

Research on Refrigerator Design Based on Computer Vision: Designed for Visually Impaired People

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Abstract. With the continuous progress of technology, artificial intelligence (AI) technology, especially computer vision, has provided new possibilities for obstacle free design. This article focuses on how to use computer vision technology to create more user-friendly refrigerator designs for visually impaired individuals. Firstly, we introduced the basic concepts of computer vision and its applications in various fields. Through user research on visually impaired individuals, we understand their needs and challenges when using refrigerators. On this basis, we propose a series of design strategies for obstacle free refrigerators based on computer vision and propose some possible design solutions. However, there are also some challenges when implementing these design solutions, such as cost, device robustness, and privacy issues. Overall, this study provides a new perspective on how to use computer vision to improve the quality of life for visually impaired individuals.

Keywords: Computer vision, visually impaired individuals, accessibility design, home appliance design, refrigerators.

1. Introduction

1.1. Background

Visual impairment has become a global disease, according to statistics from Centers for Disease Control and Prevention (CDC), out of 90 million Americans over the age of 40, three out of every five have vision problems. Visual impairment is one of the ten major disabilities faced by adults over 18 years old. According to information from WHO, 43 million people worldwide are blind, and 295 million people have moderate to severe Visual impairment. With the popularization of electronic products and the aging of the population, this data is still rising, so that the economic loss caused by visual impairment is up to 411 billion US dollar every year. The refrigerator is one of the most important interactive scenes in the lives of visually impaired people, so how to provide better services for the blind and visually impaired in the product design of refrigerators has become an urgent and important issue to be solved.

1.2. Existing research achievements and their shortcomings

As early as 2011, Yogev et al. from the Artificial Intelligence Laboratory at the Freie Universität Berlin developed a gesture manipulation device based on a camera for computer recognition, which can help visually impaired individuals recognize and operate web interfaces. However, due to its early age, this device has insufficient accuracy and is even unable to perform multi-point operations.[1]

In 2014, Dr Rabia Jafri and his team developed an electronic assistive device based on computer vision for visually impaired individuals that can recognize indoor obstacles. He mentioned in examples that it can be used to help blind people take out jelly cans from the refrigerator, but we did not see this scene in practice, and it is not clear how the device performs in recognizing objects in smaller spaces like refrigerators.[2]

In 2017, Dian Huang developed a hand based wearable device interaction model for visually impaired people and Exoskeleton robots. This model uses computer vision to identify objects for path planning and navigation. However, its application for visually impaired individuals has only developed paper currency recognition, and its practical application scenarios are still very limited.

In 2021, Tamas Nemes designed a wearable portable guidance system, but the accuracy of obstacle recognition was 74.9%. For complex road conditions, it still cannot provide a perfect sense of security for visually impaired people.

Based on the above analysis, although there have been many attempts at product design for visually impaired individuals both domestically and internationally, combined with computer vision, these attempts are mainly aimed at outdoor scenes where people with disabilities spend more time at home. However, indoor scenes have clearly received little attention in previous research. Therefore, based on the current development level of computer vision technology, I propose a design plan to improve the living standards of visually impaired people on refrigerators.[3]

2. Application Examples of Computer Vision and Analysis of Its Advantages and Disadvantages

Computer vision is an important subfield of artificial intelligence, aimed at endowing computers with the ability to simulate human vision, enabling them to extract information from images or videos and understand their inherent meanings. There is enormous potential value behind this emerging field and it is rapidly developing. According to CLOCKWORKS, an AI vision application research and development company, industries including agriculture, manufacturing, and healthcare have begun to use computer vision to replace professionals in repetitive tasks such as work monitoring, quality management, and tumor detection. In addition, in the field of autonomous driving, unmanned driving technology based on computer vision has also developed quite mature, allowing vehicles to effectively recognize different items on the road and make corresponding decisions. Henil Gajjar from Nirma University pointed out that these technologies can not only be used in vehicles, but also help disabled people change their lives.[4]

Microsoft's Seeing AI and OrCam's MyEye use computer vision technology to help visually impaired individuals identify their surroundings and provide navigation guidance. Seeing AI is a free application software for visually impaired people, which uses computer vision technology to transform the surrounding environment into text information and describe it to visually impaired people. However, it is limited by device conditions, and it is inconvenient for users to move around with a product installed with Microsoft software. Moreover, the visual ability of the software is affected by camera pixels and surrounding light. MyEye, as an auxiliary device that can be installed on glasses, has excellent portability. Correspondingly, its price is very high, and due to the limited size of the device, it is susceptible to external light and noise interference. In addition, its recognition ability is also limited, mainly used to recognize printed materials such as text and banknotes. A company called Assisted Vision's OLED Smartglasses capture images through the built-in wide-angle camera, and can transmit the processed images to visually impaired people through voice. It is also a product with high prices. Like MyEye, as a new visually impaired product, it requires users to learn its use methods from scratch.[5]

