International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

# Research Paper Title: Lakshya: Intelligent Device to Help Visually Impaired (Blind) People Visualize and Interactwith Objects and People Around Them Using Ai/Ml Models of Google Tensor-Flow

**Ronav Jaiswal**

The Bishop's Co-Ed School Kalyani Nagar,Pune. India.

**Abstract**

The daily lifestyle of visually impaired people is highly challenging wherein there daily routine activities at home or public places has made them the major of being handicapped. Among the 43 million people who are visually impaired worldwide, very fewer percentage of this population uses different technological advanced products inview to overcome their challenges. But the demerits of using such technological products is that their cost is very high and not all blind people can afford it especially in the developing and/or emerging countries. This research study aims to design and built a reasonably priced device which not only be beneficial but on the same hand also affordable. Hence looking into the main objective of this research study "raspberry Pi2" a miniature chip-based process controlling unit combined with other utility items was designed and constructed inview to overcome the daily lifestyle challenges of blind population. Different logical reasoning programs were uploaded into micro-processor controller and finally tested for its functionality. The outcome was so efficient that activities like identification of sharp objects, and/or people demonstrated significant improvement.

**Keywords:** Raspberry Pi2, IOT, Device for blind,

## Introduction

According to a 2021 report, by the International Agency for the Prevention of Blindness, there are currently 295 million people in the world who are visually impaired, out of which 43 million are completely blind. 90% of these live in under-developed countries who do not have access to expensive technology such as bionic eyes that can help them see partially.

Having interacted with visually impaired students for the past 3 years I find it saddening to see them struggle with everyday tasks such as finding and picking up a glass of water, choosing what dress to wear, or even selecting a piece of fresh fruit to eat. When they enter a room, they cannot even figure out the other people present there. This motivated me to come up with a way to help them visualize and interact with objects and people around them.

In this research paper, I presented a low-cost device that has been developed to help visually impaired people (including those who are completely blind) to visualize the environment around them. This device costs less than Rs.6000 (USD 75) and is constructed using commonly available off-the-shelf components. The entire hardware and software design of this device has been published as open-source with the goal of making it accessible and available to all sections of the society at the price point of less than a mobile phone.

**Methodology**

I studied, the various methods and techniques used by blind people to gain an understanding of their environment and to interact with it.

Three different sources of information were utilized to gather the current methods used by blind people:

(a) Literature survey - news articles, reports & studies on blind people, research papers
(b) User survey - online survey sent out to nearly 200 blind people across all age-groups
(c) User interviews - 7 blind people were interviewed with specific questions on the topic.

**Literature survey**

Articles [6] and [7] discuss the various means by which blind people identify objects around them. [8] discussed in detail how the sense of touch is used by blind people to determine the shape, size, and texture of objects. [9] talks about the sense of hearing getting enhanced by the brains of blind people asan adaptation to their handicap. Article[10] investigates an interesting aspect of vision-restored children being able to recognize by sight objects they have known by touch. Research paper [11] performs a comparison between congenitally blind people and blindfolded sighted people in terms of having better haptic object perception.

**User survey**

A custom designed online survey form was sent out to nearly 200 blind people across all age-groups including students of Niwant Andhmukt Vidyalay (Pune) and Poona School for the Blind. The survey consisted of 10 questions that specifically asked the respondents to compare their senses of touch, hearing, smell and taste as a means of detecting objects around them. Responses were received from 63% individuals and these were processed to determine the common techniques and methods used by blind people to identify objects.

**User interviews**

Seven visually impaired and blind people (with varying levels of blindness) across multiple age groups were interviewed over the phone and in person. The subjects described in detail the process they use to identify objects and the environment around them.

**Survey & Interview results**

Based on the above surveys and interviews, the following methods have been identified as the primary techniques used by visually impaired (including completely blind) people to visualize and interact with their environment. These methods are in order of usefulness (the first being the most useful).

| S. No. | **Method / technique** | **Explanation** |
|---|---|---|
| 1 | Haptic perception (touch and feel) | This is the primary means of identifying objects. Without touching they are unable to determine what object is in front of them. Many times this results in injury due to touching of sharp objects or hot objects. Touch helps identify shape of an object, but the colour cannot be determined, for example a red apple versus a green apple. |
| 2 | Auditory perception (hearing) | This is the primary means of identifying people by their voices as you cannot always touch people around you. Silent people cannot be recognized. People's presence can be determined only as long as they are speaking. |
| 3 | Olfactory perception (smell) | Smells are used to differentiate objects that have similar shapes. However, this is not possible if objects don't have any smell or if they have similar smells, for example a red apple versus a green apple. |

**Techniques proposed**

The current techniques have severe limitations in terms of being able to visualize the environment around them. In this paper I propose augmentation of the 4 working senses of blind peopleusing an intelligent device using which blind people can "see" or visualize their environment to a certainextent.

The analysis behind the augmentation of senses using a device is as follows:
*"Using a device that can provide vision information to a blind person greatly improves the life of such a person by enabling everyday tasks such as identifying objects, picking up the correct objects, identifying how many other people are around them, and avoiding injurious acts such as touching sharp or hot objects."*

The augmentation techniques include capabilities of the intelligent device such as:

A. Being able to identify the presence of a specific object in front of the person. For example, an apple kept on a table.
B. The device can guide the person's hand towards the specified object. For example, if the person wishes to pick up an apple, the device should guide the person's hand by providing voice prompts such as, "move left," "move right," "it is right in the center".
C. Being able to interact with the device using voice commands. For example, "Guide my hand to the apple."
D. Being able to differentiate between objects having similar shapes but different colours. For example, a red apple versus a green apple.
E. The device scans the room for other people and lets the person know how many people are present. For example, the person says to the device "how many people are in front of me?" And the device responds "there are 4 people in front of you"
F. The device warns the person if they approach an object that may cause injury. For instance, if the person moves their hand towards a knife or a sharp blade, or a burning candle, the device immediately gives a voice warning, "be careful, there is a knife in front of you"

