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Original Article

Pragmatic Analytics on Hybrid Computer Vision Models to Develop a Stable Framework for Visual Impairment – A Survey

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Abstract - *Computer vision is an expertise associated with artificial intelligence and image processing arenas to excerpt meaningful information from visual components like images and videos. Computer vision finds chief implications in solving pragmatic complications in the real world, like visual impairment. The major objective of thepaper is to conduct a pragmatic survey on the various hybrid computer vision Models with other thrust areas like image processing, artificial intelligence, and machine learning that could be used to develop a proposed stable framework to solve the problem of visual impairment. The paper presented an expounded survey on existing models for visual impairment and its existing algorithms. The work continues with a comprehensive survey of various models and frameworks, announced over a period from 2015 to 2022. Based on the recognised models, comparative analytics has been accomplished to ponder the best models and frameworks from different researchsources. After Review and Surveys, the Research gaps acknowledged in the prevailing models and frameworks were accessed. Finally, a glimpse of the proposed model for visual impairment was presented for emerging a stable framework in the looming future.*

Keywords - *Computer vision, Hybrid computer vision model, Visual impairment, CV Hybrid framework, Comparative analytics.*

1. Introduction

According to the National Centre for Biotechnology Information (NCBI) and Global Blindness and Visual Impairment Data in 2015 [1, 2], visual impairment is considered a destructive syndrome with the fact that it increases and will continue to increase over a period of time. In 2015, it was found that 253 million people were found with Visual Impairment Syndrome (VIS) [3], among which 36 million were found completely blind, and the remaining 217 million were found to have visual impairment from moderate to severe level [4] of infections. Among the levels of occurrence of blindness were 3.44% of distance visual impairment, 2.95% of moderate to severe visual impairment (MSVI) and 0.49% of blindness reported.

The risk factors of blindness were many, among which age, gender, socio-economic nature, and exposure of eyes to hazardous rays [5, 6] were prominent. The growth of blindness was expected to expand over time since 2015 and reached 2020 with a consistent increase in colour blindness. Hence, a framework to handle and address the problems of visually impaired people is highly relevant to the current research scenario. The urge to merge technology basic science is essential to provide artificial vision to visually impaired or challenged people.

The major objective of this survey paper is to study and identify potential methods, techniques and frameworks used to address the problem of visual impairment from 2015 to 2022 and perform comparative analytics of the results to ponder the need to build an effective framework system that could provide smart and efficient solution to the visually impaired people to walk without hindrance. This survey also reviews the best models utilised in solving the problem with awful solutions at that stage. Due to technological advancements, these models are required to be updated. Hence, the research gaps were studied with pragmatic analytics of papers published over 8 years. Computer vision is one of the relevant technologies for visual impairment that acquires quality and essential information from images and video from any visual device like a camera, mobile device, etc. Thus, merging with image processing techniques could bring an upgraded solution to the VIS problem using simple and effective methods.

The scope of the paper is entailed from 2015 to 2022, as chief strategies were industrialised during this period of study. The papers were organised based on the basics of Computer Vision (CV), hybridised models in computer technologies like image processing, big data, and artificial intelligence incorporated with CV, as well as different frameworks in existence for the formation of proposed models to solve VIS.

2. Literature Review on Computer Vision

Computer Vision (CV) incorporates computers and humans to replicate the human visual system. CV instantiated from Artificial Intelligence (AI) collects meaningful information from digital data in the form of images and videos to convert them into features. These features would be preprocessed, screened, and analysed to extract the right information and convert it into knowledge. CV enables translating visual digital content into its explicit form, where descriptive data could be generated as multi-dimensional data. Finally, the identified data could be converted into machine-readable language and then ejected to the human device using a decision-making process. On understanding these methods of CV, it was evident that it could well suit the needs of visually impaired people to detect objects, recognise them and finally render the output in the form of a voice as they could not see them. However, it is important to identify the existing models used for VIS patients and must narrow down the research gaps to be addressed for formulating a proposed framework model. Various kinds of literature were surveyed on computer vision from 2015 to 2022 to encompass these needs as presented.

(DeCost, B.L.,&Holm, E.A.,2015) [7] collected a 'bag of Visual Features' to detect the correlation between the large and diverse microstructural image datasets by creating signatures of genetic microstructures. The model was prepared by extracting key point descriptors of the microstructure in the form of clusters and mapping it with the images to form a microstructural signature. It was tested with a Support Vector Machine (SVM) under 5-fold cross-validation, achieving 80% or higher accuracy. However, (Seo, J., Han, S., Lee, S., & Kim H. 2015) [8] reviewed various models of computer vision prior to 2015 under three categories, viz., object detection, object tracking and action recognition to understand and identify various challenges in CV research where safety is considered as utmost priority. For example, the aid for visually impaired people must assist them in safely finding solutions to their problems. Instead, if the device leads them to unexpected physical problems like a misunderstanding of the location, object fake detection or repetition of objects, etc. These anomalies would prevent the VIS people from utilising the technology and solving their problems because they would feel that avoiding artificial guidance through CV is much more problematic than their personal mind training to walk and avoid obstacles, detect objects, etc.

(Medathati, N. K. et al., 2016) [9] analysed a few computer models to bridge between the biological vision and the computer vision prerequisites and the task-based progress of the features associated with it. The study focused on three major biological tasks, including image sensing, segmentation and optical flow and compared them with the computer vision perspectives. It was evident from this research that computer vision could be a better alternative to biological vision as it was successful in all three aspects of the experiments under tested algorithms. Based on this analysis, (Pereira C.R. 2016) [10] detected Parkinson's Disease (PD) through spirals and meanders in computer vision and biological images were verified using Image processing techniques for automation. The prediction from acquired CV images provides approximate results of around 67%. Hence, it was proved in 2016 that CV could be effectively used to predict biological diseases related to vision problems and solve them. (Thevenot,J., López,M.B., & Hadid,A,2017) [11] performed a survey of the current advancements of computer vision and its innovative solutions in existence for facial image analysis.

The author discussed over 30 medical conditions where possibilities for preliminary investigation and automatic detections are in existence. The survey provides insights into the impact of computer vision in handling major medical problems through image analysis and even possibilities of predictions in the future. (Leo, M., et.al. 2017) [12] also conducted a survey on how computer vision and its algorithms were highly effective in Assistive Technologies (AT) that are capable of helping human needs. This proved that computer vision-based models and algorithms are capable of assisting human needs in case of medical problems, social problems, and economic or daily domestic purposes. Thus, computer vision could be used to assist visually impaired people in capturing images and converting them into meaningful information.

(Gao, J., et.al. 2018) [13] examined the role of computer vision, image processing and pattern recognition in handling healthcare applications with pragmatic solutions. A review on medical image analysis and utilisation in the healthcare industry, predictive analytics in computer vision, its therapy and its algorithms are studied and interpreted that computer vision was capable of bringing solutions to healthcare-related problems in a significant manner. Human Machine Interaction (HMI) and its impact on building vision-based interaction systems were studied by (Qiuhong Ke et al. 2018) [14] using Convolutional Neural Networks (CNNs) with deep learning frameworks. This model presented the importance of recognising gestures through skeleton, depth and Red Green Blue (RGB) sequences.

In 2019, the research for computer vision extended to Artificial Neural Networks (ANN), where billions of images could be captured over a surveillance camera, and the face could be detected and recognised on a real-time basis. This research was performed by (Harikrishnan J.,2019) [15] using computer vision algorithms with support from deep learning methods. The user-friendly model was developed and tested to provide 74% efficiency in predicting the faces of individuals in a real-time surveillance system. (Wu, H., 2019) [16] also performed the same surveillance system during a Fire explosion in chemical industries through computer vision-based detection methods. The methodology had three major modules, viz., motion detection, fire detection and the third one being region classification. This assisted the users in classifying the images from the camera's frame by frame to determine the region of fire using the background subtraction method. The impact of the fire was also measured using precision and speed. The fire was alerted based on the region of the organisation. This model proved that computer vision could detect meaningful information from the image, as it can be converted into digital audio output in the form of alert messages. Manovich, L. (2020) [17] discussed various numerical representations and analytics of data that could present a new language to describe cultural experiences, artifacts, and dynamics of computer vision. The author proclaimed that various vision models and visual dimensions like shape, colour, contours, composition, and texture could be major factors in finding the object in a visual element or object. Based on the study of computer vision (Gargin, V. et al. 2020), [18] utilised changes in colours based on the characteristic and ratio of the area of the object in correspondence to the square of its perimeter. However, the object detection acquired results with an accuracy of 90.8%, being beneficial to the patients who undergo screening examinations in hospitals.

Hence, it has been proved recently that computer vision can analyse and acquire meaningful information like object detection, objectrecognition and object conversion at the same time, as shown in Fig. 1.

