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A Review on Travelling Assistance Smart Wearables for the Visually Impaired *

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Abstract

Difficulty in travelling has always been a problem for visually impaired people in their daily lives, and smart wearable devices have shown great potential in helping the visually impaired to travel by their portability and interactivity. Therefore, this paper provides an overview of smart wearable devices that assist the visually impaired in travelling. The paper first analyses the characteristics of visually impaired people to understand their needs, and then briefly reviews the history of travel assistance devices. The paper then analyses the working mechanisms of smart wearable devices and divides them into three categories based on how they return information to the user. Then, the paper summarises the advantages and disadvantages of different types of devices and the disadvantages common to all types by detailing the working principles, functions, and usage effects of a dozen different types of devices. Finally, it summarises the current research status and limitations, and proposes future research directions. It aims to provide a reference for the development of smart wearable devices that assist visually impaired people in travelling.

Keywords: Visually Impaired People; Smart Wearable; Travel Aids; Information Feedback

1 Introduction

According to the World Health Organisation (WHO) 2023 report, at least 2.2 billion people globally have near or distant vision impairment [1]. Visual impairment affects their physical health, mental health, and quality of life, resulting in reduced mobility, limited ability to travel independently, and increased likelihood of accidental injury [2, 3]. Due to limited vision, they may be unable to spot obstacles, other vehicles, or pedestrians on the road in time or accurately judge traffic signals and road markings. All these factors increase the likelihood of traffic accidents. The simplest and most affordable navigation tools available are trained dogs and the white cane [4]. However, the number of guide dogs is limited, and the cane does not recognise obstacles in the

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air (branches, protrusions). Even among the users of these two aids, 40% reported head injuries at least once a year (18% once a month), and as a result, 34% leave their usual routes only once or several times a month, while 6% never do [2]. Therefore, the complexity of traffic and living conditions today means that these tools alone are no longer sufficient to handle the complex tasks of navigating streets, driving, and shopping [5]. In order to help the visually impaired to travel and improve their safety, researchers have added sensors such as ultrasonic, camera and radar on top of the traditional means of guiding the visually impaired to convert the visual information that the visually impaired cannot access into tactile information, auditory information or a combination of the two, so as to help them to have a better travelling experience[6]. Therefore, smart wearables show great potential in helping visually impaired people travel with features such as portability and interactivity.

This paper provides an overview of smart wearable devices that assist visually impaired people in travelling. The paper begins by analysing and summarising the characteristics of visually impaired people, followed by a brief review of the development of assistive devices. It then describes how wearable devices work and categorises them into three groups based on how they return information. It also discusses the advantages and disadvantages of these devices. Finally, it summarises the current state of research and the limitations of the research, and proposes future development directions in three areas. Aiming to provide a reference for further research on this topic.

2 Methods

Literature search method: This paper first reviews the literature on the visually impaired to understand their characteristics and needs; it then reviews the literature on currently available assistive devices to understand their development history; and it reviews the literature on smart wearable devices to understand their working mechanism and classify them accordingly.

Combination of literature analysis and market research: through reviewing the literature about smart wearable devices for the visually impaired and researching the existing wearable devices in domestic and international markets, to understand their impact on the users' daily lives and summarise the advantages and disadvantages of the products.

3 Results and Discussion

3.1 Characteristics of Visually Impaired People

3.1.1 Physical Characteristics

Visual impairment is caused by structural or functional eye abnormalities, including total blindness and low vision [7]. Globally, the main causes of visual impairment and blindness are: refractive errors, cataracts, diabetic retinopathy, glaucoma, and age-related macular degeneration [8]. This visual impairment results in the inability to see their surroundings and objects clearly or at all. It may cause the patient to exhibit delayed or impaired development of spatial abilities [9]. As a result, they become more dependent on other senses, such as hearing and touch, to compensate for their lack of sight. [10-12]. Therefore, wearable devices may provide feedback to visually impaired people through tactile and auditory senses.

3.1.2 Mental Characteristics

Visually impaired people often face some psychological problems due to their visual impairment. They may have low self-esteem because of their disability. They may fear that they are different from others and cannot participate fully in society, leading to feelings of isolation. Visually impaired people may be prone to anxiety because of their fear of not being able to live independently or face some challenges, and this anxiety may cause them to be more dependent on others or avoid trying new things [13]. However, not all visually impaired people experience these psychological characteristics, and there are differences in each individual's situation [14]. Therefore, wearable devices for the visually impaired are deemed necessary, and the appearance of the wearable devices should be small, not conspicuous and not strange after wearing. This will reduce the psychological burden on the visually impaired.