3. The needs and challenges of people with severe visual impairment or above when using refrigerators

3.1. Understanding the needs of visually impaired individuals through user research

3.1.1 User research methods

In this study, it is necessary to restore users' daily habits as much as possible in order to gain a deeper understanding of their needs, expectations, and challenges. Therefore, structured interviews are chosen as a research method to facilitate natural dialogue. After soliciting the opinions of the interviewees, the interview was held through online communication.[6]

3.1.2 Participants

In this study, the selection needs to cover groups of different ages and genders as much as possible to ensure that their needs are sufficiently representative. In addition, all variables except for the above must be controlled. The WHO classifies visual disability into four levels (Table 1), and the group with visual acuity below 6/60 is referred to as severely visually impaired and blind people. We chose this group for the interview.

Table 1. Classification of Distant Vision Damage Degree (Source: WHO)

Degree	Impairment
Mild	visual acuity worse than 6/12 to 6/18
Moderate	visual acuity worse than 6/18 to 6/60
Severe	visual acuity worse than 6/60 to 3/60
Blindness	visual acuity worse than 3/60

A total of 6 severely visually impaired individuals with practical experience in refrigerators were invited, with a male to female ratio of 1:1. Three young people aged 25-40 (average age=33.3, standard deviation S=6.506) and three middle-aged and elderly people aged 40 and above (average age=56.3, standard deviation S=8.622) were invited, and none of the participants had any testing experience.

3.1.3 Interview Questionnaire

(For reference only, can be adjusted according to the actual situation)

1. Introduction and personal situation understanding:

Please briefly introduce yourself and tell us which activities in your daily life are affected by visual impairments?

2. Daily use of refrigerators:

How often do you use the refrigerator in your daily life?

How do you locate and find the food you need when using the refrigerator?

Do you understand the functional settings and various partitions of the refrigerator? Do you frequently use these functions?

3. Difficulties and problems encountered:

What difficulties did you encounter when trying to find specific food or beverages?

What problems do you usually encounter when trying to distinguish between various foods or beverages in the refrigerator?

What difficulties did you encounter during the cleaning and maintenance process of the refrigerator?

What challenges did you encounter when setting or adjusting the temperature of the refrigerator?

What other difficulties did you encounter while using the refrigerator?

4. Requirements and improvement suggestions:

What aspects of the refrigerator are you satisfied with? What aspects do you think need improvement?

If you could customize an ideal refrigerator, what functions or features would you like it to have?

What functions or designs do you think can help you better use the refrigerator?

5. Conclusion:

Finally, do you have any other ideas or suggestions about refrigerator design or use that you would like to share with us?

3.1.4 Result

After the online interview, a result analysis table (Table 2) was compiled based on the number of times users mentioned potential challenges in the usage scenario, as well as the challenges mentioned by half or more users (3 or more times).

Table 2. Statistical Table of Interview Results

The Challenge of Using a Refrigerator	Number of mentions
Refrigerator Function & Partition	3
Location of specific items	6
Identification of specific items	6
Function & operation issues	6
Cleaning & maintenance issues	4

During the interview, our research subjects expressed various challenges to the use of refrigerators. Firstly, severely visually impaired individuals often encounter problems in locating and searching for the food they need. Due to their inability to clearly see the inside of the refrigerator, some participants stated that they often need to use touch and memory to determine the location of food. This process is not only time-consuming, but can also sometimes lead to accidental handling or overturning of food. In addition, adjusting the temperature setting of the refrigerator is also a common challenge. Most visually impaired users express that they find it difficult to determine the current temperature settings, let alone adjust them to meet specific food storage needs. For refrigerator cleaning and maintenance, many respondents stated that they often need help from others. They cannot find areas inside the refrigerator that are leaking or full of food residue, which will cause additional difficulties for the cleaning and maintenance of the refrigerator. In addition, sometimes there may be situations where it cannot be opened or closed tightly.[7]

3.2. The needs of people with severe visual impairment or above in refrigerator usage scenarios

Based on the analysis of the results obtained from online interviews, the following table summarizes the prioritized needs of people with severe visual impairment or above when using refrigerators (Table 3):

Table 3. The needs of people with severe visual impairment and above when using refrigerators

Category	Need
Operation	A system that can provide tactile or auditory feedback to understand and control the operating status of the refrigerator
Identification	Accurately locating and identifying various areas and items inside the refrigerator
Monitor	Equipped with safety monitoring and protection functions, providing warnings in case of potential hazards
Independent using	Checking the cleanliness of the refrigerator and promptly understand if it needs to be cleaned or if there are any food leaks

Addressing these issues or meeting these needs can help visually impaired individuals better complete their daily cooking tasks, improve their quality of life, and enhance their ability to take care of themselves.

