DOG BEHAVIOURAL MONITORING SYSTEM

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DECLARATION

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The above candidate is carrying out research for the undergraduate Dissertation under my supervision.

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Signature of the co-supervisor: Date:

ABSTRACT

Dogs are considered as the most popular pets in the world. Worrying about their health and wellbeing is a noticeable characteristic of dog owners. Behavioural patterns of dogs vary from each other based on their breed and age. This research component is mainly focused on resting behavioural patterns based on their lying position. The dog owners can be acknowledged about their dog's resting behavioural pattern simply via a mobile application that is connected through WiFi, to their home surveillance camera and a sensor that is attached to their dog's collar. Video-based analysis with the ResNet50, pre-trained transfer learning model is used to recognize and classify the resting activity of the dog based on the dog's lying position and it reached the 97% of accuracy level. Dogs from different ages belonging to the Pomeranian and German Shepherd breeds have been selected for this experiment.

Keywords—dog breed, resting, sensor, surveillance camera, transfer learning, video analysis

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LIST OF ABBREVIATIONS

API	Application Programming Interface
CCTV	Closed Circuit Television
CNN	Convolutional Neural Network
IMU	Inertial Measurement Unit
REST	Representational State Transfer
RTSP	Real Time Streaming Protocol
UML	Unified Modeling Language
UI	User Interface

1 INTRODUCTION

The great interconnected bond between animals and humans comes from a long time of history. Even though it has ups and downs, that bond is unbreakable. Especially when it comes to pet animals like dogs, that bond is much stronger than anything else.

Pet owners worried about their pet dogs almost all the time, but with the busy lifestyle that they are dealing with, it becomes a little challenging to keep 24X7 continuous attention towards their pet dogs. So, they have looked forward to the technical compensation to solve their issue.

This is the place where all the dog behaviour and health tracking systems and dog watching cameras come to play along with an extensive range of facilities like getting instant notifications through the mobile application.

Resting is one of the most significant behaviours when it comes to animal health. Changes in resting patterns of animals can cause uncomfortable and dangerous diseases. Therefore, it is necessary to track resting patterns of animals.

Especially dogs have several resting patterns based on their age and breed. According to medical research and observations [1][2][3], puppies tend to sleep/rest 18-20 hours per day and adult dogs tend to sleep/rest 12-14 hours per day. And, when concentrating on breeding, large breed dogs tend to rest a greater number of hours than small breed dogs.

Sometimes dog owners get confused with their pet dog's resting pattern. So, tracking dogs' resting patterns based on their age and breed is significant, because using those tracked details dog owners can make sure that their dog gets enough rest relevant to its age and breed.

For this purpose, the concept of image processing for tracking the resting behaviour of the pet dog based on its age and breed, as an additional usage of surveillance cameras is introduced through the developed system.

1.1 Background and Literature Survey

1.1.1 Analysis of previous research studies

The study, A Combined Approach to Predicting Rest in Dogs Using Accelerometers [4] has combined a previously validated low-movement algorithm developed for humans and a posture-based algorithm developed for dogs. They have tested the hybrid approach to 12 healthy dogs from various breeds and sizes. Their system predicted the rest state with the mean accuracy of 0.86 and the method was able to recognize between head up and head down position with the mean accuracy of 0.90 when the dog was in resting state. They found that the LMR approach combines methods devised by Clarke and Fraser and Borazio and provides insights into dogs' resting behaviours within a naturalistic environment. So, as a result, they were able to identify the dog's resting state with the categorization on its head position.

The system developed in Analysis of Dog's Sleep Patterns Using Convolutional Neural Networks [5] is for analyzing sleeping patterns of kenneled dogs, which may serve as an indicator of their welfare. The system combines convolutional neural networks with classical data processing methods and works with very low-quality video from cameras installed in dogs' shelters. The video is processed by the client and frame sent to the server frame which is the input to a neural network that has two main tasks: marking the dog's position and classifying the sleep/awake state of each dog. Their training dataset consisted of 8000 frames extracted from the videos and the obtained frame annotations included two attributes for every dog visible in the frame: (i) bounding box: an axis-aligned box surrounding each identified dog, and (ii) state of the identified dog: awake or asleep. Reaching out to their neural network which has two tasks: (i) localization, i.e., marking the dog's position with a bounding box, and (ii) classification, i.e., marking sleep/awake state of each dog that was identified. Then they considered about two possibilities as Two-stage model (two distinct neural networks for the two tasks of localization and classification, packaged as one model) and One-stage model (an end-to-end model for the detection (both localization and classification) of two types of objects: a sleeping and an awake dog) Then they used two criteria as Intersection

over union and Number of unrecoverable network errors to compare those two models and choose the better one which is the end-to-end architecture. They used the TensorFlow object detection API for object detection purposes. Their post-processing was based on the possible errors produced by the network in the tasks of localization and classification that includes double detection, random detection order, high-frequency noise in bounding box coordinates, one-time classification errors, and false-positive sleep detection. The results of this research are sleep parameters such as the total amount of sleep, sleep interval count and sleep interval length.

According to the study of recognition of human and animal movement using infrared video streams [6], their system presents a technique to distinguish human motion from animal motion using infrared video sequence as in surveillance camera videos. They used image frame differencing to represent object motion. Space-time correlations capture the changes of the different motions of human vs. animal. With the space-time correlations, two statistics, Renyi entropy and mean value, are calculated as motion features. A support vector machine-based classifier is used to classify the motion features. Their research method can be divided into three main stages as a representation of motion information, extraction of motion features and classification of motion features. They have used 38 human motion sequences and 38 animal motion sequences, including 12 dogs and 26 horses. Their system could achieve a classification rate of 92.5%, which is quite impressive, considering the quality of the testing data.

K9-Blyzer - Toward Video-Based Automatic Analysis of Canine Behaviour [7], is a tool for automatic analysis of canine behaviour based on movement data extracted from video footage. One of the tool's key features is the simplicity of use, both for the human user and the canine subject: this means taking as input simple videos created at home with the cheapest camera, and absolutely no markings, sensors or loggers on the dog. Another important feature is the support for the investigation of interactions of dogs with various types of agents, including social interactions with humans and robots. Python, computer vision algorithms, OpenCV library, TK toolkit for user interfaces and Matplotlib library for data visualization are technologies used in this system. Filming should be done from a static perpendicular to the floor angle and in a well-lit area are

the restrictions on the video. The video is the input to the video analysis module and the output is movement data of two types as the distance between agents in space and distance between occurrences of the same agents in time. This data is used as input for the behaviour analysis module, whose aim is to automatically tag the video using hosen behavioural categories. Datasets are created using four dogs which is one of them is mostly blind and three videos were carefully selected according to the criteria like length 2-4 minutes and at least 20 occurrences of each of the behavioural categories (touching, approaching and retreating). As the measurement methods, they compared the behavioural categories (touching, approaching, retreating) as tagged by the tool to the manual tagging of categories, which has been taken as a baseline. Then they considered a pair of video segments as a match if they had more than 3 frames in common.

The research study in video analysis of dogs with separation-related behaviours [14] has done using 23 dogs ranging in age 5-13 years and different breeds as the dataset, to approach the following objectives. Separation-related behaviours are described as problematic behaviour that occurs exclusively in the owner's absence or virtual absence. Diagnosis is generally based on indirect evidence such as elimination or destruction that occurs during owner absence. Questionnaire studies are based on owner perception and might, therefore, underestimate the actual proportion of dogs with separation problems. The aim of this study was to film dogs with separation-related problems when left home alone and compile objective information on behaviours exhibited. In conclusion, they realize separation-related disorders could be the consequence of different underlying states such as discomfort, fear (''hyperactive'' and ''freezing'' subgroups), or anxiety, along with overlapping signs of different intensities and frequencies and if these separation-related behaviours are compatible with one or several underlying states, it is then possible that different clinical syndromes may have been grouped under the same label.

1.1.2 Analysis of current products

There are plenty of verities in the dog health tracking system and dog watching cameras in the market nowadays.

FitBark [8] is a dog activity and sleep monitor which is a new way to motivate both dogs and the owner to be active, explain changes in behaviour and make better decisions with their vet about nutrition, mobility, anxiety, skin conditions and other health issues. This tracks dog's activities and sleeps daily turn it into deep, actionable health insights. This is suitable for the dogs that belong to any age and breed. FitBark is waterproof, designed to stand ruff playtime and be submerged in up to 1 meter for 30 minutes and weighs 8 grams which have a curved design on it. It uses a 3-axis accelerometer as its sensor. It includes a battery which has 90 minutes of charge time and lives up to 14 days. This has the synchronization range of 9 meters which requires an internet connection and its memory is up to 28 days of minute-by-minute data. As they said this works anywhere in the world measuring activity counts (BarkPoints) and rest, activity and playtime, nocturnal sleep score, overall health index, activity index, calorie burn, distance travelled. A variety of research institutions and vet schools use FitBark as their monitoring tool.

Whistle [9][10][12] is called the best pet tracker and just got smarter. There are multiple Whistle products in the market now. For instance, Whistle 3, Whistle GO and Whistle GO Explore. Whistle FIT is the latest product and it was released to the market on 21st January 2020. The usage of these products is easy to understand for the dog owners. There are three main goals of the Whistle app, such as track location, monitor health and celebrate adventure. In location tracking there are four chores like making the dog owner aware of his/her dog's location, set up safe places, get proactive alerts and activate real-time tracking. And, it can view pet's day, track their favourite spots, personalize alerts, connect with the whole family, monitor multiple pets at a time and set custom reminders. When it comes to monitoring activities and health, Whistle app facilitates with various tasks as follow: set fitness goals, monitor daily activities, get gentle nudges, set a pet's health dashboard which helps the owner to identify the changes in the behaviour of their dog, share reports with their vet and provide a weekly wellness report. This app sets targets for the dog and when it is achieving those targets the owner can celebrate them with the dog. The whistle is 0.92oz – 1.25oz weighted with the attachment piece, waterproof and shockproof. It is along with the night mode

and battery life of about 7 days with good Wi-Fi and cellular coverage. This can be used throughout the United States (within AT&T cell coverage) only.

Kippy Vita S [11][12] is an innovative GPS pet tracker and activity monitor for both cats and dogs that rely on both GPS and LBS tracking technologies to pinpoint pet's exact location when lost or stolen and monitor its activity levels, keeping track of their running, walking and sleeping habits, playing, relaxing and even calorie burning. Kippy Vita is square and sleek in design and made of steel and extra-grip Velcro. It weighs 50g (1.76oz) which is more suitable only for pets weighing over 4kg. Furthermore, it is water-resistant and has an anti-shock ABS body that makes it resistant to impact, rendering high durability. It also has a night mode, battery life up to 3-4 days and communication coverage are anywhere from 300m to 2km. The device collects activity data every 60 minutes and sends the information directly to the Kippy Vita app. Kippy Vita works in most of Europe, Turkey, India, and South Africa.