As portrayed in Fig. 1, Object detection, Object Recognition, and Object Conversion are the three methods combined for computer vision models. However, Object detection was the result of processes like Image Acquisition, Image Preprocessing and Feature Extraction. In the same way, Object recognition was the result of Image matching, Image Filtering and pattern formation, respectively. Finally, the Object conversion process results from image management from the global dataset, information retrieval and text-to-speech conversion to achieve the expected output for the user. In 2021, a novel model in computer vision called "Feature Binding" was proposed by (Jin, J. et al. 2021) [19] to bind and encapsulate the features with a biological model to promote object detection and localisation process. This mechanism was an important milestone in computer vision to analyse and predict biological data either in image form or numerical format. Even more, (Ward, T. M.,2021) [20] proposed a model to utilise computer vision in intraoperative video analysis and interpretation of results.

It was successfully experimented with and proved that CV could be used in surgery or clinical analysis. (Tombe, R.,2022) [21] conducted a review of the various future techniques in Convolutional Networks using computer vision models. A few of the parameters considered were configurations of Convolutional layers, strategies of the pooling layer, network activation functions and optimisation models. The major assessment in this review was on feature selection methods and benchmarking datasets. As an advancement of computer vision models, (Ghermandi A. et al. 2022) [22] analysed approximately 10,000 photo images from social media using a computer vision-enabled machine map technique. It was found that object recognition was possible using the CV model and could detect and recognise around 80% of the object images in the collection.

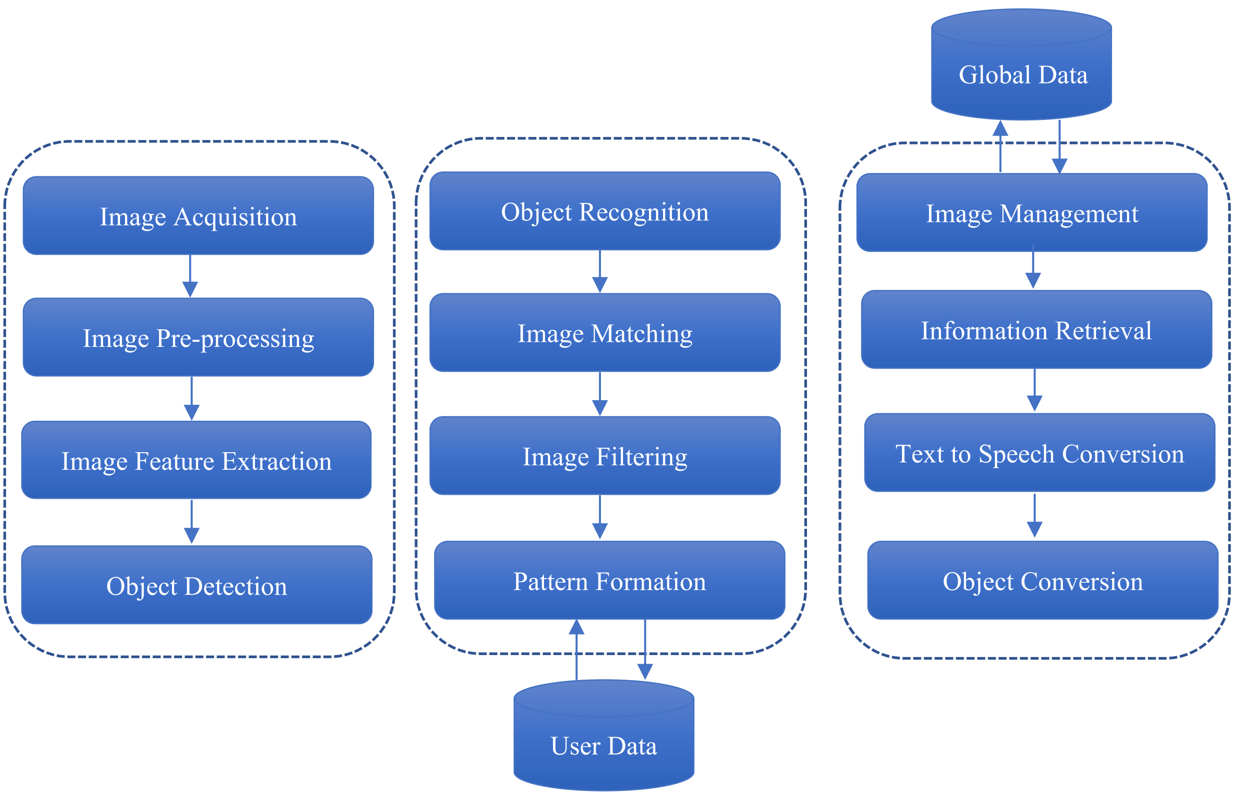

Fig. 1 Computer vision as a combination of methods including object detection, object recognition and object conversion

3. Survey on Hybrid Computer Vision Models

The formal analysis of various computer vision methods portrayed the importance of computer vision technologies in building an expert system to aid the needs of visual impairment among people. However, computer vision models would require support from other technologies to bring a collaborative solution to the visual impairment problem. Hence, hybrid models play a significant role in combining technologies with computer vision to develop a proposed framework. Various research works in combination with technologies were performed over a period from 2015-2022.

(Zareiforoush H. et al. 2015) [23] developed a hybrid model with computer vision and a fuzzy inference system (FIS) along with an image processing technique to handle the images of milled rice. The model used the degree of milling (DOM) and percentage of broken kernels (PBK) along with 25 rules generated by FIS. This model could achieve 89.8% performance agreement at the end of the experiment. (Tamayo-Quintero, J. D., et.al. 2015)

Studied and analysed various segmentation models and their hybridisation with computer vision methods to analyse the 3D point clouds [24]. The assessment was made on collected data from a Laser scanner with a combination of methods from semi-automation segmentation to detect problems in teeth. This successful method showed that hybrid CV models could be utilised in medical diagnosis. A similar hybridisation of CV models was tested by (Kachurka V. et al. 2015) [25] to detect objects in various images and calculate the probabilities of eye-fixation methods for testing the benchmarks. The intent was to develop the hybrid CV model with algorithms to detect fire, smoke or any other objects in outdoor regions. This model was found successful. (Santha., 2016) [26] conducted a deeper survey and reviews on the various hybrid CV methods to handle complex images like satellite, photo realistic images and biomedical images with enhanced performance. The author was able to present a novel hybrid method in combination with AI-based supervised or unsupervised models. Similarly, another hybrid model to integrate computer vision and biological vision was studied by (Shukla, S., Lakhmani, A., and Agarwal, A. K., 2016) [27] to prove that biological models like biomedical images, biotechnology and laboratory scans, etc., can be diagnosed and predicted using CV models and algorithms[28]. Also, various segmentation process was studied based on AI and its merits; demerits were presented. It was suggested that CV would be highly beneficial to study objects in the biological arena but needs refinement using AI or Image processing methods. Hence, hybridised models would provide a better solution to the problem. (Wiriyathammabhum, P. et al. 2016) [29] conducted a survey on around 200 papers to prove that integration of CV models and Natural Language Processing (NLP) along with robotics and multimedia could perform various tasks like object detection, captioning of images, and question answering in visual mode to result in interactions and navigations. This research survey had insights into the fact that CV models could make better solutions to problems in any domain, like biological or engineering, with the hybridisation of interdisciplinary fields.

In 2017, furthermore, various research works continued on CV models in hybridisation with other technologies. (Tang, M. C., et.al. 2017) [30] combined networking concepts like 3D cameras and Wi-Fi signals to connect smartphones and detect image information using CV models. It was found that possibilities of enhanced predictions supported image capture and recognition. Also (Chaw, J. K., & Mokji, M., 2017) [31] developed a hybrid CV and Statistical model to detect and classify objects with semantic predictions. The attributes of the objects were studied on training data, where the correctly classified rate was averaged at approximately 72% after three cycles. Also, performance measures like sensitivity and F1 Score were found to be significant in this hybrid approach. In biological combinations, Electromyography (EMG) was hybridised with CV models by (Andrade D. T. et al. 2017) [32] to analyse and find the problems related to the upper limb using a device. The device was a controlled interface where there were no limitations in the process of user interactions. This model showed that hybridised models could benefit medical diagnosis with simplified predictions.

Various hybrid models were studied in theyear 2018 with an insight into integrating complex technologies with CV models in various fields. For example, (Patrício, D. I., & Rieder, R., 2018) [33] integrated CV and AI models to form a hybrid model and found that precision agriculture could be handled by monitoring and controlling cropgrowth. Some crops tested in this experimentand survey were maise, rice, wheat, soybean, and barley. This model was found successful with imagetesting and damage predictions at the early stage. Also, a hybrid algorithm was designed by (Artime Ríos, E. M. et al. 2018) [34] that combined CV-basedmodels with genetic algorithms to detect syndromesin health problems. CV models were also found to handle Fall From Heights (FFH) problems to prevent human life dangers using hybridisation of CV with Convolutional Neural Networks (CNN) models. The experiments and results conducted by (Fang W. et al. 2018) [35] achieved 99% accuracy in detecting the danger of falls from a distant location.

