Original Article

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The Use of Artificial Intelligence in the Development of Vision Aids for the Visually Impaired

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Abstract:

The development of assistive technologies for the visually impaired has gained significant attention in recent years, with Artificial Intelligence (AI) playing a key role in advancing vision aids. This study explores the use of AI in enhancing the functionality and accessibility of vision aids for the visually impaired through a qualitative, literature-based approach. By reviewing existing studies and research on AI-powered devices such as smart glasses, object recognition systems, and AI-guided navigation tools, this paper identifies how AI contributes to improving the quality of life for individuals with visual impairments. The study highlights key AI technologies, including computer vision, machine learning, and natural language processing, that allow devices to provide real-time information about the surrounding environment, recognize objects, and assist with daily tasks. Furthermore, this paper discusses the challenges of developing AI-based vision aids, such as technological limitations, user acceptance, and affordability, while emphasizing the need for interdisciplinary collaboration in creating more effective solutions. The findings suggest that AI has the potential to significantly enhance the independence of visually impaired individuals by enabling smarter, more responsive assistive devices. Future research is recommended to focus on empirical studies, long-term user experiences, and the ethical considerations surrounding AI use in assistive technologies.

Keywords: Artificial Intelligence, Vision Aids, Visually Impaired, Assistive Technology, Computer Vision.

Abstrak:

Pengembangan teknologi bantu bagi penyandang tunanetra telah mendapat perhatian besar dalam beberapa tahun terakhir, dengan Kecerdasan Buatan (AI) memainkan peran penting dalam memajukan alat bantu penglihatan. Studi ini mengeksplorasi penggunaan AI dalam meningkatkan fungsi dan aksesibilitas alat bantu penglihatan bagi penyandang tunanetra melalui pendekatan kualitatif berbasis studi literatur. Dengan meninjau penelitian

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yang ada mengenai perangkat bertenaga AI seperti kacamata pintar, sistem pengenalan objek, dan alat navigasi berbasis AI, artikel ini mengidentifikasi bagaimana AI berkontribusi dalam meningkatkan kualitas hidup individu dengan gangguan penglihatan. Studi ini menyoroti teknologi AI utama, termasuk computer vision, machine learning, dan pemrosesan bahasa alami, yang memungkinkan perangkat memberikan informasi waktu nyata tentang lingkungan sekitar, mengenali objek, dan membantu tugas sehari-hari. Selain itu, artikel ini membahas tantangan dalam mengembangkan alat bantu penglihatan berbasis AI, seperti keterbatasan teknologi, penerimaan pengguna, dan keterjangkauan, sambil menekankan perlunya kolaborasi lintas disiplin dalam menciptakan solusi yang lebih efektif. Temuan menunjukkan bahwa AI memiliki potensi untuk secara signifikan meningkatkan kemandirian individu tunanetra dengan memungkinkan perangkat bantu yang lebih cerdas dan responsif. Penelitian lebih lanjut disarankan untuk fokus pada studi empiris, pengalaman pengguna jangka panjang, dan pertimbangan etis dalam penggunaan AI pada teknologi bantu.

Kata Kunci: Kecerdasan Buatan, Alat Bantu Penglihatan, Tunanetra, Teknologi Bantu, Computer Vision.

Introduction

Background, Problem Formulation, and Purpose Background Blindness is an individual who experiences significant vision loss or limitation, which affects their ability to live their daily lives independently. These vision limitations can include both congenital vision impairments and those that occur as a result of illness or accident. People with visual impairments face a variety of challenges in living their daily lives, including difficulty moving around, reading, identifying objects, and communicating with their surroundings.

Technological developments, especially in the field of artificial intelligence (AI), have opened up great opportunities to improve the quality of life of people with visual impairments. Artificial intelligence is a branch of computer science that focuses on developing systems capable of extracting, processing, and understanding information from data, as well as making decisions automatically. By leveraging artificial intelligence, we can develop more advanced vision aids, which have the potential to address most of the challenges faced by people with visual impairments.

Several existing visual aids, such as walking sticks and voice-based text readers, have provided assistance to the visually impaired. However, there is great room for improvement in terms of accuracy, efficiency, and availability of these vision aids. By combining AI technology and image, text, and voice recognition, we can create more advanced vision aids, which are capable of recognizing objects, reading text, providing more accurate navigation guidance, and even facilitating interaction with the surrounding world.

Therefore, this study aims to explore the potential use of artificial intelligence in the development of vision aids for the visually impaired. By utilizing the latest technology, this research will focus on the development of innovative and efficient vision aids, which will provide great benefits to visually impaired people in their daily lives. With a deep understanding of the potential and challenges faced by people with visual impairments, this research is expected to help create better and more inclusive solutions in supporting their quality of life.

