

# ParaShop: A Mobile AR App in Assisting People with ASD in Shopping

Mengting Xia, Nan Chen, Yuemin Tang, Zhigang Zhu

*Department of Computer Science*

*The City College of New York - CUNY*

New York, USA

{mxia000, nchen000, ytang001}@citymail.cuny.edu, zzhu@ccny.cunyny.edu

**Abstract**—Approximately 1 in 160 children worldwide is diagnosed with Autism Spectrum Disorder (ASD). ASD prevalence is on the rise in the United States. Virtual reality (VR) techniques have been tried in several studies to improve the shopping skills of people with ASD. However, in these VR applications, the effectiveness in training people with ASD in shopping has never been tested in the real-world environments. Our studies show that individuals with ASD become anxious when exposed to a new environment such as a supermarket, without knowing what to do next. Also, VR applications are less accessible, portable, or affordable compared to the emerging mobile augmented reality (AR) applications. Therefore, we have created a mobile AR application that augments real shopping scenes with visual-audio annotations via object recognition, barcode reading, and automatic categorization. Through a user-friendly visual interface, the app can help people with ASD learn shopping skills effectively, by guiding them through the shopping process step by step in a real environment with AR. A short YouTube demo video of ParaShop can be found at <https://youtu.be/77tp3julNZ0>.

**Keywords**—Autism Spectrum Disorder, Assistive Technology, Augmented Reality, Object Recognition, Text Classification

## I. INTRODUCTION

According to the World Health Organization, one in 160 children worldwide is diagnosed with Autism Spectrum Disorder (ASD) [1]. Recent findings of the Centers for Disease Control and Prevention (CDC) stated that 1 in 54 eight-year-old children in the U.S. is diagnosed with ASD in 2016 [2]. This is an increase from 1 in 59 children in 2014. ASD begins in people's childhood and often persists in their adolescence and adulthood. Many people with ASD cannot live independently due to severe disabilities. ASD cannot be cured [1]. People with ASD require medical care, special education programs, and therapies such as psychosocial intervention [3].

Assistive technologies such as Augmented Reality (AR) and Virtual Reality (VR) are the alternative options for psychosocial intervention that is more affordable and accessible. While VR offers a completely computer-simulated 3D environment for interaction without the physical world, AR can provide a composite view with the real-world and computer-generated images [4], which can enhance users' daily living experience (including shopping) in a real environment with the augmentation of virtual annotations with both visual and auditory means.

In this paper, we introduce a mobile AR application named *ParaShop* on both Android and iOS platforms that

can help people who are diagnosed with ASD going through the shopping process step by step in the supermarket. The key contributions in this work include:

- 1) ParaShop allows users to create grocery lists with images and automatic categorization of items, which are more intuitive to ASD users.
- 2) ParaShop provides instructions with AR scenes to help ASD users complete their tasks, which is critical for this population.

## II. STATEMENT OF THE PROBLEM

People who are diagnosed with ASD have difficulties in communication, social interaction, and social cues [6]. They become anxious when exposed to a new environment such as a supermarket without knowing what to do next [7]. According to Jason Ramirez, the supervisor of the Goodwill center at Harlem, people with ASD also experience other challenges in the new environment. If they cannot find the item they are going to buy in the supermarket, they will get lost and cannot continue their tasks. When coming to wait in line for checkout, they usually do not have the patient to wait since they do not feel the need to do it. Also, it is hard for people with ASD to continue shopping without knowing the amount of time left for them to complete their tasks. In certain cases, people with ASD leave without receiving their changes during checkout because they simply forget to do it. Recognize fruits and vegetables with similar or odd shapes is a difficult task for people with ASD, such as differentiating between apples and pears. To solve these problems, a mobile AR application is implemented to help people with ASD to learn and understand how to finish the tasks of shopping in sequences. Our application, ParaShop, shows the completion status, provides instructions when making payments, and allows users to skip to the next item on the list if they cannot find it, which is a simple yet very important feature for people with ASD. Also, it provides fruits and vegetables recognition.

## III. RELATED WORK

Few studies met the criteria of a systematic review in [5], utilizing VR systems to improve autistic people's daily living skills, especially shopping in the supermarket, and driving [5]. Bob's Fish Shop is one of the studies that used VR to help children with ASD practicing conversation skills [3]. Another study also used VR to provide real shopping scenarios to help children with ASD [12]. All these studies utilizing VR technology do provide simulated scenarios for people with ASD. However, these scenarios are still not real enough compared to the real-world environment.

In addition, VR required headsets to bring users to the virtual world. Controllers are also required to interact with the virtual world. Computers with high-end graphics cards or smartphones may also be necessary to simulate a virtual world. A fully functional setup of the VR system may be complicated and costly. In contrast, smartphones or tablets are the only devices required to interact with mobile AR apps [5]. Mobile AR applications are more portable, affordable, and accessible compared to the VR system.