The computer vision from 2019 had tremendous improvements in the hybridisation of CV models with medical, deep learning and Internet ofThings (IOT) services. (O'Mahony N. et al., 2019) [36] performed a review on various computer vision models and their ability to form hybrid patterns with deep learning algorithms to handle complex visionslike 3D vision and Panoramic vision of the cameras in surveillance. This review also presented the various merits and demerits of hybridising CV and Deep learning models. To prove the hybridisation of CV with medical diagnosis, a gene analysis was performed for 71Koolen–de Vriessyndrome patients by (van der Donk R. et al. 2019) [37] to detect facial features and identify pathogenic genes. The CV algorithms were trained to optimise the dysmorphism and facial recognition of hospital patients. The outcomes showed that facial recognition to identify the syndromes from faceanalysis is possible through CV hybridisation models. Similar research was conducted (Chen, C. et al. 2019) [38] to detect objects using hybridised CVmodels using drone-based image capturing and analysis. The experimentation analysed the VisDrone2018 dataset with adaptive resample and data segmentation to retrieve essential information from city information.

The study on hybridised CV models followed the real-time models with the inception of wireless and sensor technologies in 2020. An embedded bus passenger flow calculation model was developed by (Haq, E. U. et al. 2020) [39] using the hybridisation of machine learning and CV models on a real-time basis. The hybrid model was able to detect image-based information from images collected from trajectories, whereas the machine learning models and classifiers performed a predictive analysis on the frequency of passengers inthe bus with flow analysis. Furthermore, the machine learning classifiers found a performance of 94.50% using Support Vector Machine (SVM) and 81.30% using Histogram Oriented Gradients (HOG), respectively. Ontology and knowledge extractionmodels were hybridised with computer vision models to determine the safety mechanisms during the accident. This hybridised model was proposed by (Fang W. et al. 2020) [40] to integrate computer vision with knowledge extraction andontological semantics and proved a successful model. (Dino, I. G., 2020) [41] determined a hybrid CV model with sensor-based image thermography methods to design an automated image segmentationmodel and bring quality images at the end of the process. This hybrid model could predict the building location independently or on a perpendicular axis.

The research on the hybridisation of computer vision models continued in 2021 with the utilisation of machine learning and CV models to automatically determine the damages in the skull. This model was created by (Mangrulkar, A., Rane, S. B., & Sunnapwar, V. et al. 2021) [42] and performed denoising and image enhancement with Region of Interest (ROI) and CNN hybridised with CV models. The model combined with Long-Short Term Memory (LSTM) was capable of extracting the best features used in skull damage predictions. In 2021, computer vision with sensors and deep learning models werehybridised. For example, (Yang, A. M. et al. 2021)[43] hybridised CV models with sensor and deeplearning methods to detect the security of blast furnaces using the Variational Mode Decomposition (VMD) algorithm. The algorithm could identify the dataset's best features and achieved a 97.4% fault diagnosis rate. A similar hybridisation wasperformed by (Chouhan, SS et al. 2021) [44] to analyse the segmentations of the leaf in biofuelplants using the superpixel clustering method and hybrid neural networks. The prediction results were accurate, with an approximation of 98%, with the evaluation of seven different machine learning classifiers. The sensitivity and specificity were also convincing.

In 2022, the real-time devices were hybridised with CV models like cameras and accelerometers as designed by (Ma Z. et al. 2022) [45] to perform structural displacement of images. The calibration and CV algorithms were used to resample images using adaptive multi-rate Kalman filters. This showed an enhancement in the quality of the images. In the same way, biophysical pastures were also measured by (Franco, V. R. et al. 2022) [46] using hybridised CV models with machine learning algorithms. A cross-validation examination was conducted at the end of the research to determine performance. It was found that biomass was equal to 0.496 of Coefficient of Determination (R2), and pasture height was estimated. (Nguyen, H., & Hoang, N. D., 2022) [47] used optimisation models like gradient boosting and CNN with CV models to determine the best features of the images collected in binary or ternary patterns. The examinations with real- world data showed positive signs of enhanced predictions using hybridised CV models. Hence, based on the surveys conducted on hybridised models from 2015 to 2022, it was evidentthat hybrid models performed better with enhanced results in predictions and helped to achieve better results.

4. Frameworks in Existence for Visual Impairment

Based on the survey of hybridised models, computer vision was found to have augmented performance when combined with another computer technology. To encompass those hybridised models, it was important to study the different existing frameworks to benefit visually impaired people. In 2015, various authors proposed basic frameworks to aid visually impaired people in detecting obstacles and objects. (Takizawa, H., et.al. 2015) [48] developed a framework to detect three-dimensional objects using Microsoft Kinect cane and recognise the objects under basic equipment like a white cane, keypad, sensor and other tangible devices[49]. A similar Framework for assisting Visually impaired syndrome was designed by (Xiao J. et al. 2015) [50] to handle context-aware navigation services by incorporating advanced intelligence into the machines. The author focused on handling social media images using visual cueing and distance sensing of objects. This assisted in bringing smart navigation for social media and its analytics. The same navigation system was created as the Electronic Guidance Framework (Agarwal N. et al. 2015) [51] on a real-time basis to guide the walk of visually impaired people to detect obstacles and enhance outdoor navigation. The robotics-based walking assistant was developed as the framework by (Ni D. et al. 2015) [52] using the perception of tactile information and computer vision models. It was capable of detecting images in depth and promoting communication in voice and text between visually impaired people.

New innovative methods boomed in 2016 with the hybridised computer vision frameworks with other technologies like AI and Smart devices. For example, the Integrated Artificial Vision Framework was proposed by (Chessa M. et al. 2016) [53] to aid visually impaired people in performing video analysis and, semantic annotations and 3D scene creations using the integration of functionalities of algorithms. Obstacle detections were performed by various authors to enhance object detection. A hardware-based design using an IOT-enabled framework was given by (Khade S. & Dandawate Y. H., 2016) [54] using computer vision and external devices like cameras and sensors. The detected images were verified using motion vectors and were successfully implemented using Raspberry Pi 2-B in MATLAB and Python. The Microsoft Kinect wearable device used by (Takizawa H. et al. 2015) [48] was further refined by (Neto, L. B. et al. 2016) [55] not only for object detection but also to detect facial features using 600 videos collected from 30 people [56]. This model framework proved the fact that a global database could be assessed for object detection as face and recognition of the same.

In 2017, new detection methods like object detection, tracking of objects and recognition using computer vision frameworks were proposed. A novel framework, DEEP-SEE, was developed by (Tapu R. et al. 2017) [57] to identify and detect objects using CV algorithms and CNN. Also, the voice recognition and output were performed with a maximum accuracy of above 90%. An edge detection framework was designed by (Chan K. Y. et al. 2017) [58] to assist visually impaired people in detecting objects using the Deblur algorithm. This algorithm and framework resulted in the reduction of errors in detecting the images and gaining information about them. (Rizzo, J. R., et.al. 2017) [59] also designed technology for the assistance of the visually impaired using CV and sensors. This framework was successful in detecting objects and preventing collisions of data.

Various sensor-based object detections were given importance in 2018. (Patel, C. T., et.al. 2018) [60] developed a framework for detecting objects using multisensory and statistical models to enhance accuracy and performance. The object and obstacle were directly detected in this model using sensors. The prediction accuracy was further improved using another framework using a novel obstacle avoidance algorithm (Elmannai, W. M., & Elleithy, K. M. 2018) [61]. This framework not only identified the objects or obstacles but also found ways to avoid the obstacles. The performance was effective with 98% accuracy and highly reliable to detect and avoid obstacles with 100% accuracy. This framework combined fuzzy logic with a CV algorithm to assist visually impaired people.

Another framework called JUVO was designed by (Gianani S. et al. 2018) [62] with an augmentation to improve the quality of the image and its positioning in the internal environment. A wearable vision-assisting framework was created by (Jiang B. et al. 2018) [63] to assist the visually impaired in removing noise and distortion during image capture. The binocular vision and CNN with CV models were used to design the framework. (Azeta, A. A., & Daramola. A., 2018) [64] developed a voice-enabled framework to conduct e-examination for the visually impaired. To make this possible, the distance of the objects and scripting codes were incorporated, and we successfully achieved 3.5 out of 5 scores in the usability tests respectively.

In 2019, real-time-based frameworks were reviewed and created by various authors. (Islam, M. M., et.al. 2019) [65] reviewed and suggested a digital walking assistant framework for visually impaired people. The issues in the real-time functioning of the model in terms of movability and safety were discussed in the paper. To eradicate the issues, a guide dog robot was designed with support from Amazon cloud service (Zhu J. et al. 2019) [66] that was found to have real-time control over the issues in obstacle detection, voice recognition and traffic recognition for visually impaired people. Another novel framework for assisting visually impaired people in mobility as well as audio receiving mode was implemented by (Khan W. et al. 2019) [67]; that could assist VI people in outdoor real-time situations by tracing obstacles in the environment, identifying and recognising the object and promoting spatial information for the same. The framework provided audio-visual support for the VI people as well.