Above mentioned products mainly use sensors to track the dog's health but they do not allow the dog owner to watch how his/her dog is doing while he/she is away. That is the most stressful situation for them although they can track their dog's health using the above-mentioned products. This is the perfect place for dog watching cameras[13] to start its roll. These cameras have mainly three features: two-way communication, sending noise and motion alerts to the owner's phone and capturing footage while the owner is away. PetChatz Pet Treat Camera, Furbo Dog Camera, YI Dome Camera, Tooge Pet Camera, and Pawbo Life Pet Camera are some of the best-rated dog watching cameras with the mentioned features. It is a fact that both types of these products (using sensors and dog watching cameras) are quite expensive to handle.

1.1.3 Compare existing system and related work

Table 1.1: Compare Existing Systems and Related Work

Product / Feature	PetChatz Pet Treat Camera [13]	Furbo Dog Camera [13]	Tooge Pet Camera [13]	FitBark [8]	Whistle [9]	Kippy Vita S [11]	Proposed System
Two-way communication	Yes	Yes	Yes	No	No	No	No
Send motion and noise alerts to the owner's phone	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Capture footage while the owner is gone	Yes	Yes	Yes	No	No	No	Yes
Clear night vision	No	No	Yes	No	No	No	Yes
Ability to analyze resting behaviour	No	No	No	Yes	Yes	Yes	Yes
Comparison of resting behaviour based on age and breed	No	No	No	Yes	No	No	Yes
Notify owner about the unusual resting behavioural changes	No	No	No	Yes	Yes	Yes	Yes
Generate Daily Report	No	No	No	Yes	Yes	Yes	Yes

1.2 Research Gap

According to this literature survey, most of the dog health tracking systems which can track the resting behaviour of dogs have been created using sensors. And, there are considerably expensive dog watching cameras that can be used by the dog owner to watch their pet dog while he/she is away from home and communicate with the dog [13]. The behaviour tracking systems in the market and previous research mentioned in the literature survey [8][9][11], compare the dog's own behaviour and notify the owner about the unusual changes but they do not compare the dog's behaviour changes based on its breed and age to know whether the dog has the appropriate behaviour according to its breed and to its age.

Previous research studies have proved that computer vision can be used to track resting patterns of canines but most of them used expensive cameras for filming purposes. Surveillance cameras were used for tracking walking and other motion behaviours but not for tracking resting behaviour [4].

In the developed system, the dog's video feed was taken from a non-expensive surveillance camera which is set in the restricted area where the dog can stay in comfort. Using that video feed or an image, its breed was identified and the features (usual behavioural patterns such as resting, walking, and barking) were stored in the database according to its breed and age. The age of the dog was inserted into the database as user input from the mobile application. Then the CCTV video feed was used to recognize the unusual changes in the resting behaviour of the dog as below.

The number of total resting hours was calculated using that video feed. Another resting time value was already stored in the database by the walking pattern recognition component. Then the mean resting value was calculated using both of those resting values. That final resting value got compared with the average resting hours of the dog based on its breed and age which is already stored in the database. If there is a considerable change in those two values, then the dog owner will be notified through the mobile application.

This comparison will be applied to identify unusual changes in walking behaviour patterns also but the walking patterns will be tracked using a sensor. The different barking patterns of the dog at unexpected times in the day such as barking to a stranger or barking in a fight also will be notified to the owner through the mobile application. At the end of the day, the dog owner can view a report with all the details about his/her pet dog's behavioural changes.

The ability to compare the dogs' behavioural patterns based on their breed and age using both sensors and surveillance cameras brought the novelty to the solution since they had been researched less in the past work.

1.3 Research Problem

According to the previous research work, most of them have used only either sensors or computer vision to track animals, especially dogs' behavioural changes. Therefore, one of the research problems is how sensors and computer vision can be combined to track dogs' behavioural patterns.

Since the products which are currently in the market do not compare the dog's behaviour patterns based on its breed and age to know whether the dog has the appropriate behaviour according to its breed and to its age, the developed system has addressed that problem too.

The main research problem in the resting behaviour pattern recognition research component was to track resting pattern changes in the dog using a surveillance camera and notify the dog owner about the unusual changes through the mobile application.

In summary, the following are the three research problems that were able to address through the implemented system:

- How can sensors and computer vision be combined to track dogs' behavioural patterns?

- Check whether the pet dog has the appropriate behaviour according to its breed and to its age?

- How to track the changes in resting hours using surveillance camera video feed?

1.4 Research Objectives

Main Objective

Recognizing the unusual resting behaviour patterns of the pet dog associated with the analysis of pet dog's resting patterns according to their breed and age using surveillance camera video feed and sensor data.

Sub Objectives

- Track the dog positions(lying) using surveillance camera video feed.
- Receive walking analysis from sensor data to make sure whether the dog is not moving at the relevant period.
- Find the total number of resting hours of the dog by calculating the mean value of resting times that are tracked from the CCTV camera and the sensor.
- Compare the resulting total number of resting hours of the dog with the average number of resting hours of the dog based on its breed and age.
- Notify the dog owner about the unusual changes in the resting patterns of the dog.
- Add the analysis of the resting behaviour of the dog to the daily report.

2 METHODOLOGY

2.1 Methodology

The research problem of this component was to track and monitor the changes in the resting activity pattern of the dog. In this area, we portrayed the strategies, explicit methodologies and techniques that have been followed to accomplish the research objectives. When it comes to the implementation of behavioural tracking systems, many systems have been implemented using sensors with the incorporation of Machine Learning algorithms for activity detection. But in this research component, the system was able to track the resting behavioural patterns of the dog and analyze the behavioural changes based on its breed and age using image processing which was applied for the video feeds that was obtained from the CCTV camera.

The topmost priority of the discussed research component was to track the resting patterns of the dog. The developed framework requires a particular arrangement of segments to work as one to accomplish its goals.

2.1.1 Methodological approach

Combination of data collection from the surveillance camera and the sensor was used to recognize the resting behaviour pattern. The HD resolution (1280*720) indoor Wi-Fi camera (EZVIZ C1C camera) was fixed to the restricted area, where the video can be easily taken with more details of the dog's behaviour like whether the dog is in a lying position or not in a lying position. The camera has the ability to capture videos in two modes: full-colour mode, where space is illuminated by the daylight (sun or a lamp), and grey-scale mode, where space is illuminated by infrared camera light (enhanced night vision with 40ft/12m). The IMU sensor (6DOF MPU6050) which consists of a triaxial accelerometer and a triaxial gyroscope is attached to the collar of the dog.

The Convolutional Neural Network (CNN) model[20] is created using the ResNet50 pre-trained transfer learning[21] model for the purpose of recognizing the resting activity patterns of the dog. A video is a set of images but in a video, those images are called frames. Breaking down the video that is captured from the CCTV camera, into video frames is the next step which is essential for the prediction process through the

created transfer learning model. It was done using OpenCV on the basis of 1fps (frames per second).

Prediction process started with detecting the frames that included the dog using the CNN model. After that, the other frames were discarded. The ResNet50 model used to apply the classification of lying and not lying positions of the dog to predict the dog's resting state. The frames that were resulted with a lying prediction were considered as the resting state of the dog and total count of those lying position frames were multiplied by the frame size(1fps) to find the total resting time of the dog which was obtained from the camera data.

At this moment, the walking activity recognition component was also predicted whether the dog is running, walking or resting along with the time that was spent for each activity using the data that was gained from the sensor. So the next step was to acquire the resting time using API methods that were tracked from the sensor and calculate the mean resting time using both resting time values that were detected from the camera and the sensor.

Since the goal of this component is to find whether the pet dog is showing any kind of unusual resting behaviour, the system needed to compare values such as the dog's current resting time and the standard resting time based on its breed and age. Previously calculated mean resting time was the dog's current resting time and the standard resting time based on its breed and age was already stored in the database by the dog breed recognition component.

If the comparison did not result in a huge difference between those two values, the system sent a notification to the dog owner via the mobile application, notifying that his/her dog was healthy with its usual behaviour. On the other hand, if there was a major difference was shown in the comparison, the system notified that the dog was going through an unusual resting behaviour pattern.

2.1.2 Feasibility study

The feasibility study that was done related to the domain of this research was an absolute investment for figuring out the initial steps that need to be covered in the implementation of the dog resting activity monitoring systems this study aimed such as image processing, transfer learning and machine learning algorithms.

The conducted feasibility study reveals that the technologies and the datasets that were possible to use and the accuracy levels that were gained by the current products which needed to be achieved from our system by utilizing the created models.

Following are some of the factors that were highlighted in the conducted feasibility study for resting activity detection:

- There was no, a specific dataset to utilize the model. Therefore, a couple of different datasets needed to be merged.
- It is important to perform data preprocessing steps to make the data ready to be trained from the model.
- To find the best accurate predictions, the system needed to be trained with a lot of data with a significant amount of time.

2.1.3 Technological approach

The following table represents all the technological approaches that were applied in the development process of the resting pattern recognition research component. The mentioned feasibility study assisted the choices of these technological approaches to render the best accurate results for dog owners with pleasant user experience.

Table 2.1: Technical Feasibility Study

Model	ResNet50
Programming Languages	Python, Dart
Libraries	Keras, SciKit learn, Pandas, Numpy, Matplotlib
API Development	Django REST framework
Database	MongoDB
Version Controlling	Gitlab

The above choices were made due to the reasons that are described below:

- Model - ResNet50

  Since the research component is required to deal with video data, it is essential to use image processing with CNN to detect the dog in the video frames. One of the major considerations that needed to be addressed was the unrelated datasets which cannot be used to predict the resting activity of the pet dog. Therefore, 4 databases were customized and merged to proceed with the model building process. Even though the final dataset was merged with other datasets, the amount of data was not enough to train the model. ResNet50 pre-trained transfer learning model was utilized to categorize the classes based on lying position and not lying position and predict the dog's rest state with the assumption of lying position indicates the resting activity of the dog.

  The ResNet50 model was able to reach the accuracy level of 97% while VGG16 and VGG19 pre-trained models were reaching the accuracy level of 94%.

- Programming Languages - Python & Dart

  Python - Python was used to train the CNN model with the ResNet50 pre-trained model and for the implementation of the Django REST framework as they are based on python.

Dart - Dart is the language that is used by the Flutter framework which was used to develop the mobile application to provide instant updates for the dog owners about the changes in their dog's usual behavioural pattern.

