Chapter 15
Development of Walking Support System for Visually Impaired People

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Abstract Currently, shortage of trainers for visually impaired people with professional knowledge is a big problem in Japan (Japan Ministry of Health in Labour and Welfare: Annual Report on Government Measures for Persons with Disabilities, 2014; Fukui in Nippon Hojyoken Kagaku Kenkyu 2(1), 22–25, 2008) [1, 2]. In addition, children with congenital blindness are so difficult to learn to walk by themselves, because they cannot get the visual image. In this research, the authors aim to develop a new support device for walking training that can rise for visual impairment and visually impaired children's spatial perception. The method involves three stages of training, hand cart type stage, wearable type stage, and final stage. The authors focus on developing a safe, lightweight walking support system that can be worn in children's waist belt at the second and the third stage. In this paper, the authors proposed the wearable type walking support system that consists of infrared sensor and ultrasonic wave sensor. In addition, the equipment is used at each stage so that it can finally walk independently.

15.1 Introduction

Currently, there are concerns about an increase in visually impaired children for three reasons: ① Increase in children with disabilities due to population growth, ② popularization of medical infrastructure in the world, and ③ increase in premature infants. There is also a concern that the shortage of qualified trainers for the visually impaired with expert knowledge due to the increase in children with visual impairment will become more serious than ever. In addition, children with congenital blindness have no irritation on the vision, and independent walking is extremely difficult. In this research, the authors aim to develop a new support device for walking training for mobility and spatial capacity development of visually handicapped and visually impaired children.

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In order to become a support device that can be used at normal family, the cost must be reduced. So, the authors use ultrasonic distance measuring sensor and infrared distance measuring sensor, which is inexpensive and easy to construct system. The authors also use SH7125F microcomputer with high processing speed and low price for control. Moreover, this device will be worn for a long time, and therefore, the authors designed and proposed walking training system with emphasis on weight reduction.

The authors assume three sensor module attachment devices, a backpack type, a stick type, and a push car type. Among three types, the push-pull type has a large payload, so it is supposed to install additional equipment.

In this paper, the authors investigated the present condition of visually impaired people and developed the walking training system that supports vision as a means of solving each problem and its mounting device. The authors devised three sensor module mounting devices and designed the sensor module and developed the system.

15.1.1 Background

Recently, visually impaired people are increasing steadily. As one of the indicators, the research team at Anglia-Ruskin University in England predicts that visually impaired people will increase from current 36 million to 150 million by 2050 unless improving treatment by budget enlargement [3]. The cause is aging, rising age of childbirth, improvement of medical technology. Figure 15.1 [3] shows the visually impaired people with severe and moderate vision disorders among the increasing visual impairments. The vertical axis shows the number of people, and the horizontal

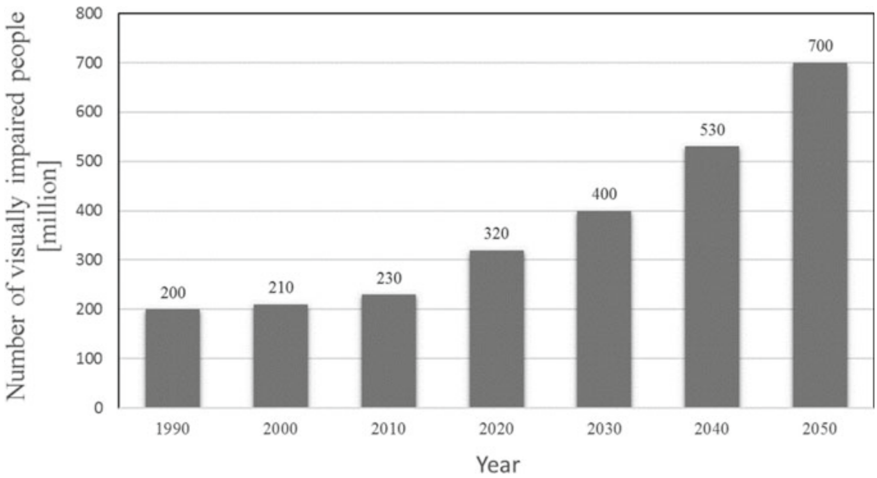


Fig. 15.1 Increase in the number of moderately and severely blind people

Table 15.1 Number of qualified care workers of various types

Profession	Number of people
Physical therapist	120,072
Occupational trainer	70,672
Vision trainer	**12,085**
An artificial prosthetist	4447
Language hearing expert	23,750

axis shows the year. In their paper, the authors know that Southeast Asia, China, South Africa are the most frequent increased [3, 4].

