SBC-Based Cataract Detection System using Deep Convolutional Neural Network with Transfer Learning Algorithm

Kenneth C. Karamihan, Ivan Dave F. Agustino, Ronnick Bien B. Bionesta, Ferangelo C. Tuason, Steven Valentino E. Arellano, Phillip Amir M. Esguerra

Abstract*: *This Raspberry Pi Single Board Computer-Based Cataract Detection System using Deep Convolutional Neural Network through GoogLeNet Transfer Learning and MATLAB digital image processing paradigm based on Lens Opacities Classification System III with Python application, which would capture the image of the eyes of cataract patients to detect the type of cataract without using dilating drops. Additionally, the system could also determine the severity, grade, color or area, and hardness of cataract. It would also display, save, search and print the partial diagnosis that can be done to the patients. Descriptive quantitative research, Waterfall System Development Life Cycle and Evolutionary Prototyping Models was used as the methodologies of this study. Cataract patients and ophthalmologists of one of the eye clinics in City of Biñan, Laguna, as well as engineers and information technology professionals tested the system and also served as respondents to the conducted survey. Obtained results indicated that the detection of cataract and its characteristics using the system were accurate and reliable, which has a significant difference from the current eye examination for cataract. Generally, this would be a modern cataract detection system for all Cataract patients.

Index Terms*: *Cataract detection, Deep Convolutional Neural Network, Digital image processing, Transfer learning.

I. INTRODUCTION

Cataract is a clouding of the eye lens, which is the transparent portion of the eye that aids on focusing the illumination or image on the retina that affects the visual quality. Approximately 253 million cases of people worldwide were visually impaired, with 36 million blind and 217 million experiencing poor eyesight [1]. In the Philippines as of the year 2017, there were an estimated 332,150 bilaterally blind people and 33% or around 109,609 cases were due to cataract [2]. In diagnosing eye cataracts, Slit lamp and dilating drops are used for a dilated eye examination, which enables the ophthalmologist to analyze and observe the retina, optic nerve and other internal parts of the eye [3]. Moreover, dilating drops can produce side effects like light sensitivity, blurred vision, swelling of eyelids and the rise in eye pressure, which can all last for four hours to two weeks depending on the drug used [4]. Nowadays, camera modules are widely used and integrated with numerous kinds of devices such as mobile phones, personal computers (PC) or single board computers (SBCs) like the Raspberry Pi (RPi). The RPi SBC is a credit-sized computer that performs the same way as a desktop PC [5] and allows the users to program internally or even import ready-made programs for different operations like image processing [6]. Besides, Matrix Laboratory (MATLAB) is the much-preferred mathematical computing software of the researchers utilizing system designs and algorithms to define input data sets in a simulation environment. In addition, Machine learning has a technique called Transfer Learning where it can train a model by reusing these parts or modules of existing developed models and haste the time it takes to train and develop a pre-trained Deep Convolutional Neural Network (DCNN) model [7]. For instance, GoogLeNet v4 (version 4) is a DCNN model with an error rate of only 3.08%, which is extremely close to a human level of performance [8]. DCNNs are extremely efficient in analyzing huge loads of images automatically as well as classifying features that can identify images with least error, and they are infrequently trained from scratch, as it is relatively unusual to have a domain-specific dataset of sufficient size. For developing websites, web applications, and desktop graphical user interface (GUI) applications, Python can be utilized to build a prototype of the software application rapidly and it also provides an interface for working with SQLite (Structured Query Language) database [9].

The developed system could help the cataract patients as well as the ophthalmologists to provide a convenient method of detecting the presence of cataract by utilizing a camera embedded with the RPi SBC through digital image processing and machine learning. This study could help the cataract patients as well as the ophthalmologists to reduce the use of dilating drops along with the subjectiveness of the eye examination for cataract. Compelling results of technology take humanity one step closer to unravel some of the biggest health challenges of the world, and, in a matter of time,

Revised Manuscript Received on July 16, 2019.

Kenneth C. Karamihan, Computer Engineering Department, College of Engineering, University of Perpetual Help System Laguna, City of Biñan, Laguna, 4024 Philippines. E-mail: kckaramihan@gmail.com

Ivan Dave F. Agustino, Computer Engineering Department, College of Engineering, University of Perpetual Help System Laguna, City of Biñan, Laguna, 4024 Philippines. E-mail: ivandaveagustino@gmail.com

Ronnick Bien B. Bionesta, Computer Engineering Department, College of Engineering, University of Perpetual Help System Laguna, City of Biñan, Laguna, 4024 Philippines. E-mail: bionesta21@gmail.com

Ferangelo C. Tuason, Computer Engineering Department, College of Engineering, University of Perpetual Help System Laguna, City of Biñan, Laguna, 4024 Philippines. E-mail: gelotuason@gmail.com

Steven Valentino E. Arellano, Computer Engineering Department, College of Engineering, University of Perpetual Help System Laguna, City of Biñan, Laguna, 4024 Philippines.

Phillip Amir M. Esguerra, Electronics Engineering Department, College of Engineering, University of Perpetual Help System Laguna, City of Biñan, Laguna, 4024 Philippines.

transform the diagnosis, management, and treatment of patients with sight-threatening conditions [10].

A. *Conceptual Model*

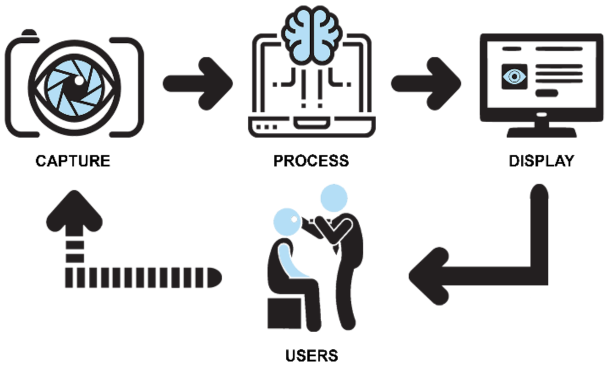


Fig. 1. The Conceptual Model of the Study.

