IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

A SYSTEMATIC SURVEY ON MEDICINE PILLS RECOGNITION FOR VISUALLY IMPAIRED PEOPLE USING MACHINE LEARNING TECHNIQUES

[1]S. Shunmuga Priya, [2]Dr.P.Velvizhy

[1]Research Scholar, Department of [1]Computer Science and Engineering, College of Engineering Guindy, Anna University, Chennai-600025, Tamilnadu, India

[2]Assistant Professor, Department of [1]Computer Science and Engineering, College of Engineering Guindy, Anna University, Chennai-600025, Tamilnadu, India

Abstract

Nowadays, world is experiencing unexpected growth in total population and it is well known that physiology of a person deteriorates with age. Global population includes a notable proportion of peoples with disabilities. One of the major disabilities which largely affects day to day life is vision impairment. Although vision impairment affects people of all ages, older people are the most impacted. Aging is the unavoidable process which may happens with multiple chronic diseases and so taking medicines is the regular part of their daily activity. This becomes a very difficult task for the visually impaired peoples especially the aged peoples as they need to identify correct medicines when they lack support from care takers. Consuming wrong medicine can cause serious harms which may even leads to death. This issue can be solved by developing a recognition system which correctly recognize the prescribed medicine. Machine learning algorithms has the capability to provide successful results for recognition system. Therefore, medicine pills recognition system can be developed using machine learning algorithms which helps the visually impaired peoples for self-medications. This article provides an in-depth survey about machine learning techniques for pill recognition and its contribution in developing assistive devices and mobile applications for visually impaired peoples for medicine pill recognition.

Key Words: Medicine pills, Recognition system, Visually Impaired, Machine learning, Deep learning.

1. Introduction

Visually impaired refers to less vision and it may be fully or partially blind. Contact lenses or glasses are unable to provide cure for blindness. Loss of vision is another way of loss of independent life. People who are visually impaired or blind always require constant assistance from other people even for simple tasks like walking, identifying people or items, shopping, and recognizing medications. The major causes of vision impairment are blindness due to refractive error, macular degeneration, cataract, glaucoma, diabetic retinopathy [1] and presbyopia [2]. The most common fact is that old aged peoples are mostly affected by vision impairment when compared to young peoples or children. Generally, health conditions are highly associated with ageing and almost all aged peoples are affected by chronic diseases or any other diseases. One of the important requirements for their life is the consistent consumption of medications. Both the visually impaired adults and young people find it challenging to take their medications as prescribed. When taking numerous medications, there is a high likelihood that they will forget or take the wrong medication. Most of the patients greatly depend on the sighted people around them for their medication and this becomes a burden if the patient is affected by chronic disease as the patient need to take medicine regularly for a long period of time. So, it is necessary for the visually impaired peoples to identify and classify their medicine pills by themselves.

Recent advances in technology aids the blind or visually impaired peoples to live their life independently. To ensure safe medications by the visually impaired persons, medicine pills recognition system can be developed. This can be accomplished by the following methods.

- Capture the pills and develop a recognition system using image processing and Machine learning techniques.
- Gather or generate a dataset by storing tablet names, details etc. and use Machine learning techniques for recognition of medicine pills.
- Develop mobile applications that helps to identify the pills with alert system.
- Design tools or wearable smart glasses to recognize medicine pills.

Machine learning proved to the successful technique which is widely utilized in numerous fields. Developing the medicine pills recognition system using machine learning or deep learning which is the advancement of machine learning can provide accurate results than other methods. Many existing techniques for medicine pill recognition are available which takes pill image or pill dataset as input for recognition. The pill images or pill dataset is transformed into inputs that can be incorporated into a machine learning model, and the machine learning model is then in responsible for extracting useful patterns from the images and features from the dataset. The outcome of the existing approaches is not accurate enough as it depends on many factors such as image clarity and data consistency. Additionally, the reliability, availability and timeliness of the pill recognition is significant yet crucial and is completely depends on the system architecture and resources [3]. In this case, existing methods needs improvement or a novel medicine pill recognition system must be developed to overcome the issues faced by the existing systems and to

achieve better recognition accuracy. This article presents a deep survey about the techniques in medicine pill recognition for visually impaired peoples.

This paper is organized in four sections. Section 1 provides a brief introduction about vision impairment and the need of medicine pill recognition for visually challenged peoples and section 2 presents the statistical analysis of vision impairment. Section 3 provides the review of past literatures regarding medicine pill recognition system using machine learning techniques. Resources related to pill recognition for vision impairment are presented in Section 4 and Section 5 concludes the survey.