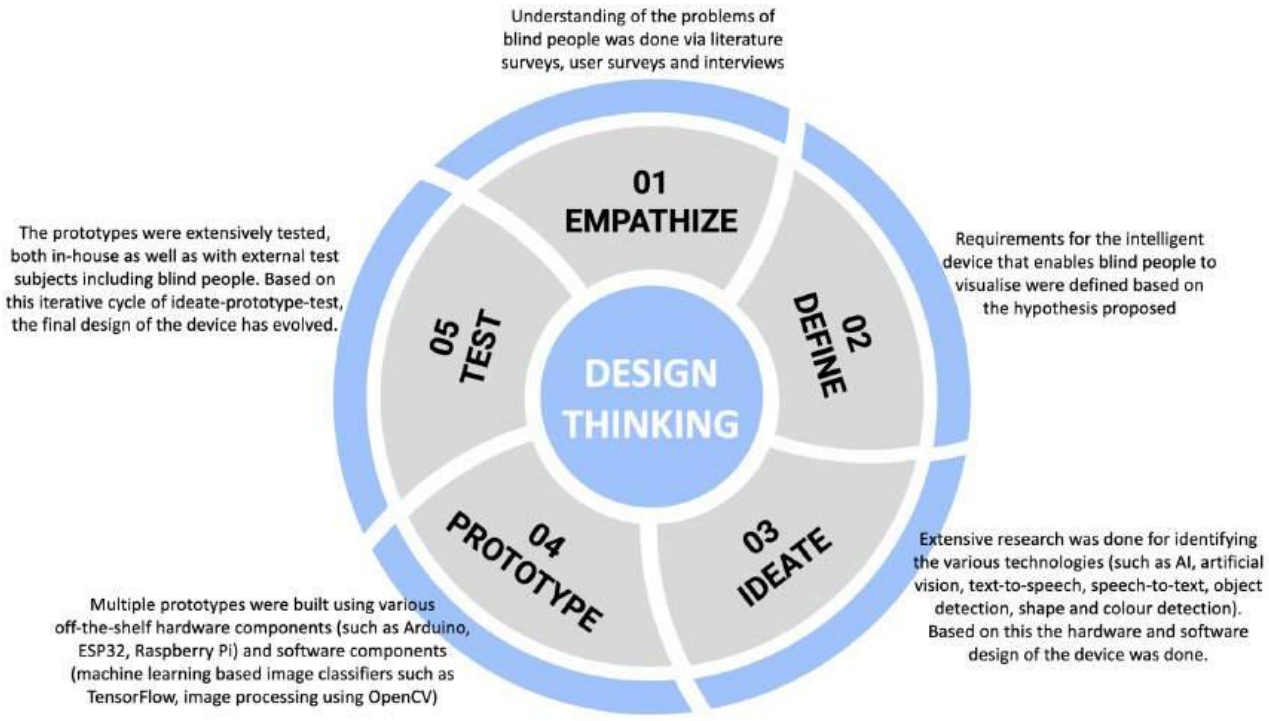
**Literature survey of state of the art in object detection using technology**

Paper [1] talks about providing navigation and pathfinding capabilities to blind people using computer vision. Paper [2] discusses advanced deep learning techniques to detect outdoor objects for blind people using Feature Pyramid SSD. Research in paper [3] describes a navigation system for blind and visually impaired people using stereoscopic sonar system and vibro-tactile feedback. Paper [4] is a vision substitute system designed to assist blind people for autonomous navigation based on image to sound conversion. Paper [5] talks about an aid for blind people for indoor object detection.

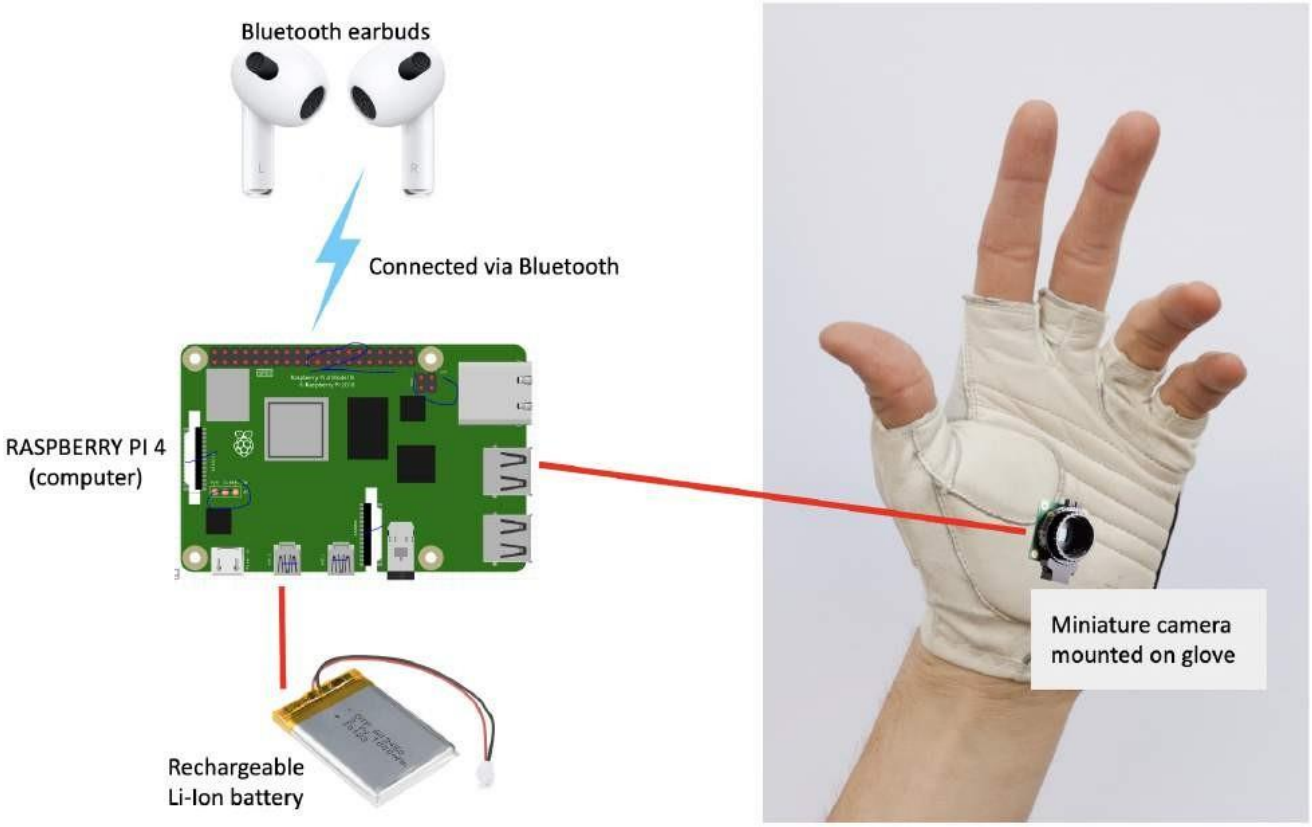
Based on the information gathered from these research papers and studying the various capabilities of machine learning based detection systems such as Google TensorFlow, I have designed an intelligent device LAKSHYA as described in the following sections.

