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Identification of deadliest mosquitoes using wing beats sound classification on tiny embedded system using machine learning and edge impulse platform

Dr Kirankumar Trivedi, Harsh Shroff
Vishwakarma Government Engineering College, Ahmedabad, India

Session 5: Augmented reality and machine learning for future spatial applications and services

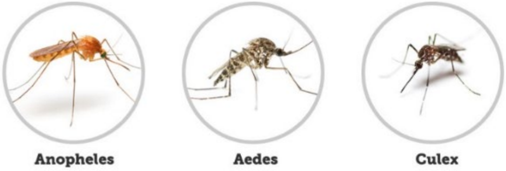
Paper S5.3: Identification of deadliest mosquitoes using wing beats sound classification on tiny embedded system using machine learning and edge impulse platform

Introduction

- Mosquitoes are the deadliest animal on the planet, infecting about 700 million people each year and causing over one million deaths[1].
- Sir Ronald Ross discovered that Anopheles mosquitoes were responsible for the spread of the malaria parasite on August 20, 1897.
  - Every year on 20 August, World Mosquito Day is celebrated to honor this pivotal finding in the fight against malaria.
- The use of machine learning to solve the challenge of manual mosquito type identification is efficient and has the potential to have a large impact on vector-borne illness management.
  - With 88.3% accuracy, the TinyML system developed using Edge Impulse based on the HumBug project's mosquito wing beats dataset recognizes mosquito types.

Vector-borne diseases caused by mosquitoes

- Aedes Aegypti mosquitoes are an excellent vector of potentially serious illnesses such as dengue fever, chikungunya fever, yellow fever, and Zika virus[2].
- Anopheles mosquitoes may be a source of additional brain tumor viruses. The connection between malaria outbreaks in the United States and reports of brain tumor incidence by state provides evidence of a correlation between anopheles and brain tumors[3].
- Culex mosquitoes are the primary vectors of some of the most common diseases, such as West Nile fever and Japanese encephalitis. They are found across the world in tropical and temperate climates and feast on humans and animals at night[4].



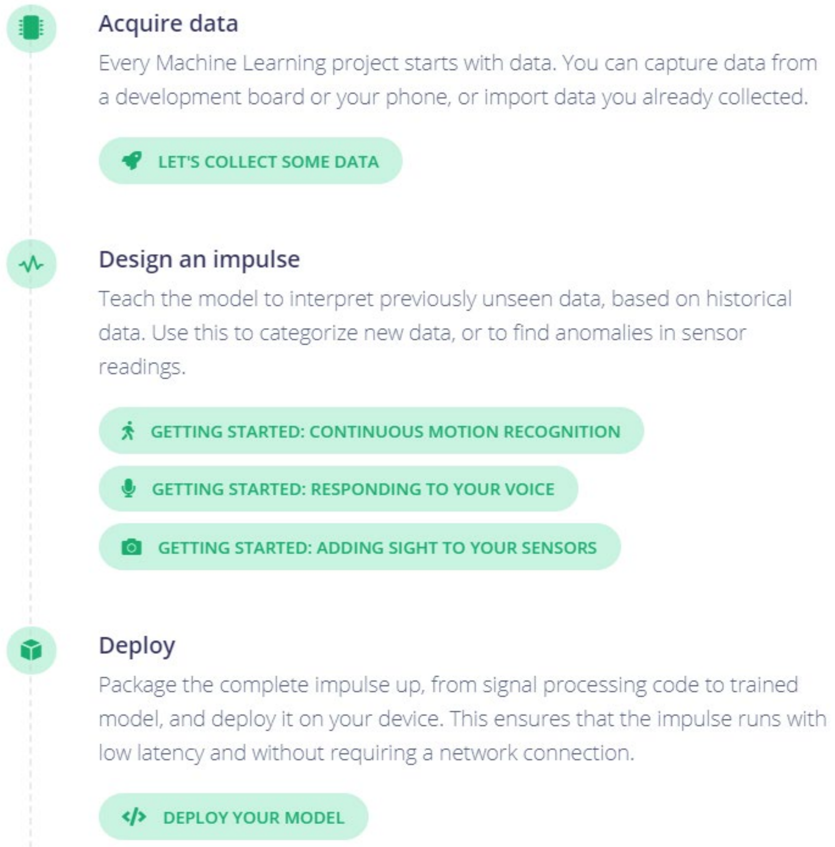
Source: http://www.bigstockphoto.com

Vector		Disease caused	Type of pathogen
Mosquito	*Aedes*	Chikungunya	Virus
		Dengue	Virus
		Lymphatic filariasis	Parasite
		Rift Valley fever	Virus
		Yellow Fever	Virus
		Zika	Virus
	Anopheles	Lymphatic filariasis	Parasite
		Malaria	Parasite
	Culex	Japanese encephalitis	Virus
		Lymphatic filariasis	Parasite
		West Nile fever	Virus

