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STRATEGIC EMPOWERMENT OF VISUALLY IMPAIRED COMMUNITY (SE-VIC) VIA INTELLIGENCE MOBILITY

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14. ABSTRACT
Visual impairment (VI) has gained increasing concern in the eyecare realm due to rising population in society globally. Over 1 billion are compelled to live with this condition simply because they cannot get the treatment and cure that they needed. Visual impairment, especially in developed countries, has serious implications. Its detrimental effects reduce the ability of individuals affected to work independently and can have a negative impact on personal and quality of life. The visually disabled person had to depend on another person whenever they had to walk around. This contributes to the lack of motivation to travel alone for the visually impaired person. Navigation plays a fundamental role amongst the activities that affected by visual impairment. Their ability to move independently in safety are restricted and difficult. The world has become more and more involved in supporting the disabled persons to improve their life by providing many healthcare systems. Even though there is modernized solution that exist nowadays but there are also disadvantages to that which are the possibility of poor connectivity, poor video performance in specific situations (like low-ambient light, high dynamic contrast scenes or motion blur) and the cost of training and employing guidance personnel.

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ABSTRACT

Visual impairment (VI) has gained increasing concern in the eyecare realm due to rising population in society globally. Over 1 billion are compelled to live with this condition simply because they cannot get the treatment and cure that they needed. Visual impairment, especially in developed countries, has serious implications. Its detrimental effects reduce the ability of individuals affected to work independently and can have a negative impact on personal and quality of life. The visually disabled person had to depend on another person whenever they had to walk around. This contributes to the lack of motivation to travel alone for the visually impaired person. Navigation plays a fundamental role amongst the activities that affected by visual impairment. Their ability to move independently in safety are restricted and difficult. The world has become more and more involved in supporting the disabled persons to improve their life by providing many healthcare systems. Even though there is modernized solution that exist nowadays but there are also disadvantages to that which are the possibility of poor connectivity, poor video performance in specific situations (like low-ambient light, high dynamic contrast scenes or motion blur) and the cost of training and employing guidance personnel. Thus, this report showcased innovative research on miniaturised robotic assistive device to help visually impaired in mobility by using ultrasonic sensor to detect obstacle and notifies the user using haptic feedback if there are obstacles that may lie ahead of the user's path. This work also explores on the implementation of IoT into this miniaturized robot by pairing mobile phone to it for GPS tracking and navigate the user to arrive their destination safely.

1.0 INTRODUCTION

The World Health Organization (WHO) has reported that there are at least 2.2 billion people have a near or distance vision impairment which includes 246 million low vision and 39 million blind people worldwide (WHO, 2021). Persons who are visually impaired (including those who are blind and those who have low vision) support their mobility basically in four different ways. They use the assistant of a (sighted) human guide, enhance their independent travel with the aid of a long (white) cane, a dog guide or Assistive Mobility Aids (AMA).

Blindness or visual impairment refers to someone who are limited with their vision. Unlike a normal person, they often encounter challenges in carrying out their normal lives. This limitation certainly causes problems even doing a simple task such as obtaining information, mobility, and recreational activity. They can only depend on the other senses which are hearing, touch, smell and taste. However, nowadays even more so with the Covid-19 pandemic outbreak makes it unsafe for them to depend only in the other senses especially in touch since they may get infected. Therefore, a lot of devices that help to guide them had been built and developed for them to ease their problems.

Expanding the performance of AMA is of prime importance to efficiently improve and increased the quality of visually impaired person's daily activities. By using a low cost, easy operation, less maintenance, dual communication capability system, it helps encourage their motivation to explore a new, unfamiliar route, making them confident to travel alone or in a communicative group. With the obstacle avoidance mechanism based on the lidar sensor prediction embedded in the system it provides assurance for accident-free situation due to tipping or falling on uneven surface. Moreover, it also could assist manoeuvring within rough terrain and stair climbing.

Mini guide dog is one of the robots that purposely designed to help visually impaired people to ensure safety and independent mobility. It holds the same functions as the traditional guide dog as this robot contain a suitable sensor to detect obstacle and warn the user except the part that it can provide the low-vision people with all information and features for safe mobility. Given it is pocket-sized, mini guider dog can be stored easily and convenient to bring everywhere. The robot is built with several parts including the robot body, gripper and robot head. An ultrasonic sensor had been attached to the robot head to detect obstacle that may lie directly in user's path. It then notifies the user through vibration, allowing the user to safely navigate around. Other than that, mini guider dog can be paired with mobile phone for GPS tracker and navigator to route the destination chosen by the user. Besides, the user can still use their white cane since the gripper had been attached the mini guider dog so that the user can clipped onto it.

The multipurpose and multi functioning system highlighted in this book, is not only increases the safety level and group interaction capability, but also help boost up and contributes to the tourism industry with special tour guided travelers features for visually impaired people. In fact there is none of the research has been done on the group interaction between visually impaired people among themselves for safety precaution. The proposed AMA system and travelling algorithm offers solution for a visually impaired person to travel unguided, avoid collision frequency and minimise the time required to go to the destination that combines the merit of lidar sensor and miniaturized AMA system for obstacle avoidance prediction will be discussed further in the next chapters.

The controller is one of the important components that any autonomous mobile robot needs to have. It functions as the brain of the robot which decides the behavior of the robot such as how the robot moves and process the data. Controller is a set of code that has been written in the microprocessor with multiple of conditions and algorithms in order to make the robot act according to desired goal. Arduino and Raspberry Pi is the most basic and well-known microcontroller in order to create an autonomous robot. An integrated development environment (IDE) is a software application that available to simulate and test the efficiency of the controller. Arduino IDE is one of the most popular when it comes to designing and implementing the controller of the robot.

The increasing intensity of global knowledge and advancement in technology flows points to 4th industrial revolution with the increasingly widespread internet of things (IoT). With the steady developments of technology, lots of areas in the industry like Military, Agriculture, Industry, Healthcare, Robotics, Nanotechnology are pursuing IoT for advanced solutions. There are many IoT platform that are available to us such as Microsoft azure, AWS IoT, Adamos and others. These platforms manage the information from sensors, devices, networks and software. In this research, IoT platform use and paired with the mini guider dog to use the features of GPS and navigation. In general, the aim of implementing IoT is to enable the interconnection of the real world and the cyber space.