Fig. 1 illustrates the conceptual model of this study that depicted the Cataract Detection System for patients and ophthalmologists with the use of the captured image of the eye. The input and processing phases are being implemented by the SBC, which generated the presence and state of the cataract through the monitor of the system. The system performed an operation wherein the captured image of the eye of patient serves as the input data then by the processing phase of the system, which is the machine learning algorithm that the SBC performs. Captured image of the eye of patient is analyzed using the camera embedded with the SBC. The output phase is the analyzed image with the cataract type, grade, color or area, and hardness being displayed on the Touch-Enabled Liquid Crystal Display (LCD) monitor of the system to show the generated results to the users.

B. *Statement of the Problem*

This Cataract Detection System was developed with the use of Raspberry Pi Single Board Computer through MATLAB Digital Image Processing paradigm and Deep Convolutional Neural Network with GoogLeNet Transfer Learning Algorithm to reduce the use of dilating drops and subjectiveness of the eye examination for cataract patients. This study specifically sought answers to the following sub-problems:

1. What is the rate of accuracy of the algorithm used in detecting the presence of the cataract using the developed system?
2. What is the rate of reliability of the developed system in terms of detecting the presence of the cataract according to its type, severity, grade, color or area, and hardness?
3. Is there any significant difference between the current eye examination for cataract and in using the developed system in terms of the rate of reliability?

C. *Scope and Delimitation*

The system was able to produce the severity, grade, color or area, and hardness of the captured cataract images from the patients. The application (app) has a database that would store, save, search, and delete the profile of the patient including the results of the test using the developed system. The ophthalmologists who have the privilege to use the app and access the database must provide their registered username and password on the system. The database contained the name, age, occupation, medical history and the results of the diagnostic tests, which are printable in Portable Document File (PDF) format. Other possible interruptions should be considered as delimitation such as power disruption and patients with pupils less than 4mm (millimeters) wide upon dilation. Moreover, the developed system was not able to produce the severity, grade, color or area, and hardness of the Posterior Sub-Capsular Cataract but it is possible to classify it. Furthermore, the selection of the Region of Interest (ROI) for area computation and color sampling for cataract of the user could affect the result as well as the image quality and the lens flare.

II. LITERATURE REVIEW

Digital image processing is a common way of extracting image data under a series of processes using algorithms to produce accurate results [11][12][13]. Meanwhile, machine learning was utilized to train the machines on how to collect such data more effectively. By analyzing the image, the system was the one who would automatically sort according to its classification it belongs with [14]. Additionally, TensorFlow allows machine learning to perform more data-intensive computing and training of machine models [15]. Moreover, transfer learning uses existing DCNN machine learning architectures like GoogleNet in order to improvise and utilized its error rate of only 3.08% to be trained using new classifications according to its use [16]. Furthermore, with the use of the standard images of Lens Opacities Classification System (LOCS) III, the image of cataract could be classified according to its type, grade, color, and area. Additionally, to capture the image of the lens of the eye, dilation time of 2 to 10s (seconds) under the dark must be observed to achieve the maximum size of the pupil [17][18]. Furthermore, prototyping image processing algorithm in hardware is much easier on RPi SBC due to its low cost and form factor packed with multiple functions [5].

This related literature and studies served as a basis to widen and deliver a reliable as well as an accurate method of detecting the type of cataract for patients and ophthalmologists. DCNN and SBC were the main modules used in this study and the output data of the developed system were the type of Cataract, severity, grade, color or area, and hardness. It would serve as an assistive device for ophthalmologists. Throughout the development of this study and based on the related literature along with the studies referenced above, the distinguished gaps as there were no further studies made using SBC that included making an assistive device for ophthalmologists especially those involving the application of digital image processing along with neural network. Additionally, no local studies measured the rate of accuracy and reliability of an assistive device for ophthalmologists.

The aim of this study was to resolve the problems experienced by the ophthalmologists on an everyday routine by providing them with a convenient assistive cataract detection system. The combinational use of SBC, digital image processing, and DCNNs can potentially introduce an accurate and reliable way of cataract detection. This system would also provide an application that would get the personal information of the patient with cataract for display or for printing using Python and SQLite database application. Convincingly, the researchers have developed a source for further study in the field of ophthalmology, digital image processing, machine learning, transfer learning, and assistive technologies.

III. METHODOLOGY

A. *Research Design*

The descriptive quantitative method was used for research design in order to illustrate existing conditions so that these could be manipulated later on as an outcome of the research. Quantitative research would be used since it inspects the connection among variables about testing objective systems [17].

B. *System Development Model*

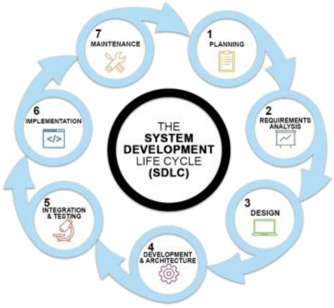


Fig. 2. System Development Life Cycle.

Waterfall approach of this System Development Life Cycle (SDLC) model was used in developing the system, in which the development process flows through separate phases, to develop a Cataract Detection System especially the hardware modules and software suites of the developed system since the evolutionary prototyping model as shown in Fig. 2 was below the analysis phase of the SDLC model.

