

Computer Vision for Supporting Visually Impaired People: A Systematic Review

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Abstract – Globally around the world in 2010, the number of people of all ages visually impaired is estimated to be 285 million, of whom 39 million are blind according to the study of World Health Organization (Global Data on Visual Impairments, 2010). Visual impairment has a significant impact on individuals' quality of life, including their ability to work and to develop personal relationships. Almost half (48 %) of the visually impaired feel “moderately” or “completely” cut off from people and things around them (Hakobyan, Lumsden, O’Sullivan, & Bartlett, 2013). We believe that technology has the potential to enhance individuals' ability to participate fully in societal activities and to live independently. So, in this paper we focused to presents a comprehensive literature review about different algorithms of computer vision for supporting blind/vision impaired people, different devices used and the supported tasks. From the 13 eligible papers, we found positive effects of the use of computer vision for supporting visually impaired people. These effects included: the detection of obstacles, objects, door and text, traffic lights, sign detections and navigation. But the biggest challenge for developers now is to increase the speed of time and improve its accuracy, and we expect the future will have a complete package or solution where blind or vision impaired people will get all the solution together (i.e., map, indoor-outdoor navigation, object recognition, obstacle recognition, person recognition, human crowd behavior, crowd human counting, study/reading, entertainment etc.) in one software and in hand-held devices like android or any handy devices.

Keywords: Visually Impaired People (VIP); Computer Vision (CV).

I. INTRODUCTION

Globally around the world, in 2010, the number of people of all ages visually impaired is estimated to be 285 million, of whom 39 million are blind, according to the study of World Health Organization (Global Data on Visual Impairments, 2010).

Regrettably, this percentage is expected to increase in the coming decades. Visual impairment has a significant impact on individuals' quality of life, including their ability to work and develop personal relationships. Almost half (48%) of the visually impaired feel “moderately” or “completely” cut off from people and things around them (Hakobyan, Lumsden, O’Sullivan, & Bartlett, 2013). Visual loss inevitably leads to impaired ability to access information and perform everyday tasks. In today’s knowledge-intensive society, information access is increasingly crucial, not just for performing daily activities but also for engaging in education and employment. Also, even the simple tasks around the home can be hazardous if our vision is deteriorating. It’s critical for visually impaired people to detect and recognize objects around them, especially in a new environment.

Computer vision is the science that gives the capability to computers to sense visually like humans. Computer vision is concerned with methods for acquiring, processing, analyzing, and of useful information from a single image or a sequence of images. It provides features to see and recognize objects like humans that are very helpful for impaired people (Shapiro & Stockman, 2001). We are very interested in computer vision to support a better quality of life for individuals with disabilities, including visual impairment. We realize and believe that technology can enhance individuals' ability to participate fully in societal

activities and live independently.

Many technologies in computer vision have been developed to assist people who are blind or visually impaired. This paper focused on presenting a systematic literature review about different algorithms, devices, and supported computer vision tasks for supporting vision-impaired people.

II. METHODS

A systematic approach for reviewing this literature is chosen. A systematic literature review is a means of identifying, evaluating, and interpreting all available research relevant to a particular research question, or topic area, or phenomenon of interest. Individual studies contributing to a systematic review are called primary studies; a systematic review is a form a secondary study (Kitchenham, 2004).

2.1 Research Questions

The research questions (RQ) were specified to keep the review focused. They were designed with the Population, Intervention, Comparison, Outcomes, and Context (PICOC) criteria (Kitchenham, 2004). Table 1 shows the (PICOC) structure of the research questions.

Table 1. Summary of PICOC

Summary of PICOC	
Population	Computer Vision, Systems
Intervention	Interface, approach, technology, supported tasks
Comparison	-
Outcomes	Approach in CV used, technology and interface used, covered supported tasks
Context	Visually Impaired

The research questions and motivation addressed by this literature review are shown in Table 2.