**Design and prototype of the device ("lakshya")**

Based on the above requirements for the intelligent device listed in **Techniques proposed** section above, I have come up with the following design. This design has evolved over multiple prototypes spanning a period of several months from March 2022 till date. In order to develop the device starting from functional requirements as explained in the previous section, the **DESIGN THINKING** process has been used as explained in the diagram below.



**Hardware design**




The hardware design of the device is as follows. It consists of a miniature camera mounted on a biker's glove that is worn by the blind person. The camera is connected to a Raspberry Pi computer that is kept in the shirt or trousers pocket. The device interacts with the blind person using voice commands and voice replies via the bluetooth earbuds worn by the person.

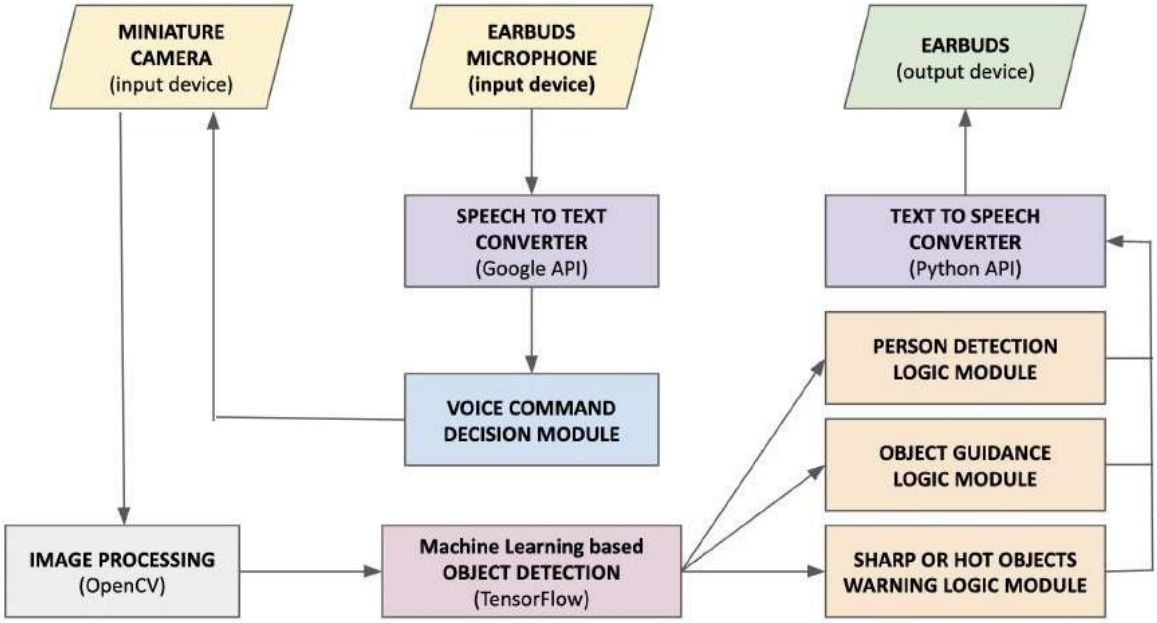
**Hardware Bill of Materials (BOM)**

| COMPONENT | QUANTITY | COST |
|---|---|---|
| Raspberry Pi 4 (4 GB) | 1 | 4200 INR (USD 55) |
| Miniature camera (5 MP module) | 1 | 400 INR (USD 5) |
| Bluetooth earbuds | 1 | 600 INR (USD 7) |
| Lithium battery (7.4 V, 2000 mah) | 1 | 500 INR (USD 6) |
| Biker's glove | 1 pair | 300 INR (USD 4) |
| **TOTAL** | | **6000 INR (USD 75)** |

The total cost of the device is Rs.6000 (USD 75). Upon mass manufacturing the cost is expected to go down further.

**Software design**

The software design of the device is as follows.




The software that powers this device uses multiple Artificial Intelligence technologies such as speech to text conversion, image processing (opencv), machine learning based object detection (tensorflow), text to speech conversion and custom developed logic for object detection and guidance instructions to user, sharp or hot object detection and person detection.

The software logic is as follows:

1. Device receives voice command from blind user (microphone on earbuds)
2. Speech to text conversion determines the command issued by the user
3. Based on the command, the Voice Command Decision Module starts capturing video feed from miniature camera
4. The video frames are analyzed using open-cv and passed on to tensorflow for object detection
5. Depending upon the command that was issued by blind user, the appropriate logic is executed bythe various logic modules as described in the diagram above
6. The result is communicated to the blind user by converting text to speech and transmitting it tothe earbuds via Bluetooth

**Experiments plan**

The following is the plan for conducting experiments with the device.