4. Design Strategy for Accessible Refrigerator Products Based on Computer Vision Technology

4.1. Design Principles for Accessible Refrigerator Products Based on Computer Vision Technology

Based on the interview results and combined with the personas of disabled individuals using refrigerators by Yong Min Kim in 2018, we have identified several principles to follow in accessibility products.

4.1.1 Safety

Safety is the primary consideration in home appliance design, especially for visually impaired individuals. Firstly, in terms of appearance, sharp corners and other structures that can easily cause danger cannot be designed. Secondly, while fully ensuring that users can operate the equipment normally, computer vision can help monitor the environment, identify hazards, such as unclosed refrigerator doors, poured drinks, etc., and promptly issue alarms. If necessary, the power can be directly turned off to ensure user safety.[8]

4.1.2 Accessibility

Designers should fully study and design the ergonomics, psychology, and physiology of visually impaired individuals when designing products, in order to provide more intelligent and user-friendly equipment for a small number of people. The complexity of the design should be adjusted appropriately based on the learning ability of the user group, and users should not spend too much learning cost on the device. Design based on the principle of users enjoying cooking fun and satisfying the self-esteem of minority groups.[9]

4.1.3 Inclusive principle

The design should consider different levels of visually impaired users and provide flexible customization options to meet the needs and abilities of different users. This can be achieved by providing multiple operating modes or adjusting the feedback strength of the device.

4.1.4 Fault tolerance

Visually impaired users may need a longer adaptation period during the learning process, and may also make mistakes during product use. However, product design should adopt restrictive measures to reduce errors. For example, if the refrigerator door is not tightly closed, it can be considered to directly use the electric suction door technology on the car instead of reporting errors to the user every time.[10]

4.2. Design Ideas for Refrigerator Products for Visually Impaired Individuals based on Computer Vision

4.2.1 Item identification and positioning

Inside the refrigerator, item partitions with RFID (Radio Frequency Identification) tags can be set up to identify and track the location of items through computer vision and machine learning technology. When the user receives an item, the voice device will prompt the user what the item is. When a user queries a specific item through voice, the refrigerator can provide voice feedback to inform the user of the location of the item.

4.2.2 Feedback and Interaction

By using computer vision and sensor technology, as well as setting up voice or tactile feedback systems, the status of items in the refrigerator (such as whether food has expired or leaked), the operating status of the refrigerator (such as temperature, humidity, etc.), and safety issues (such as whether the refrigerator door is not closed or whether the cold and hot areas are improperly set) are

converted into voice or tactile information and transmitted to users. In addition, the operation of the refrigerator can also be carried out through voice commands, thereby reducing the difficulty of operation for visually impaired individuals.[11]

4.3 Final Implementation of Design Scheme

To implement computer vision technology for refrigerators targeting visually impaired individuals, in addition to understanding user needs and following design principles, there are also other challenges that need to be considered.

The first is the cost. In China alone, in a survey of Visual impairment people, 43% of the respondents had an average monthly income of less than 280 dollars. At the same time, the commercial insurance coverage rate of Visual impairment groups is less than 13%. User groups may not be able to accept expensive products, so controlling costs is one of the top considerations for designers. Secondly, considering the special environment of the kitchen in terms of hardware devices, for example, when integrating cameras and sensors in the refrigerator in order to provide visual information for the product, these hardware devices should have some characteristics that are suitable for the kitchen environment - waterproof, smoke proof, and have a certain degree of durability. Thirdly, before officially entering the market, in order to ensure that the product truly meets the needs of visually impaired individuals, more user experience tests should be conducted to optimize the product based on user feedback. Similarly, after the product enters the market, computer vision and machine learning technology should also be used to continuously iterate the product. Finally, the privacy of users should be respected and protected. This includes taking necessary security measures during data collection and storage processes, and transparently explaining to users how data is used.[12]

5. Conclusion

Computer vision has proven its enormous value in fields such as agriculture and manufacturing, and we have also seen its potential in product design for the refrigerator category. However, although we have found certain design strategies and directions in designing and implementing accessible refrigerators, there are still many issues that need to be addressed, such as technology accessibility, cost-effectiveness, and data protection. In addition, we also need to further understand and understand the specific needs and behaviors of visually impaired individuals when using household appliances, so that we can design more refined and personalized solutions. In the future, we look forward to computer vision continuing to provide new opportunities for the accessibility design of refrigerators. For example, computer vision can be combined with other emerging AI technologies (such as deep learning and Natural language processing) to discover and learn users' implicit needs and behavior patterns, so as to provide more personalized and predictive services. At the same time, computer vision can also be combined with IoT devices and services to create a more intelligent and connected home environment for people with disabilities, providing them with more possibilities and freedom in their lives.

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