LEVERAGING FROM ARTIFICIAL INTELLIGENCE (AI) IN ADVANCING THE AUGMENTED REALITY (AR) GROCERY SHOPPING EXPERIENCE

by

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Abstract

Globally, people are extremely eager to save time and money while maintaining healthy life choices, especially when performing essential activities such as in-store grocery shopping. This paper presents a system that integrates Artificial Intelligence (AI) methods with Augmented Reality (AR) techniques to enhance the grocery shopping experience through the use of smart glasses. Our proposed framework deploys a Convolutional Neural Network (CNN) object detection model that allows for item identification. By simultaneously retrieving data from a large nutrition database, personal medical reports, and other grocery store related datasets, our intelligent system is able to provide user-centric nutrition facts, health and wellness tips, and unhealthy selection warnings that are augmented on a real time broadcasting of the smart glasses. Our state-of-the-art framework (CoShopper) demonstrates high accuracy in detecting grocery items, improves product selection, increases cost efficiency, and reduces the time spent in the process.

Keywords: Augmented Reality | Artificial Intelligence | Deep Learning | Smart Grocery Shopping | Digital Media | Smart Glasses | Wearables

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Introduction

Over the last few years, drastic changes in the retail industry has been forcing the permanent closure of a large number of physical retail stores which is what experts refers to as the “retail apocalypse” (Helm et al., 2020). However, that level of disruption is pivotal for traditional grocery retailers. While many supermarkets have adopted online shopping through their own websites and mobile applications, consumers by far are still in favour of being in the grocery store discovering new products in addition to seeing, feeling, and smelling the fresh assortment (Bauerova, 2019). At the same time, the convenient and personalized shopping experience that online shopping offers has transformed customers’ perception of grocery shopping (Singh, 2019). That is encouraging grocery retail giants to adopt emerging technologies that would improve customers’ in-store experience and exceed their expectations, as they are progressively realizing the need for people to save more time, spend less money and make healthier food choices all at the same time.

The current advancements in software and hardware technologies alongside people’s greater understanding of Augmented Reality (AR) are allowing engineers and researchers to develop innovative applications that effectively improve human performance in public environments and private sects. Numerous brands are developing a growing interest in integrating AR with shopping and many have already implemented the technology. A recent study has shown that 63% of retail stores are willing to use AR as part of their in-store customer experience (Williams, 2019). In the year 2020, 100 million individuals are shopping using AR in-store and online (Egham, 2019). As this interest grows, research shows that 75% of customers look forward to new technologies that could enhance their shopping experience (Afshar, 2019).

In addition, surveys have been conducted showing that 40% of shoppers are willing to pay more for an item if they experienced it through AR. Also, up to 61% of shoppers prefer to shop from brands that have AR over other brands that do not. Similar percentage (71%) of people would visit a store with AR more often than one that does not (Retail Perceptions, 2016). In response to this growing interest, technological advancements extended to include the industry of traditional grocery shopping. Specifically, AR technology has been utilized through hand-held mobile and tablet applications to provide shoppers assistance in locating products faster (Cruz et al., 2019), making healthy food choices (Ahn et al., 2015), as well as advertising for products (Zhu et al., 2004).

This research paper describes the architecture of CoShopper, a prototype of a system that employs AR as an intelligent guide that transforms the traditional grocery shopping into a personalized and rich user experience. CoShopper system adds a real-time digital layer to the traditional grocery store environment through the use of smart glasses. The main intention of our proposed system is to analyze the health status of the user then help in making healthy food choices to the fullest extent possible directly at the grocery store. Besides, CoShopper framework improves cost efficiency by featuring current discount deals offered by each individual grocery store.

Our system involves several components that are collaboratively functioning to provide user-centric assistance while at the grocery store. These components are, first and foremost, the health organization that will be feeding our databases with up-to-date medical information including medical reports and lab results specific to every user of our system. Accessing such information allows CoShopper to become aware of the amount of each nutritional element that the user needs to maintain a healthy diet. Our intelligent system will also consider all the diagnosed food allergy data and use them to warn the user from purchasing certain products. In other words, when facing products at the grocery store, our state-of-the-art system has the ability to directly distinguish between healthy and unhealthy products based on the user's own health records. This feature is achieved through the integration between the user's medical database and Nutritionix.com, which is the second component of CoShopper and the largest verified database of nutrition information in the world. Saving money is another feature that we considered in the development process. The usefulness of our system extends to display weekly-deals applied on certain items in real-time while at the grocery store. The autonomous flow of such data is derived from the connection between our system and each individual store's up-to-date discount deals.

CoShopper seamlessly integrates technology into the grocery shopping experience to increase clarity and improve product selection that best fit the user's needs. The idea of utilizing personal health and wellness data of each user to provide useful information is derived from the fact that today's consumers are constantly seeking new ways for technology to help them live a healthier lifestyle. Globally, many people are willing to share their personal health data with non-healthcare corporations such as Amazon, Apple, and Facebook for the purpose of getting access to healthcare and wellness services (PricewaterhouseCoopers, 2019). Three-fourth of smartphone users are concentrating on enhancing the quality of their lifestyle through the use of up to three health-related mobile applications (PricewaterhouseCoopers, 2019).

Literature Review

Online Grocery Shopping Research

Despite the current small percentage (5.5%) that online grocery shopping holds in relation to the total grocery shopping experiences, Brick Meets Click (2018), indicates that by 2022, online grocery shopping is projected to move into a growth phase of (13%), which is approximately 10 folds faster when compared to in-store sales (1.3% only). In addition, (Shanghai Daily, 2017) predicts a rapid growth in the market value of online grocery shopping from the current US$134.998 billion to reach US$170 billion by the year 2025.

According to (Research and Markets, 2020), several factors have influenced the increase of the online grocery shopping market across the globe. One being the fact that a higher percentage of the world's population are now using the internet than ever in the past and more people are connected to the web through their smartphones. The recent years of rapid technological advancements and increasing convenience have allowed people to purchase items at cheaper prices while saving time. This flourishment in the demand for online grocery shopping is also attributed to the ever-busier work schedules and the complexity in which commuting to work has become. This drives people to save more time and money using smart technology as the new method of grocery shopping.