2. Statistical Analysis of Vision Impairment

According to World Health Organization (WHO) report on vision 2022, 2.2 billion peoples suffer from near or distance vision impairment worldwide [4]. Among them, half of the cases are treated and around 1 billion cases are yet to be addressed. In these 1 billion cases, presbyopia accounts for a significant portion as it is the prevalent cause of vision impairment. The contributing factors of vision impairment is displayed in Figure 1.

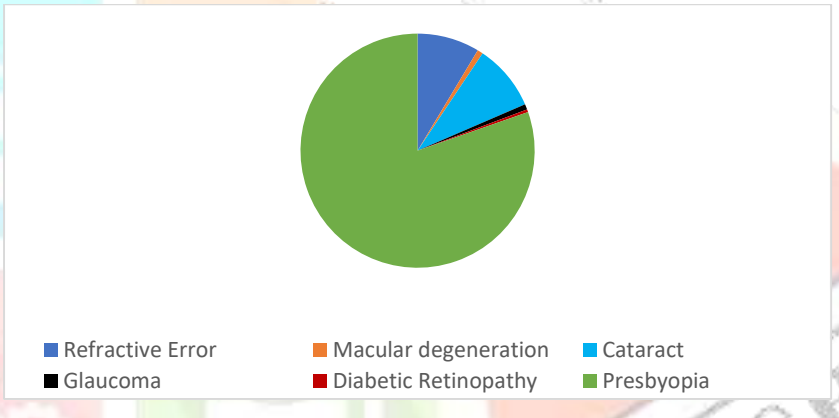

Figure 1. Causes of vision impairment

From Figure 1, it is observed that the percentage of peoples affected by Presbyopia is high when compared to other causes and is 80%. Presbyopia is the uncorrected refractive error and is a part of aging in which the people's loss the vision of near objects. Vision impairment is classified into blind, mild, moderate to severe and near vision problem. The percentage of peoples with different stages of vision impairment is shown in Figure 2.

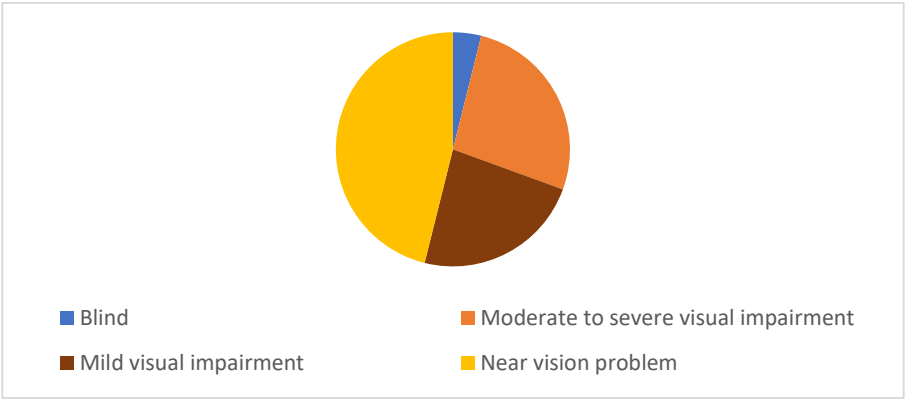

Figure 2. Classification of vision impairment

It is proved from Figure 2 that near vision problem is the most common vision impairment which mainly affects aged peoples. Around 82% of the peoples with vision impairment or blindness are over the age group of 50. The bar chart representation of age groups versus percentage of peoples affected by vision impairment is depicted in Figure 3.

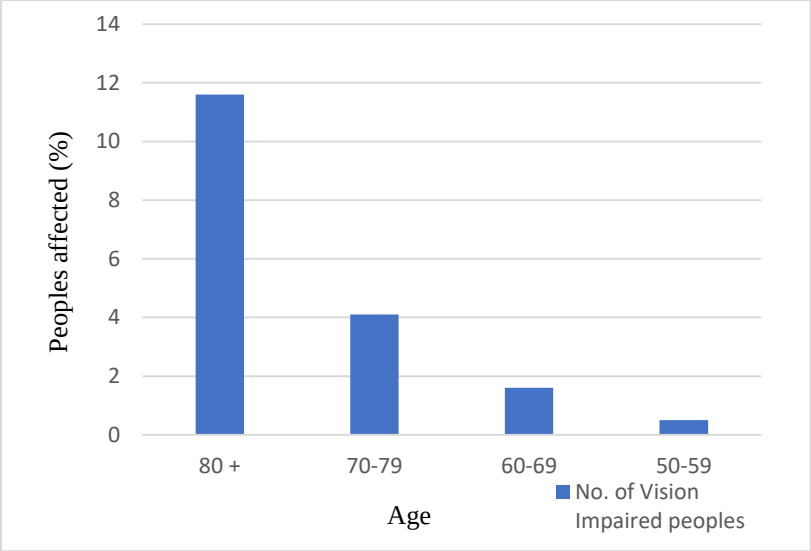

Figure 3. Age Vs Vision impairment

The population of the world is expected to increase by 25% in 2050 which is 9.7 billion. It is estimated that the number of peoples over the age of 65 and 80 will be double and triple respectively in 2050. Projections of vision impairment as per the report released by National Eye Institute (NEI) [5] is shown in Figure 4.