Source: https://www.who.int/news-room/fact-sheets/detail/vector-borne-diseases

Approach towards the proposed solution

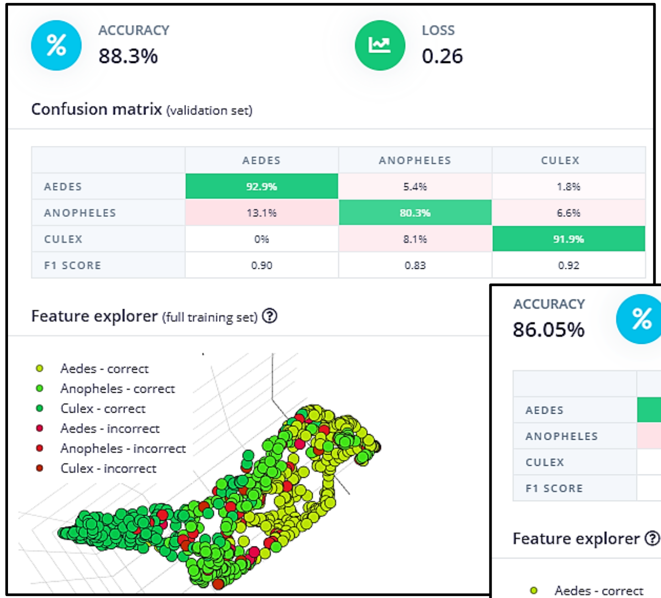
- With integrated machine learning, Edge Impulse allows developers to design the next generation of intelligent device solutions[5].
- Database acquisition, impulse design, Mel-Filterbank Energy (MFE), Neural Network (NN) classifier, model training, testing, and deployment were all performed using Edge Impulse.
- **Database acquisition**
  - In order to train the Convolutional Neural Networks (CNN) model, the database acquired by HumBug was re-sampled to 16 kHz.
  - This database was created to help people in Sub-Saharan Africa to detect and identify mosquito species.
- **Impulse design and model training**
  - An impulse takes raw data, uses signal processing to extract features, and then uses a learning block to classify new data.
  - There are four blocks in impulse including, Input, MFE, Neural Network, and Output.



Source: https://www.edgeimpulse.com/

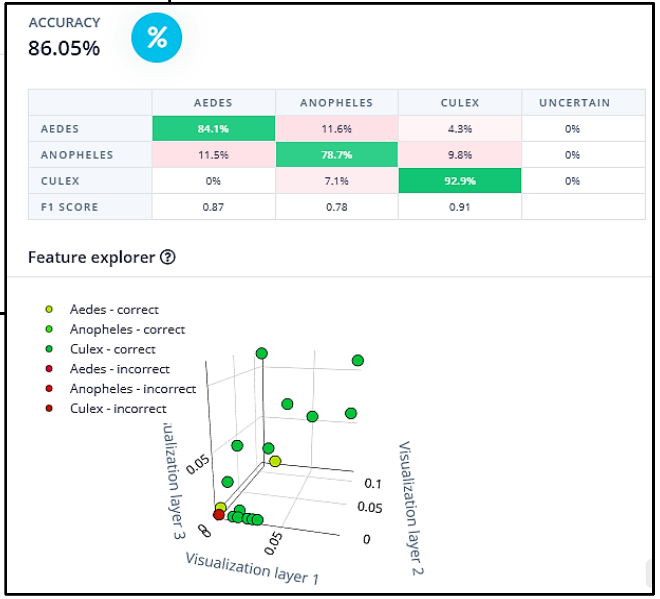
Approach towards the proposed solution

- **Model testing**
  - The test set data is data that the model has never seen before and may be used to evaluate whether the model works on the unseen data.
  - This will guarantee that the model does not learn to over-fit the training data[5].
- **Model deployment**
  - The model may be deployed to Arduino Nano 33 BLE Sense once the impulse has been created, trained, and evaluated.
  - This allows the model to function without an Internet connection, with little latency and battery consumption.
  - Edge Impulse can compile the whole impulse into a single Arduino library\cite{Ref10}.