It is crucial to understand what an average customer looks for when shopping for groceries. Over 40 percent of online grocery shopping individuals are interested mostly in faster and cost-efficient shipping methods, in addition to store promotions. Furthermore, about a third of online grocery shoppers are interested in being able to easily utilize online coupons to their checkouts. Out of every ten online grocery shoppers, three have mentioned that the offers made by the store are the primary determinant behind any decision they make to switch from buying a certain product to another (Supermarket News, 2019). When it comes to grocery shopping, more and more online users are looking for a smoother process in which the store provides a more convenient method in ensuring a maximum return of investments to customers (Singh, 2019). When this experience is not delivered, and the expectations are not met, it is noted that online customers will look for a different retailer that would fulfill these expected qualities (Singh, 2019).

It is therefore indicated that the vision behind the production of CoShopper is aligned with the projection of the grocery shopping experience in recent years, as it uses internet-based technologies to enhance the efficiency of the shopping experience. It also successfully brings the convenience features of the online world (i.e. comparisons, access to deals, and ease of navigation) and augments it onto an actual in-store environment.

Traditional In-Store Grocery Shopping Research

In-store grocery shopping, on the other hand, has remained to this day the dominant type of grocery shopping methods across the globe (Bauerova, 2019). This dominance is noted to be more prominent particularly when compared to other domains of retail such as electronics, office supplies and others. Electronic retail for example, have started to close down some of its branches to cope with the decreased demand on their in-store traffic while focusing more on online sales that have shown to drastically increase over the years. In contrast, research has shown that there are certain factors and features in grocery shopping that contribute to the continuous demand on in-store shopping experiences (Ocepek, 2018). Grocery stores have been utilizing human sensory perception as a key element in the determination of which product to be purchased. While there is a great amount of reading that customers typically do in stores when grocery shopping, they also often rely on their eyes, hands and nose to see, feel and smell the products before determining what to buy. The study by (Ocepek, 2018) addressed information processing and behavior, with emphasis on the value of sensory based experiences while grocery shopping. The study showed a significant link between those elements. Also, recent study by (Pratt, 2019) has shown that in-store experience is still the preferred and dominant method for an average consumer. The vast majority of the sample studied (64%) showed a preference towards looking at a product and touching it before buying it to insure freshness. Also, around (50%) of the sample reported enjoying the experience and routine of in-store grocery shopping. About a third of the sample mentioned that in-store grocery shopping is a reason for them to get out of the house. It is also important to note that only four percent of the sample studied reported that in-store grocery shopping is an inconvenience. This goes to show that the recent gravitation by shoppers to online shopping did not affect in-store grocery shopping as much, and technological advancements need to be utilized in an environment where the use of human senses remains intact. For an average in-store consumer, the top driver for the purchases made is the reputation of the brand and the sustainability of the product's quality (Pratt, 2019). It was shown that the infusion of technologies in grocery stores only drives customer's excitement when it is linked to the betterment of the food item itself (Pratt, 2019). Around 35% of consumers are interested more in the reputation of the grocery brand and 31% care more about the sustainability of certain qualities of products (Pratt, 2019). It follows that high technology should accentuate those values that are held important by consumers and retailers. This can perhaps be done in an aim to display certain promotions, compare two items, and recommend certain products based on customer's liking or purchase history.

In store technologies can help consumers make healthier and cheaper options inside grocery stores. (Adam & Jensen, 2016) has indicated that technological interventions can be introduced to traditional grocery shopping stores in a method that would stir people toward making healthier options. Numerous studies and research have shown that placing a person in an environment where unhealthy foods are promoted while healthy choices are discouraged would ultimately lead to a higher chance of developing obesity (Adam & Jensen, 2016). The opposite can be done in effort to promote healthy living and nutritional foods in grocery stores. In other words, methods including easy access to information, interactive nutrition box, and creative technological advertising of healthy foods inside stores can create changes in the shopping environment and therefore lead to healthier decisions made by consumers. It is worthy to note that there are no significant concerns of generational discrepancies between consumers when it comes to processing and utilizing new technologies in store while grocery shopping. The differences have been identified to be within only 10% between Generations X and Y and Baby Boomers (Bauerova, 2019).

A study by (Bartels et al., 2018) suggests that important nutritional information should be conveyed on the front of products in a stylistic, simple, and easy to understand display. This is because grocery shoppers funnel their attention more towards brand or product name, product imagery, and product pricing in comparison to nutritional facts at the back or side of the item. Implementation of such a suggestion does not only lead to consumers making healthier choices when deciding on what to purchase, but also empower them to make a highly educated choice. In Australia, however, it was shown that including nutritional information on the front cover of products, especially those related to fat, sodium and sugars strongly influenced consumers' choices positively and increased support for more nutritional facts being displayed at the face of items (Kelly et al., 2009). Therefore, it is predicted that using an instant creative augmented display of important nutritional information and health facts is pivotal in influencing shoppers' choice, enhancing their experience and ultimately increasing financial gains for the business.

AR has shown to be a superior technology to be used inside grocery stores when compared to Virtual Reality (VR). This is because AR allows for the use of all the natural human senses, which has shown to be a very critical element of the grocery shopping experience. VR on the other hand, has shown to be a useful technology in furniture stores and home decor. This is because consumers in those environments are more interested in item dimensions, shapes, colors, in addition to visualising how different furniture pieces can look together.

Augmented Reality Research

The term "Augmented Reality" was first introduced in 1990 by Tom Caudell, who was an employee by the American aerospace giant Boeing (Yianni, 2018). However, the first person to use a head mount display was Ivan Sutherland (Sutherland, 1964). This event is believed to pave the path for the current understanding of AR. The conceptualization of AR was actively put in use during the 1990s (Zak, 2014). This decade was the period where AR was used by the U.S. Air Force and Research Laboratory. It was also around the same time when NASA started using AR in their spacecraft (Yianni, 2018). The early 2000s is when the first AR game (AR Quake) was launched, with a head mount display (Piekarski & Thomas, 2002). AR was then introduced in smart phones, and NOKIA was the major player in this shift (Adema, 2016). Later in that decade, BMW used AR in their commercials, and utilized it for ads visual enhancements (Yianni, 2018). Closer to 2010, AR was infused with magazines when Esquire allowed its readers to scan the cover for AR stimulation (Yianni, 2018). In 2012, the first AR smart phone app was launched by Blippar (Yianni, 2018). Following that, more extensive use of AR in popular technologies was rapidly emerging. This manifested in the first AR game for Google glasses by Blippar, followed Pokémon Go by Nintendo. (Yianni, 2018) In 2017, the number of AR users in the US alone reached 37 million, and the number is expected to be 67 million this year. (Yianni, 2018)

Today, AR is not only involved in electronic games, smartphones, and entertainment technologies, but also brands from various industries such as Budweiser beers, Victoria's Secret, Audi Motors and Ikea Furnitures who are actively including AR in their advertising and business relations with their clients (Candy, 2017). Mirrors with embedded AR technology were used by major companies like MAC cosmetics and Uniqlo allowing customers to virtually try on their products without having to go through the process of wearing them (Lempert, 2018). The development and technological innovation of software and hardware is progressing with a growing understanding of AR by the public. This is allowing for a highly interactive environment that makes the future very promising.