3.2 Travel Aids for Visually Impaired People

Travel aids for the visually impaired are continuously evolving due to technological advancements. The traditional blind cane is a simple aluminium alloy folding bar, as shown in Fig. 1. The user swings the cane from side to side to detect whether obstacles in the surrounding environment or the road surface have a height difference. However, with the rapid development of science and technology, the traditional blind cane can no longer meet the needs of modern travelling, and the electronic guide cane has begun to rise. The electronic guide cane on the market is mainly an ultrasonic detection guide cane, as shown in Fig. 2, which can detect obstacles above the ground within 3 metres in front of it and promptly remind them by voice, siren and vibration. It has a red flash warning function when travelling at night. With the rapid development of the Internet of Things, artificial intelligence, big data and other cutting-edge technologies, smart wearable devices provide unprecedented opportunities for travel assistance for the visually impaired. Wearable products to assist the visually impaired in travelling mainly include guide glasses, and some scholars have even developed smart clothing and gloves for the visually impaired based on embedded systems. The following section will introduce them in detail. This paper organises and summarises representative products of assistive devices for the visually impaired at different stages, as shown in Table 1 [15-18].

Fig. 1: Traditional white cane [22]

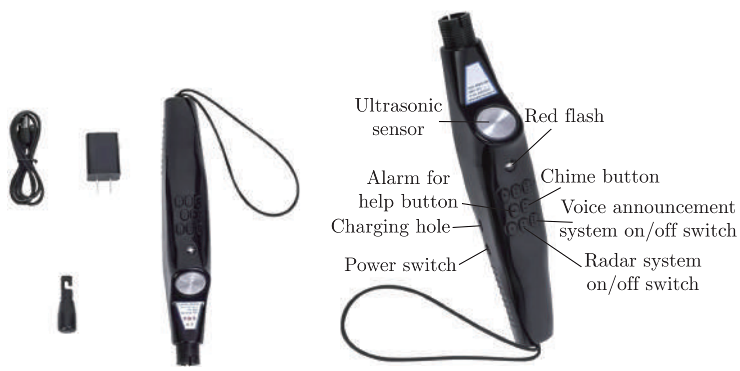

Fig. 2: Electronic white cane [23]

Table 1: History of the development of assistive devices for the visually impaired

Stage	Assistive devices	Example	Characteristic	Reference
Phase I	Mechanical aids	White cane	Limited detection range, inconvenient to use	[19]
Phase II	Electronic aids	Electronic white cane	Detecting obstacles with electronic sensors	[20]
Phase III	Smart aids	Smart glasses	With integrated functions	[21]

3.3 Classification and Analysis of Smart Wearable Devices for Visually Impaired People

With the development of social science, the problem of inconvenience in the daily life of the visually impaired has received increasing attention from the public. Many researchers have researched and developed smart wearable devices for the visually impaired. This paper collects smart wearable devices for the visually impaired and analyses and categorises them accordingly, as shown in Table 2. Wearable devices typically incorporate cameras, sensors, and other components for in-depth recognition of the surrounding environment. The environmental information captured by the electrical signals is transmitted to the central system of the device or cloud processing. The central system uses algorithms to determine the input environmental information and perform a systematic evaluation. Then, the evaluated environmental decision-making information is fed back to the machine [24] and transmitted to the device's corresponding actuators. Actuators of different information provide feedback to the user through auditory and/or tactile means, assisting the visually impaired in correctly grasping information about the environment [25-28], as shown in Fig. 3. In this paper, smart wearable devices are classified into three categories according to the way they return information: (1) using tactile feedback; (2) using auditory feedback; (3) using both tactile and auditory feedback.

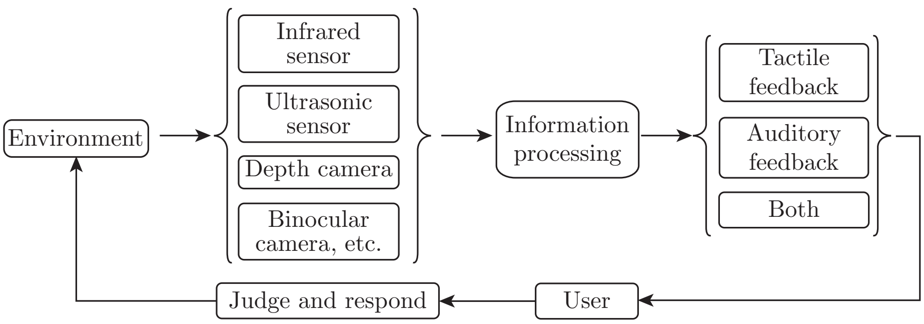

Fig. 3: Wearable device working mechanism

3.3.1 Utilising Tactile Feedback

(1) Barrier detection function

Shen et al. [29] proposed an obstacle avoidance wearable device using a novel haptic display made from a shape memory alloy (SMA) actuator as shown in Fig. 4 and Fig. 5. The device indicates the presence or absence of obstacles by vibrating at different frequencies and indicates obstacles in different directions by vibrotactile sensations in different parts of the device. And the