Several teams are developing or have developed indoor shopping AR solutions for navigation. For example, Dent Reality provides indoor AR navigation for shopping malls [11]. But it does not provide any accessible instructions for people with ASD going through shopping sequences. Therefore it is highly desirable for developing a mobile AR shopping application that allows people with ASD to engage in the real environment of shopping, and to follow the sequence given by the system to finish the trip, as indicated in [7].

#### IV. DESIGN AND DEVELOPMENT

ParaShop is our mobile AR application developed for both Android and iOS users. The major features of ParaShop include shopping list, automatic categorization, AR, barcode scanner, and fruits and vegetables recognition.

##### A. Technology Stack

Fig. 1 shows the tech stack of the ParaShop app. We chose to use React Native as our mobile application framework because it allows us to create native applications for both Android and iOS using React. Essentially, one single code base in JavaScript can support both platforms. ViroReact is used to develop AR features on both platforms. All user data are sent to our RESTful API written in Node.js and hosted on Heroku. Our RESTful API communicates with a Database Management System (DBMS) called PostgreSQL, hosted on Amazon Relational Database Service (RDS). Both the text classification model for automatic categorization and the recognition model for fruits and vegetables are written in Python Flask, the former is hosted on Heroku and the latter is hosted on Google Cloud Compute Engine. We access the UPCitemdb API [13] to obtain an item's information using barcode scanning.

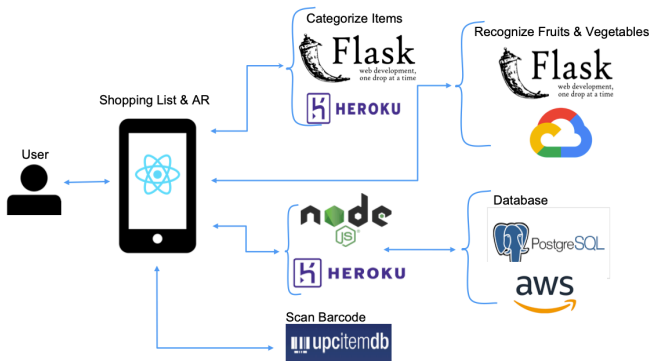


Fig. 1. ParaShop Tech Stack

##### B. Shopping List and Automatic Categorization

Our mobile AR app allows users to create, edit, delete, and share shopping lists (Fig. 2 left). The *sharing feature* of the app allows a service provider to share shopping lists

with all the participants. Therefore, they do not need to re-type the same shopping lists for every participant. Even with this sharing feature, it may not be user-friendly for some individuals with ASD to create shopping lists through typing. So, we also implement an *item selection feature* using images. Users can simply tap on the images of the items they want to add to the shopping list (Fig. 2 right). Currently, there are three categories available in image selection: Beverages, Dairy, and Produce.

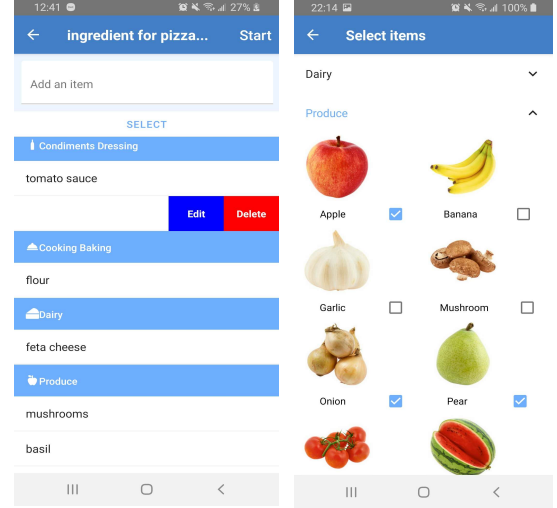


Fig. 2. A shopping list with items (Left). Select items based on images (Right)

After users save their grocery lists, the ParaShop app automatically rearranges the order of the items in lists based on their categories. This helps users to speed up the shopping process by allowing them to find every item in the same section of the supermarket. The automatic categorization of items involves a text classification model [8], hosted on Heroku. To classify the item based on its name, we use a Multi-Layer Perceptron classifier, which relies on neural-network-based supervised learning algorithms.