After taking all contemporary research and relevant innovations into consideration, we define AR as a technology where a real time digital layer is added to the traditional environment, which in turn transforms the user's innate experience into a phenomenological integration of continuous synchronized data display onto the real world.

Augmented Reality Smart Glasses

AR smart glasses have already been introduced in several fields and have been designed to be used for various types of reasons including agriculture, tourism, public safety, construction sites, education, music and others. A recent study by (Litvak & Kuflik, 2020) concluded that museum visitors and tourists had an enhanced experience when using augmented reality at cultural heritage sites when compared to controlled visits without AR. Visitors also reported better learning experience with AR when it was used at cultural heritage sites. Another study has shown that when AR and smart glasses were used in livestock farming, farmers were able to utilize real time file consulting and collect necessary data in a hands-free fashion (Caria et al., 2019). Farmers were also able to share their data and even seek assistance remotely, which increased the efficiency of field operations and ultimately productions (Caria et al., 2019). Smart glasses were also used by (Baek & Choi, 2020) to measure the change in stress levels of construction workers during the day while they wear smart glasses that detect approaching pedestrians and machines. Construction and mine workers reported less stress and more concentration during their shifts when wearing smart glasses in comparison to the time when they did not (Baek & Choi, 2020). Educational institutions have recently started introducing smart glasses to aid in information processing for students, especially those who need enhanced visual or auditory stimulation (Berger & Maly, 2019). This method has been shown to produce positive effects on education and learning (Berger & Maly, 2019). There is a continuous growth not only in the market size for glasses but also in technological advancements. For example, adding audio features to smart glasses and even sunglasses are also a recent technology and an emerging business. The recent studies show that the smart glasses market is projected to have a value of 22.45 Billion US dollars by the year of 2025 (M2 Presswire, 2019). The key advantage in using AR integrated smart glasses is the ability to perform certain tasks and acquire information completely hands-free. This is a pivotal progression from the older method of using hand-held devices to utilize AR.

Integration Between AR and Artificial Intelligence (AI)

We define AI as a technology that allows machines to be programmed in a way that replicates the learning process of the human brain and take actions on their own rather than on command by a human. For instance, deep learning is the technique that allows driverless cars to take actions on their own when recognizing a stop sign or a pedestrian. The capabilities of AI extend with its power to process massive amounts of datasets and provide users with the most relevant information that ultimately personalizes their experiences in real time. As content personalization continues to grow among customers (Genchur, 2020), the combination of AI models with AR techniques bridges the real and digital worlds.

The integration between AR and AI drastically improves the potential capabilities of the smart-glasses. Over the past decade, many major companies have been heavily investing in the development of wearable smart-glasses that could benefit various sectors including healthcare, airlines, and the military. For example, HoloLens2 is a pair of AR smart-glasses that was developed by Microsoft to deliver an immersive experience for the user. The tech giant believes that the combination of AR capabilities and AI services on their comfortable headset empowers the user to increase productivity and build innovative, reliable, and secured solutions. Envision is a start-up that partnered with Google to develop an AI-powered software to assist blind and visually impaired individuals to see through the use of Google Glasses.

Augmented Reality in Grocery Shopping

The current advancements in integrating AR with the grocery shopping experience are stemming from a series of projects and studies aiming to save customers money or help them make better choices in a shorter amount of time. (Asthana et al., 1994) were one of the pioneers who introduced the concept of personalized shopping assistance through a “walkman-like” device placed on the customer’s cart. The device interacts personally with the customers aiding them in making shopping choices based on their previous preferences.

Employing AR technology into the grocery stores enables shoppers to select healthy food products when bombarded with hundreds of products in each grocery store aisle. A study was conducted in a traditional grocery store environment to evaluate the performance of a mobile-based augmented reality system (Ahn et al., 2015). The results indicated that employing AR technology into the grocery shopping experience helps shoppers not only in making healthier food choices, but also in reducing the amount of time spent in the process by at least two to three times the speed usually spent on finding healthy products (Ahn et al., 2015).

Using AR in grocery shops has additionally helped in utilizing contextualized marketing strategies to offer the appropriate content to the proper receiver at the proper time. PromoPad, for example, is a device that is designed to provide customers with personalized advertising and shopping assistance (Zhu et al., 2004). It is a hand-held pad that provides dynamic contextualization through the use of augmented reality (Zhu et al., 2004). Even though a device like PromoPad is considered to be a great step towards personalized, contextualized advertisement, the utility and ease of use is fairly limited. PromoPad, however, is not the first attempt to introduce tablets as a way of helping customers have a better grocery shopping experience. MyGrocer is a pervasive retail system that uses a tablet which connects to the smartphone/home appliances and detects the customers shopping list (Kourouthanassis & Roussos, 2003). From there, it would guide the customer towards saving time and money during shopping. Participants in the project appreciated the value it added to their shopping experience as it also featured a continuous evaluation of the value of their cart, which also saved them time at the checkout (Kourouthanassis & Roussos, 2003). A more recent study, by (Cruz et al., 2019), showed how AR is used to help people utilize their phones to locate themselves within giant stores and provide them with guidance to a desired location. This project however, was limited to location detection and was not tailored to detect items, much fewer displaying promotions and items comparisons.

The major source of limitation for the mentioned projects and studies is that they utilized a method by which the hand of the shopper is occupied with a device that is either hand-held or mounted on a cart. The device itself tends to distract the shopper from having a smooth and efficient shopping experience. Therefore, the use of a tool like smart glasses can be more superior as it frees the shopper's hand and minimizes visual disturbance and interruptions.

