Aedes Larvae Classification and Detection (ALCD) System by Using Deep Learning

Conference Paper · October 2020

DOI: 10.1109/ICCI51257.2020.9247647

Aliza Sarlan
Universiti Teknologi PETRONAS, Bandar Seri Iskandar, Malaysia

Muhammad Izzul Azri Zainol Azman
Universiti Teknologi PETRONAS

Aedes Larvae Classification and Detection (ALCD) System by Using Deep Learning

Muhammad Izzul Azri Bin Zainol Azman, Aliza Binti Sarlan
Computer & Information Sciences Department
Universiti Teknologi PETRONAS
Bandar Seri Iskandar, 31750 Tronoh, Perak, Malaysia
muhammadizzulazri@yahoo.com, aliza_sarlan@utp.edu.my

***Abstract*— Nowadays, the presence of the latest technologies like Artificial Intelligence and lenses that can capture the micro-living being like larva have been used in our surrounding environment. Deep Learning technologies which are a subset of Artificial Intelligence have been implemented in used for processing the image. As before this, there is a study to detect the possible place of Aedes mosquito breeding place with the use of Internet of Things (IoT) technologies to detect the humidity of certain places and relate it to the possibility of Aedes mosquito breeding present. To support the study and have verification of the place is the breeding place of Aedes mosquito, a study to classify the larva and detect it has been proposed. The Aedes Larvae Classification and Detection (ALCD) System by using Deep learning is a system that uses deep learning technologies to detect the pattern of the larva and classify it according to its type. The proposed developed system ALCD because Malaysia is having a rapid increase in dengue cases throughout the year. While there are many approaches from the government and non-government organizations (NGOs) to help combat the dengue virus outbreak, this study is focusing on preventing the virus from spreading in the early stages. The life cycle of an Aedes mosquito is starting from the egg to larva to pupa and lastly became an adult mosquito. The early stages of Aedes mosquito that can be used to differentiate between Aedes and Non-Aedes were at the larva stages. This study is meant to do a background study on using the latest technology of deep learning subset of Artificial Intelligence technology to find the pattern of the Aedes and Non-Aedes on the larva. After the pattern of the larva type is recognized, the process to classify it between the Aedes larvae and Non-Aedes larvae can be continued for classification. Real-time classification testing will be conducted to test the accuracy and efficiency of the ALCD system.**

Keywords—aedes mosquito, IoT, ALCD, CNN, Deep Learning, aedes larvae, larva, outbreak.

I. INTRODUCTION

Nowadays, the presence of the dengue virus that is affecting our society has increased yearly. This virus also has affected our neighboring countries, western countries, and European countries. Dengue virus is not only Affected by Malaysia, but neighboring countries such as Singapore, Philippines, Taiwan, Vietnam, Cambodia, Laos, and China also experienced the increases of dengue cases [1]. The causes of the dengue virus are divided into four types of virus which is DENV-1, DENV-2, DENV-3, DENV-4 that is belong to the Flaviviride family [2], [3]. The way of the virus transmitted is by the bite of infected female Aedes aegypti and Aedes albopictus that is actively fed during the daytime. The dengue virus is usually outbreaks in tropical countries, where the humidity is high due to the often raining season which is a suitable breeding place for the Aedes aegypti and Aedes albopictus. This dengue virus is not possibly transmitted by the interaction between humans, it can only be transmitted from the mosquito itself to another human by biting it. Malaysia has recorded the highest dengue virus outbreak by hitting nearly 80, 000 cases and causes 113 deaths from January till August 3, 2019 [1]. With the number of recorded cases are increasing, the Malaysian government has come out with a new method which is by releasing the Aedes mosquito that is infected with the Wolbachia bacteria to tackle down the population of the dengue-infested mosquitoes.

With the arrival of the latest technologies such as deep learning from the subset of artificial intelligence, a faster way of preventing the breeding of the Aedes mosquito is might be useful for fighting down the spread of the dengue virus. An initiative way of preventing the Aedes mosquito from the early stage of its production which is from the larva stage. There is a method of image classification the is using deep learning to classify the object in the images. By this method, we can differentiate between Aedes larvae and Non Aedes larvae. From this method, we can kill the larva and reducing the production of Aedes mosquito.