If the number of people with visual impairment that cannot be self-sustained increases, the burden on social welfare such as child rearing support expenses for visually impaired children and living assistance expenses for visually impaired people becomes immeasurable [5].

The other problem is the shortage of qualified trainers. As given in Table 15.1, there are 300,000 people with visual impairment in Japan. On the other hand, there are 12,000 qualified trainers [6]. The ratio is 25:1, and the shortage of this qualified trainer is said to become even more severe in the future. Figure 15.2 [6] shows the breakdown of caregivers.

Moreover then, it is extremely difficult to walking training people with visual impairment, it places a heavy burden on trainers and guardians during training such as colliding with obstacles in front of the face, falling into grooves/holes missed by white sticks. Therefore, the ratio of this qualified trainer to the visually impaired is a big problem to be solved [7].

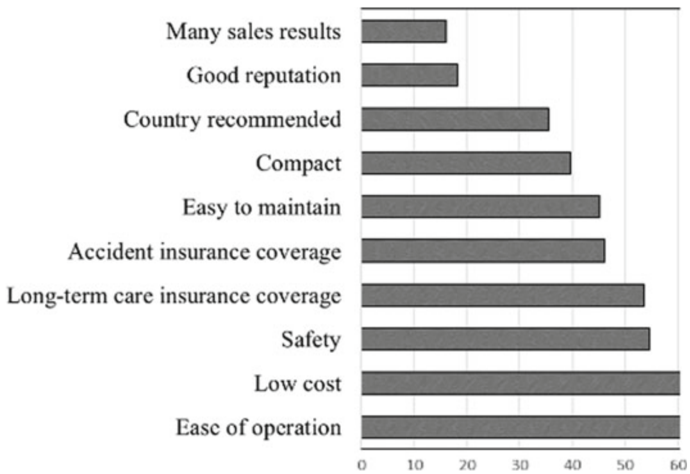


Fig. 15.2 Emphasis on selecting nursing robots

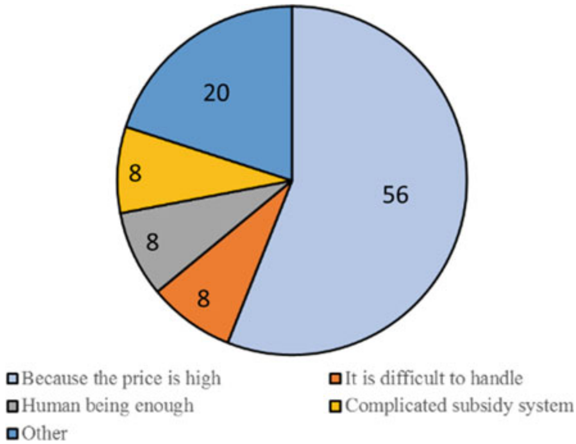


Fig. 15.3 Reason about not to introduce care robot

15.1.2 *Opinions from the Field*

Next, the opinions of nursing care sites are shown at Fig. 15.2 [8, 9]. This data is on public opinion survey conducted in Japan. The graph is needed for the support device/support robot. The vertical axis represents the item, and the horizontal axis shows the percentage that answered "Yes." Items are numerous sales results, good reputation, national recommendation, compact, easy to maintain, accident insurance, long-term care insurance, safety, low price, and ease of operation. The authors can see that low cost which is required from more than 60% of nursing side.

Next, Fig. 15.3 [10, 11] shows the reason why the caregiver does not introduce support devices/support robots. Items are in clockwise order, high prices, so handling is difficult, adequate human, complex subsidy system, others, etc. The graph shows that high price is a bottleneck in the introduction of support equipment/support robot.

15.1.3 *Purpose*

Therefore, the purpose of this study is to solve spatial problems in the training of visually impaired people and accompany various findings accompanying autonomous behavior, making it low cost and easy to handle.

The goal is to develop a new support device for walking training for visually impaired people who can realize the above. In addition, eventually, it will strengthen the connection between the movement ability and the environment of the spatial ability and create an opportunity to learn the perception, cognition, language, society, etc., of the visually impaired and visually impaired children, the social reintegration of visually impaired person. It aims to be useful for independence of children.