2.0 METHODOLOGY AND EXPERIMENT ANALYSIS

2.1 Rovision Testing real time

Figure 2.1 showcases the field work for miniaturized Rovision Guide Dog for visually impaired person's travelling assistance. In order to ensure accurate real-time results and emphasize findings, the experimental work is done outside building.

a) User using prototype (Side view) b) User using prototype (Front view)

Figure 2.1: Field Work For Miniaturized Rovision Guide Dog For Visually Impaired Person's Travelling Assistance

From the real time experimental set up, as shown in Figure 2.1, the miniaturized guide dog can travel smoothly forward on clear and clean surface. The user also seems very much comfortable in using the system due to sleek and small design which does not hinder or adding extra weight to the normal white cane.

2.2 The Position Of The Robot Mounted On White Cane

In this work, braille is used for the user to locate the position to attach the robot to the white cane. The word "help" in the form of braille will be embossed on the paper using a slate (two pieces of metal, plastic, or wood joined together with a hinge on one side) and a stylus (a pen).

The slate and stylus are used to create raised, tactile bumps or dots on a paper (embossing). It wouldn't do to attempt to punch dots free-hand onto a sheet since Braille is such an exact system—the dots in the Braille cell must be accurately spaced. To hand-Braille accurately, a puncher (the stylus) must be used to raise a tactile Braille dot when pressed into the paper, and a guide (the slate) must be used to punch the dots into precise positions. Then the paper is glued to the white cane so it will stay on the same spot shown in Figure 2.2.

Figure 2.2: Embossed braille attached to the white cane

2.3 Obstacle Detection

An obstacle detection system uses LiDAR sensor that contained in the robot. This sensor can measure the distance between the robot and nearby obstacles directly around the front of the robot itself. If any obstacles is detected, the user is alerted by microvibrator. The field view and the accuracy of LiDAR sensor is discussed below.

2.3.1 Field View of the LiDAR Sensor

This section review on how to use 1D lidar data to detect barriers and warn of potential collisions. Many LiDAR had been used in automatic guided devices nowadays that mounted in robot for navigation because of the reasonable cost, extended range of view, and good resolution. Collision detection is aided by the sensors, which is critical for the safe navigation of AGDs in complicated environments. This example demonstrates how to describe a robot workspace with obstacles, generate 1D lidar data, detect barriers, and issue a warning before a collision occurs. Ego literally means the view of someone towards himself. In figure above, the ego view of LiDAR can be seen. LiDAR is represented as the triangle. LiDAR sensor is simulated, and it returned the range and angle readings to generate LiDAR scan shown in Figure 2.3.

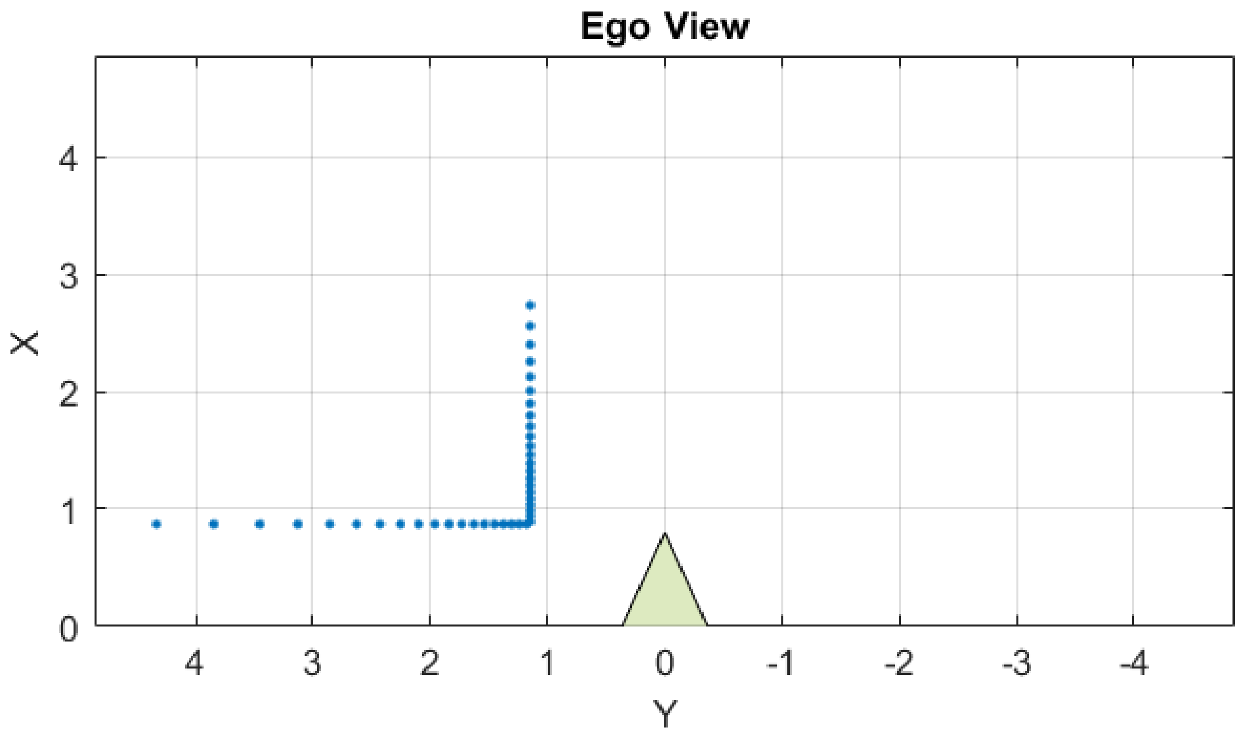

Figure 2.3: Ego view of LiDAR sensor

If an obstacle is detected within the detection area, a collision warning will occur. In Figure 2.4, detection area is divided into three levels of specific degree of danger. Yellow means it applies only a caution measures, while red means high chance of the collision between the robot and obstacles will occur is while black means the collision is imminent.