C. *Population of the Study*

The population of this study was composed of 15 male and 15 female patients, 10 engineers and IT (information technology) professionals, and 5 ophthalmologists, for a total of 45 respondents. The researchers used the stratified type of sampling since the primary sources of data would be fractionalized into two (2) groups, the gender of the patients, and the ophthalmologists. The locale of this study was in Asia-Pacific Eye Center (APEC) located in Brgy. San Antonio, City of Biñan, Laguna. This is one of the eye clinics in the said city, which handles patients with different cases of eye problems such as Cornea and external eye disease, Cataract, Strabismus, and Glaucoma.

D. *Data Gathering Procedure*

Closed-ended questionnaires with Likert scale, initial and final structured type of interviews, consultation from engineers and IT professionals, as well as evaluation of the developed system was used as research instruments to collect important details for an insightful understanding of this study. Moreover, weighted mean and composite mean or average was used to verify the rates of accuracy and reliability of the current eye examination for cataract and the developed system for the statistical treatments. In addition, the percentage was also used to identify the rate of reliability of the developed system, and t-test to verify the significant difference between the current eye examination for cataract and the developed system in terms of the reliability percentage. Validation by the thesis adviser as well as the coordinator was executed, which included the authenticating, maintaining and studying of every data collected. It offered important information to the performance absences under contemplation and head to the good quality performance of the system.

IV. SYSTEM DEVELOPMENT

A. *System Requirements and Specifications*

Table I. System Requirements

System Requirements	Characteristic Properties
Operating System Used:	Raspbian 8 (Jessie) - Raspbian 9 (Stretch)
Programming Language(s):	MATLAB R2018b Python 3.0-3.7
Database Language(s):	SQLite 3.0.0 – 3.26.0
Integrated Development Environments (IDEs):	Thonny IDE 2.1.19 - 3.0.8 MATLAB IDE R2018b
Input Data/Device(s):	Captured Eye Image Touch-Enabled LCD Monitor Keyboard
Output Data/Device(s):	Touch-Enabled LCD Monitor SMD LED 5050 PDF File (Inkjet Printer)
No. of LEDs Used:	2
Sensor(s) / Camera(s):	Raspberry Pi Camera V2
No. of Sensor(s) / Camera(s) Used:	1
Single-Board Computer(s):	Raspberry Pi 3 Model B+
No. of Single-Board Computer Used:	1
Switch(es):	SPST (Single-Pole, Single-Throw)
No. of Switch Used:	1
Power Source:	DC Power Supply • Input: 100~240V_{ac} 50/60Hz • Output: 5V_{dc} 0.6A-3A

Table II. System Specifications

System Specifications	Characteristic Properties
Types of Cataract:	Cortical Nuclear Posterior Sub-Capsular
Types of Images:	JPEG PNG
Working Temperature:	20^{O}C – 70^{O}C
Indicator(s):	PWR LED ACT LED
Operating Voltage:	5V_{dc}
Operating Current:	0.6A-3A
Internal Memory:	1 GB
External Memory:	32 GB – 64 GB
Weight:	542.23g / 1.20 lbs.
Height:	10.2 cm / 4.0157 in.

LED Flash:	5050 SMD LED
Screen Resolution:	1024x768
Camera Resolution:	640x480 1024x768 1280x720 1920x1080

B. *System Block Diagram*

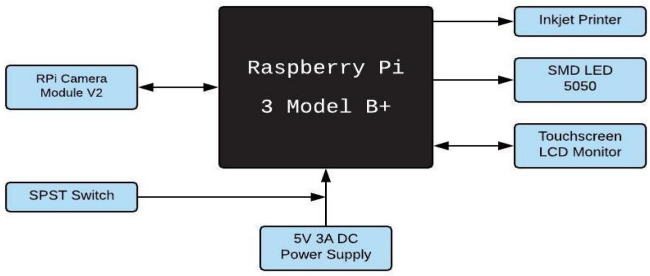


Fig. 3. System Block Diagram.

C. *System Flowchart Diagram*

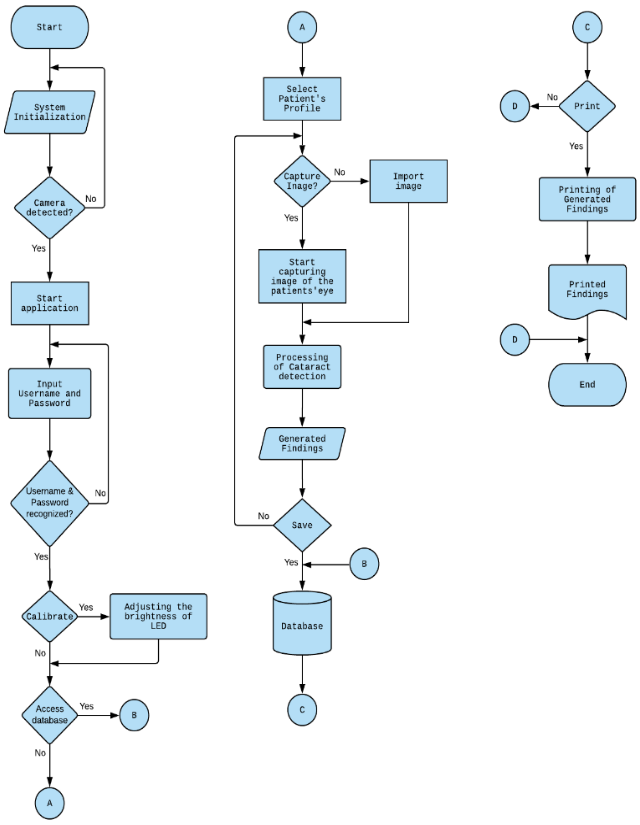


Fig. 4. System Flowchart Diagram.