**Purpose of experiments**

The purpose of these experiments is to determine the effectiveness of **LAKSHYA** device for blind people to help them visualise the environment around them in order to identify and interact with objects in their field of view.

**Variables in the experiments**

The following table describes the variables in these experiments with LAKSHYA.

| S. No. | VARIABLES | DESCRIPTION |
|---|---|---|
| 1 | Type of object | Examples of object types are fruits (apple, orange, banana, etc.) |
| 2 | Shape of object | Objects to be identified based on shape (such as ball, banana) |
| 3 | Colour of object | Objects to be identified based on colour (such as red apple, green apple) |
| 4 | Position of object | Position of object with respect to the hand of blind person (LEFT, RIGHT or STRAIGHT AHEAD) |
| 5 | Whether the object is sharp and may cause injury? | Sharp objects such as knives and blades that may cause injury to the blind person if touched |
| 6 | Whether there are other harmful objects in the vicinity? | Presence of other harmful objects (such as scissors, fire, etc.) In the vicinity of the object to be picked up |
| 7 | Number of humans in field of view | LAKSHYA can tell how many humans are present in front of the blind person. Can also distinguish humans from animals. |

**Constant parameters**

The following table describes the constant parameters in these experiments with LAKSHYA.

| S. No. | CONSTANT PARAMETERS | DESCRIPTION |
|---|---|---|
| 1 | Object is in field of view | The objects to be identified and picked up should always be in the field of view of the blind person. For example, an apple placed on a table in front of the blind person. |
| 2 | Blind person should wear earphones | The device LAKSHYA provides feedback to test subject (blind user) via voice prompts. The person should wear the earphones (included with LAKSHYA) all the time during the experiments. The person should not have hearing disabilities. |

**Expected outcomes**

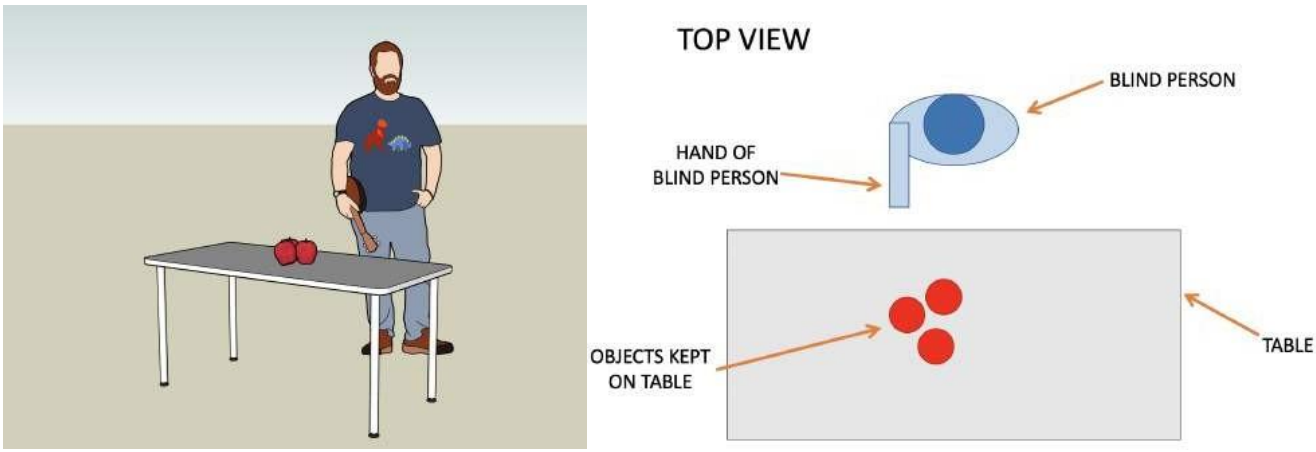
The expected outcomes from the experiments are as follows:

| S. No. | EXPECTED OUTCOMES |
|---|---|
| 1 | Using LAKSHYA, blind people can identify objects placed in front of them with high accuracy |
| 2 | Objects can be identified from far without the need to touch them |
| 3 | Colour of objects can be identified, and red apple can be differentiated from green apple |
| 4 | Blind person can be effectively guided by LAKSHYA to the correct location of object (using voice prompts) |
| 5 | Blind person can be warned if their hand moves near sharp objects (such as knives, blades) or other harmful things such as a burning candle or lamp |

| | |
|---|---|
| 6 | Blind person can be informed of how many humans are present in front of them |

**Experiment methods**

The following layout is used for conducting the experiments:




At the beginning of each experiment, the test subject (blind person) stands in front of the table. The test subject then follows instructions from the experiment to reach out, identify and pick up objects from the table.

**Experiment Vs. Control**

In the experiment, the test subject (blind person) performs the experiment wearing the LAKSHYA device on their hand. In the control, the test subject performs the experiment without wearing the device.

**Hypotheses**

The following table describes the hypotheses that will be tested during experiments with LAKSHYA. Eachhypothesis is tested using specially designed experiments as listed in the last column below.

| ID | HYPOTHESIS | VARIABLE | EXPERIMENT NUMBER * |
|---|---|---|---|
| H-1 | Using LAKSHYA, blind people can identify objects placed in frontof them with high accuracy | Type and shape of object (fruit,bowl, tumbler, pen, etc.) | E-1 |
| H-2 | Objects can be identified from far without the need to touchthem | Distance of object from testsubject | E-2 |
| H-3 | Colour of objects can be identified (e.g. Red apple can bedifferentiated from green apple) | Colour of object | E-3 |
| H-4 | Blind person can be effectively guided by LAKSHYA to the correctlocation of object (using voice prompts) | Position of object on table with respect to hand of person | E-4 |
| H-5 | Blind person can be warned if their hand moves near sharp objects (such as knives, blades) or other harmful things such as a burning candle or lamp | Presence of sharp or injurious objects near the hand of test subject | E-5 |

| | | | |
|---|---|---|---|
| H-6 | Blind person can be informed of how many humans arepresent in front of them | Number of humans in front ofthe test subject | E-6 |

* Experiments are described in detail n the section below

**Experiments conducted**

In order to validate the hypotheses proposed, the following experiments were conducted using blind persons as test subjects. For each of the experiments, a control was set up that defined the benchmark of the experiment.