Methodology

CoShopper Dataset: Grocery Store Dataset

In this section we illustrate the procedure that we used to collect the visual data samples for the store items and label them to generate a qualified dataset that can be used to train our object detection agent. One part of our framework uses a Convolution Neural Network (CNN) based object detection model. In order for these models to be able to recognize objects in the scene, they need to be trained on a large size visual dataset containing labeled and Bounding Boxes (BBX) annotated items. This brings us to the first problem which is insufficient visual representations for grocery items. There is no dataset that is specialized for grocery items that we can use. For instance, COCO dataset has 91 randomly selected items in which all are labeled with unique names and annotated with BBXs over more than 1.5 million images (Lin et al., 2014). PascalVOC has 20 different items in its 27,450-image size dataset (Xiang et al., 2014). The process of gathering these visual data is time consuming and needs human resources even with the engagement of labeling and annotating tools (Russell et al., 2008). However, it is possible to collect grocery items dataset interactively and learn a network on a smaller size dataset.

As our prototype employs an object recognition agent that its task is to recognize the item in the live video broadcasting feed and predict its class, our target is to video record different items in the store. We created a list of 11 randomly selected grocery store items taking in consideration that these items have data in the largest verified nutrition database in the world, Nutritionix (Nutritionix, 2020). To extend the flexibility of our framework, our shopping list contained items from different categories including food and non-food items (See table A). In addition, some of the items selected are placed on the store shelves individually, such as the dates (See Appendic C – Figure C-4), while others were placed as a group, such as the pineapples (See Appendix C – Figure C-2).

Training and testing videos were all filmed using a smartphone camera which was held from a height that mimics the experience of the user wearing a pair of smart glasses with a mounted frontal camera. Our dataset contained a training video for each item individually while the testing videos were filmed for each item individually then they were all combined into one two-minutes video. With the training videos, each video focuses on the appearance of one item per frame in different locations which is the standard procedure that is followed in COCO dataset generation (Lin et al., 2014). Videos duration is set to 45 seconds for each item to give us enough time to move around the object of interest. An example of the training videos can be viewed on YouTube channel (Alhamdan, 2020). Training videos were focused on filming each item from different angles and depths with minimum recording time equals 60 seconds (See Appendix A – Figure A-1). This procedure helps us to eliminate redundancy between image samples. The testing videos on the other hand, focused on filming the actual shopping experience of the user facing the item, grabbing it, and placing it in the shopping cart. An example of the testing videos can be viewed on our YouTube channel (Alhamdan, 2020).

Images from the collected videos are extracted every other nine frames to have more variations between the image samples for the item's objects and backgrounds. Manually labeling the frames of the collected videos is a hard task. Therefore, we need to employ a tracker to facilitate labeling our object instances. Therefore, after all items' videos are being collected, we follow a similar procedure in DUNET model to assign the BBXs around the objects of interest. First, we assign the initial BBX coordinates around the item in the first frame of each video manually (See Appendix A – Figure A-2). Then, we used a tracker (Re3) to assist us in generating the BBXs autonomously around the item in the successive frames in each video by calculating the BBX coordinates (*minX, minY, maxX, maxY)* and save them in a separate sheet inside our dataset (Farhadi, 2018). Some coordinates are manually adjusted in order to build a precise ground truth dataset. Our dataset contains images for the items: pineapples, red pepper, dates, cheese, corn oil, olive oil, and mouthwash. The dataset is divided into training set (75%), validation set (25%). All images are 640 by 360 pixels taken in the rate of 30 Frames Per Second.

CoShopper Architecture

Now that we have our database ready, in this section we present the key components of CoShopper framework including the Object Recognition Agent, Nutrition Data Analysis Agent, Health Agent and finally the Smart Glasses Agent (See Appendix B, Figure B-1). The experience of the user begins with a welcoming message that is unique to every brand as part of their branding strategy (See Appendix C – Figure C-1). One of the key elements that will be augmented for the user multiple times for an easier and quicker shopping experience is the user's shipping list (See Appendix C – Figure C-7 and Figure C-12). To increase the reliability of CoShopper, we included the barcode reader feature that would be activated when the detection does not run as smoothly as intended (See Appendix C – Figure C-11).

Object Recognition Agent

Deep Learning (DL) is an Artificial Intelligence (AI) method that can be used to learn the machines and predict actions correctly in the real world based on its learned experience. In our framework, we deployed DUNet (Dense Upscale Network) object detection model, a CNN based network, to predict the objects' labels and bounding boxes through Supervised Learning (SL) on our in-store collected dataset (Alabachi, 2019). Object recognition models contain two loss functions, one for classification and one for regression that by minimizing their values the model learns to localize object instances with a BBX and identify their labels by analyzing visual representations in the live video broadcasting feed that is coming from the glass's camera. These tasks are done through extracting visual features and applying the multi-box procedure on different scales and offsets of the training samples. However, in order to make our framework able to perform on a live streaming, we need a fast object detection model that has the ability to provide the item label in real-time in addition to the ability to perform adequately on a small dataset with a limited number of samples. Keeping in consideration that there is no similarity between our collected dataset and any other generic dataset such as COCO and PascalVOC which needs a model that would be trained from scratch and not adopt transfer learning techniques. For the mentioned reasons, we employ the DUNet object detection model (Alabachi, 2019). DUNet collects images dataset using Augmented Reality (AR) Drone and after the training phase, the same drone is used to detect the learned objects on live broadcasting video streaming from the drone perspectives (Alabachi, 2019). Upon experiments, we found that the DUNet model performs a good balance between speed and accuracy. After the training phase, the learned weights that are used in the inference on a full video version in the store with different item categories. The predicted label is passed to the nutrition database to get the nutrition facts and check the medical report for any alerts or recommendations. However, it is important to note here that the detection process for some items on the shopping list such as the rice and the kidney beans did not run accurately. That is mainly due to the fact that the packaging of these items is identical to the items placed next to them on the same shelve.

Nutrition Data Analysis Agent

First, this agent takes the predicted label from the object recognition agent and passes it as a query to the online Nutritionix dataset through the provided API and our framework credentials. The aim of our prototype is to assist users from different genders and ages in having a healthy lifestyle by making grocery selections that best fit their health and wellness needs. Augmenting the nutrition facts of every store items in real-time is a much easier task than using mobile applications that require the user to scan and upload the barcode of each item in order to read the nutrition facts. That process is time consuming and deviates customer's attention from the shopping experience itself. Our framework can run on smart glasses to keep track of a healthy diet based on the user personal medical report while grocery shopping in completely hands-free fashion. All vitamins and minerals are viewed to the user just by facing any kind of fruits, vegetables, or commercial products. Our framework is connected to the largest verified nutrition database to retrieve all the required nutrition facts for any kind of food or beverage.