Table 2: Smart wearables for the visually impaired

Device name	Feedback method	Function	Strengths	Weaknesses	Reference
Tactile Display	Tactile	Barrier detection	The algorithmic model was compressed and accelerated to achieve high-performance object detection while keeping the device small.	Less effective in complex environments	[29]
A Smart Clothing System For Obstacle Avoidance	Tactile	Barrier detection	Embedding the entire system into the garment frees the hands of the visually impaired.	Only for avoiding static obstacles	[30]
NaviBelt	Tactile	Navigation	Good looking and easy to wear.	Simple and single function	[31]
Tactile Wristband	Tactile	Navigation	Continuous sliding tactile direction guidance solves the problem of discontinuous commands.	Contact trajectories are lost to varying degrees during navigation	[32]
Lechal	Tactile	Navigation	Good device concealment.	Simple and single function	[33]
Flying Guide Dog	Tactile	Navigation	Tactile traction is more intuitive and can be mastered without using your brain.	The real object doesn't live up to the hype and has a strange appearance.	[34]
Unfolding Space Glove	Tactile	Barrier Detection & Navigation	Good looking and easy to carry around.	Takes a long time to learn to use proficiently	[35]
BrainPort	Tactile	Visual aid	Judges the shape, size and movement of objects by different stimulus intensities on the tongue	It takes a long time to learn, and prolonged holding of foreign objects in the mouth can cause discomfort to the user.	[36]
Auxiliary Clothing for the Blind	Auditory	Barrier detection	Integrates devices into clothing to improve wearability.	Poor practicality and can only be used with a blind cane.	[37]
Smart Obstacle Avoidance Shoe Cover	Auditory	Barrier detection	Based on gait angle detection, it prevents the alarm from being triggered by mistakenly identifying the ground as an obstacle.	Use is limited by shoe style and is not suitable for rain or snow	[19]
Krvision Smart Glasses	Auditory	Barrier Detection & Navigation	Multiple types of obstacles can be detected with high accuracy and aesthetic appearance.	Higher failure rate in recognising small hills and steep slopes	[38]
Intelligent Guide Vest	Auditory	Barrier Detection & Navigation	The vest is connected to a smartphone terminal with obstacle detection, navigation, and warning functions.	Did not make a physical object to test its actual performance	[39]
Smart Wearable Jacket	Auditory	Barrier Detection & Navigation	Reliable detection of obstacles and navigation paths using machine learning techniques.	Difficulties in washing garments	[40]
Smart Protective Clothing for the Blind	Auditory	Barrier Detection & Protection	Not only can it detect obstacles, but it also has a safety function.	Low detection accuracy and poor clothing comfort	[41]
Horus	Auditory	Navigation & Visual aid	Processing using deep learning and computer vision techniques transforms images into information delivered through headphones.	High prices	[42]
InnoMake Shoe	Tactile & Auditory	Barrier detection	Warnings are given through a tactile feedback system, while an audible alert is sent out on a Bluetooth-connected smartphone.	The device is susceptible to collision damage	[43]
Wrist-worn vibrotactile Device	Tactile & Auditory	Barrier Detection & Navigation	The system can notify the user's family when the user trips or needs help.	The device is large and not easy to carry	[7]
Navigation Headgear	Tactile & Auditory	Barrier Detection & Navigation	The system uses a mobile phone camera to capture images of the subject's surroundings and wirelessly transmits them to the back office.	The obstacle detection function is not effective and the operator must process the information in the background	[44]

researchers compressed and accelerated the high-performance object detection algorithm model to achieve high-performance object detection while keeping the device small. After testing, subjects were able to identify the left and right positions of stationary obstacles with 96 per cent accuracy using the wearable assistive device, and successfully avoided collisions with moving obstacles. However, the device's accuracy could be improved in dynamic environments such as streets with large numbers of people and vehicles.

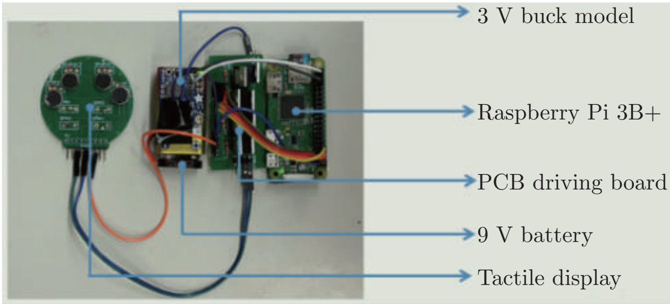

Fig. 4: The tactile presentation device [29]