**Experiment E-1 : identification and pickup of specified objects that differ in their shapes**

**Aim:**

To determine the improvement in ability of blind people using the LAKSHYA device toidentify and pickup objects based on their type and shape

**Materials & subjects:**

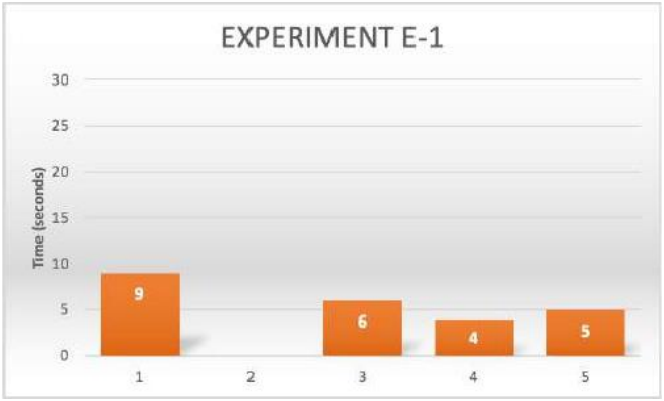
Blind person with device, apple, banana, tumbler, bowl, phone

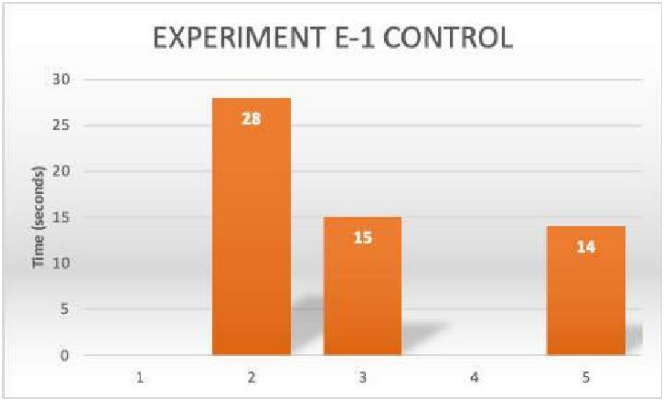
**Control:**

Blind person without device, same objects as above


**Observations:**

Experiment Success Rate = 80%, Average time taken = 6 seconds Control Success Rate = 60%, Average time taken = 19 seconds



**Conclusions:**

1. Test subject is able to identify and pick up objects using the device faster than withoutthe device (6 seconds versus 19 seconds).
2. Success rate using the device (80%) is higher than Control (60%).

**Experiment E-2 : Identification Of Specified Objects Without Touching Them**

**Aim:**

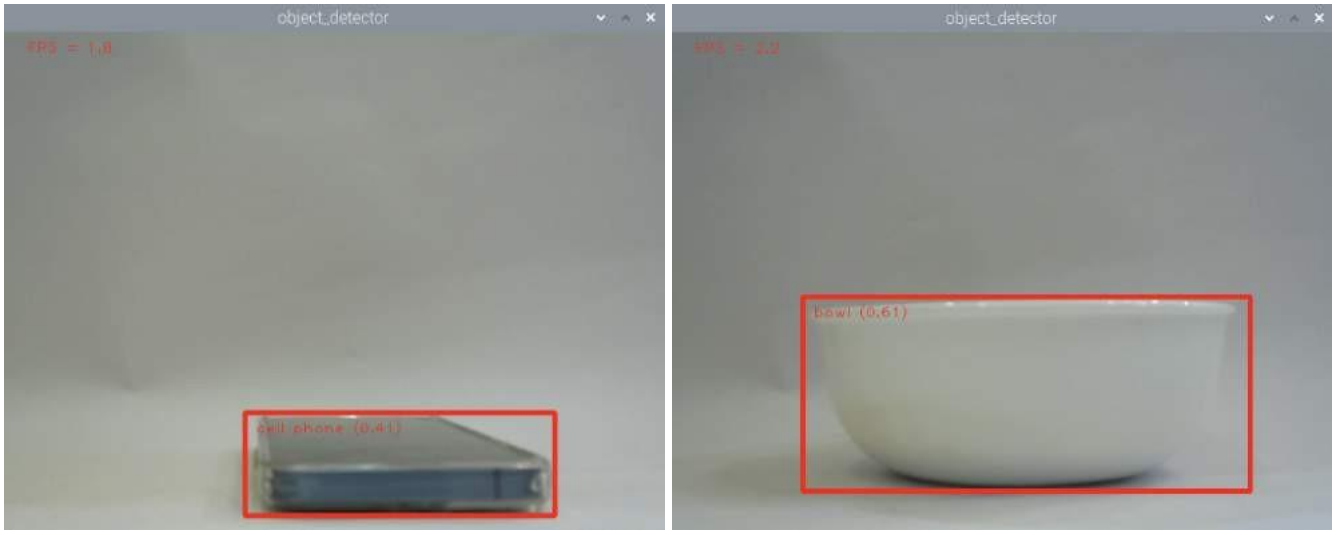
to determine the ability of blind people using the lakshya device to identify objectswithout touching them