II. THE NEED TO USE ALCD SYSTEM FOR DETECTING THE AEDES LARVAE AND NON AEDES LARVAE

ALCD system using CNN model from the deep learning technique to identify the pattern of the larvae and classify it according to their type. It will use the dataset received from Jabatan Kesihatan Petaling, Selangor which is larvae sample. The process of dataset is manually by capturing the specimen received which is already classified according to their types. The dataset is use for the model training for finding the pattern and train the model to classify the larva according to their type. The testing process will be a real time capturing images by using the Blips micro lens that will be attach to the smartphones. The reason for the project study is further justified as below.

A. Issues of Dengue Cases in Malaysia

The number of dengue outbreak is increasing yearly throughout Malaysia. The number of dengue fever cases in Malaysia has reached up to 80, 000 cases and 113 deaths reported from January until August 3, 2019[1]. As shown in the Fig. 1 are the cases of dengue and death caused by the dengue from 2000 to 2019, we can see that Malaysia has reached the highest number of cases in 2015 which is 120, 836 cases, from that number of cases the death reported was

336 people died cause of dengue virus. The dengue virus is not a small thing as it keeps increasing throughout the year. An initiative that has been taking by the government is still not enough as the number of cases is still increasing. The right action is needed for combatting the dengue outbreak.

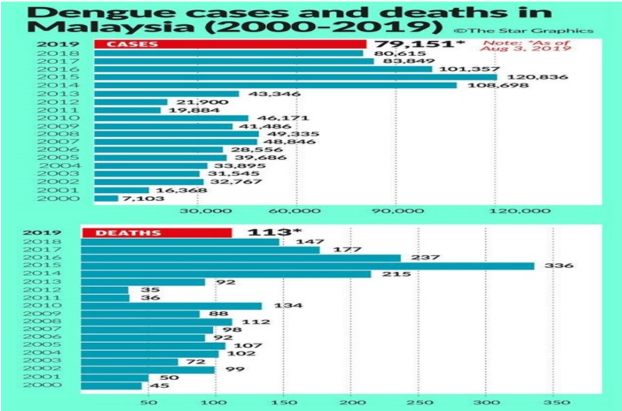

Fig. 1. Dengue cases and death in Malaysia (2000- 2019) [1]

B. *Hot Spot For Dengue Cases In Malaysia*

Malaysia consisting of 16 states which is Johor, Kedah, Kelantan, Melaka, Negeri Sembilan, Pahang, Perak, Perlis, Pulau Pinang, Sabah, Sarawak, Selangor, Terengganu, Wilayah Persekutuan Kuala Lumpur, Wilayah Persekutuan Labuan and Wilayah Persekutuan Putrajaya. As shown in Fig. 2 the states that records the highest number of daily dengue cases is Selangor with 198 cases followed by Wilayah Persekutuan Kuala Lumpur with 35 cases and Johor with 31 cases. The statistics also show that accumulated cases from 30 December 2019 till 13 November 2019 for the highest accumulated cases was Selangor with 62, 757 cases followed by Wilayah Persekutuan Kuala Lumpur with 12, 916 cases and Johor with 9, 609 cases. These three states of Selangor, Wilayah Persekutuan Kuala Lumpur and Johor has the Highest number among 14 states due to the population at 3 of the states was the highest. Due to the density of the population at the 3 of the highest dengue cases mentioned, it became a factor that growing of Aedes mosquito was increasing. A fast action would require to combatting the Aedes mosquito to avoid the spreading of dengue virus.

C. *Prevention Approach- Ministry of Health*

There is various type of prevention method of Aedes Dengue virus from different countries. According to Dr Lee in [1], the ministry has used the method of fogging and removing the mosquito breeding sites. Recently, the Ministry of Health has using a new method which is they will release Aedes mosquito infected with the Wolbachia bacteria to fight with dengue- infested mosquitoes. The Wolbachia infected Aedes mosquito will lead to tissue damage to the mosquito and it will reduce the lifespan of the mosquitoes as it is also will reduce the blood-feeding success [4] – [6]. As the new method has been implemented, the number of dengue cases keeps increases. The need for an effective method is still in the finding of the right way of the implementation to make sure the new method is helping in reducing the Aedes mosquito.