By 2020, with the pandemic outbreak in all parts of the world, many frameworks were designed for handling emergent situations with network models. Similarly, many network-based CV model frameworks were created to assist VI people. (Zhu, J., et.al. 2020) [68] developed a framework that augmented the robot dog model developed by (Zhu J. et al. 2019) [66] using a fog computing framework. The author used the PEN method, meaning Phone + Embedded board + Neural compute stick, to control the activities of visually impaired people and bring a simulation to the real-time walking system to test and avoid the issues. Deep learning methods also provided support to the Real-time assistive framework designed by (Dahiya, D., Gupta, H., & Dutta, M. K., 2020) [69]. The framework was tested with 450 images retrieved from various public places, and after applying the model, it resulted in 92.13% efficiency in predictions. A wearable speech-based feedback and assessment framework was designed by (Abraham, L. et al. 2020) [70] under the name VISION to locate walkable locations, recognise text, convert it to speech, and identify the type of objects found in the location. This framework was found to be highly significant to VI people as they could simultaneously hear speech with object detection and recognition.

In 2021, various pragmatic frameworks were introduced to assist the VI people with CV and intelligent models and algorithms. (Singh, S., Jatana, N., & Goel, V., 2021) [71] developed HELF (Haptic Encoded Language Framework) to assist the VI and deaf people in detecting obstacles and recognising objects using gestures with 91% accuracy. Following this framework, a Deep learning framework known as Path Lookup was presented by (Das, U., Namboodiri, V., & He, H., 2021) [72] to determine the objects in outdoor locations using a Global Positioning System (GPS).

Though different frameworks were predominantly available using computer vision, it was also identified that many major hybrid frameworks were successful and could achieve maximum accuracy of (>90%) in many experiments furnished in the survey.

5. Comparative Analytics on Framework Models

Based on the survey performed on computer vision models and frameworks over the period of 2015 to 2021, it was evident that the impact of innovations in the design of aids for visual impairment had been tremendous. The frameworks developed and tested successfully laid hopes for building more advanced models in the future perspectives. The overall models surveyed in this study are presented in Table 1.

Table 1. Visual Impairment Assistance Frameworks based on survey from 2015-2021

Ref. & Year		Framework Model	Technologies used with ComputerVision	Objectives Achieved for Visually impaired
[48]	2015	Kinect cane	Microsoft Kinect Sensors	Object Recognition
[50]	2015	Assistive NavigationFramework	Intelligent Network System	Context-aware navigation services
[51]	2015	Electronic guidance system	Audio and Digital Interface	Smart Electronic Guiding Stick
[52]	2015	Walking Assistant Robotic System	Wearablesensors devices and motion	Wearable Vibro-Tactile Belt
[53]	2016	Integrated Artificial Vision Framework	Biological Vision methods	Object detection and recognition
[54]	2016	Camera-based ObstacleDetection Framework	Raspberryalgorithms Pi 2B and relevant	Object detection of stationary or non-stationary objects
[55]	2016	Kinect-Based Wearable Face Recognition System	Wearable Devices	Object detection Facial Recognition
[57]	2017	DEEP-SEE framework	Deep Convolutional NeuralNetworks (CNNs)	High performance in Object detection(>90%)
[58]	2017	Modified Sigmoid Function(MSF) framework based onInertial Measurement Unit (IMU)	Deblurring algorithms	Object edge detections with enhancedclarity
[60]	2018	Multi Sensor-Based System	Support Vector Machine Algorithm	Object detection in an indoor environment
[61]	2018	Novel Obstacle Avoidance Framework	Image Depth Information and FuzzyLogic	Detecting object accuracy 98%, avoidingobstacles – 100% efficiency.
[62]	2018	JUVO Framework	Sensors and Machine Learning	Detect lost objects through object detection and recognition
[63]	2018	Wearable Vision Assistance System	Binocular Sensors Big Data	Image Quality Evaluation for Objects
[64]	2018	voice-based e-examination framework	Server-side scripting, rule-based reasoning	Voice recognition system Text-to-speech conversion
[66]	2019	Edge Computing Framework based on Intel Up-Squared board and neural computing stick	Image processing and real-time voice control	Guide Dog's Obstacle Avoidance, Traffic Sign Recognition, Voice Interaction with human
[67]	2019	Intelligent Wearable Auditory Display Framework	Machine Intelligence Sensor devices	Outdoor Mobility Assistance and Auditory Display
[68]	2020	PEN (Phone + Embedded board + Neural compute stick)	Fog computing system	Simulated Guide Dog System
[69]	2020	Real-Time Assistive Framework	Deep Learning CNN	Handle unfamiliar environments with 92.13% accuracy
[70]	2020	VISION Framework	Speech Recognition YOLO algorithm	Wearable Speech-Based Feedback System
[71]	2021	HELF (Haptic Encoded Language Framework)	Swiping Gestures Haptic Technology	Digital Script for Deaf-Blind and Visually Impaired (91% Accuracy)
[72]	2021	PathLookup Framework	Deep Learning-based image localisation framework GPS location tracking	Outdoor Wayfinding

5.1. Computer Vision Hybridised Technological Analytics

The frameworks presented in Table 2 apprise those various technologies combined with the computer vision models and algorithms to build an expert assistance system for visually impaired people. The frameworks, starting from Kinect, cane stick of visually impaired to the path Lookup framework using deep learning for enhanced outdoor object detection and wayfinding showed that the urge to build quality frameworks was in the rising trends. The analysis of various computer vision models found that various technologies were involved in building this assistive system. Their frequencies are portrayed in Fig. 2.

As shown in Fig-2, Artificial Intelligence (21%), Deep Learning (17%), Networks (17%), and Sensors (17%) have become most part of the computer vision models and have achieved more than 90% accuracy with high performances. On the other hand, technologies like Image Processing (12%), Machine Learning (8%) and Big Data (8%) were found least but also gave better results on par with the high-frequency models.

5.2. Classifiers and Algorithms Analytics

Computer vision is an upcoming technology with many models, classifiers and algorithmsbooming over the years. This was evident in the survey conducted in this paper. Some of the successful models, classifiers and their accuracy performance are depicted in Table 2.

Table 2. Visual impairment assistance frameworks based on a survey from 2015-2021

Ref. & Year		Classifier, Model or Algorithms	Purpose	Performance (Accuracy)
[7]	2015	Support Vector Machine	Mapping Microstructural signature	80%
[10]	2016	Image Processing Techniques	Detect Parkinson's disease	67%
[15]	2019	Deep Learning Methods	Real-time Surveillance system	74%
[18]	2020	Colour detection models	Object detection	90.8%
[22]	2022	Machine map technique	Object recognition	80%
[23]	2015	Fuzzy Inference System (FIS)	Handle image milled images	89.8%
[39]	2020	Support Vector Machine	Predict the frequency of passengers	94.50%
[43]	2021	Variational Mode Decomposition (VMD) Algorithm	Detect security of blast furnace	97.4%
[44]	2021	Super Pixel Clustering Method Hybrid neural networks	Analyse the segmentation of leaves in biofuel plants	98%
[61]	2018	Novel Obstacle Avoidance Algorithm	Object detection and Obstacle avoidance	98%
[69]	2020	Deep Learning Model	Real-time assistance for VI People	92.3%
[71]	2021	Intelligent Models and Algorithms	To detect obstacles and recognise objects for VI people	91%

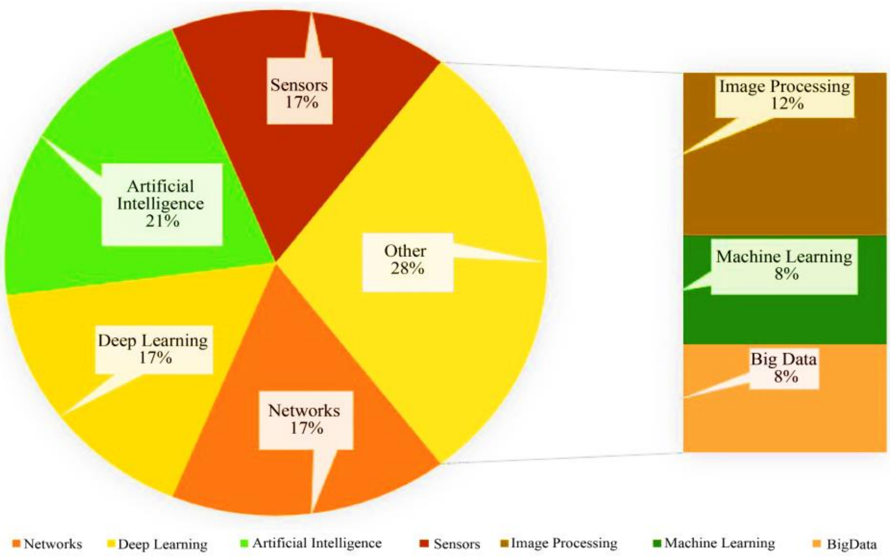

Fig. 2 Percentage frequencies of technologies hybridised with computer vision models

Thus, with the survey of classifier, models or algorithms depicted in Table 2, it is evident that novel algorithms (Yang, 2021; Chouhan, 2021; Elmannai, 2018) have achieved a maximum of approximately 98% accuracy, whereas models like Deep Learning (Dahiya, 2020), Intelligent Models (Singh, 2021), Support Vector Machines (Haq, 2020) and Colour Detection models (Gargin, 2020) have achieved accuracy close to 90% to 95% respectively. However, the remaining models have not achieved the expected performance. The image processing methods achieved the lowest performance with approximately 67% in the experiment conducted by (Pereira, 2016) to detect Parkinson's disease. The analytics revealed that novel frameworks with advanced technologies have provided the best solutions to the problems but require refinement in their hybridised computer vision form.