The objectives of the research are formulated as follows: Researching and integrating image, text, and voice recognition technology to create more effective and responsive solutions to the needs of people with visual impairments. To assess the effectiveness of vision aids developed in improving the independence and quality of life of people with visual impairments.

Based on the facts presented in the background above, this study has several important aspects obtained from several related studies or research, namely: Increased Independence:

a. Visually impaired people often face limitations in carrying out daily activities independently. The development of AI-based vision aids can significantly improve their independence, enable safer and more effective navigation, and better access to visual and textual information. Research by Manduchi and Kurniawan (2011) shows that assistive technology can expand navigation capabilities for people with visual impairments, reducing their dependence on human assistance[5].
b. Technological Innovation: Artificial intelligence offers new possibilities in the development of assistive technology, especially through more accurate image and text recognition. Research [6] highlights the potential of AI in developing tools that are more adaptive and responsive to individual needs.
c. Quality of Life: Improving the quality of life of the visually impaired is the main goal of the development of assistive technology. With more advanced devices, individuals can enjoy wider access to different aspects of social, educational, and work life. Studies by [6] show that effective vision aids can improve quality of life by providing better access to information and communication.
d. Response to Evolving Needs: With the increasing prevalence of vision loss due to age factors and other health conditions, the need for effective technological solutions is becoming more urgent. Research [7] shows a global increase in the prevalence of conditions affecting vision, which emphasizes the need for innovative solutions in assistive technology
e. Inclusive Social Development: Developing solutions that allow people with visual impairments to participate more fully in society is an important step towards greater social inclusion. This research aims to reduce the barriers faced by people with visual impairments and promote equality in access to technology and information. [7]

The development of the assistive device module for the deaf that has been described above is limited to one module (image, text, sound) that is not integrated into a unit. So, the proposer team plans to develop better aids for the visually impaired.

Methods

This study employs a qualitative research design to explore the use of artificial intelligence (AI) in the development of vision aids for the visually impaired. A qualitative approach is chosen because it allows for an in-depth exploration of complex, technology-driven topics where human experiences, perceptions, and interactions with AI-based tools can be studied thoroughly (Creswell & Poth, 2018). This approach is particularly suitable for understanding the social, cognitive, and emotional impacts of AI technologies on the visually impaired and for capturing the insights of various stakeholders, including users, developers, and experts in assistive technologies.

The primary data sources for this research consist of semi-structured interviews and document analysis. The participants include visually impaired individuals who have experience using AI-based vision aids, developers of such technologies, and experts in AI and assistive technology. Purposive sampling is used to select participants who can provide rich, relevant data about their experiences and expertise with AI in vision aids (Patton, 2015). This method ensures the inclusion of participants who have direct interaction with or deep knowledge about AI-based assistive tools for the visually impaired. Additionally, secondary data from relevant documents, such as product manuals, research papers, and technical reports on AI in assistive technologies, are analyzed to complement the interview data.

Data is collected through semi-structured interviews and document analysis. Semi-structured interviews are conducted with 15 participants, including visually impaired users of AI-driven vision aids, AI developers, and experts in assistive technology. These interviews allow for flexibility, enabling the interviewer to explore various aspects of the participants' experiences while maintaining a structured guide that ensures the study's key themes are addressed (Merriam & Tisdell, 2016). Each interview lasts approximately 45-60 minutes and is recorded with participants' consent. Additionally, document analysis is used to examine research papers, technical reports, and product guides related to AI-based vision aids, providing further insights into how these technologies are designed and applied in real-world contexts.

Data is analyzed using thematic analysis, a qualitative method that allows for identifying, analyzing, and reporting patterns (themes) within the data (Braun & Clarke, 2006). Thematic analysis is conducted in several phases: (1) familiarization with the data through reading and re-reading transcripts and documents, (2) generating initial codes by systematically coding important features of the data relevant to the research question, (3) searching for themes by organizing codes into potential themes, (4) reviewing themes to ensure they align with the coded data and the overall dataset, (5) defining and naming themes to create a clear narrative about the findings. This process ensures that the complex interplay between AI, user experiences, and technological development is captured.

In addition, triangulation is used to enhance the validity of the findings by comparing data from multiple sources, including interviews, documents, and expert opinions (Denzin & Lincoln, 2018). This approach helps to corroborate the data, providing a more comprehensive understanding of how AI technologies are being used in vision aids for the visually impaired. Member checking is also employed, where participants review summaries of the findings to ensure the accuracy and credibility of the interpretations (Lincoln & Guba, 1985).

By employing these methods, this study provides a deep exploration of the current landscape of AI-based vision aids, highlighting the benefits, challenges, and potential improvements from the perspectives of both users and developers.