15.2 Walking Training System

In this research, the authors use one three-dimensional range image camera and one sensor to recognize surrounding environment. First, confirm the operation and the performance of the 3D range image system. Next, the distance image is acquired, and the object having the same distance from the distance image is extracted as one object. For each extracted object, discrimination between the moving object and the stationary object is performed. After that, the stationary object records the position of the living beings and recognizes it as an obstacle and aims at tracking the movement for the moving object. Furthermore, by detecting the object by distance measurement using a sensor, this is assisted to improve safety.

First, appropriate obstacles are corresponded to obstacles analyzed by image processing. At this time, infants with visual impairment are delayed in the concept of "there are obstacles in walking in the space," so the authors repeated the experiments at school to determine the timing of the best utterance and the type of sound. Next, the authors will support training of direction sense by changing the sound to be output depending on who is walking toward. As for this, the authors adopt a method which tests both the absolute direction based on the east, west, north, and south and the direction relative to the entrance of the room and has a large blind angle effect.

Table 15.2 below shows the responsible range of the department of collaborative research and the contents of each subject of this research.

15.2.1 Sensor

The device detects approach by two distance measuring sensors. Figure 15.4 [12] shows the infrared distance measuring sensor used, and Fig. 15.5 [13] shows the ultrasonic distance measuring sensor. The infrared distance measuring sensor has high accuracy with respect to price and has few errors. However, there is a weak point that permeate cannot be detected. Therefore, by compensating for that part by the ultrasonic distance measuring sensor, it is possible to measure with high precision

Table 15.2 Division of research with collaborative research members

Affiliation/duties	Sharing
National Institute of Technology, Tsuyama College. Mechanical System Course	Understand the progress of the whole plan, construction of a fall prevention mechanism, introduction of sensors
National Institute of Technology, Tsuyama College. Communication and Information System Course	Image processing
National Institute of Technology, Tsuyama College. Communication and Information System Course	Audio output system

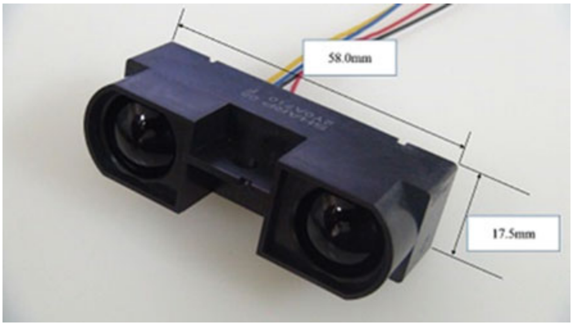


Fig. 15.4 Infrared distance measuring sensor

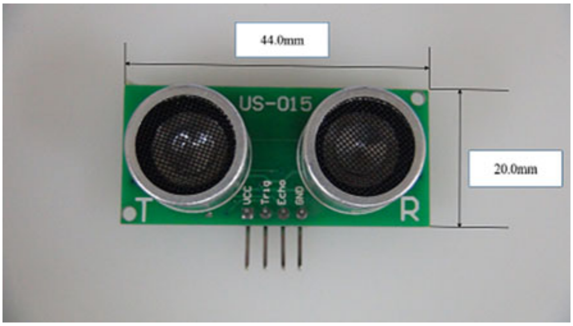


Fig. 15.5 Ultrasonic distance measuring sensor

regardless of the type of the object to be measured. Table 15.3 [12] and Table 15.4 [13] show the performance tables.

The infrared distance measuring sensor uses "sharp distance measuring module GP2Y0A710K." The power supply voltage V_{cc} is -0.3 to $+7$ V, and the output terminal voltage is -0.3 to $V_{cc} + 0.3$ V. The operating temperature is -10 to $+60$ °C. The infrared distance measuring sensor uses "ultrasonic distance sensor module US-015." The measurable distance is 0.02–4.0 m, the operating current is 2.2 mA, the power supply voltage V_{cc} is 5 V, and the operating temperature is 0 to $+70$ °C.

