TesGo: Revolutionizing Shopping Experience Through an Augmented Reality Indoor Navigation System

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Introduction

This paper explores the problem of supermarket indoor navigation for the case of locating one or multiple items within the given store. The final product proposal consists of a tablet mounted on a shopping trolley as displayed on *Figure 1*. The trolley has a forward facing camera to allow for augmented reality (AR) navigation displayed on the tablet. A large part of the proposed system is the selection of an optimal user interface (UI) for the seamless shopping experience. This paper further describes the testing methods and data analysis supporting the overall product decisions as well as a proposal for future development.

Figure 1: Final system proposal

Background

Problem definition

One of the common problems among large supermarkets' customers is the difficulty of finding a specific item. Wandering around the aisles until the customer gives up and asks for help. This issue is prevalent with frequent shoppers familiar with the store and even more so with new customers. In fact, some other companies raise a similar issue. Aisle411 (Aisle411, 2014), for example, collaborates with Google and works on project Tango, an indoor navigation system for retail stores.

Technical background

Indoor Navigation Technologies

Though outdoor navigation is already well documented, a navigation system for the indoor purpose, which prefers an accurate position with minimal infrastructure, is still a challenge (Bitsch et al., 2011). Since Global Positioning System (GPS) is only accurate for outdoor purpose, new positioning method is required for indoor navigation. Here are some of the achievable indoor navigation technologies:

- ***Lateration***
  This method requires a set of beacons placing around. With the beacons set around, it is possible to calculate the relative position between users and a set of beacons. Nonetheless, this method needs very precise placing and calibration, and is impractical in the long run.

- ***Wi-Fi Fingerprints***
  Similar to Lateration, this method relies on relative distance calculation. It collects the identities and signal strengths of the WiFi access points in the vicinity at various points in the covered area. However, new calibration is needed every time when the environment is physically changed or the number of people inside is counted. Furthermore, using Wi-Fi is difficult to define the building floor with high delay measurement time comparing with other systems.

- ***Smartphone Footpath*** (Bitsch et al., 2011)
  By utilising step detection function on smartphone combined with prior generated an indoor map, this method uses First Fits and Best Fits algorithms to estimate the location of the user. As their evaluation, the Best Fits algorithm precision for outdoor location, such as parking lot, was almost the same level of GPS. As for indoor testing, both algorithms returned almost the same result. Nevertheless, the limitation is the elevator and metal objects which generated noise for smartphones causing miscalculation of footstep which is a parameter for the algorithm.

- ***Li-Fi***
  According to Ryan - the interviewee, Light field communication, or Li-Fi as some refer to the medium, operates very similar to Bluetooth Low Energy in terms of

being low energy, highly responsive and accurate (Stroh, 2014). Li-fi utilises ubiquitous LED lighting that is mostly installed along the pathway. These ubiquitous LEDs are able to beam out a code that's imperceptible to the human eye (Cooper, 2015). Combined with the geomagnetic sensor for a method to survey the travel direction and the geomagnetic information beneath the LED lights for accuracy, it is possible to make an accurate indoor navigation system (Nakajima et al., 2013).

Based on the technical knowledge, we found that Li-Fi is the best solution compared with the other choices. The first reason is that it requires smaller infrastructure compared with Lateration method. In addition, unlike placing the beacons around there is a chance users can maliciously damage the system, the LEDs are on the ceiling which means no one can damage the system in Li-Fi context. The second reason is the accuracy of building floor which Wi-Fi footprints has a difficulty differentiating. Lastly, since the device will be attached to the trolley, the Footpath approach is not the viable option. All in all, Li-Fi has been found to be the most reasonable approach.

Augmented Reality (AR)

Although some research suggests 2D mapping for navigation is superior to Augmented Reality (Esen et al., 2016), there are a number of AR capabilities that overcome 2D indoor mapping. The main reason that 2D mapping gave superior result than AR because is the demographic of the tested users. None of them used an AR application before, whereas all of them used a 2D digital map application (Esen et al., 2016). However, the choice of AR we have considered user safety and further improvements that are possible in future. For navigation system, it is not safe if users look at the screen all the time because it reduces awareness of surroundings. This is where AR can overcome 2D mapping, showing the real time surroundings obtained from the camera. Moreover, this attempt does not deteriorate the purpose of supermarket psychological display. Thus, showing the real environment that users still aware of surrounding and see items on the shelves is what AR can give over 2D mapping.

Notifications

The other technology included in the system is vibrating handlebar, for the purposes of notifying the customer of a nearby item. Generally, other systems like Google Maps or Spacebook provide user feedback and notifications by either visual or auditory clues; however, the sense of sight and hearing is crucial for safe traveling. Out of the 5 human senses, the usable one left is the sense of touch. Furthermore, nearly all users push the trolley by grabbing the handle. Thus, vibrating handle is the finest solution above other choices of human senses to notify the user of the proximity of an item.

Design Guideline

Design Approach and Process

We draw from the British Design Council's Double Diamond approach (Design Council, 2005) and revamp it to suit our project better (see *Figure 2*). In the 'discover' phase, we explored topics from everyday problems to emerging technologies regarding navigation. Following this, we investigated related work and applications of new navigation technologies such as Li-Fi and AR. Based on the research, we gathered insights and determined the area to focus upon. We opted for an iterative approach to explore potential solutions. By rapid prototyping, running different tests, collecting feedbacks from users and evaluating the system, eventually, we have reached our final proposal.

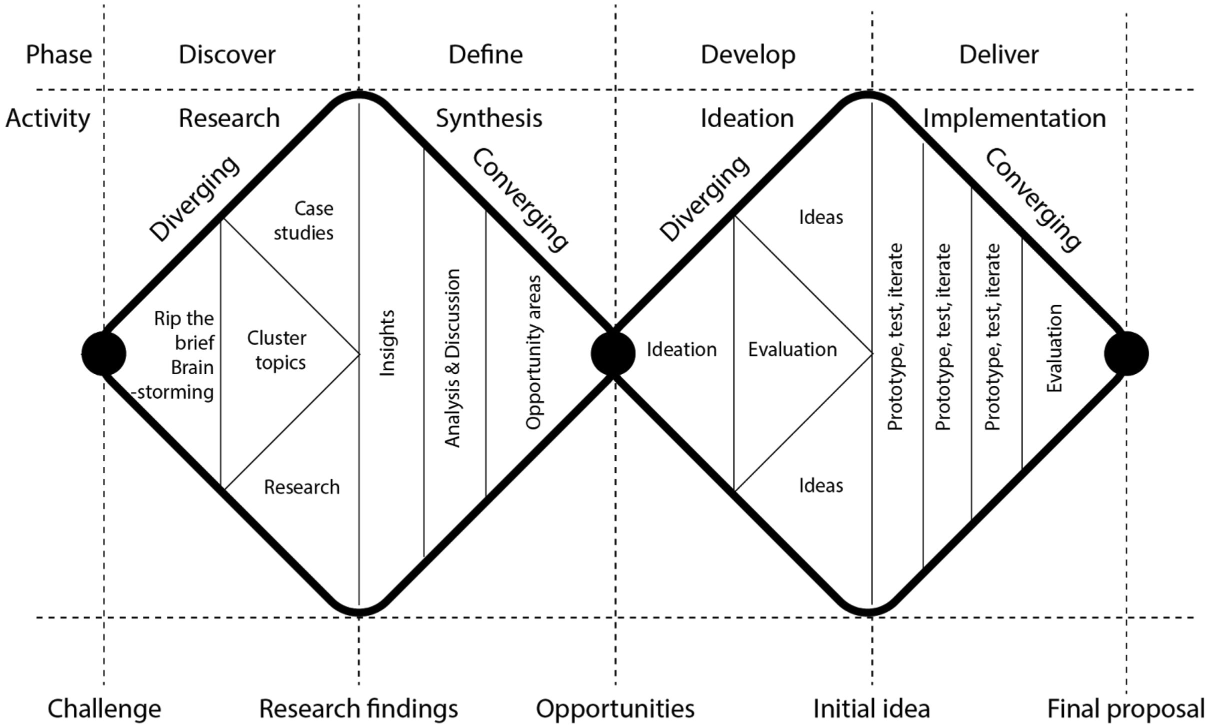

Figure 2: Our design approach and process

Design Guidelines

In approaching our proposal, we examined the literature of design guidelines in the field of human-computer interaction (HCI). Numerous studies have provided principles and frameworks for technology empowered design. Multimodal system, in particular, emerging in recent years, has brought a paradigm shift. Compared to traditional graphical user interfaces (GUI), multimodal interfaces and systems provide users more communication channels and leverage humans' capacities such as multiple sensations. Hence, multimodal systems tend to offer more natural and seamless interactions between humans and machines. According to Oviatt (Oviatt, 2003), "Multimodal interfaces process two or more combined user input modes (such as speech, pen, touch, manual gesture, gaze, and head and body movements) in a coordinated manner with multimedia system output". Thusly, the fusion of multiple types of data and the real-time information processing are the main features of the architecture of multimodal systems (Nigay and Coutaz, 1993). Given the fact that there is a range of design guidelines available, we investigated different models and frameworks and grouped these into six main categories for this project:

- **General applicability and adaptivity**

The multimodel system should be designed for a broad range of users and changing environments, as well as support flexibility to adapt to the needs of different types of users. Different users can benefit from the dynamic adaptivity in spite of individual differences and different contexts of use (Reeves et al., 2004).