- Server Implementation

  All the technologies listed above were combined to create the proposed system.

2.1.4 Requirement gathering

Since all the decision making, planning and executions regarding system implementation and testing depending on the requirement of the system, requirement gathering is considered as one of the most important and critical phases in the software development process. The gathered requirements of the dog's resting pattern recognition component are described as below:

Dog's resting activity should be tracked using a surveillance camera which can be fixed into a controlled area that has much space for the dog to move around and rest in its comfort zone and also the video footage can be easily captured.

The CCTV camera should have a Wi-Fi facility for increasing the user-friendliness of the system.

Prediction of the resting activity of the dog should be done using the categorization of lying position class and not lying position class while the lying position indicates the resting state of the dog.

In order to increase the accuracy of the system, the resting pattern recognition component should be combined with the walking pattern recognition component and calculate the mean resting value using the resting values that are resulted from both of those components.

This component should be able to monitor the unusual resting behaviour by comparing the standard resting time amount which is stored to the database from the dog breed identification component and the calculated mean resting time.

This research study has to be conducted subjecting the dogs from different ages belonging to the Pomeranian and German Shepherd breeds.

2.1.4.1 Functional Requirements

Following are the functional requirements of the resting pattern recognition research component.

- Setting up the CCTV camera and capture the video feeds of dog.
- Find the resting time using video feed.
- Access the resting time tracked by the sensor.
- Calculate the mean resting time using both resting time values from video feed and sensor.
- Compare the calculated mean resting time with standard resting time of the dog based on its breed and age which is stated by Wag Walking Site.
- If the comparison result with huge deference between mean resting time and standard resting time, report it as an unusual resting behavioural pattern.

2.1.4.2 Non-functional Requirements

Following are the non-functional requirements of the resting pattern recognition research component.

- Accuracy
- Efficiency
- Performance
- Reliability
- Accessibility
- User friendliness
- Easy understandability

2.1.5 System architecture

The system architecture diagram shown below depicts the component analyzing Resting Pattern Recognition.

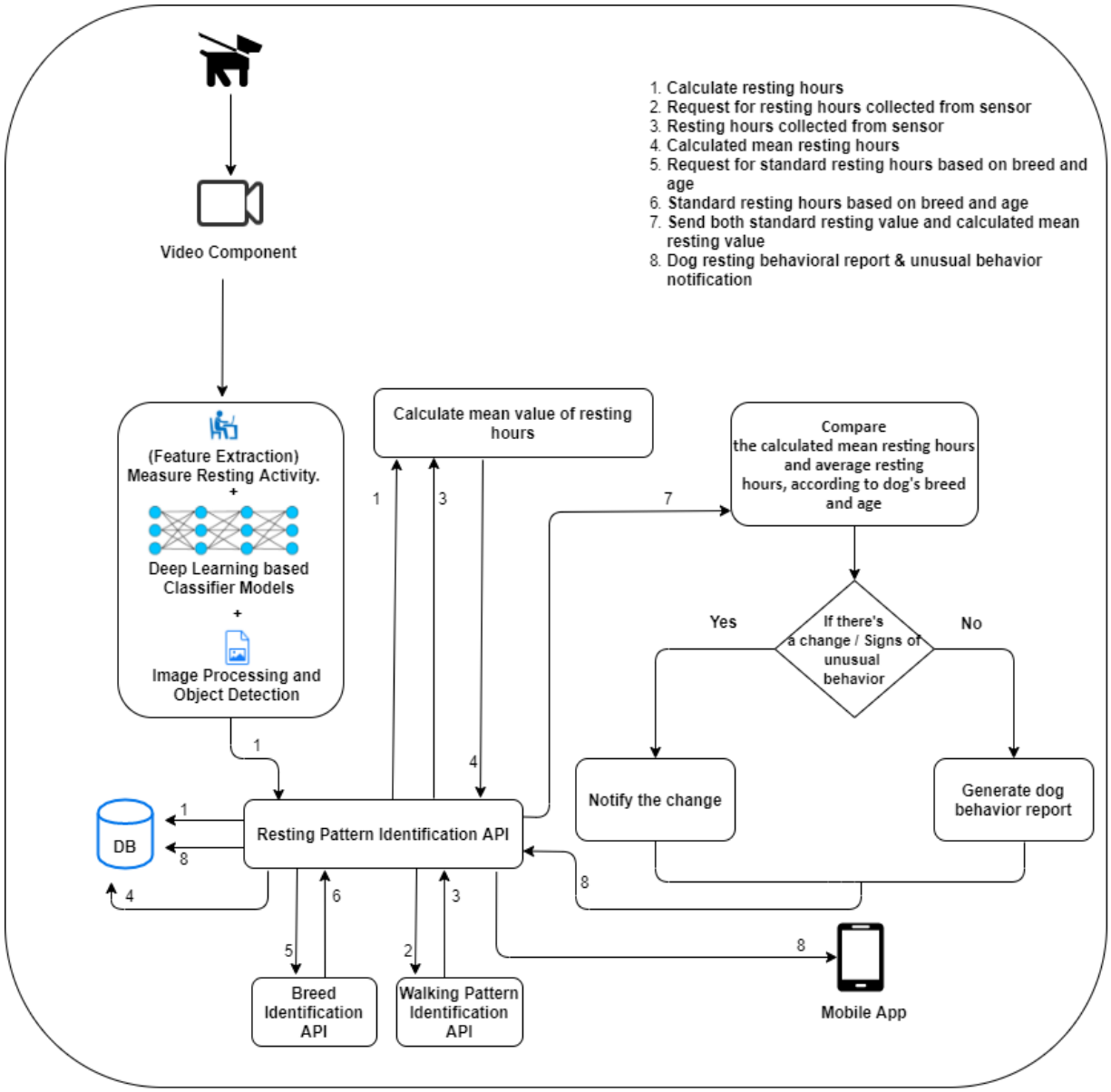

Figure 2.1: System Architecture Diagram - Resting Pattern Recognition

2.1.6 Design

Since all the research components are connected for the whole execution of the system, all 4 components of the system should be developed and tested parallel. Therefore, following the Agile SCRUM concept throughout the system development and evaluation process was a smart choice that has been made in the beginning. This helped

to successfully complete the establishment of the pipeline for integrating the different models for further experimentation.

User Interface Design

A product that does not provide better user experience is useless. So rendering the best user experience throughout the mobile application was one of the main goals when the user interfaces were designed. All the colours, type and size of the fonts, section alignments, straightforward, easily understandable and predictable directions between pages related to all four research components were chosen after many hours of planning. As an example, colours and fonts were selected to go along with the theme of animals and all the graphs and notifications were created with the features that grab the pet owner's attention as quickly as possible.

User interface design planning was done using a tool called Figma, which is used to create prototypes of the user interfaces. The user interface prototypes that were created for the resting pattern recognition component are shown below:

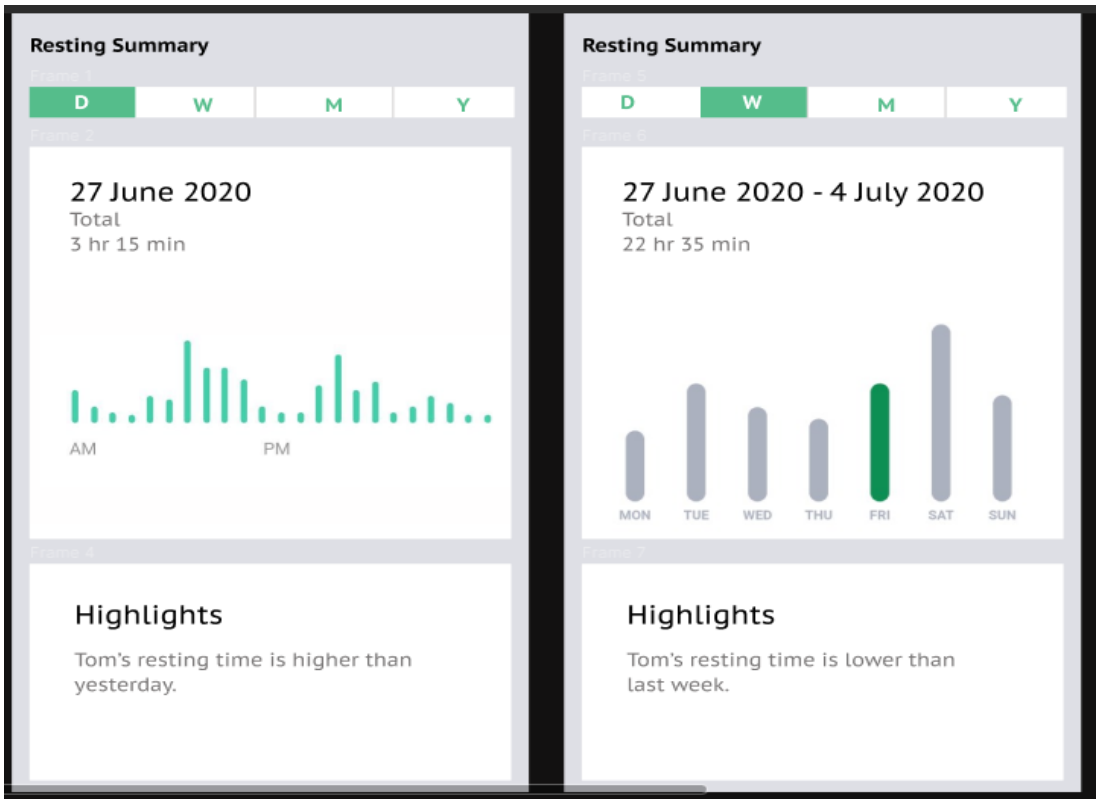

Figure 2.2: UI Prototypes of Resting Pattern Recognition - Daily & Weekly Reports

