2018 Intel Cup Undergraduate Electronic Design Contest

- Embedded System Design Invitational Contest

Final Report

Intel Cup Embedded System Design Contest

Project Name：Animal Healthcare Monitoring System Based on Visible Disease Symptoms

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Declaration of Originality

We hereby declare that this thesis and the work reported herein was composed and originated entirely by ourselves. Information derived from the published and unpublished work of others has been acknowledged in the text and a list of references is given in the references.

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ANIMAL HEALTHCARE MONITORING SYSTEM BASED ON VISIBLE DISEASE SYMPTOMS

ABSTRACT

Animals have a close relationship with human. Animals health is always a concerning point because the inflected animals can cause serious problems to human. These problems may affect public health or cause a huge economic lost. However, not everyone can spot out the diseases from the animals directly. They usually need to spend high cost for healthcare. Motivated by the above, the objective of this project is to simplify the process of monitoring animal healthcare, by collecting data set from animals with visible disease symptoms, we use the symptoms photo to train the model, using computer vision to distinguish different types of disease. In this project, the target user will be focus on pet owner and the target animals will be dog and cat.

Key words: Animals, Healthcare, Disease, Computer Vision, Machine Learning, AI

Content

Chapter 1 Introduction

1.1 Background

Animal Healthcare Monitoring System can provide a mechanism for normal people to check their animals' health with a simple portable device. The system can monitor not only the health level of the animals but also acuminate the monitoring history as to use the healthcare history to ensure animal's health in long term. In this project we will focus on the pet owner group and the testing animal will be cat and dog.

Although pet owners can bring their pet to the vet, they need to pay high cost such as expensive fee and queuing time. It is not easy that pets can receive a diagnosis whenever they want. In some case, the treatment maybe delays because of the non-concurrent diagnosis. As owner cannot distinguish or discover the disease as quickly as possible, it may also cause a delay of treatment which is detrimental to pets. On the other hand, different disease will cause different consequence to health, disease which are infectious should be pay attention in the early stage for preventing the spread of disease in order to protect both human and animal health.

In order to improve these situation, we design and implement a monitor to detect disease base on visible symptoms. The aim of this project is to simplify the process of monitoring animal healthcare. Provide a low-cost solution to allow users having a frequency health check for animals without the limitation of time and space. We will provide a portable monitor for user to keep check animals status at any time and a monitoring system for using to use in digital gadget.

1.2 System Schema

1.2.1 Overview

As Figure 1, the system was composed of three major parts, one is the data input module which was used to scan the disease by the symptoms and it may simple use the camera to capture the feature. The second part is the data processing module which contains the UP Squared board as central processing for all the data storage and classification. It is also expected that the data inside the system can be updated through the network in order to obtain the latest model and data. Another is the output part which may include the data and result visualization task the health check result will not store inside the board since the machine may handle different animals in the future.

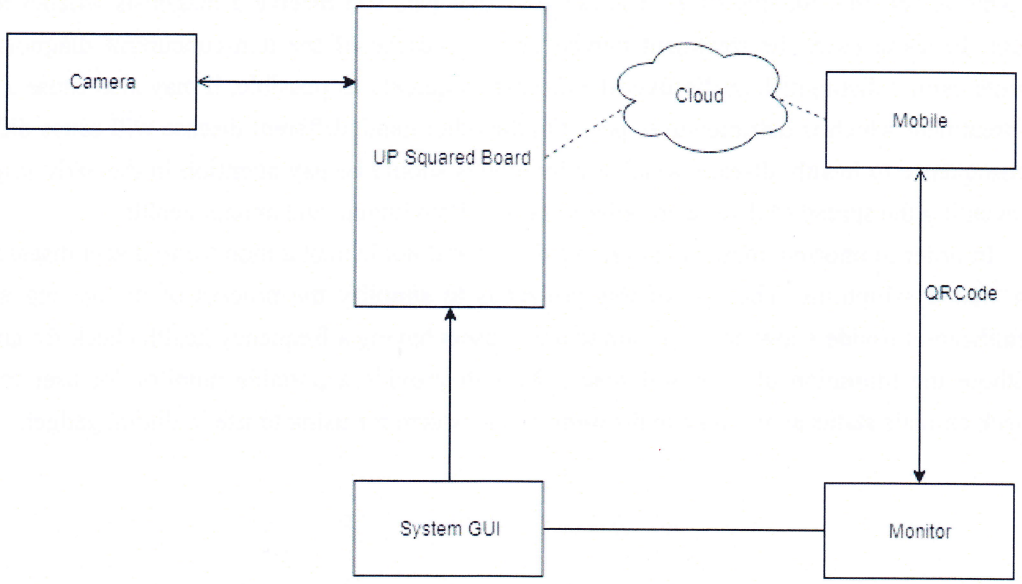

Figure 1 System Overview

1.2.2 System flow

As this project aim to help the pet owner to get a basic diagnosis for pets. It is required to get the raw photo from pet for health check base on the visible symptoms. Therefore, cameras will be used to capture the symptoms from the pets directly. The system then will process the image and forward to the deep learning model inside the system. After the classification has been completed, the result will appear in the LCD monitor with the system graphical user interface (system GUI). It is supposed that the pet owner can get back their own pet health check result by scanning the QR Code generated by the system and view the history on their mobile phone.