- **Coincidence of multimodal input and output**
  In order to provide effective and intuitive interaction, the system should be able to match output to an acceptable user input. The modalities, in particular, should be integrated in a manner compatible with user preferences, capabilities, and system functionality (Reeves et al., 2004).

- **Consistency**
  The system should have standard controls and use consistent features and patterns to reduce cognitive load for users.

- **Visibility and feedback**
  The system should enable users to be informed about the current connectivity and status by giving them appropriate feedback within reasonable time (Nielsen, 1995). Users should be made aware of alternative interaction options (Reeves et al., 2004) and be given control over the selection of different functions.

- **Error prevention**
  The system should minimize user errors by constraining the types of input users can make (Laubheimer, 2015), offering users a confirmation option before the action (Nielsen, 1995), and allowing users to undo a previous action or exit the system (Reeves et al., 2004).

- **Simplicity of design**
  The design should be simple and focus on the most relevant information.

Tests, Iteration, and Evaluation

First Round of Tests - Wizard of Oz

Based on the initial idea, we adopt Wizard of Oz (WoZ) approach to simulate the potential system, test functionalities, as well as discover problems. Developed in the early 1980s (Gould et al., 1983), the WoZ approach is widely used in the field of human-computer interaction (HCI). It is well-suited for both low-fidelity ideas at the early design stage and high-fidelity interfaces in the accomplishing phase (Dahlback et al., 1993). In particular, WoZ is remarkably useful in testing multimodal systems such as conversational user interfaces and mixed reality applications (Dow et al., 2005). SpaceBook, for example, a speech-based navigation system that supports pedestrian orientation and exploration of urban environments, utilized WoZ experiments to collect data and determine pedestrian behaviour (Hill et al., 2013).

After examining its concept and applications, we conducted a WoZ experiment. The goals were to validate the initial idea (that our system solves a real pain-point) and to observe users interacting with such a system to gain insights into potential problems. We approached the test by splitting up into groups of four people. One person acted as the shopper, and one worked as the navigation Wizard who was responsible for guiding the shopper to a certain shelf where the wanted items were located. The shopper and the wizard were communicating via an instant messaging (IM) application on the mobile phone, as can be seen on *Figure 3*. The other members worked as observers and recorders, recording the user behaviour and identifying issues during the process. Everyone on the team served as evaluators to provide insights from different perspectives.

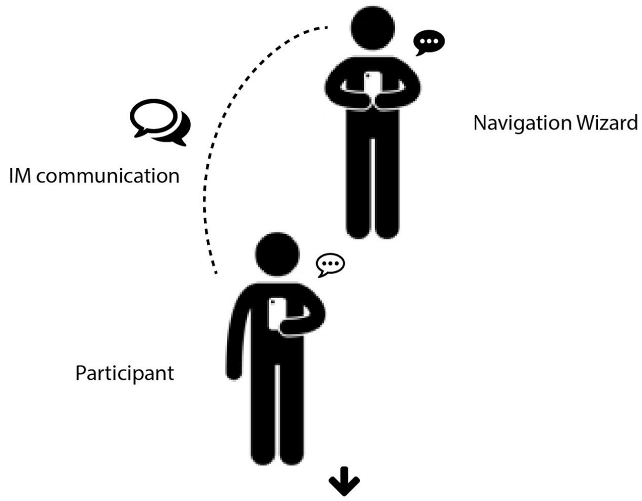

Figure 3: A conceptual WoZ setup

In this round of WoZ test, the shoppers picked up a shopping basket or trolley after entering the supermarket (Tesco Metro in this case), typed a list of items into an IM app (Messenger and Wechat) on a mobile phone (both Android and iOS), then got navigation instructions, which were provided by the navigation Wizard who followed behind.

Figure 4: WoZ testing with multiple participants

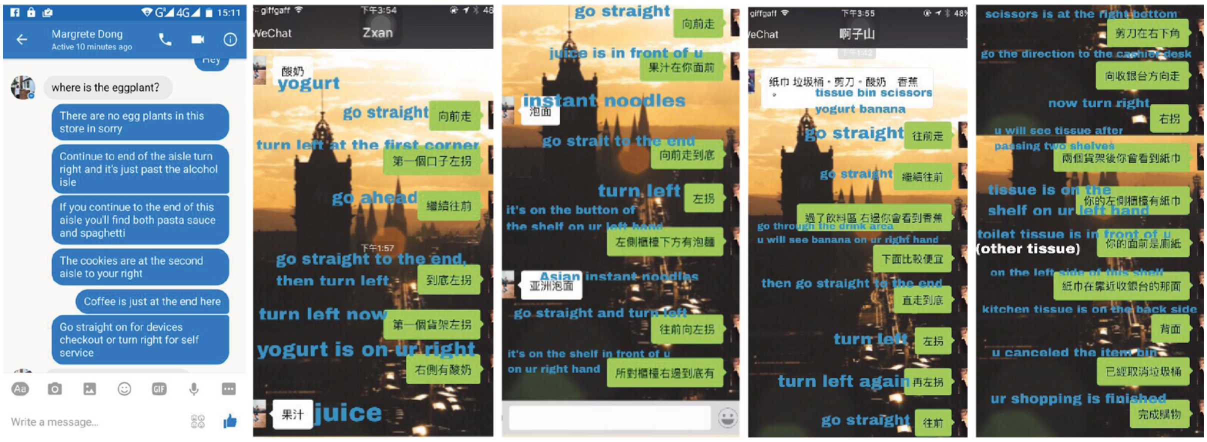

Figure 5: The wizard device UI: IM applications

Based on users' feedback the test validated two hypothesis:

- Locating items within a supermarket is indeed a problem.
- A version of a navigation assistant could remedy this issue.

Observation of users using such a system revealed valuable insights, which drove further progress of this project. Namely :

- The system must provide an intuitive way to create a shopping list. Allowing the user to add either, single item, multiple items or a whole shopping list at once.
- The physical device for the platform should be a trolley mounted tablet, in contrast to the user's own smartphone. Using a handheld device during trolley operation proved to be rather cumbersome. Further, connectivity stability and application installation were further influencers.
- The system needs to navigate the user effectively as well as providing a notification alerting the user of the sought item proximity.

Second Round of Tests - Lo-Fi Prototyping and Testing

Validating the system concept allowed for development and iterative testing of the UI. Based on the observations from the previous round of tests the UI needed to support : adding a single item, multiple items and a whole shopping list at once.

The optimal solution for adding a whole shopping list at once was based on observation that many users either handwrite or create a digital shopping list before entering the store. Using preliminary assumption of an AR based navigation this feature exploits the use of a camera. Optical Character Recognition (OCR) systems have been around for a while and current advances in Convolutional Neural Networks can achieve over 99% accuracy in reading handwritten text (Brownlee, 2016). This fact supported the need for a "Scan shopping list" button.

The User Interface has to provide an intuitive way to add single item or a multiple of items at once. Two types of interfaces were explored and their performance was tested based on time and 'number of errors' metric when performing a simple task. The interfaces can be seen on *Figure 6* and both are based on different principles. The top interface relies on the user’s familiarity with the supermarket’s self-checkout systems, bearing a clear resemblance with letter ranges. The bottom interface uses the idea of categorical grouping of items.

