Toward Comprehensive Smartphone Shopping Solutions for Blind and Visually Impaired Individuals

Vladimir Kulyukin
Computer Science Assistive Technology Laboratory
Department of Computer Science
Utah State University
Logan, UT, USA

1. Introduction

Many sighted shoppers, unless they closely know someone who is blind or visually impaired, may never think about how their sensory-motor systems seamlessly handle the amazing complexity of the modern supermarket with an average of 45,000 products and a median size of 4,529 square meters. They successfully find the right aisles, locate the shelves with the desired products, identify the products on the shelves, read their ingredients, and deal with relocated or discontinued products.

Unlike sighted individuals, many visually impaired (VI) people do not shop independently. They rely on friends, relatives, volunteers, and store employees. When these individuals are unavailable, VI shoppers reschedule or postpone shopping trips. If they can reach the supermarket by themselves, they may experience delays, waiting for store employees to assist them. However, some assigned staffers are unfamiliar with the store layout, others become irritated with long searches and requests to read aloud product ingredients, and still others do not have adequate English skills to read the products' ingredients or answer basic questions about the supermarket layout. These difficulties cause VI shoppers to abandon searching for desirable products or settle for distant substitutes.

PeaPod (www.peapod.com) and similar home delivery services provide grocery shopping alternatives. However, such services are not universally available and, when available, require shoppers to schedule and wait for deliveries, thereby reducing personal independence and making spontaneous shopping difficult. Nor do such services offer VI individuals opportunities to explore stores independently and to socialize.

To overcome these access barriers, accessible shopping solutions are needed that increase personal independence, enable spontaneous shopping, and, most importantly, do not require that supermarkets undergo extensive technological adjustments. Such systems will make VI individuals less dependent on external assistance and improve their quality of life.

2. Design Requirements

What features would blind and VI individuals, who are interested in shopping independently, like to see in accessible shopping solutions that would enable them to shop independently in modern supermarkets? To answer this question, we conducted two focus groups on accessibility barriers to independent blind supermarket shopping at the Utah State University's Center for Persons with Disabilities (USU CPD). The first focus group consisted of five VI individuals from Logan, Utah. The age ranged from 16 to 47. Two used white canes; three used guide dogs. We met with each individual separately to minimize peer pressure. Each interview lasted one hour. The second group with different participants was conducted during a regular monthly meeting of the Logan Chapter of the National Federation of the Blind (NFB) hosted by the USU CPD. This group consisted of six individuals from Cache Valley, Utah, all of whom held part-time or full-time jobs, used public transportation, and walked independently around their neighborhoods. The age ranged from 19 to 51. Four were white cane users; two used guide dogs. This focus group was an open forum and lasted three hours.

Written transcripts of both focus groups were combined into one electronic master transcript. The master transcript was analyzed to identify *task functions*, i.e., things that the blind shopper must do in the supermarket, and to match task functions with the shopper's abilities. Unmatched or partially matched task functions were used to identify *performance gaps*. The identified performance gaps became *design requirements* for *accommodation systems*, i.e. software and hardware devices, training techniques, and other procedures designed to bridge the performance gaps.

This analysis, rooted in occupational therapy, establishes a meaningful framework for comparing different accommodation systems operating in supermarkets. Of course, caution should be used in interpreting our findings because it is difficult, due to the uneven distribution of the blind and VI population in the U.S., to find statistically significant groups with the exact same level of blindness and physical ability. Variability in vision and physical ability, primarily due to age or onslaught of blindness, within locally available groups is also the norm acknowledged in the literature.

Our analysis of the master transcript resulted in the identification of six broad design requirements: 1) mobile product selection, 2) store navigation, 3) product search, 4) product identification, 5) utilization of existing devices, and 6) minimal environmental adjustment. This list should not be construed as complete. As product marking, distribution, and inventory control technologies change, some requirements will become obsolete and new requirements will appear. The list does not include payment, because all participants indicated that they handled payment with credit cards. We readily acknowledge, however, that for individuals who prefer cash, individual bill recognition is an important design requirement.

Design requirements 1 – 4 are self explanatory and ensure that the shopper can select products, navigate the store, search for products in aisles, and accurately identify the products. Requirement 5 states that adding new devices not only increases the cost of ownership but also has a negative ergonomic impact, because VI persons already handle numerous navigation tools (e.g., white canes and guide dogs, Braille note takers, personal GPS devices) and everyday wearable objects (e.g., purses, backpacks, and bags). Nor should one forget that some VI shoppers must also handle their children, who accompany them to the store.

Requirement 6 states that accessible shopping systems must operate not only in research laboratories but also in real supermarkets with established business processes (e.g., restocking, inventory control, cleaning, advertisements, etc.). An exclusive focus on technological means to bridge performance gaps, which the computer science and engineering literature tends to take due to its concentration on the end user, runs the risk of developing accommodation systems that require unreasonable adjustments by the supermarket. If the introduction of an accommodation system causes significant disruptions to the existing business processes, the supermarkets will resist or reject its adoption.