In this project, the vibration from the microvibrator is represented as the collision warning as shown in Figure 2.5. As state before this, the distance of collision has been set up. The vibrator will vibrate to warn the user if the TF-Luna detected object within 4m. Since the average step length for a person is 78.74cm, the vibrator will vibrate 5 steps before the collision can occur. Thus, the user can avoid the obstacle beforehand.

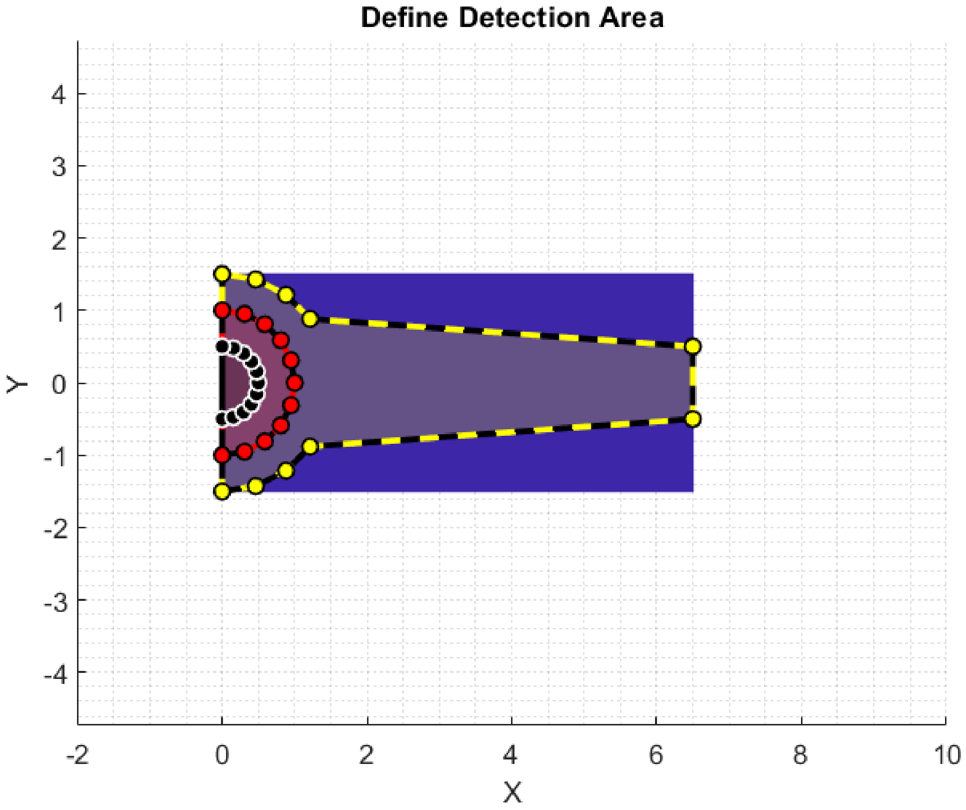

Figure 2.4: Detection area of LiDAR sensor

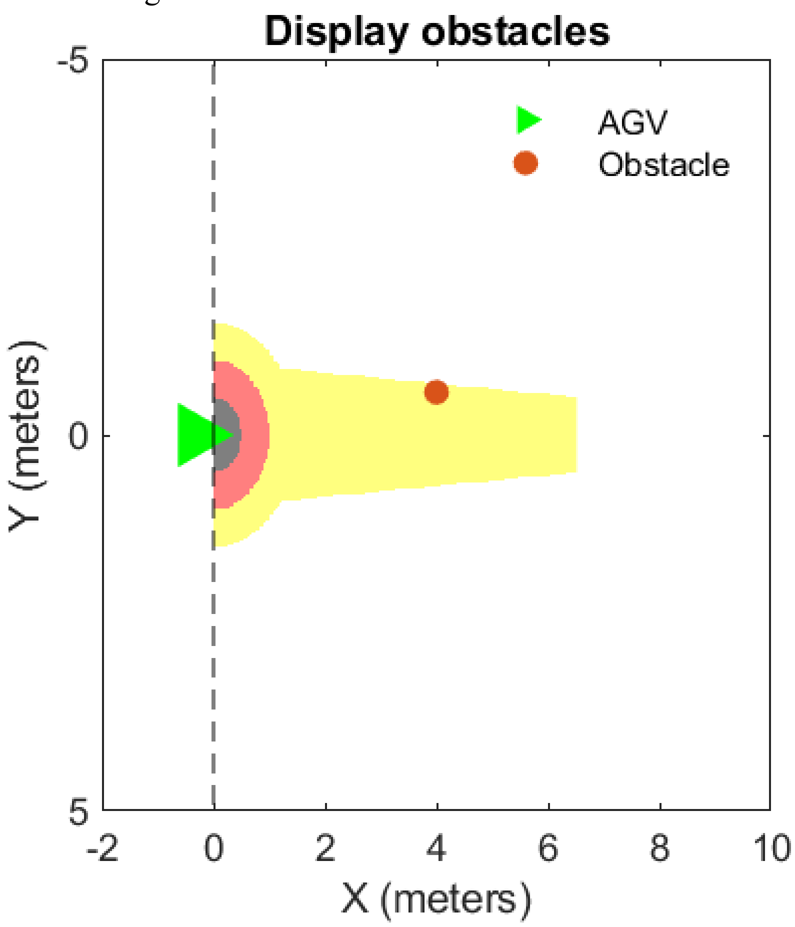

Figure 2.5: Collision warning

2.3.2.The comparison of accuracy between LiDAR and Ultrasonic sensor

LiDAR sensor offer a wide measuring range and excellent precision. In this section, accuracy of TF-Luna is measured by setting up the distance between the sensor and the targeted object. There are three distance that was set up in this project includes 3m, 4m and 5m. The data collection is for 10 trials for each distance makiing it mre reliable and accurate. All the data are saved in excel sheet by logs in to Tetra Term as shown in appendix. In each trial, average of detection(mean), percentage error, standard deviation and variance is calculated. In this project, the total number of observations are fixed which is 1000 for each trial.