Health and Wellness Agent

Another key component of our framework is the health and wellness agent. This agent is responsible for retrieving information from the user's recent medical report. The medical report contains important information regarding grocery store items that must be avoided by the user and their effect on the user's health condition. This report is to be completed by a verified health organization. When the user is facing or hand-holding a certain item, the health agent retrieves the dataset related to that item from the medical report. Warnings would be augmented for the user upon the detection of non-healthy items along with healthy alternative suggestions (See Appendix C – Figure C-8). The detection of healthy items would display for the user user-centric health tip (See Appendix C – Figure C-6 and Figure C-9). This goes for non-food items as well such as the mouthwash (See Appendix C – Figure C-10).

Data Augmentation on the Smart Glasses

This agent is responsible for extracting the frames from the live broadcasting and passing them to our platform agents for processing. It is also able to get all the deals and ads of the grocery store for different kinds of foods and products based on optional subscription.

After capturing the results from all of our agents, the AR agent views the augmented frames on the glasses. The AR agent is also supported with a text reader that can inform the user with the warnings and recommendations through the glass's headset.

Evaluation

Development Environment

Google Collaboratory (Google Colab) is a cloud service that allows users to write and execute Python scripts through the browser. There are multiple reasons for choosing Google Colab as the main platform to build CoShopper. The first reason is that Google Colab supports Keras, TensorFlow, and OpenCV which are the deep learning libraries utilized for training and testing processes. Google Colab also offers a high-performance Graphics Processing Unit (GPU) of 12 GB. However, purchasing the Google Colab subscription is necessary for increased usage limits. Finally, the fact that Colab notebooks are stored on Google Drive enables the user to easily read and share files. We stored all of our project files, datasets and outputs on a Google Drive folder.

Dataset Collection Environment

To create the visual dataset that we will be using to train our object detection agent, we visited multiple stores across the Halton-Peel region seeking for the store that offers the best video recording environment. The ideal environment is the one that has a suitable visual environment when it comes to lightning, item organization, variation of item brands, and aisle dimensions. The videos we film require adequate brightness that is consistent across all aisles as poor setups and excess of misplaced items could affect the reliability of system detection. Therefore, the store of interest is required to have the proper maintenance and organization of items across all departments. The items in our targeted environment are required to be diversified enough to accommodate for the limited amount of comparisons and information display retrieved from the nutrition data source, since the source we intend to use may not contain information regarding every single item in Canadian grocery stores. In addition, the dimensions of every aisle in the store need to be wide enough not only for the recording to take place, but also to allow for multiple viewpoints and depth in order to enhance the performance of the object detection model. After explaining the concept of our project and requesting filming permission from three different grocery stores (Metro, Loblaws, and Longos), Loblaws store was the most receptive and accommodating to our project.

Color-Coded Nutrition Facts

We want to assist the users of our system in understanding the nutrition facts of every item they face at the grocery store. Therefore, we decided to display color-coded key nutrition facts based on the user's current health condition. We first created a CSV file containing a list of nutrients that are most important for the user's health condition along with their threshold values which represents the amount that user need of each one of them (See Table B). These values were used to color code the key nutrition elements. The colors range from white to orange and from white to green. Nutrition elements colored in the range between white and orange represent healthy and unhealthy items. White being healthy while orange being unhealthy. Other nutrition elements colored in the range between white and green represent healthy and essential items. White being healthy while green being essential. For instance, Welsh Cheddar Cheese contains Carbohydrate, Calories, and Sodium that are color coded with white, light orange and orange respectively (See Appendix C – Figure C-3). This means that this whole item contains a healthy amount of carbohydrate, moderate number of calories, and unhealthy amount of Sodium.

Unhealthy Selection Warnings and Healthy Alternative Suggestions

A hypothetical individual with certain medical conditions and specific dietary needs was created to thoroughly test the health agent of CoShopper system. This process started with the conduction of multiple virtual discussions with a medical doctor with regard to how a person with multiple common health concerns will benefit from our proposed framework. We were able to create a hypothetical health and wellness recommendations list of a 55 years old male patient with High Blood Pressure (HBP), Diabetes and allergy to corn (See Table C). This patient already has three risk factors for developing a heart attack or stroke. One of the major factors in preventing these tragic outcomes is controlling his diet. We learned that a healthy diet plays a major role in improving such patients’ quality of life and prolonging their lifespan. Therefore, we included a set of items that our user must be avoiding along with recommended ones based on his health condition. Essential nutrients that our patient must consume on his diet to cope with his health condition were also included in the health and wellness recommendations list. In addition to the International Statistical Classification of Diseases and Related Health Problems (ICD) code for HBP, food allergy, and diabetes.

With the help of our consulted medical doctor, we created a sample medical report for our health agent (See Table D). This report lists every grocery item (food and non-food) that the user must be avoiding as these items negatively affect his health condition. Our hypothetical patient's medical report also includes a warning messages that will be augmented for the user upon the detection of any of the mentioned unhealthy items. The report also included healthy alternatives for each of the unhealthy items and they will be augmented for the user to encourage him to switch to the healthy alternative. The Excel sheet was converted to a CSV file and uploaded in CoShopper Google Drive account.

Grocery Store Weekly Discount Deals

CoShopper offers the user a cost-efficient shopping experience through the augmentation of current discount deals offered by each individual store. Considering the fact that we were not able to retrieve the weekly deals flyer issued by Loblaws from their website, we decided to create a CSV file as an alternative solution (See Table E). The list contained categories, brand, item, original price and discount deal. For example, while the user is holding a pack of Whole Wheat Loaf, discount deals applied on other types of loaf will be displayed (See Appendix C, Figure C-5).

Conclusion

Implications for Future Research

This research project provides a solid foundation for future work aimed towards further enhancements on the grocery shopping experience. Further research can be done on the possibility of utilizing a smart fridge and synchronizing it with CoShopper. Smart fridges can be used to supply CoShopper with instant information on the quantity left of certain groceries. This helps users save time creating their shopping list and remind them about items they may be running low. The electronics giant, SAMSUNG, has recently launched a smart fridge called "The Family Hub" enabling shoppers to have instantaneous access to the inside of the fridge (Cocco, 2017). As the technology advances in the making of fridges, more opportunities are available to integrate in a project like CoShopper.