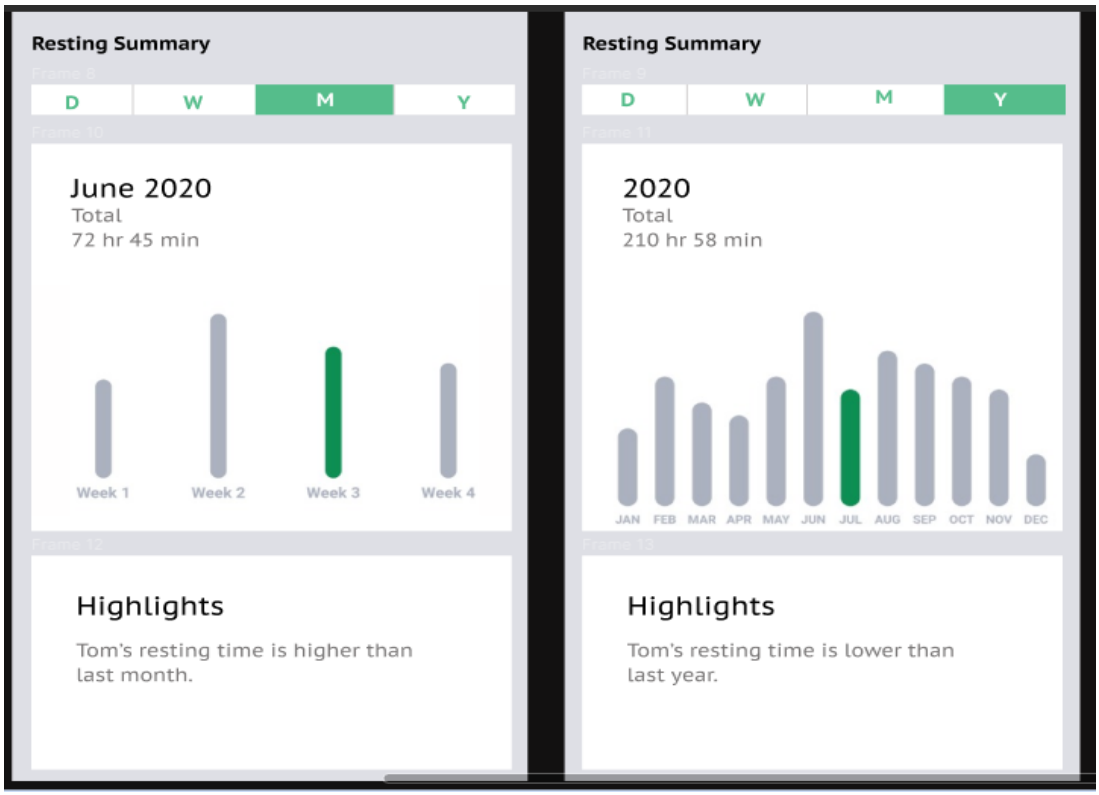

Figure 2.3: UI Prototypes of Resting Pattern Recognition - Monthly & Annual Reports

System Design

After requirement gathering, a couple of UML diagrams were drawn for the purpose of understanding the system requirements. Those diagrams were the key assistance of the implementation and testing phases of the system development process because they saved a lot of time that could have been spent for understanding the complexity of the research problem. Those diagrams are listed as below:

- Use case diagrams
- Activity diagrams
- Sequence diagrams
- Class diagrams

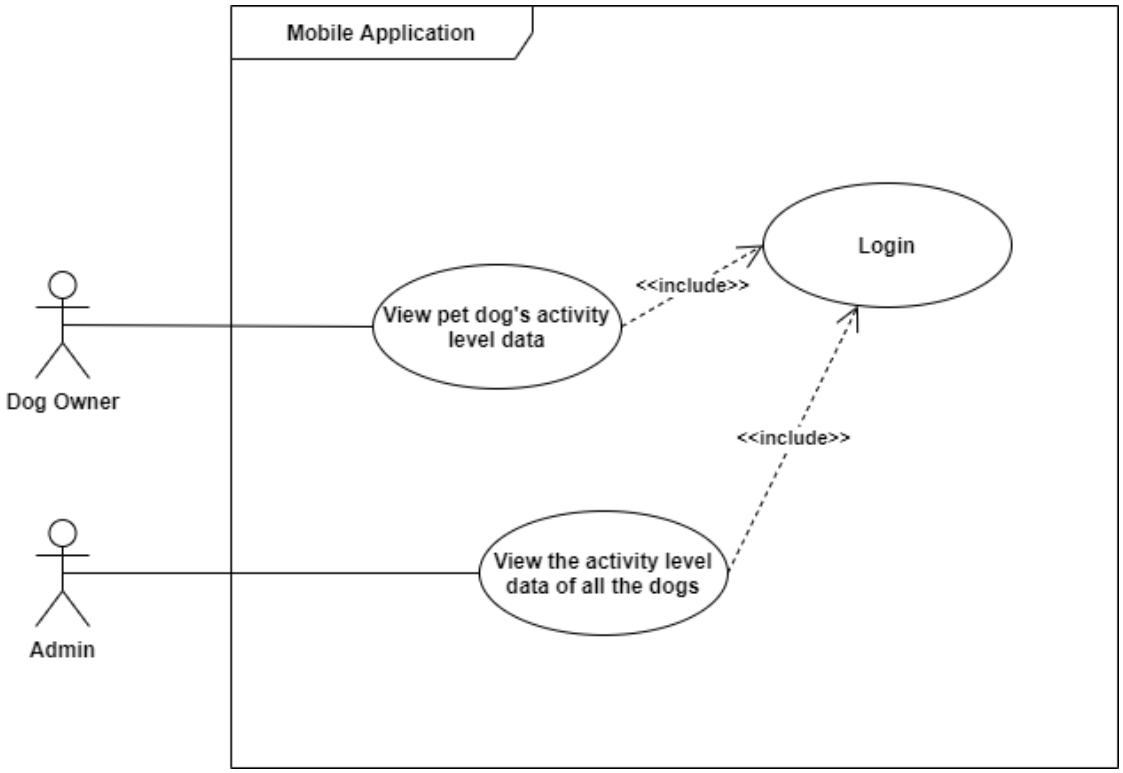

Figure 2.4:Use Case Diagram of the Application

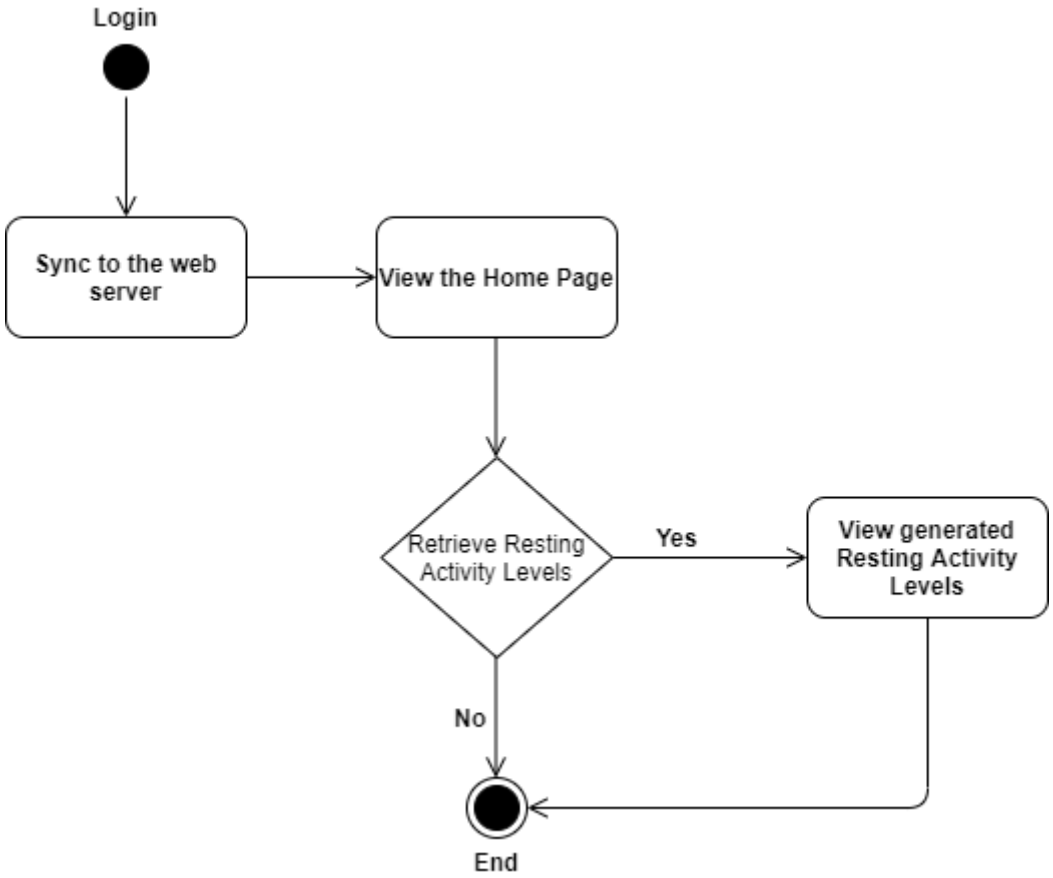

Figure 2.5: Activity Diagram of Resting Pattern Recognition Component

2.2 Commercialization Aspect of the Product

In the current market, there are behaviour trackers which use sensors to track health issues of dogs and dog watching cameras which do not track the health factors of the dog but only watch the dog while the owner is away. Here we use a combination of both above aspects and provide a better product with easily understandable usage and less expensive for dog owners.

This system was built with the lowest budget possible. It was just a matter of buying a basic IMU sensor and Wi-Fi surveillance camera. If the dog owners already have a security camera fixed up, then they can connect it to the system via a Wi-Fi connection. Therefore, this becomes an extra advantage of the security cameras.

Dog's current activity level (resting) is compared with the standard activity level (resting) that should be shown by the dog according to its breed and age. It is very rare to find behaviour pattern recognition based on that concept from the products that are currently in the market.

Dog owners are facilitated with the instant notification via the mobile application about the unexpected behavioural changes in their dog's usual behavioural pattern. And also the system generates the full activity level report of the pet dog on the basis of daily, weekly, monthly and annually.

This system is very easy and simple to set up by any person because it does not require technical expert knowledge. And also most significantly the pet dog does not get disturbed or distracted from any of the hardware components of the system.

Recognizing resting behaviour of the dog using CCTV camera video footage with the assistance of image processing is a new concept which is introduced from this system to the animal activity tracking production industry.

It is absolutely rare to find a system like this in Sri Lanka. Therefore, this system has great market value.

2.3 Social Aspect of the Product

The social aspect, security aspect, ethical aspect and limitations of the whole dog behavioural monitoring system are elaborated as below.

Social aspect

The utilization of the MPU6050 sensor and CCTV camera helped to track the physical behaviour of the dogs and recognize unusual patterns of them. Our system is very easy to understand and set up in anyone's home. Dog owner's privacy is 100% safe since system only tracks dog-related data with high-level validations. This product is very suitable for the Sri Lankan environment.

Security aspect

The mobile application is built by covering all the possible security aspects such as integrity, confidentiality and availability. User authentication and authorization mechanisms are implemented. Only the authenticated users have access to the data and information on the mobile application regarding the dog, at any time of the day without any downtime. So, the privacy of the user data is protected.

The sensor is attached to the dog with a comfortable dog collar and the video footage is taken without a single disturbance to the dog. Therefore, dog is safe from unexpected health issues like allergies and harmful panic attacks due to sound harassments.