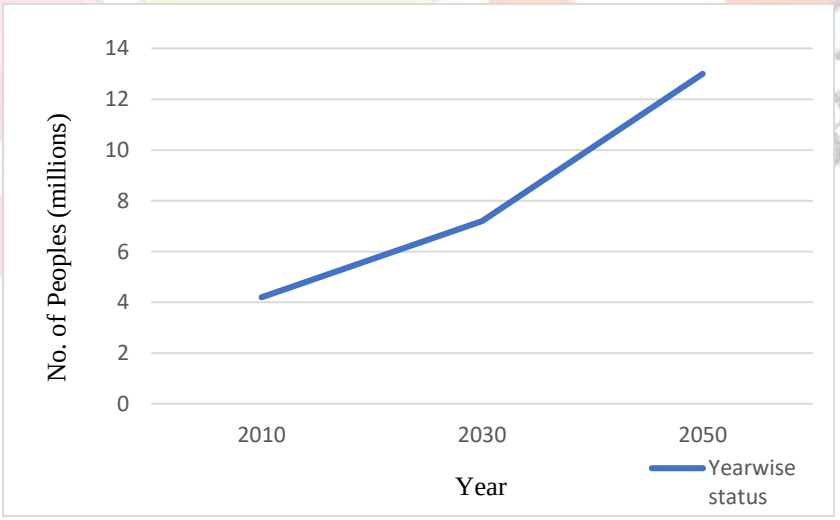

Figure 4. Projections for vision impairment

From Figure 4, it is observed that the number of peoples with vision impairment is increasing year by year and it will reach 13 million in 2050. So, it is necessary to develop a medicine pill recognition system which provides better accuracy to help for the life of visually impaired peoples.

3. Literature Review

Many researches were carried out by the researchers worldwide for medicine pill recognition system. Some relevant research works are reviewed and the survey of medicine pill recognition system is provided with the introduction of Medicine pill recognition system followed by the review of Machine learning technologies for pill recognition along with its involvement in Assistive devices, Mobile applications, and some key discoveries for medicine pill recognition.

3.1 Medicine Pill recognition system

Medication safety issues of visually impaired peoples perceives less attention when compared to other medical related issues [6]. To facilitate safe medication use, few surveys are carried out for medicine pill recognition. One such survey was presented by Aarya Naik et al. [7] in which few research methodologies and datasets for pill recognition are discussed. Another study explores descriptors for pill detection and characterization using the newly released National Library of Medicine (NLM) pill image database [8]. The authors provide feature matrices for pill images and assess 1000 most popular medications in United States of America (USA). The authors also discussed strategies of content-based image retrieval. A study was carried out by Giles et al. [9] to provide a summary of the research on medication safety and visual impairment. The authors analyze the existing literatures that discuss about the association between vision impairment and medication safety. Various types and causes of medication safety issues are also discussed to promote the health care of visually impaired patients. Almuzaini et al. [10] presented a literature survey by analyzing the opportunities provided by the computer technologies to find a practical solution for the visually impaired patients to identify medications. The authors discussed about the technologies such as smart labeling solutions, computer vision techniques and crowdsourcing approaches with its advantages and disadvantages.

3.2 Machine Learning techniques for Medicine Pill recognition

Machine learning is one of the computer technologies and is a part of Artificial Intelligence which makes machine to learn automatically from the past behavior or data. The primary difference between machine learning and conventional methods is that a machine learning model learns from examples rather than being programmed with rules [11]. Therefore, the possibilities of providing accurate results are more for machine learning techniques than traditional methods.

Machine learning technology are growing constantly and finds its applications in the areas such as speech recognition, disease prediction, voice recognition, traffic prediction, product recommendation and image recognition etc. A machine learning model takes features as input and provides labels or class as output. Deep learning is the advanced concept of machine learning has the capability to provide better accuracy. From the past literatures, it is observed that most of the medication recognition system for visually impaired peoples are developed using deep learning approaches.