Table 2. Research Questions

ID	Research Question	Motivation
RQ1	What kind of algorithm in CV are proposed?	Identify the algorithm in CV used in the systems for Supporting VI
RQ2	What kind of devices are used?	Identify the devices used in the systems for supporting VI
RQ3	What are the supported tasks?	Identify the supported tasks in the proposed systems

2.2 Study Selection

The inclusion and exclusion criteria were used for selecting the primary studies. These criteria are shown in Table 3 below.

Table 3. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Focused on approach in CV for VI	Studies not written in English
Focused on the supported tasks for visually impaired	The outcomes of the articles were not related to VI people

2.3 Identification of Papers

Included papers were published between 2016 and 2020. There were three elements to our searches: Keyword searching using the search engines: google scholar, an issue-by-issue manual reading of paper titles in relevant journals and conferences, and the identification of papers using references from included studies. A total of 45 papers were screened, and from that, 13 papers were selected.

2.4 Data Extraction and Synthesis

The selected primary studies are extracted to collect the data that contribute to addressing the research questions concerned in this review. The properties were identified through the research questions and used to answer the research questions shown in Table 4. The data extraction is performed in an iterative manner.

Table 4. Data Extraction Properties Mapped to RQ

Property	RQ
CV Algorithm	RQ1
Devices	RQ2
Supported Task	RQ3

The data extracted in this review is qualitative data the narrative synthesis method was used.

III. RESULT AND DISCUSSION

In this review we aim to answer the research questions conducted, all the research question will be described one by one. But all the summaries can be seen in appendix Table 5.

3.1 Proposed Algorithm in CV Used

There are several techniques used to create CV systems for supporting VIP. In our review, we found six techniques. Those are edge detection, object and obstacle detection, image classification, image segmentation, character recognition, and feature extraction.

For Edge detection, we found two algorithms methods; canny edge detector that is used to detect doors (Sivan & Darsan, 2016) and line segment detector, which is also used to detect doors with an accuracy rate of up to 93.2% for the ImageNet dataset (Talebi & Vafaei, 2018). For objects and obstacle detection, we found three algorithms; first is CNN to recognize the color and sign of traffic got mAP of 96% (Li, Cui, Rizzo, Wong, & Fang, 2020); in another research, CNN is also used to detect objects, but not accurate for multi objects in one scene, so they implemented RCNN (Balasuriya, Lokuhettiarachchi, Ranasinghe, Shiwantha, & Jayawardena, 2017), second is YOLOv1 used to detect objects and obstacles and the detection rate is up to 89% for all kind of obstacles (Mocanu, Tapu, & Zaharia, 2017), and third is YOLOv3 also used to detect objects, and the mAP is 73.19% (Afif, Ayachi, Pissaloux, Said, & Atri, 2020), and in the other research the accuracy rate is up to 95.19% (Joshi, Yadav, Dutta, & Travieso-Gonzalez, 2020) and 92% (Mahmud, Sourave, Islam, Lin, & Kim, 2020). For image classification, we found two algorithms; the first is KNN to match the descriptor extracted (Elmannai &

Elleithy, 2018) and SVM to produce a category label for a scene (Zientara, et al., Feb. 2017). For Image segmentation, we found two algorithms as well: K-Means clustering to cluster n extracted points of a particular frame (Elmannai & Elleithy, 2018) and FRRN (Duh, Sung, Chiang, Chang, & Chen, 2020). For character recognition, we only found optical character recognition (OCR) in three studies, where both studies show high accuracy results (Jiang, Gonnot, Yi, & Saniie, 14-17 May 2017) (Sivan & Darsan, 2016) (Joshi, Yadav, Dutta, & Travieso-Gonzalez, 2020) and feature extraction using BRISK (Sivan & Darsan, 2016); SURF (Dahiya, Issac, Dutta, Řiha, & Kříž, 4-6 July 2018) (Mahmud, Sourave, Islam, Lin, & Kim, 2020) (Zientara, et al., Feb. 2017) and ORB (Duh, Sung, Chiang, Chang, & Chen, 2020) (Elmannai & Elleithy, 2018). The summary can be seen in appendix Table 6.