Ethical aspect

The technologies that were used to build this system, make the system perform its functionalities faster and better. So the system is able with giving more accurate results. This leads the users to relay on the system with an unbreakable trust.

As the system is built by combining both machine learning algorithms and image processing, the demand for this kind of product is high in the current market due to the best quality of the product and the reliable outcomes of it.

This product is beneficial in an extreme level due to many reasons such as helping the dog owners to keep up with their dog's behavioural changes, be acknowledged about the predictable future physical disease of their dog and helping the veterinarian with the past behaviour of the dog in order to diagnose the issue with the dog.

Limitations

This system is created using a controlled environment. Even though the dogs can easily move around, they are in a restricted and limited space. And also only the walking, running, resting and barking behavioural patterns of dogs are tracked using this system.

2.4 Testing and Implementation

2.4.1 Implementation

Resting Pattern Recognition Model Implementation

The first step of the prediction model creation is to find a relevant dataset to train, validate and test the model. But it was rare to find a particular one dataset to utilize the prediction of a dog's resting state. Therefore, the decision to combine a couple of simple dog datasets was made. As it is mentioned earlier, the model classifies two classes such as lying dog position and not lying dog position. Dog datasets were downloaded from Kaggle[16]. So at the end of the datasets combination process, there were 3500+ images for each class. The final dataset was split into training and validation. Testing of the dataset was done using real data which are collected from CCTV camera video footage.

As a data preprocessing method, all the images were resized into 224*224 and applied normalization for all training, validation and testing datasets. 70% of the finalized dataset was allocated to training and the rest of the 30% was allocated for the validation.

Since the amount of data that was assigned for the training was less, it was hard to build a model from scratch. That was the place where transfer learning with pre-trained models came in handy. Since the transfer learning models were already trained for a task, it can be reused as the starting step of a new task [6]. ResNet50, ResNet101, VGG16, VGG19 and Inception V3 are few examples for pre-trained transfer learning models.

The ResNet50 model is a pre-trained model on the ImageNet dataset which contains images of more than a million from 1000 classes. Training extremely deep neural networks with 150+ layers are allowed by the ResNet50 model [5]. This model was taken and then transfer learning was applied to that model using the preprocessed data set. Utilizing a custom dense and pooling neural network, pre-trained knowledge of the ResNet50 model was leveraged to do the resting pattern recognition of the dog. While applying transfer learning the model was trained for 5 epochs using training and validation data sets.

Application Programming Interface (API) Implementation

API is the bridge that connects both backend and the front of the system. The Django framework was used to implement the API for this research component[15]. All the endpoints that are implemented using Django framework are described in detailed as below.

Video prediction endpoint – Real time dog video capturing starts with RTSP which is stands for Real Time Streaming Protocol. This protocol is designed for use in entertainment and communications systems to control streaming media servers and it used for establishing and controlling media sessions between endpoints[18]. After capturing the video, it is broken into frames on the basis of 1 frame per second using OpenCV. Then all the frames go through the prediction model and predict whether the dog is lying or not lying with scores 0 (for a not lying dog in the frame) and 1 (for a lying dog in the frame). Then all the frames along with their frame IDs and predictions are stored to the local server file.

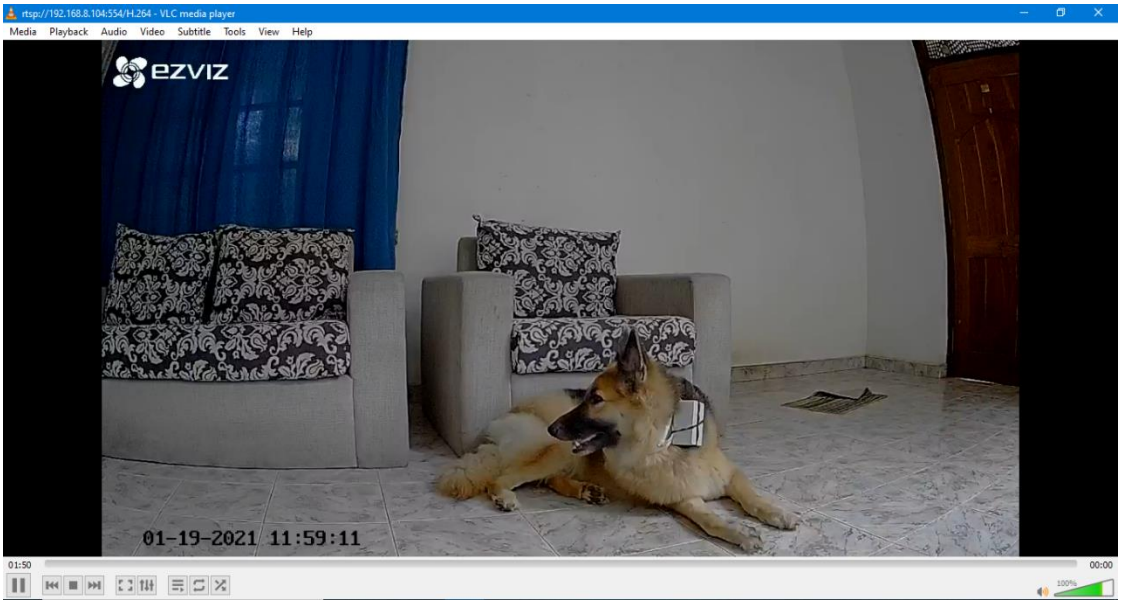

Figure 2.6: Real Time Video Capturing with RTSP

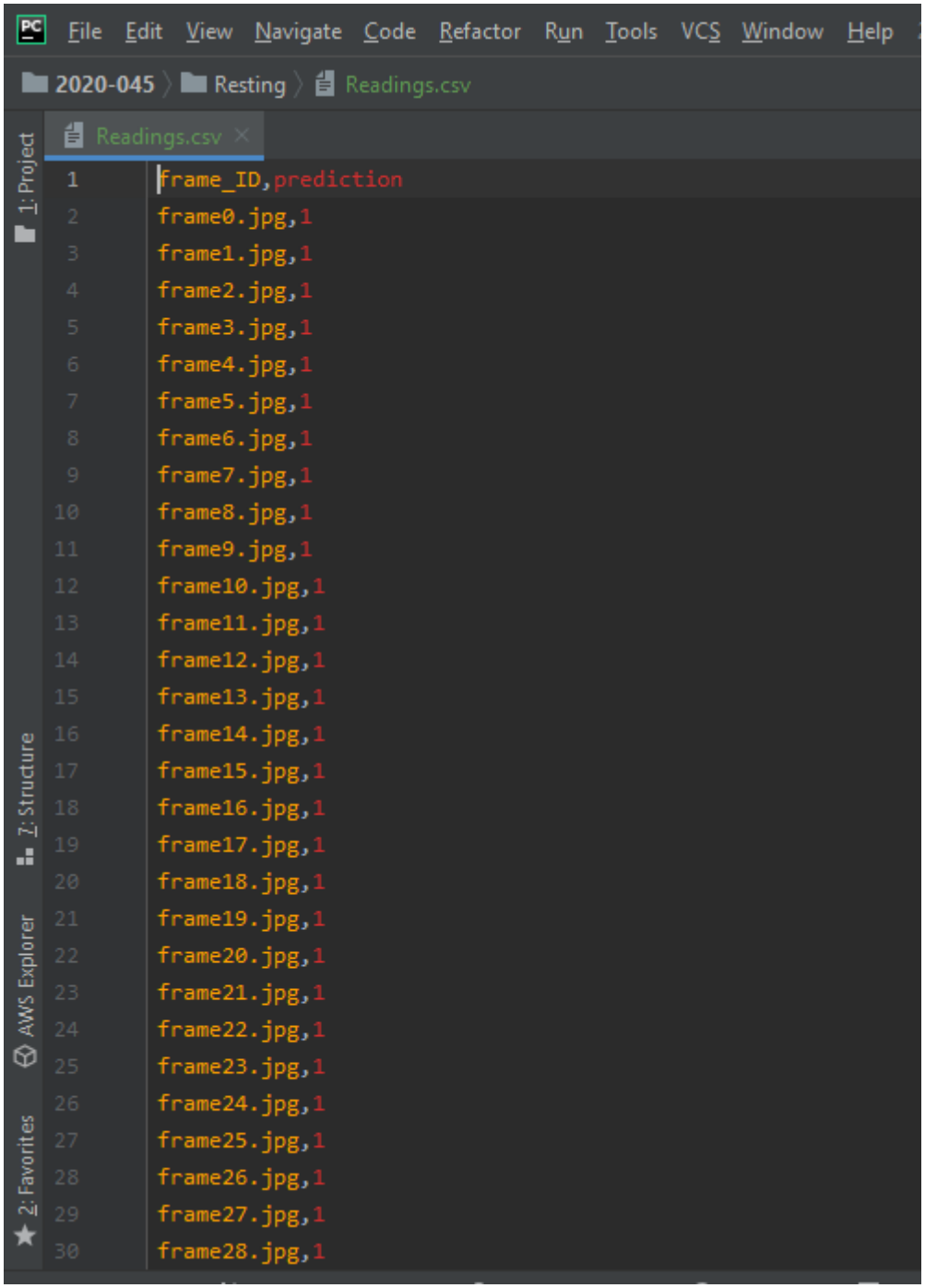

Figure 2.7: Frames with their predictions

Resting time from video calculation endpoint – Function is built to read the predictions from the database. Then it calculates the total number of the frames which are predicted with score 1 because it is equals to the total number of seconds that the dog has been rested. POST method is built to update the database with the calculated resting time in every 30 seconds.

Mean resting time calculation endpoint – Since the goal is to provide more accurate resting time value of the dog by incorporating the sensor readings, a POST method is built to access the updated resting time value from the sensor and then calculate the mean resting time value of resting time value from the sensor and resting time value from the video. After that it updates the database with the calculated mean resting time value in every 30 seconds.

Further explanation on the reason why these sensor reading and video data are combined even though those two values looks same. In this system, it only considers the activities like walking, running, resting and barking and finds behavioural changes based on breed and age only in walking, running and resting activities. Mainly the sensor readings are included with walk, run and rest activities but, the video footage is used to predict only the resting activity based on the lying and not lying positions of the dog. Walking pattern recognition component mainly focuses on walking and running data. So the remaining resting data is used to find the mean resting value with the resting time from the video footage.

Unusual resting activity level identification endpoint – This POST method is built to access the standard resting activity levels of the dogs based on their breed and age, which is stored to the databased by breed identification component according to the Wag Walking Site. Then it compares the standard resting activity level with the calculated mean resting activity level in order to find whether the resting activity is low or high with regards to its breed and age. Then it updates the database with the resting activity level change to be accessed through the mobile application notification endpoint.