D. *Prevention Approach- General Dengue Prevention Method*

For effective ways to reducing the Aedes mosquito population, Malaysian citizens need to practice a prevention start from their home. Aedes mosquito will breed in clean water [7] – [9]. There are few targeted place for Aedes breeding sites which is Rain gutters. Besides that, drains are always the favorite spot for the mosquito to breed. Next, if there is left tires, cans, bottle, plastic bags or lunch boxes, they have to make sure to dispose all of it or consider to recycle it as it is one of effort to keep our places clean and avoiding the water contained in the left item. Usually, some people like to have a water container for backup if water shortage is happening, make sure the water container is covered with a lid and add a larvicide each week as it will as a killing agent for the larva breeding. Lastly, the flowerpots or vases are considered as an Aedes mosquito breeding sites.

E. *Dengue Causes*

There are few causes of the dengue case is increasing through the year. As quoted from Dr Noor Hisham in [1], “The changing rainy and hot seasons resulting in stagnant water collected, people movement and increase in population density in urban areas also facilitated the spread”. Malaysia have annual population growth rate of 1.1 % for the local citizens and (3.6%) for Non-citizens [10]. From this numbers, we can see that the number of people live in Malaysia is increasing as they will populate the urban areas for working and live at there and it will lead to the increases of mosquito breeding.

F. *Image Classification Using Deep Learning*

As there are various type of larva, with the help of image classification technologies that are using deep learning, the ability to identify the pattern of certain larva type and classify it according to their type is now achievable. By using CNN, we can find the pattern of the image and classify it with the model that we built to identify it [11], [12]. CNN is a Deep learning algorithm to process an image type input as it will assign a learnable weights and biases to the image and able to differentiate it according to the specific type as required [13], [14]. Fig. 2 visualize how the process of the classification works.

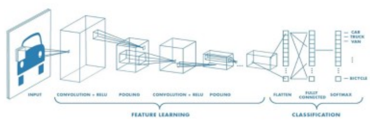

Fig. 2. Process of Image Classification [13]

III. METHODOLOGY

In this project development, the suitable methodology is needed. The suitable methodology will act as a framework to helping in guiding the entire project flow. The methodology that has been chosen for Aedes Larvae Classification and Detection (ALCD) System are research phase methodology model. The research phase methodology consists of five phases which is background studies, literature review, pattern finding and classification, development of portable ALCD system and testing of ALCD system based on Fig. 3.

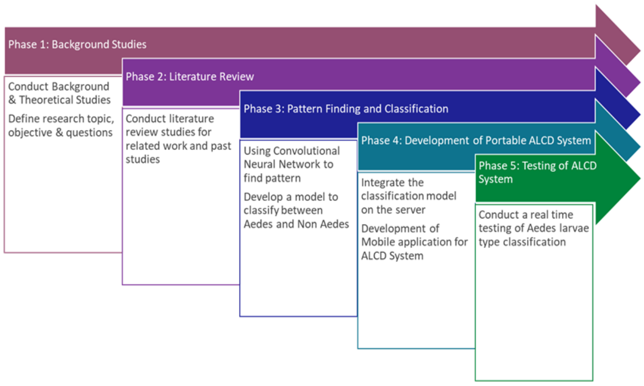

Fig. 3. Research Phases

The first phase of the research phase for the ALCD system is background studies. This phase is to determine the right cycle to detect the Aedes infected mosquito and doing the theoretical studies to know the behaviour of the larvae when in breeding phases. In the second phase, the author must conduct the literature review studies for related work and past studies to see the project is relevant and have a possibility to deliver it. The third phase will be the pattern finding and classification of the mosquito larva type. This phase is very important in order to achieve the objective of this project. In this phase, an approach of deep learning that using CNN model will be used for finding the pattern of the larva according to specific type. After the pattern is recognised, the next move was to develop a model to classify between Aedes larvae and Non Aedes larvae. When the classification is done, then the author will train the model for prediction with the available dataset from the google dataset and from manual dataset gathering. Next phase is the development of Portable ALCD system based on the phase 3. After the phase 3 is done, the ALCD system will be implemented to smartphones system. The objective of this phase was to create a portability of the system for the normal people usage. This portable system will help a normal people to detect the Aedes larvae and get rid of it to stop it breeding to become Aedes mosquito. This phase required a very high knowledge for combining the deep learning system inside the mobile application as it will result of slowing down the process time and reduce the efficiency. The last phase of this project was to conduct a testing for the ALCD System in a real time situation. The objective for this phase was to get the accuracy rate of the detection and the error rate in determining the larvae type.