An automatic medicine pill recognition system for visually impaired peoples was developed by Vasavi et al. [12]. The techniques used in the system are text to speech engine, feature extraction and deep learning. Text recognition is utilized to identity the text on the labels of the pills. Features are extracted from the text and fed into Convolutional Neural Network (CNN) [13], a deep learning model. CNN correctly classifies the name of the medicine and is converted into audio which helps the visually impaired peoples to take correct medicines. A deep learning system is developed for drug recognition by Sudharshan borde et al. [14] which takes pill images as input and extracts features based on their shape, size and color. CNN is utilized to classify the pill images using the extracted features and this system is helpful for monitoring the medications of the visually impaired peoples. Heo et al. [15] developed a deep learning-based system to reduce the medication errors. The authors collected pill image data from open database of USA and South Korea. Text recognition and image classification are the two techniques adopted to extract features and classification of pill images using similarity scores of the pill images. This work can also be extended to visually impaired peoples by incorporating the concept of text to voice system.

A CNN based drug recognition model with braille embosser system for smartphones was developed. The approach utilizes smartphone to take pictures of the drug and CNN model is used for the purpose of classification. The braille embosser can be connected to the smartphone using Bluetooth which helps to print the result of classification. The CNN based drug recognition model provides an accuracy of 99.6% [16]. An intelligent alert-based medication system is developed by Yeh et al. [17] which integrates two technologies namely Optical Character Recognition (OCR) and text to speech conversion with Chinese spell-checking mechanism. The system utilizes Convolutional Neural Network (CNN) for optical character recognition and HMM/DNN-based speech synthesis system is utilized for the functionality of text to speech. Leung et al. [18] developed a hybrid intelligent assistive system for visually impaired peoples which helps to overcome the issues of self medications. The system includes MongoDB database, a flask server and android application. The server recognizes the medicine by combining Optical Character Recognition (OCR) and image classification by Convolutional Neural Network (CNN). From the experimental results, it is observed that the recognition accuracy of the assistive system is 96.1%.

In most of the cases, both Machine learning and Deep learning techniques are utilized for medicine pill recognition by developing assistive devices and mobile applications etc.

3.2.1 Assistive devices for Medicine pill recognition

Assistive devices aim at easing the life of visually impaired people by assist them in their daily activities such as walking, reading and medications etc. Numerous studies discuss about the technologies utilized for developing the assistive devices along with its significance and benefits for disabled peoples. While developing the assistive devices for visually impaired peoples, three significant factors need to be considered [19]. They are

- Human-Machine Interface
- Machine learning technologies
- Performance evaluation

Tapu et al. [20] presented a detailed survey of various assistive or wearable devices for visually impaired peoples along with its advantages and disadvantages. The purpose of the survey is to educate the research community and the visually impaired peoples about the abilities of existing and current systems, the development of assistive technologies, and potential research directions that can enhance current assistive devices. Another comparative survey of assistive devices is presented by Elmannai et al. [21]. The main objective of this survey is to highlight the current issues and limitations of the existing system which helps in the development of assistive devices in future.

A smart glass was designed for visually impaired peoples by Monica. R et al. [22] which utilizes image processing techniques and deep learning techniques. A camera and raspberry pi are fixed in the smart glass. The camera helps to capture the pill image and Convolutional Neural Network (CNN), a deep learning technique is utilized to read the name of the medicine and this algorithm is embedded in raspberry pi. The name of the recognized medicine is sent as audio signals which aids for medications of visually impaired peoples. Chang et al. [23] developed MedGlasses, a wearable smart glass-based drug pill identification system. This system makes use of deep learning, mobile device application and cloud-based information management platform. The deep learning module namely ResNet50 is utilized in this research work for drug pill recognition which achieves recognition accuracy of 95.1%.

3.2.2 Mobile Applications for Medicine pill recognition

A real time survey was conducted by Griffin-Shirley [24] on the usage of mobile applications by the visually impaired peoples. The survey was taken from 259 users and the participants rated the mobile applications as useful (95.4%) and accessible (91.1%). According to the findings of the survey, it is concluded that the people with visual impairments frequently use apps to complete everyday tasks. Moreover, it is also noted that the peoples are satisfied with the mobile applications and expecting updates for the ease. Another evaluation-based study and systematic literature review on usability of mobile applications by visually impaired peoples was done by Hussain et al. [25] and Al-Razgan et. al [26]. So, it is observed that the visually impaired peoples are highly comfortable with mobile applications. Designing a mobile application which specifically met the issues of self medications for visually challenged peoples need more attention. A real time survey was conducted by generating a questionnaire to identify the expected requirements of the visually impaired peoples in their mobile applications [27]. As a result of the survey, few requirements such as educating the applications with the more details of drugs, frequent software update and user-friendly nature are considered as the most significant requirements.