1.2.3 Equipment List

Equipment list in this system is shown in Table 1. Figure 2,3,4,5,6,7 are the hardware we used in this project.

Name	Function
Camera	Capture Image
UP Squared Board	Process the images and pass through the deep learning model
LCD Monitor	Display the diagnosis result

Table 1 Equipment List

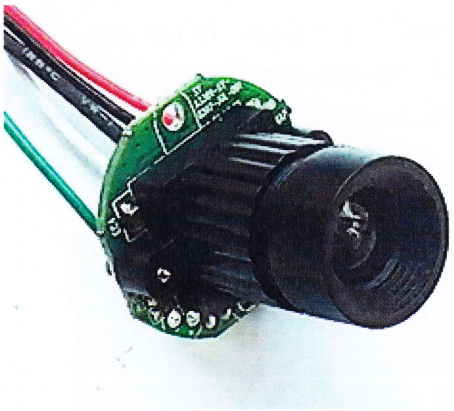

Figure 2 Camera

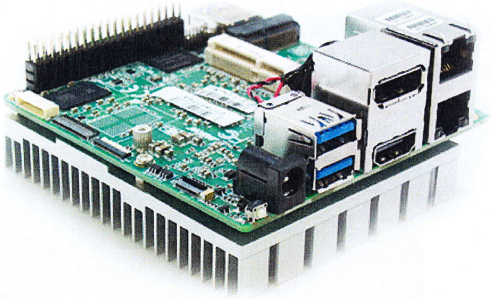

Figure 4 UP Squared Board

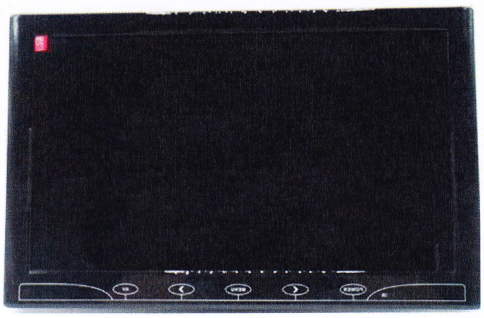

Figure 5 LCD Touch Screen Monitor

Chapter 2 Working Principle and Algorithm

In this project, user can choose to scan dog or cat. There will be 4 scanning part for dog and 5 scanning part for cat. Each scanning part should scan in sequence because each part has its particular training set.

2.1 Data Sampling and Cleaning

On the market, there is no existing dataset to use for our system. In order to obtain high quality dataset, we setup a script to crawl the data source on the internet. Moreover, our university also have College of Veterinary Medicine and Life Sciences and our team may try to cooperate with them to get higher quality data and improve our system in the future. In our case, we need particular part of the animals such as ear, eyes and so on. Our team has flitter and crop the image from internet manually to fulfil our expectation and the model requirement such as size, color depth.

Figure 5 Cats with Normal Ear Data Sources

Figure 6 Cats with Ear Mites Data Sources

2.2 System Mechanism

The device receives images taken by the user as the inputs and that the images will go through serval steps until the final diagnosis result as illustrated below:

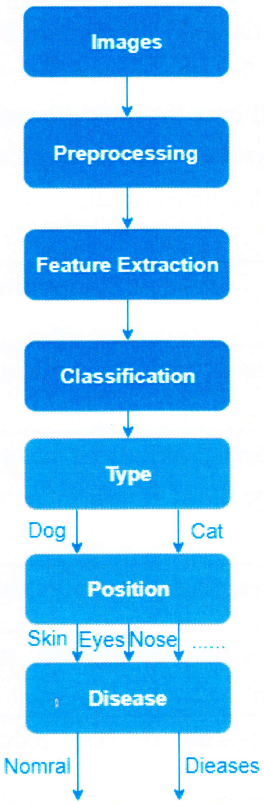

Figure 7. Generic Process for Disease Detection

2.3 Classification

Our system is designed to detect some symptoms of the animals such that the pet owner can help their pet to check health status. Our system based on Convolutional neural network (CNN) is developed to distinguish between different type of animals, positions and diseases for diagnostic decisions. The convolutional neural network CNN consists of convolutional layers, max-pooling layers, dropout layers, fully connected layers. The convolutional layer is a sequence of filters to perform a 2D convolution on the input image where the output of this layer is called the feature map. Max-pooling layer is a subsampling layer where the feature map is down-sampled. Dropout layer is a regularization technique to reduce the overfitting. Fully connected layer is a final layer in CNN where each neuron completely connected to other neurons. The CNN is usually trained under cross-entropy loss function that measures how compatible the network parameters with respect to the ground-truth values in the training dataset. Soft-max layer is used to make the output of CNN lies between zero and one for a categorical target variable.