IV. PROPOSED DESIGN

This section provides the details of the proposed design of the ALCD system and the required hardware.

A. *Hardware*

For the development of the ALCD system project involves various of hardware as listed in TABLE I for the hardware use.

TABLE I. Hardware use to Develop ALCD System

Component	Description
Smart Micro Optics Blips Full Kit Lenses	The Blips lens provide a thin lens that can be attach to smartphone to capture a micro image without having to using a microscope. It helps this project in capturing the larva specimen at the finest detail that needed for processing to find a pattern.
Samsung Galaxy J3 Pro	The Samsung smartphone that I am using with the blips micro lens for capturing the image for dataset.
Blips Phone Stage	The Blips phone stage is used for holding the smartphone for capturing the larva image precisely. It features the stability, alignment for light source and adjustable focal distance
Blips Light Source	The Blips light source is used with the blips phone stage as the source of light for lighten up the larva image
Plastic Transfer Pipettes	The small plastic pipette is used to transfer the larva sample from the glass bottle to glass slide
Slide Plain Glass	The slide plain glass is used to put the larva sample on it for camera to capture it
Round Microscope Slide Coverslip Cover	The round microscope slide coverslip cover for cover the larva specimen on the glass slide

B. *Software*

For the development of the ALCD system project involves various of software use as listed in TABLE II for the system use to develop.

TABLE II. Software use to Develop ALCD System

Software Name	Description
QT Designer	Development framework for GUI application and uses Qt API
TensorFlow	The TensorFlow is an open source platform for machine learning and deep learning.
Keras	Keras is a high level neural networks API, which are written in Python languages and able to work with TensorFlow for developing deep learning model.
PyCharm	PyCharm IDE is an open-source software used to develop a software and it able to work along with machine learning and deep learning model.

C. *ALCD System Architecture*

Fig. 4 shows the architecture of the ALCD system in conducting a classification testing scenario. It consists of total 6 steps for the ALCD system to predict the aedes larva type. The steps are:

- Step 1: Prepare the larva sample.
- Step 2: Using ALCD portable application to capture the larva image.
- Step 3: After the image has been captured, upload the image to the google drive from the ALCD portable system.
- Step 4: Open the ALCD Desktop system and the process of prediction start when user press start button. It will reload the training dataset and validation dataset and saved model for prediction.
- Step 5: User will hit the retrieve button for retrieve the image from google drive that is uploaded from ALCD portable application.
- Step 6: The prediction will start and output the accuracy rate of the prediction and type of the larva.