A medical assistance based mobile application for visually impaired peoples was developed by Mishra et al. [28] which makes use of Optical Character Recognition (OCR) using deep learning and text localization techniques for extracting details from the medicine. The application is designed with alert system for timely reminder of medications. A mobile application namely “Eye Assistant” was developed by Shishir et al. [29] which integrates two techniques namely object detection and text detection. The application uses tensorflow machine learning API to segment the object from the background and then recognize the object or text which is further converted into voice signal by text to speech conversion technique. Negi et al. [30] developed a

mobile application using techniques such as Optical Character Recognition (OCR), Text to speech system and Computer vision. The mobile application takes image of medicine strips as input and identify the text in the image using YOLO [31] which in turn utilizes Darknet-53 to extract features.

3.2.3 Some other key discoveries for Medicine pill recognition using Machine learning

The application of machine learning is constantly growing in the field of medical science. From the past literatures, it is observed that machine learning and deep learning techniques plays a major role in Medicine pill recognition not only for visually impaired peoples but also for the normal human beings. Some key discoveries for medicine pill recognition using machine learning for medications of normal peoples which can also be extended for visually challenged peoples are discussed in this section.

An automatic classification system for pill images using image processing techniques was developed by Cordeiro et al. [32]. The authors utilized image processing techniques to specify attribute set and classifiers such as Support Vector Machine (SVM) [33], MultiLayer Perceptron (MLP) [34] for classification based on shape and color of pill images. Experiments are carried out using PIR dataset and as a result, SVM provides better accuracy of 99.5%. Another research is carried out for pill image classification using the same dataset but the authors utilize deep learning model namely Convolutional Neural Network (CNN) instead of machine learning model [35]. The authors used four different deep learning architecture namely ResNet50 [36], MobileNet [37], SqueezeNet[38] and InceptionV3[39]. It is evident from the experimental results that ResNet50 provides an average accuracy of 95.3%. A mobile pill recognition system namely MobileDeepPill was developed by Zeng et al. [40] which uses multi-CNN for classification of unconstrained pill images. Multi-CNN model provides an average accuracy of 95.6%.

A novel framework to recognize pill images using deep learning was introduced by S. Prabhu [41]. The author uses YOLOv5 for identification of pill strip and the text information in the pill strip is detected by text detection model. At last, text is recognized and the pill name is identified using text recognition module of the framework. Kwon et al. [42] implemented a deep learning algorithm to identify individual pills in an image which contains multiple pills. To accomplish this, the authors developed an efficient database expansion technique for a single pill and then perform pill detection. Look Alike and Sound Alike (LASA) is one of the most important issue faced by the patients at the time of medication. To solve this issue, a total of 250 blister packaged drug images from Out Patients Department of a hospital in Taiwan are collected and the deep learning framework namely YOLO is utilized to identify the pill images [43].

Table 1. Summary of existing research works for Medicine pill recognition

References	Machine Learning Algorithm	Methodology	Description
Vasavi et al. [13]	CNN	Text recognition + CNN	Text recognition to detect text from labels and extracted features from the text is given as input to CNN
Sudharshan borde et al. [14]	CNN	Feature extraction +CNN	Features based on shape, size and color of pill images are extracted and passed as input to CNN
Lee et al. [16]	CNN	Braille embosser system + CNN	Pill images are captures using smartphone with braille embosser system and CNN is used for classification which provides 99.6% accuracy.
Yeh et al. [17]	CNN	CNN + Text to speech conversion	CNN is used for Optical Character Recognition and the recognized text is converted into voice signals
Leung et al. [18]	CNN	OCR + CNN	Text in pill images is recognized using OCR and CNN is used for classification which provides 96.1% accuracy
Monica. R et al. [22]	CNN	Image Processing + CNN + raspberry pi	Pill images are captured and name of the pill can be read by CNN and sent as audio to the smart glass where raspberry pi is attached.
Chang et al. [23]	CNN – ResNet50	CNN – ResNet50 + Mobile application + Cloud-based information management platform	A wearable smart glass is designed using ResNet50 which provides 95.1 % accuracy.
Negi et al. [30]	YOLO	OCR+ Text to Speech + YOLO	Developed a mobile application by using OCR to identify text in pill images and extract features using YOLO.
Cordeiro et al. [32].	SVM + MLP	Image processing techniques + SVM +MLP	Image processing techniques are used to specify attribute set and SVM, MLP are used for classification. SVM and MLP provides 99.5% and 99.3% accuracy respectively.
Larios Delgado et al. [35]	CNN	Image processing techniques + CNN (ResNet50, MobileNet, SqueezeNet and InceptionV3)	Image processing techniques are used to specify attribute set and four different CNN architectures are utilized for classification. Among four architectures, ResNet50 provides 95.3% accuracy.
Zeng et al. [40]	CNN	Multi-CNN model	MobileDeepPill was developed using multi-CNN which provides 95.6% accuracy
Prabhu [41]	YOLOv5	Text detection model +YOLOv5	Text on the pill image is recognized using text detection model and YOLOv5.
Ting et al. [43]	YOLO	YOLO	Blister packaged pill images are identified using YOLO framework