2.4 Visible Symptoms on Dog

The scanning part for dog will be eyes, nose, skin and feet. For eyes, the system can check for cataract and glaucoma. For nose, the system can check for distemper. For skin, the system can check for atopy, flea allergy dermatitis and Hemangiopericyoma. For abdomen, the system can check for hyperadrenocorticism. For feet, the system can check for canine atopic dermatitis and Alabama rot. Most of the disease will have symptoms together in different body part. Therefore, by scanning different body part, the system will analyze the unusual body symptoms from all body part and return the diagnosis with the predicted result.

Disease	**Visible Symptoms**	**Related Body Part**
Cataract	Certain degree of vision impairment, Cloudy eye	Eyes
Glaucoma	Cloudy appearance at front of the eye, Redness of the blood vessels in the whites of eyes, Dilated pupil	Eyes
Distemper	Reddened eyes, watery discharge from nose and eyes	Nose, Eyes
Atopic dermatitis	Face and feet may be irritated, redden, moist and damaged skin	Skin, Feet
Flea allergy dermatitis	Hair lost and scabs on skin, redness, papules and pustules skin	Skin
Hemangiopericytoma	Small but slowly growing bump or nodule on the body, slowly growing mass which can be soft fluctuant or firm on limb	Skin
Alabama rot	Skin lesions, ulcers or sores	Feet, Skin
Hyperadrenocorticism	Recurrent infections of skin, ears, urinary tract, etc., Loss of hair	Abdomen

Table 2 Summary of Common Dog Disease Detected by Our System

Base on the visible symptoms of each disease, we collect those symptoms photo as data to train the model. For each symptom, we collect 30 to 40 photo images for training. These images will be analyzed using computer vision. Analyzing different components and identical symptoms in the image and output an interpretation of the image.

2.5 Visible Symptoms on Cat

Similar to the process of monitoring dog's health, the scanning part for cat will be eyes, nose, skin, ear and tail. Common disease such as cataract and glaucoma are found in both Dog and cat. Other diseases such as bulging eyes and stomatitis found in mouth. The system can also check nose diseases: aspergillosis and sunburn; skin diseases, like abscesses, mange and rhinotracheitis and lastly ear diseases include outer ear infections. Table 3 show some common disease of cat.

Disease	Visible Symptoms	Related Body Part
Cataract	Certain degree of vision impairment, Cloudy eye	Eyes
Glaucoma	Cloudy appearance at front of the eye, Redness of the blood vessels in the whites of eyes, Dilated pupil	Eyes
Stomatitis	Ulcers and bleeding in lips, tongue, gums, and back of the throat	Mouth
Aspergillosis	Nosebleed	Nose
Sunburn	Redness, thickened and scaly areas on the skin where the burn developed	Nose
Abscesses	Limping or swelling, Redness of the skin, Hair loss in a circumscribed area	Skin
Mange	Patchy hair loss and a moth-eaten appearance to the skin	Skin
Rhinotracheitis	Development of ulcers on tongue, hard palate, tip of nose, lips or around claws	Skin
Infections of the Outer Ear	Black or yellowish discharge, Redness or swelling of the ear flap or ear canal, Waxy buildup on or near the ear canal, Hair loss	Ear
Ear Mites	Hair loss and dermatitis, Black or brown waxy secretion	Ear

Table 3 short summary of some common cat disease

Base on the visible symptoms of each disease from cat. We collect images from cat which contain the symptoms and images which show normal case with 30 to 40 photo images respectively. So that there is a comparison between normal cat and infected cat.

