A Systematic Review of Assistive Tools for Individuals with Visual Impairments: Advancements in Assistive Technologies, Internet of Things and Computer Vision

Nicolás E. Caytuiro-Silva[1], Eveling G. Castro-Gutierrez[1] and Jackeline M. Peña-Alejandro[1]

[1] *Universidad Católica de Santa María, Urb. San José s/n Umacollo, Arequipa, Perú*

Abstract

Visual impairment significantly impacts the lives of millions globally, affecting daily activities and independence. Assistive technologies have emerged as promising tools to enhance autonomy and inclusion for individuals with visual disabilities. Despite numerous tools addressing mobility, navigation, orientation, and object recognition, many remain as proposals or prototypes, with limited impact on the visually impaired community. A comprehensive systematic review is crucial to assess the current state of assistive technology, IoT, and Computer Vision, identifying limitations, areas for improvement, and opportunities for new solutions. This review aims to analyze and synthesize theoretical and practical literature related to assistive tools for individuals with visual impairments. Conducting an exhaustive search on academic databases such as IEEE and Scopus, the review focuses on keywords like computer vision, deep learning, blind or visually impaired. Inclusion and exclusion criteria will guide study selection, with a focus on evaluating study quality. The systematic review analyzes recent technological advancements in assistive tools for the visually impaired, assessing limitations and contributions found in the literature. Key aspects, such as the accuracy and reliability of IoT and Computer Vision-based assistive technologies, are thoroughly evaluated. The University Isabel I systematic review method is employed, involving a manual search of 71 articles from journals, conference proceedings, and books. The findings provide valuable insights for future research, offering a current overview of existing assistive tools for visual impairment. Limitations and improvements identified guide and inspire future research in assistive technologies, IoT, and computer vision. Results reveal a higher publication rate in the Institute of Electrical and Electronics Engineers (IEEE) journal from the United States. The predominant limitation is technological dependence (16.46%), while the most significant contribution lies in the accuracy of detecting objects of interest (11.70%). This systematic review aims to broaden the understanding of existing assistive tools for visual impairment, focusing on technological advancements in Computer Vision and IoT. It anticipates guiding future research towards developing more effective assistive tools for visually impaired individuals.

Keywords

Visual Impairment, IoT Technology, Computer Vision, Assistive Technologies.

1. Introduction

Visual impairment affects millions worldwide, hindering the perception, interpretation, and access to visual information [1]. Over the years, various assistive technologies have been developed to enhance the quality of life and independence of individuals with visual impairments [2]. In the last decade, advancements in assistive technologies, the Internet of Things (IoT), and artificial vision have opened new possibilities for innovative tools supporting individuals with visual disabilities [3]. These technologies enable object detection, real-time information access, secure navigation, and efficient communication [3]. Given the growing interest in these technologies, a comprehensive systematic review is essential to identify and evaluate available assistive tools for visual impairment [4]. This review aims to provide an updated view of technological advancements, identify strengths and limitations, and highlight areas requiring

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nicolas.caytuiro@ucsm.edu.pe (N. Caytuiro); ecastrog@ucsm.edu.pe (E. Castro); jackeline.pena@ucsm.edu.pe (J. Peña)

0000-0003-1656-396X (N. Caytuiro); 0000-0002-0203-041X (E. Castro); 0000-0002-3586-1826 (J. Peña)

further research and development. The article presents a detailed analysis of relevant assistive technologies, including wearable devices, mobile applications, navigation systems, e-readers, among others. Key aspects such as technology accuracy, reliability, user-friendliness, interoperability, and user acceptance are examined. Ethical and privacy challenges associated with these technologies, as well as barriers and opportunities for large-scale implementation, are also addressed. The document structure includes the method of research in Section 2, SLR results in Section 3, a discussion of the research question in Section 4, and study limitations, research gaps, and suggestions for future studies in Section 5.

2. Method

The presented review aims to analyze and synthesize theoretical and practical literature related to assistive tools for individuals with visual disabilities, identifying the main limitations and contributions to date. This study has been conducted as a systematic literature review based on the guidelines proposed by Kitchenman [5], which suggests three phases: (1) Planning, (2) Conducting, and (3) Reporting. The planning phase includes determining the needs of the systematic review and developing an appropriate protocol to eliminate biases in the research [6]. The conducting phase involves formulating the Quality Question (RQ) to guide central themes of the review, developing the search process, identifying inclusion and exclusion criteria to select appropriate studies, examining quality assessment to evaluate previously selected studies in terms of quality, applying data extraction for detailed documentation, synthesizing the data, and finally summarizing results and discussions to answer the research question [7]. The final stage involves presenting the results and discussions to answer the previously formulated research question. The steps of the systematic literature review method are documented in figure 1.

