REDLab and Coconut Rhino Beetles

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REDLab also known as Renewable Energy and Design Lab is all about utilizing the engineering process in effective, efficient, and clean ways. Environmental awareness is becoming increasingly more significant year after year and because there is a growing need for solutions to combat these environmental issues, REDLab has taken up the fight against environmental degradation. There are several ways to join the fight against these degradations and help with preservation, however this year REDLab focused their efforts into the removal of the invasive species of the Coconut Rhinoceros Beetle (CRB) in Hawaii. This beetle is non-native to Hawaii and is normally home to Africa, China, Myanmar/India, and Southeast Asia. It has unfortunately spread to Hawaii most likely through the interisland transport of goods as Hawaii isn't the only island CRBs have infested such as Guan or Samoa. What makes these beetles so dangerous to the environment in Hawaii is because they will damage the coconut palm trees or kill the tree indirectly because of the damage it inflicts opening the tree up to other insects and pathogens. The Coconut Rhinoceros Beetles will chew into the growing fronds of the coconut trees to eat its sap and create large holes in the fronds. The holess may not be noticeable until after the fronds grow and at that point it may be too late for the tree. If the situation wasn't worse enough, the beetles will mate and reproduce and leave their eggs that hatch into larva in the trees. The amount they reproduce over their lifespan of approximately four to nine months is a startling 50 to 100 eggs. After less than a month the larvae are old enough to spread to other trees and repeat the cycle of reproduction, thus creating a dangerous and urgent situation for Hawaii. Currently the situation is being handled by the Department of Agriculture, where they came to the conclusion of using traps with pheromones to lure the Coconut Rhinoceros Beetles away from the coconut palm trees. While these traps are an effective method in attracting the Coconut Rhinoceros Beetles there are too many traps set up across the island to keep track of.

The number of traps set up on the island of Oahu rivals 3,000 and the amount of manpower and hours required to check all of those traps constantly is far too demanding and costly. REDLab has stepped into the scene to help aid the Department of Agriculture with the use of machine learning at the edge.

REDLabs project objectives involve creating a machine learning model to detect Coconut Rhinoceros Beetles at a high accuracy, determining cost effective equipment that meets specifications and low power costs, utilizing an integrated development environment (IDE) to as an interface between hardware and software to save and send images to an online server, and building said hypertext processor (PHP) server to store images, data, and other information to be easily accessed instead of going to locations blindly. The criteria surrounding the project involves being as cost effective as possible and staying within a budget of 200 dollars for an effective total of $600,000 over 3,000 traps. The device must be able to connect to Long Term Evolution (LTE) for internet connectivity or at the very least some wifi available in the near area surrounding. The device must be able to support a small camera, SD card, and be able to run on low power as low as 250mA at 3.3 volts as it would be powered by a solar panel. This way the project stays environmentally friendly while reducing its environmental footprint as much as possible and makes the process of trapping Coconut Rhinoceros Beetles as automated as possible with real-time data analytics and collection.

For related works in regards to the trapping and extermination of the invasive Coconut Rhinoceros Beetle, there are several types of traps and methods that have been used in the past. Traps include the Hoyt trap, Log trap, bucket trap, pipe trap, and the modern CRB trap, that are all relatively straight forwards based on their individual names. The main concept used in creating these traps were for monitoring, early detection and prevention, and mass trapping and

removing the Coconut Rhinoceros Beetles from the surrounding environment. They need to be attractive to the beetles, hard for them to exit, cheap, and strong or else they can make their way out of the trap. The Hoyt trap is a simple but effective trap of a capped metal can on top of a coconut trunk with a hole in it so that the beetles can climb in. The Log traps are logs cut in half for the beetles to crawl under with the attractant of pheromones. The bucket trap was made by the Pacific Community (SPC) and involved some pheremones such as ethyl4-methyloctanoate (E4-MO) and a couple holes for the beetle to crawl into. Then finally the pipe trap, developed by the oil palm industry, is more expensive than its competitor the bucket trap, but is also more suitable for long term developments as it is a 2-meter tall pipe with two holes at the top for beetles to fall into. Now aside from the traps there have been other methods in dealing with the Coconut Rhinoceros Beetles that involve more manual and mechanical control, chemical control, and biological control. For mechanical control, we can manually use tools such as wire hooks, called winkling, and other methods in removing the beetles from the palm trees, but come at the risk of going up and down the tall palms. Chemical control includes insecticides such as cypermethrin but are limited due to regulation and safety requirements. Then there are two main biological control approaches that are a virus and a fungus. The Oryctes rhinoceros nudivirus pathogen infects the larvae and adults resulting in death within a month, and the biopesticide from strains of fungus named Metarhizium majus is applied to breeding sites to exterminate the Coconut Rhinoceros Beetles. There have been many other methods used in the extermination of these beetles and all have been quite successful in their own right, however REDLab's project is very different. REDLab's approach isn't to create a new method or trap, but instead to improve upon, optimize, and automate the traps that have already been created. Because traps are checked on a weekly to monthly basis, it would require on average 175 traps to be checked daily. By