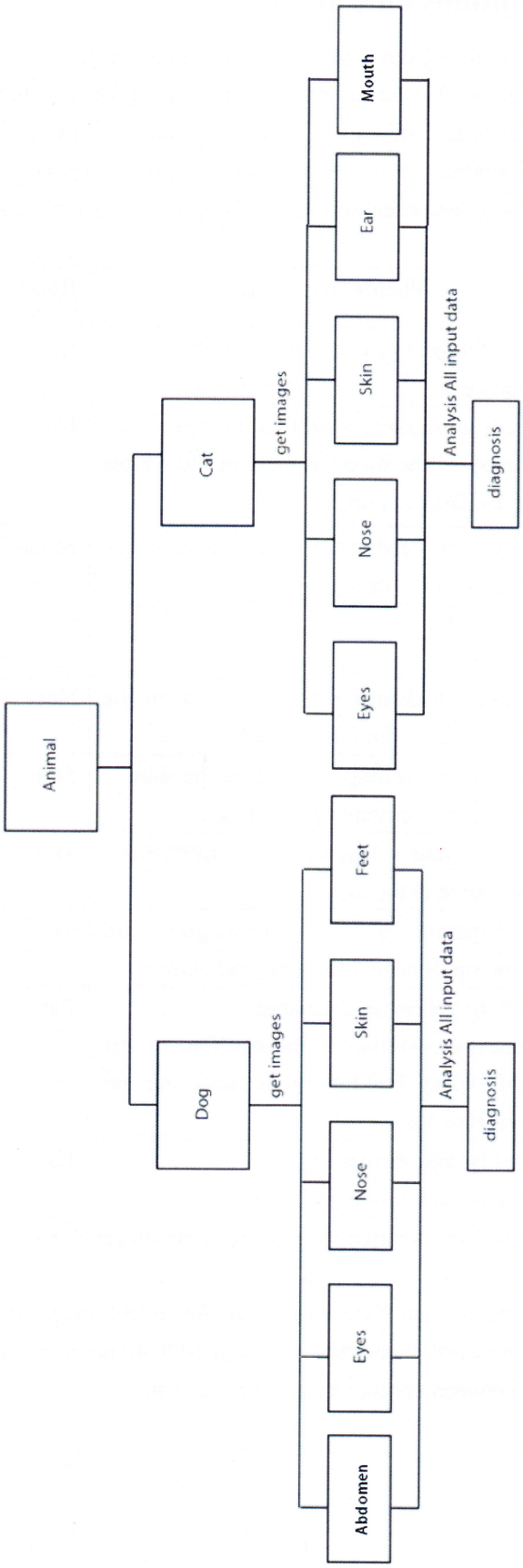

Figure 8 System's Diseases Diagnosis Structure Overview

Chapter 3 Design and Implementation

3.1 Design (User Interface)

The key user interfaces of the monitoring system GUI and external mobile application will be discussed in this chapter.

3.1.1 System GUI

3.1.1.1 Home

User first choose to check dog or cat by selecting the animal corresponding button. Once an animal is chosen, the user can start the scanning and our system will analysis the images with that particular chosen animal's data sources. All the scanning is supposed to follow the scanning guide and it is not suggested to change the type of target animal while scanning the symptoms.

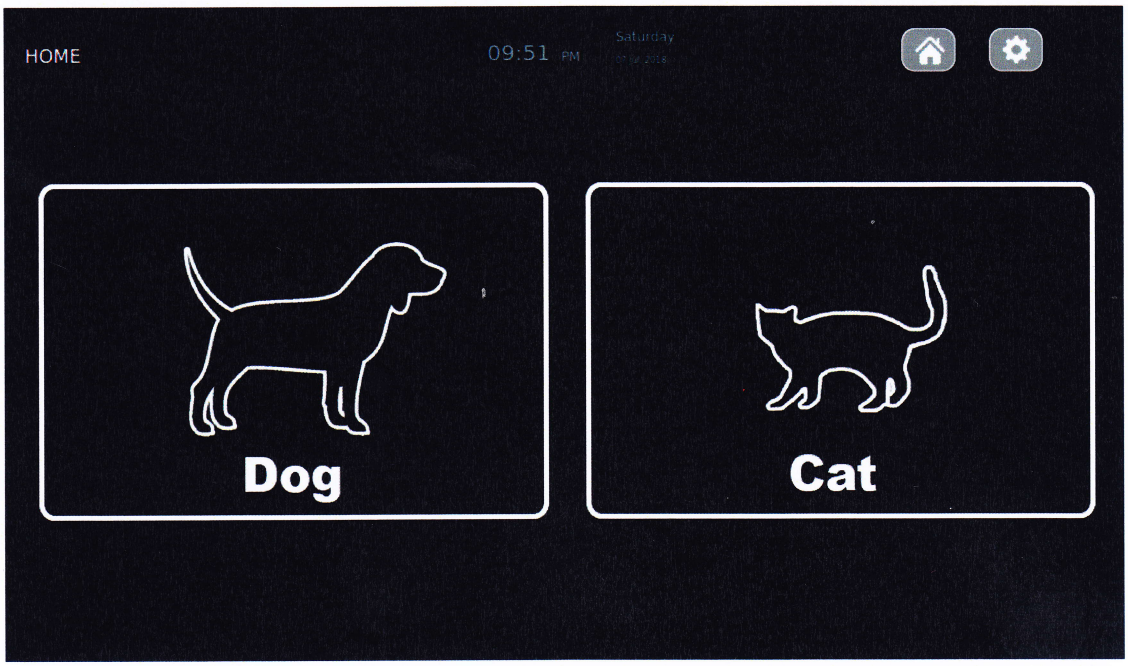

Figure 9 Select Target Animal in Home Page

3.1.1.3 Cat/ Dog Health Check

Once the scanning of animal's body part is done, the system will start analyzing the image captured and the health checking page will be shown as figure 10 for dog and figure 11 for cat. The two pages have similar features. There are two buttons in both pages i.e. 'cancel' and 'restart' to cancel the current checking and to restart the system for new check respectively. However, the parts for health checking is different in between dog and cat according to the data source that the model covered (details listed in chapter 2.4 and 2.5).