3.2 Devices used

There are many types of equipment as well that were used to build CV systems or applications for supporting VIP. Some of the research are still in the software or application development stage, but other research has reached the prototype development stage. Because there are different stages of research, the tools used are also quite diverse. Studies that proposed a wearable device usually use single board computer, but in a study the researcher use ultra-book laptop to be carried in a backpack (Mocanu, Tapu, & Zaharia, 2017), another study also use robot to assist VIP (Mahmud, Sourave, Islam, Lin, & Kim, 2020).

For camera use, there are only two studies that use depth cameras. The depth camera used is the Zed Camera (Li, Cui, Rizzo, Wong, & Fang, 2020), however, in this study the researcher did not focus on the depth of the information because it would be used in further studies and Astra S Camera (Mahmud, Sourave, Islam, Lin, & Kim, 2020) which was used for path planning. Another researcher used smart glass camera for assisting VIP when shopping (Zientara, et al., Feb. 2017). The complete summary can be seen in appendix Table 7.

3.3 Supported Tasks

It's quite rare for researchers to include all the features in one project at once. From 13 eligible papers, we found several categories of supported tasks. Those are sign detection, text detection, object detection, door detection, traffic light detection, object tracking, and navigation.

We found an eligible research that help VIP to recognize symbols in toilets, pharmacies, and trains (Dahiya, Issac, Dutta, Řiha, & Kříž, 4-6 July 2018), while another studies help2ed VIP to recognize signs-based-text, then the text will be converted into sound (Jiang, Gonnot, Yi, & Saniie, 14-17 May 2017) (Sivan & Darsan, 2016). To detect objects, two studies try to help VIP to detect moving and not moving objects in the outdoor area (Mocanu, Tapu, & Zaharia, 2017) (Joshi, Yadav, Dutta, & Travieso-Gonzalez, 2020), while another study proposed a system that can detect objects in the indoor area (Sivan & Darsan, 2016) (Afif, Ayachi, Pissaloux, Said, & Atri, 2020). Another study helped to assist VIP by detecting surrounding obstacles so that VIP can navigate their own way with the help of audio feedback (Elmannai & Elleithy, 2018) (Duh, Sung, Chiang,

Chang, & Chen, 2020).

A research uses robots to help VIP to navigate and detect objects with a camera attached to the robot (Mahmud, Sourave, Islam, Lin, & Kim, 2020). Another researcher proposed shopping assistants using smart glasses cameras (Zientara, et al., Feb. 2017), a learning medium for visually impaired children by detecting objects around them by giving a description via voice command (Balasuriya, Lokuhettiarachchi, Ranasinghe, Shivantha, & Jayawardena, 2017).

There are also two other studies that help VIP to detect doors (Sivan & Darsan, 2016) (Talebi & Vafaei, 2018), and another research focus on helping VI to detect the colors of pedestrian signals (Li, Cui, Rizzo, Wong, & Fang, 2020). The complete summary can be seen in appendix Table 8.

IV. CONCLUSION

The included studies are so diverse that it would not be possible to pool the results from them. However, in the majority of studies, positive effects of the use of computer vision for supporting visually impaired people. These effects included: the detection of obstacles, objects, door and text, traffic lights, sign detections and navigation. The results of this systematic review stress that computer vision really have promising potential for persons who are visually impaired. But the biggest challenge for developers now is to increase the speed of time and improve its accuracy, and we expect the future will have a complete package or solution where blind or vision impaired people will get all the solution together (i.e., map, indoor-outdoor navigation, object recognition, obstacle recognition, person recognition, human crowd behavior, crowd human counting, study / reading, entertainment etc.) in one software and in handheld devices like android. We believe that this will happen in the future, and this paper will help the developer to know the very background in broad models.