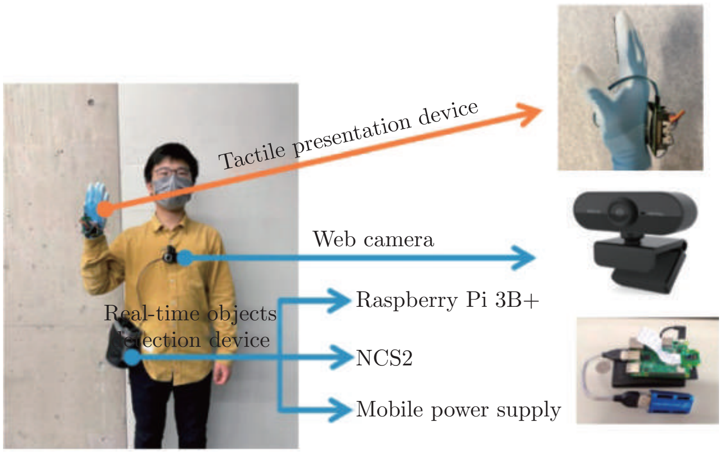

Fig. 5: Subject wearing devices [29]

Bahadir et al. [30] embedded the entire system into the garment to free the hands of the visually impaired, as shown in Fig. 6. In this system, four ultrasonic sensors are used to detect obstacles, and eight vibration motors (four on the left and four on the right) are used to recommend turning directions and angles to the user. The function of the circuit is to digitise and convert the analogue signals captured by the sensors into vibration signals. It modulates the analogue signals into different vibration levels by recognising the correlation between the obstacle's position and the user's desired turning movement (direction and angle). However, clothing is only suitable for avoiding static obstacles.

(2) Navigation function

A German company, feelSpace, has introduced a smart belt, naviBelt [31], as shown in Figs. 7 and 8. The belt has three micromotion sensors that use sixteen vibration elements. The sixteen evenly spaced vibration units cover 360° with tactile vibration stimulation to alert the user of which direction to go. The naviBelt can be used as a tactile compass without using the app.

Fig. 6: A smart clothing system for obstacle avoidance [30]

Fig. 7: Physical picture of naviBelt [31]

Fig. 8: NaviBelt wearing effect [31]

Zhang et al. [32] proposed a continuous sliding haptic directional guidance wearable device to address the problem of discontinuous commands - a sliding tactile feedback wristband, as shown in Figs. 9 and 10. The Arduino-driven tactile wristband was mounted on the participant's wrist to provide directional guidance, and a Bluetooth module was used to receive real-time guidance information. Providing uninterrupted and flowing instructions via sliding tactile sensors resolved many constraints of existing acoustic and vibrational orientation guidance solutions. However, subjects reported varying degrees of losing touch with the trajectories with the guidance wristband contactor during navigation.

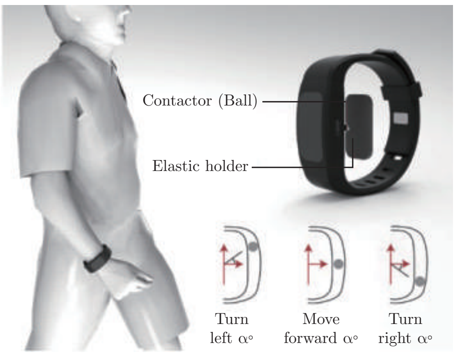

Fig. 9: Conceptual design of the tactile wristband [32]

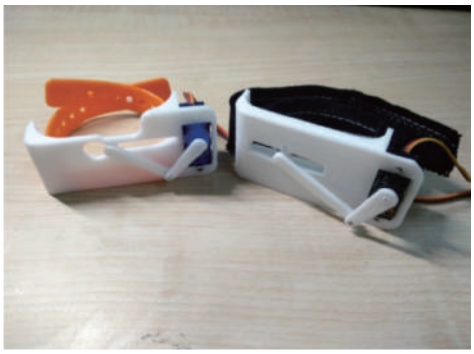

Fig. 10: Tactile wristband physical picture [32]

Indian entrepreneur Ducere Technologies Pvt has launched a Bluetooth-enabled smart shoe called Lechal [33]. It connects to mobile phone signals through a built-in Bluetooth device. It gets the location information from the mobile phone's navigation map and plans the owner's walking route based on the map. When it is time to turn left or right, the two shoes vibrate separately to guide the way. The shoes and insoles are washable, although the user must remove the electronic module before cleaning.

Fig. 11: Smart shoes Lechal [33]

(3) Barrier detection and navigation function

Yu et al. [34] developed a wearable flying guide dog inspired by guide dogs, as show in Fig. 12. The visually impaired person perceives the direction of the traction force at the point of contact between the flying guide dog and the human body through the sense of touch to judge the orientation of the guide assistive device. The user only needs to walk in the direction of the traction force without the need for brain analysis. Suppose the user needs to change direction in the middle of the journey or encounters obstacles. In that case, the guide assistive device can be switched to the intelligent guidance prompt mode at any time, which is as convenient and free as using a guide dog. Through its binocular visual perception system, the device identifies environmental information, converts it into ordered electrical signals and transmits it to the computer for calculation and judgement, which can provide real-time navigation to the destination according to the user's voice input, and can also transmit the environmental information to the guardian, so that the guardian can remotely monitor and manually manipulate the blindness guiding function of the guide assistive device. However, the product does not ultimately achieve the full effect of flying traction to the point where the user unconsciously follows the traction and walks. Secondly, the appearance of the product is also strange and may not be accepted by the visually impaired.