Fig. 4 shows the system flowchart diagram where the flow of the system started from the initialization of the system; afterwards, the detection of the camera would occur. Then, the user must open the application and log in their username and password. By logging in, the user could calibrate the brightness or access database to view or print the generated findings. Moreover, after calibrating, the user must input the profile of the patient to be diagnosed for Cataract detection. Furthermore, the user could select the operation of Cataract detection whether to capture the image in frontal view or slit view, or manually import an image to the application. After the image was processed, the system will generate the results showing the captured or imported image with its cataract type, relevance score, grade, color or area, hardness, and severity. The results were recorded in the database if the user agreed to save it, otherwise, the user should capture an image again. In addition, the user could print the results as the system also generates a PDF file through the View Records button or after agreeing on the message dialog box and saving the results.

D. *System Schematic Diagram*

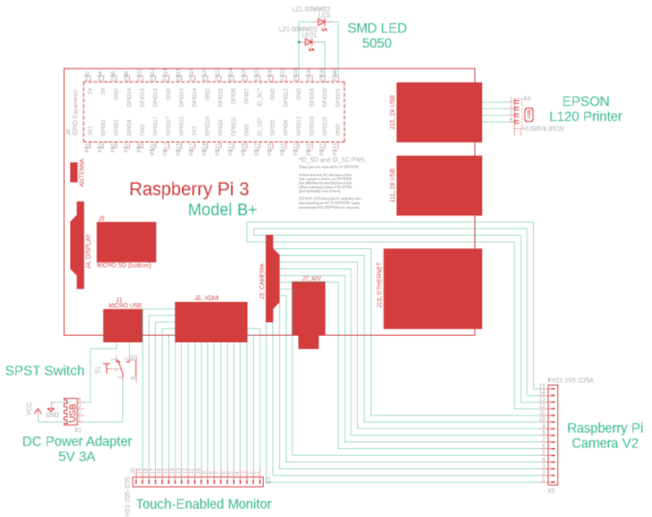


Fig. 5. System Schematic Diagram.

E. *System Structural and Hardware Architecture*

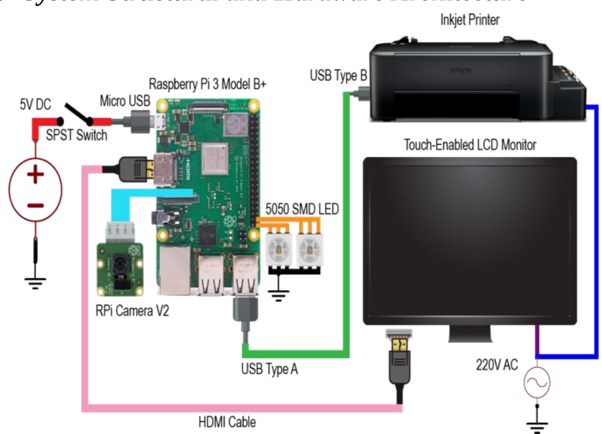
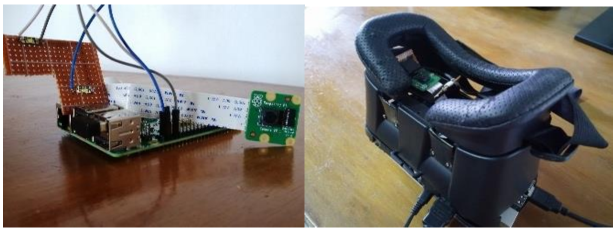


Fig. 6. System Hardware Architecture Model.

Fig. 6 shows the hardware architecture model of the system conducted, which illustrated the electrical and electronic components of the system, a $5V_{dc}$ power supply with SPST Switch which was connected to the Micro USB port of Raspberry Pi 3 Model B+ SBC. Touch-Enabled LCD Monitor was connected using HDMI Cable, while the Inkjet Printer was connected using a USB Type A to USB Type B printer cable, whereas they have a separate AC supply. 5050 SMD LEDs was connected through GPIO pins. Moreover, the RPI Camera V2 was also connected to the Camera Serial Interface (CSI) port of the SBC.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication



(a) (b)

Fig. 7. (a) Actual System Hardware Architecture and (b) Actual System Structural Architecture.

F. *System Software Architecture*

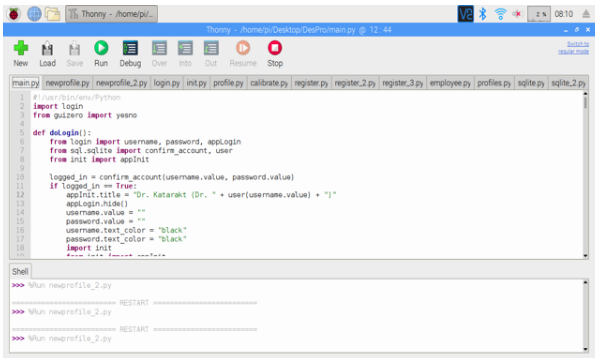
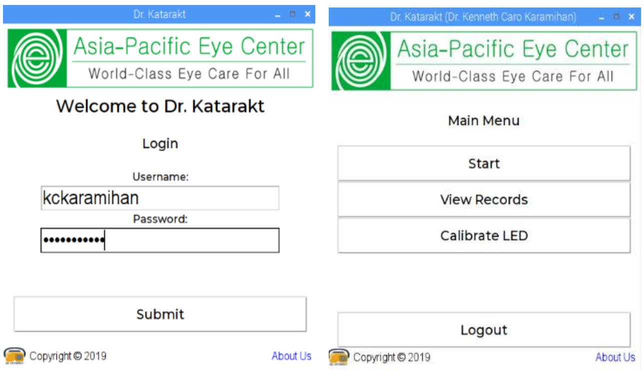


Fig. 8. Thonny IDE.