REFERENCES

- Afif, M., Ayachi, R., Pissaloux, E., Said, Y., & Atri, M. (2020). Indoor objects detection and recognition for an ICT mobility assistance of visually impaired people. *Multimedia Tools and Applications*, 79(41), 31645–31662.
- Balasuriya, B., Lokuhettiarachchi, N., Ranasinghe, A., Shivantha, K., & Jayawardena, C. (2017). Learning platform for visually impaired children through artificial intelligence and computer vision. *11th International Conference on Software, Knowledge, Information Management and Applications (SKIMA)*.
- Dahiya, D., Issac, A., Dutta, M. K., Řiha, K., & Kříž, P. (2018). Computer Vision Technique for Scene Captioning to Provide Assistance to Visually Impaired. *41st International Conference on Tele-*

communications and Signal Processing (TSP).

Duh, P.-J., Sung, Y.-C., Chiang, L.-Y. F., Chang, Y.-J., & Chen, K.-W. (2020). V-Eye: A Vision-based Navigation System for the Visually Impaired. *IEEE Transactions on Multimedia.*

Elmannai, W., & Elleithy, K. M. (2018). *Computer Vision-Based Framework for Supporting the Mobility of the Visually Impaired.* Bridgeport, CT: University of Bridgeport.

Global Data on Visual Impairments (2010). Geneva, Switzerland: World Health Organization.

Hakobyan, L., Lumsden, J., O'Sullivan, D., & Bartlett, H. (2013). Mobile assistive technologies for the visually impaired. *Survey of Ophthalmology*, 58(6), 513-528.

Jiang, H., Gonnot, T., Yi, W.-J., & Saniie, J. (2017). Computer vision and text recognition for assisting visually impaired people using Android smartphone. *IEEE International Conference on Electro Information Technology (EIT).*

Joshi, R. C., Yadav, S., Dutta, M. K., & Travieso-Gonzalez, C. (2020). Efficient Multi-Object Detection and Smart Navigation Using Artificial Intelligence for Visually Impaired People. *Entropy*, 22(9), 941.

Kitchenham, B. (2004). Procedures for performing systematic reviews. *Keele, UK, Keele University*, 33(2004), 1-26.

Li, X., Cui, H., Rizzo, J.-R., Wong, E., & Fang, Y. (2020). Cross-Safe: A Computer Vision-Based Approach to Make All Intersection-Related Pedestrian Signals Accessible for the Visually Impaired. *Advances in Intelligent Systems and Computing.* Cham.

Mahmud, S., Sourave, R. H., Islam, M., Lin, X., & Kim, J.-H. (2020). A Vision based Voice Controlled Indoor Assistant Robot for Visually Impaired People. *IEEE International IOT, Electronics and Mechatronics Conference (IEMTRONICS).*

Mocanu, B., Tapu, R., & Zaharia, T. (2017). Seeing Without Sight — An Automatic Cognition System Dedicated to Blind and Visually Impaired People. *International Conference on Computer Vision Workshops (ICCVW).*

Shapiro, L., & Stockman, G. (2001). *Computer Vision.* Prentice Hall.

Sivan, S., & Darsan, G. (2016). Computer Vision based Assistive Technology for Blind and Visually Impaired People. *Proceedings of the 7th International Conference on Computing Communication and Networking Technologies.* Dallas, TX, USA.

Talebi, M., & Vafaei, A. (2018). Vision-based entrance detection in outdoor scenes. *Multimedia Tools and Applications*, 77(20), 26219–26238.

Zientara, P., Lee, S., Smith, G., Brenner, R., Itti, L., Rosson, M., . . . Narayanan, V. (2017). Third Eye: A Shopping Assistant for the Visually Impaired. *Computer*, 50(2), 16-24.