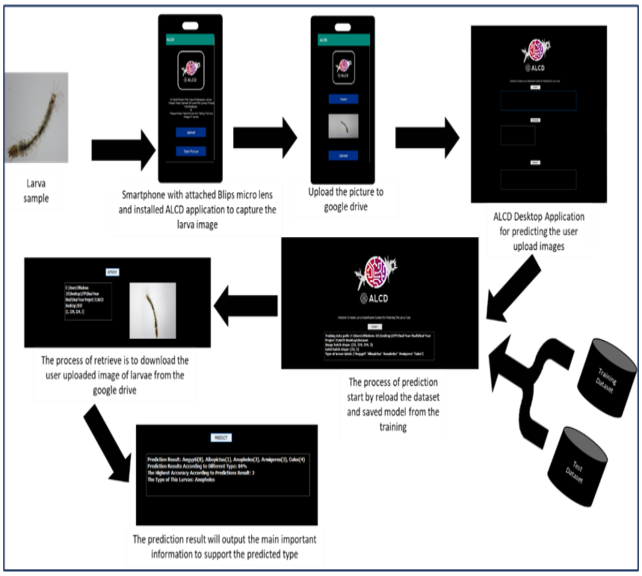

Fig 4. ALCD System Architecture

D. System Process Flow

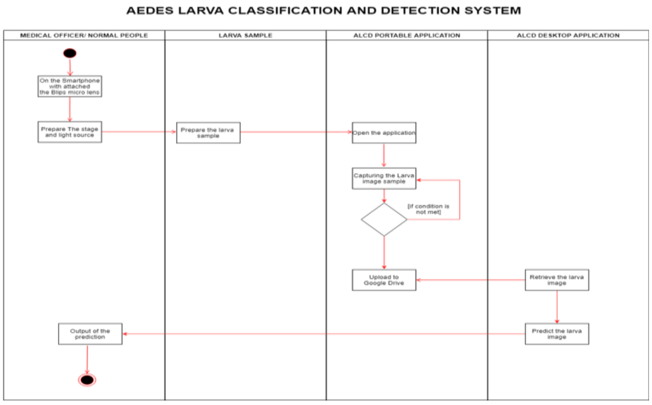

Fig. 5. Activity Diagram for ALCD System

The Fig. 5 shows the activity diagram for ALCD System which is having four swim lanes that are medical officer or normal people, larva sample, ALCD Portable application and ALCD Desktop application. The process will start from medical officer or normal people which acts as the user. It starts with on the smartphone that are already attached the blips micro lens and followed by preparing the stage for the smartphone and light source. After that, it continues with preparing the larva sample which is put the larva under the glass slide and put on the stage with the light source directly points under it. Next, open ALCD Portable application and start to capture the image of the larva sample. If the image captured is not met the condition in terms of details and resolutions, it will recapture the image to get the highest details and resolutions. The image will be uploaded straight to the Google Drive. From the ALCD Desktop application, it will retrieve the image and start the process of predicting the larva image uploaded from the ALCD Portable application located at Google Drive. Lastly it will output the prediction result to the Medical Officer or Normal People. The system will turn off after the result is output.

V. BENEFIT AND ADVANTAGES

ALCD system was developed for upgrades the current traditional method which is eye observation and by sending to the selected laboratory for analysis of the larva type. A comparative is done to find out the effectiveness of ALCD system and the current approach which is the traditional method. This study will compare the current method of Aedes larva classification method and the ALCD system by the differences of time taken, current approach limitation and the effectiveness of the approach.

TABLE III. Comparative study between traditional method and ALCD system

Comparison	Traditional Method (Eye observation and send to laboratory for testing)	ALCD (Proposed approach)
Description	Take the larva sample and observe the movement and the details of the larva. After recognizing it, send it to the laboratory for the confirmation of the larva type.	Take the larva sample and use the smartphone with attached blips micro lens to capture the larva and upload it to the google drive. Only need a laptop to retrieve the image from google drive and predict the larva type. Able to cover large areas and mark the aedes breeding hotspot much faster.
Time Taken	Process of eye observation will take roughly around 10 minutes and the time for the result from the lab will take minimum of 1 day.	Process of the capturing the larva sample will approximately take around 5 minutes include uploaded it to the google drive. The ALCD Desktop application will take roughly the same 5 minutes to predict the larva type.
Limitation	The whole process will take a lot of time and only can cover up small areas.	The accuracy of ALCD system to predict is not as high as the laboratory test output.
Effectiveness	Able to verify the current larva type with the highest accuracy and validate the larva type.	Able to reduce the time taken for detect the aedes larva and cover up large areas.

The TABLE III summarize the comparisons of both approaches between Traditional method and the ALCD system approach. Both have the advantages and disadvantages. The traditional method which the eye observation and send the larva sample to laboratory for testing is current approach by the Jabatan Kesihatan Negeri Selangor. The approach was meant to capture the breeding place of the aedes larvae and destroy the breeding place to avoid it become adult mosquitoes that able to infect people with the dengue virus. Medical officers will go to the local neighbourhood for doing an inspection of the aedes larva breeding place and if there is a presence of larva breeding while inspections, they will collect it and send to their laboratory for testing to find out the larva type. While the proposed system which is ALCD system will help them fasten up the process by do not have to send the sample to their laboratory. They can perform the test while the inspection was run. The comparison of the time taken between the traditional method and ALCD system shows that ALCD system takes around 10 minutes to completely identify the larva type while the traditional method might take days to find out the larva type. In terms of effectiveness, the traditional method has the advantages because the accuracy of the test is unquestionable. The limitations of the traditional method were the time taken and the areas cover for the detections. While the limitations of the ALCD system were the prediction output was the accuracy is not as high as the laboratory test output.