Table 1 provides the summary of literature survey for Medicine pill recognition using Machine learning techniques which also includes deep learning approaches. It is observed from the table that most of the existing researchers use CNN model for medicine pill recognition system. While analyzing all the existing approaches, CNN with Braille embosser system provides better recognition accuracy which is 99.6%. It is also observed that second and third highest accuracy is provided by machine learning algorithms such as SVM and MLP respectively. One of the common facts is that results greatly rely on the dataset and the machine learning or deep learning model selected.

4. Resources

Some of the Databases and Websites/URLs related to Medicine Pill Recognition is provided in this section which helps the researchers in this area.

4.1. Databases

Details of few databases of pill images or pill datasets are summarized in Table 2.

Table 2. Datasets for Medicine pill recognition

Dataset	Source	URL
Pill Image data	National Library of Medicine	https://www.nlm.nih.gov/databases/download/pill_image.html
1k Pharmaceutical Pill Image Dataset	Kaggle	https://www.kaggle.com/datasets/trumedicines/1k-pharmaceutical-pill-image-dataset
Pharmaceutical Tablet dataset	Kaggle	https://www.kaggle.com/datasets/trumedicines/pharmaceutical-tablets-dataset
ePillID Dataset	Github	https://github.com/usuyama/ePillID-benchmark
Pillbox dataset	Kaggle	https://www.kaggle.com/datasets/dhuh137/pillbox
Pillbox dataset	National Institute of Health	https://data.world/nih/pillbox

4.2. Websites and URLs

Some of the useful websites and URLs related to Medicine pill recognition are as follows.

- https://www.scriptability.com/scriptalk-talking-labels - A mobile application namely "Scriptalk" which contains talking prescription labels specifically designed medications of visually impaired peoples.
- https://www.crunchbase.com/organization/trumedicines - A software for pill recognition namely "Trumedicines" which is developed using deep learning technology for visually challenged and low vision peoples.
- https://payorsolutions.cvshealth.com/insights/spoken-rx-new-talking-prescriptionlabel -app - A prescription reader application for visually impaired peoples.
- https://nfb.org/programs-services/knfb-reader - A mobile application for blind peoples which includes text detection as its significant feature which helps the medications of visually impaired peoples.

5. Conclusion

This research article reviews and presents numerous machine learning and deep learning techniques for identifying medicine pills. The review provides detailed introduction and statistical analysis of vision impairment. The survey is presented under different categories such as pill recognition using assistive devices, mobile applications and some other key discoveries using machine learning techniques. Details about databases, URLs/websites for pill recognition are also provided. Most assistive devices are wearable and it may not be affordable to all visually challenged peoples. Mobile applications help their medications but sometimes it may need minimum human intervention which is challenging for visually impaired peoples. So, developing a low-cost assistive device or system using a machine learning framework and developing a mobile application without human intervention will be the solutions for this issue. The survey

revealed that most of the existing medicine pill recognition system was developed using Convolutional Neural Network. Future researchers may focus on improving the recognition accuracy of CNN or using other deep learning models such as Artificial Neural Network and Recurrent Neural Network etc.