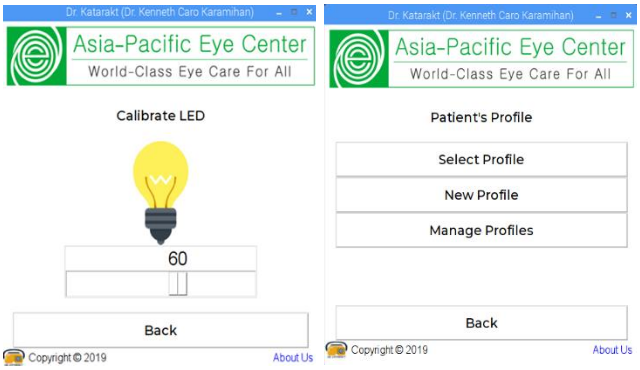
Fig. 8 shows the Thonny IDE Python programming was responsible in generating the GUI of the system, and the said application was also the one that manages its overall database management through SQLite and manipulates the camera module for the image processing and machine learning capabilities.

G. *System Implementation*

(a) (b)

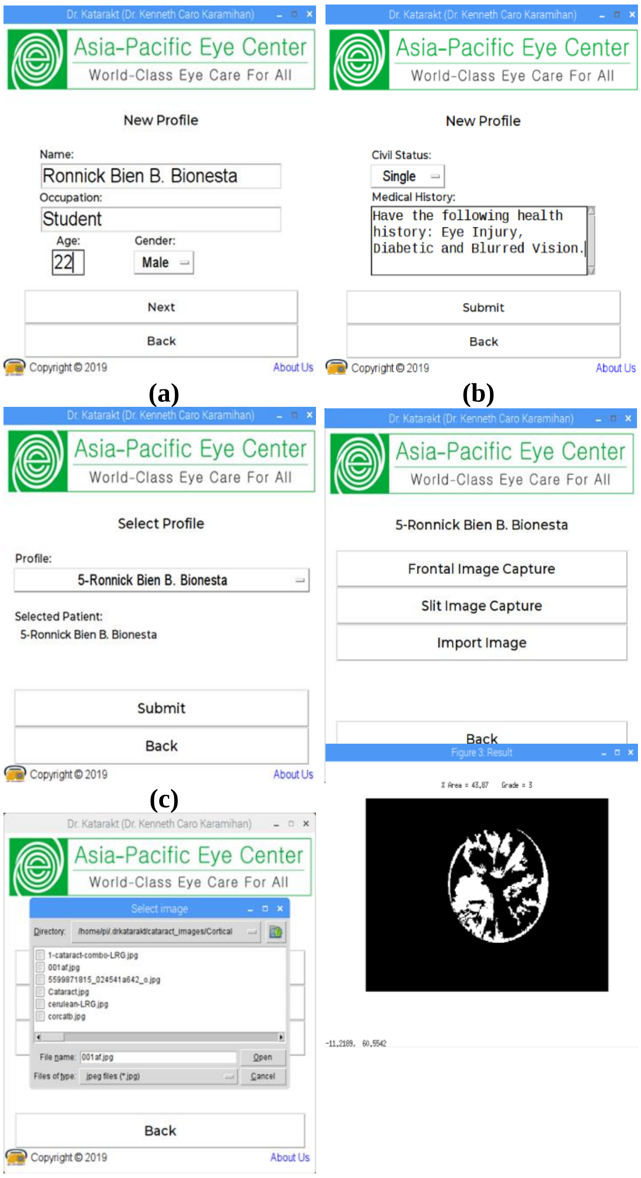


(c) (d)



(e) (f)

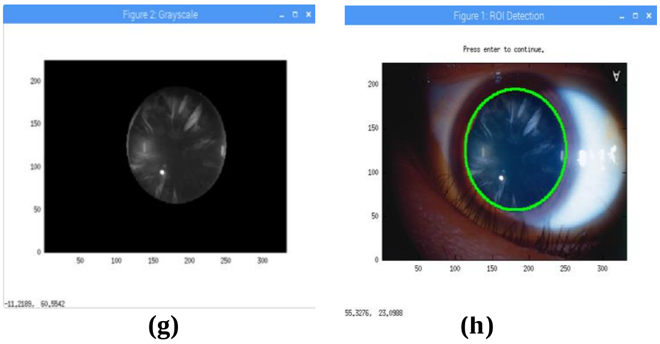
Fig. 9. (a) Actual System Prototype and (b) Wearable Device of the System, (c) Log-in Window User Interface and (d) Main Menu, (e) LED Calibration Window User Interface, and (f) Profile Menu.



(a) (b)

(c)

(e) (f)



(g) (h)

Fig. 10. (a) New Profile A Window User Interface, (b) New Profile B Window User Interface, (c) Profile Selection Window User Interface, (d) Cataract Detection Menu, (e) Import Image Window User Interface, (f) ROI Window, (g) Grayscale Image Result, and (h) Binarized Image Result (for classification of Cortical type of cataract).

(a)

Fig. 11. (a) Cataract Detectio

Fig. 12. Dr. Katarakt: System Logo.

V. RESULTS AND DISCUSSION

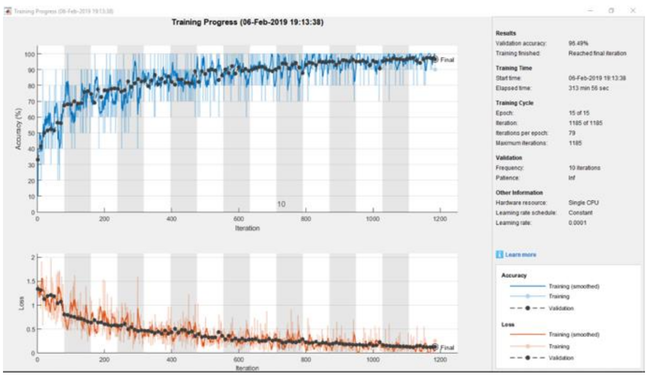


Fig. 13. MATLAB DCNN Transfer Learning Result.