Results and Discussion

A. Provisional Findings and Partner Roles (if any)

1. Provisional Findings

The development of assistive devices in research refers to the prototype development model. The selection of this model is very appropriate to use in the case of model development that has results close to a ready-to-use product.

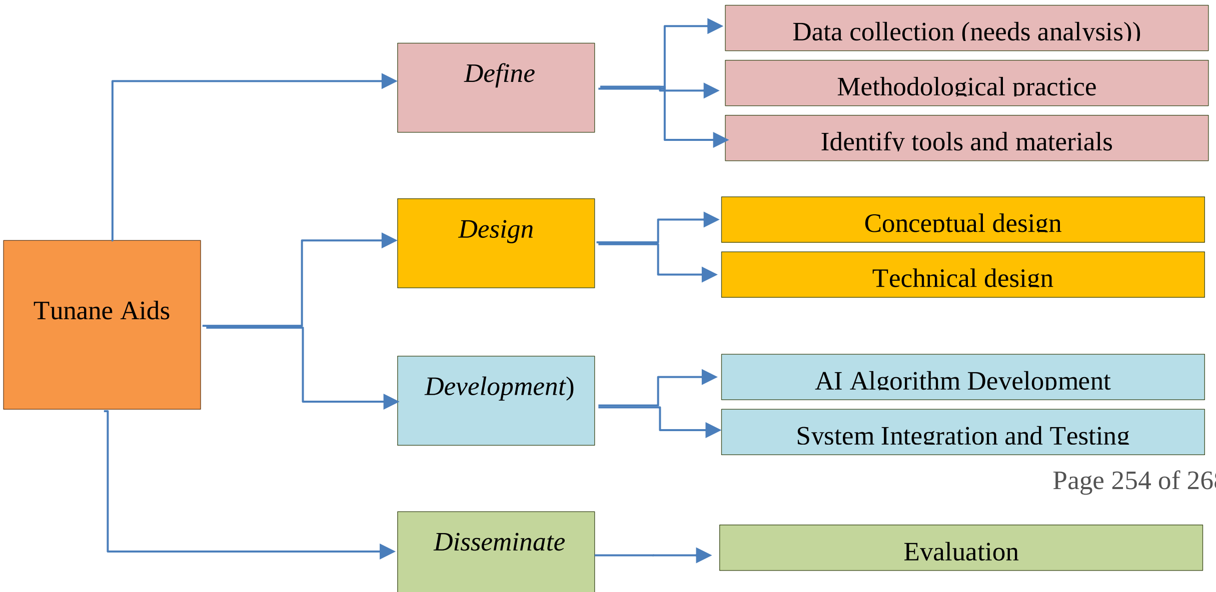


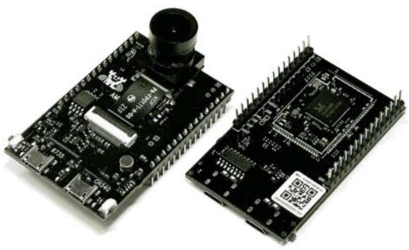
Figure 1. Assistive Devices for the Visually Impaired

The provisional findings in this study can be described based on Figure 1 above:

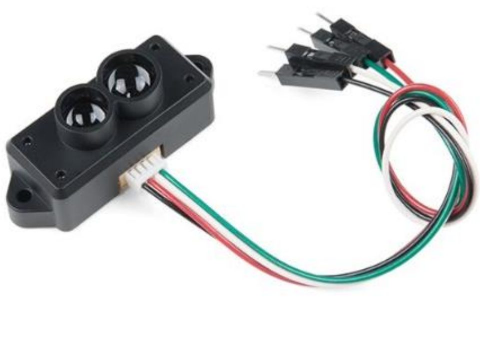
a. **Define**

Several activities were carried out, namely needs analysis, methodological analysis, and identification of tools and materials (resources).

1. Needs Analysis, at this stage the team conducts a needs analysis to identify the problem. The output of this activity is that the team has identified several needs that can determine the model of the tool to be used.
2. Methodological Analysis, at this stage the team determines the methodology to be used to develop and test vision aids. This includes the selection of AI technology, image and sound recognition algorithms, and testing methods with participants. The output of this activity is that the team uses several AI methods used in identifying images, sounds, and text with the Yolo Algorithm.
3. Identify the tools and materials, at this stage the team compiles a list of tools and materials required for the development and testing of the device, including the necessary hardware and software. The output of this activity is that the team has identified the tools and materials used are:



Picture 1. Realtek AMB82-Mini IoT AI Camera Board



Picture 2. TF Mini Lidar

Picture 3. 3D Printer

a. Software, consisting of Arduino IDE, Jupiter Notebook, VSCode

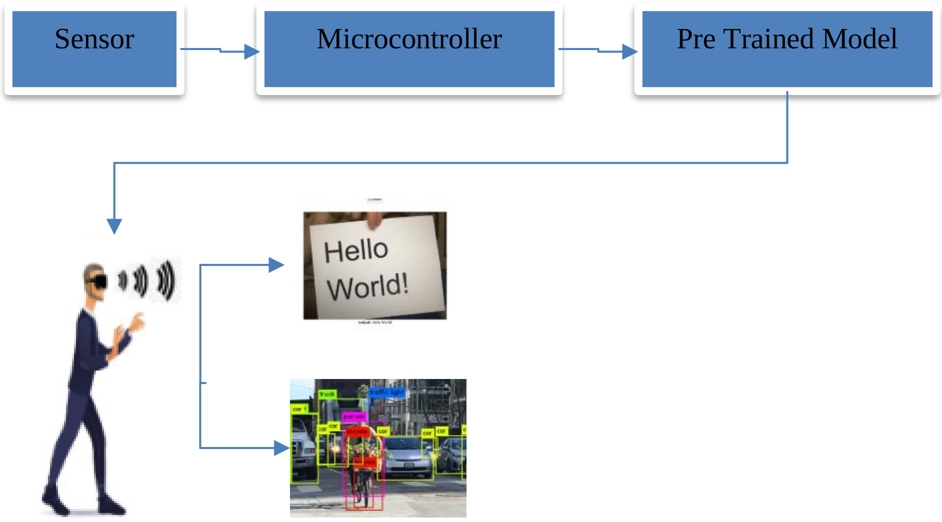
Picture 4. Arduino IDE

b. **Design**

Several activities were carried out, namely conceptual design and technical design.

1. Conceptual Design, at this stage a device concept has been developed that integrates AI technology for navigation, object recognition, and text reading, which is specifically designed to meet the needs of the visually impaired as well as technical specifications have been set, including a choice of sensors for object detection, microphones for voice input, and speakers for audio output

2. At this stage artificial intelligence technologies such as deep learning (Yolo) for object recognition and natural language processing for voice interaction have been chosen, as well as system architecture has been designed, including data flow diagrams and interactions between system components showing how data is processed and responses are generated, shown in the figure belowAt this stage artificial intelligence technologies such as deep learning (Yolo) for object recognition and natural language processing for voice interaction have been chosen, as well as system architecture has been designed, including data flow diagrams and interactions between system components showing how data is processed and responses are generated, shown in the figure below.



Picture 5. AI solutions in helping the visually impaired

c. Algorithm Model Design Stage, at this stage, an algorithm model is designed which is used as a model that can be applied in various test cases. Some of the steps taken in this stage are:

1. Dataset Capture,
   Dataset collection is carried out by taking pictures using cellphone cameras and downloading from the internet to enrich the dataset. This dataset consists of images of objects that are commonly encountered in daily life and relevant to people with visual impairments, such as: people, cars, motorcycles, bicycles, sticks, stairs, holes, poles, line guiding blocks, and point guiding blocks. The total dataset collected amounted to 2040 images.

Table 1. number of data sets

Class Name	Amount of data
Person	220
Car	220
Motor	220

Bicycle	220
Stick	220
Ladder	220
Hole	220
Pole	220
Guiding block lines, and guiding block point.	280
Total	2040