Appendix:

Table 5. Summary of Research Result

Research Number	Authors	Title	Algorithms (RQ1)	Devices (RQ2)	Supported Tasks (RQ3)
RS1 (Jiang, Gonnot, Yi, & Saniie, 14-17 May 2017)	Hao Jiang, Thomas Gonnot, Won-Jae Yi and Jafar Saniie	Computer vision and text recognition for assisting visually impaired people using Android smartphone	Character Recognition: Optical Character Recognition	Mobile Phone: Google Nexus 5X phone, running Android 6.0	Text Reading, Object/Obstacle Detection
RS2 (Sivan & Darsan, 2016)	Shankar Sivan and Gopu Darsan	Computer Vision based Assistive Technology For Blind and Visually Impaired People	Edge Detection: Canny Edge Detector; Character Recognition: Optical Character Recognition; Feature Extraction: BRISK	Single Board: Raspberry Pi 3 Model B; Camera: Logitech C310 webcam 5 mega-pixels	Text Reading, Object/Obstacle Detection, Door Detection
RS3 (Dahiya, Issac, Dutta, Říha, & Kříž, 4-6 July 2018)	Dhruv Dahiya, Ashish Issac, Malay Kishore Dutta, Kamil Říha, Petr Kříž	Computer Vision Technique for Scene Captioning to Provide Assistance to Visually Impaired	Feature Extraction: SURF	Computer: CPU 1.8 GHz, 8GB RAM, 64bit	Sign Detection
RS4 (Li, Cui, Rizzo, Wong, & Fang, 2020)	Xiang Li, Hanzhang Cui, John-Ross Rizzo, Edward Wong, and Yi Fang	Cross-Safe: A Computer Vision-Based Approach to Make All Intersection-Related Pedestrian Signals Accessible for the Visually Impaired	Object/Obstacle Detection: CNN;	Single Board: NVIDIA Jetson TX2 256 CUDA cores; Camera: Zed Camera 1080p HD video at 30FPS or WVGA at 100FPS.	Traffic Light Detection
RS5 (Mocanu, Tapu, & Zaharia, 2017)	Bogdan Mocanu, Ruxandra Tapu, and Titus Zaharia	Seeing without sight – An automatic cognition system dedicated to blind and visually impaired people	Object/Obstacle Detection: YOLOv1;	Computer: Ultra book laptop and NVIDIA GTX 1050	Object Tracking, Object/Obstacle Detection
RS6 (Afif, Ayachi, Pissaloux, Said, & Atri, 2020)	Mouna Afif, Riadh Ayachi, Edwige Pissaloux, Yahia Said, and Mohamed Atri	Indoor objects detection and recognition for an ICT mobility assistance of visually impaired people	Object/Obstacle Detection: YOLOv3	Computer: Intel Xeon E5–2683 v4 Processor; NVIDIA Quadro M4000 GPU	Object/Obstacle Detection
RS7 (Joshi, Yadav, Dutta, & Travieso-Gonzalez, 2020)	Rakesh Chandra Joshi, Saumya Yadav, Malay Kishore Dutta and Carlos M. Travieso-Gonzalez	Efficient Multi-Object Detection and Smart Navigation Using Artificial Intelligence for Visually Impaired People	Object/Obstacle Detection: YOLOv3; Character Recognition: Optical Character Recognition	Single Board: DSP processor 64-bit, quad-core, and 1.5 GHz, 4 GB SDRAM; Camera: 8 MP Camera	Text Recognition, Object/Obstacle Detection
RS8 (Duh, Sung, Chiang, Chang, & Chen, 2020)	Ping-Jung Duh, Yu-Cheng Sung, Liang-Yu Fan Chiang, Yung-Ju Chang, and Kuan-Wen Chen	V-Eye: A Vision-based Navigation System for the Visually Impaired	Feature Extraction: ORB; Image Segmentation: FRRN	Computer: Intel Core i7-6700HQ (8 cores @ 2.40GHz) and 16GB RAM; Camera: GoPro5	Navigation