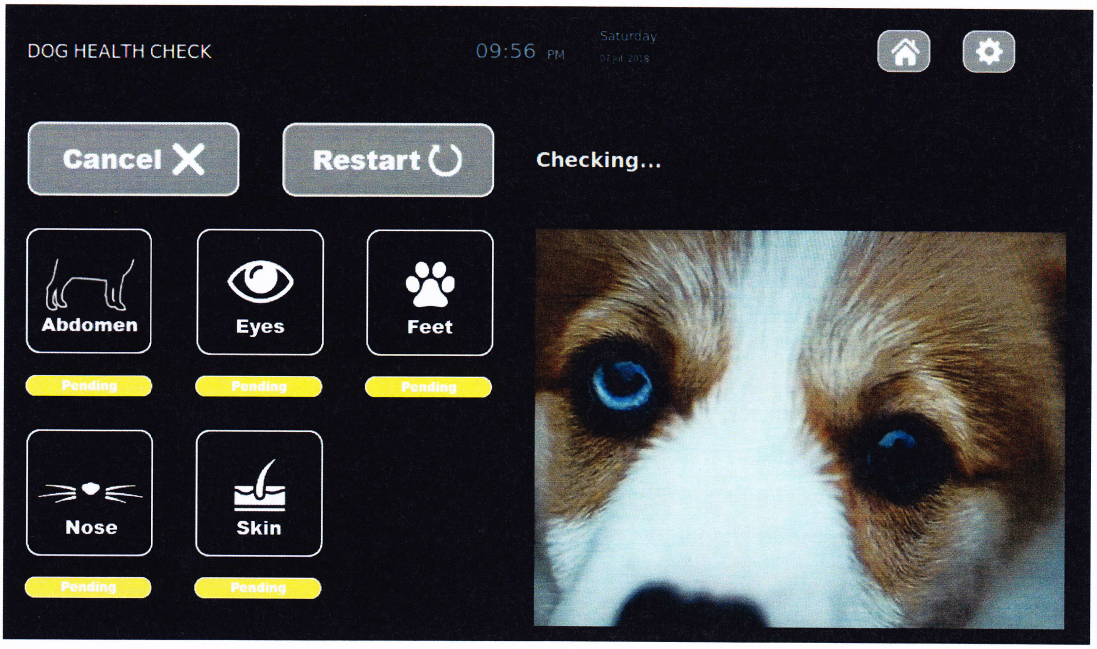

Figure 10 Dog Health Checking Screen

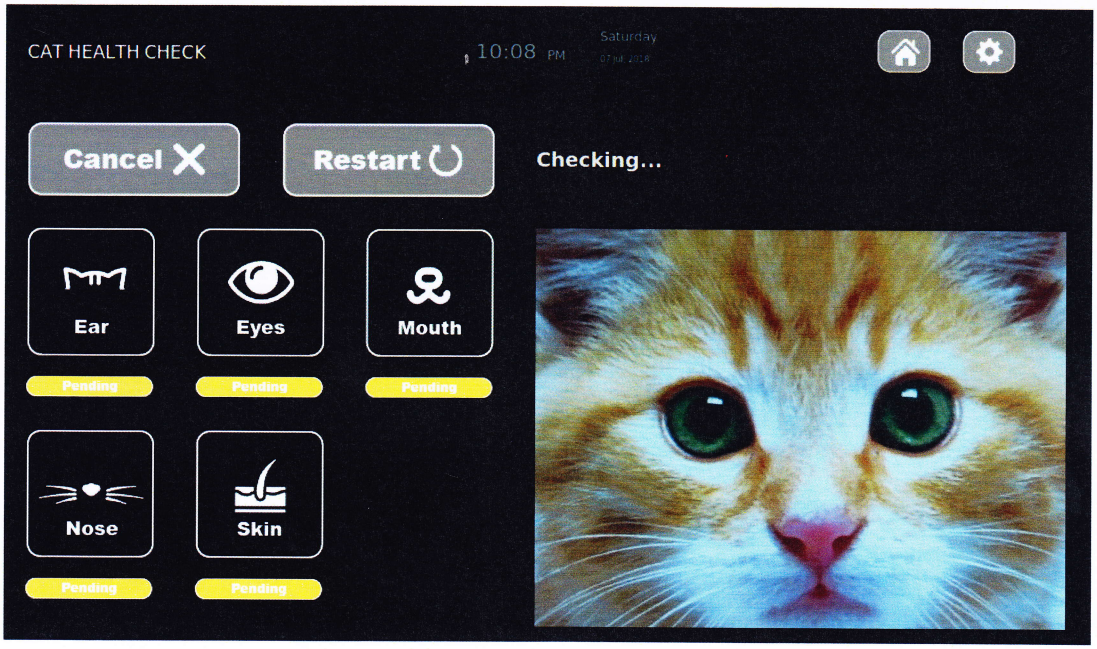

Figure 11 Cat Health Checking Page

With reference to figure 12, each body part is labelled with a state to show the preliminary result. Each unfinished checking part is labelled as 'pending' with yellow color. If a body part is found with a low probability of having the symptoms of any diseases, a green 'safe' label will be shown. Lastly, if the symptoms of one or more diseases are found, a red 'significant alert' label will be shown to warn the user that the health of the animal is in danger and attention is needed.