$$\mu = \frac{Sum\ of\ the\ terms(distance)}{number\ of\ terms} \tag{2.1}$$

$$Percentage\ eror = \frac{|Measured\ value - Real\ Value|}{Real\ Value} \cdot 100\% \tag{2.2}$$

$$\sigma = \frac{\sqrt{\Sigma(X-\mu)^2}}{N} \tag{2.3}$$

$$\sigma^2 = \frac{\Sigma(X-\mu)^2}{N} \tag{2.6}$$

$$Standard\ error = \frac{\sigma}{\sqrt{N}} \tag{2.7}$$

where μ is mean, σ is standard deviation, X is the value in the data distribution(distance), N is total number of observations. The standard deviation is a measure of how far a set of data deviates from its mean. It measures a distribution's absolute variability; the higher the dispersion or variability, the higher the standard deviation, and the greater the magnitude of the value's divergence from its mean. The standard error method is used to calculate a sample's efficiency, accuracy, and consistency. In other words, it assesses the degree to which a sampling distribution accurately represents a population.

Table 2.1: Distance measurement using TF-Luna and Ultrasonic in 3m

	Mean		Percentage of error		Standard Deviation		Variance	
No. of Trial	LiDAR	Ultrasonic	LiDAR	Ultrasonic	LiDAR	Ultrasonic	LiDAR	Ultrasonic
1	300.7	360.88	0.23	20.29	0.5025	226.76	0.2525	35099.48
2	301.09	307.55	0.36	2.52	0.4286	88.534	0.1837	35043.29
3	301.12	300.2	0.37	0.07	0.4090	1.9016	0.1672	18104.76
4	301.26	299.22	0.42	0.26	0.4845	1.4040	0.2347	29534.97
5	301.17	308.18	0.39	2.73	0.4507	88.472	0.2031	2.005657
6	301.55	298.79	0.52	0.40	0.5389	0.9243	0.2904	12957.66
7	301.27	298.89	0.42	0.37	0.5096	0.9308	0.2597	23915.02
8	301.15	317.09	0.38	5.70	0.5000	124.49	0.2500	18119.54
9	301.21	307.53	0.40	2.51	0.4560	88.537	0.2080	45804.52
10	301.08	299.65	0.36	0.12	0.4188	2.2579	0.1753	12199.62

As shown in the Table 2.1, all the percentage of error for LiDAR sensor is below than 1% while for Ultrasonic sensor, some of the trial has even above 10%. Furthermore, the graph of standard error shows an erratic behaviour of means for Ultrasonic while for LiDAR, it has consistent lines. Thus, it means Ultrasonic is likely has inaccurate representation from the true means as also shown in the Graph of standard error for LiDAR and Ultrasonic sensors for 3m in Figure 2.6.