a. Pictures of People

Picture 6. Examples of Pictures of people

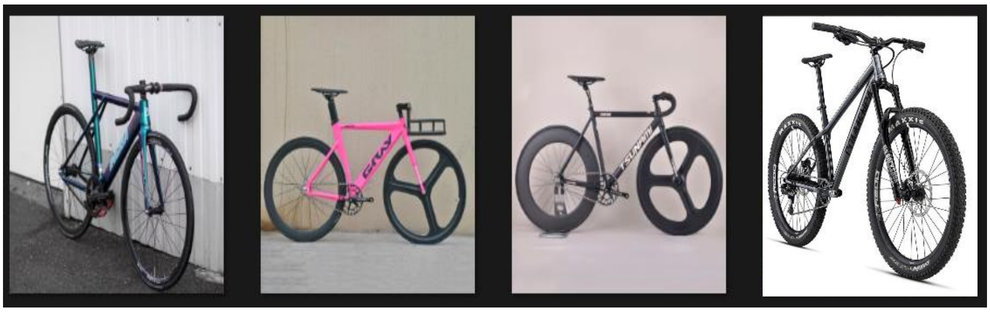
b. Car Picture

Picture 7. Eample of car image

c. Motorbike Picture

Picture 8. Example of a motorbike image

d. Bicycle Image

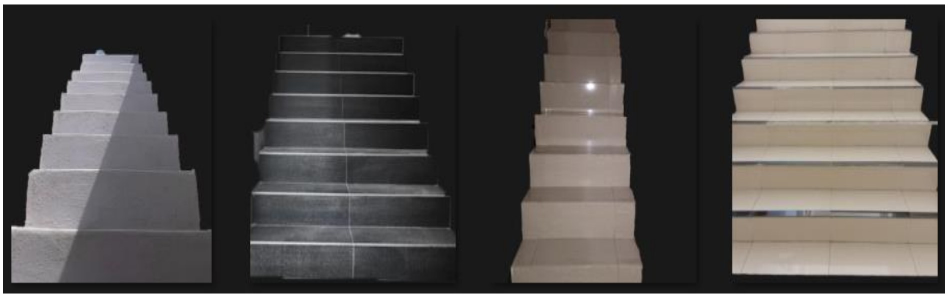


Picture 9. Example of a bicycle image

e. Drawing of the Stick

Picture 11. Stick Example of Motorcycle Images

f. Staircase Drawing

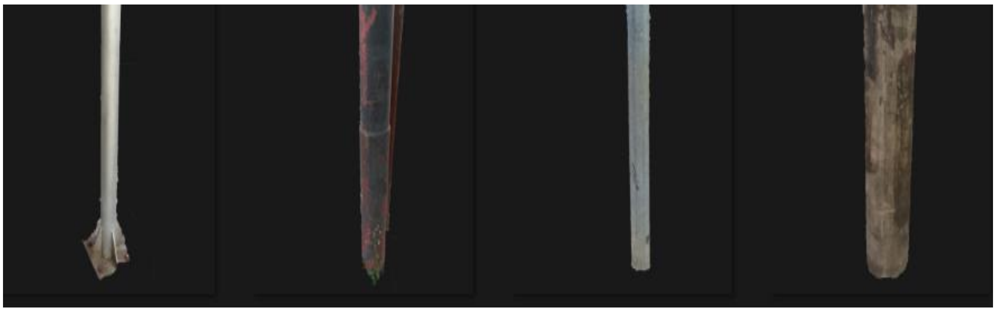


Picture 12. Ladde

g. Hole Drawing

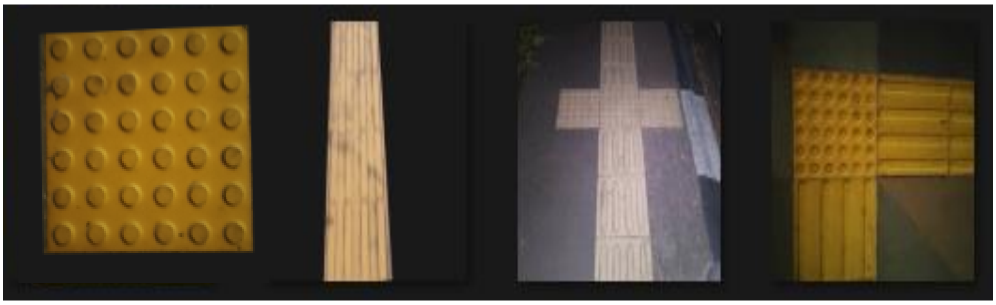
Picture 13. Hole

h. Pole Drawing



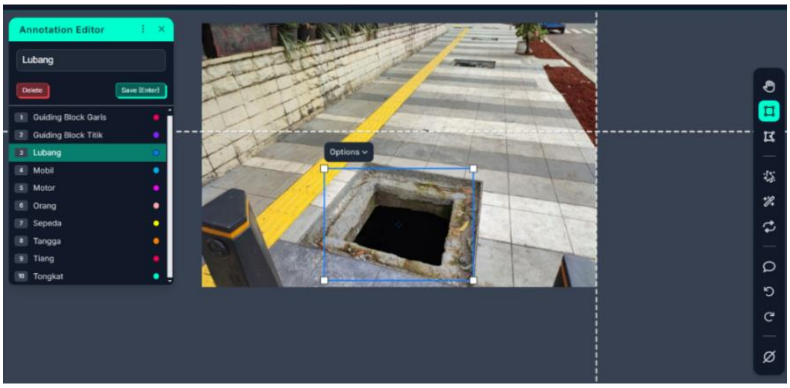
Picture 14. Pole

i. Drawing a Guiding block line, and Guiding block point.