using machine learning to send pictures, dates, times, messages, and other information regarding the traps location, REDLab can automate the process of checking all the traps at once on a daily or scheduled basis resulting in a much more accurate and efficient way of checking the traps instead of doing it individually and in person. Because of this, the number of people needed to check the traps and hours taken to check the traps can be significantly reduced. Data can also be stored and used analytically to create an accurate map of outbreaks of Coconut Rhinoceros Beetles across Hawaii.

REDLab, after a lot of research and implementation, created its final design that can be easily combined with the current traps spread out across Hawaii. The final design includes an OpenMV Camera H7 that features an OV5640 image sensor with 2.8mm lens and M12 lens mount. The weight of the OpenMV Camera H7 weighs in at just 17g with dimensions of 45mm by 36mm by 29mm. While active it consumes only 240mA at 3.3V and while inactive or idle it consumes only 140mA at 3.3V and thus fits perfectly within the specified criteria. It also has an SD card slot that is able to read/write at 100Mb/s with the ability to stream video if needed. Most importantly this piece of technology supports machine learning libraries by utilizing the MicroPython OS so that machine learning models can be loaded onto the device. Additionally, REDLab's final design includes a wifi shield that gives the OpenMV Camera H7 the ability to stream JPEG compressed images to web browsers at speeds up to 48Mbps. The wifi shield weighs in at just 7g for a combined total with the camera of 24g separate from an SD card or any other factors thus creating an extremely light weight design. The dimensions of the wifi shield include 36mm by 27mm by 20 mm design which is smaller but similar to the camera it's connected to, thus can effectively be implemented into the trap. The trap that is already set up by the Department of Agriculture features a trap with pheromones that when the beetle runs into it,

they would fall into a cup like trap at the bottom and be unable to climb or fly out. The OpenMV Camera H7 and wifi shield can be placed at the top of the cup because of their small design without obstructing the beetles from falling into the cup trap. The OpenMV Camera H7 costs a total of 80 dollars per part and the Wifi Shield costs 30 dollars per part for a grand total of 110 dollars combined. After deciding on the hardware, it was sequential that REDLab went through the process of deciding on what type of machine learning model and getting the data to train the model to correctly detect the Coconut Rhinoceros Beetles. After some research REDLab concluded that using MobileNet, a pretrained network, to help with training the model would be best suited because of its high accuracy, fast training, and can be implemented into a mobile model such as the OpenMV device. MobileNet is a convolutional neural network (CNN), which is a class of a deep neural network and does well with analyzing visual images. MobileNet was originally created by google in 2017 with 1001 unique classes which can include cats, dogs, etc. Images input into MobileNet are 224 by 224 pixels so it is important to keep the same dimensions while using it to help train models. The technique of utilizing pre-trained networks such as MobileNet is called transfer learning and it's an integral part in machine learning to help use past learning to improve future learning. For the final project transfer learning with MobileNet was used to classify 17 unique insects such as: ants, bees, butterflies, caterpillars, centipedes, cicadas, dragonflies, coconut rhinoceros beetles, etc.. After creating the model a training accuracy of approximately 98% was reached with a 94% testing accuracy of the images input. By utilizing tensorflow when creating the model, it was easily exported to the OpenMV IDE to be programmed into the hardware. Without a proper IDE, exporting the model onto the device would prove to be difficult and time consuming, therefore by using a device that comes with an IDE interface that can be programmed accordingly was very important. The OpenMV

IDE is a free integrated development environment that uses micropython to have the camera track colors, detect faces, and much more. For example the OpenMV IDE can import lots of different libraries to complete different tasks such as the MQTT Client and the Network Time Protocol (NTP) that will be discussed in the design tools and methodology section. The last section to the final design is the PHP server that is necessary to collect the images and data so that they can be viewed anywhere. PHP is a server side scripting language that can be implemented into a url or domain name to complete specific actions. These specific actions can involve listening for POST requests from the OpenMV devices that are connected through LTE or wifi. These POST requests are essentially the OpenMV sending the images, date, messages, and other notifications to a specified server url. That server url is CRBvision.com created by REDLab that features a Gallery to view all the images of the Coconut Rhinoceros Beetles taken with their respective date, time, and location stamps. REDLab utilized a PHP server because it is easy to implement, there's a lot of resources and information available online to create one and test it, and lastly that it is free to make and use.