**Materials & subjects:**

blind person with device, apple, banana, tumbler, bowl, phone

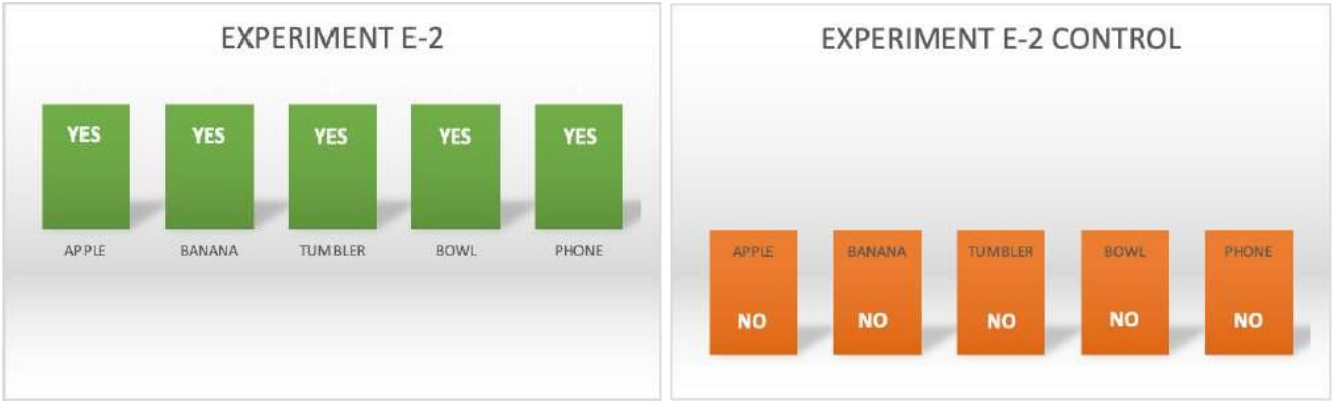
**Control:**

blind person without device, same objects as above




**Observations:**

Experiment Success Rate = 100% Control Success Rate = 0%




**Conclusions:**

1. Test subject is able to identify objects using the device (100% success rate)
2. Without touching, the control subject is not able to identify any object

**Experiment e-3 : identification and pickup of specified objects that have similar shapes butdifferent colours**

**Aim:**

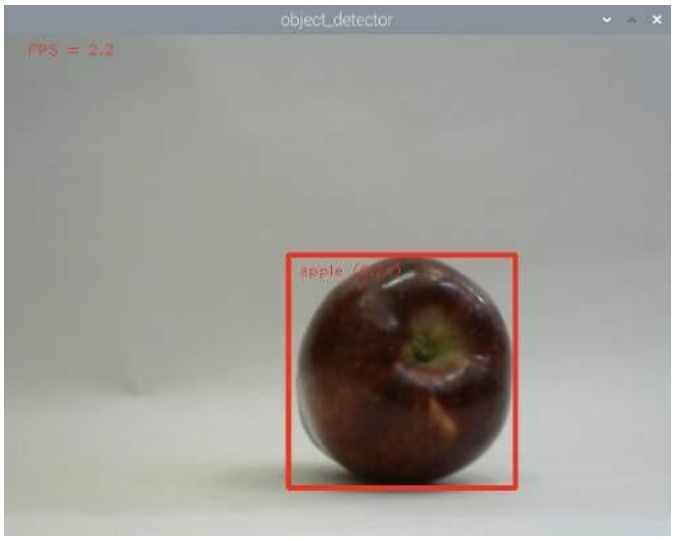
To determine the ability of blind people using the LAKSHYA device to identify and pickupobjects that have similar shapes but differ in their colours

**Materials & subjects:**

Blind person with device, red apple, green apple

**Control:**

Blind person without device, same objects as above





**Observations:**

Experiment Success Rate = 100% Control Success Rate = 0%



**Conclusions:**

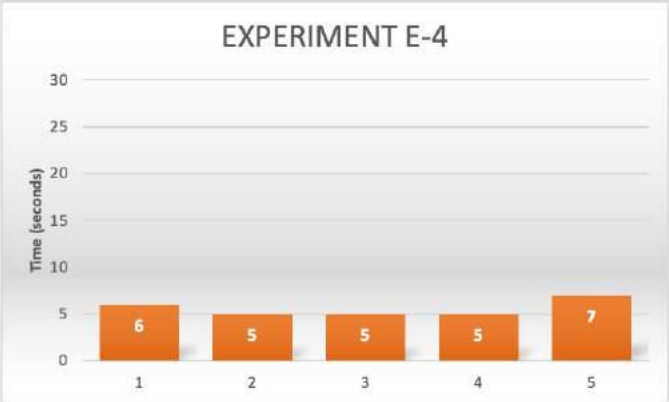
1. Test subject is able to correctly identify red coloured and green coloured objects using thedevice (100% success rate)
2. Control subject is not able to identify the colour of any object

**Experiment E-4 : guiding the hand of blind person using voice prompts**

**Aim:**

Blind person can be effectively guided by LAKSHYA to the correct location of object (usingvoice prompts)

**Materials & subjects:**
Blind person with device, apple placed on table
**Control:**
Blind person without device, same objects as above
**Observations:**
Experiment Success Rate = 100%, Average time taken = 5.6 seconds
Control Success Rate = 80%, Average time taken = 17 seconds





**CONCLUSIONS:**
1. Test subject can identify and pick up objects using the device faster than withoutthe device (5.6 seconds versus 17 seconds).
2. Success rate using the device (100%) is higher than without the device (80%).