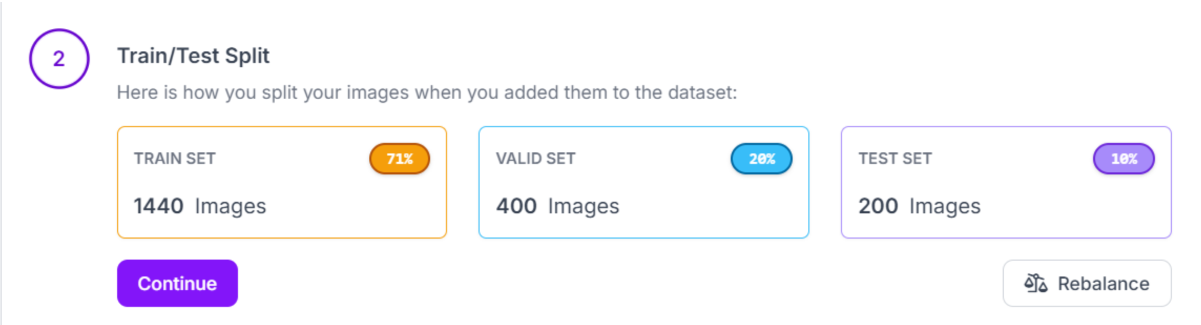
Picture 15. Guiding Blok

2. Labeling
Labeling is done by uploading all these images to the Roboflow platform.



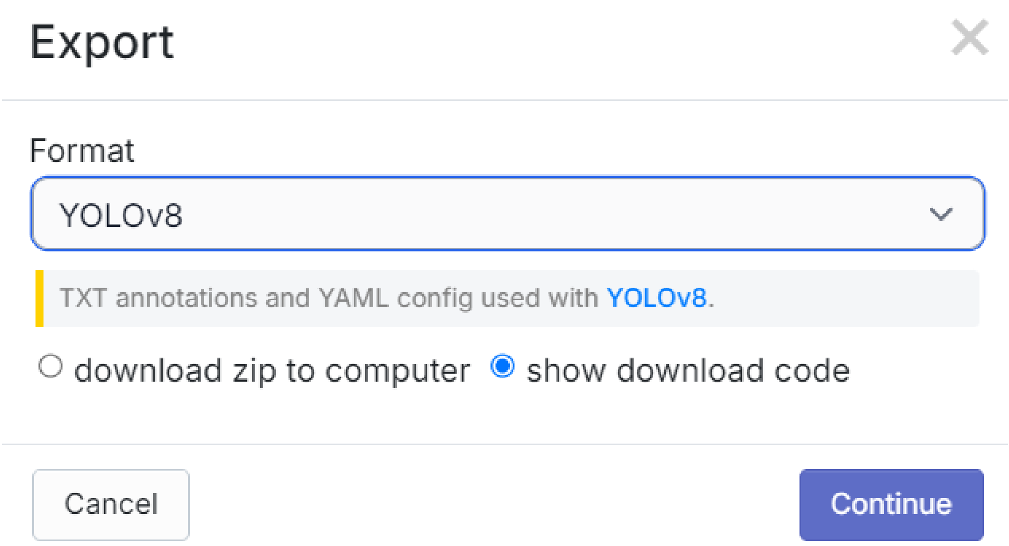
3. Preprocessing

In this stage, the dataset that has been obtained from the labeling process above which amounts to 2040 images, then the data is divided into 2, namely 70% training data and 30% test data.



1. Training

Data that has been processed according to specific requirements will be exported for use in the training process in Google Colab. This export process produces a dataset in a form that is ready to be used for the development and training of YOLOv8 models. With the dataset already optimized, the resulting API will enable seamless integration with Google Colab, so that it can be leveraged to effectively train YOLOv8 models. The end result of this export is to provide an API that serves as a bridge to facilitate the training of YOLOv8 models in a Google Colab environment, ensuring that the data used is appropriate and ready to maximize the model's performance in detecting objects. Once the annotation process on the dataset is complete, the next step is to export the dataset into a format that corresponds to YOLOv8. This export process ensures that all the annotated data can be used properly by YOLOv8 for model training purposes.



The export results obtained, then a training process is carried out on the Googlecolab platform with the results in the image below.

```
50 epochs completed in 1.661 hours.
Optimizer stripped from runs/detect/train/weights/last.pt, 22.6MB
Optimizer stripped from runs/detect/train/weights/best.pt, 22.6MB

Validating runs/detect/train/weights/best.pt...
Ultralytics YOLOv8.0.196 🚀 Python-3.10.12 torch-2.3.1+cu121 CUDA:0 (Tesla T4, 15102MiB)
Model summary (fused): 168 layers, 11129454 parameters, 0 gradients, 28.5 GFLOPs
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 13/13 [00:10<00:00,  1.21it/s]
                   all        399        540      0.943      0.899       0.94      0.746
   Guiding Block Garis        399         64      0.952      0.929      0.935      0.755
   Guiding Block Titik        399         49      0.917      0.939      0.932      0.826
                Lubang        399         44      0.976      0.914      0.964      0.638
                 Mobil        399         55      0.912      0.891      0.923      0.745
                 Motor        399         54      0.936      0.944      0.984      0.829
                 Orang        399         51      0.966      0.824      0.924      0.758
                Sepeda        399         43      0.933      0.953      0.985      0.886
                Tangga        399         44          1      0.993      0.995      0.916
                 Tiang        399         80      0.903      0.819      0.914      0.495
               Tongkat        399         56      0.936      0.786      0.847      0.614
Speed: 0.5ms preprocess, 7.1ms inference, 0.0ms loss, 4.2ms postprocess per image
Results saved to runs/detect/train
```

From the results of the training, an accuracy value of 94% was obtained.