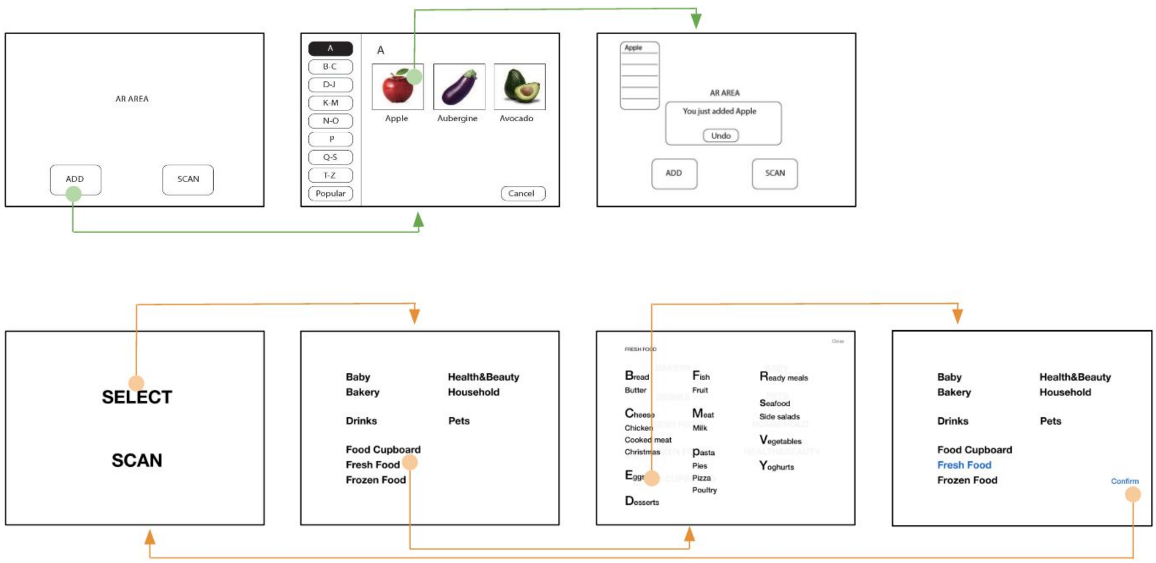

Figure 6: Two versions of UIs for adding shopping list

Both interfaces were sketched and uploaded to a prototyping tool on a tablet device. A group of 5 users were tasked to perform a simple task of adding 3 distinct items into their basket. The time and number of mistakes in performing this task were measured and the results are displayed on *Figure 9*. The metrics clearly indicate the self-checkout based interface as the better performer. The observed problems with the categorical interfaces stemmed from choosing appropriate and intuitive categories for items.

Figure 7: Testing of the first UI

Figure 8: Testing of the second UI

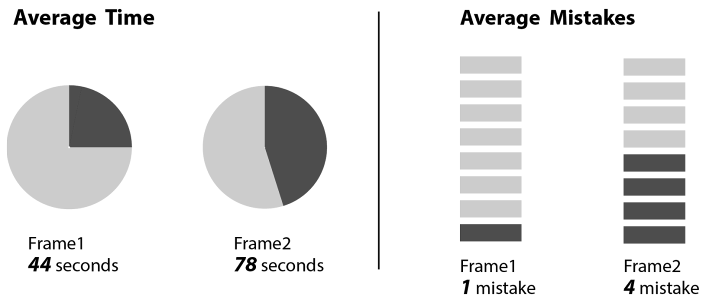

Figure 9: Comparison of time and number of mistakes between two versions

Third Round of Tests - Mi-Fi testing and iterations using Cognitive Walkthroughs
Based on results from the Lo-Fi testing the self-checkout based interface was taken further into the design of Mi-Fi and the results of these were measured using iterative Cognitive Walkthrough tests. During these users were asked to add/remove items to proceed with navigation. Similarly, number or mistakes were observed, but these tests included a structured questionnaire at the end to gather usability feedback.

Cognitive Walkthrough (CW) is an evaluation method based on Norman's action theory (Norman, 1986), which is used to examine the usability of a system and enable the designer to find usability issues in the early design phase (Abowd, 1995). We opted for CW for evaluating the user interface and detecting design flaws.

The Mi-Fi design at the last iteration stage can be seen on *Figure 10*. Based on the observations during testing and feedback questions, two key observations were made. First proving high usability of the system by most of the users being able to perform their tasks without any mistakes. The second observation was rather informative as it reveals a problem with the store self-checkout systems themselves. Both native and non-native speakers take longer to locate a relevant starting letter (e.g. P for Pear) if it is hidden within a letter range. This means if there a range P-S present users will locate this correct range immediately, however, if there is a range O-F users will take extra time locating this correct range. This letter range observation inspired one of the major changes from the lo-fi designs, that all letters must be present on the screen to improve time of carrying tasks of adding items as can be seen on *Figure 11*.