Table 15.3 Infrared distance measuring sensor data sheet

Parameter	Rating
Operating voltage	DC 5 V
Working current	2.2 mA
Operating temperature	0 ~ +70°
Output mode	GPIO
Sensing angle is less	15°
Detection distance	2–400 cm
Detection accuracy	0.1 cm + 1%
Resolution higher	1 mm

Table 15.4 Ultrasonic distance measuring sensor data sheet

Parameter	Rating
Supply voltage	V_{cc} −0.3 to +7 V
Output terminal	V_o −0.3 to V_{cc} + 0.3 V
Operating temperature	−10 to +60 °C
Storage temperature	−10 to +70 °C

Therefore, it can be used under normal temperature, has a measurement distance enough to avoid obstacles, and can be fed from the same power supply.

Next, the authors show the distance detection method of each sensor. The infrared distance measuring sensor outputs a voltage corresponding to the distance. This is converted to a digital value by AD conversion. Calculate this value to find the distance. Examples are shown below.

(Ex) When the 10-bit AD conversion value is 400

$$\frac{5}{2^{10}} \times AD(=400) = 1.953\ldots[V]$$

From the graph of Fig. 15.6 [12], the distance at this example is

$$0.006[1/\mathrm{cm}] = 166.666\ \ldots[\mathrm{cm}]$$

The distance can be measured from the above.

Next, the ultrasonic distance sensor outputs a pulse of a time corresponding to the distance. Therefore, calculate the distance by calculating the time of the pulse.

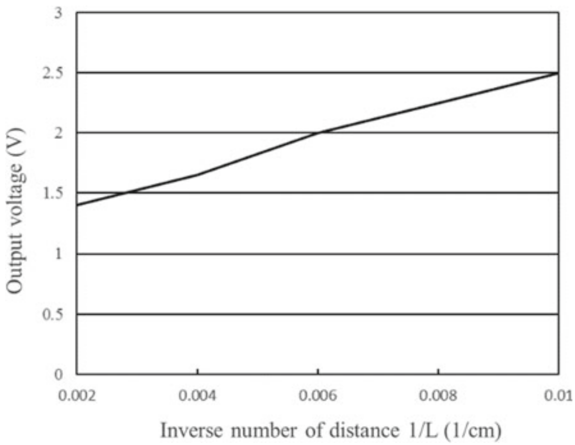


Fig. 15.6 Output characteristic of infrared distance sensor

15.2.2 Equipment Device

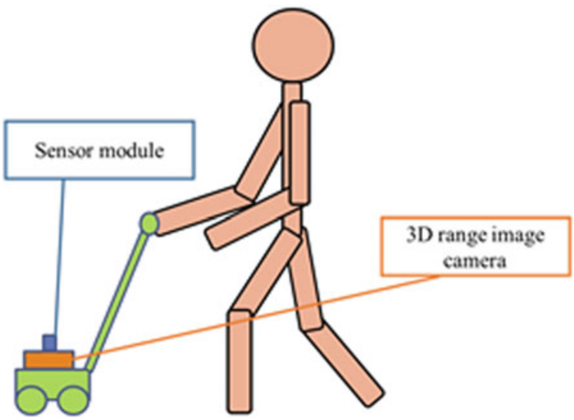
The mounting apparatus will be described. Figure 15.7 ~9 shows the outline of the device. The authors assume three types of mounting devices: “shoulder type,” “white cane type,” and “hand cart type.” Among them, the hand cart type has a large payload, so it is supposed to install 3D range image camera equipment. The attachment device’s main body is in green, the sensor module is in blue, and the 3D range image camera is in orange to indicate it.

Explain why multiple types of production are assumed? The visual impairment is roughly divided into three types, blindness, lack of vision, and amblyopia. In addition, the each level of symptoms is further divided, additionally visually impaired is often complicated with other disorders, and it is difficult to completely manualize the walking training. Therefore, it is to cope with this by selectively using multiple types or joint use.

Next, each mounting apparatus will be described. The hand cart type shown in Fig. 15.7 shall be used at the initial stage of walking training. This hand cart type guarantees safety, reduces fear of walking, and helps smooth transition to subsequent training. Shoulder type shown in Fig. 15.8 shall be used during walking training. This shoulder type is assumed to be used in combination with other mounting devices. When walking training in hand cart type, with white cane, the authors support walking training by installing it additionally. The white wand type shown in Fig. 15.9 assumes danger avoidance at the final stage of training and assistance during autonomous walking. Also, by combining these as described above, it is possible to support optimal walking training and autonomous walking according to individual levels.

Finally, prototype sensor module is shown in Fig. 15.10 and explained. In the prototype, the authors implemented the sensor most easily. Create a prototype sensor module as a book. The authors are also planning experiments on prototype operation and measurement system.