6. Research Gap Analysis for Stable Framework

It was evident that various Frameworks were introduced and presented by various authors and creators over a period of eight years (2015-2022), as surveyed in this paper. The analytics also showed that computer vision always merges with technology to bring stable solutions to the problem of visually impaired people, as recognising objects, detecting obstacles, etc., were a few of the challenges that could be completed with the assistance of other technologies like networks, image processing, etc. To counteract the needs of future generations, the following research gaps were identified in the current research works.

The existing models can detect objects, but there is no guarantee that images will be captured with the quality required to detect the objects. Hence, a pragmatic method like the image processing filter method has to be employed to refine the images captured from the device of a visually impaired person; all the facial detection was based on the fact that they are normal images. However, detecting Personal Protective Equipment (PPE) based facial images with equipment like gloves, head covers body gowns, shoe covers, facial masks and respirators, eye protection glasses, face shields and goggles. Hence, it must also be included in the proposed model for assisting VI people in detecting PPE-based people.

Feature Selection and Feature Extraction methods were not utilised in the current context of computer vision models as they were considered part of image processing techniques. Combining these methods with CV models would bring an augmented solution to facial detection and recognition on the right note. The Frameworks for the visually impaired focused on the separate use of different methods like object detection, obstacle detection, facial recognition and speech conversion in different research works. However, a hybridised model would bring a simple solution to the problem of visually impaired people as they need a simpler version of solving the problem; the existing frameworks for VI people were found cost-effective with the high cost and better performance. The major social motive was to make the technology reach the common people. Technologies like Deep Learning, Wearable devices, Sensors, Body Area Networks, etc., are highly insufficient for common people. Hence, basic technologies with manageable costs, like image processing and machine learning, could be a better choice for designing the proposed framework.

Visually impaired people in all the existing models could not remember the people they meet every day. Every time, the model only recognises the objects in a general form. The model could not recognise individual personalities with names and identities. Hence, the proposed model is expected to provide insights into these research gaps to be addressed and give reliable solutions.

7. Proposed Framework Model

In the existing scenario, major accomplishmentswere achieved in the context of achieving a solutionfor visual impairment using computer vision in terms of object detection, object recognition and object conversion.

7.1. Review on base Paper Analysis

(Leela Pravallika Siriboyina & Venkata Sainath Gupta Thadikemalla., 2021) [73] developed a VI simulation model in the VI assisting cane to navigate and detect obstacles or objects using the IOT-enabled Hybrid CV model. The model was capable of detecting objects in terms of humans, household objects and plants, and animals in both indoor and outdoor environments. The matching of objects was based on a training set of data incorporated with an Arduino chip embedded in a stick using sensors. This model was significant for VI people to detect the obstacles and objects. The paper followed various steps to complete the model as furnished below:

- The VI stick was configured with Raspberry pi and Pi camera along with an electric supply.
- The stick detects an obstacle and measures the distance between the object and VI people.
- The threshold limit was fixed earlier and tested for the calculated distance between the object and VI people being less than the threshold to be true. When true, the camera and sensor would be activated.
- The object and obstacle detection program identifies the object and alerts the user with a Voice message using an Arduino kit with Raspberry pi sensors.

The above existing model does not meet a few requirements, so research gaps were identified.

- The image captured by the camera was not processed as moving objects in the camera might be noisy, blurred or even sometimes scrambled.
- Object detection assumes it possesses a normal face with no mask or Personal Protective Equipment (PPE) [74]. However, objects with such masks or PPE remain undiscovered.
- The object is detected as an object, and the identity is not known based on a server or dataset,
- The final speech output is the common recorded voice that outputs the same response for all objects with little differentiation for humans, households and animals.

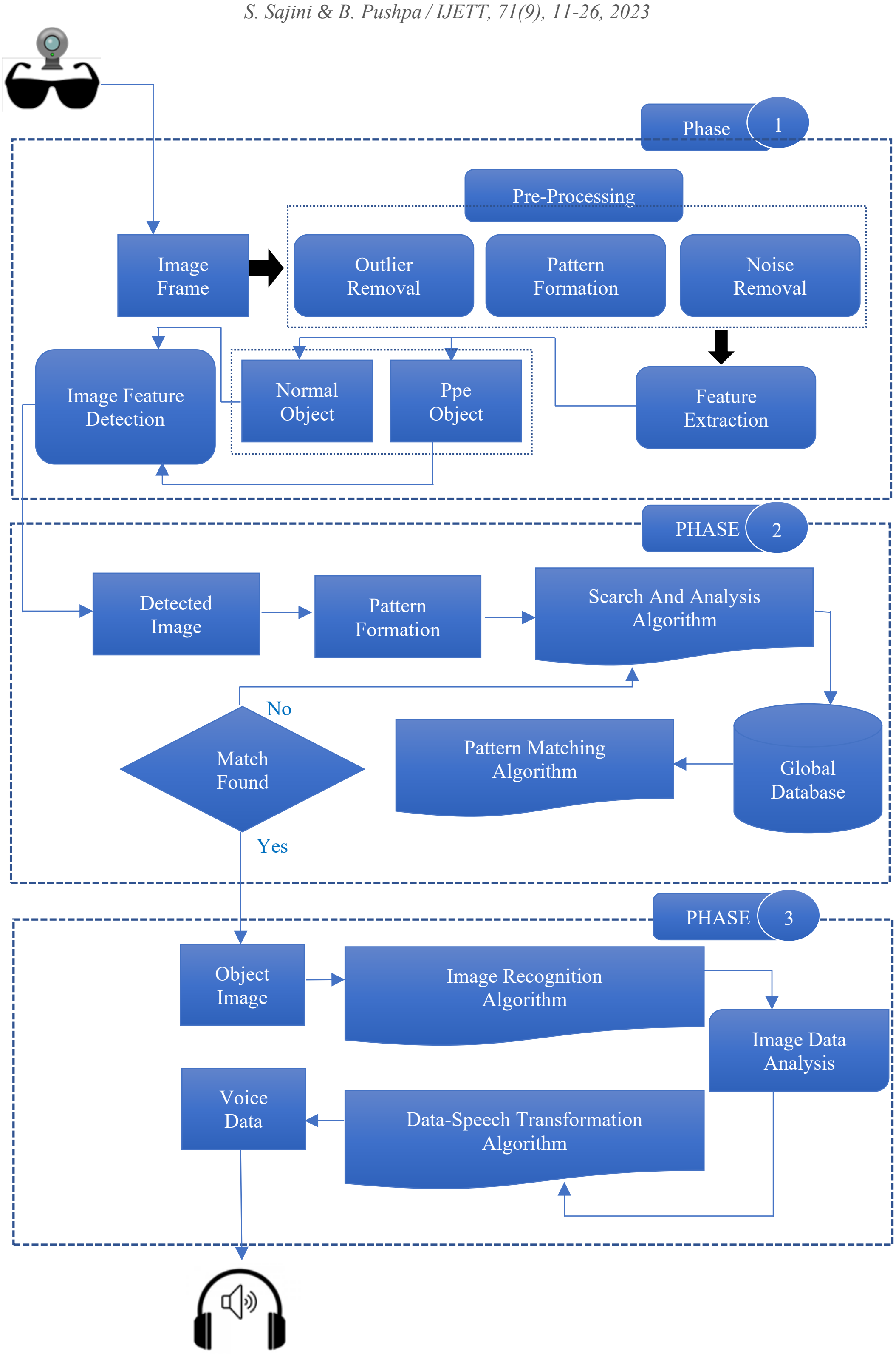

Fig. 3 Proposed stable framework for visually impaired using hybridised computer vision models

7.2. Proposed Model for VI using CV Hybridised Model

To outperform these gaps in the base analysis, the following proposed model is proclaimed. The model comprises three phases that initiate object detection, followed by object recognition, and finally, object conversion, where the object is converted from digital text to digital audio to output the device. The computer vision models were hybridised with image preprocessing methods and Text-to-Speech conversion algorithms to design a stable framework. The proposed stable framework is depicted in Fig. 3.