Other research horizons to be explored is the further enhancement of detection reliability and precision of CoShopper. The current state of CoShopper requires a high level of organization of items and shelving in order for proper detection to take place. Future research can be done to allow a system like CoShopper to detect groceries even if they are misplaced, poorly organized or even poorly labeled.

Customers ratings feature can be added to the framework in the future. The system can be programmed to either allow users to leave ratings and review verbally or manually through an online website linked to CoShopper. This helps the customer obtain an instant evaluation of the product's quality in addition to another consumer's impression of the product. This also opens the door to develop another feature subsequently, which is the display products comparisons based on popularity and ratings across one shelf.

Implications for Practice and Future Recommendations

Compared to other progressive countries across the globe such as Sweden and Finland, Canada is still behind in providing citizens a convenient access to their medical records (Glauser et al., 2018). However, in recent years, more and more Canadian health organizations are working with the government on creating systems and online platforms where Canadians can access their health information whenever they want instantly. Therefore, there can be a progression towards creating the ultimate method by which medical information can potentially be automatically transferred from the doctor's note, passing through a mediating electronic agent, and installed into CoShopper. Currently, LifeLabs in Ontario allow their patients to view their results online and access their personal records anytime they desire. MyChart is also an internet medium that is being used in most hospitals in southern Ontario, currently allowing patients to have permanent access to their medical records. These recent changes could open the door for an automatic transfer of medical information from platforms like the ones mentioned to a framework like CoShopper. Such integration can only be achieved through a consented process that honors the Health Insurance Portability and Accountability Act (HIPPA) and prioritizes the security of information.

Limitations

Multiple limitations were noticed, and some can definitely be attributed to the unfortunate pandemic of Covid-19. The first limitation was the fact that many stores were generally discouraged from allowing us to freely film inside their store. For some, the reason behind the restriction was a general strict policy from the higher management, and for others it was the current situation of Covid-19. This complication has prolonged our process of obtaining the filming permission and limited our store options.

Secondly, the initial project executive plan was to purchase smart glasses with an open source and then have our framework installed on it. However, this would require multiple visits to the store to test our framework. Due to the pandemic, we were limited to 3 filming visits in Loblaws, our filming place of choice. Therefore, it was necessary to switch to an alternative solution which is the live video broadcasting as it does not require as many store visits.

The third source of limitation was the fact that some items were packaged with a high visual and lingual similarities and placed next to each other. This has caused some difficulty with detection, especially when compared to items that have high contrast in relation to the ones next to them.

To reduce the effect of the potential shortcoming, a bar-code reading feature was programmed and integrated into CoShopper to instantly detect and identify the item of interest when the default method of detection is not smoothly operating. The issue with this is that the shopper will need to maneuver the item manually in order to expose the barcode. Finally, even though we were successful in choosing a very large nutritional facts data agent (Nutritionix.com), not every item in Loblaws and other Canadian stores is available on this dataset. This could limit our system from providing information regarding certain items desired by or recommended to the user. All the mentioned limitations could be an area to further explore, research and enhance in the future to come up with a more reliable framework.

Adaptation with the Pandemic of Coronavirus Disease (COVID-19)

Certain factors such as the weather, the political atmosphere, and even a pandemic can influence the supermarkets and grocery stores industry. The unforeseen crisis of COVID-19 pandemic has brought the online grocery shopping market to the forefront as one of the most growing fields in the past months. The number of people staying home has exponentially increased and therefore spiking numbers of online purchases for essential groceries was shown (Keyes, 2020). However, that transition is preventing customers from enjoying the advantages of the in-store grocery shopping experience. This raises new horizons of research that are primarily focused on allowing individuals to take advantage of our CoShopper framework while the new guidelines of COVID-19 are remain intact for the protection of the employees and the customers.

During the current health crisis, giant grocery stores are searching for innovative ways to improve store operations, increase cost efficiency, and ensure health and safety for the shoppers and essential workers. According to experts, robots and AI is the ultimate solution that will help grocers stay competitive during the crisis. For example, Broad Branch Market closed its stores to customers and partnered with Starship, which is a mobile application that allows shoppers to create grocery orders that are delivered via autonomous robots at a lower cost than the traditional delivery services (Meyersohn, 2020). Walmart executives also believe that robots are the future of retail automation as they deploy Auto-C, a self-driving floor scrubber, across 40% of their stores (Harwell, 2019). Given the direction that many grocery stores are heading towards, we believe that CoShopper is able perform its full potential for the users while they are safe at their own place. With a combination of our framework installed on smart glasses, computer screen, and in-store robots controlled by the user, we provide a rich and personalized grocery shopping experience.

The experience begins with the customer logging into the store's website through which they access a feature that allows for a thorough, up to date, video-based store experience. The video will be streamed by a robot that is placed in the physical store and controlled by the user. As the video is live streaming on the computer/laptop screen, data augmentation by our framework will be activated on the user's smart glasses. This will enable the user to make the picks that best fit their needs and ultimately proceed for the online checkout. This method is not only a potential solution for the COVID-19 pandemic, but also an important projection to how future grocery shopping experiences will look like after the COVID-19 crisis has passed.

Summary

This project proposed CoShopper which is a system that integrates Augmented Reality techniques with Artificial Intelligence methods to offer a personalized and rich user experience through the use of smart glasses. Our framework deploys a Convolutional Neural Network (CNN) object detection model that allows for items identification while at the grocery store. Our framework is linked with multiple data sources including the largest nutrition dataset in the world Nutritionix, personal medical reports, and other grocery store related datasets. Our system demonstrated high accuracy in the detection of each grocery store item on our shopping list. CoShopper has the ability to simultaneously retrieve all data relate to the detected item. Our deployed agents are also successful in analysing the retrieved data based on the user's current health condition. User-centric nutrition facts, health and wellness tips, and unhealthy selection warnings are all augmented on the live video broadcasting. Our system increases the cost efficiency of the grocery shopping experience through the deployment of the discount deals agent. The development of CoShopper framework with all of the capabilities it offers could open the door for further research on the deployment of AI- powered AR smart glasses to enhance the grocery shopping experience for customers.