Figure 12 Health Checking State Labels

3.1.1.4 QR Code

It is used to export the healthcare data that the system just analyzed. Users can use their personal electronic gadget installed with our application to scan the code and retrieve data from the system. Details of the result such as the possible diseases could be found and the data can be saved locally in the users' devices.

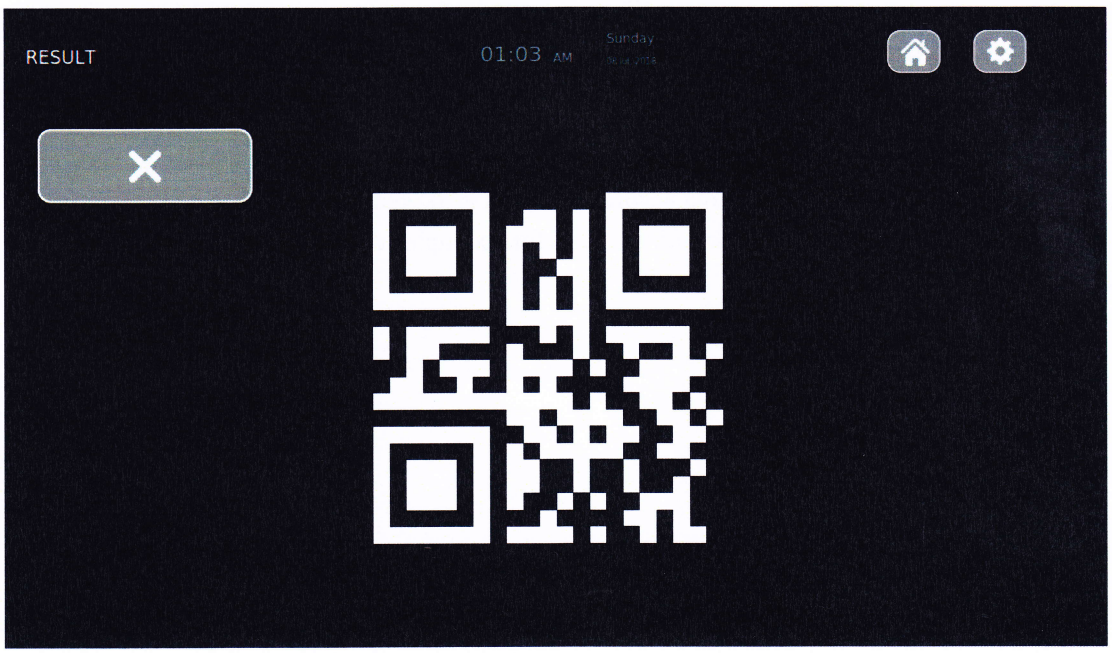

Figure 13 QR Code Result

3.1.1.5 Setting

Setting can be found in the top right corner, next to the home button. There are three buttons namely 'update model', 'clear cache' and 'about us'. The first button used to update the system's model for example, when there are new diseases classification available. The second button helps to clear cache and free up storage space while the last button shows information about our team.