Fig. 13. Shows the progress results in training the DCNN model for classifying the cataract types using MATLAB, which lasted for about 5.5 hours. In addition, the DCNN model acquired a 96.49% validation accuracy rate for the data set size D illustrated in Table III. Specifically, MATLAB digital image processing paradigm was responsible with the cataract grading by extracting the ROI, producing binarized image and color comparison.

Table III. Lens Opacities Classification System (Locs) Iii In Classifying The Severity, Grade, Color Or Area, And Hardness Of Cataract

Severity	Grade	Color	Area Occupied	Hardness
Normal	0.0	N/A	0 – 1	N/A
Minor	1.0	Pale Gray	2 – 5	Very Soft
Mild	2.0	Yellowish-Gray	6 – 25	Soft
Moderate	3.0	Yellowish	26 – 50	Fairly Soft
Moderately Severe	4.0	Amber Yellow	51 – 75	Hard
Severe	5.0	Dark Brown	78 - 100	Very Hard

Note. Retrieved from Nuclear Sclerosis Cataract Grading by Healio. Copyright 2019.

On the other hand, Table III shows the LOCS III, which was used in order to classify the different characteristics of the cataract such as severity, grade, color, area occupied, and hardness. Furthermore, this portrayed the extremity of the cataract, and helped the ophthalmologists to determine the appropriate procedures the patient must undergo.

Table IV. Likert Scale Of The Rate Of Reliability Of The System In Classifying The Type Of Cataract, Severity, Grade, Color Or Area, And Hardness

Numerical Value	Reliability Percentage Yield	Interpretation
5	91% - 100%	Very Reliable
4	81% - 90%	Reliable
3	71% - 80%	Fairly Reliable
2	61% - 70%	Unreliable
1	60% and below	Very Unreliable

Table IV shows the Likert Scale which was used by the researchers in evaluating the rate of reliability of the developed system. In addition, the scale served as the basis of the researchers in terms of the classifications of the cataract such as the type of cataract, severity, grade, color or area, and hardness.

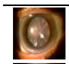
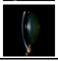
Table V. Accuracy Rate Evaluation For Different Data Set Sizes

Data Set	Size	TP	TN	FP	FN	Accuracy Percentage
A	100 images	12	8	33	7	33.33%
B	200 images	27	13	18	2	66.67%
C	300 images	38	15	7	0	88.33%
D	400 images	45	15	0	0	100.00%

Note.

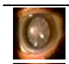
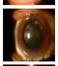
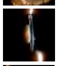
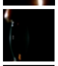
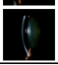
TP (True-Positive) - Positive instances classified
TN (True-Negative) - Negative instances classified
FP (False-Positive) - Positive instances misclassified
FN (False-Negative) - Negative instances misclassified

Table VI. Classification Of The Type Of Cataract, Severity, Grade, Color Or Area, And Hardness Using The Developed System

Test	Type	Severity	Grade	Color/ Area	Hardness	Reliability Percentage
	CC	Severe	5.0	80.94%	Very Hard	100%
	CC	Moderate	3.0	48.47%	Fairly Soft	100%
	NC	Severe	5.0	Dark Brown	Very Hard	100%
	NE	Normal	0.0	N/A	N/A	100%
	NC	Minor	1.0	Pale Gray	Very Soft	100%
Composite Mean						100%

Note. NE (Normal Eye) - Clear lens with no signs of Cataract, NC (Nuclear Cataract) - Opaque cloudiness in the lens nucleus, CC (Cortical Cataract) - Opaque cortical spikes in the lens cortex, and PSC (Posterior Sub-Capsular Cataract) - Granular deposits in the lens capsule.

Table VII. Classification Of The Type Of Cataract, Severity, Grade, Color Or Area, And Hardness Using The Current Eye Examination For Cataract

Test	Type	Severity	Grade	Color/ Area	Hardness	Reliability Percentage
	CC	Severe	5.0	80.94%	Very Hard	100%
	CC	Moderately Severe	4.0	75%	Hard	20%
	NC	Severe	5.0	Dark Brown	Very Hard	100%
	NE	Normal	0.0	N/A	N/A	100%
	NC	Minor	1.0	Pale Gray	Very Soft	100%
Composite Mean						84%

Note. NE (Normal Eye) - Clear lens with no signs of Cataract, NC (Nuclear Cataract) - Opaque cloudiness in the lens nucleus, CC (Cortical Cataract) - Opaque cortical spikes in the lens cortex, and PSC (Posterior Sub-Capsular Cataract) - Granular deposits in the lens capsule.

Table VIII. Significant Difference Between The Current Eye Examination For Cataract And In Using The Developed System In Terms Of The Rate Of Reliability

Rate of Reliability		t - Value	p - Value	Interpretation
Current	Developed			
84%	100%	2.3060	0.0040	Significant

Note. Significant @0.05

Current - Rate of Reliability of the Current Eye Examination for Cataract in terms of Reliability Percentage Yield (RPY)

Developed - Rate of Reliability of the System in terms of Reliability Percentage Yield (RPY)

Table VIII shows that a significant increase in data set sizes gave positive effects on the accuracy of the model, thus providing a better model for classifying cataracts for each increase. The results portrayed in Table V shows that the developed system had an average Reliability Percentage Yield of 100% in comparison with the readings of the ophthalmologists with 84% reliability as shown in Table VI. Captured eye images from the patients were tested in both the current and developed systems as shown in Tables V and VI together with the assistance of the ophthalmologist and the researchers as well. In addition, Table VII portrayed the rates of reliability between the current eye examination for cataract and the developed system, as well as the t and p-values in order to identify the significant difference. With this, the t-value attained 2.3060 and the p-value with 0.0040 at 0.05 significance, thus the interpretation is significant.