There are many alternate solutions or aspects that could be changed to achieve a similar result if not better. In regards to the machine learning model, there are a number of alternate convolutional neural networks other than MobileNet such as ResNet-50. ResNet-50 is a pretrained deep neural network similar to MobileNet that is also used for image classification. It would be a valid alternative to the final design model and could potentially result in even higher accuracy in a shorter amount of training time denoted as epochs. For example ResNet-50 can achieve a higher accuracy such as 85% in 30 epochs as compared to MobileNet’s 65% in 100 epochs. The reason why MobileNet was choses over ResNet-50 is mainly because given enough epochs the pre-trained MobileNet model can essentially beat ResNet-50 with a higher accuracy

and requires less parameters comparatively over all. For some additional alternate solutions for the modeling process, REDLab used TensorFlow to create the machine learning model for the trap, however there are other available resources to be used in the same way. For example, it is possible to create convolutional neural networks using Matlab and Jupyter Notebook. However the downsides to using these applications are that Matlab is not a free-open source platform and is fairly expensive, especially for the commercial license as high as 2,150 dollars for the perpetual license or 860 dollars for the annual. Then for Jupyter Notebook, while it is an open-source web application it isn't specifically designed for machine learning where TensorFlow is a specifically made end-to-end open-source platform for machine learning. On the server side of the project, there are numerous alternatives to a PHP server such as Javascript or Python for example. Although PHP is free and easy to use, the other types of servers could potentially lead to faster and easier platforms to build simply because there are far more resources available and PHP is outdated. PHP was created in 1994 while the others such as Python 3 was made in 2008 and Javascript has a runtime system for server-sided applications called Node.js which was designed in 2009. PHP is still viable and easy to learn, however it is simply outclassed and outdated comparatively. Another alternate solution to the final design could be utilizing different hardware such as the Arduino system. It is able to do just about anything OpenMV can do, however it is far more bulky in comparison. A way around this may be to store it safely on the side of the trap, but unfortunately it would reduce the overall effectiveness of the trap in the process by approximately 25% because it is a 4-sided trap. Reducing a traps effectiveness is counter productive to the team's objective, therefore storing it in another location such as above or below the trap may be the most effective. This way it wouldn't be in the way, but would have to have a camera extension to still view the Coconut

Rhinoceros Beetles within the trap. Having it anywhere else such as on the ground or tree may cause potential damage to the hardware and is generally not a safe practice. Similarly with the Arduino a raspberry pi could be swapped in to do the similar task as OpenMV and would even be able to import libraries similar to what is possible on the IDE Spyder which can utilize request libraries which was done for testing before implementation. Unfortunately this too falls prey to its own size similar to Arduino and difficulty finding a place to put the hardware without directly affecting the trap or creating complications with safety and or potentially damaging itself from falling. In terms of a completely different design as an alternate solution to solving the Coconut Rhinoceros Beetle issue, it may be possible to use similar hardware to send messages to a server, but instead of machine learning and a camera perhaps a weighing device as the trap is held by a string. Because there are pulley devices that can detect certain amounts of weight, it may be possible to achieve a similar result without viewing what is in the cup directly. This could potentially be more cost effective than the final design of REDLab, however the downsides may outweigh the benefits. For example it may be hard to detect the weight of the beetles unless there are several in the cup. There may be false positives depending on the weather creating a drag or pull on the trap weight system because of wind or rain. Likewise for other insects or debris from the trees they are hung from. There would not be any way to check the traps that have these issues without going on-site which is the opposite of REDLab's objective of automating the trapping of Coconut Rhinoceros Beetles.

Leading up to this project, there is a lot of material that is required to know and understand beforehand. For example, in REDLab's previous project, machine learning was utilized to monitor cloud cover to make solar panels more energy efficient. By checking the sky for clouds, it was possible to send a signal to the device onsight to conserve energy when cloud

cover is present and return to normal functions when a certain level of sky is viewable. Without the aforementioned project and knowledge, it would not have been possible to create the final design that REDLab created for the Coconut Rhinoceros Beetle. The IDE used for the previous project involved Sony's neural network which is complicated and difficult to understand. A lot of the information is written in another language, so there were some language barriers and was overall not a well used software for machine learning. The resources available were extremely limited and without realizing this, the current project would not have been nearly as successful. Other necessary coursework that is related to the project could be computer science and web development as there was a lot of code that was required to do specific tasks such as creating the server that the images are posted to. Having the foreknowledge of how use different coding languages to talk with each other is very important and sometimes it is necessary to understand that when two coding languages don't work together there can sometimes be a middleman in terms of busses or networks to do the translating so they can work together like the MQTT Client. This will be explained in more detail in the design and methodology section. Additionally for concurrent course work related to the project, it is vital to have some background in machine learning and continue learning about the different types of models and how they can be utilized. For example, without enough research into the types of models and what they can do for image classification, the level of accuracy may not have reached the optimal level wanted in the objective. Even having a slightly lower accuracy rate if ResNet-50 was used over MobileNet, using an arbitrary number of 2%, could result in false positives as high as 100 traps. This would be a large amount of misfires and an unnecessary collection of images and data to the server and potentially leading to manually checking more traps than necessary, however this would be based on human error viewing the images on the web. CRBvision.com, the website REDLab used,

would be cluttered with images that are not Coconut Rhinoceros Beetles and must be manually removed.