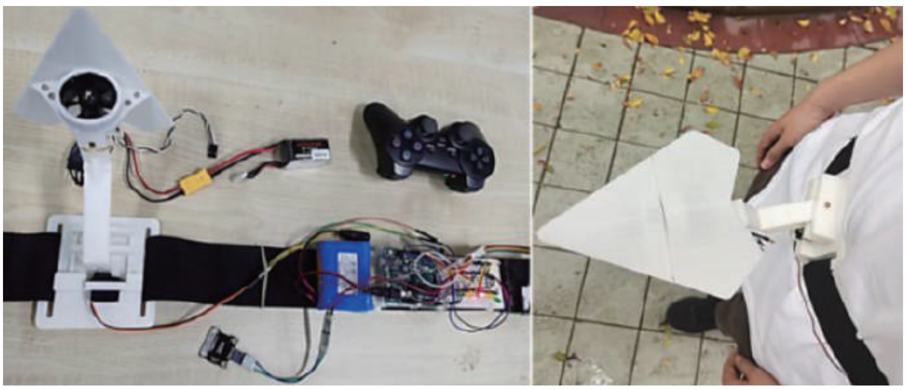

Fig. 12: Flying guide dog prototype [34]

Kilian [35] designed a wearable sensory replacement device, the Unfolding Space Glove, for visually impaired people, as shown in Fig. 13. Depth images from a 3D camera are projected haptically onto the back of the hand using vibrating motors. The position of the vibration indicates the object's relative position in space, and the intensity of the vibration indicates its distance. This enables blind people to explore the depth of the surrounding space haptically, assisting with navigation tasks such as object recognition and wayfinding. The device requires no external hardware, is highly portable, operates in all lighting conditions, and provides continuous and immediate feedback while being visually unobtrusive. However, it was found through testing that this sensory substitution takes a long time to learn to be proficient.

Fig. 13: Unfolding space glove wearing effect and detail picture [35]

(4) Visual aid function

Visual aids can also be achieved using tactile feedback. BrainPort [36], an oral electronic visual aid developed by Wicab in the United States, as shown in Fig. 14, converts digital information from a wearable camera into a mild electrical stimulation pattern on the tongue's surface. The tongue array contains 394 electrodes connected to the headset via a flexible cable. When used, white pixels from the camera are felt as strong stimulation on the tongue, black pixels indicate no stimulation, and grey levels represent moderate stimulation. The user senses a moving bubble-like pattern on the tongue, interpreted as the shape, size, position, and movement of objects in the environment, allowing the blind to "see the world" with their tongue. But BrainPort gives blind people visual perception rather than vision. The visually impaired need to judge the shape, size, and movement of objects based on stimuli on the tongue. The establishment of visual perception is a process, and it takes a long time for a blind person to be able to "see the world" with his or her tongue. Prolonged holding of foreign objects in the mouth can also cause discomfort and a poor experience for the user.

Fig. 14: Tongue array and wearing effect of BrainPort [36]

In summary, most current studies have used vibrotactile sensation, and very little research has been done on sliding tactile sensation and traction tactile sensation. Vibrotactile can indicate the distance to an obstacle based on the vibration frequency, and the part of the vibration can indicate the orientation of an obstacle, but it lacks precision. Using sliding and traction haptics to indicate bearing can somewhat overcome the inaccuracy of vibrotactile bearing indication, and is therefore commonly used for navigation. Devices used for tactile feedback are usually gloves, bracelets, belts and shoes, so the area of tactile feedback is usually in the hands, waist and feet. The advantages of tactile feedback are that it does not affect the auditory perception of the visually impaired and can be used in noisy environments. The disadvantage is that tactile feedback provides less information about the type of obstacle. Secondly, the information provided is not intuitive enough and requires training to become proficient in its use.

3.3.2 Utilising Auditory Feedback

(1) Barrier detection function

According to the travel characteristics and special needs of the blind, Zhu et al. [37] combined conductive sewing threads and an easy-to-remove connection design with the Arduino intelligent clothing platform, creating wearable electronic hardware with ordinary clothing and produced non-motion interference, low-cost, removable and washable assistive clothing for the blind, as shown in Fig. 15. The garment contains 3 ultrasonic sensors, which can actively emit ultrasonic waves and perform distance detection. The control core of the garment will judge the distance of the signals from the 3 ultrasonic sensors. When the distance detected by any one of the sensors is at the preset alarm distance, the buzzer will sound an alarm. The buzzer will change the tone according to the distance between the person and the obstacle. When the distance is greater, the sound is high-frequency bass. The sound will change to a low-frequency treble when the distance is smaller. However, the assistive clothing cannot be used independently and still needs to be used with the basic guide equipment, improving the accuracy and response time.