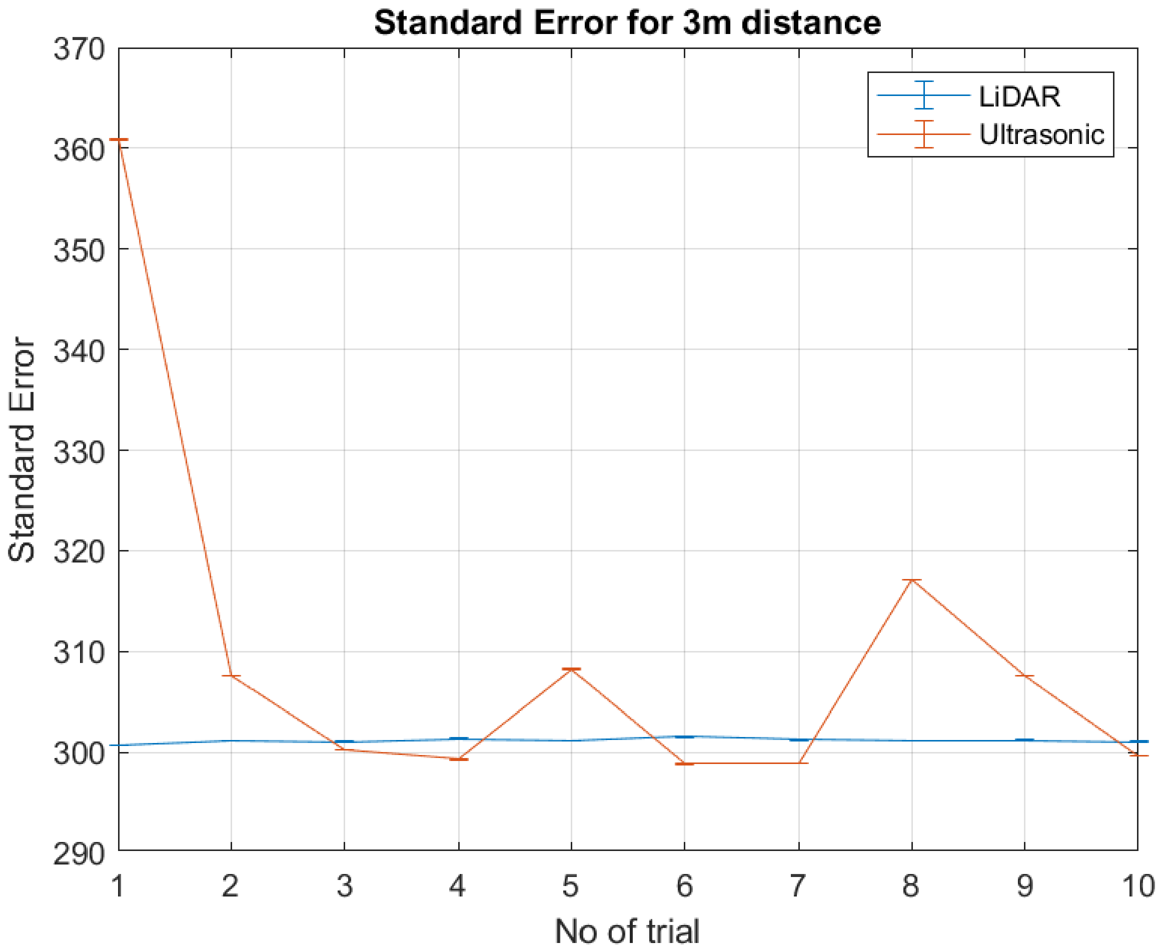

Figure 2.6: Graph of standard error for LiDAR and Ultrasonic sensors for 3m

Table 2.2: Distance Measuremennt using TF-Luna in 4m

	Mean		Percentage of error		Standard Deviation		Variance	
No. of Trial	LiDAR	Ultrasonic	LiDAR	Ultrasonic	LiDAR	Ultrasonic	LiDAR	Ultrasonic
1	401.97	446.18	0.49	11.55	0.7029	187.35	0.4940	35099.48
2	402.00	394.85	0.50	1.29	0.8762	0.9326	0.7677	0.8698
3	402.27	395.39	0.57	1.15	0.7635	2.4097	0.5830	5.8064
4	402.74	395.66	0.69	1.08	0.7470	1.7109	0.5580	2.9271
5	402.94	403.15	0.73	0.79	0.7762	78.488	0.6024	6160.41
6	403.38	395.14	0.84	1.22	0.6633	0.8773	0.4400	0.7696
7	403.85	410.81	0.96	2.70	0.8211	110.45	0.6742	12199.22
8	403.76	400.63	0.94	0.16	0.7537	82.997	0.5681	6888.55
9	403.94	395.02	0.98	1.25	0.7497	0.9975	0.5620	0.9951
10	404.05	395.21	1.01	1.20	0.8211	0.8587	0.6742	0.7374

The Table 2.2 shows the distance measurement of TF-Luna and Ultasonic sensor that has been set up by 4m. Eventhough in the 10th trial of percentage of error for LiDAR sensor is above 1%, but it still shows better results than percentage of error for Ultasonic sensor. As same for standard error graph for 3m distance, Ultrasonic sensor still shows inconsistent graph compared to LiDAR sensor for 4m distance as shown in Figure 2.7.