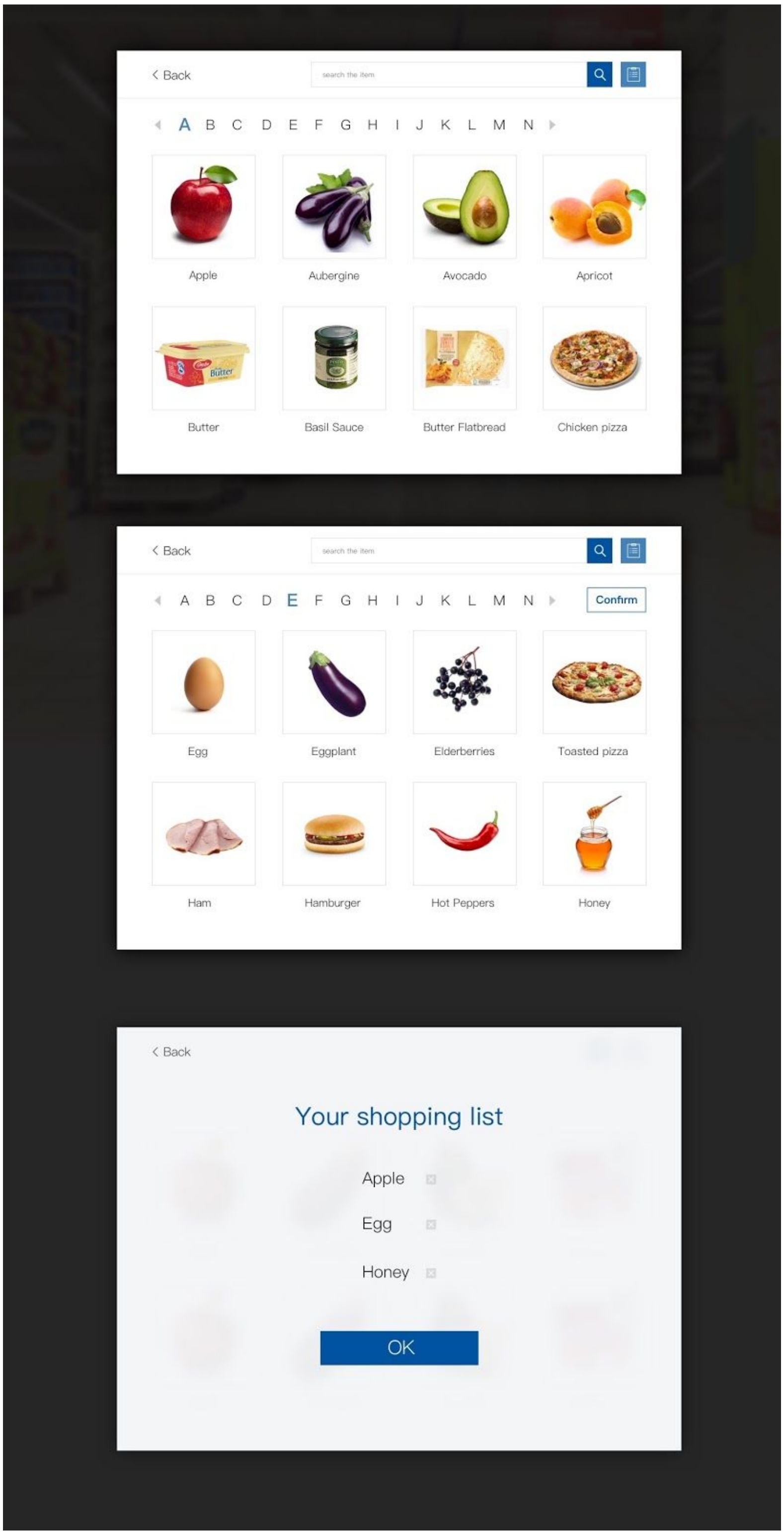

Figure 10: Mi-Fi and adding item interface

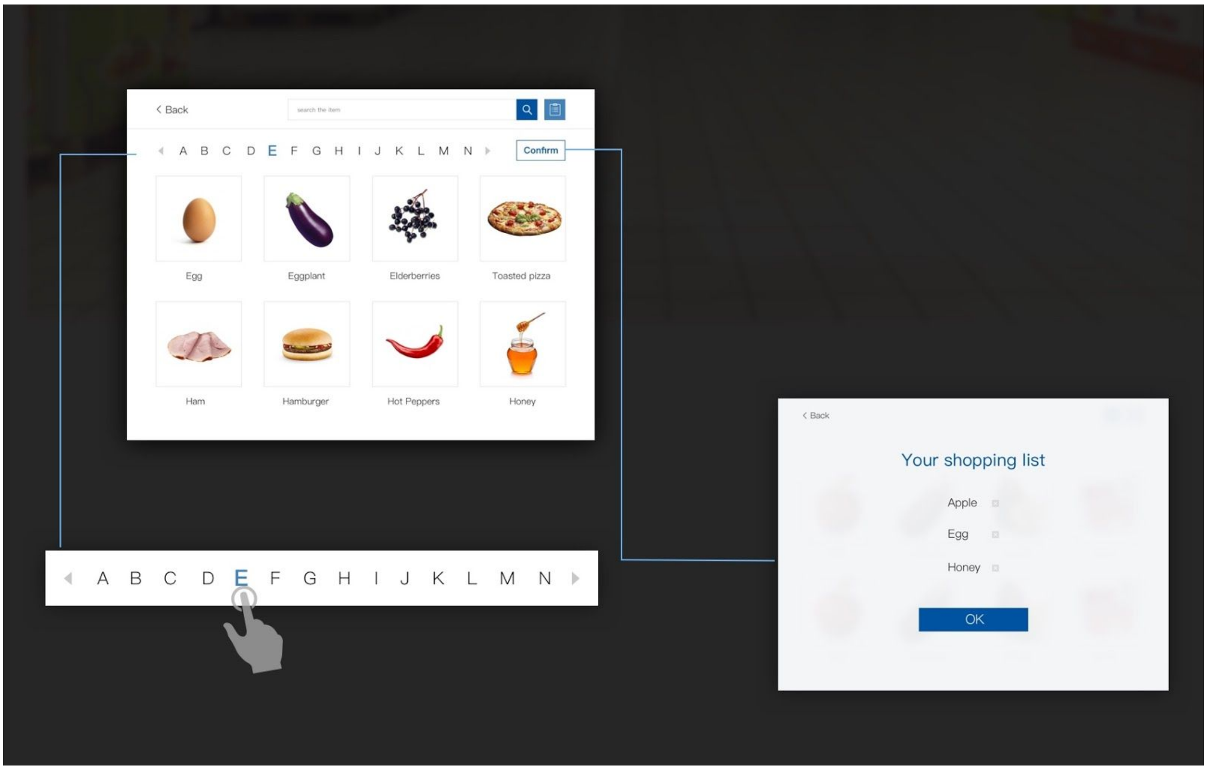

Figure 11: Mi-Fi and adding item interacting process

Fourth round of Tests - Hi-Fi testing and non standard users

Translation of Mi-Fi design into Hi-Fi revealed a new feature of the system and a non-standard user. Not only this but also potential flaw in the previous testing stages. All testing till this point used well-known, pre-selected items (Apple, Eggs, Honey), however when user were given free hand to choose any item they might actually need, an issue arose. Non-native speakers struggled with adding less-common items (e.g. Aubergine), having to look for translations, prolonging the time of achieving the given task.

A language selection feature was added (Displayed on *Figure 12*) and tested. Time of adding items into the basket was measured once again. However, this time users were given the items to be added in their native tongue in contrast to English which was used previously. The time of task completion was compared between the English and the translated interface.