Fig. 15.7 Hand cart type



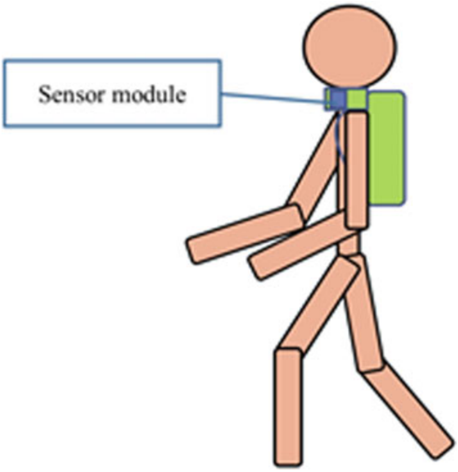


Fig. 15.8 Shoulder type

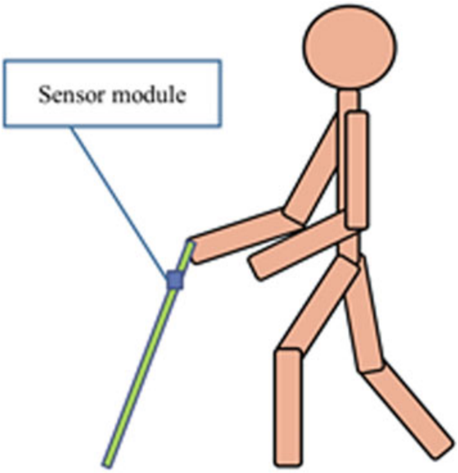


Fig. 15.9 White cane type

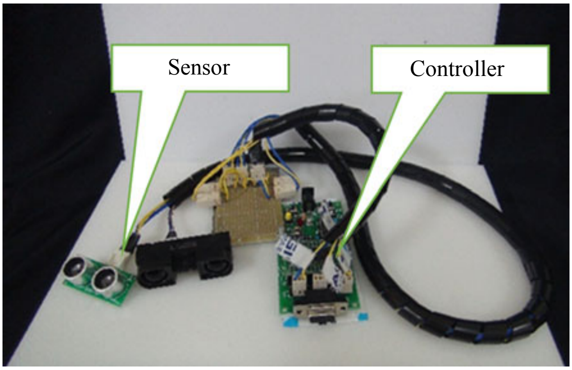


Fig. 15.10 Prototype of support system [14]

15.2.3 Equipment Production

In this research, the design concept of the part in charge of the laboratory is as follows.

1. Make the device wearable.
2. It is a device used for training of single walk.
3. Even children with visual impairment can safely use it.
4. The sensor detects an obstacle in front of the wearer and sounds it to the wearer.
5. There is little burden on the body when worn.

The authors made a device to realize the above concept.

Figure 15.11 shows the 3D CAD of the mounting device. Also, Fig. 15.12 shows the manufactured device, and Fig. 15.13 shows a photograph of it when worn.