There are several improvements and future work or subsequent development with the REDLab machine learning project. One of which is getting more images of the Coconut Rhinoceros Beetle in the white cup of the trap to feed into the model when training, this way the model will have examples that will be used in the real implementation. This will essentially raise the accuracy level after some more optimization to around 99% which could drastically improve the number of false positives sent to the server. Additionally after the beetle is detected, there will be more subsequent development in getting the MQTT bus to transfer the images and other data to the servers or finding other possible avenues to send the data on the OpenMV IDE. After sending the images, its possible to store the data and messages into a MYSQL database which is much easier method in storing information instead of having it as an image title will be focused on in the future for further improvements to the project

For the section of Design methodology and Design tools, my efforts were based in designing the PHP code for the server CRBvision.com to listen for POST requests sent to the url. The design tools being the software such as PHP for server sided implementation, Spyder for testing, and MQTT for OpenMV for execution. The design methodology would be the code I used and why I used it, for example listening for POST requests can be done with the code if (isset($_POST)) {} which checks to see if a POST request has been sent to the url that the PHP server is being run on. If $_POST is not null then the following code would be run which involves moving files and without this, it would be far more difficult to use another indicator of when to move the files or could become too complicated resulting in errors. Files sent to the server have a title attached to them so it is important to give them a temporary name instead of

renaming them, which can cause complications, when being moved to the designated upload folder that the images will be stored into for example the code $movefile=move_uploaded_file($_Files["file"]["tmp_name"],$uploaded_folder); highlights this. Of course there is much more than just moving files, such as how the images are displayed on a specified url extension such as a gallery. In PHP the file that stores the images would be counted shown by the code for ($i=0; $i<count($files); $i++) {} and for each file counted with the supported file extensions ‘jpg’, ‘png’, etc they would be echoed to the server url extension with their designated name to be viewed online. Then because images and names aren't the only things being sent to the server, such as date, time, location, and other notifications, MYSQL database was used to collect this information in tables. After creating the table labeled ‘messages log’ on PHPmyadmin, an additional php document was created so that depending on the location submission, the required information aforementioned could be inserted into the table as shown in the code mysql_query("INSERT INTO 'message log' (Location, Message, Date, Time) VALUES(...). By accomplishing this, administrators can access the tables and effectively and efficiently monitor important data over 3,000 traps across Hawaii with high accuracy.

REDLab’s project meets nearly all of the engineering standards and practical constraints. Economically speaking, while it may reduce the number of jobs for checking the traps for CRBS, that was the intended goal of the project; however, it will be satisfied with spending on the required equipment for the upgraded trap. This project was specifically designed for protecting and preserving the environment therefore the environment constraint can be satisfied. There would not be any danger to the environment because if the devices become dislodged, they will simply fall into the cup of the trap. In terms of sustainability it meets our needs for saving the coconut trees from the invasive species without being at the expense of future generations. For

manufacturability, the OpenMV Camera H7 and Wifi shield can be ordered but it may take some time to fill an order for over 3,000 devices especially if they are created by hand. Ethically the project stands to hold paramount the safety, health, and welfare of the public and environment and is held to the highest standard of integrity. This project aids in the health and safety of the environment as well as the workers checking the traps in the case of bad neighborhoods, becoming injured from the traps falling, as well as staying safe during pandemics. While it may reduce the amount of social interaction, in the case of a pandemic, this may be for the better as mentioned above. This project does not involve politics, but it can be if nothing is done. Because there can be serious lasting impacts to the coconut trees and others alike, therefore it could be used to gain political favor in Hawaii, but this is highly unlikely.

In conclusion, the objectives for project were to create a machine learning model to detect Coconut Rhinoceros Beetles, find small and effective equipment with low power costs, use an IDE to program the equipment with the machine learning model, and to send the images of the Coconut Rhinoceros Beetles to an online server to be accessed anywhere instead of physically going to locations. We successfully met all objectives by creating a model with the use of transfer learning and MobileNet, found the OpenMV Camera H7 and Wifi Shield that features small designs with low power costs and are able to be programmed by the OpenMV IDE, then by utilizing PHP and MYSQL to create a server and database to view the images and other data sent to the server CRBvision.com. The plans for the future of REDLabs project using machine learning involve properly implementing MQTT to send the information properly to the server on the OpenMV IDE or looking for similar solutions. Altogether, REDLab has been successful in the design, development, and implementation of machine learning at the edge.