Table A – User Shopping List

Sample User Shopping List – Randomly Selected Items

Item	**Quantity**	**Department**
Apple	1 LB	Fruits & Vegetables
Pineapple	1 Fruit	Fruits & Vegetables
Red Pepper	1LB	Fruits & Vegetables
Orange Juice	1 Bottle	Beverages
Oil	1 Bottle	Pantry
Sugar	1 Box	Pantry
Rice	1 Pag	Pantry
Kidney Beans	1 Can	Pantry
Cheese	1 Bar	Dairy & Eggs
Bread	1 Loaf	Bakery
Mouthwash	1 Bottle	Oral Care

Table B – Key Nutrition Elements

Nutrition Fact	***Threshold***
Calories (Kcal)	460
Total Fat (g)	60
Cholesterol (mg)	300
Sodium (mg)	205
Sugars (g)	90
Carbohydrate (g)	120
Dietary Fiber (g)	13
Potassium (mg)	987
Protein (g)	8
Vitamin A (%)	75
Vitamin C (%)	722
Vitamin E (%)	2
Calcium (%)	22
Iron (%)	15
Magnesium (mg)	109
Manganese (mg)	10
Folic Acid (%)	5

Table C – Health and Wellness Recommendations

Hypertension (I10)

Avoidable Foods	**Recommended Foods**	**Key Nutrients**
Canned Food	Fruits	Magnesium
Croutons	Vegetables	Vitamin C
Salt	Brown Rice	Vitamin A
Pickles / Olives	Whole Wheat Pasta	Vitamin E
Chips	Low-Sodium Cheese	Calcium
Sunflower Seeds	Milk 1% / Skim	Fibers
Teriyaki Sauce / Hot Sauce	Light Yogurt	Protein
Grated Parmesan	Fresh Herbs	Iron
Bacon	Fish	
Deli Meats	Dried Beans and Peas	

Diabetes (E11.9)

Avoidable Foods	**Recommended Foods**
White Bread	Fruits
White Rice	Eggs
Fried Food	Oatmeal
Sugar (Soda, Candy, Cookies)	Lentil
Meat	Beans
Ice-Cream	Whole Wheat Bread
Corn / Potatoes	Whole Wheat Pasta
Whole Milk	Nuts / Seeds
Crackers	Zucchini Chips

Allergies (Z91.018)

Allergy to Corn	Avoid all corn-containing Items

Periodontal Disease (K05.6)

Dental hygiene	Avoid alcohol-based products

Table D – Medical Report

Item	***Warning***	***Warning Message***	***Health Tip***	***Healthy Tip Message***
Corn Oil	Allergy warning	Contains corn	Olive oil	Helps lowering blood pressure
Canned Beans	Canned item warning	High sodium leads to high blood pressure	Dried beans	Good Source of Protein
White Pasta	Refined item warning	Contains high calories	Whole wheat Pasta	Rich in nutrients and fiber
White Rice	High carbs warning	Removed essential nutrients	Brown rice	Helps lowering cholesterol
Potato Chips	High fat warning	Leads to weight gain	Zucchini chips	Contains Antioxidants
Sugar Cubes	High calories warning	Increase your blood sugar and triglycerides	Natural Sweetener	Stabilizes blood sugar levels
Whole Milk	High calories warning	Product contains high calories	Skim Milk	Protection for teeth bones and muscle function
Soda	High sugar warning	Product contains high sugar	Flavoured Sparkling Water	Stabilizes blood sugar levels
Mouthwash	Alcohol-based item warning	Alcohol is a drying agent	Alcohol-free Mouthwash	Fights gum diseases

Table E – Weekly Discount Deals

Category	***Brand***	***Item***	***Original Price***	***Discount Deal***
Body Wash	Softsoap	All Scents	$6.49/each	$3.50 min 2
Bread	Country Harvest	Cinnamon Raisin	$3.49/each	$3.00 min 2
Dried Fruits	PC Organics	Dried Mango	$5.99/each	$4.99/each
Body Wash	Live Clean	All Scents	$7.49/each	$6.50 min 2
Detergent	Tide	3in1 Pods 96 Count	$25.79/each	$22.99/each
Water	Bubbly Sparkling	Cherry Bubbly	$1.79/each	$1.50 min 2
Soap	Dove	Men + Care Bars	$9.99/each	$5.99/each
Toothpaste	Crest	Whitening	$3.49/each	$2.49/each
Soap	Dove	Cool Moisture Bars	$9.99/each	$5.99/each
Dairy	Naturel	Lactose Free 2%	$6.09/each	$4.99/each
Personal Care	Philips	Electric Shaver	$109.99/each	$89.99/each
Bread	Ditaliano	Thick Slice	$3.49/each	$3.00 min 2
Soap	Olay	Vanilla Indulgence	$3.99/each	$3.33 min 3
Granola Bar	Nature Valley	Dark Chocolate	$2.59/each	$2.00 min 3

Table F - The Technologies Used in The Development Process

Technology Category	***Technology***	***Description***
Software	Adobe Illustrator CC 2018	A software to create vector graphics
	Adobe Premier CC 2018	A time-lined based software for video editing
	Adobe Photoshop CC 2018	A software to edit images
File Storage	Google Drive	A service offered by Google for file storage and synchronization
Online Development Environment	Google Colab	Cloud service to write and execute Python scripts through the browser
Programming Language	Python	A general-purpose coding language
	Jupyter Notebook	An open source web application
Learning Framework	Keras with TensorFlow backend	Deep learning libraries

Appendix A – CoShopper Dataset

Figure A - 1: Training video – Cheese. This figure shows an example of how each item on the shopping list was filmed from different viewpoints and depths.

Figure A - 2: Grocery Items Annotated with Bounding Boxes (BBX). This figure shows the first frame of the training videos with annotated bounding boxes.