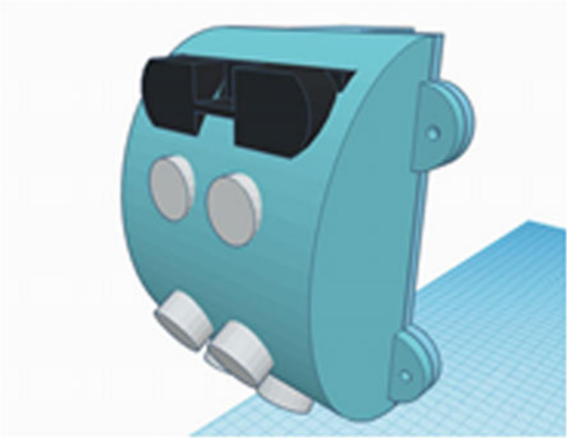


Fig. 15.11 Mounting device image

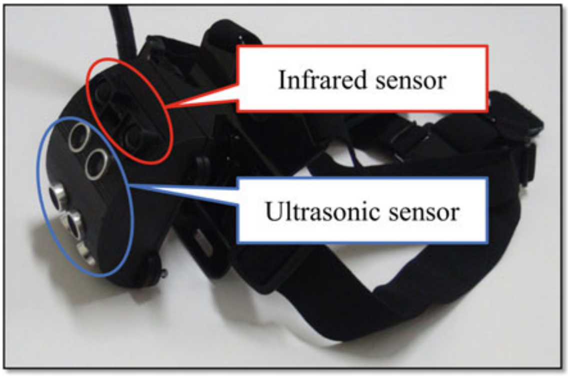


Fig. 15.12 Production equipment outline

Fig. 15.13 Production equipment mounting photograph

15.3 Experiment

15.3.1 Experimental Method

An experiment was conducted on the performance of the fabricated sensor module and the correction program for the temperature sensor. Perform experiments using a mobile battery as a power source. Use a measure to measure distance. Three types of obstacles are used: concrete wall, acrylic board, and cloth. The reason for adopting an acrylic board is to check whether a transparent object can be detected in each sensor, and the reason for adopting a cloth is to check if a soft object can be detected in each sensor. Figure 15.14 shows an outline of the experimental setup. The detection distance of the measurement object is 1 m, and the detection range of ultrasonic waves is conical with a tip angle of 15° as shown in Fig. 15.14.

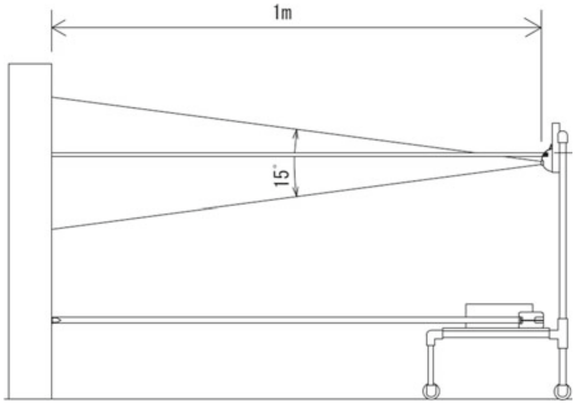


Fig. 15.14 Outline of experiment equipment

Table 15.5 Results of measurement by each sensor

	Concrete	Acrylic board	Cloth
Ultrasonic sensor average	100.8 cm	98.3 cm	
Same sensor standard deviation	0.71	0.63	
Infrared sensor average	96.7 cm		98.1 cm
Same sensor standard deviation	0.71		0.49

Table 15.6 Comparison of standard deviation of ad value measured by temperature sensor

	AD without correction	AD with correction
Average	377.87	360.70
Standard deviation	66.10	6.19

15.3.2 Results and Discussion

Table 15.5 shows the measurement results of the ultrasonic sensor and the infrared sensor. When the cloth was measured by the ultrasonic sensor, the sensor reacted, but the measurement distance was large, and the value was not stable. The reason for this is that the ultrasonic sensor measures the distance by the echo of the sound, so it is considered that the measured value becomes unstable with the cloth that the sound hardly echoes. In addition, when the acrylic plate was measured by the infrared sensor, the sensor did not react at all even if the object entered the set distance range. The reason for this is that the infrared sensor measures the distance by reflection of infrared light, so it is considered that the infrared light does not reflect, and it cannot detect the passing acrylic plate. From this, it was found that it is necessary to use an ultrasonic sensor and an infrared sensor in combination to detect all obstacles.

Next, Table 15.6 shows the results of experiments on the temperature sensor correction program. The set temperature is 76 °F. The ad value of the temperature sensor is read by a microcomputer and displayed on seven segments. The standard deviation of the ad value of the temperature sensor could be reduced to the original 9.36% after correction. It is considered that this makes it possible to greatly improve the correction of other sensors by the temperature sensor and make the accuracy in the distance measurement of the device more accurate.

15.4 Improvement

Figure 15.15 shows the detection range of the existing sensor module. As shown in the figure, in the existing sensor module, a gap exists between the 15° detection

