and rarely see all the items in the shopping bag. The transmission power does not make a significant difference in the detection of shelf items, as we expect most missed detections are due to shielding of tags by other items inside the bag. To our surprise, the shielding did not make a significant difference. FLOOR produced the best results, detecting most bag items, but at higher transmission levels it also detected items from the shelves.

3.2 RSSI of Detected Objects

Next, we analyze the average, minimum and maximum RSSI values of the detected objects, separating them again according to whether they are in the bag or on the shelves. As expected, Figure 3 shows that objects on the shelf are detected at lower signal strength. Still, a simple threshold would be insufficient to separate them in all cases, especially because some of the items in the bag are also at a low signal strength. Again, this is likely due the items' shielding in the bag, but also by the body of the person carrying the bag, which shields items from one of the wall-mounted antennae.



(a) WALLS. (b) WALLS+SHIELD. (c) FLOOR.

Figure 4: Number of times each object is detected.

3.3 Count of Object Detections

Finally, we consider the number of times that each item is detected. We recall that in all antenna configurations, no items are detected until the customer crosses the threshold of the exit hallway. As seen in Figure 4, items on the shelves are detected infrequently, while items in the bag are typically detected multiple times during exit.

3.4 Putting it Together

As no single metric above is sufficient to provide obvious thresholds for formation of the virtual bag, we consider one additional view of the data. Here, we focus on a single virtual bag created at a single TX power as this is what the RFID sub-system would provide during operation. Figure 5 shows both the mean detected RSSI as well as the number of detections per object for a single customer exit at 1W. The closer the point is to the origin, the higher the probability that the item was on the shelf and not in the bag. Interestingly, in all experiments, we saw that the shelf items are always closer to the origin than the bag items.

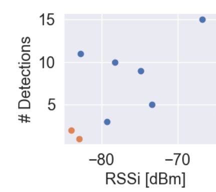


Figure 5: Per item evaluation.

4 Conclusions

These experiments demonstrate that RSSI alone is insufficient to create a reliable virtual shopping bag as tag shielding by the user and the items themselves inhibit detection and reflections cause shelf items to be erroneously detected. Nevertheless, the signal strength values combined with the frequency of detection provide valuable information that can be fused with data from other technology of the Smart Micro Market to increase reliability and system confidence.

Acknowledgment

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5 References

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