Methods in the API are called through a class inside the service. In that class, Django open-source HTTP client library is used to interface with API. A method is developed inside that class with the type of HTTP Response which is a generic response interface.

User Interface (UI) Implementation

This is the client application where the user can view his/ her pet dogs daily behaviour. In this application the user logs into the system. Sessions are used to create the login

process. Initially the user is asked to upload an image or video feed of the dog and the system can identify the breed. Next the user is asked to input the details of the pet dog such as gender and age. Once the input data is analyzed, the activity time count and details are shown to the user in the main view. The user is displayed the activity status of the dog until the current time period.

In the Resting pattern recognition component, the total activity count is displayed to the user in graphical format. The total amount of time spent doing each activity daily, weekly, monthly and annually is displayed to the user. The dog owner is also given a few highlights of the dog's activities accordingly.

The development of the user interfaces is done using the flutter framework which is based on the dart language. The interfaces implemented for this research component are shown below.

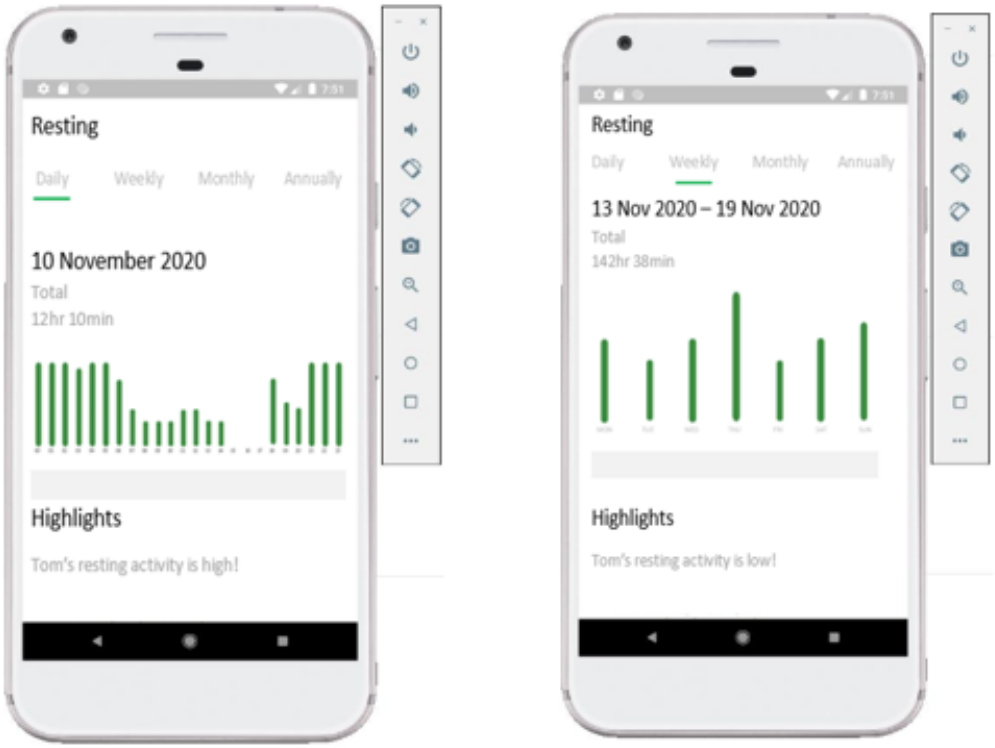

Figure 2.8: User Interfaces - Resting Pattern Recognition Daily and Weekly Highlights

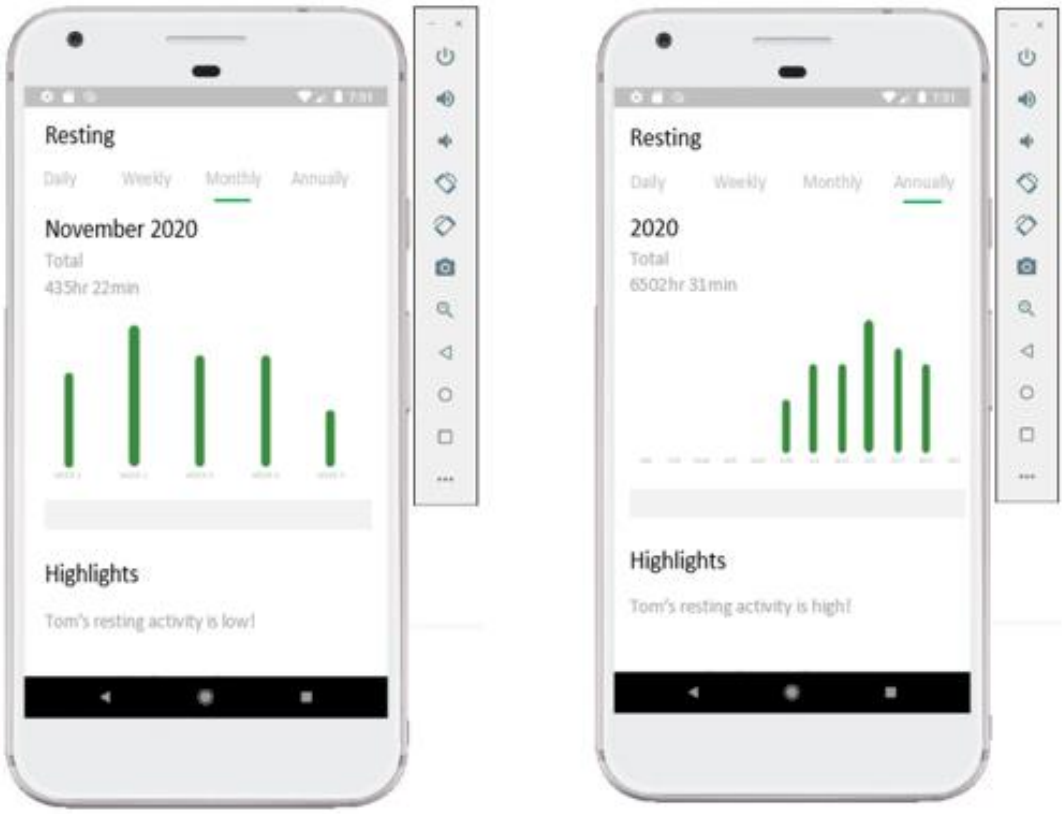

Figure 2.9: User Interfaces - Resting Pattern Recognition Monthly and Annually Highlights

2.4.2 Testing

Each step in the implementation of the whole dog behavioural monitoring system is tested continuously in order to provide accurate and trusted results to the end user without any performance issues. Best practices and coding standard were followed according to the development methodology. Unit testing, integrated testing and system testing that were conducted with resting pattern recognition component is described as below.

2.4.2.1 Unit testing

Resting pattern prediction model testing was completed with the re-trained ResNet50 model and it was able to gain an accuracy level of 97%.

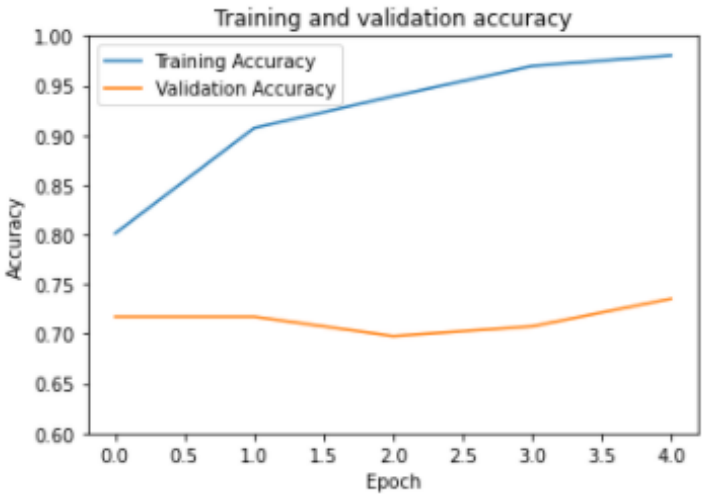

Figure 2.10: Re-trained ResNet50 Model Training and Validation Accuracy

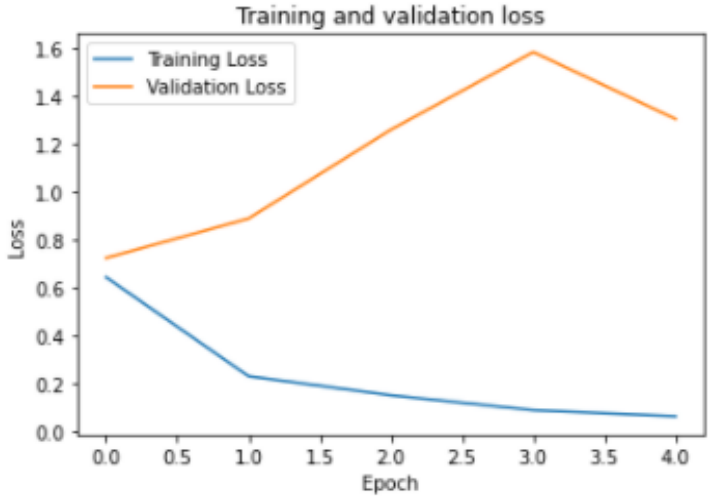

Figure 2.11: Re-trained ResNet50 Model Training and Validation Loss

Unit Test 01 – Lying position prediction

Table 2.2: Unit Test 01

Unit Test Id	Description	Input	Expected Output	Pass/Fail
1	Letting an image with lying dog go through the prediction model and getting the prediction as lying with score 1.		Score = 1 Lying	Pass

Actual Output:

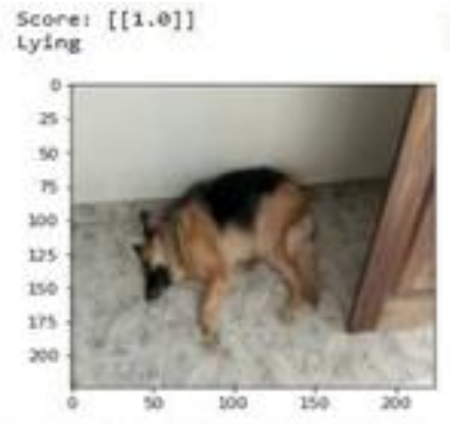

Figure 2.12: Actual Output for Unit Test Id 1

Unit Test 02 – Not lying position prediction

Table 2.3: Unit Test 02

Unit Test Id	Description	Input	Expected Output	Pass/Fail
2	Letting an image with not lying dog go through the prediction model and getting the prediction as not lying with score 0.		Score = 0 Not Lying	Pass

Actual Output:

Figure 2.13: Actual Output for Unit Test Id 2

After setting up the EZVIZ surveillance camera in the restricted area, it should be connected to the VLC network streaming server, using real time streaming protocol with the IP address of the camera.