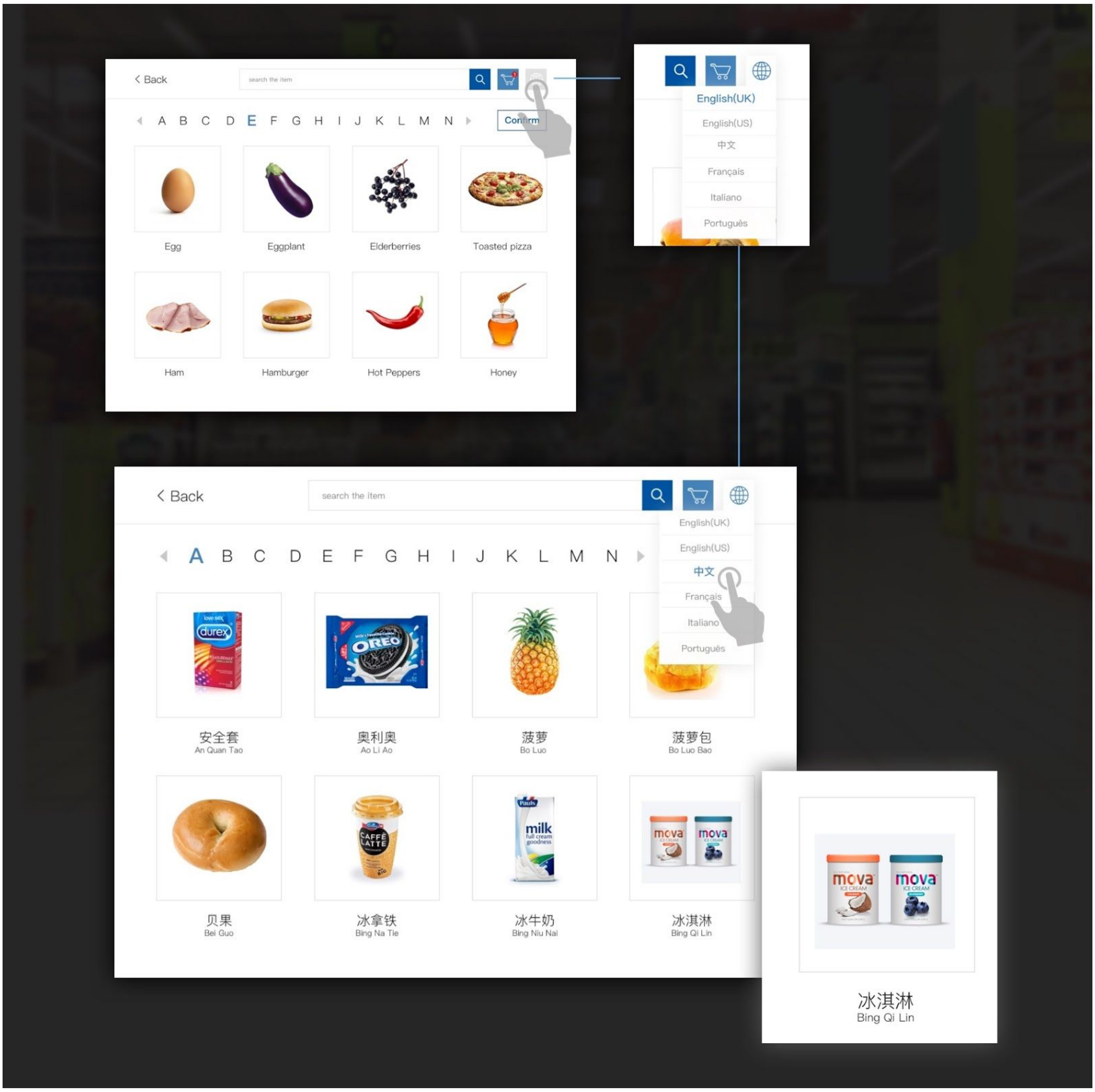

Figure 12: Hi-Fi and a translated interface

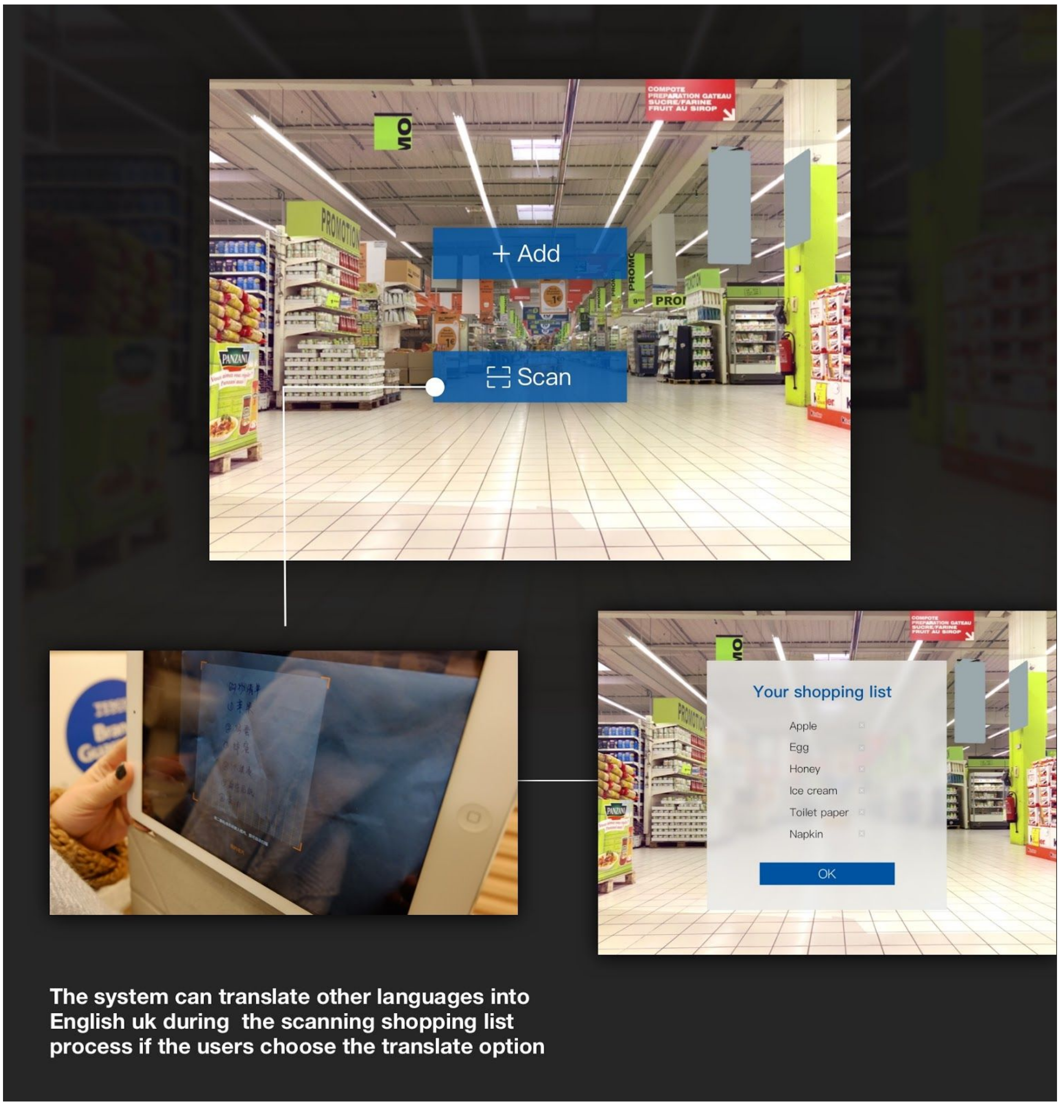

Figure 13: Hi-Fi and a translated interface during the scan process

Figure 14 shows a significant average time improvement for non-native English speakers when using our system. Proving the usefulness of the "switch language" feature.

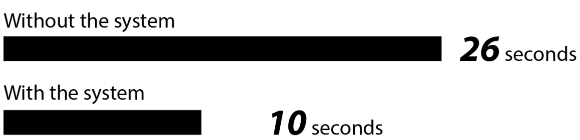

Figure 14: Average time of successful task completion between English and translated interfaces.

Fifth Round of Tests - Wizard of Oz

The fifth and final part of testing aimed to test overall system usability and the AR navigation system. Due to a lengthy development time of an AR system this part was also tested using WoZ testing with two users. In addition to WoZ testing, the users filled out

System Usability Scale (SUS) (Sauro, 2011) questionnaire and participated in informal interviews to collect both quantitative and qualitative data.

The test involved one participant and a human operator who followed behind and simulated the AR navigation system, and an observer who walked along to observe and record time. The test started with the participant adding items by manipulating the interactive prototype and entering the supermarket with a shopping trolley. After the shopping list was created, the operator called the participant using live video messaging application, and held some printed signs in front of the phone camera. Next, the participant followed the simulated AR navigation to find items. When approaching a wanted item, the participant would receive a notification sent by the operator, the process being described on *Figures 15,16* and *17*.

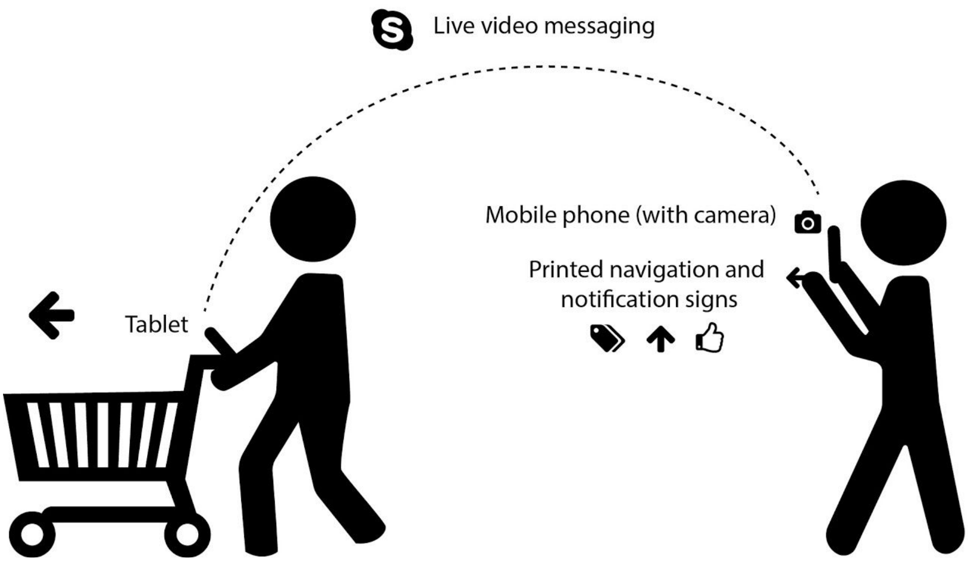

Figure 15: A conceptual WoZ setup

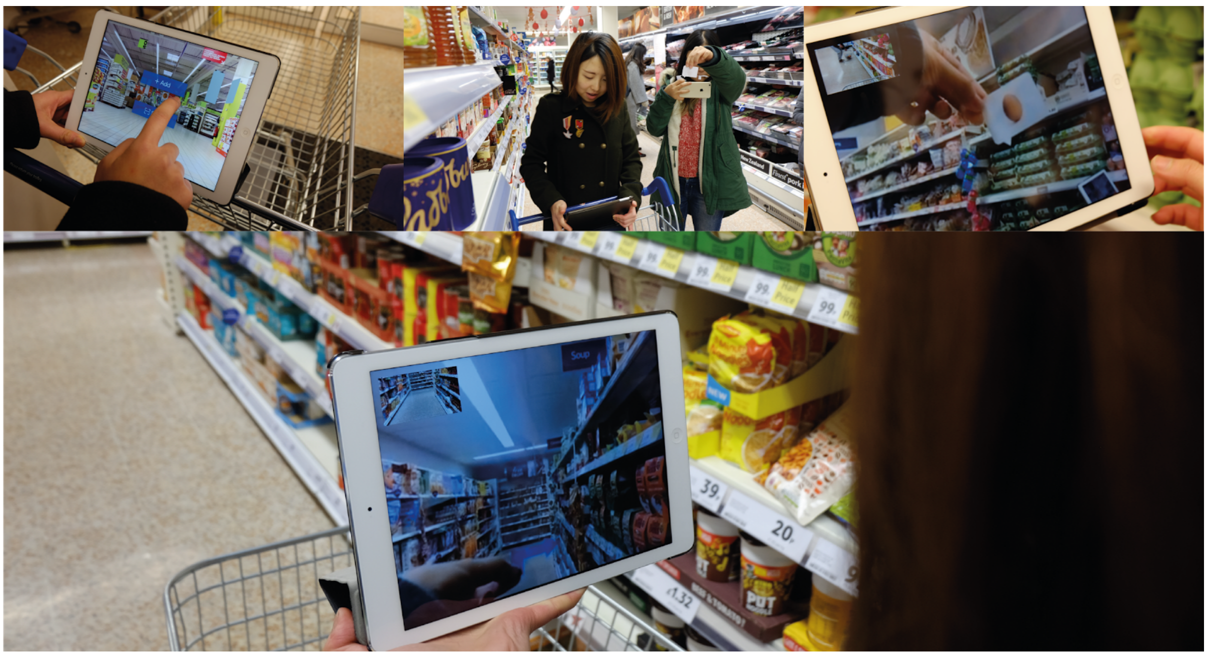

Figure 16: WoZ testing with participant 1 (group member)

Figure 17: WoZ testing with participant 2

The goal of the WoZ experiment is to test the functionality of the system, but also to evaluate its usability. Overall, both participants accomplished the shopping tasks and enjoyed the experience. We compared the average time spent on the same shopping list of people using our system and people just using their knowledge of the store. There was a significant time decrease with participants who were semi-familiar with out system as can be seen on *Figure 18* and *Table I*.

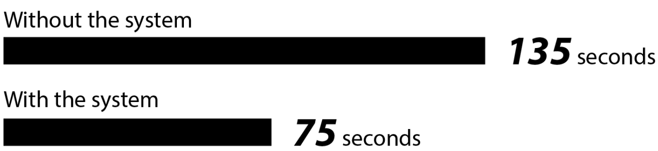

Figure 18: Time comparison of user's shopping time with and without using our system.

To measure the usability, we utilized the SUS method. Using Likert scale, the questions cover different categories, such as effectiveness, efficiency, learnability, and satisfaction. The participants' scores were converted to a new SUS number, added together and multiplied by 2.5. The results were positive (as can be seen on *Figure 18*), the usability scores were above the average score 68 according to industry standards, especially regarding learnability and integration of functions. In the follow-up interview session, participants raised several issues caused by the limitation of the WoZ testing method which are displayed on *Table II*.