The Phases of the proposed model, as shown in Fig.3, comprise three phases, namely Object Detection, Object Recognition and Object Conversion. In Phase I, the image acquisition is performed by capturing the visitor's image in front of the VI person using any external device like a camera. The captured image is preprocessed for errors like outliers [75]and noisy data [76], and a pattern is formed. Then, the best features to detect the objects are extracted and tested for detecting the normal and Personal Protective Equipment (PPE) objects. The detected object is tested for humans and non-humans.If human, the object recognition phase is initiated. InPhase II, the image matching and pattern recognition algorithm is applied to find the human object for face recognition.

The detected face isexamined using the Search and Analysis algorithm withthe personal or global dataset to determine whether the face is within the list. If it is within the list, the object conversion phase is initiated; otherwise, the new faceis added to the database by collecting the details of the visitor. In Phase III, the final image is recognized using an image recognition algorithm to find the detailsof the visitor and acquire them in digital text form. The acquired digital text is then converted to speechand digital audio [77] to output through the device. This model will assist the visually impaired personnot only in detecting the object but also in identifying the person in front of them based on the available resources.

The proposed model has various special features implemented apart from the normal models in existence discussed in this survey paper. The model showed three different major algorithms to be created to detect objects, classify or match objects and then recognise objects to inform the user. Various models were analysed throughout this survey, and every model showed that only detecting normal faces was possible. The existing models haven't concentrated on the detection of faces with Personal Protective Equipment (PPE). Inthis proposed model, PPE was given importance as wearing a mask or protective equipment is more common, especially after the COVID-19 situation. Models like Dual Shot Face Detector (DSFD) were analysed as a choice to detect normal faces through the pipeline process. This algorithm was more effective and accurate, but it was a complicated process.

In the case of masked people, a modified model called ResNet50 was applied to remove the mask from the person after capturing the image, and then object detection was performed. In addition, hybridisation of the models along with ResNet50 with advanced models such as AveragePooling2D and Softmax classifiers with dense and abundant layers were used to reduce the problem of overfitting and enhance the performance of detecting masked PPE objects with good accuracy. These models, along with the classifiers, could be tested with an assorted dataset collected from various sources under numerous environmental conditions to confirm that errors are fewer in detecting objects. This is because different climates and lighting conditions could result in invalid object detections. Also, sexual orientations, aging factors, and even the emotional status of the individual during object detection with the normal and masked states could be completed using this proposed model. When moving from one place to another, the people in masks were found to be complex in the existing models and are expected to be solved in the future model of this study. In the preprocessing stage, for outlier detection, Alibi Detect, an open-source Python library, is used, which includes several powerfulalgorithms and techniques for outlier, adversarial, and drift detection. Regarding noise reduction, algorithms such as chroma and luminance noise separation, linear smoothing filters, and anisotropicdiffusion are used to improve performance. PCA (Principal component analysis) is used for feature extraction to identify the image's best features identified from the object.

There were also other important contributions of the model to the future perspectives of visually impairedpeople, as given below:

- It assists in detecting normal and PPE or masked faces in the object detection process.
- It hybridises image processing methodswith computer vision models like YOLO to bring a pragmatic solution to the problem of identifying objects.
- The Proposed model brings a solution to matching the personalities with the global datasets and finding interaction with the local servers.
- The computer vision model algorithms will be created, and a new dimension of data modelling will be presented at the completion of the research.
- The study also focuses on creating a novel dataset with objects in different lighting and sequences to be incorporated in identifying the objects in numerous circumstances andenvironments.

Thus, the proposed model provided various contributions and insights into detecting the right objects at the right sequences. However, it has to beproved for its performance using various parametersassessment shown in the evaluation methods.

7.3. Evaluation Methods for the Proposed Model

The proposed model will be examined after implementation with the Visually Impaired people with the intent that the results are always correct withthe visitor. The evaluation of the proposed model isbased on the confusion matrix [78], which has four outcomes viz. True Positive (TP), True Negative (TN), False Positive (FP) and False Negative (FN) [79] respectively. The evaluation with respect to the proposed VI model has the expected outcomes as depicted in Fig. 4.

From Fig. 4, it is evident that True Positive identified the existing person as the right person, and False Positive identified the new person as the wrong person as the correct output. The remaining two outcomes of the Confusion matrix are found to be wrongoutputs.

Thus, the accuracy [80] of the prediction can be calculated using the formula given in Eq.1.

$$Accuracy = \frac{\sum TP + \sum FN}{\sum TP + \sum TN + \sum FP + \sum FN} * 100 \qquad (1)$$

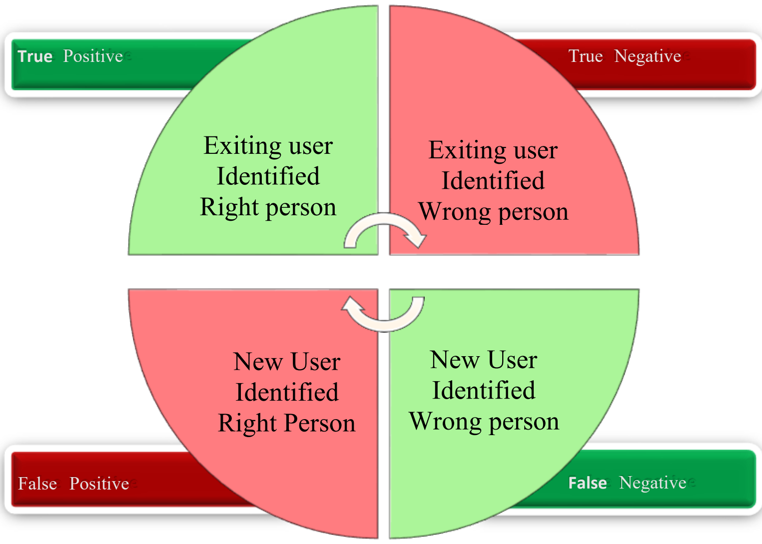

Fig. 4 Performance evaluation for the proposed CV hybrid model

The TP and FN are the positive values. Hence, the percentage of the summation of positive and correct predictions would provide the accuracy of the predictions. The accuracy is calculated by the summation of True Positives and True Negatives divided by the summation of all the confusion matrix values in the nearest percentage terms. Also, sensitivity, specificity, F1 Score and likelihood tests [81] are conducted to confirm the reliability and efficiency of the device created for the VI user.

8. Conclusion

In the scientific world, Computer Vision (CV) is recognised as an emerging field as it has numerous applications for building different models. Also, from this survey, it is evident that CV could be used as a hybrid with any computer technology like image processing, big data, artificial intelligence, machine learning, Internet of Things, etc. The research survey in this paper predominantly focused on computer vision models, Hybridised CV models and existing computer vision frameworks in a nutshell from 2015 to 2022. The framework analysis for the visually impaired is compared and analysed in this paper. The research gaps were identified, and it was found that the hybridisation of computer vision with image processing and Natural Language Processing could bring a pragmatic solution to the problem of detecting andrecognising objects for visually impaired people. Especially the research paper highlighted the proposed model involving different phases and stages for designing a practical model for the same. At the maximum level, this model would bring solutions to the problems of the visually impaired to intelligently detect and recognise objects in the form of virtual assistants from computer vision models.

In the near future, a real-time system is highly recommended to handle big data and embedded applications from computer vision models. Furthermore, many challenging applications in industries, healthcare, education andother upcoming fields could be handled with ease using computer vision and its hybridisationwith other computer technologies to develop massive, innovative and intelligent machines. The automation of image detections from real-time devices would assist in bringing smart applications that would be capable of assisting human beings in generations to come.