Unit Test 03 – Connecting to the RTSP with correct IP address

Table 2.4: Unit Test 03

Unit Test Id	Description	Input	Expected Output	Pass/Fail
3	Successful connection to the streaming network.	192.168.8.104:554 (correct IP address)	Start video capturing just after establishing the connection	Pass

Actual Output:

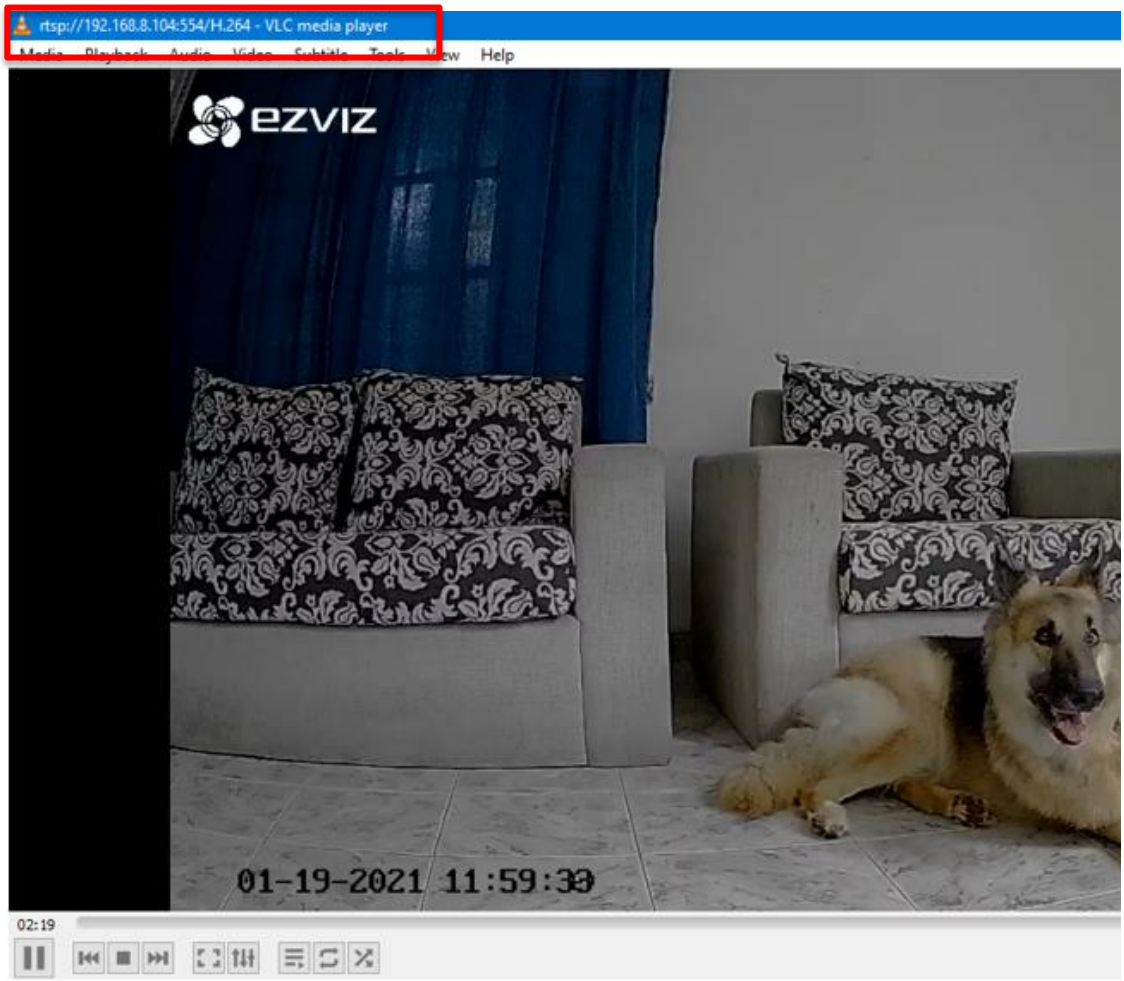

Figure 2.14: Actual Output for Unit Test Id 3

Unit Test 04 – Connecting to the RTSP with wrong IP address

Table 2.5: Unit Test 04

Unit Test Id	Description	Input	Expected Output	Pass/Fail
4	Unsuccessful connection to the streaming network.	192.168.0.100:554 (wrong IP address)	Error message saying connection issue occurred	Pass

Actual Output:

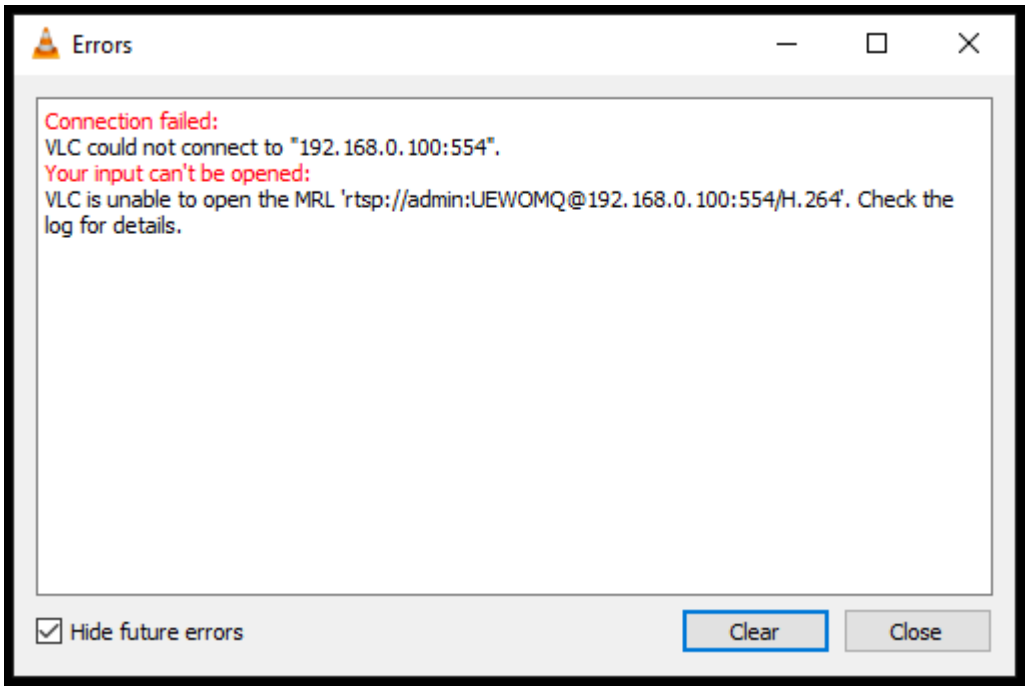

Figure 2.15: Actual Output for Unit Test Id 4

After connecting to the streaming server, API method makes the call to the video prediction endpoint and start the prediction process with the broken frames. Then write those predictions to the local server file.

Unit Test 05 – Local server file in the initial stage of the prediction process

Table 2.6: Unit Test 05

Unit Test Id	Description	Input	Expected Output	Pass/Fail
5	Frame IDs with respective predictions.	0 frames (No frames at the initial stage)	No frame IDs and predictions	Pass

Actual Output:

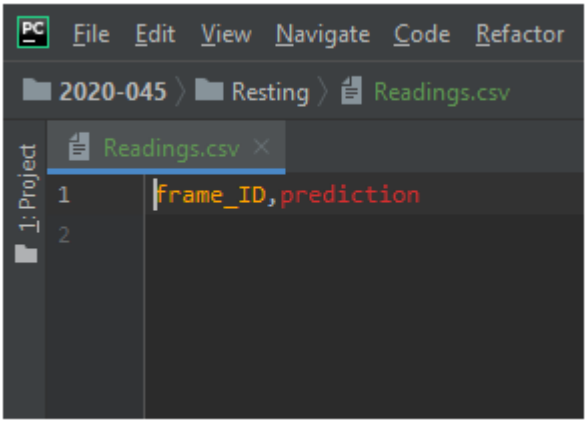

Figure 2.16: Actual Output for Unit Test Id 5

Unit Test 06 – Local server file after 6 seconds of the prediction process

Table 2.7: Unit Test 06

Unit Test Id	Description	Input	Expected Output	Pass/Fail
6	Frame IDs with respective predictions.	6 frames (first 6seconds of the real time video)	Frame IDs from 0 to 5 and the respective predictions	Pass

Actual Output:

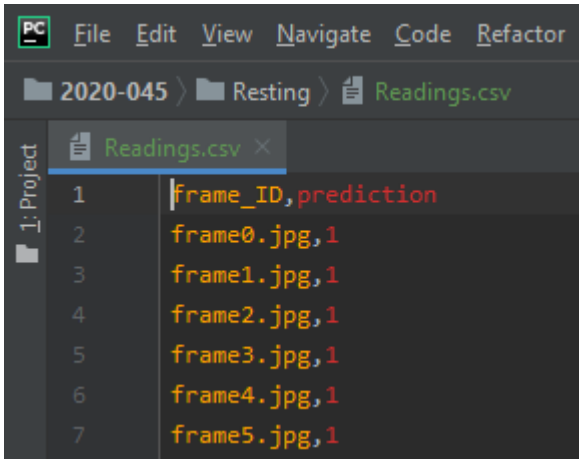

Figure 2.17: Actual Output for Unit Test Id 6

2.4.2.2 Integration testing

Final resting time of the dog is calculated after integrating the walking pattern recognition component with the resting pattern recognition component. Then the resting time updates are pushed to the mobile application through API calls. 60 seconds of lying dog from the video is used to test the integration between those components and the resting time update in the mobile application.