VI. CONCLUSIONS AND RECOMMENDATIONS

The developed system was exceedingly accurate in detecting the presence and type of cataract due to the great amount of data set size used. With this, the accuracy of the model increased significantly, which enabled the system to classify the cataract type successfully for further diagnosis. In addition, the developed system underwent a series of tests and was able to attain a high rate of reliability since it produced valuable results with the readings of the ophthalmologists as a reference. Consequently, this proved that the system was capable of being a dependable assistive device for the ophthalmologists in detecting cataracts. As such, the reliability percentage yield of the developed system was much higher than the current system, and have the edge over it which was subjective and relied on using dilating drops. The obtained results proved and signified that the main problem of this study was provided a credible solution using the developed system. For further improvement of the system, including additional classifications on the DCNN model such as the subtypes of cataract since the researchers only focused on its 3 main types. Likewise, in order to classify the characteristics of the Posterior Sub-Capsular Cataract come upon a method that enables a camera to capture the red reflex of the eye through retro-illumination. For the accuracy and reliability of the developed system, improve the automatic selection of ROI in extracting the pupil of the eye image in order to produce a more accurate classification of cataract.

ACKNOWLEDGMENT

The researchers would like to thank their thesis coordinators, Dr. Flocerfida Laza-Amaya, ASEAN Engineer – Dean of the College of Engineering, Architecture and Aviation; Engr. Kierven R. de Mesa of the College of Engineering, and Engr. Rodolfo V. Mendoza – Assistant Dean of the College of Engineering, Architecture and Aviation at University of Perpetual Help System Laguna. Secondly, the researchers would also like to thank Dr. Marino S. Duran and Dr. Khristine, Ophthalmologists, Asia Pacific Eye Center Biñan Branch for being accommodating and helpful in providing the list of respondents and consultations in this research. Furthermore, the researchers would like to thank as well Dr. Corazon B. Rebong – Dean School of Engineering, Colegio de San Juan de Letran Calamba and President of Institute of Computer Engineers of the Philippines – Region 4A for her unending support and guidance for the CpE students of Region 4A. The researchers would like to express their profound gratitude to their parents, brothers, sisters, and friends for providing them with unfailing support and continuous determination. Finally, overwhelming gratefulness to our God Almighty for giving the researchers strength and humility to do good things above all.

REFERENCES

1. World Health Organization. (2017, October). Causes and Magnitude of Blindness and Visual Impairment [Online]. Available: http://www.who.int/en/news-room/fact-sheets/detail/blindness-and-visual-impairment
2. Department of Health. (2017, August 6). Public Told: Protect Your Eyes From Blindness [Online]. Available: https://portal2.doh.gov.ph/node/10735
3. Encyclopedia Britannica. (2018). Ophthalmoscope [Online]. Available: https://www.britannica.com/technology/ophthalmoscope
4. S. Perkins. (2017, August). Side Effects of Dilating Eyes [Online]. Available: https://www.livestrong.com/article/56805-side-effects-dilating-eyes/
5. Raspberry Pi Foundation. (2019, March). What is a Raspberry Pi [Online]. Available: https://www.raspberrypi.org/help/faqs
6. G. Anbarjafari. (2014, November 9). Introduction to Image Processing [Online]. Available: https://sisu.ut.ee/imageprocessing/avaleht
7. B. Curry. (2018, July 27). An Introduction to Transfer Learning in Machine Learning [Online]. Available: https://medium.com/kansas-city-machine-learning-artificial-intelligen/an-introduction-to-transfer-learning-in-machine-learning-7efd104b6026
8. S. Tsang. (2018, September 27). Review: Inception-v4 — Evolved From GoogLeNet, Merged with ResNet Idea (Image Classification) [Online]. Available: https://towardsdatascience.com/review-inception-v4-evolved-from-googlenet-merged-with-resnet-idea-image-classification-5e8c339d18bc
9. Mindfire Solutions. (2017, October 3). Python: 7 important Reason Why You Should Use Python [Online]. Available: https://medium.com/@mindfiresolutions.usa/python-7-important-reasons-why-you-should-use-python-5801a98a0d0b
10. M. Suleyman. (2018, August 14), Alphabet's Deep Mind Uses A.I. to Detect Signs of Eye Disease [Online]. Available: https://www.cnbc.com/2018/08/14/deepmind-uses-ai-to-detect-signs-of-eye-disease.html
11. W. Burger & M. Burge. *Digital Image Processing: An Algorithmic Introduction Using Java*. New York: Springer-Verlag, 2016, pp.1-2.
12. W. Thielicke & E. Stamhuis. (2014, October 16). PIVlab – Towards User-Friendly, Affordable and Accurate Digital Particle Image Velocimetry in MATLAB. *Journal of Open Research Software* [Online]. 2(1), p.e30. DOI: http://doi.org/10.5334/jors.bl
13. J. Madhuri. *Digital Image Processing: An Algorithm Approach.* 3rd ed. India: PHI Learning Pvt. Ltd., 2017, pp. 1-2.
14. D. Fagella. (2017, May 19). Unsupervised Machine Learning Could Help Us Solve the Unsolvable [Online]. https://www.huffpost.com/entry/unsupervised-machine-lear_b_10010452
15. G. Zaccone, R. Karim & A. Menshawy. *Deep Learning with TensorFlow.* 2nd ed. England: Packt Publishing, 2018, p. 30.
16. N. Donges. (2018, April 23). Transfer Learning [Online]. Available: https://towardsdatascience.com/transfer-learning-946518f95666
17. X. Gao, D. Wong, T. Ng, C. Cheung, C. Cheng & T. Wong. (2013) Automatic Grading of Cortical and PSC Cataracts Using Retroillumination Lens Images. *ACCV'12 Proceedings of the 11th Asian conference on Computer Vision* [Online]. 7725(2), pp. 256-257. DOI: https://doi.org/10.1007/978-3-642-37444-9_20
18. S. Mathot. (2018, February 21). Pupillometry: Psychology, Pysiology, and Function. *Journal of Cognition* [Online]. 1(1), p. 16. DOI: http://doi.org/10.5334/joc.18