V. RESULTS AND DISCUSSION

The ALCD Model have been development by using TensorFlow model with python as the programming language. The process of development ALCD Model is started with dataset. The dataset act as the main important part to the model as it will feed into the ALCD Model algorithm to find the pattern in the dataset and classify the pattern according to set types. The ALCD Model is built on the deep learning algorithm which is Convolutional Neural Network (CNN). CNN will take the dataset as the input for the model training and go through the feature learning to learn the pattern exist in the image of the dataset and continue to classification process. The ALCD Model has been using the MobileNetV2 model.

After the training with the model is done, we can see that the final loss for the model was 0.88 and the final accuracy that the model can produce was 64.58%. The final loss indicates the number of how bad the model's prediction based on the single input. The final accuracy indicates the number of correct predictions based on the input. In Fig. 6, it visualizes the loss and the validation loss. The orange line is label as the loss and the blue line is the validation loss. As we can see the number of both loss and validation loss is decreasing as the training steps increases. The training steps is set to 20 according to the size of dataset. As in Fig. 7, it visualizes the accuracy and the validation accuracy. The orange line is label as the accuracy and the blue line is the validation accuracy. The accuracy are increases as the training step increases because the model getting the increase in the hidden layers and the changes of activation functions.

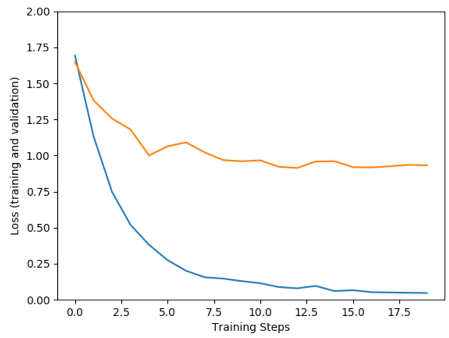

Fig. 6. Graph Representation of ALCD Model Training for LOSS

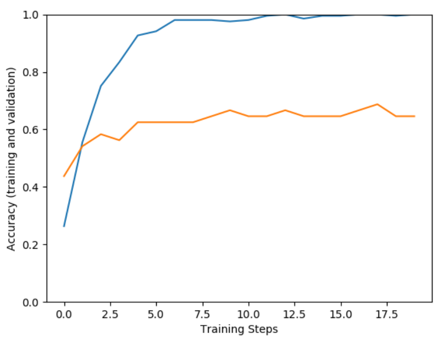

Fig. 7. Graph Representation of ALCD Model Training for Accuracy

A. *Model Prediction Accuracy by Using Validation Dataset*

From the model that have been successfully created, the ALCD model is test with the validation dataset. The process was to select 20 random images from validation dataset to predict the type of larvae. The process of classification and prediction of the larva type based on the number of points that show the most according to certain type of larva. In Fig. 8, shows that the first picture has the biggest number of accuracies to Anopheles larva type. The Fig. 8 shows the result of the prediction according to the larva type and the Fig. 9 visualize the image of the predicted and the label the larva type according to table in Fig. 8. The Fig. 9 shows that out of 20 images, the model able to predict correct larva type was 14 and 6 incorrect larva type.

Prediction results for the first elements

	Aegypti	Albopictus	Anopheles	Armigeres	Culex
0	0.01682686	0.14065480	0.80433118	0.02255562	0.01563153
1	0.02242459	0.95299178	0.01318483	0.00850866	0.00289013
2	0.01315173	0.08270663	0.84042627	0.01848167	0.04523375
3	0.88714057	0.00922746	0.01410416	0.07226358	0.01726415
4	0.24064906	0.13209802	0.08074585	0.13342316	0.41308385

Fig. 8. ALCD Model Prediction Accuracy to The Larva Type Based on Validation Dataset