**Experiment E-5: identification of sharp objects (such as knives, scissors) or other harmful objects such as a burning candle or lamp**
**Aim:**
Blind person can be warned if their hand moves near sharp objects (such as knives,scissors) or other harmful objects such as a burning candle or lamp
**Materials & subjects:**
Blind person with device, scissors, burning candle
**Control:**
Blind person without device, same objects as above



**Observations:**

Experiment Success Rate = 100% Control Success Rate = 0%



**Conclusions:**

1. Test subject can correctly identify the presence of sharp and harmful objects such asknives, scissors, burning candles, etc.
2. Control subject is unable to identify such objects before touching them

**Experiment E-6: identification of presence of humans in front of blind person**

**Aim:**

Blind person can be informed of how many humans are present in front of them

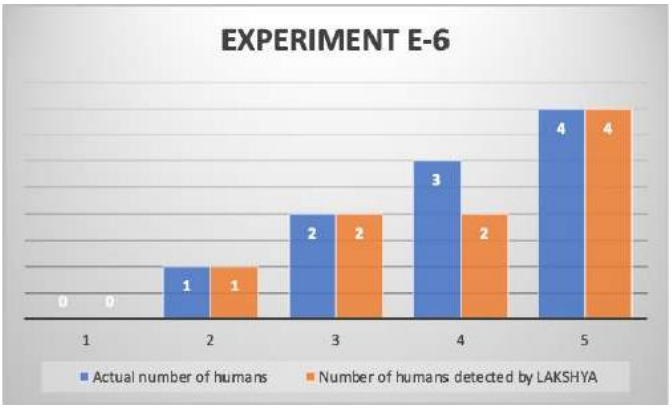
**Materials & subjects:**

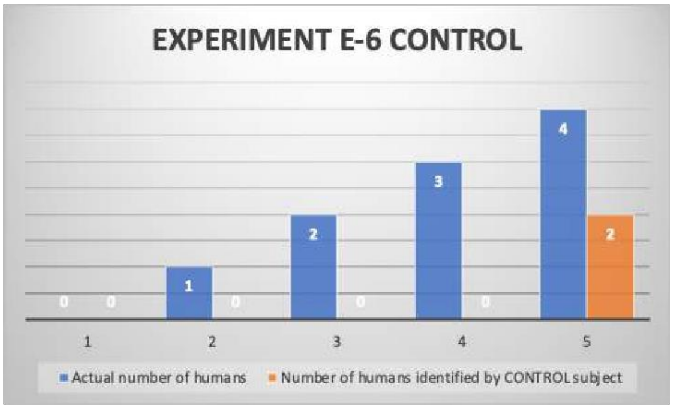
Blind person with device, multiple humans in front of subject

**Control:**

Blind person without device, multiple humans in front of subject

**Observations:**




Experiment Success Rate = 90% Control Success Rate = 20%

**Conclusions:**

1. Test subject can correctly identify the presence of humans in front of them.
2. Test subject can identify the number of humans with 90% accuracy
3. Control subject is not able to identify the presence of humans or number of humansaccurately.

**Summary**

The following is the summary of results of the above experiments conducted to verify our hypotheses.

| ID | EXPERIMENT | RESULTS | HYPOTHESIS PROVED |
|---|---|---|---|
| **E-1** | Identification and pickup of specified objects that differ in their shapes | Test subject can identify and pick up objects using the device faster than without the device (6 sec versus 19 sec) with a higher success rate (80% versus 60%). | **Yes H-1** |
| **E-2** | Identification of specified objects without touching them | Test subject can identify objects using the device (100% success rate). Without touching, the control subject is not able to identify any object. | **Yes H-2** |
| **E-3** | Identification and pickup of specified objects that have similar shapes but different colours | Test subject can correctly identify red coloured and green coloured objects using the device (100% success rate). Control subject is not able to identify the colour of any object. | **Yes H-3** |
| **E-4** | Guiding the hand of blind person using voice prompts | Test subject can identify and pick up objects using the device faster than without the device (5.6 secs versus 17 secs). Success rate using the device (100%) is higher than without the device (80%). | **Yes H-4** |
| **E-5** | Identification of sharp objects (such as knives, scissors) or other harmful objects such as a burning candle | Test subject can correctly identify the presence of sharp and harmful objects such as knives, scissors, burning candles, etc. Control subject is unable to identify such objects before touching them. | **Yes H-5** |
| **E-6** | Identification of presence of humans in front of blind person | Test subject can correctly identify the presence of humans in front of them as well as the number of humans with 90% accuracy. Control subject is not able to identify the presence of humans or number of humans accurately. | **Yes H-6** |

**Discussion**

The device LAKSHYA's primary goal is to help blind people identify and interact with everyday objects and people around them. The experiments were designed to measure how much LAKSHYA improves the daily life and activities done by blind people. The first hypothesis H-1 was about the ability to identify objects of various shapes such as round (apple, ball), elongated (banana, pencil) and other shapes of everyday objects. Normally blind people identify shapes by touching and feeling the objects and they are very good at it. However, in the absence of sight they may not always be able to identify which object it is. This is where LAKSHYA has an advantage as it uses machine learning based object detection using

the camera mounted on the device. The accuracy ofLAKSHYA is high (80%) as it provides additional information about the object to the blind person. LAKSHYA is faster too as it begins detecting objects from far.

Hypothesis H-2 was specifically about the ability to identify objects from a distance without touching them. This ability is not possible without vision, and therefore blind people without LAKSHYA (the control test subjects) were not able to identify any of the objects unless they touched them. In such scenarios LAKSHYA has a clear advantage as it relies on computer vision to detect objects from far. However, if the test subjects had partial vision, they would be able to identify the objects to a certain Extent depending upon their level of partial vision. However, even for such partial vision people LAKSHYA is useful because now they can be surer about the object when confirmed by the device. One major challenge faced by blind people is that even if they are able to identify the shape of an object(say apple) by touching and feeling it, they cannot be sure what kind of apple it is (whether it is a Red coloured Washington Apple or a Green coloured Granny Smith apple). Unfortunately, it is not possiblefor blind people to differentiate between colours, and that is where LAKSHYA provides the missing information - the colour of the object. Hypothesis H-3 covers this aspect of LAKSHYA being able to differentiate between a red apple and a green apple by identifying colours. Experiment E-3 proved this hypothesis by correctly identifying the colour of the object each time (100% success rate). As with the previous hypothesis H-2, the maximum benefit of a device such as LAKSHYA is for blind people with zerovision. If the person has partial vision, they may be able to identify colours to a certain extent, unless they are colour blind.