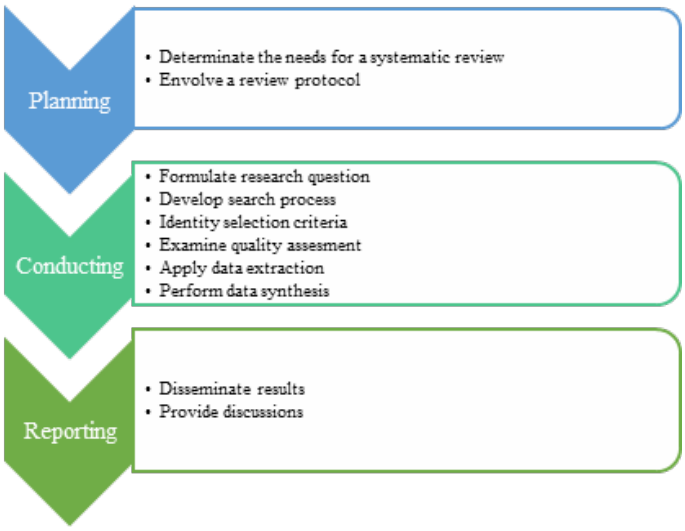

Figure 1: The Systematic Literature Review Framework [5]

2.1. Research Questions

The research question addressed in this study is:

RQ1: Is the development of an assistive system based on IoT and artificial vision for individuals with visual disabilities possible?

Regarding RQ1, it is considered important to evaluate the possibility of developing an assistive system based on IoT and Artificial Vision for individuals with visual disabilities. To address RQ1, the frequency of published journals, the frequency of countries of origin, and the predominance of limitations and contributions found in the articles have been identified.

2.2. Search Process

The search process involved a manual search for journal articles related to the development of assistive tools for individuals with visual disabilities over the last 5 years. Articles were selected as they were known to include applied and theoretical studies related to assistive tools for visually impaired individuals based on technologies such as IoT and Artificial Vision. The databases used were:

- Scopus
- IEEE Explorer

2.3. Inclusion and Exclusion Criteria

Clear inclusion and exclusion criteria were established to select relevant studies. These criteria were based on the research topic, study type, article quality, and publication period from 2018 to 2023. Inclusion criteria included:

- Studies addressing the topic of systematic literature reviews in the field of software engineering.
- Studies presenting a clear and reproducible methodology for conducting systematic reviews.
- Studies published in peer-reviewed journals or conferences.

Studies that did not meet the inclusion criteria, as well as duplicates, studies not available in full text, and articles of low quality, were excluded.

2.4. Quality Questions

Each article was evaluated using criteria from Scopus and IEEE databases. The criteria are based on a quality assessment question derived from the previously formulated research question.

QA1: What limitations and contributions have been identified in existing studies?

The quality question aims to gather information on the limitations and contributions identified in existing studies, providing a general overview of advances in assistive technologies, the Internet of Things, and Artificial Vision for individuals with visual disabilities. It also helps understand areas that require improvement or further research.

2.5. Data Collection

Relevant data were extracted from selected studies, including article title, author information, year of publication, topic variable, study type, methodology used, country and language of publication, subjects/sample, as well as the main results and conclusions of the studies.

2.6. Data Analysis

The data analysis for this systematic review followed a rigorous methodology and used techniques established by Kitchenman [5]. Relevant studies were collected and evaluated, data were extracted, and a comprehensive analysis was conducted to answer the research question through tables, bar charts, grouped and scatter plots. These visual aids allowed for a comparative analysis between selected studies, enhancing the quality of presentation.

3. Results

This section summarizes the research results:

3.1. Selection of Initial Studies

The search in indexed databases such as Scopus and IEEE, using the search string "(computer vision AND deep learning) AND (blind people OR visually impaired)," aimed to obtain a broad and comprehensive view of advancements in the field of artificial vision and deep learning applied to blind or visually impaired individuals. These databases are known for their extensive coverage of scientific and technical articles, spanning various disciplines, including computer vision and artificial intelligence. By obtaining 57 articles in Scopus and 14 articles in IEEE, a solid foundation of scientific and technical information is expected to conduct a thorough and rigorous analysis of the most relevant advancements in this field and identify trends and promising research areas.