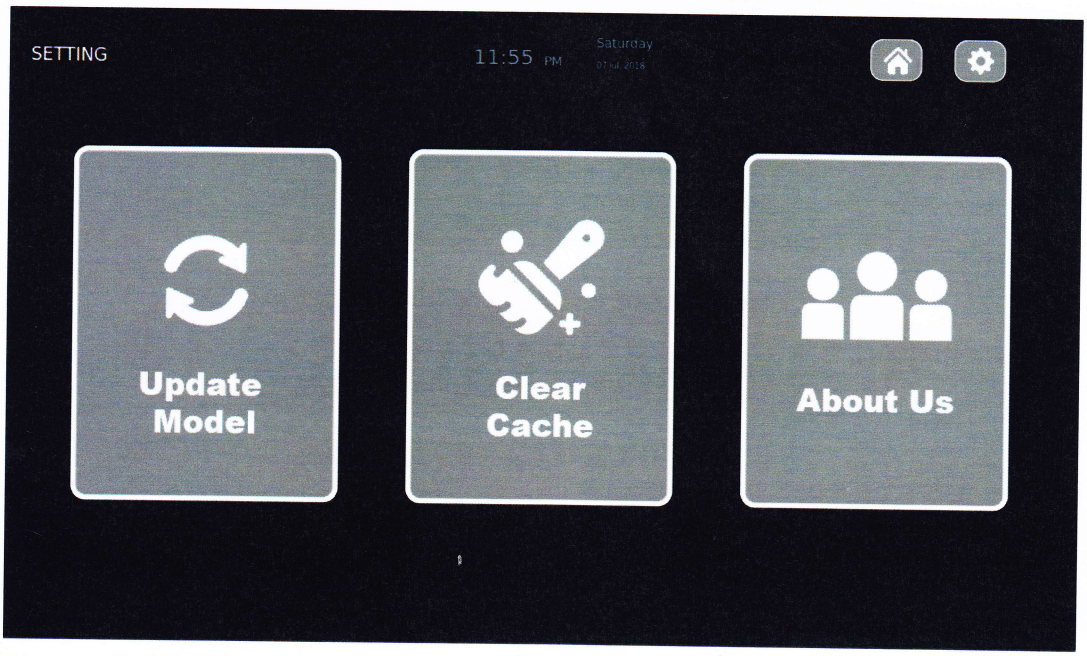

Figure 14 Setting of System GUI

3.1.2 External Mobile Application

Alongside with the system, we also provide a mobile application. It is mainly used to scan the QR code generated in each health scan so that the user can view the details in their own personal devices and save the records accordingly. It is also connected to the cloud which allow animal health care data transfer for further use for example, data exchange between vet and animal owners.

Chapter 4 Test Plans and Result Analysis

4.1 Deep Learning Model Performance Evaluation

In order to improve our classification models on our system, the F1 Score will be used to evaluate the performance. The higher F1 Score means that the performance of the models would be better. The probability threshold in our modes are set to 50%. The calculation details and formulas are as follows. (M = Our supposed set of collection, N: Actual set of collection).

$$Precision = \frac{|(M \cap N)|}{|M|}$$

$$Recall = \frac{|(M \cap N)|}{|N|}$$

$$F1\ Score = \frac{2 \times Precision \times Recall}{Precision + Recall}$$

Figure x Calculation of Precision, Recall and F1 Score

Types	**Precision**	**Recall**	**F1 Score**
Dog	97.2%	90.4%	93.7%
Cat	90.3%	87.2%	88.7%
Overall	95.4%	89.7%	92.5%
Position (Dog)			
Feet	83.5%	75.7%	79.4%
Eyes	80.9%	75.5%	78.1%
Skin	74.3%	45.6%	56.5%
Nose	71.6%	67.0%	69.2%
Abdomen	63.2%	56.5%	59.7%
Overall	76.0%	66.2%	70.8%
Position (Cat)			
Mouth	95.0%	87.5%	91.1%
Ear	74.2%	65.1%	69.4%
Eyes	68.6%	71.4%	70.0%
Skin	61.7%	64.6%	63.1%
Nose	56.6%	58.3%	57.4%
Overall	68.4%	68.4%	68.4%
Disease (Dog Feet)			
Alabama Rot	61.2%	53.3%	57.0%
Canine Atopic Dermatitis	54.3%	32.2%	40.4%
Normal	83.1%	88.8%	85.9%
Overall	71.3%	64.9%	68.0%
Disease (Dog Skin)			
Atopy	72.5%	60.6%	66.0%
Flea Allergy Dermatitis	63.9%	43.3%	51.6%

Hemangiopericytoma	55.0%	26.1%	35.4%
Normal	93.3%	59.5%	72.7%
Overall	67.0%	46.6%	55.0%
Disease (Dog Abdomen)			
Hyperadrenocorticism	85.4%	64.3%	73.4%
Normal	74.1%	61.5%	67.2%
Overall	77.4%	63.3%	69.6%
Disease (Dog Nose)			
Distemper	71.5%	62.3%	66.6%
Normal	86.3%	85.2%	85.8%
Overall	81.8%	77.7%	79.7%
Disease (Dog Eyes)			
Cataract	54.0%	49.4%	51.6%
Glaucoma	52.3%	56.6%	54.4%
Normal	37.2%	27.1%	31.4%
Overall	49.8%	44.3%	46.9%
Disease (Cat Skin)			
Mange	69.4%	58.5%	63.5%
Abscesses	52.6%	45.2%	48.6%
Rhinotracheitis	46.7%	35.1%	40.1%
Normal	74.2%	86.3%	79.8%
Overall	60.8%	60.8%	60.8%
Disease (Cat Nose)			
Aspergillosis	56.0%	62.5%	59.1%
Sunburn	42.5%	60.3%	49.9%
Normal	84.7%	45.7%	59.4%
Overall	54.4%	54.4%	54.4%
Disease (Cat Mouth)			
Stomatitis	96.7%	93.6%	95.1%
Normal	93.9%	96.7%	95.3%
Overall	95.2%	95.2%	95.2%
Disease (Cat Eyes)			
Cataract	50.6%	39.1%	44.1%
Glaucoma	44.0%	56.7%	49.6%
Normal	69.4%	61.8%	65.4%
Overall	53.1%	53.1%	53.1%
Disease (Cat Ear)			
Ear Mites	61.4%	92.6%	73.8%
Infections of the Outer Ear	61.0%	51.1%	55.6%
Normal	80.6%	42.9%	56.0%
Overall	64.3%	63.5%	63.9%

Table 4 Result of F1 Score Regarding All models of System

4.2 Result Analysis

From the above table, there are some class with a low F1 score since we may not provide enough data to train the model and the quality of the image may be not good enough. However, for the overall performance in terms of type of our model, it is with more than 90% of f1 score which implies a high accuracy. The performance of the dog model is relatively slightly higher than that of cat with 93.7% and 88.7% F1 score respectively. For each position check, the overall F1 score in the dog's model is 70.8% and 68.4% in cat. For dog, there is a high accuracy in feet and eyes position check with both more than 78% F1 score while the least F1 score is the skin position i.e.56.5%. For cat, the top F1 score is more than 90% in mouth position and the least F1 score is the nose position with only 57.4%.