	AEDES	ANOPHELES	CULEX
AEDES	92.9%	5.4%	1.8%
ANOPHELES	13.1%	80.3%	6.6%
CULEX	0%	8.1%	91.9%
F1 SCORE	0.90	0.83	0.92

Model training performance



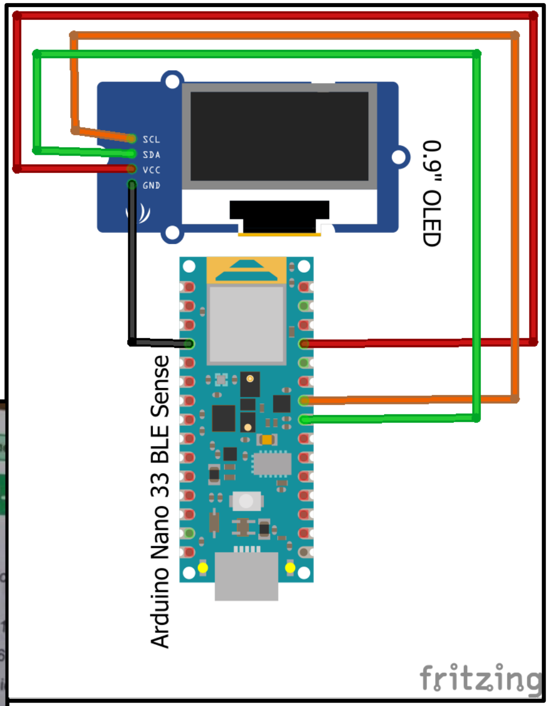
	AEDES	ANOPHELES	CULEX	UNCERTAIN
AEDES	84.1%	11.6%	4.3%	0%
ANOPHELES	11.5%	78.7%	9.8%	0%
CULEX	0%	7.1%	92.9%	0%
F1 SCORE	0.87	0.78	0.91	

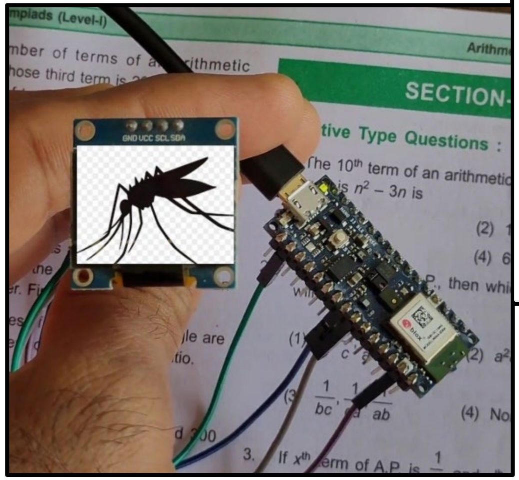
Model testing results

Approach towards the proposed solution

- **Hardware implementation**
  - The hardware implementation is done using the Arduino Nano 33 BLE Sense development board and a 0.9 inch OLED display.
  - The Arduino and OLED are connected via I2C pins. Arduino uses these pins to display the binary image of the mosquito on the OLED display.
  - When a mosquito is identified from its wing beat via on-board microphone, the screen displays a photograph/name of the mosquito.
  - Edge Impulse has previously calculated on-device performance for a low-power micro-controller (Cortex-M4F @ 80MHz), with inferencing time of 337 milliseconds, peak RAM consumption of 9.2 kb, and flash usage of 43.4 kb to evaluate one second of data.
  - The images of the circuit schematic and the prototype are shown on the right hand side.

Circuit Schematic





Prototype

References

1. Caraballo H, King K. Emergency department management of mosquito-borne illness: malaria, dengue, and West Nile virus. Emerg Med Pract. 2014 May;16(5):1-23; quiz 23-4. PMID: 25207355.
2. Regional Committee for Europe, 68th session. (2018). Sixty-eighth Regional Committee for Europe: Rome, 17–20 September 2018: implementation of the Regional Framework for Surveillance and Control of Invasive Mosquito Vectors and Re-emerging Vector-borne Diseases 2014–2020: lessons learned and the way forward. World Health Organization. Regional Office for Europe.
3. Mosquito-Borne Diseases: https://www.bcm.edu/departments/molecular-virology-and-microbiology/emerging-infections-and-biodefense/mosquitoes
4. Mukundarajan H, Hol FJH, Castillo EA, Newby C, Prakash M. Using mobile phones as acoustic sensors for high-throughput mosquito surveillance. Elife. 2017 Oct 31;6:e27854. doi: 10.7554/eLife.27854. PMID: 29087296; PMCID: PMC5663474.
5. Edge Impulse Documentation: https://docs.edgeimpulse.com/docs

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Thank you!