The figure below illustrates the number of journals classified by year and the corresponding database.

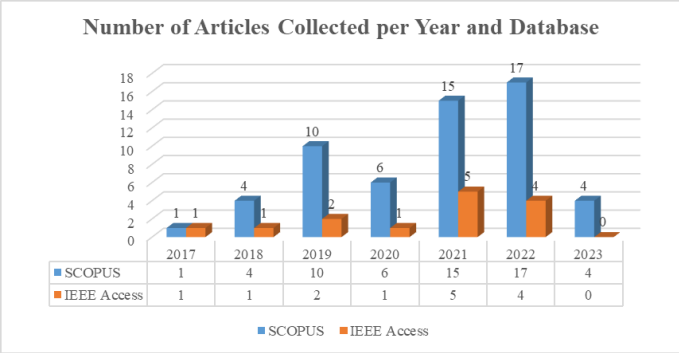

Figure 2: Number of Articles Collected per Year and Database

The data indicates that the Scopus database has a higher number of articles related to the search string "(computer vision AND deep learning) AND (blind people OR visually impaired)," with a total of 57 articles, while IEEE Explorer compiled a total of 14 articles. Based on this information, the analysis was carried out based on journals (including the number of publications per journal and their quartile), as well as the limitations and contributions found in the research.

3.2. Publication Journals

Table 1 shows the journals and the number of publications in each, represented by frequency.

Table 1
Number of Articles Published per Journal

N°	Journals	f	Q	%
1	Lecture Notes in Electrical Engineering	2	Q4	2.86%
2	Lecture Notes in Computational Vision and Biomechanics	1	Q3	1.43%
3	Journal of Real-Time Image Processing	2	Q2	2.86%
4	Journal of Emerging Technologies and Innovative Research	1	-	1.43%
5	ICIC Express Letters Office	1	Q3	1.43%
6	The Institute of Electrical and Electronics Engineers	40	Q1	55.71%
7	Multidisciplinary Digital Publishing Institute (MDPI)	1	Q1	1.43%
8	Communications in Computer and Information Science	1	Q4	1.43%
9	Advances in Computing Systems and Applications	1	-	1.43%
10	Eastern-European Journal of Enterprise Technologies	1	Q3	1.43%
11	Universal Access in the Information Society	1	Q1	1.43%
12	SN Computer Science	1	-	1.43%

13	Electronics (Switzerland)	1	Q2	1.43%
14	ACM International Conference Proceeding Series	1	Q4	1.43%
15	Engineering and Applied Science Research	1	Q3	1.43%
16	SPIE Proceedings	2	Q4	2.86%
17	Communications in Computer and Information Science	1	Q3	1.43%
18	Sensors	1	Q1	1.43%
19	Multimedia Tools and Applications	1	Q1	1.43%
20	Neural Processing Letters	1	Q2	1.43%
21	International Research Journal of Engineering and Technology	2	-	2.86%
22	Advances in Intelligent Systems and Computing	2	Q3	2.86%
23	Proceedings - Frontiers in Education Conference, FIE	1	Q3	1.43%
24	International Journal of Innovative Technology and Exploring Engineering	1	Q4	1.43%
25	ACM International Conference Proceeding Series	1	Q4	1.43%
26	Journal of Universal Computer Science	1	Q2	1.43%
27	Conference on Human Factors in Computing Systems - Proceedings	1	Q1	1.43%
		71		100%

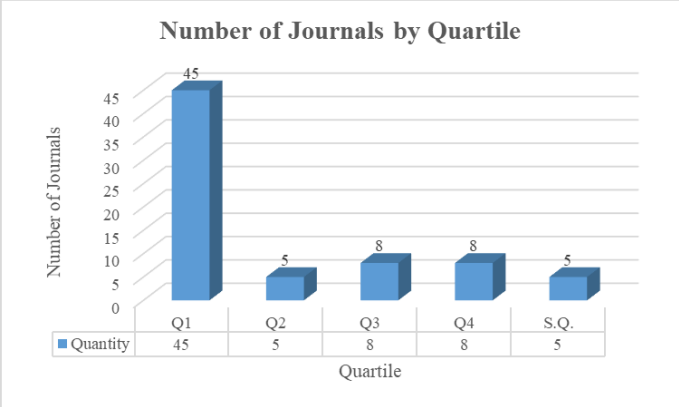

Figure 3: Number of Journals by Quartile

Figure 3 shows the number of journals by quartile, where 41 journals are in the first quartile, representing 63.4% of the total journals. The remaining 29.6% of journals are distributed among the other quartiles, while the remaining 7% of journals do not have a quartile.