3. Smartphone as Primary Shopping Device

We believe that the smartphone is one hardware and software platform that can serve as the base for comprehensive accessible shopping solutions that meet the design requirements outlined in the previous section. Smartphones are equipped with digital compasses, orientation sensors, cameras, touch screens, and have increasingly powerful CPUs. More and more blind and VI individuals become smartphone users. Once comprehensive accessible shopping software solutions are available for download, the end users will not have to purchase new hardware devices in addition to what they already use. Such solutions can leverage powerful image processing capabilities of smartphone cameras, digital compasses, orientation sensors, and wireless Internet connectivity to reduce or, in some cases, even eliminate the adjustments required of supermarkets to accommodate them.

The Computer Science Assistive Technology Laboratory of Utah State University (USU CSATL) is currently developing ShopMobile 2, a smartphone accessible shopping system for blind and VI individuals. The current version of the system supports static eyes-free barcode recognition and remote guidance. Remote guidance enables a remote sighted guide to help the blind shopper with navigation or product recognition problems. Remote sighted guides can be relatives, friends, or volunteers. It can also be used by professional O&M instructors teaching life skills to blind and VI individuals. To use the remote guidance mode, the shopper simply calls a remote guide and begins to stream real time video to the guide's smartphone or desktop. The guide watches the stream and gives directions to the shopper over the phone.

Figure 1. ShopMobile 2, an Accessible Shopping System for the Blind on the Smartphone.

Figure 1 shows some of the features that the end version of our system will have. In addition to static eyes-free barcode recognition, it will have eyes-free barcode recognition in video mode, product annotation, and store sign recognition. Product annotation will allow the shopper to create his or her store-specific database of audio or text notes. Such databases can be created not only by the end users but also by sighted caregivers (e.g., a relative, a friend, a volunteer, an O&M professional). They can also be shared, which presents interesting research opportunities in collaborative knowledge engineering. The system is currently implemented on the Google Nexus One smartphone running Android 2.2. The iPhone port will be considered depending on our funding levels.

In this section, we will briefly describe the eyes-free barcode recognition module of our system that we demoed at the Rehabilitation Engineering and Assistive Technology Society (RESNA) of North

America in June 2010. An important feature of this module is that the camera does not have to be aligned with barcodes for the barcode recognition process to succeed. To put it differently, the module tries to solve the camera alignment problem for the blind user.

To scan a barcode, the user places the phone camera on the fixed surface where the user wants to find a barcode (e.g., a box, a can, a bottle, a shelf) and initiates the interactive camera alignment loop by tapping on the screen. This causes the accelerometer's pitch and yaw readings to be stored as the initial references. The user then moves the phone away from the surface to take a static picture. While the user is moving the phone, the accelerometer readings are monitored and if the user deviates from the initial reference readings in either the pitch or yaw planes, vibratory signals are issued until the camera is realigned with the surface. This interactive camera alignment procedure ensures that the camera is always aligned parallel to the barcode surface. The user stops moving the camera away when the camera is approximately 10cm from the surface of the package and takes a picture by tapping on the screen.

After a static picture is taken, the system runs its barcode localization algorithm. This algorithm identifies barcode regions in the static image and passes them to the barcode decoding algorithm. Barcode are characterized as image regions with high alternating frequencies and vertical continuities. Alternating frequency is defined as the number of 0-1 and 1-0 transitions in a one pixel wide bit string. Vertical continuity is defined it as the continuity of black and white lines along the y-axis.

The image is first passed through a line filter to filter out elements such as graphics and text. This filter is designed to let only the vertical lines in the image pass through. The filter output is rapidly scanned to identify regions with alternating frequencies and vertical continuities. Fast histogram analysis is then used to further isolate such areas. These areas represent candidate barcode regions and are sent to the barcode decoding algorithm for decoding.

Our barcode decoding algorithm is based on scan lines. Multiple scan lines are generated until a valid barcode is obtained. If a valid barcode is not obtained even after all scan lines are decoded, it is assumed that the barcode may be perpendicular to the image. The original picture from the camera is rotated by 90 degrees and subjected to the entire procedure of barcode localization and decoding. An interested reader can look at the online resources described in the next section for technical papers and live video demonstrations.

4. Supplemental Online Materials

Our technical papers on eyes-free barcode recognition can be downloaded from http://digital.cs.usu.edu/~vkulyukin/vkweb/research/eyesfree_barcode_scanning.html. Readers interested in live demonstrations can watch our research videos on the CSATL USU YouTube channel at http://www.youtube.com/user/CsatlUSU.

5. Acknowledgments

Parts of this article have previously been published in the Proceedings of the Rehabilitation Engineering and Assistive Technology Society of North America (RESNA) conference, the Proceedings of the Envision 2010 conference, the Proceedings of the 2010 International Conference on Image Processing, Computer Vision, & Pattern Recognition (IPCV 2010), and the Open Rehabilitation Journal.