Questionnaire statement	Use1's rating	SUS score1	Use2's rating	SUS score2
S1. I think that I would like to use this system frequenctly	3	2	3	2
S2. I found the system unneccssarily complex	2	3	1	4
S3. I thought the system was easy to use	5	4	5	4
S4. I think that I would need the support of a technical person to be able to use the system	1	4	1	4
S5. I found the various functions in this system were well integrated	4	3	4	3
S6. I thought there was too much inconsistency in this system	1	4	2	3
S7. I would imagine that most people would learn to use this system very quickly	4	3	4	3
S8. I found the system very cumbersome to use	4	1	2	3
S9. I felt confident using the system	4	3	5	4
S10. I need to learn a lot of things before I could get going this system	2	3	1	4
SUS score		**75**		**85**

Table : The System Usability Scale Scores

Issue	Description	Time of occurrence
Unstable connection	Due to the unstable Internet connection (personal hotspot), the live video call sometimes stopped. As a result, the image was blurred, making it difficult to distinguish navigation signs.	Participant 1
Congestion	Because the participant (with a shopping cart), human operator, and observer walked in a row, and the participant needed to stop at times to get items, the test caused some congestion in the supermarket.	Participant 1 and participant 2
Confusion about precise location	Participants were informed when approaching the wanted item. But some participant was confused about the distance between the location where he got notification and the location of wanted item.	Participant 2

Table : Issues raised during the test

Final Proposal

Full System

The final product proposal consists of a tablet mounted on a shopping trolley as displayed on *Figure 19*. The trolley has a forward facing camera to allow for augmented reality (AR) navigation displayed on the tablet.

Design

The design of the trolley was influenced by functional consideration as well as theory of ergonomics. The size, position, and angle of the tablet were examined in order to provide better experience. Vibration module is embedded into the handlebar, which is able to inform the user through tactile feedback when approaching the wanted item.

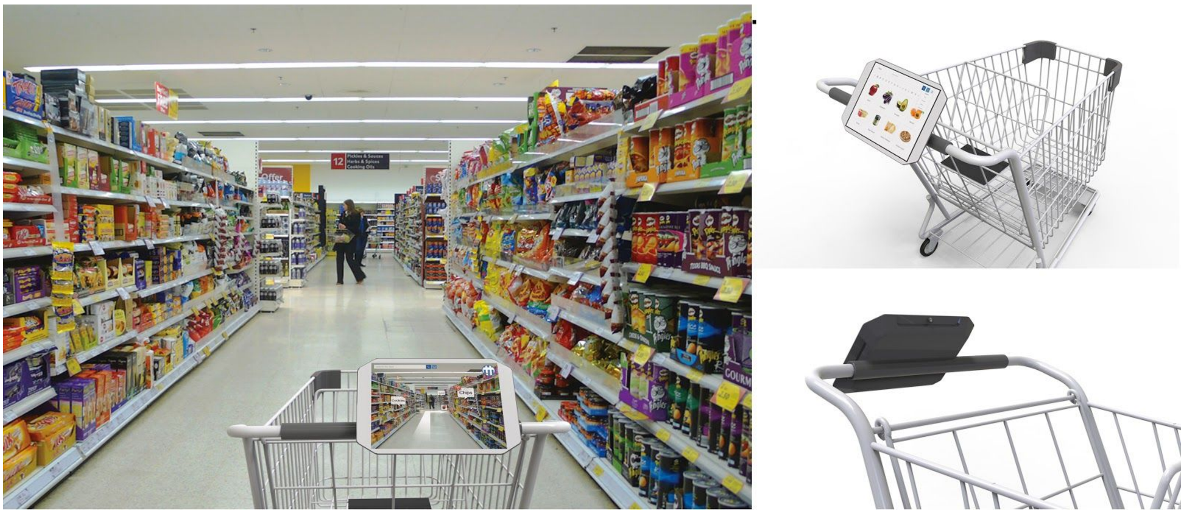

Figure 19: 3D design of the trolley

An effective and usable UI requiring the minimal number of steps to perform a task is a significant part of the system. Based on user testing the UI was inspired by alphabetical order common in self-checkout terminals. *Figure 20* shows user flows to add single or multiple items into a shopping list as well as scanning a handwritten one.

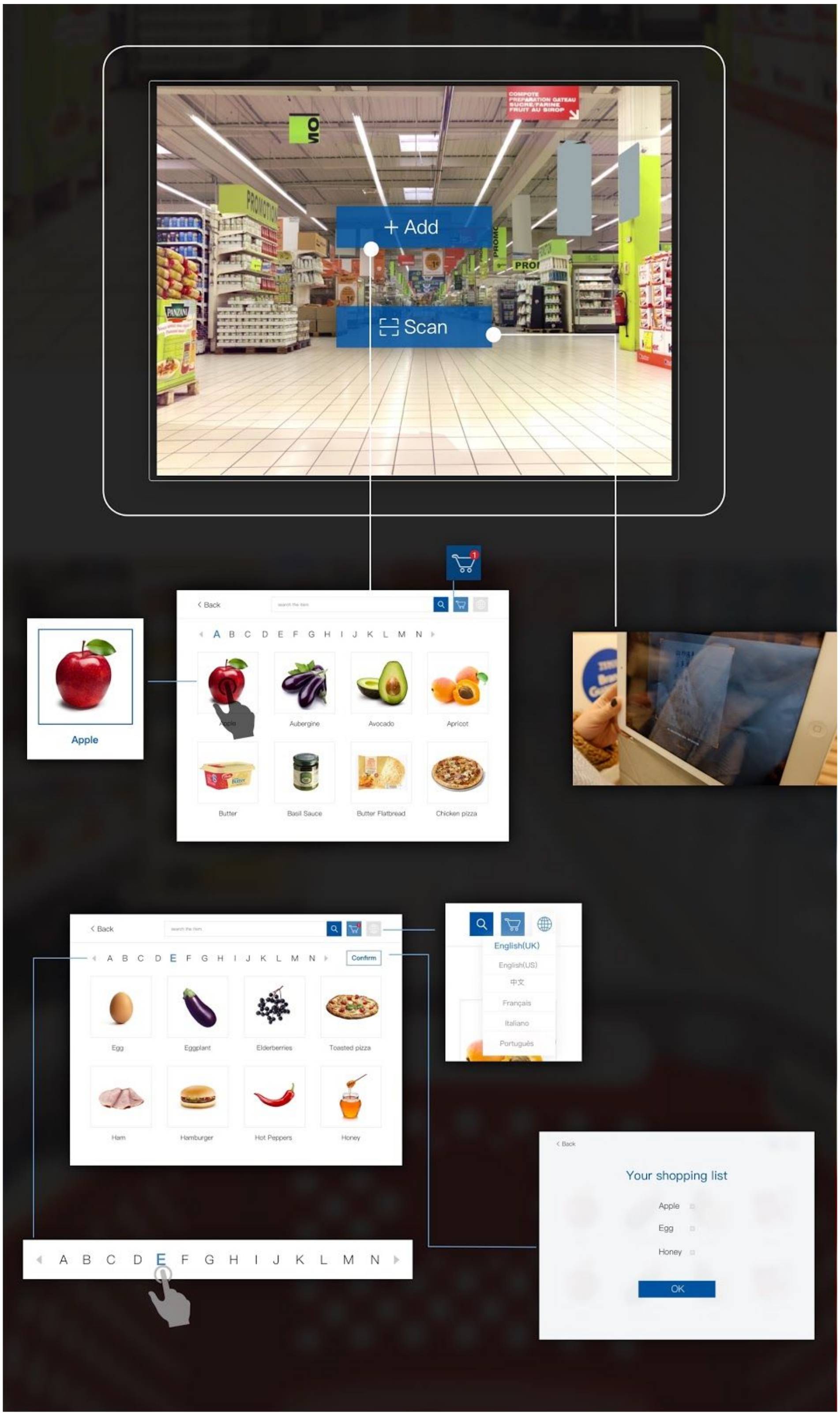

Figure 20: Interface design - creating shopping list

The system navigates the user through the store using Augmented Reality view making use the trolley's front facing camera. This view can navigate the user showing arrows and a map towards the sought item highlighting it as the user approaches as shown on *Figure*

21. When the system isn't in the navigation mode, when they have not added any items into the basket the system can still be useful by showing relevant information about items around. This information could be either discounts or categories of items in an aisle as shown on *Figure 22*.