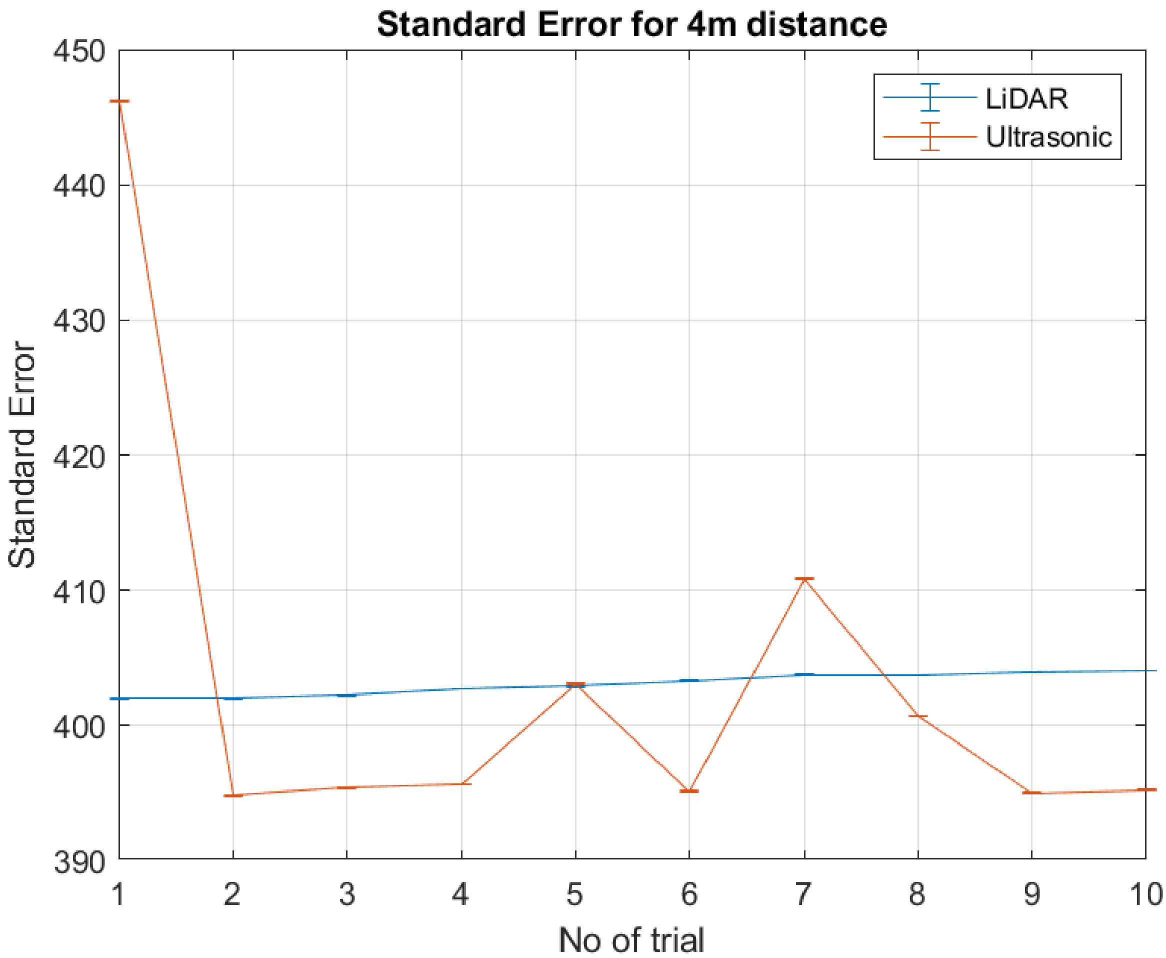

Figure 2.7: Graph of standard error for LiDAR and Ultrasonic sensors for 4m

Table 2.3: Distance measuremennt using TF-Luna in 5m

	Mean		Percentage of error		Standard Deviation		Variance	
No. of Trial	LiDAR	Ultrasonic	LiDAR	Ultrasonic	LiDAR	Ultrasonic	LiDAR	Ultrasonic
1	503.75	499.12	0.75	0.18	1.0384	1.8480	1.0783	3.3592
2	502.47	498.64	0.49	0.27	1.0960	0.8863	1.2011	0.7782
3	502.61	498.49	0.52	0.30	1.0626	0.8994	1.1292	0.8181
4	503.44	499.95	0.69	0.01	1.0378	3.2122	1.0772	10.128
5	503.7	522.08	0.74	4.42	1.1591	118.22	1.3434	13704.8
6	503.78	498.94	0.76	0.21	1.1063	1.0135	1.2238	1.0065
7	504.04	498.79	0.81	0.24	1.2303	0.8470	1.5135	0.7332
8	504.09	541.25	0.82	8.25	1.2234	164.83	1.4968	26659.7
9	504.12	498.97	0.82	0.21	1.0757	1.0960	1.1572	1.2011
10	504.19	498.97	0.84	0.21	0.9816	1.0823	0.9635	1.0379

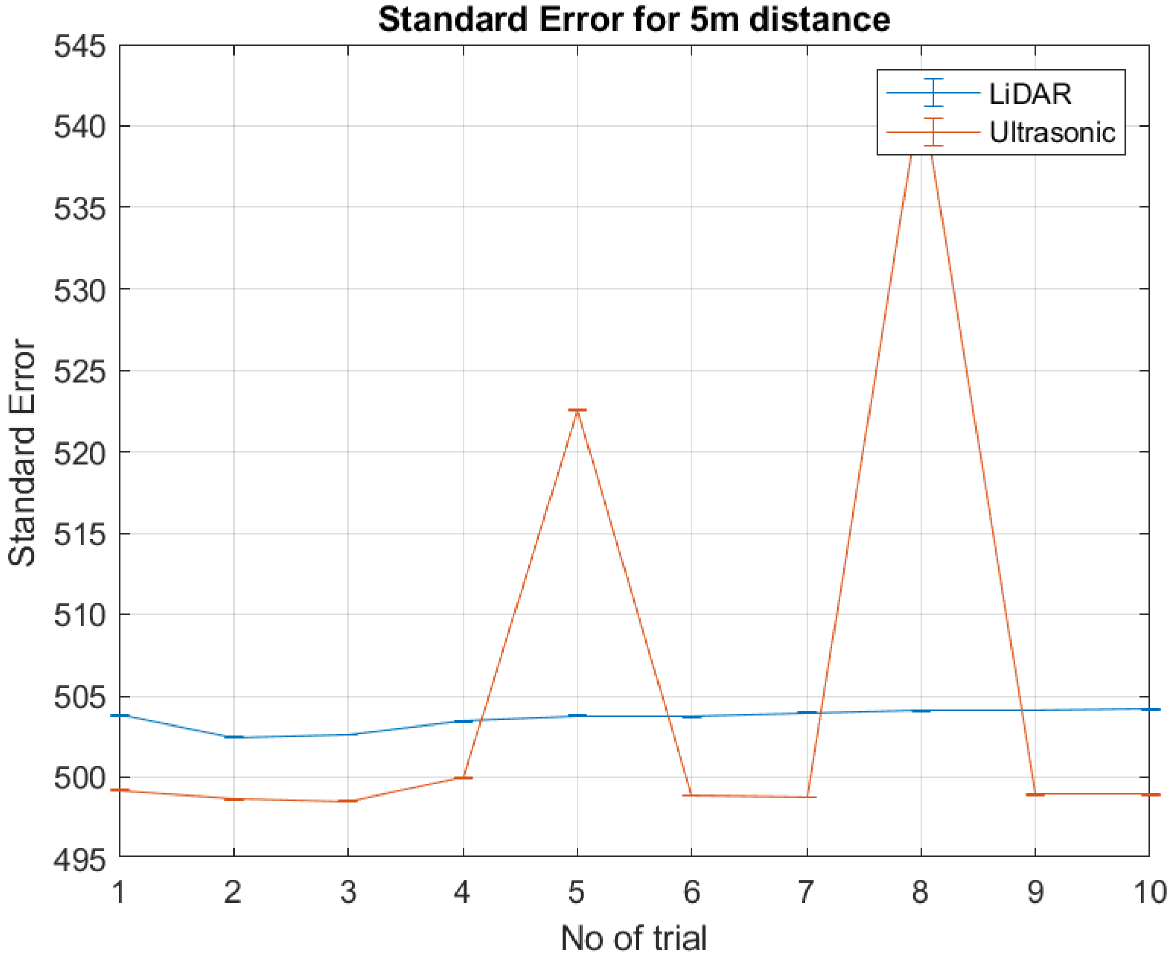

Figure 2.8: Graph of standard error for LiDAR and Ultrasonic sensors for 5m

The last distance is 5m which is shown in the Table 2.3. The percentage of error of LiDAR is below than 1% while for Ultranic sensor is not consistent throughout all the trial. Besides that, the standard deviation for LiDAR sensor has lower values compared to Ultrasonic which indicates the data points is close to the means compared to LiDAR sensor for 5m distance as shown in Figure 2.8.

All the graphs shown in Figure 2.6, Figure 2.7, and Figure 2.8, point out that Ultrasonic sensor has incosistent standard error and also high standard deviation compared to LiDAR sensor which pinpoint the datapoint of Ultrasonic sensor are spread out over a large range of values. This shows that, LiDAR sensor is more accurate and reliable to use in this research instead of Ultrasonic sensor.

3.0 RESULTS AND DISCUSSION

3.1 Bio Inspired AI-based System

The RoVision is equipped with high-tech Bio inspired artificial intelligence based system. Where the latest design of Rovision V3.0 is aspired by the pedal-muscle structure of Escargot which can be exploited to embedded clip while the Rotatable Rovision to get wider frame of vision using Lidar sensor for object detection is exploited from vision of escargot from the two tentacle eyes. The rovision capability is strengthen with the use of hybrid ant colony optimisation and Particle swarm optimisation in which we are able to boost up the merits of both algorithm combines to predict not only the accurate but shortest route for travelling.