It can be concluded that, for the most part, the consulted research has relevance in the field of study, hence a significant impact.

3.3. Limitations and Contributions

Tables 2 and 3 present the limitations and contributions of the research, showing each limitation and contribution with its respective frequency.

Table 2
Limitations in Research

N°	Limitations	Frequency	Percentage
1	Validation of the proposal with people with visual disabilities	1	1.27%
2	Limitations in text-to-speech reading systems	1	1.27%
3	Limitation in object detection	7	8.86%
4	Sample size	3	3.80%
5	Dependency on cloud-based services	3	3.80%
6	Interpretation of complex images	3	3.80%
7	Number of samples	6	7.59%
8	Uncontrolled environments	7	8.86%
9	Restriction of resources on mobile devices	2	2.53%
10	Prototype limitation	3	3.80%
11	Research focus	6	7.59%
12	Conversion from RGB images to deep images	2	2.53%
13	Dependency on technology	13	16.46%
14	Limitations in accuracy and efficiency	6	7.59%
15	Scarcity of research on other challenges of people with visual disabilities	3	3.80%
16	Dependency on the use of CNN for detection tasks	2	2.53%
17	Limitation of applicability for detection in other contexts	11	13.92%
		79	100

Table 3
Contributions in Research

N°	Contributions	Frequency	Percentage
1	Comprehensive analysis of methods	10	10.64%
2	Classification of approaches	4	4.26%
3	Evaluation of current approaches	9	9.57%
4	Improvement in independence and safety of people with visual disabilities	9	9.57%
5	Personalized recognition of objects	9	9.57%
6	Integration of advanced techniques	3	3.19%
7	Resource efficiency and customization	8	8.51%
8	Precision in the detection of objects of interest	11	11.70%
9	Development of a real-time CV system	6	6.38%
10	Use of online image processing services	2	2.13%
11	Extensible mobile vision architecture	1	1.06%
12	Development of a currency/bill recognition system	5	5.32%
13	Access to information, materials, or resources	4	4.26%
14	Visual analysis	1	1.06%
15	Network architecture for detection	1	1.06%
16	Facilitation of movement or navigation	5	5.32%
17	Autonomous detection and classification method	5	5.32%
18	Face recognition	1	1.06%
		94	100

A total of 17 limitations and 18 contributions were identified in the found research. Figures 3 and 4 below show each limitation with its respective frequencies.