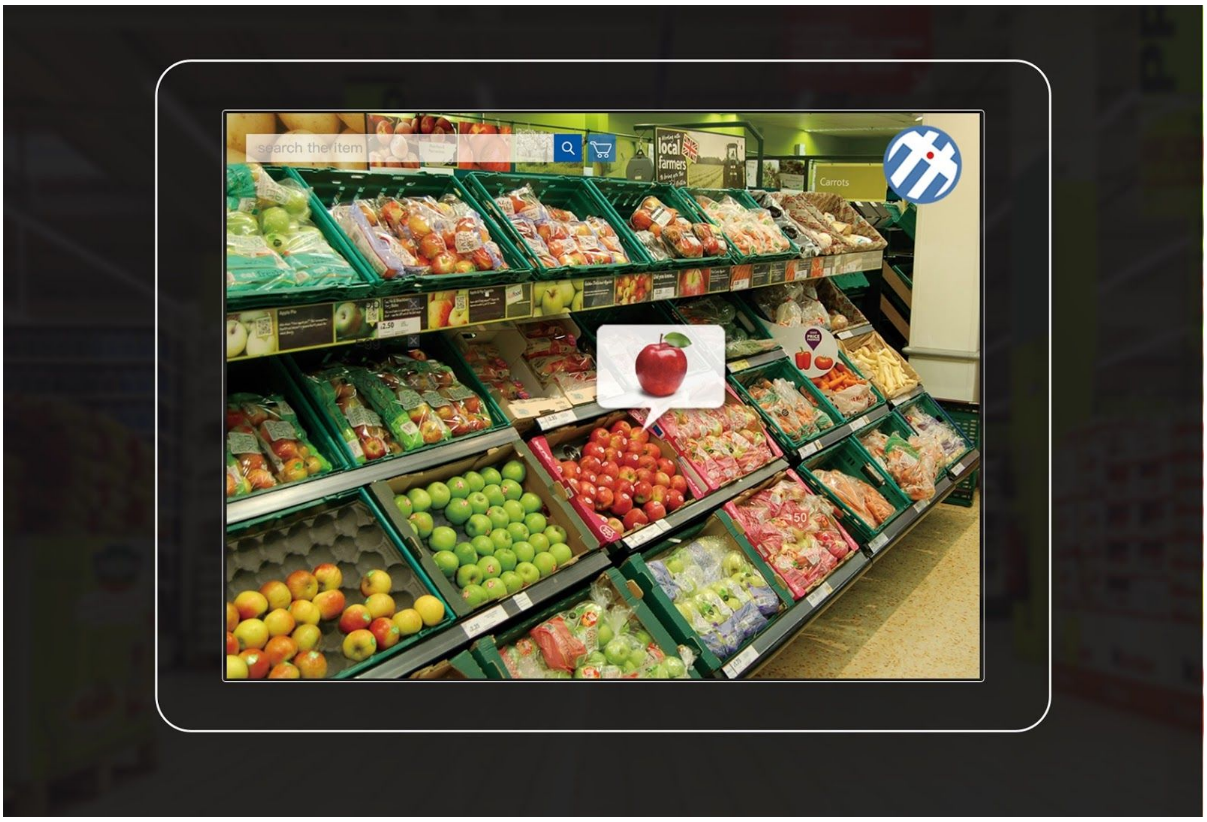

Figure 21: Interface design - AR notification

Figure 22: Interface design - AR navigation

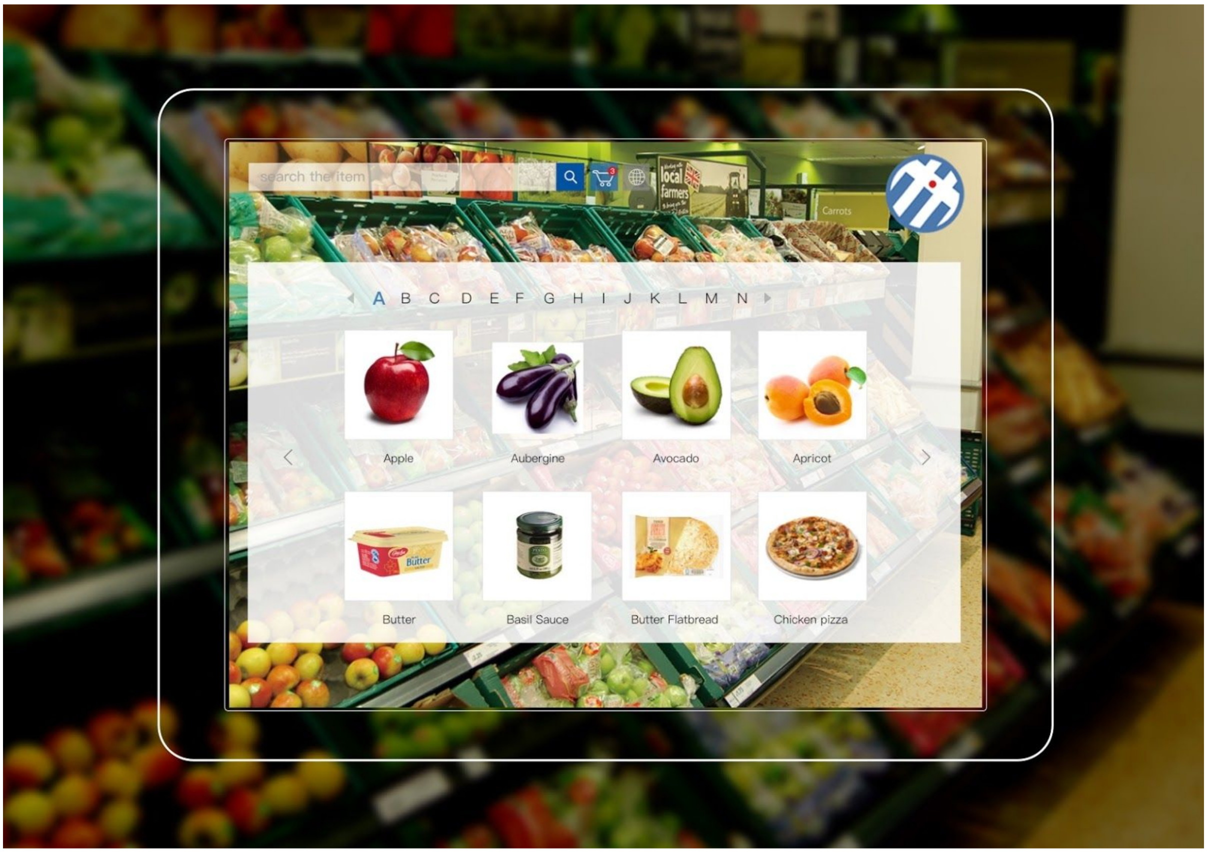

Figure 23: Interface design - adding items during navigation

Technical Diagrams

The system's indoor navigation uses Li-Fi technologies as it has been evaluated as the most precise and appropriate. Li-Fi based indoor position system has three main function blocks as can be seen on *Figure 24*:

1. Sample collection, aims to collect field strength;
2. Li-Fi position, used to locate items' and user's location;
3. Dynamic tracking, based on user location algorithm, to calculate dynamic tracking route.

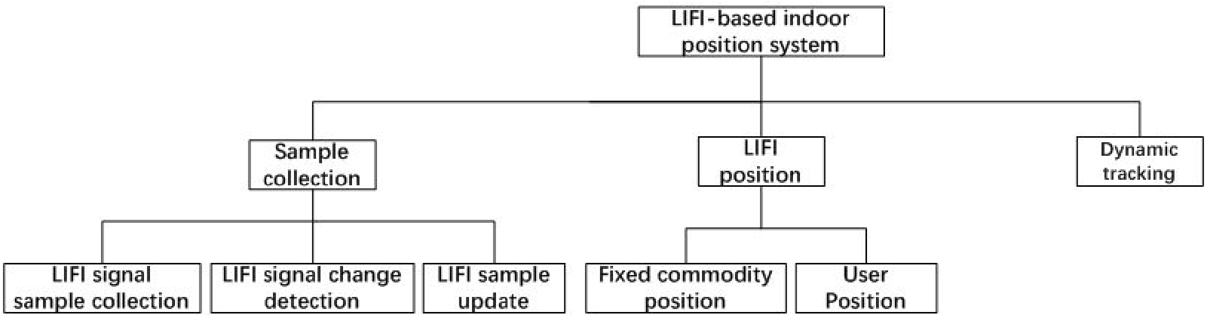

Figure 24: Indoor navigation flow-chart

The system's User Interface which requires the minimal amount of steps to achieve a task whilst being intuitive is displayed on *Figure 20* and a flow-chart showing precise states of the system is displayed on *Figure 25.*

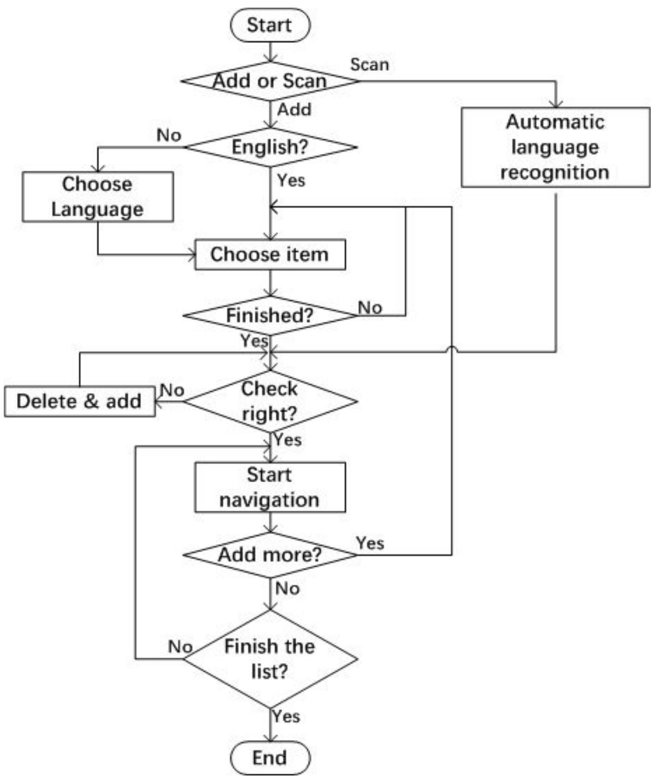

Figure 25: User interface flow-chart

Language selection use case for non-typical user

Testing phases revealed a non-typical user of our system, non native English speaker. Since our needs to adhere to general usability and adaptivity a lange selection button was added. The user flows for a general and non-typical use cases are depicted in *Figures 26 and 27*.