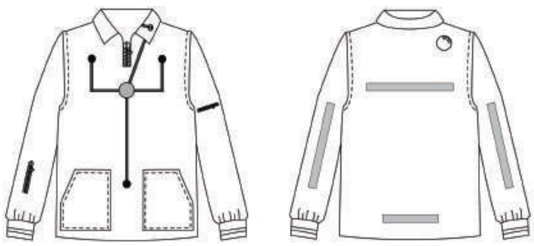

Fig. 15: Auxiliary clothing for the blind [37]

Li et al. [19] designed a smart obstacle avoidance shoe cover for visually impaired people based on their daily travelling problems and needs and the current smart wearable technology, as shown in Fig. 16. Through gait angle detection, they prevent the human from walking in the process of gait angle to the ground, mistakenly regard the ground as an obstacle and triggering a buzzer alarm. The shoe cover adopts different sensors and interacts with audible reminders for different motion states and road conditions, effectively assisting their daily travel. However, the functional system components of the shoe covers are fixed on the instep using an electronic control box, and their functions are affected by the style of the shoes worn by the users themselves. Unfortunately,

Fig. 16: Wearing effect of smart obstacle avoidance shoe cover [19]

the device is unsuitable for rainy or snowy weather.

(2) Barrier detection and navigation function

Hangzhou Krvision [38] Technology Company Limited developed smart glasses, as shown in Fig. 17. These glasses can acquire stereo information about the surrounding environment through binocular cameras, process the acquired information, carry out special three-dimensional stereo voice coding, and then transmit the information to the blind. Through continuous learning and trial and error, the blind will judge the surrounding environmental information according to the received sound. The main functions of these glasses are obstacle detection, access detection, pothole detection, stair detection, and up and down slope detection, with a detection accuracy of 3 cm. At the same time, they can provide accurate positioning and navigation functions. However, some users have reported that the glasses have a high failure rate in recognising small hills and dips.

Fig. 17: Krvision smart glasses [38]

Zheng et al. [39] designed an intelligent guide vest with an obstacle detection function and warning function for the physical and mental characteristics of the blind group, as shown in Fig. 18, through function setting, style design and circuit system design. The guide undershirt uses ultrasonic distance measurement, infrared rays, and image detection to detect obstacles. The undershirt is connected to the smartphone terminal so the blind can dictate the destination. Then the software recognises the navigation path information and provides voice feedback and real-time positioning. Reflective tape is used on the surface of the undershirt for structural segmentation or decoration, which produces a stimulating visual effect on pedestrians and warns them of the need to avoid pedestrians. However, the paper did not make a physical object to test its performance.

Bhatlawande et al. [40] proposed an assistive system to augment the mobility of such visually impaired people. This system is realised by using a smart clothing approach for the wearable convenience of the subject. In this system, five ultrasonic sensors, a web camera and a global positioning receiver (GPS) are integrated on a wearable jacket, as shown in Fig. 19. This multi-sensory arrangement is proposed to translate human navigation ability into an electronic system. It employs machine learning for the reliable detection of obstacles and navigation paths. The proposed system also assists in knowing information about current or nearby locations, planning a journey from a reference location to a desired destination, and tracking the navigation path to reach the destination. But there are difficulties in cleaning the garments.

(3) Barrier detection and protection function

Jin et al. [41] proposed a blind suit with safety and protection functions from the perspective of intelligent clothing design for the blind given the difficulty of travelling and the lack of safety,

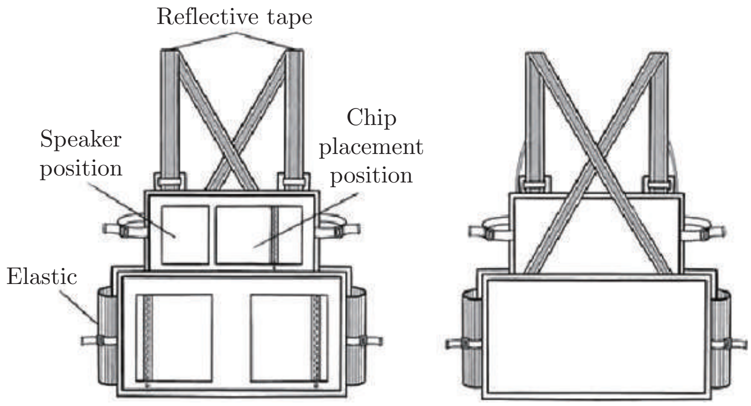

Fig. 18: Intelligent guide vest [39]