References

1. Fricke, TR, Tahhan N, Resnikoff S, Papas E, Burnett A, Suit MH, Naduvilath T, Naidoo K, "Global Prevalence of Presbyopia and Vision Impairment from Uncorrected Presbyopia: Systematic Review, Meta-analysis, and Modelling", Ophthalmology. 2018 May 9.
2. Burton MJ, Ramke J, Marques AP, Bourne RR, Congdon N, Jones I, et al. "The Lancet Global Health commission on Global Eye Health: vision beyond 2020". Lancet Glob Health. 2021; 9(4):e489–e551.
3. Liu, Lijuan, Yanping Wang, and Wanle Chi. "Image recognition technology based on machine learning." IEEE Access (2020).
4. https://www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment
5. https://www.nei.nih.gov/learn-about-eye-health/eye-health-data-and-statistics/all-vision-impairment-data-and-statistics/vision-impairment-tables
6. Zhi-Han, Ling, Yow Hui-Yin, and Mohd Makmor-Bakry. "Medication. handling Challenges among Visually Impaired Population." Archives of Pharmacy Practice 8, no. 1 (2017): 8-14.
7. Aarya Naik, Ghawate, AyushMahajan, Shreya Pawar, Pallavi Patil, "A Survey Paper on Drug Pill Recognition Using Artificial Intelligence". International Journal for Science and Advance Research in Technology.Vol. 8, No.11, Nov (2022).
8. Ushizima, Daniela, Allan Carneiro, Marcelo Souza, and Fatima Medeiros. "Investigating pill recognition methods for a new national library of medicine image dataset." In *Advances in Visual Computing: 11th International Symposium, ISVC 2015, Las Vegas, NV, USA, December 14-16, 2015, Proceedings, Part II 11*, pp. 410-419. Springer International Publishing, 2015.
9. Giles, Sally J., Maria Panagioti, Lisa Riste, Sudeh Cheraghi-Sohi, Penny Lewis, Isabel Adeyemi, Karen Davies et al. "Visual impairment and medication safety: a protocol for a scoping review." Systematic Reviews 10, no. 1 (2021): 1-6.
10. Almuzaini, Moudhi Ali, and M. Abdullah-Al-Wadud. "A review on medication identification techniques for visually impaired patients." In 2018 21st Saudi Computer Society National Computer Conference (NCC), pp. 1-6. IEEE, 2018.
11. Rajkomar, Alvin, Jeffrey Dean, and Isaac Kohane. "Machine learning in medicine." New England Journal of Medicine 380, no. 14 (2019): 1347-1358.
12. Vasavi, S., P. R. S. Swaroop, and Roshni Srinivas. "Medical assistive system for automatic identification of prescribed medicines by visually challenged from the medicine box using invariant feature extraction." Journal of Ambient Intelligence and Humanized Computing (2019): 1-10.
13. O'Shea, Keiron, and Ryan Nash. "An introduction to convolutional neural networks." arXiv preprint arXiv:1511.08458 (2015).
14. Sudarshan Borude, Sakshi Patil, Roshni Bhoirkar, Isheeta Shirsath, "Drug Pill Recognition System Using Deep Learning". International Research Journal of Engineering and Technology.Vol. 9, No.11, Nov (2022).
15. Heo, Junyeong, Youjin Kang, SangKeun Lee, Dong-Hwa Jeong, and Kang-Min Kim. "An Accurate Deep Learning–Based System for Automatic Pill Identification: Model Development and Validation." Journal of Medical Internet Research 25 (2023): e41043.
16. Lee, Soyeong, Sunhae Jung, and Hyunjoo Song. "Cnn-based drug recognition and braille embosser system for the blind." Journal of Computing Science and Engineering 12, no. 4 (2018): 149-156.