RS9 (Talebi & Vafaei, 2018)	Mehdi Talebi, Abbas Vafaei, and Amirhassan Monadjemi	Vision-based entrance detection in outdoor scenes	Edge Detection: Line Segment Detector	Computer: Intel Core i7 2.1GHz	Door Detection
RS10 (Elmannai & Elleithy, 2018)	Wafa M. Elmannai, and Khaled M. Elleithy	A Novel Obstacle Avoidance System for Guiding the Visually Impaired through the use of Fuzzy Control Logic	Image Classification: KNN; Image Segmentation: K-Means Clustering; Feature Extraction: ORB	Single Board: FEZ Spider; Camera: L2 Module	Navigation, Object/Obstacle Detection
RS11 (Mahmud, Sourave, Islam, Lin, & Kim, 2020)	Saifuddin Mahmud, Redwanul Haque Sourave, Md. Milon Islam, Xiangxu Lin, and Jong-Hoon Kim	A Vision based Voice Controlled Indoor Assistant Robot for Visually Impaired People	Object/Obstacle Detection: YOLOv3; Feature Extraction: SURF	Robot: TeleBot R2; Camera: 4K Camera, Astra S Camera	Object/Obstacle Detection
RS12 (Zientara, et al., Feb. 2017)	Peter A. Zientara, Sooyeon Lee, and Gus H. Smith, Rorry Brenner, Laurent Itti, Mary B. Rosson, John M. Carroll, Kevin M. Irick, and Vijaykrishnan Narayanan	Third Eye: A Shopping Assistant for the Visually Impaired	Image Classification: SVM; Feature Extraction: SURF	Computer: IBM POWER8 160 cores 3.6GHz; NVIDIA GPU K1200; Camera: Smart Glass Camera	Object/Obstacle Detection
RS13 (Balasuriya, Lokuhettiarachchi, Ranasinghe, Shiwantha, & Jayawardena, 2017)	B. K. Balasuriya, N. P. Lokuhettiarachchi, A. R. M. D. N. Ranasinghe, K. D. C. Shiwantha, and C. Jayawardena	Learning Platform for Visually Impaired Children through Artificial Intelligence and Computer Vision	Object/Obstacle Detection: CNN;	Not Mentioned	Object/Obstacle Detection

Table 6. Algorithm Used

Used in	Algorithms	Research Number
Edge Detection	Canny Edge Detector	RS2 (Sivan & Darsan, 2016),
	Line Segment Detector	RS9 (Talebi & Vafaei, 2018)
Objects/Obstacle Detection	CNN	RS4 (Li, Cui, Rizzo, Wong, & Fang, 2020)
	YOLO	RS5 (Mocanu, Tapu, & Zaharia, 2017)
	YOLOv3	RS6 (Afif, Ayachi, Pissaloux, Said, & Atri, 2020), RS7 (Joshi, Yadav, Dutta, & Travieso-Gonzalez, 2020), RS11 (Mahmud, Sourave, Islam, Lin, & Kim, 2020)
Image Classification	KNN	RS10 (Elmannai & Elleithy, 2018)
	SVM	RS12 (Zientara, et al., Feb. 2017)
Image Segmentation	K-Means Clustering	RS10 (Elmannai & Elleithy, 2018)
	FRRN	RS8 (Duh, Sung, Chiang, Chang, & Chen, 2020)
Character Recognition	Optical Character Recognition	RS1 (Jiang, Gonnot, Yi, & Saniie, 14-17 May 2017), RS2 (Sivan & Darsan, 2016), RS7 (Joshi, Yadav, Dutta, & Travieso-Gonzalez, 2020)
Feature Extraction	BRISK	RS2 (Sivan & Darsan, 2016)
	SURF	RS3 (Dahiya, Issac, Dutta, Řiha, & Kříž, 4-6 July 2018), RS11 (Mahmud, Sourave, Islam, Lin, & Kim, 2020), RS12 (Zientara, et al., Feb. 2017)
	ORB	RS8 (Duh, Sung, Chiang, Chang, & Chen, 2020), RS10 (Elmannai & Elleithy, 2018)