Fig. 19: Smart wearable jacket [40]

as shown in Fig. 20. to protect and warn the users, reflective strips are sewn at the chest, waist, and wrist of the garment, and removable airbags are sewn at the neck, crotch, elbow, and knee parts; to accommodate the daily travelling needs of the blind, the embedded technology is utilised to design the wayfinding function, fall detection and protection function, and failure to get up alarm function for the garment carrier. Pathfinding is achieved using a distance sensor and buzzer controlled by the Arduino Lite. After testing, the daily travelling environment was simulated to test the effect of clothing on obstacle recognition when worn. The results show that the suit has a 100% success rate in identifying rear and left/right obstacles and a 95% success rate in identifying front obstacles. But real-life environments are far more complex than simulated environments. Moreover, the combination of embedded hardware and the garment affects the comfort of the garment.

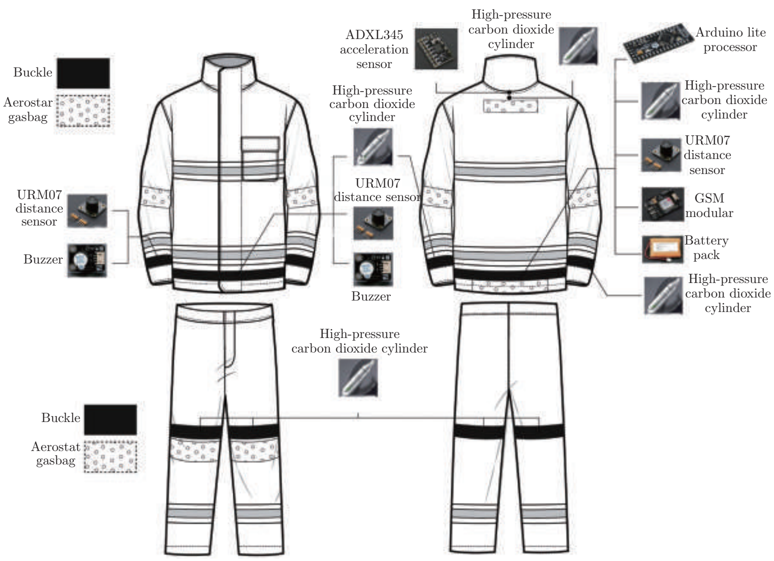

Fig. 20: Smart protective clothing for the blind [41]

(4) Navigation and visual aid function

Eyra, a company from Switzerland, has developed Horus, a wearable device with integrated functionality [42]. The Horus wearable device consists of two parts, as shown in Fig. 21. One is a bone-sensing headset worn on the head, and two high-definition cameras are on its right side. The other part is a black plastic box containing a chip and a battery. The two high-definition cameras will be responsible for scanning the obstacles in front of them and processing them using deep learning and computer vision technologies to convert the image into information delivered through the headset. Horus can describe the environment through language. When travelling, the closer the obstacle, the louder the alarm sounds. The device can also be used to inform acquaintances through face recognition technology. In addition to this, Horus has a text recognition function. However, the device is overpriced and beyond the reach of many visually impaired people.

Fig. 21: Bone conduction headset and battery of Horus [42]

In summary, devices that utilise auditory feedback usually include buzzer alarms or voice announcements. The devices are usually glasses or head-mounted, and some are embedded in clothing or shoes. The advantage of auditory feedback devices is that the feedback information is richer and more intuitive. They can describe the road conditions, the specific location of obstacles and other information in detail through voice so that the visually impaired can understand the surrounding situation more comprehensively and intuitively and thus react more quickly. Its disadvantage is that it takes up the hearing of the visually impaired and is greatly interfered with by environmental noise. In a noisy environment, the sound of auditory feedback is easily covered by background noise, making it difficult for the visually impaired to hear the feedback information, thus affecting the effectiveness and safety of the device.

3.3.3 Utilise Tactile and Auditory Feedback

(1) Barrier detection function

The InnoMake shoe [43], developed by Tec-Innovation, a company from Austria, in collaboration with the University of Graz, uses ultrasonic signals to detect curbs, walls, and crowds of people, as shown in Fig. 22. Each InnoMake shoe has a proximity sensing module mounted on the toe of the shoe, which emits ultrasonic pulses and receives the echoes of these pulses on objects in front of it. This way, it can detect potential obstacles up to 4 meters before the user. Warnings are given through a haptic feedback system, while an audible alert is sent out on a Bluetooth-connected smartphone. However, visually impaired people may experience inconvenience and difficulty installing the device, and it is also very easy to bump the sensor device on the toe of the shoe.