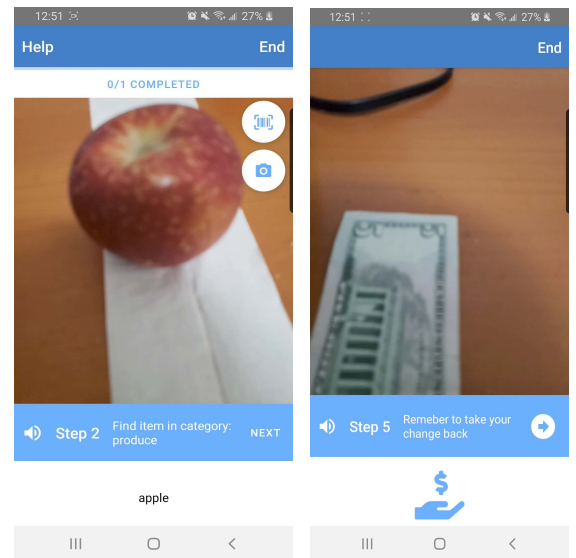


Fig. 3. Two of the AR instruction screens

### C. Augmented Reality

Our app provides step by step instructions for shopping sequences. When users are in the supermarket and start shopping, they can open our app and press the “Start” button on the list page. The app would navigate to the AR scenes. AR technology integrates the virtual elements (such as annotations) into the real-world environment.

Through their phone, users can see the real-world supermarket with the instructions being rendered at the bottom of the screen. Users follow the instructions on the screen to pick up a shopping cart or basket, find the item based on the ordered list, wait in line, and finally checkout at the end of the shopping trip. When users finish one instruction, they can press the arrow button to go to the next step. During the process of finding items, if the user cannot find the item in the supermarket, they can choose to skip the current item and jump to the next one. Our app also shows the completion status which is the number of items left to find. During the checkout process, our app lets users choose the payment methods (card or cash), and each method has its instructions. For better understanding, our application also provides simple voice instructions in case the user has difficulties to read texts.

### D. Fruits and Vegetables Recognition

In the current implementation, users can use their phone cameras to identify fruits and vegetables through our machine learning model. The model used Mask R-CNN and was intended for object detection [9]. A photo of the product taken by the user will be sent to our model in base64 format, then the model will return the name of the product as an array of strings in response. Fig. 4 (left) shows an example of the fruits and vegetables recognition model. It allows the user to take pictures and the returned item name would display on the top of the screen. The dataset for the model is made of images we collected from a website called Pixabay [14] that provides copyright-free images. There are 950 images of fruits and vegetables, and we annotate each image before training the model. It takes images of size 256 x 256 and can return an array of labels, along with bounding boxes and scores of detected fruits or vegetables. We set it to only return the labels to make it easier to use. There are about 2 to 3 seconds of latency for the model to return the results. This is due to the limited storage offered by the Google Cloud Platform. In the future, we will try to turn the model into a TensorFlow Lite file and run directly on the mobile phone.

Currently, our model recognizes apple, banana, carrot, lemon, lime, orange, pear, potato, tangerine, and tomato, which are in this dataset. For other fruits and vegetables, it is more difficult to collect enough copyright-free images with different shapes and angles for training. Collecting enough images of them will be our future work; one idea is to use our ParaShop app to collect data when our users do grocery shopping.

### E. Barcode Scanner

Our app allows users to scan the barcode on items for identifying objects other than fruits and vegetables, which have had automatic recognition functions in our app. The npm package [15], “react-naïve-camera” allows us to extract barcodes in the camera view into a string. We send the

string in an HTTP request to UPCitemdb API to obtain the item’s title (i.e., product name) and its product image. UPCitemdb API accepts strings for Universal Product Code (UPC) and European Article Number (EAN). UPC and EAN barcodes are widely used to track and identify the products. On the ParaShop interface, an “ADD ITEM” button only shows up when the scanned item is in the shopping list.

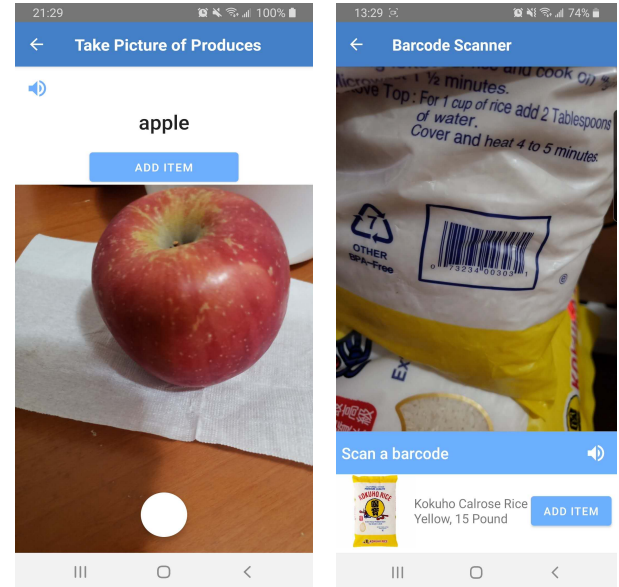


Fig. 4. Fruits and vegetables recognition (Left); Barcode scanning (Right).

Fig. 4 (right) shows an example of barcode scanning function. The barcode scanner displays title and image of the item (Kokuho Calrose Rice Yellow). A video tutorial is also provided if the user does not know how to use this feature.