Table 7. Devices Used

	Devices Used	Research Number
Mobile Phone	Google Nexus 5X phone, running Android 6.0	RS1 (Jiang, Gonnot, Yi, & Saniie, 14-17 May 2017)
Single Board Computer	Raspberry Pi 3 Model B	RS2 (Sivan & Darsan, 2016)
	DSP processor 64-bit, quad-core, and 1.5 GHz, 4 GB SDRAM	RS7 (Joshi, Yadav, Dutta, & Travieso-Gonzalez, 2020)
	FEZ Spider	RS10 (Elmannai & Elleithy, 2018)
	NVIDIA Jetson TX2 256 CUDA cores	RS4 (Li, Cui, Rizzo, Wong, & Fang, 2020)
Camera	Logitech C310 webcam 5 mega-pixels	RS2 (Sivan & Darsan, 2016)
	Zed Camera 1080p HD video at 30FPS or WVGA at 100FPS.	RS4 (Li, Cui, Rizzo, Wong, & Fang, 2020)
	8 MP Camera	RS7 (Joshi, Yadav, Dutta, & Travieso-Gonzalez, 2020)
	GoPro5	RS8 (Duh, Sung, Chiang, Chang, & Chen, 2020)
	Astra S Camera	RS11 (Mahmud, Sourave, Islam, Lin, & Kim, 2020)
	Smart-glass camera	RS12 (Zientara, et al., Feb. 2017)
	4K Camera	RS11 (Mahmud, Sourave, Islam, Lin, & Kim, 2020)
	L2 Module	RS10 (Elmannai & Elleithy, 2018)
Computer	CPU 1.8 GHz, 8GB RAM, 64bit	RS3 (Dahiya, Issac, Dutta, Říha, & Kříž, 4-6 July 2018)
	NVIDIA GTX 1050	RS5 (Mocanu, Tapu, & Zaharia, 2017)
	Intel Xeon E5-2683 v4 Processor; NVIDIA Quadro M4000 GPU	RS6 (Afif, Ayachi, Pissaloux, Said, & Atri, 2020)
	Intel Core i7-6700HQ (8 cores @ 2.40GHz) and 16GB RAM	RS8 (Duh, Sung, Chiang, Chang, & Chen, 2020)
	Intel Core i7 2.1GHz	RS9 (Talebi & Vafaei, 2018)
	IBM POWER8 160 cores 3.6GHz; NVIDIA GPU K1200	RS12 (Zientara, et al., Feb. 2017)
Robot	TeleBot-R2	RS11 (Mahmud, Sourave, Islam, Lin, & Kim, 2020)

Table 8. Supported Tasks

Supported Tasks	Research Number
Sign Detection	RS1 (Jiang, Gonnot, Yi, & Saniie, 14-17 May 2017), RS3 (Dahiya, Issac, Dutta, Říha, & Kříž, 4-6 July 2018), RS2 (Sivan & Darsan, 2016)
Text Detection	RS1 (Jiang, Gonnot, Yi, & Saniie, 14-17 May 2017), RS2 (Sivan & Darsan, 2016)
Object Detection	RS5 (Mocanu, Tapu, & Zaharia, 2017), RS6 (Afif, Ayachi, Pissaloux, Said, & Atri, 2020), RS7 (Joshi, Yadav, Dutta, & Travieso-Gonzalez, 2020), RS8 (Duh, Sung, Chiang, Chang, & Chen, 2020), RS10 (Elmannai & Elleithy, 2018), RS11 (Mahmud, Sourave, Islam, Lin, & Kim, 2020), RS12 (Zientara, et al., Feb. 2017), RS13 (Balasuriya, Lokuhettiarachchi, Ranasinghe, Shivantha, & Jayawardena, 2017)
Door Detection	RS2 (Sivan & Darsan, 2016), RS9 (Talebi & Vafaei, 2018)
Traffic Light Detection	RS4 (Li, Cui, Rizzo, Wong, & Fang, 2020)
Object Tracking	RS5 (Mocanu, Tapu, & Zaharia, 2017)
Navigation	RS8 (Duh, Sung, Chiang, Chang, & Chen, 2020), RS11 (Mahmud, Sourave, Islam, Lin, & Kim, 2020)