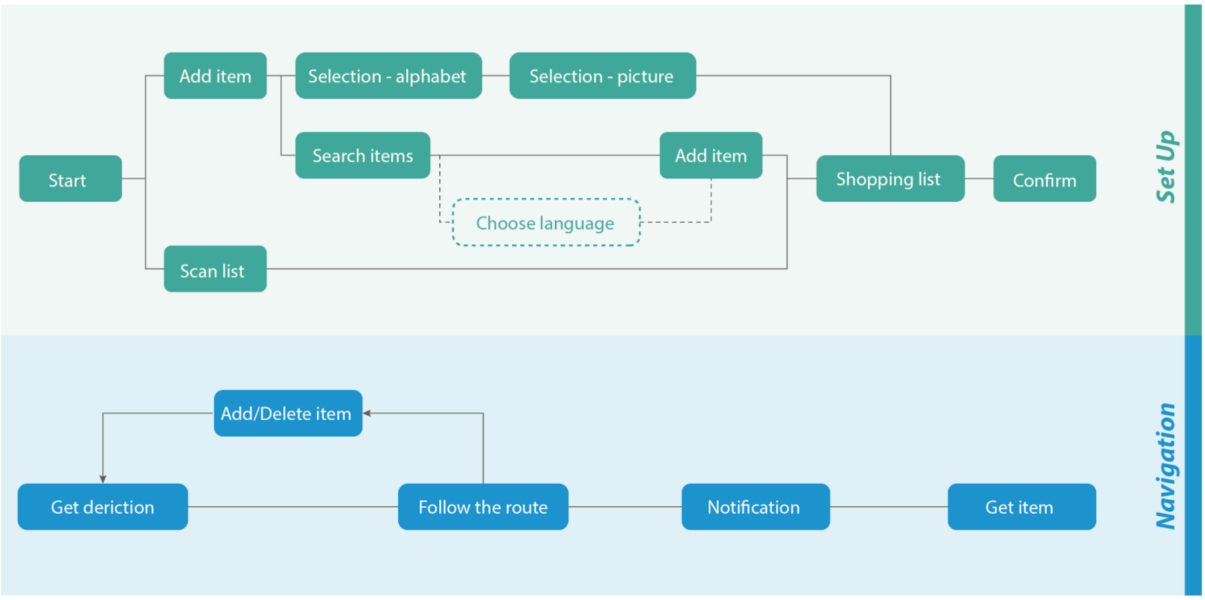

Figure 26: General user flow

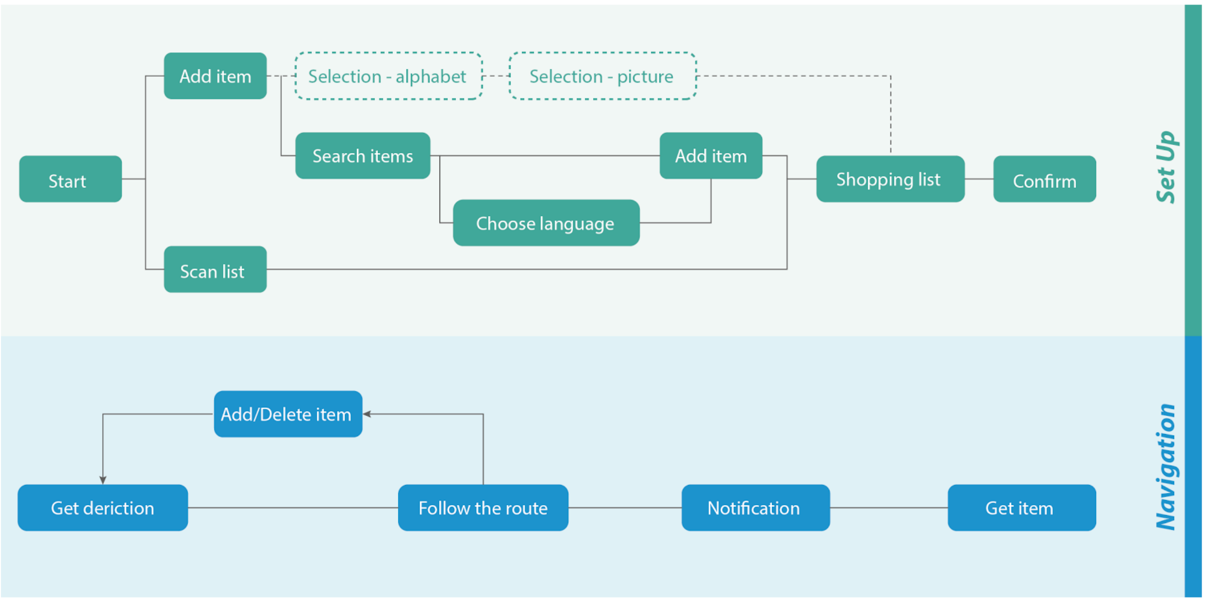

Figure 27: Non-typical user

Further Development

The proposed system focuses on carrying out a single core task of navigating the user to a single or multiple items within a supermarket. However, the tablet and the AR system can serve as a powerful platform to further enhance the customer's shopping experience.

This section provides examples of potential additional features and uses cases that could be implemented into the proposed platform. These ideas are hypothesis based on our observations and should be proven by testing with both customers and stakeholders to prove their usefulness.

- According to psychological item arrangement *(The Economist, 2008),* the system needs the way to engage the customers and keep them longer in the store and prompt them to purchase more. A common way the stores are already engaging customers is by offering promotions and discounts. The AR display of our system can provide further clues to highlight these promotions as can be seen on *Figure 28*.

Figure 28: *Interface design - discount items in AR navigation*

- Items could be segmented and clustered allowing the supermarkets to identify relationships between the products (McColl). This link will lead to showing not only popular items, but also certain items that are always bought together. For example, if someone has bought diapers then they might also require milk formula and consequently the supermarket offers a voucher for the associated product (McColl).

- The system should provide a way to understand synonyms, due to discrepancies between British and American English when referring to certain items (e.g. Eggplant vs Aubergine).

- Personalization is a very popular topic. Our system could provide a way of authentication for the customer. Allowing to show suggestions based on previous purchases, aligning users shopping behaviour with their personal goals (e.g. losing weight) or integration with other platforms (e.g. the store's online shopping features). The user authentication could be implemented in many different ways : using loyalty cards, through smartphone near field communication (NFC), image recognition (the system remembering customer's facial features), fingerprint scanning and many others. This feature would not only benefit the user but also allow the store to create better user profiles for marketing purposes.

- The system could display the current cost of items in the basket. Based for example on scanning each item. However, this might not align with the supermarket's goals as seeing the current price of the basket might discourage users from buying more.

- Optimal route calculation should be also implemented. When the user adds multiple items or a whole shopping list, the system should navigate the user by the most "optimal" way. In this case, "optimal" could mean shortest, but also could align with the store's goals and lead the user in a way that would prompt the user to purchase more items.

- Congestion avoidance could be a slightly more challenging but interesting task. Knowing the position of all trolleys within a store as well as some time based shopping patterns, our system should be able to provide the best route for each user to avoid congestion in different parts of the store. For example, if there is a lot of customers in the fruit section at the given time, other customers will be re-routed to get other items first, before visiting the fruit section.

- Suggesting or scanning recipes. The system's shopping list scanner could be extended to accept a whole recipe, where the whole list is transcribed and relevant ingredients are extracted. The system could also suggest recipes based on what the user has already in the basket, providing a good opportunity to increase store's sales. Further ingredients can be suggested to purchased in order to complete new recipes, prompting users to buy more.

Conclusion

In this proposal, we have outlined TesGo, an AR indoor navigation system which creates seamless shopping experience. We investigated the theoretical and technical background to better understand the context and define the problem. Following this, we outlined design guidelines to set theoretical principles. To approach an appropriate solution, we utilized a range of iterative testing methods such as WoZ to gain insights, collect data, and evaluate concepts and prototypes. We introduced the final solution from both design and technical standpoints. Finally, a variety of scenarios and future developments which were informed by the evaluation were discussed.

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