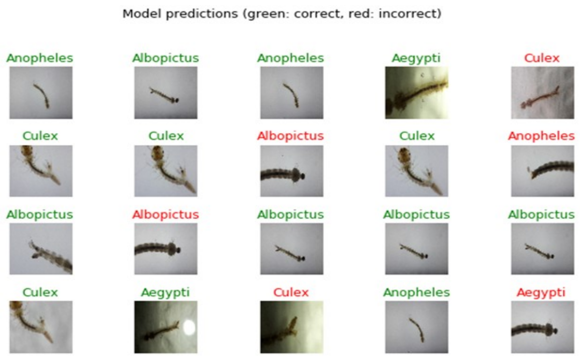

Fig. 9. ALCD Model Prediction Based on Validation Dataset

B. *Test 1: Detecting The Larvae Type- Seri Iskandar (UTP)*

The purpose of this test is to detect the larva types and measure the time taken for the whole process to be completed. The testing was done at Universiti Teknologi PETRONAS, Seri Iskandar. The specimen is using the larva samples that received from Jabatan Kesihatan Negeri Selangor. It was tested with an open condition, using the blips phone stage, blips micro lens, Samsung galaxy j3 and blips light source. The first step to start the experiment was to prepare a clear container and pour the larva sample into it. Then by using pipette, take one larva and put it on glass slide. After that prepare the blips phone stage and put the light source on. Next, attached blips micro lens at the smartphone and open the ALCD Mobile application. After completed that, start capturing the images of larva and using the function upload in ALCD Mobile application to upload it and open ALCD Desktop application to retrieve the image and start to predict the larva types. After finishing retrieving the image, continue to predict the larvae type as seen in Fig. 10.

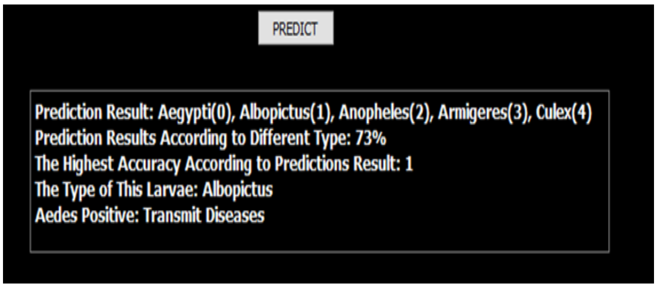

Fig. 10. ALCD Desktop Application Result Output of Prediction

From Fig. 10, we can see that the result of the prediction is:

- Prediction Result: Aegypti(0), Albopictus(1), Anopheles(2), Armigeres(3), Culex(4)
- Prediction Results According to Different Type: 73%
- The Highest Accuracy According to Predictions Result: 1
- The Type of This Larvae: Albopictus
- Aedes Positive: Transmit Diseases

TABLE IV. The Prediction Result of Larva Type

	Larva Type				
	Aegypti	**Albopictus**	**Anopheles**	**Armigeres**	**Culex**
1	0.21725653	0.73173362	0.01602928	0.0277818	0.00719875

As the Prediction Result According to Different Type stated that the result was 73% and it belong to case number 1 which is Albopictus. The TABLE IV shows that the larva image that have been predicted and been compared to five different types of larvae. The first type of the larvae that ALCD Model compare was Aegypti Aedes larvae which result in only 22% match then it moves to Albopictus Aedes larvae that shows 73% match but it did not stop there, it continues to Anopheles larvae type with 2% match followed by Armigeres larvae type with 3% match and lastly Culex larvae type with 0.7% match. So, we can conclude that, the ALCD Model will pick the highest accuracy match according to larvae type to determine the result.

VI. CONCLUSION AND FUTURE WORKS

To conclude for this project, the objective of Aedes Larvae Classification and Detection (ALCD) system has been successfully achieved its objective that is to do a background study using deep learning on the finding the pattern of larva body structure between Aedes larvae and Non Aedes larvae, to find the pattern of the larva body and able to classify between the type of larva, to conduct testing of real time classification of Aedes larvae and Non Aedes larvae and to develop a portable ALCD system that a normal people can use. Recently, there is a project that is related to combatting dengue, it is detecting a high possibility place for Aedes breeding which determined by the level of humidity. With the presence of ALCD System, we can verify that the place is Aedes mosquito breeding site. Hence, ALCD System will help the medical officer that do surveying for mosquito breeding place in terms of accuracy of determining whether the larva is Aedes or Non Aedes and allowing normal people to do early prevention in view to combat for dengue.