References

[1] Rohit Varma, Kristina Tarczy-Hornoch, and Xuejuan Jiang, "Visual Impairment in Preschool Children in the United States: Demographic and Geographic Variations from 2015 To 2060," *JAMA Ophthalmology*, vol. 135, no. 6, pp. 610-616, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[2] Peter Ackland, Serge Resnikoff, and Rupert Bourne, "World Blindness and Visual Impairment: Despite Many Successes, the Problem is Growing," *Community Eye Health*, vol. 30, no. 100, pp. 71-73, 2017. [Google Scholar] [Publisher Link]

[3] Rohit Varma et al., "Visual Impairment and Blindness in Adults in the United States: Demographic and Geographic Variations from 2015 to 2050," *JAMA Ophthalmology*, vol. 134, no. 7, pp. 802-809, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[4] Kristen A. Eckert et al., "A Simple Method for Estimating the Economic Cost of Productivity Loss due to Blindness and Moderate to Severe Visual Impairment," *Ophthalmic Epidemiology*, vol. 22, no. 5, pp. 349-355, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[5] Antoine Gbessemehlan et al., "Association between Visual Impairment and Cognitive Disorders in Low-and-Middle Income Countries: A Systematic Review," *Aging & Mental Health*, vol. 25, no. 10, pp. 1786-1795, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[6] Clarissa Ng Yin Ling et al., "Visual Impairment, Major Eye Diseases, and Mortality in a Multi-Ethnic Asian Population and a Meta-analysis of Prospective Studies," *American Journal of Ophthalmology*, vol. 231, pp. 88-100, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[7] Brian L. DeCost, and Elizabeth A. Holm, "A Computer Vision Approach for Automated Analysis and Classification of Micro Structural Image Data," *Computational Materials Science*, vol. 110, pp. 126-133, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[8] JoonOh Seo et al., "Computer Vision Techniques for Construction Safety and Health Monitoring," *Advanced Engineering Informatics*, vol. 29, no. 2, pp. 239-251, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[9] N. V. Kartheek Medathati et al., "Bio-Inspired Computer Vision: Towards a Synergistic Approach of Artificial and Biological Vision," *Computer Vision and Image Understanding*, vol. 150, pp. 1-30, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[10] Clayton R. Pereira et al., "A New Computer Vision-based Approach to Aid the Diagnosis of Parkinson's Disease," *Computer Methods and Programs in Biomedicine*, vol. 136, pp. 79-88, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[11] Jérôme Thevenot, Miguel Bordallo López, and Abdenour Hadid, "A Survey on Computer Vision for Assistive Medical Diagnosis from Faces," *IEEE Journal of Biomedical and Health Informatics*, vol. 22, no. 5, pp. 1497-1511, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[12] M. Leo et al., "Computer Vision for Assistive Technologies," *Computer Vision and Image Understanding*, vol. 154, pp. 1-15, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[13] Junfeng Gao et al., "Computer Vision in Healthcare Applications," *Journal of Health Care Engineering*, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[14] Qiuhong Ke et al., "Computer Vision for Human–Machine Interaction," *Computer Vision for Assistive Healthcare*, Academic Press, pp. 127-145, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[15] J. Harikrishnan et al., "Vision-Face Recognition Attendance Monitoring System for Surveillance using Deep Learning Technology and Computer Vision," *International Conference on Vision towards Emerging Trends in Communication and Networking, IEEE*, pp. 1-5, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[16] Hao Wu, Deyang Wu, and Jinsong Zhao, "An Intelligent Fire Detection Approach through Cameras based on Computer Vision Methods," *Process Safety and Environmental Protection*, vol. 127, pp. 245-256, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[17] Lev Manovich, "Computer Vision, Human Senses, and Language of Art," *AI & SOCIETY*, vol. 36, pp. 1145-1152, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[18] Vitaliy Gargin et al., "Application of the Computer Vision System for Evaluation of Pathomorphological Images," *IEEE 40th International Conference on Electronics and Nanotechnology*, pp. 469-473, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[19] Jing Jin et al., "A Feature Binding Model in Computer Vision for Object Detection," *Multimedia Tools and Applications*, vol. 80, no. 13, pp. 19377-19397, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[20] Thomas M. Ward et al., "Computer Vision in Surgery," *Surgery*, vol. 169, no. 5, pp. 1253-1256, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[21] Ronald Tombe, and Serestina Viriri, "Effective Processing of Convolutional Neural Networks for Computer Vision: A Tutorial and Survey," *IETE Technical Review*, vol. 39, no. 1, pp. 49-62, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[22] Andrea Ghermandi, Yaella Depietri, and Michael Sinclair, "In the AI of the Beholder: A Comparative Analysis of Computer Vision-Assisted Characterizations of Human- Nature Interactions in Urban Green Spaces," *Landscape and Urban Planning*, vol. 217, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[23] Hemad Zareiforoush et al., "A Hybrid Intelligent Approach based on Computer Vision and Fuzzy Logic for Quality Measurement of Milled Rice," *Measurement*, vol. 66, pp. 26-34, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[24] J.D. Tamayo-Quintero, S. Arboleda-Duque, and J.B. Gómez-Mendoza, "Semi-Automatic Teeth Segmentation in 3D Models of Dental Casts using a Hybrid Methodology," *Emerging Trends in Image Processing, Computer Vision and Pattern Recognition*, pp. 433-446, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[25] Viachaslau Kachurka et al., "Visual Saliency based Approach to Object Detection in Computer Vision Systems: Real Life Applications," *IEEE 8th International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications*, pp. 239-244, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[26] T. Santha, and V. Mohana Maniganda Babu, "The Significance of Real-Time, Biomedical and Satellite Image Processing in Understanding the Objects & Application to Computer Vision," *IEEE International Conference on Engineering and Technology*, pp. 661-670, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[27] Shruti Shukla, Ashish Lakhmani, and Ambuj Kumar Agarwal, "Approaches of Artificial Intelligence in Biomedical Image Processing: A Leading Tool between Computer Vision & Biological Vision," *International Conference on Advances in Computing, Communication, & Automation, IEEE*, pp. 1-6, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[28] S. Prathiba, and B. Sivagami, "Newfangled Applications of Digital Image Processing," *SSRG International Journal of Computer Science and Engineering*, vol. 6, no. 11, pp. 28-32, 2019. [CrossRef] [Publisher Link]

[29] Peratham Wiriyathammabhum et al., "Computer Vision and Natural Language Processing: Recent Approaches in Multimedia and Robotics," *ACM Computing Surveys*, vol. 49, no. 4, pp. 1-44, 206. [CrossRef] [Google Scholar] [Publisher Link]

[30] Mu-Cyun Tang et al., "A Hybrid Computer Vision and Wi-Fi Doppler Radar System for Capturing the 3-D Hand Gesture Trajectory with A Smart Phone," *IEEE MTT-S International Microwave Symposium*, pp. 1251-1254, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[31] Jun-Kit Chaw, and Musa Mokji, "Analysis of Produce Recognition System with Taxonomist's Knowledge using Computer Vision and Different Classifiers," *IET Image Processing*, vol. 11, no. 3, pp. 173-182, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[32] Dandara T. G. Andrade et al., "A Hybrid Approach for the Actuation of Upper Limb Prostheses based on Computer Vision," *Latin American Robotics Symposium, and 2017 Brazilian Symposium on Robotics (SBR) IEEE*, pp. 1-6, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[33] Diego Inácio Patrício, and Rafael Rieder, "Computer Vision and Artificial Intelligence in Precision Agriculture for Grain Crops: A Systematic Review," *Computers and Electronics in Agriculture*, vol. 153, pp. 69-81, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[34] Eva María Artime Ríos et al., "A Hybrid Algorithm for the Prediction of Computer Vision Syndrome in Health Personnel based on Trees and Evolutionary Algorithms," *International Conference on Hybrid Artificial Intelligence Systems, Springer, Cham*, pp. 597-608, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[35] Weili Fang et al., "Falls from Heights: A Computer Vision-Based Approach for Safety Harness Detection," *Automation in Construction*, vol. 91, pp. 53-61, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[36] Niall O'Mahony et al., "Deep Learning Vs. Traditional Computer Vision," *Science and Information Conference, Springer, Cham*, pp.128-144, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[37] Roos van der Donk et al., "Next-Generation Phenol Typing using Computer Vision Algorithms in Rare Genomic Neuro Developmental Disorders," *Genetics in Medicine*, vol. 21, pp. 1719-1725, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[38] Changrui Chen et al., "RRNet: A Hybrid Detector for Object Detection in Drone-Captured Images," *Proceedings of the IEEE/CVF International Conference on Computer Vision Workshops*, 2019. [Google Scholar] [Publisher Link]

[39] Ejaz Ul Haq et al., "A Fast Hybrid Computer Vision Technique for Real-Time Embedded Bus Passenger Flow Calculation through Camera," *Multimedia Tools and Applications*, vol. 79, no. 1, pp. 1007-1036, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[40] Weili Fang et al., "Knowledge Graph for Identifying Hazards on Construction Sites: Integrating Computer Vision with Ontology," *Automation in Construction*, vol. 119, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[41] Ipek Gursel Dino et al., "Image-Based Construction of Building Energy Models using Computer Vision," *Automation in Construction*, vol. 116, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[42] Amol Mangrulkar, Santosh B. Rane, and Vivek Sunnapwar, "Automated Skull Damage Detection from Assembled Skull Model Using Computer Vision and Machine Learning," *International Journal of Information Technology*, vol. 13, no. 5, pp. 1785-1790, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[43] Ai-Min Yang et al., "Computer Vision Technology based on Sensor Data and Hybrid Deep Learning for Security Detection of Blast Furnace Bearing," *IEEE Sensors Journal*, vol. 21, no. 22, pp. 24982-24992, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[44] Siddharth Singh Chouhan et al., "Leaf Disease Segmentation and Classification of Jatropha Curcas L. and Pongamia Pinnata L. Biofuel Plants using Computer Vision-Based Approaches," *Measurement*, vol. 171, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[45] Zhanxiong Ma et al., "Structural Displacement Estimation by Fusing Vision Camera and Accelerometer using Hybrid Computer Vision Algorithm and Adaptive Multi-Rate Kalman Filter," *Automation in Construction*, vol. 140, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[46] Victor Rezende Franco et al., "Hybrid Machine Learning Methods Combined with Computer Vision Approaches to Estimate Biophysical Parameters of Pastures," *Evolutionary Intelligence*, vol. 16, pp. 1271-1284, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[47] Hieu Nguyen, and Nhat-Duc Hoang, "Computer Vision-based Classification of Concrete Spall Severity using Metaheuristic-Optimized Extreme Gradient Boosting Machine and Deep Convolutional Neural Network," *Automation in Construction*, vol. 140, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[48] Hotaka Takizawa et al., "Kinect Cane: An Assistive System for the Visually Impaired based on the Concept of Object Recognition Aid," *Personal and Ubiquitous Computing*, vol. 19, no. 5, pp. 955-965, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[49] P. Priyadarshini et al., "Smart Backing Cane For Visually Impaired," *SSRG International Journal of Computer Science and Engineering*, vol. 7, no. 5, pp. 21-24, 2020. [CrossRef] [Publisher Link]