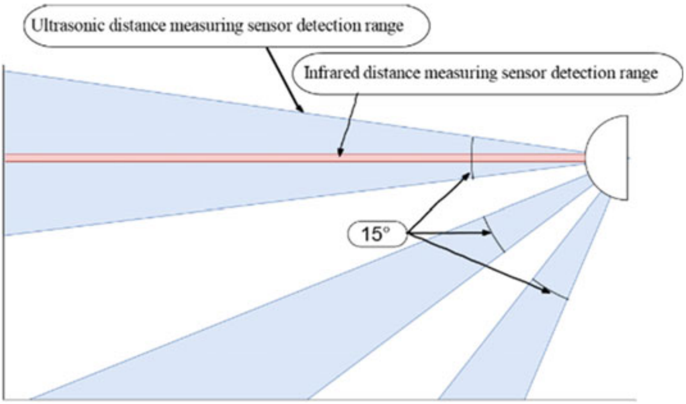
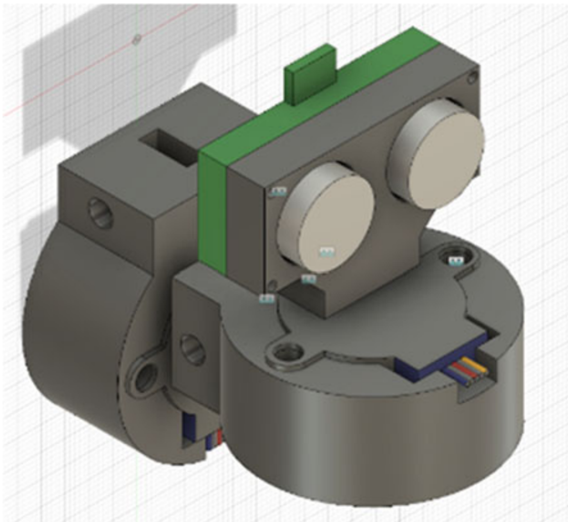


Fig. 15.15 Detection range of prototype

range of each sensor. Therefore, the authors will improve the detection part of the device. The image of the improved part is shown in Fig. 15.16.

In the improvement, the detection range is expanded by reciprocating the sensor in the *x* and *y* axial directions using two motors. Figure 15.17 shows the detection range of the improved device. The detection range is 60° vertically and 90° horizontally. This improvement has eliminated gaps in the detection range. In addition, more accurate detection of obstacles is possible. By conducting measurement that concentrated around the detected obstacle by the operation of the motor, it is possible to determine the shape and angle of the obstacle, and it becomes possible for the visually impaired to transmit accurate information of the obstacle.

Fig. 15.16 Image of improved equipment



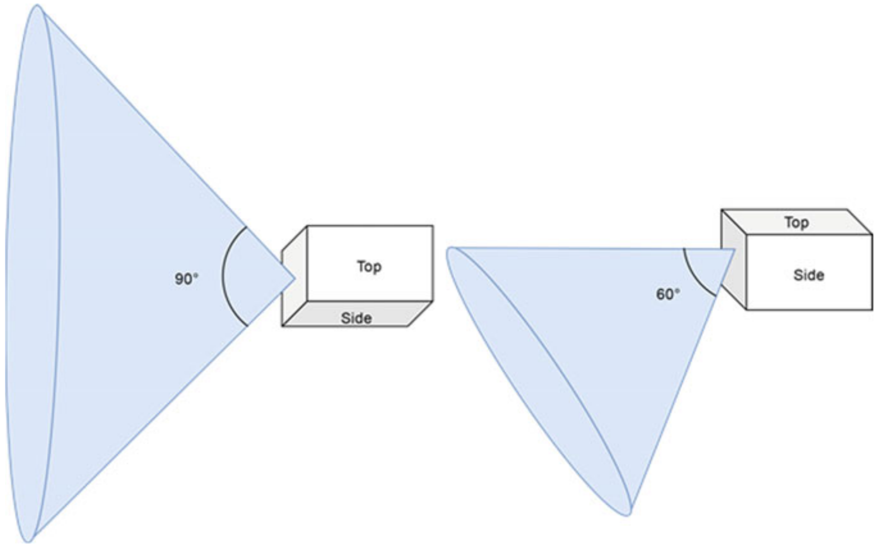


Fig. 15.17 Detection range of improved equipment

15.5 Conclusion

In this study, the authors investigated the present condition of the visually impaired and analyzed the spatial problems in the training of visually handicapped people (including congenital blind people and children with blindness) as a means of solving problems such as increasing tendencies of visually impaired people and lack of trainers. The authors are developing a novel support device for walking training for the visually impaired who can realize the above thing more than making it possible to experience the solution of the autonomous behaviors and various findings accompanying the self-sustaining behavior, making it cheap and easy to handle. The authors devised three sensor module mounting devices, designed a sensor module, and developed a highly safe system using two sensors. In the future, the authors will combine the whole research and production work done in each laboratory, produce prototypes of three sensor module mounting devices, and conduct evaluation tests at the blind school.

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