After the first particles initialisation in the population, ACO is used where the pheromone trail is updated for finding local best path. The final population obtained from the ACO is going to be fed to PSO. The optimisation process continues with calculation of fitness value with the help of objective function. if a particle’s current position is better than the previous best position, it will be upgraded as the global best position. The update of velocity and position is continue until reaching the stopping criteria. In this case number of iteration.

Inspired from the fascinating observation of swarms of social insects the hybrid AI is also used for a localised swarm-like cooperative system. This would be useful for the targeted user to travel in a larger group with assurance that they know their company and also for safety precautions. For example here as shown in Figure 3.1, 4 visually impaired individuals started travel from different starting point, where multiple RoVisions can effectively communicate with each other to find the best routes to reach to the destination point together. This is very impactful to solve issue of traveling at unfamiliar environments and positively could boost up confidence and avoid social isolation.

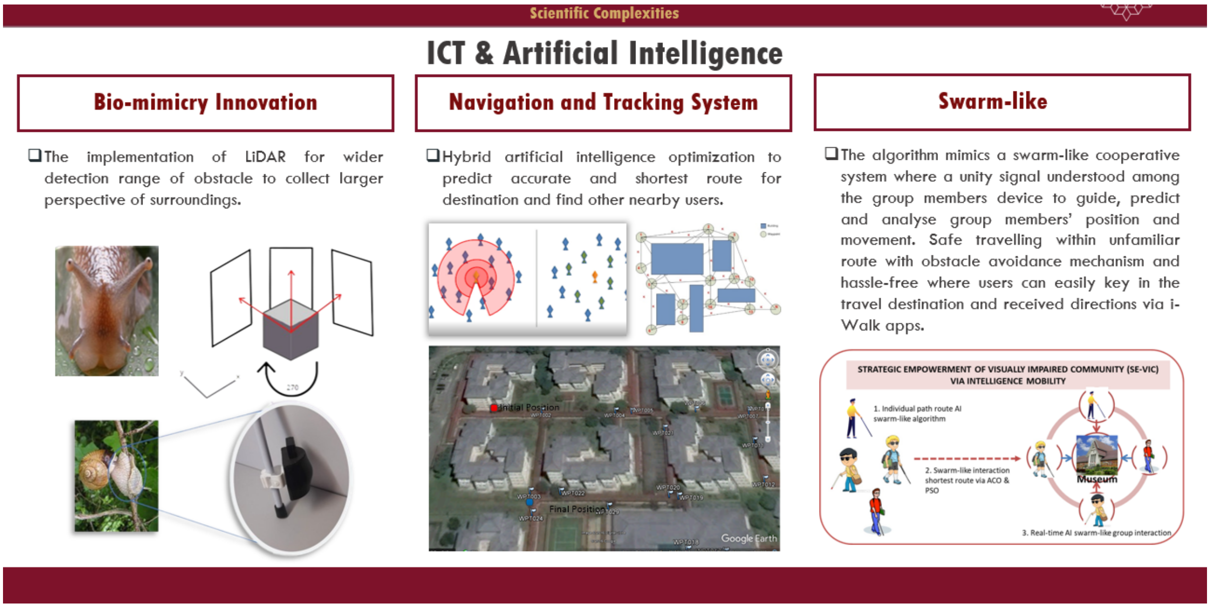

Figure 3.1: Bio Inspired AI-based System

3.2 Machine Learning

Another challenge is the ability to avoid dynamic obstacles. Where Static obstacles may have less causality compared to dynamic obstacles. Our solution aims to quickly and accurately alert to surroundings using Feature Extraction For Sparse Lidar Point Cloud Object Recognition &

Obstacle Avoidance. With combination methods of Clustered Extraction (CE) and Centroid Based Clustered Extraction (CBCE). The experimental data used is concentrated on moving object detection are human, motorcyclist, car with 4 different pose orientation headings (front, right, left, back).

Figure 3.2 shows - Point cloud data examples of human, motorcyclist and car showing raw data point cloud, followed by filter process and point cloud post clustering. We will start with the Clustered extraction (CE) method. The LiDAR point cloud gives output in Cartesian coordinate system with the x, y & z origin. The data, are extracted into three parts. The first part is alpha α, which stores the values of width (w), length (l), height (h) of the object, and the number of points in the cluster (N). The second part is array beta β which stores the number of elements within the segregated intervals. The third part is the minimum and maximum value of each axis in the clusters, denoted by gamma γ. The stored elements of the coordinate and the number of elements within a determined interval, will be the input for the classifier detection.