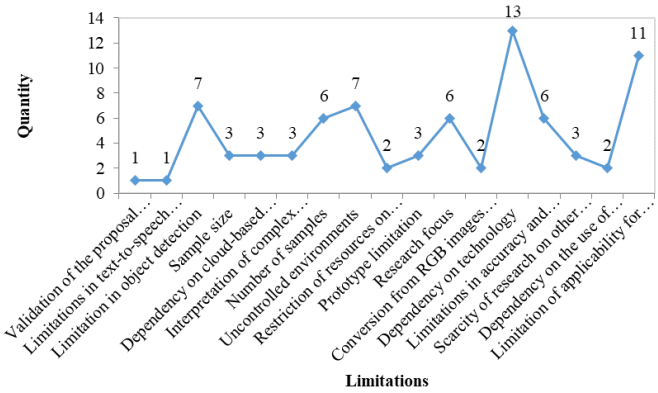

Figure 4: Frequency of Limitations

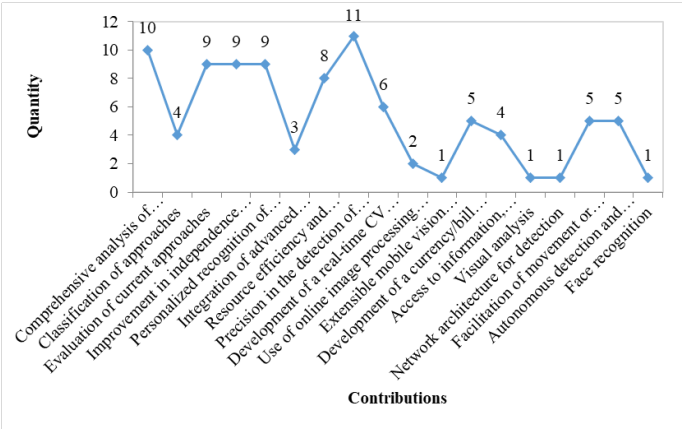

Figure 5: Frequency of Contributions

Figure 4 reveals that the most frequent limitation is "Technological dependence," with a total of 13 articles having this limitation, representing 14.46% of all identified limitations. On the other hand, limitations such as "Validation of the proposal with visually impaired individuals" and "Limitations in text-to-speech reading systems" each have a frequency of 1 article, representing 2.53% of the limitations. Similarly, in terms of contributions, Figure 4 shows that the contribution with the highest frequency is "Precision in the detection of objects of interest," with a total of 11 articles having this contribution, representing 11.7% of all identified contributions. Additionally, contributions such as "Extensible mobile vision architecture," "Visual analysis," "Network architecture for detection," and "Face recognition" each have a frequency of 1 article with these contributions, representing 4.26% of the contributions.

4. Discussion

Firstly, it is observed that the Scopus database provided a higher number of articles related to the search string "(computer vision AND deep learning) AND (blind people OR visually impaired)," with a total of 57 articles, compared to the 14 articles found in IEEE Explorer. This indicates that Scopus is an important source of research in this field, offering extensive coverage of scientific and technical information.

Examining the distribution of articles by journals and quartiles, it is noteworthy that most journals are in the first quartile, representing 63.4% of the total. This suggests that the consulted research is highly relevant and has a significant impact on the field of study. On the other hand, approximately 29.6% of the journals are in the remaining quartiles, while the remaining 7% do not have a quartile classification.

Regarding the limitations and contributions identified in the research, it is observed that the most frequent limitation is "Technological dependence," present in 13 articles and representing

14.46% of all identified limitations. This highlights the importance of addressing this challenge to ensure the viability and accessibility of assistive tools for visually impaired individuals. In terms of contributions, "Precision in the detection of objects of interest" stands out, mentioned in 11 articles and representing 11.7% of all identified contributions. This indicates significant progress in the field of artificial vision and deep learning, providing better capabilities for recognizing and analyzing visual information. In summary, the results reveal the importance of databases like Scopus for accessing a wide range of research in the field of assistive tools for visually impaired individuals. Following [5], the relevance and impact of the consulted research are highlighted, as well as the need to address technological dependence and improve the precision in the detection of objects of interest. These findings provide a comprehensive view of advancements in this field and point to promising research areas for future developments.

5. Conclusions

The systematic review conducted on assistive tools for visually impaired individuals has allowed for a broad and up-to-date understanding of the state of technology in this field. Through an exhaustive search in academic databases and the evaluation of numerous studies, significant advances have been identified in assistive technologies, the Internet of Things, and artificial vision, aimed at improving the autonomy and inclusion of visually impaired individuals.

It has been observed that there are various available assistive tools addressing issues related to mobility, navigation, orientation, and object recognition. However, it has been evident that many of these tools are in early stages of development, being proposals, projects, or prototypes with low impact on usage by visually impaired individuals. On the other hand, among the identified limitations, technological dependence stands out as one of the main barriers to the widespread adoption of these tools. Additionally, challenges related to the accuracy and reliability of IoT and artificial vision-based technologies have been identified, requiring continuous improvements to ensure their effectiveness in real-world environments. Despite the limitations, significant contributions have been observed in terms of precision in the detection of objects of interest. This demonstrates the potential of assistive technologies in the recognition and interpretation of visual information for visually impaired individuals.

The findings of this systematic review are relevant for both future research and the development of new solutions in the field of assistive technologies. The obtained results provide guidance on areas that require more attention, such as overcoming technological dependence and improving the precision and reliability of the tools. Furthermore, opportunities for the development of new solutions that can be more effective and widely used by visually impaired individuals are highlighted. In this regard, it is considered that this systematic review has been a valuable opportunity to deepen the knowledge of assistive technologies for visually impaired individuals. Through this study, the positive impact that these tools can have on the lives of visually impaired individuals, improving their autonomy, independence, and quality of life, has been appreciated. It is recommended that research in this field continues, with the aim of overcoming the identified limitations and developing more accessible and effective solutions. Additionally, the importance of collaboration between researchers, health professionals, visually impaired individuals, and other relevant stakeholders is emphasized, ensuring that assistive technologies are developed considering the real needs and preferences of users.

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