LAKSHYA has a computer (Raspberry Pi) inside, and it has advanced capabilities such as guiding the handof the blind person towards the object to be picked up. Blind people have no way of locating the position of an object unless they touch and feel the surroundings looking for the specific shape. LAKSHYA has a powerful advantage here as it can detect objects from far and provides instructionsto the blind person to move their hand in the correct direction towards the object. For example, if the object (say apple) is to the left of the person's hand, LAKSHYA gives a voice prompt saying "LEFT" to the person using the Bluetooth earphones. The person keeps getting such voice prompts such as "LEFT", "RIGHT" or "IN FRONT OF YOU" depending on the position of the hand with respect to the object. Dueto this capability LAKSHYA successfully validated hypothesis H-4 with a high success rate (100%) as well as requiring less time to do so (5.6 seconds versus 17 seconds in control).

Since blind people always rely on touch and feel to identify objects, they often end up hurting themselves when they encounter sharp objects such as knives, blades, scissors or other harmful objects such as a burning candle or lamp. Hypothesis H-5 is all about verifying whether LAKSHYA, with its computer vision, can warn blind people if they are about to touch such objects that may cause injury. In experiment E-5 we see that control subjects cannot identify such harmful objects unless they touch them, by which time it is too late and the damage is done. LAKSHYA on the other hand accurately identifies such objects and warns the user by voice prompts ("Warning! That is a knife!"). In the experiment, such harmful objects were accurately identified 100% of the time.

When blind people enter a room or a place where other people might be present, they are unable to identify the presence of other people unless someone speaks. To overcome this, LAKSHYA has a person-face identification capability using which it can inform the blind person about the number of people in front of them. The purpose of hypothesis H-6 and experiment E-6 is to determine the effectiveness of such a capability. As observed during the experiments, LAKSHYA was able to identify thepresence of people (100% accuracy) as well as number of people (90% accuracy). On the other hand, thecontrol test subject was able to identify the number of people only 10% of the time, and that too only if the person spoke something.

**Cost analysis**

The cost of producing a prototype of LAKSHYA was Rs.6000 (USD 75) as explained in the **Hardware**

**Design** section above. Upon mass production this is estimated to go down below Rs.5000. Further relaxation of customs duty of Raspberry Pi can bring it down to nearly Rs.3000 per piece. At this price point, LAKSHYA would be affordable to all including underprivileged sections of the society.

**Conclusion**

The world has a large population of visually impaired and blind people (295 million) and most of them live in under-developed countries. Their daily life activities are severely hampered due to lack of vision and they are in dire need of technological help. LAKSHYA is one step in that direction as it allows them tovisualize and interact with the environment around them.

Identifying objects and being able to pick them up forms an important part of everyday tasks of blind people. LAKSHYA helps them do that with high accuracy (80% to 100%) and in a lesser time (5 to 6 seconds) than simply relying on touch-and-feel for this purpose. The experiments E-1 to E-6 conclusively prove the hypotheses, H-1 to H-6, with a notably high success rate. LAKSHYA can make a big difference inthe lives of blind people by providing them with “eyes” using which they can now “see” the world to a certain extent. And most importantly, at an affordable price point of less than Rs.5000 on mass production.

**Future scope**

LAKSHYA can be further improved by adding more capabilities that benefit the blind people, such as:

(a) Identity of person (by training on a set of pictures of the person)
(b) Integrating the device in a smart watch instead of wearing as a glove
(c) Ability to navigate streets and inside public spaces such as shopping malls and offices
(d) Communication with other blind people in the vicinity

**Acknowledgement**

I would like to thank Mr. Gaurav Ahir, who has been of immense help in understanding the problems faced by blind people and how to overcome them. I am eternally thankful to Mr. Sumesh Jaiswal for mentoring and guiding me through every stage of this project. I am also thankful to the Niwant Andhmukt Vidyalay and Poona School for the Blind for helping me improve LAKSHYA by their immenselyuseful feedback. And finally, I am extremely grateful to The Bishop’s Co-Ed School (Kalyani

Nagar), Principal Mr. Shayne McPherson, Headmaster Mr. Ashley Eates and all the teachers for supporting me inall my endeavours.

**References**

1. Jamal S. Zraqou et al. Real-Time Objects Recognition Approach for Assisting Blind People. International Journal of Current Engineering and Technology (2017), 7 (1).
2. Zhou, Zhigong & Lan, Xiaosong & Li, Shuxiao & Zhu, Chengfei & Chang, Hongxing. Feature Pyramid SSD: Outdoor Object Detection Algorithm for Blind People. (2019). 650-654.
3. M R, Sunitha & Khan, Fathima & R, Gowtham & S, Hemaya. Object Detection and Human Identification using Raspberry Pi. (2019). 135-139.
4. Bangar S. et. al., Vocal vision for visually impaired. The International Journal of Engineering and Science. (2013). 2 (3). 1-7.
5. Real Time Indoor Object Detection Aid for Blind. International Advanced Research Journal in Science, Engineering and Technology. (2021). 8 (6). 613-627.
6. Jennifer Lawson. What Do Blind People See. Healthline. (2019)
7. Heller, Morton, and Ballesteros. Soledad. Visually-Impaired Touch. Scholarpedia. (2012). 7. 8240.
8. Kim Eckart. Brains of blind people adapt to sharpen sense of hearing, University of Washington. (2019). April.
9. Bhirud BG, Chandan LM, Chawla A. Do Congenitally Blind Individuals have Better Haptic Object Perception Compared to Blindfolded Sighted Individuals? Indian J Physiol. Pharmacol. 2016 Jul-Sep;60(3):230-4.