4.3 System Performance

With reference to table 5, the response time of the system in generating the scan results are tested and the average performance response time is around 6.42 seconds. The time is within the expected timeframe i.e. within 8 seconds so that a pleasant user experience is provided.

Testing Trial	System Response Time
1st	6 seconds
2nd	7.4 seconds
3rd	7 seconds
4th	6.2 seconds
5th	5.5 seconds

Table 5 Testing Result of System Response Time

Further, the system was tested with sample diseases images to see if the correct diseases are resulted. Details are as follow:

Type	Position	Expected Result	Actual Result	Match?
Dog	Feet	Alabama Rot	Alabama Rot	True
		Canine Atopic Dermatitis	Canine Atopic Dermatitis	True
		Normal	Normal	True
	Skin	Atopy	Atopy	True
		Flea Allergy Dermatitis	Flea Allergy Dermatitis	True
		Hemangiopericytoma	Normal	False
		Normal	Normal	True
	Abdomen	Hyperadrenocorticism	Hyperadrenocorticism	True
		Normal	Normal	True
	Nose	Distemper	Distemper	True
		Normal	Normal	True
	Eye	Cataract	Cataract	True
		Glaucoma	Glaucoma	True
		Normal	Normal	True
Cat	Skin	Mange	Mange	True
		Abscesses	Rhinotracheitis	False
		Rhinotracheitis	Abscesses	False
		Normal	Normal	True
	Nose	Aspergillosis	Aspergillosis	True
		Sunburn	Aspergillosis	False
		Normal	Normal	True
	Mouth	Stomatitis	Stomatitis	True
		Normal	Normal	True
	Eye	Cataract	Cataract	True
		Glaucoma	Glaucoma	True
		Normal	Normal	True

Table 6 Testing Result with Data Samples

From table 6, all the normal cases can be correctly identified by the system. The system can correctly classify more than 80% of the test data with little misclassifications. In the future, more data can be collected in order to update the current model.

Chapter 5 Conclusion

This project covers an affordable scanning device which helps to classify and identify common animal diseases (currently covering dog and cat diseases). With the leverage of Up squared board, deep learning models are embedded into the system and hence the device can help animal owner faster distinguishes their animal's health condition. It safeguards not only the animal's health but also human mankind's health and the cost of taking care of animals because our device provides a cheaper and convenience alternative for keep tracking animal's health.

After the system test, it is ready for the competition. We have met some difficulties during the whole process, including the choose of animal type, the diseases, the system design and some implementation. In the end, we have achieved the portable scanning device to manage animal health. But there is still some limitation in our system such as the disease coverage is not comprehensive and some disease which do not have visible symptoms is hard to detect. In the future, we hope to enlarge the scale of our system as to make the system more comprehensive. We aim to cover more disease and animal type. And we hope this device one day can applicate in human being. This can help human to do self-checking without paying a high cost.

References

[1] Khalil, T., Khalid, S., & Syed, A. M. (2014, August). Review of Machine Learning techniques for glaucoma detection and prediction. In *Science and Information Conference (SAI), 2014*(pp. 438-442). IEEE.

[2] Chen, X., Xu, Y., Wong, D. W. K., Wong, T. Y., & Liu, J. (2015, August). Glaucoma detection based on deep convolutional neural network. In *Engineering in Medicine and Biology Society (EMBC), 2015 37th Annual International Conference of the IEEE* (pp. 715-718). IEEE.

[3] Al-Bander, B., Al-Nuaimy, W., Al-Taee, M. A., & Zheng, Y. (2017, March). Automated glaucoma diagnosis using deep learning approach. In *Systems, Signals & Devices (SSD), 2017 14th International Multi-Conference on* (pp. 207-210). IEEE.

[4] Gross, T. L., Ihrke, P. J., Walder, E. J., & Affolter, V. K. (2008). *Skin diseases of the dog and cat: clinical and histopathologic diagnosis*. John Wiley & Sons.

[5] Prymak, C. A. R. O. L. I. N. E., McKee, L. J., Goldschmidt, M. H., & Glickman, L. T. (1988). Epidemiologic, clinical, pathologic, and prognostic characteristics of splenic hemangiosarcoma and splenic hematoma in dogs: 217 cases (1985). *Journal of the American Veterinary Medical Association*, *193*(6), 706-712.

[6] Paterson, S. (1998). *Skin diseases of the dog* (pp. 297-302). Oxford: Blackwell science.

[7] Paterson, S. (2009). *Manual of skin diseases of the dog and cat*. John Wiley & Sons.