AUTHORS PROFILE

Engr. Kenneth C. Karamihan acquired his Bachelor of Science in Computer Engineering (BSCpE) degree last 2019 at University of Perpetual Help System Laguna (UPHSL). During his college years, he once served as the President of Institute of Computer Engineers of the Philippines Student Edition (ICpEP.SE) in Region 4A for two consecutive years with four years of service on different positions. He was also the President of the Computer Engineering Department's MicroSociety and the Vice President for External Affairs of the Engineering, Architecture and Aviation Student Council of the university. He was the Associate Layout Artist of EngGenius Magazine and Digital Graphic Designer of Engineering Student Council and College of Engineering. During the 3rd ICpEP General Assembly, he was recognized as Regional Champion in the ICpEP Region 4A CpE Challenge 2017 Quiz Bowl Competition held at Lyceum of the Philippines University, Batangas City, Batangas, and became the 4th Runner-Up in the National ICpEP CpE Challenge 2017 at the same category held at Legazpi City, Albay. He was also recognized with Proficiency in Computer Programming, Best in Object-Oriented Programming, Best in On-the-Job Training, Dean's Lister and ICpEP Leadership Award. His undergraduate thesis was recognized as Best in Design Project in Computer Engineering program and the 8th Engineering Research Forum Outstanding Research Paper.

Engr. Ivan Dave F. Agustino is a graduate of Bachelor of Science in Computer Engineering (BSCpE) degree at University of Perpetual Help System Laguna (UPHSL) year 2019. During his college years, he was the Business Manager for External Affairs of the Computer Engineering Department's MicroSociety and a member of the Institute of Computer Engineers of the Philippines Student Edition (ICpEP.SE) Region 4-A. His undergraduate thesis was recognized as Best in Design Project in Computer Engineering program and the 8th Engineering Research Forum Outstanding Research Paper.

Engr. Ronnick Bien B. Bionesta obtained his Bachelor of Science in Computer Engineering (BSCpE) degree last 2019 at University of Perpetual Help System Laguna (UPHSL). He was a member of the Computer Engineering Department's MicroSociety of the same university as well as the Institute of Computer Engineers of the Philippines Student Edition (ICpEP.SE) Region 4-A. His undergraduate thesis was recognized as Best in Design Project in Computer Engineering program and the 8th Engineering Research Forum Outstanding Research Paper.

Engr. Ferangelo C. Tuason graduated with a degree of Bachelor of Science in Computer Engineering (BSCpE) last 2019 at University of Perpetual Help System Laguna (UPHSL). During his college years, he was once a board member of the Computer Engineering Department's MicroSociety and a member of the Institute of Computer Engineers of the Philippines Student Edition (ICpEP.SE) Region 4-A. His undergraduate thesis was recognized as Best in Design Project in Computer Engineering program and the 8th Engineering Research Forum Outstanding Research Paper.

Engr. Steven Valentino E. Arellano is a degree holder of Master of Science in Management Engineering (MSME) conferred last 2017 at University of Perpetual Help System Laguna (UPHSL). He finished his Bachelor of Science in Computer Engineering (BSCpE) degree program last 2015 at the same university. He is a Freelance Digital Graphic Designer and Editor; Web Developer; Undergraduate Thesis Adviser for Computer, Electrical, and Electronics Engineering of UPHSL; and Professional Member of Institute of Computer Engineers of the Philippines (Region IV-A), respectively. During his college years, he once served as Vice President-Internal of MicroSociety (Computer Engineering Society) of UPHSL. He was the Chief Layout Artist, Writer, and Editor of EngGenius (Engineering) Magazine; and Digital Graphic Designer of Engineering Student Council and College of Engineering. During the 40th Commencement Exercises of UPHSL held in Philippine International Convention Center, Pasay City, he was awarded a Plaque of Recognition for his Outstanding Graduate Thesis entitled "Child Detector Android Application through Smartphone Using Bluetooth Low Energy (BLE) Beacon Technology", which was also published in the International Journal of Engineering and Advanced Technology (IJEAT), ISSN: 2249-8958, Volume 8, Issue 2, December 2018.

He had also scholarly published researches in different international research journals such as the International Journal of Innovative Technology and Exploring Engineering (IJITEE), ISSN: 2278-3075, Volume 7, Issue 12, September 2018, entitled “Sign Language and Speech Translation Wearable Device for Special Education Schools in the Philippines”. IJEAT and IJITEE are published by Blue Eyes Intelligence Engineering and Sciences Publication.

Engr. Phillip Amir M. Esguerra earned his Bachelor of Science in Electronics Engineering (BSECE) last 2015 at University of Perpetual Help System Laguna (UPHSL). During his college years, he served as President of Engineering Student Council (ESC), Perpetual Institute of Electronics and Communications Engineering Society (PIECES), and Engineering Mathematical Society. For his undergraduate thesis, he has done Application of Mimicking for the Control of Anthropomorphic Robotic Arm in Bomb Disposal Robot which consists of a telemetry suit worn in a human arm that can control a robotic arm. He is also currently taking his Master of Science in Management Engineering at the same university. Currently he is working as a Software Development Engineer. He is also a freelance Web Developer. He also has done various projects including an entry in a hackathon that involves an Android based application that uses Bluetooth Low Energy for applications such as anti-theft, object tagging and search, and other related functions.