Appendix B – CoShopper Architecture

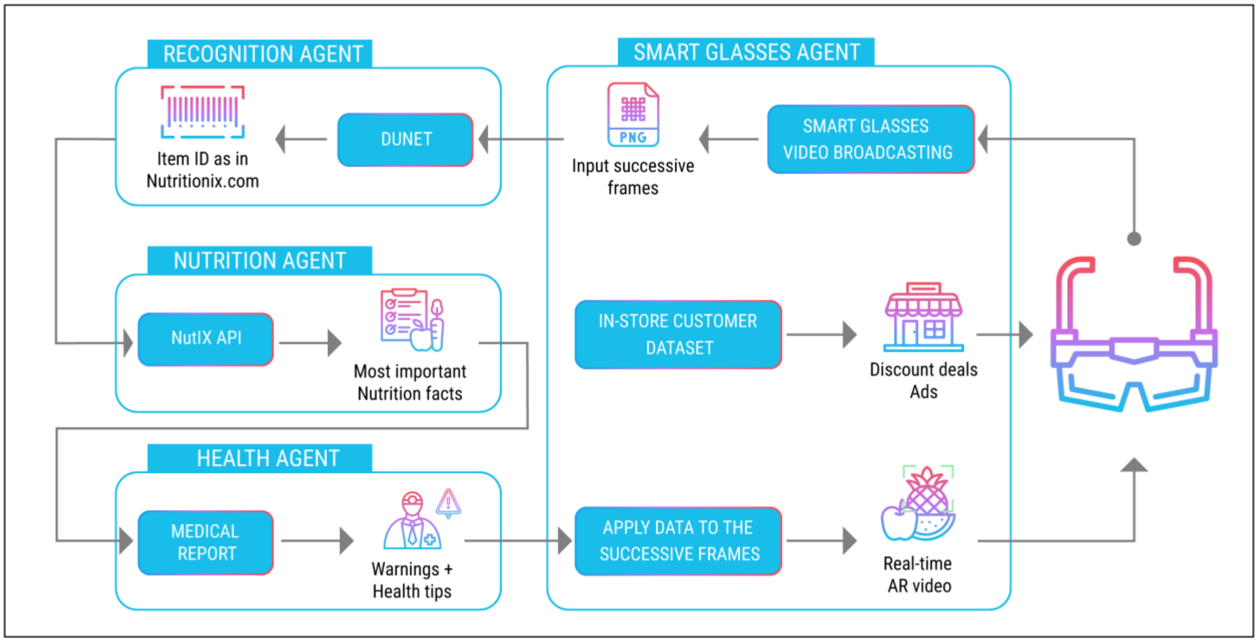

Figure B - 1: The architecture of CoShopper framework. This figure shows the key components of CoShopper framework

Appendix C – CoShopper Framework Output

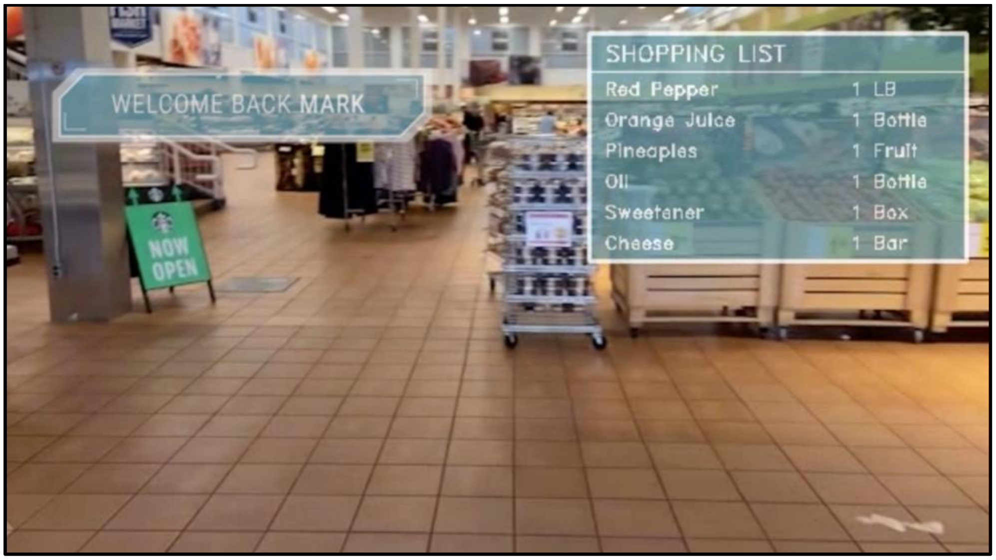

Figure C - 1: User-personalized welcoming message.

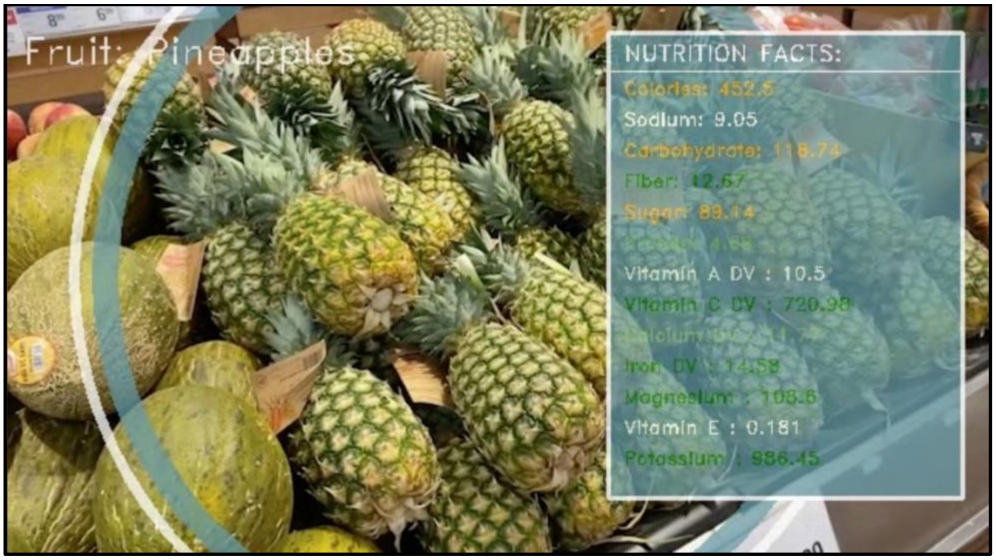

Figure C - 2: Pineapple color-coded nutrition facts.

Figure C - 3: Cheese color-coded nutrition facts.

Figure C - 4: Dates color-coded nutrition facts.

Figure C - 5: Whole wheat bread nutrition facts and Discount deals example.

Figure C - 6: Sweetener nutrition facts and healthy tip example.

Figure C - 7: User shopping list – Example 1.

Figure C - 8: Corn allergy warning and healthy alternative suggestion.

Figure C - 9: Olive Oil nutrition facts and health tip.

Figure C - 10: Non-food item detection and health tip.

Figure C - 11: Orange Juice nutrition facts augmentation - barcode reader.

Figure C - 12: Shopping List – Example 2.

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