[50] Jizhong Xiao et al., "An Assistive Navigation Framework for the Visually Impaired," *IEEE Transactions on Human-Machine Systems*, vol. 45, no. 5, pp. 635-640, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[51] Namita Agarwal et al., "Electronic Guidance System for the Visually Impaired—A Framework," *International Conference on Technologies for Sustainable Development, IEEE*, pp. 1-5, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[52] Dejing Ni et al., "A Walking Assistant Robotic System for the Visually Impaired based on Computer Vision and Tactile Perception," *International Journal of Social Robotics*, vol. 7, no. 5, pp. 617-628, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[53] Manuela Chessa et al., "An Integrated Artificial Vision Framework for Assisting Visually Impaired Users," *Computer Vision and Image Understanding*, vol. 149, pp. 209-228, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[54] Sanket Khade, and Yogesh H. Dandawate, "Hardware Implementation of Obstacle Detection for Assisting Visually Impaired People in an Unfamiliar Environment by Using Raspberry Pi," *International Conference on Smart Trends for Information Technology and Computer Communications*, pp. 889-895, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[55] Laurindo Britto Neto et al., “A Kinect-Based Wearable Face Recognition System to Aid Visually Impaired Users,” *IEEE Transactions on Human-Machine Systems*, vol. 47, no. 1, pp. 52-64, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[56] S. Senthamizhselvi, and A. Saravanan, "Visual Place Recognition Model using Deep Learning with Arithmetic Optimization Algorithm," *SSRG International Journal of Electronics and Communication Engineering*, vol. 10, no. 7, pp. 74-86, 2023. [CrossRef] [Publisher Link]

[57] Ruxandra Tapu, Bogdan Mocanu, and Titus Zaharia, "DEEP-SEE: Joint Object Detection, Tracking and Recognition with Application to Visually Impaired Navigational Assistance," *Sensors*, vol. 17, no. 11, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[58] Chan Kit Yan, Ulrich Engelke, and Nimsiri Abhayasinghe, "An Edge Detection Framework Conjoining with IMU Data for Assisting Indoor Navigation of Visually Impaired Persons," *Expert Systems with Applications*, vol. 67, pp. 272-284, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[59] John-Ross Rizzo et al., "Sensor Fusion for Ecologically Valid Obstacle Identification: Building a Comprehensive Assistive Technology Platform for the Visually Impaired," *7th International Conference on Modeling, Simulation, and Applied Optimization, IEEE*, pp. 1-5, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[60] Charmi T. Patel et al., "Multi Sensor-Based Object Detection in Indoor Environment for Visually Impaired People," *Second International Conference on Intelligent Computing and Control Systems, IEEE*, pp. 1-4, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[61] Wafa M. Elmannai, and Khaled M. Elleithy, "A Highly Accurate and Reliable Data Fusion Framework for Guiding the Visually Impaired," *IEEE Access*, vol. 6, pp. 33029-33054, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[62] Sejal Gianani et al., "Juvo-An Aid for the Visually Impaired," *International Conference on Smart City and Emerging Technology, IEEE*, pp. 1-4, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[63] Bin Jiang et al., "Wearable Vision Assistance System based on Binocular Sensors for Visually Impaired Users," *IEEE Internet of Things Journal*, vol. 6, no. 2, pp. 1375-1383, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[64] Ambrose A. Azeta, İtorobong A. Inam, and Olawande Daramola, "A Voice-Based E-Examination Framework for Visually Impaired Students in Open and Distance Learning," *Turkish Online Journal of Distance Education*, vol. 19, no. 2, pp. 34-46, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[65] Md. Milon Islam et al., "Developing Walking Assistants for Visually Impaired People: A Review," *IEEE Sensors Journal*, vol. 19, no. 8, pp. 2814-2828, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[66] Jinhui Zhu et al., "An Edge Computing Platform of Guide-Dog Robot for Visually Impaired," *IEEE 14th International Symposium on Autonomous Decentralized System*, pp. 1-7, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[67] Wasiq Khan et al., "Novel Framework for Outdoor Mobility Assistance and Auditory Display for Visually Impaired People," *12th International Conference on Developments in eSystems Engineering, IEEE*, pp. 984-989, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[68] Jinhui Zhu et al., "A Fog Computing Model for Implementing Motion Guide to Visually Impaired," *Simulation Modeling Practice and Theory*, vol. 101, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[69] Dhruv Dahiya, Hardik Gupta, and Malay Kishore Dutta, "A Deep Learning based Real Time Assistive Framework for Visually Impaired," *International Conference on Contemporary Computing and Applications, IEEE*, pp. 106-109, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[70] Leo Abraham et al., "VISION-Wearable Speech-Based Feedback System for the Visually Impaired using Computer Vision," *4th International Conference on Trends in Electronics and Informatics, IEEE*, pp. 972-976, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[71] Simerneet Singh, Nishtha Jatana, and Vasu Goel, "HELF (Haptic Encoded Language Framework): A Digital Script for Deaf-Blind and Visually Impaired," *Universal Access in the Information Society*, vol. 22, pp. 121-131, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[72] Uddipan Das, Vinod Namboodiri, and Hongsheng He, "Path Lookup: A Deep Learning-Based Framework to Assist Visually Impaired in Outdoor Wayfinding," *IEEE International Conference on Pervasive Computing and Communications Workshops and other Affiliated Events (PerCom Workshops)*, pp. 111-116, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[73] Leela Pravallika Siriboyina, and Venkata Sainath Gupta Thadikemalla, "A Hybrid System to Assist Visually Impaired People," *SN Computer Science*, vol. 2, no. 4, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[74] Saurav Kumar et al., "YOLOv4 Algorithm for the Real-Time Detection of Fire and Personal Protective Equipments at Construction Sites," *Multimedia Tools and Applications*, vol. 81, no. 16, pp. 22163-22183, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[75] Yu-Yun Tseng, Alexander Bell, and Danna Gurari, "VizWiz-FewShot: Locating Objects in Images Taken by People with Visual Impairments," *European Conference on Computer Vision*, pp. 575-591, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[76] R. Wang, C. Jung, and Y. Kim, "Seeing through Sounds: Mapping Auditory Dimensions to Data and Charts for People with Visual Impairments," *Computer Graphics Forum*, vol. 41, no. 3, pp.71-83, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[77] Kashif Iqbal, Zahid Majeed, and Samina Ashraf, "Exploring the Challenges of Digital Literacy among Students with Visual Impairment Studying at Higher Education Level," *Pakistan Journal of Humanities and Social Sciences*, vol. 10, no. 1, pp. 199-208, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[78] Harsh Dokania, and Nilanjan Chattaraj, "An Assistive Interface Protocol for Communication between Visually and Hearing-Speech Impaired Persons in Internet Platform," *Disability and Rehabilitation: Assistive Technology*, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[79] Mostafa Elgendy, Cecilia Sik-Lanyi, and Arpad Kelemen, "A Novel Marker Detection System for People with Visual Impairment using the Improved Tiny-YOLOv3 Model," *Computer Methods and Programs in Biomedicine*, vol. 205, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[80] Steindor Ellertsson, Hrafn Loftsson, and Emil L. Sigurdsson, "Artificial Intelligence in the GPs Office: A Retrospective Study on Diagnostic Accuracy," *Scandinavian Journal of Primary Health Care*, vol. 39, no. 4, pp. 448-458, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[81] V. Deepa, C. Sathish Kumar, and Thomas Cherian, "Automated Detection of Diabetic Retinopathy Images using Pre-Trained Convolutional Neural Network," *International Conference on Communication, Control and Information Sciences, IEEE*, vol. 1, pp. 1-5, 2021. [CrossRef] [Google Scholar] [Publisher Link]