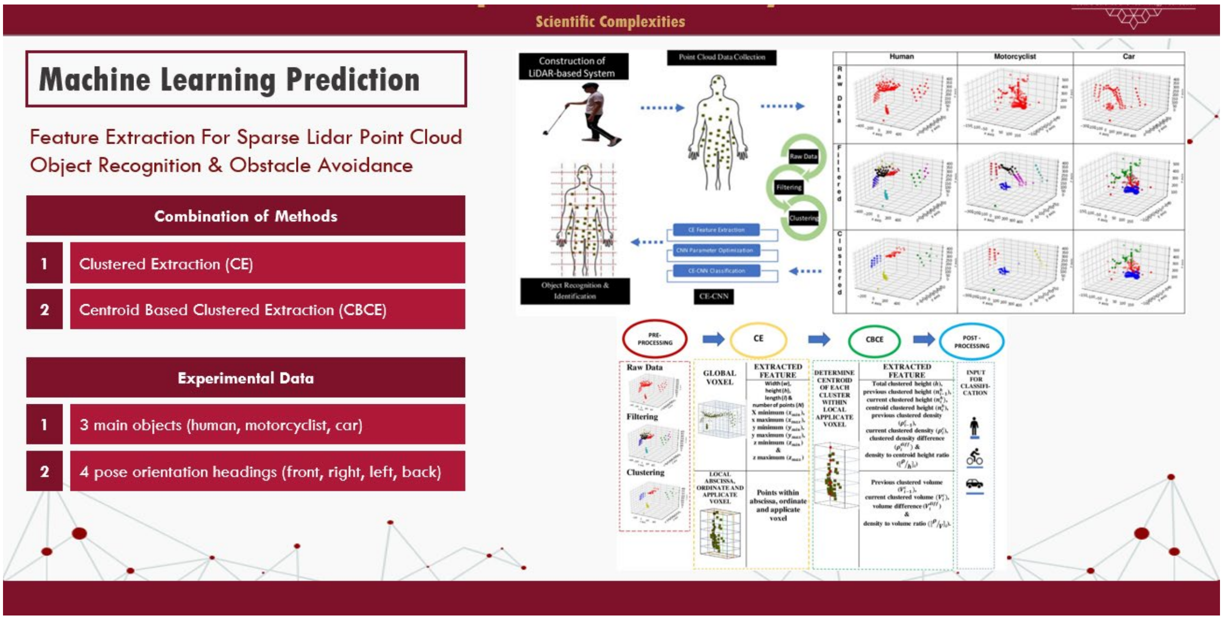

Figure 3.2: Machine learning for accurate predictions

3.2.1 Centroid Based Clustered Extraction (CBCE) method

From here onwards, two additional features are extracted for Centroid Based Clustered Extraction (CBCE) method denoted by delta δ (for features related to density to centroid height ratio (r=h) and epsilon ε (for features related to density to volume ratio (r=V). For each part, the centroid height is calculated as a reference point.

From the extracted features, classifications are done with 75%-25% split of training and testing data. The collective features are optimised with CNN with the number of hidden layers is ranged between 1 to 10, with the batch size of 10, 1000 number of epochs, and an activation function of Rectified Linear Units (ReLUs) and Softmax function.

Equipped with feature extraction and convolutional neural network (CNN) object classifier, RoVision has the capability to detect both static and moving objects with 97% accuracy that increases the safety level and group interaction capability and hence established sustainable wellbeing and high economy lifestyle.

4.0 IMPACT

The research presented in this report is in line with the Ministry of Women, Family and Community Development`s mission which is to empower persons with visual impairment which falls under the category of vulnerable group, by providing them opportunity to travel smoothly in an interactive environment with the help of assistive mobility aid. It is not only will increase safety level and group interaction capability, but also will help boost up and contributes to the economic growth in view to one of the NKEA sectors, the tourism industry with special and unique quasi-interactive tour guided travelers features for visually impaired person.

Disability is referenced in various parts of the Sustainable Development Goals (SDGs) and specifically in parts related to education, growth and employment, inequality, accessibility of human settlements, as well as data collection and monitoring of the SDGs, for instance (United Nation, Sustainable Development Goals):

Goal 4 on inclusive and equitable quality education and promotion of life-long learning opportunities for all focuses on eliminating gender disparities in education and ensuring equal access to all levels of education and vocational training for the vulnerable, including persons with disabilities. In addition, the proposal calls for building and upgrading education facilities that are child, disability and gender sensitive and also provide safe, non-violent, inclusive and effective learning environments for all.

In **Goal 8**: to promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all, the international community aims to achieve full and productive employment and decent work for all women and men, including for persons with disabilities, and equal pay for work of equal value.

Closely linked is **Goal 10**, which strives to reduce inequality within and among countries by empowering and promoting the social, economic and political inclusion of all, including persons with disabilities.

Goal 11 would work to make cities and human settlements inclusive, safe and sustainable. To realize this goal, Member States are called upon to provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, such as persons with disabilities. In addition, the proposal calls for providing universal access to safe, inclusive and accessible, green and public spaces, particularly for persons with disabilities.

Goal 17 stresses that in order to strengthen the means of implementation and revitalize the global partnership for sustainable development, the collection of data and monitoring and accountability of the SDGs are crucial. Member States are called upon to enhance capacity-building support to developing countries, including least developed countries (LDCs) and small island developing states (SIDS), which would significantly increase the availability of high-quality, timely and reliable data that is also disaggregated by disability.

5.0 ACCOMPLISHMENTS

5.1 AWARD RECEIVED:

1. **MTE 2023 Gold Award and Outstanding Award.** Title Miniaturized Rovision: A Revolutionised Travelling Aid for Visually Impaired Community (VIC).

5.2 JOURNAL & BOOK PUBLICATIONS

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1. Toha, Siti Fauziah and Nordin, Nor Hidayati Diyana (2023) ENHANCING ACCESSIBILITY: ASSISTIVE DEVICES PAIRING MOBILE APPS FOR VISUALLY IMPAIRED PEOPLE. PLATFORM - A Journal of Engineering, 7 (3). pp. 32-39. E-ISSN 26369877 https://myjms.mohe.gov.my/index.php/paje/article/view/241352.

2. M. A. Mohd Razin, M. A. Husman, S. F. Toha, A. Ibrahim, M. O. Tokhi, (2023) AN EFFECTIVE INSOLES SHOES FOR BLIND PEOPLE FOR MOBILITY ASSISTANCE. Journal of Engineering and Technology, 14 (2). pp. 1-13. ISSN 2180-3811 E-ISSN 2289-814Xhttps://jet.utem.edu.my/jet/article/view/6345

3. Hakim, Galang P. N. and Habaebi, Mohamed Hadi and Toha, Siti Fauziah and Islam, Md. Rafiqul and Yusoff, Siti Hajar and Adesta, Erry Yulian Triblas and Anzum, Rabeya (2022) Near ground pathloss propagation model using adaptive neuro fuzzy inference system for wireless sensor network communication in forest, jungle, and open dirt road environments. Sensors, 22 (9). pp. 1-18. E-ISSN 1424-8220

4. Merrad, Yacine and Habaebi, Mohamed Hadi and Toha, Siti Fauziah and Islam, Md. Rafiqul and Gunawan, Teddy Surya and Mesri, Mokhtaria (2022) Fully decentralized, cost-effective energy demand response management system with a smart contracts-based optimal power flow solution for smart grids. Energies, 15 (12). pp. 1-27. ISSN 1996-1073

5. Miniaturised robotic guide dog: for visually impaired travelling assistance. Persatuan Saintis Muslim Malaysia (PERINTIS), e-ISBN: 978-967-17775-2-7.