2. Validasi.

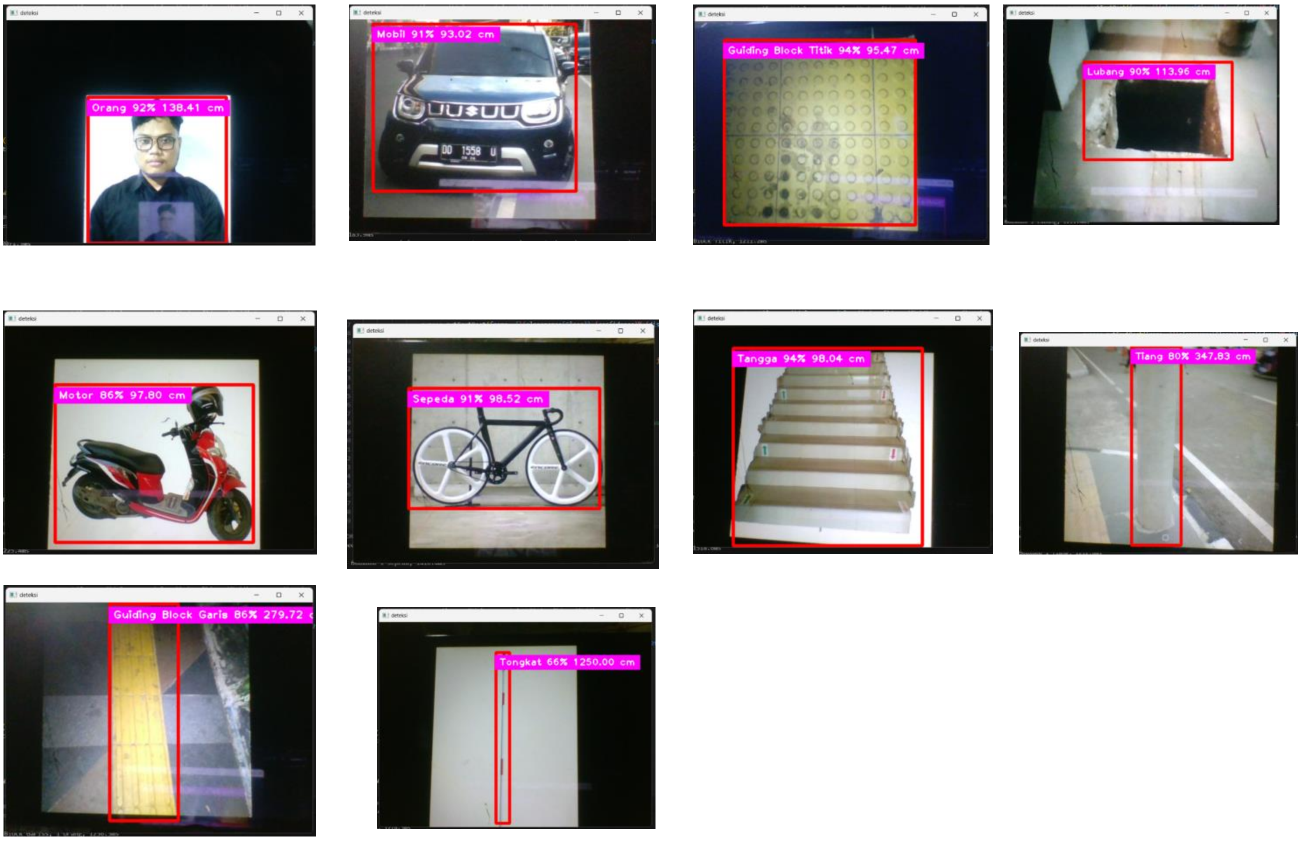
After the training process above is completed, the model that has been obtained will be validated using new image data that is not in the dataset. The validation process was carried out using the YOLO model with the model obtained from training with several configurations in the YAML dile.

```
Ultralytics YOLOv8.0.196 🚀 Python-3.10.12 torch-2.3.1+cu121 CUDA:0 (Tesla T4, 15102MiB)
Model summary (fused): 168 layers, 11129454 parameters, 0 gradients, 28.5 GFLOPs
val: Scanning /content/datasets/datasets/Deteksi-Objek-Sekitar-Di-Jalan-7/valid/labels.cache..
WARNING ⚠️ Box and segment counts should be equal, but got len(segments) = 126, len(boxes) = !
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%
                   all        399        540      0.943      0.899      0.941      0.747
   Guiding Block Garis        399         64      0.952       0.93      0.936      0.755
   Guiding Block Titik        399         49      0.917      0.939      0.932      0.826
                Lubang        399         44      0.976      0.914      0.964       0.64
                 Mobil        399         55      0.912      0.891      0.923      0.747
                 Motor        399         54      0.936      0.944      0.984      0.831
                 Orang        399         51      0.965      0.824      0.924      0.756
                Sepeda        399         43      0.933      0.953      0.985      0.887
                Tangga        399         44          1      0.993      0.995      0.913
                 Tiang        399         80      0.904       0.82      0.914      0.495
               Tongkat        399         56      0.935      0.786      0.851      0.616
Speed: 1.4ms preprocess, 13.6ms inference, 0.0ms loss, 3.4ms postprocess per image
```