17. Yeh, Jui-Feng, Chan-Yi Liu, Sheng Chen, Jia-Yu Lin, and Li-Ting Zhang. "Intelligent Medication Reminding System for Visually Challenged Groups." International Journal of Machine Learning and Computing 10, no. 5 (2020).
18. Leung, Man-Fai, Hangjun Che, Chin-Hung Kwok, and Lewis Chan. "A hybrid intelligent system for assisting low-vision people with over-the-counter medication." In 2022 12th International Conference on Information Science and Technology (ICIST), pp. 38-44. IEEE, 2022.
19. Walle, Helene, Cyril De Runz, Barthélemy Serres, and Gilles Venturini. "A Survey on Recent Advances in AI and Vision-Based Methods for Helping and Guiding Visually Impaired People." Applied Sciences 12, no. 5 (2022): 2308.
20. Tapu, Ruxandra, Bogdan Mocanu, and Titus Zaharia. "Wearable assistive devices for visually impaired: A state of the art survey." Pattern Recognition Letters 137 (2020): 37-52.
21. Elmannai, Wafa, and Khaled Elleithy. "Sensor-based assistive devices for visually-impaired people: Current status, challenges, and future directions." Sensors 17, no. 3 (2017): 565.
22. Monica, R., K. Nirmala, B. Divya, and L. Suganthi. "Recognition of medicine using cnn for visually impaired." In 2020 International Conference on Communication and Signal Processing (ICCSP), pp. 1462-1466. IEEE, 2020.
23. Chang, Wan-Jung, Liang-Bi Chen, Chia-Hao Hsu, Jheng-Hao Chen, Tzu-Chin Yang, and Cheng-Pei Lin. "MedGlasses: A wearable smart-glasses-based drug pill recognition system using deep learning for visually impaired chronic patients." IEEE Access 8 (2020): 17013-17024.
24. Griffin-Shirley, Nora, Devender R. Banda, Paul M. Ajuwon, Jongpil Cheon, Jaehoon Lee, Hye Ran Park, and Sanpalei N. Lyngdoh. "A survey on the use of mobile applications for people who are visually impaired." Journal of Visual Impairment & Blindness 111, no. 4 (2017): 307-323.
25. Hussain, Azham, and Ahlam Mohamed Omar. "Usability evaluation model for mobile visually impaired applications." (2020): 95-107.
26. Al-Razgan, Muna, Sarah Almoaiqel, Nuha Alrajhi, Alyah Alhumegani, Abeer Alshehri, Bashayr Alnefaie, Raghad AlKhamiss, and Shahad Rushdi. "A systematic literature review on the usability of mobile applications for visually impaired users." PeerJ Computer Science 7 (2021): e771.
27. Dinari, Fatemeh, Kambiz Bahaadinbeigy, and Khadijeh Moulaei. "Analysis of requirements for developing a mobile device-based medicines management application for people who are blind and visually impaired." Journal of Pharmacy Practice and Research 52, no. 3 (2022): 236-246.
28. Mishra, Anubhav, and R. Vedhapriyavadhana. "Medicine assistance application for visually impaired people." In 2022 Third International Conference on Intelligent Computing Instrumentation and Control Technologies (ICICICT), pp. 850-855. IEEE, 2022.
29. Shishir, Md Amanat Khan, Shahariar Rashid Fahim, Fairuz Maesha Habib, and Tanjila Farah. "Eye Assistant: Using mobile application to help the visually impaired." In 2019 1st International Conference on Advances in Science, Engineering and Robotics Technology (ICASERT), pp. 1-4. IEEE, 2019.
30. Negi, Angel, Aishwarya Bhure, Dhanashree Patil, Akshita Maskara, and Madhuri Bhalekar. "Medicine Identification Application for Visually Impaired People." Turkish Journal of Computer and Mathematics Education (TURCOMAT) 12, no. 14 (2021): 748-755.
31. Jiang, Peiyuan, Daji Ergu, Fangyao Liu, Ying Cai, and Bo Ma. "A Review of Yolo algorithm developments." Procedia Computer Science 199 (2022): 1066-1073.
32. Cordeiro, Luan Sousa, Joyce Saraiva Lima, A. Iedo Rocha Ribeiro, Francisco Nivando Bezerra, Pedro P. Rebouças Filho, and Ajalmar R. Rocha Neto. "Pill image classification using machine learning." In 2019 8th Brazilian Conference on Intelligent Systems (BRACIS), pp. 556-561. IEEE, 2019.
33. Suthaharan, Shan, and Shan Suthaharan. "Support vector machine." Machine learning models and algorithms for big data classification: thinking with examples for effective learning (2016): 207-235.
34. Delashmit, Walter H., and Michael T. Manry. "Recent developments in multilayer perceptron neural networks." In Proceedings of the seventh Annual Memphis Area Engineering and Science Conference, MAESC. 2005.

35. Larios Delgado, Natalia, Naoto Usuyama, Amanda K. Hall, Rebecca J. Hazen, Max Ma, Siva Sahu, and Jessica Lundin. "Fast and accurate medication identification." NPJ digital medicine 2, no. 1 (2019): 10.

36. He, Kaiming, Xiangyu Zhang, Shaoqing Ren, and Jian Sun. "Deep residual learning for image recognition." In Proceedings of the IEEE conference on computer vision and pattern recognition, pp. 770-778. 2016.

37. Howard, A. G. et al. MobileNets: efficient convolutional neural networks for mobile vision applications. ArXiv e-prints (2017).

38. Iandola, F. N. et al. SqueezeNet: AlexNet-level accuracy with 50× fewer parameters and <0.5MB model size. ArXiv e-prints (2016).

39. Szegedy, C., Vanhoucke, V., Ioffe, S., Shlens, J. & Wojna, Z. Rethinking the Inception Architecture for Computer Vision. CoRR abs/1512.00567 (2015).

40. Zeng, Xiao, Kai Cao, and Mi Zhang. "MobileDeepPill: A small-footprint mobile deep learning system for recognizing unconstrained pill images." In Proceedings of the 15th Annual International Conference on Mobile Systems, Applications, and Services, pp. 56-67. 2017.

41. Prabu, S. "Real-Time Pill Detection and Recognition Framework Based on a Deep Learning Algorithm." In Advancement, Opportunities, and Practices in Telehealth Technology, pp. 117-137. IGI Global, 2022.

42. Kwon, Hyuk-Ju, Hwi-Gang Kim, and Sung-Hak Lee. "Pill detection model for medicine inspection based on deep learning." Chemosensors 10, no. 1 (2022): 4.

43. Ting, Hsien-Wei, Sheng-Luen Chung, Chih-Fang Chen, Hsin-Yi Chiu, and Yow-Wen Hsieh. "A drug identification model developed using deep learning technologies: experience of a medical center in Taiwan." BMC health services research 20, no. 1 (2020): 1-9.