## V. USER STUDY AND EVALUATION

The ParaShop app was developed in a year-long senior design class. In the fall of 2019, our team visited the Goodwill site in Harlem. Goodwill NY/NJ is a non-profit organization that empowers people with disabilities through employment. The staff trainers there told us that people with ASD have trouble finishing daily living tasks. It is hard for them to go shopping. This motivated us to design ParaShop to assist people with ASD to go shopping.

In the earlier spring of 2020, we visited Goodwill again. This time Aris, a staff member at Goodwill told us that they have a cooking class every Thursday. The staff would help print out a shopping list based on the recipe. Then, the participants there would go shopping in the supermarket nearby with Goodwill staff. Participants at Goodwill mention that they also use credit or debit cards during shopping. Therefore, we included both card and cash payment methods in our AR instructions. After listening to our idea, Aris believed ParaShop can help them better go shopping.

During the later stage of our app development, we sent our design to Goodwill several times. Tasha, another staff trainer from Goodwill, gave us a lot of helpful feedback. For our initial mockup, she liked our categorization of items. As she said, “it is a great feature to help people learn how to shop and look for aisle markings in the supermarket.” Also,



she thought that our font size and visual components are good for people with ASD to use. At the end of our conversation, she would like us to have an audio component as well. We also asked her if she can forward our email to staff who work with participants directly for more feedback. But unfortunately, we did not manage to receive feedback yet due to the severe situation with COVID-19 in New York City.

After that, we added the video tutorial for the barcode scanning and fruit and vegetable recognition to help users with ASD using these assistive tools. The image selection feature was also added. These are the features she requested during our midterm evaluation in the spring semester. We also added voice instruction as she mentioned during our first conversation. Then, we contacted Tasha again with our new design for more suggestions. According to Tasha, our tutorial was a little fast. But she liked the image selecting design when adding items to the shopping list. These designs make ParaShop more user friendly for people with ASD.

When developing our fruits and vegetables recognition model, we also received suggestions from Tasha. She mentioned one challenge people with ASD may meet during shopping: they cannot identify similar looking items such as apple and pear. Therefore, fruits and vegetable recognition can help them pick the right item.

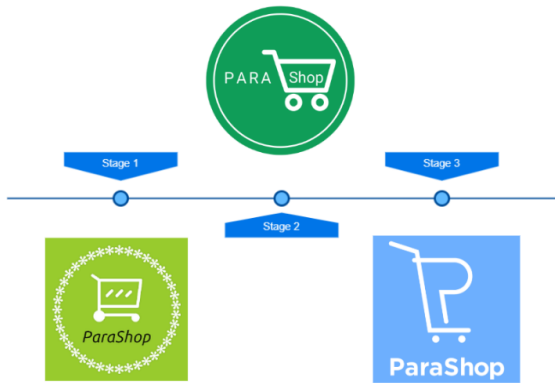


Fig. 5. The evolution of ParaShop logo design

For better connecting with our targeted users, we also have spent time in the branding aspect of the app, i.e., the name and logo designs of the app. Fig. 5 shows our logo designs in three stages. Shopping carts are used throughout the stages to symbolize shopping. In stage 1 and stage 2, we chose green as the background color to represent growth and peace. Stage 3 is our current logo design with a blue background color to represent trust and strength. Based on the interaction with our ASD users, the stage 3 blue logo is our final choice. The overall color theme of the app is also in this light blue. The name “ParaShop” emphasizes the major focus of our application: shopping. “Para” is a prefix in Ancient Greek that means besides, near, and alongside. “ParaShop” signifies our application guides people with ASD side by side during their shopping trips.

A video demo of the ParaShop app can be found at <https://youtu.be/77tp3julNZ0>. A formal user study is planned after the reopening of businesses in New York City, and we have had the IRB approval ready for the tests with ASD users.

## VI. FUTURE WORK

ParaShop is a tool for family members and service providers to teach shopping sequences to autistic people who can also use it to do shopping themselves. ParaShop is portable, user-friendly, and accessible to people with ASD.

In the future, we would like to add more images and categories to our image selection feature so users can add items easily to their shopping lists. We can expand our images set through the photo users take when they use the fruits and vegetables recognition. Furthermore, we would like to add more fruits and vegetables to our model so it can help users recognize more products in the supermarkets.

## ACKNOWLEDGMENT

This work is supported by a CCNY CEN Course and Innovation Grant from Moxie Foundation. Additional technical advice given by Dr. Hao Tang and Dr. Erik K. Grimmelmann is greatly appreciated. We would also like to extend our thanks to Celina Cavalluzzi, Tasha Stanton, Jason Ramirez, their colleagues, and ASD participants at Goodwill NY/NJ for their guidance and their feedbacks, and to Mary Ann Louie for the logo design.

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