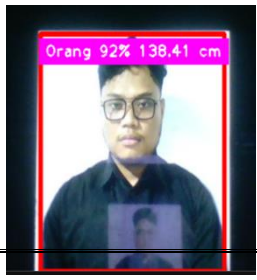
From the figure above, showing the validation results of 399 images show quite satisfactory performance with a precision value of 0.943 and a recall of 0.899. In addition, this model is able to produce an mAP50 value of 0.941 with an average processing of 13.6 ms per image.

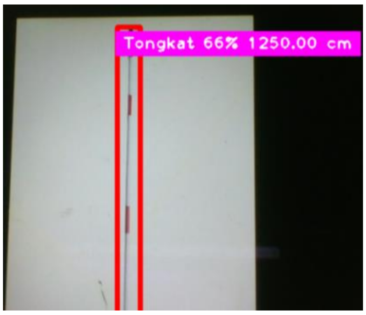
b. Testing and System Integration Stages

This stage is carried out after obtaining the best algorithm model for the process of integrating the model into the microcontroller which will later be tested in real conditions in the field. Here are the test results:



The image above is the Results of the testing process carried out by taking image objects in the field.

Test data	Dataset classes	Detection Results	Level of Certainty
	People		92%

	Car		91%
	Motor		86%
	Bicycle		91%
	Cane		66%

	ladder		94%
	Hole		90%
	Pole		80%
	Drawing Guiding Block Lines		86%

During the process, the tested data consisted of 10 classes of object images, which included people, cars, motorcycles, bicycles, sticks, ladders, holes, poles, line guiding blocks, and point guiding blocks. Each class contained 220 image data. In the detection test using the YOLOv8 model, the certainty values obtained showed significant variation. The highest certainty value achieved was 94%, while the lowest certainty value was 66%. This low-certainty data indicates that the YOLOv8 model has difficulty detecting or classifying objects with an adequate level of accuracy. One of the main factors affecting the low certainty level is the diversity of image backgrounds in the tested objects. Highly varied backgrounds can cause the YOLOv8 model to struggle in recognizing and categorizing objects appropriately, thus reducing overall detection accuracy. This suggests that to improve the model's performance, further adjustments or training may be needed with more homogeneous data in terms of background.

Conclusion

The use of artificial intelligence (AI) in the development of vision aids for the visually impaired has demonstrated significant potential to improve the quality of life for users by enhancing their ability to navigate, interact, and perceive their environment more independently. This study has explored how AI-driven technologies, such as object recognition, obstacle detection, and smart navigation systems, are being implemented in assistive devices. The findings indicate that AI not only provides practical assistance in daily activities but also fosters a greater sense of autonomy and confidence among visually impaired users. However, challenges related to cost, accessibility, and the need for continuous improvement in AI algorithms remain. These factors highlight the importance of further refinement in the design and deployment of AI-based vision aids to maximize their effectiveness and inclusivity.

The implications of this research are far-reaching, especially in guiding future development in the field of assistive technologies. The integration of user-centered design and feedback from visually impaired individuals is crucial to ensure that AI-based tools address their real needs effectively. Furthermore, policymakers and developers should consider the affordability and accessibility of these technologies to make them more widely available. As a recommendation, future research should focus on improving AI's adaptability in various environments, exploring partnerships with healthcare and social sectors for better integration of these devices, and conducting longitudinal studies to assess the long-term impact of AI-based vision aids on the visually impaired. By addressing these areas, AI can play an even more transformative role in enhancing the lives of those with visual impairments.

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