(2) Barrier detection and navigation function

Ramadhan [7] developed a wrist-worn vibrotactile device that helps visually impaired people cross streets independently, navigate public places, and ask for help. The main components of the device include a microcontroller board, various sensors, cellular communication and GPS modules, and a solar panel, as shown in Fig. 23. The system uses a set of sensors to track the path and alert the user to obstacles ahead. The user is alerted through a sound emitted by a buzzer and a vibration on the wrist. Additionally, when the user stumbles or requires assistance, the system alerts those nearby and transmits the notification, along with the system's location, via a phone message to the registered mobile phones of family members and caregivers. However, the device is not wearable enough, and its relatively large size is not conducive to wrist movement.

Fig. 22: InnoMake shoe [43]

Fig. 23: Wrist-worn vibrotactile device [7]

Ge et al. [44] developed a prototype system that uses tactile and speech to assist blind or visually impaired people in acquiring images of the external environment and navigating information, as shown in Fig. 24. The system uses a mobile phone camera to collect images of the subject's surroundings and wirelessly transmit them to the backend, where the operator analyses and processes the image information, and then wirelessly transmits the commands in the form of tactile coding to a wearable device, such as a headgear, which is activated by driving circuits to stimulate the multi-site tactile sensation of the head, to provide the subject with accurate action commands. The system is supplemented with voice messages to provide additional information about road conditions and the environment. The system's head-tactile device consists of 11 micro-vibrating motors fixed to a special elasticated headgear liner, which a normal hat can cover. However, obstacle detection is ineffective; an operator must process the information in the background.

Fig. 24: Navigation headgear [44]

In summary, the advantage of auditory and tactile feedback is that it allows both sides to complement each other. The disadvantage is that the device generally requires more components, and therefore, its wearability deteriorates.

Overall, each wearable device has its advantages and disadvantages. However, one disadvantage of either device is the lack of accuracy; most of the devices mentioned above can only detect static obstacles or can only be used in simple dynamic environments. However, real-life travelling environments are much more complex. Secondly, the devices are not comfortable to wear [7] [29] [36] [41] [44]. This is because some devices have many parts that are inconvenient for normal people, let alone the visually impaired. Finally, some of the devices have a rather odd appearance [7] [30] [34] [44]. Visually impaired people do not want others to think that they are different from others, and the odd appearance of the devices can easily attract attention, which will increase the psychological pressure on visually impaired people. Finally, a comparison of the advantages and disadvantages of different types of devices is summarised in Table 3.

Table 3: Comparison of devices with different feedback categories

Category	Advantages	Disadvantages	Future research directions	Reference
Tactile feedback	Unoccupied hearing and unaffected by noise environments	The information that can be fed back is poor and not intuitive enough	Exploring the effects of different tactile types and tactile receptive sites on feedback information	[29-36]
Auditory feedback	The information that can be fed back is rich and intuitive	Occupy the hearing and are not effective in noisy environments	Exploring the optimal duration of audio feedback to reduce auditory occupancy	[19] [37-42]
Tactile and auditory feedback	Unaffected by environmental noise, the feedback is rich and intuitive	With more components in the device, less wearability	Increased wearability through miniaturisation, lightweight and integrated design of the devices	[7] [43, 44]
All categories		Low accuracy, poor wearing comfort and strange appearance	Improved accuracy, wearing comfort, and aesthetic appearance	[7] [19] [29-44]

4 Conclusion

Smart wearables hold great promise for helping visually impaired people get around. Researchers fused multiple sensors on a capture device to improve the detection performance of wearable devices, improving detection range and accuracy. The researchers optimised feedback methods to make it easier for visually impaired people to get feedback from the device, such as developing sliding tactile and traction tactile feedback messages. The researchers embedded the system in everyday clothing such as jackets and shoes to improve the device's aesthetics.

However, these studies have not led to a breakthrough. Today's wearable devices generally suffer from low detection accuracy, low wearer comfort, and odd appearance. This is why smart wearable devices cannot completely replace the blind cane. Therefore, future research in improving device accuracy will further optimise multi-sensor fusion algorithms and technologies to improve the device's ability to perceive complex environments and dynamic scenes and achieve faster and more accurate information capture and updating.

To improve wearing comfort, the focus is on the device's miniaturisation, lightweight, and integrated design. From the ergonomics perspective, optimise the device's shape, structure, and wearing mode to make it more in line with the physiological characteristics and exercise habits of the human body.

In terms of improving aesthetics, develop wearable devices that can be better combined with daily wear, such as embedding sensors and electronic components into common wearable items, such as clothing, hats, glasses, and so on, to make their appearance more natural and hidden, while not affecting the wearer's overall aesthetics. In conclusion, the future requires cross-fertilising multiple disciplines, such as computer science, electronic science, ergonomics and design, to develop practical, comfortable and aesthetically pleasing smart wearable devices to help the visually impaired in their travels. This will bring more convenience to the visually impaired.

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