Integration Test 01 – Initial resting time in the mobile application

Table 2.8: Integration Test 01

Integration Test Id	Description	Input	Expected Output	Pass/Fail
1	Mobile application display the final resting time of the dog.	Video resting time = 0min Sensor resting time = 0min	Mean resting time = 0min So app should display: 0 hr 0 mins	Pass

Actual Output:

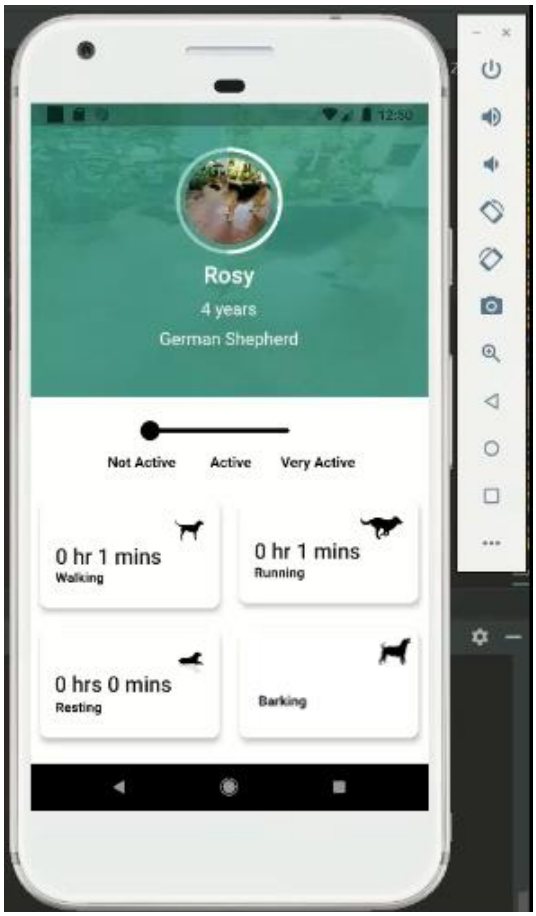

Figure 2.18: Actual Output for Integration Test Id 1

Integration Test 02 – Resting time update in the mobile application after 60 seconds

Table 2.9: Integration Test 02

Integration Test Id	Description	Input	Expected Output	Pass/Fail
2	Mobile application display the final resting time of the dog.	Video resting time = 1min Sensor resting time = 1min	Mean resting time = 1min So app should display: 0 hr 1 mins	Pass

Actual Output:

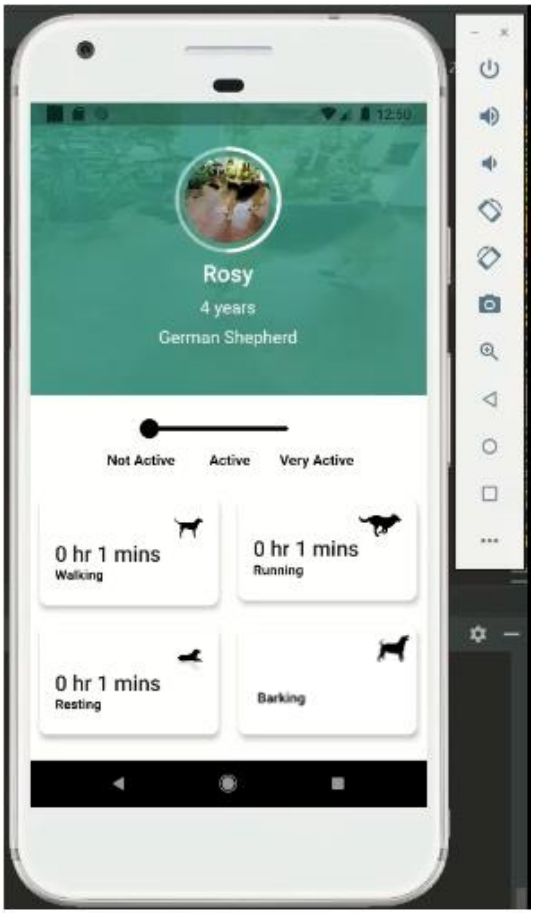

Figure 2.19: Actual Output for Integration Test Id 2

2.4.2.3 System testing

The last testing that was conducted was the system testing. It was done after combining all 4 components of the system in order to check whether all the requirements of the proposed system have been covered.

In the resting pattern recognition component point of view, at the end of the day dog owner should be notified with the resting activity level changes of the dog using the comparison between the standard resting time and calculated final resting time.

System Test 01 – Final resting activity results of the dog at the end of the day

Table 2.10: System Test 01

System Test Id	Description	Input	Expected Output	Pass/Fail
1	Final results of activity levels of the dog	1440mins of real time video footage and sensor readings	End of the day activity times and resting activity level change notification	Pass

Actual Output:

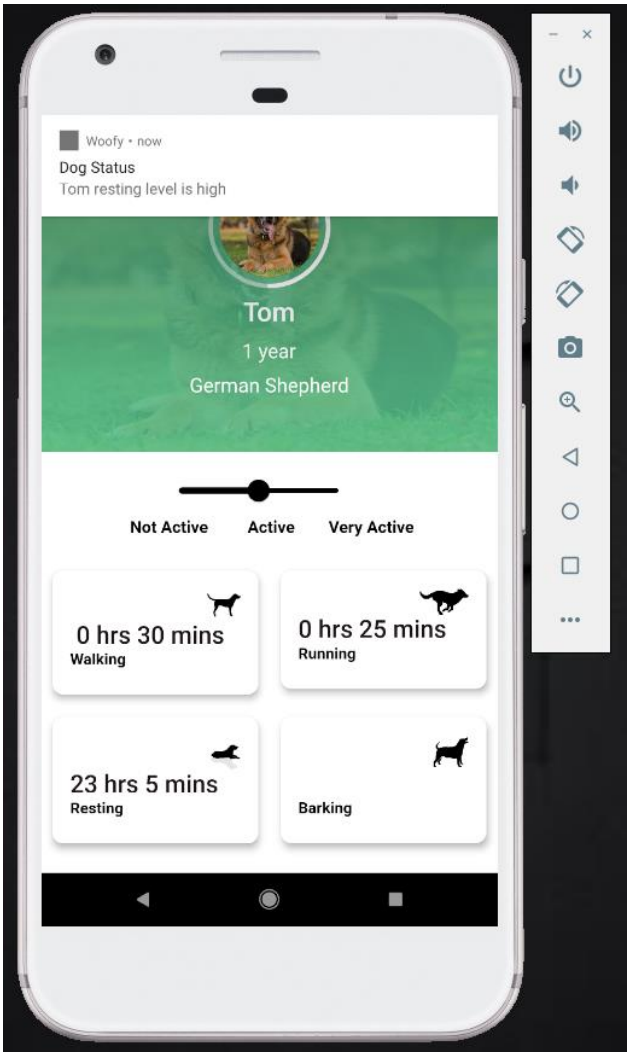

Figure 2.20: Actual Output for System Test Id 1

3 RESULTS & DISCUSSION

3.1 Results

The implemented research component of the resting pattern recognition system of the dog behavioural monitoring system shows significant importance. The objective of it being able to monitor the dynamic resting activity level of the pet dog was successfully demonstrated in the mobile application.

With the implementation, we have managed to achieve this target and prove that it is possible to use this system to monitor the pet dog's behavioural patterns and notify the user in case of any unusual behaviour. When it comes to the individual modules the results are discussed below.

The dog video was captured from the CCTV camera and broken into frames. Those frames were gone through the prediction model and the prediction results were stored in the database and all the calculation and the comparisons have done using API calls. Utilizing those values dog's behavioural changes are tracked and notified the dog owner via the developed mobile application along with the generated behavioural reports.

3.2 Research Findings

The main focus of this research was to develop a system which monitors the behavioural patterns of the pet dog and notify the user in case of unusual behaviour.

Data were collected and classified as lying position class and not lying position class. The created dataset was containing 3500+ images for both classes. The dataset was separated 70% for the training set and 30% for the validating set. Initially, CNN was trained from scratch with 5 epochs and it achieved only 10% of testing accuracy which is a very low score. Then transfer learning was applied to three different pre-trained models with ImageNet: ResNet50, VGG16 and VGG19 with the same dataset and same number epochs (5). The re-trained ResNet50 model was able to reach the accuracy level of 97% while VGG16 and VGG19 re-trained models were reaching the accuracy level of 94%.

3.3 Discussion

Issues looked by the group during the project life cycle and the activities (solutions) taken to illuminate those issues are inspected in this area. Besides, in this segment, we describe how we made progress in this task. A large portion of the product items comprises various types of bugs. It is our responsibility to limit the number of bugs before delivering the product to the end client.

How the system achieved the existing problem?

In January 2020 a group of four was shaped and began the project. This was considered as the fourth-year research project. Since our group was engaged with pets, we examined numerous issues pets experience in everyday life. At that point, we understood that we expected to make an answer to fill that difficult hole.

As indicated by the Background Literature Survey directed, we understood that there is no framework in Sri Lanka that includes both machine learning and image processing techniques to break down pet dog behaviour. As an outcome, our group chose to make an answer to this issue.

We distinguished the fundamental functionalities of the solution and designed the high-level architecture of the system. And also decided on the technologies which will be used according to the background analysis to implement each functionality.

In the proposed research component, Resting Pattern Recognition, the system monitors and analyzes the dog's resting activity level according to its breed and age by utilizing a surveillance camera video feed.

With the budget, we decided to use one surveillance camera with WiFi facility to collect the dog video feed. The main issue with this process was that the dog moves everywhere and it was hard to set up the camera at one place and record the video. As a solution, we created a simple and controlled area where the dog can move around comfortably and rest when it wants. Then the camera was set up into that area.

When computing the accuracy score, it was needed to compute the predicted labels and compare them with the true label. So, to compute the predicted labels, we took the lying

score and decided that the model predicts the dog is lying if that lying score is smaller than the given threshold. Estimation of the accuracy is provided by Keras during the training. The threshold of 0.5 was used by Keras for our estimation. At this point, we saw that the prediction labels got really similar to the true labels due to the accuracy being close to 100%. That issue was fixed using a fraction of misclassified examples [17][19].

As mentioned above, these were some of the issues faced during the implementation of the proposed system and the actions taken to overcome those problems.

4 CONCLUSION

The dog behavioural monitoring application mainly targets pet dog owners who are interested in knowing about the health status of their pet dog. This system can notify the owner of the pet dog is not conforming to its average activity levels based on its breed and age.

The main objective of this research was to provide an efficient and accurate product which monitors and analyzes the behaviour of the pet dog. The main areas of this research project are Dog Breed Identification, Walking and Running Pattern Recognition Module, Resting Pattern Recognition Module, and Barking Pattern Recognition Module. The system uses these sections to give a final result to the dog owner regarding its behavioural patterns.

Before developing the system, several literature reviews related to that section were carried out. The different research papers and current products in the market were analyzed and compared with the current problems pet dogs are undergoing. We studied further to come up with a better solution.

With the use of an API, the proposed research component, Resting Pattern Recognition was implemented successfully. The implemented research component was able to detect dog resting-state successfully using the ResNet50 re-trained model by processing the video frames as input. The implementation of the API was done using Python language and the Django framework.

In this research study, the surveillance camera was used to get the video feed of the pet dog. The system was able to successfully identify dog activity and analyze the behaviour of the pet dog and abnormalities to notify its user in a controlled environment setting of their own home.

In the future, the system can expand the core elements demonstrated herein with a fully-automated system where the dog can be in a natural setting of their own which has the potential to deliver real-time results.

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