This further improvement and recommendation for the ALCD system project is to create a custom ALCD Model that will have a custom parameter for improving the accuracy of the detection and predictions. The ALCD Mobile application will need to have kit packages that include with application, the lens for capturing the larva sample, the phone stage, and the light source for the user to easily use the system. An integrated prediction system will be developed inside the ALCD Mobile application for a much faster process of detecting the larvae types.

VII. ACKNOWLEDGMENT

This material is based on work supported by Universiti Teknologi PETRONAS (UTP). I would like to express my gratitude to my supervisors, lecturers, staff and student from Department of Computer Information Sciences, Universiti Teknologi PETRONAS (UTP), Jabatan Kesihatan Negeri Selangor especially Pn Nurul Ainni for giving me a valuable resource and helping through the project.

VIII. REFERENCES

[1] L. F. FONG, "The Star," Star Media Group Berhad, 10 August 2019. [Online]. Available: https://www.thestar.com.my/news/nation/2019/08/10/dengue-cases-at-an-all-time-high.

[2] A. Tuiskunen Bäck and Å. Lundkvist, "Dengue viruses – an overview," *Infect. Ecol. Epidemiol.*, vol. 3, no. 1, p. 19839, 2013.

[3] C. F. Yung *et al.*, "Dengue serotype-specific differences in clinical manifestation, laboratory parameters and risk of severe disease in adults, Singapore," *Am. J. Trop. Med. Hyg.*, vol. 92, no. 5, pp. 999–1005, 2015.

[4] A. P. Turley, L. A. Moreira, S. L. O'Neill, and E. A. McGraw, "Wolbachia infection reduces blood-feeding success in the dengue fever mosquito, Aedes aegypti," *PLoS Negl. Trop. Dis.*, vol. 3, no. 9, pp. 1–6, 2009.

[5] W. A. Nazni *et al.*, "Establishment of Wolbachia Strain wAlbB in Malaysian Populations of Aedes aegypti for Dengue Control," *Curr. Biol.*, vol. 29, no. 24, pp. 4241-4248.e5, 2019.

[6] H. Zhang and R. Lui, "Releasing Wolbachia-infected Aedes aegypti to prevent the spread of dengue virus: A mathematical study," *Infect. Dis. Model.*, vol. 5, pp. 142–160, 2020.

[7] R. Ahmad, I. Suzilah, W. M. A. W. Najdah, O. Topek, I. Mustafakamal, and H. L. Lee, "Factors determining dengue outbreak in Malaysia," *PLoS One*, vol. 13, no. 2, pp. 1–13, 2018.

[8] W. K. Cheah, K. S. Ng, A. R. Marzilawati, and L. C. S. Lum, "A review of dengue research in Malaysia," *Med. J. Malaysia*, vol. 69, no. August, pp. 59–67, 2014.

[9] E. J. Kweka *et al.*, "Ecology of Aedes Mosquitoes, the Major Vectors of Arboviruses in Human Population," *Dengue Fever - a Resilient Threat Face Innov.*, no. December, 2019.

[10] M. U. Mahidin, "Current Population Estimates, Malaysia, 2018-2019," 15 July 2019. [Online]. Available: https://www.dosm.gov.my/v1/index.php?r=column/cthemeByCat&cat=155

[11] S. Regina Lourdhu Suganthi, M. Hanumanthappa, and S. Kavitha, "Event Image Classification using Deep Learning," *ICSNS 2018 - Proc. IEEE Int. Conf. Soft-Computing Netw. Secur.*, no. March, 2018.

[12] S. Sakib, A. 1#, A. Jawad, K. 2@, and H. Ahmed, "An Overview of Convolutional Neural Network: Its Architecture and Applications," no. November, 2018.

[13] S. Sumit, "A Comprehensive Guide to Convolutional Neural Network- The ELI5 way," 18 December 2018. [Online]. Available: https://towardsdatascience.com/a-comprehensive-guide-to-convolutional-neural-networks-the-eli5-way-3bd2b1164a53.

[14] L. Perez and J. Wang, "The Effectiveness of Data Augmentation in Image Classification using Deep Learning," 2017.