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Smart Dairy Cattle Farming and In-Heat Detection through the Internet of Things (IoT)

Nilo M. Arago[1*], Chris I. Alvarez[1], Angelita G. Mabale[1], Charl G. Legista[1], Nicole E. Repiso[1], Timothy M. Amado[1], Romeo Jr. L. Jorda[1], August C. Thio-ac[1], Lean Karlo S. Tolentino[1,2], Jessica S. Velasco[1]

[1]Department of Electronics Engineering, College of Engineering,
Technological University of the Philippines, Ermita, Manila, 1000, PHILIPPINES

[2]University Extension Services Office,
Technological University of the Philippines, Ermita, Manila, 1000, PHILIPPINES

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Abstract: Smart farming is the practice of intelligent agricultural management based on technological data gathered from farm practice for the purpose of increased levels of quality, production and environmental protection. The Internet of Things (IoT) technology is revolutionized in various aspects of agriculture around the world and its application found success in some countries. In this paper, a non-invasive and non-contact estrus detection system integrated IoT technology to improve the detection efficiency of standing-heat behaviors of cows is proposed. The outcome of this study will improve the farm's management practices through the integration of IoT technology that can remotely monitor the activities of the cows and provide data for analysis and evaluation, will increase the likelihood of future estrus instances for every correct prediction, and will improve the fertility and milk production rates of the cows. Such benefits can contribute to the growth and development of the dairy cattle industry in the Philippines. This study also shows the application of IoT in improving the detection efficiency of standing-heat behaviors of cows through automated detection using Pan-tilt-zoom (PTZ) cameras and a Python-driven Web Application. The dimensions of the barn are measured, and the Cameras' Field of Views (FOVs) is pre-calculated for the strategic positions of the cameras atop of the cowshed. The program detects the cows and any estrus events through the surveillance cameras. The result is sent to the cloud server to display on the web application for analysis. The web app allows updates on cow information, inseminations, pregnancy, and calving records, estimate travel time from the user's geolocation to the farm, provide live monitoring and remote camera accessibility and control through the cameras and deliver reliable cross-platform push-notification and call alerts on the user's device(s) whenever an estrus event is detected. The system initially and correctly detected 4 standing-heat signs, but with 2 false predictions and identifications leading to 2 "True Positive" and 2 "False Positive" results, attaining a 50% detection efficiency. Based on the results, the program performed satisfactorily at 50% detection efficiency.

Keywords: Internet of Things, standing-heat, estrus, cows, web application, surveillance camera, notification

1. Introduction

Smart farming is the practice of intelligent agricultural management based on technological data gathered from farm practice for the purpose of increased levels of quality, production and environmental protection [1]. Smart Dairy Farming (SDF) is a concept that meets the growing demand for quality dairy products. This practice includes sensor applications, data analysis, and cloud-based data centers. Farmers increases milk productivity and cattle production, improve the management of livestock, and detect standing-heat activities through the integration of smart farming technology.

**Corresponding author: nilo_arago@tup.edu.ph*

Farmers place sensors to the cows' neck, back, or tail to determine the cows' lameness and health status and build a sensor-based system or a surveillance system to monitor the cow activities and identify possible standing-heat behaviors.

Farmers efficiently perform timed insemination techniques whenever the smart system identifies estrus events. Precise and accurate operation of insemination to the cows increases the cow fertility and milk production rates. Through the Internet of Things (IoT), small and large-scale dairy farms meet the demands of a large population [2]. Various key players in the smart farming industry in America and Europe incorporated SDF strategies into small or large-scale farms to improve farming management and increase profits. Researchers developed "afimilk", "Fullwood", and "ConnectedCow" to detect estrus and monitor the herd status [3]. However, only a small number of farms in the Asia-Pacific region employs SDF practices. In the Philippines, no present companies or startups offer high-tech products and services. This shows the dairy cattle industry in the Philippines is behind other countries across the globe. According to the Philippine Statistics Authority (PSA), the total cattle production in 2019 is approximately 61.31 thousand metric tons. Today, it is approximately 61.02 thousand metric tons exhibited a difference of 0.473 percent in volume [4]. These records proved that Philippines' cattle production performance is slower than other countries. For these reasons, farmers and researchers shall improve farming management practices and develop new methods to meet the demands of the country.

In this paper, a non-invasive and non-contact estrus detection system integrated IoT technology to improve the detection efficiency of standing-heat behaviors of cows is proposed. The research specifically aims to: (1) develop an automated estrus detection system that captures image instances of standing-heat activities, (2) employ Internet of Things (IoT) technology through a web application that visualizes data and cattle performances, generates reports on the relevant herd information, allows remote camera control for monitoring, and estimates travel time between a location to the designated farm, and (3) integrate notification subsystems into the application and the server to inform the farmers whenever the system detected an estrus event. The outcome of this study will improve the farm's management practices through the integration of IoT technology that can remotely monitor the activities of the cows and provide data for analysis and evaluation, will increase the likelihood of future estrus instances for every correct prediction, and will improve the fertility and milk production rates of the cows. Such benefits can contribute to the growth and development of the dairy cattle industry in the Philippines.

Nomenclature	
IoT	Internet of Things
PTZ	Pan-tilt-zoom
FOV	Field of View
SDF	Smart Dairy Farming
PSA	Philippine Statistics Authority
NB-IoT	Narrow-band Internet of Things
SVM	Support Vector Machine
DT	Decision Tree
LPR	Long-Range Pedometer
TI MSP430	Texas Instrument Mixed Signal Microprocessor Ultra Low Power 430
GPS	Global Positioning System
STM32L431	ST Microprocessor 32L431
BC95-HB	NB-IoT Module
ATMega	Atmel Mega 8 bit microcontroller
MQTT	Message Queue Telemetry Transport
NVR	Network Video Recorder
DH-SD22404T-GN	Dahua SD22404T 4Megapixel 4X PTZ
RCNN	Regional based Convolutional Neural Network
SSH	Secure Shell
IPO	Input Process Output
IP	Internet Protocol
DHI-NVR4108	Dahua Technology Network Video Recorder
CCTV	Closed Circuit Television
USB	Universal Serial Bus
UTP	Unshielded Twisted Pair
HP	Hewlett Packard
ArduinoUNOR3	Arduino One (Italian) microcontroller based on ATMega 328P

SMS	Short Message Service
ISP	Internet Service Provider
API	Application Programming Interface
VPN	Virtual Private Network
LTE	Long Term Evolution
CGNAT	Carrier Grade Network Address Translation
RTSP	Real Time Streaming Protocol

2. Literature Review

In other countries, researchers integrated IoT technology helped farmers monitor and manage the detection of estrus in cows. In a case study [5], the researchers presented reviews from the application of sensor devices such as digital bracelets for tracking, genomic testing for herd maturity predictions, sensing devices for data analysis and transmission, and GPS-driven equipment for crop management. Through the sensor devices, workers kept track of the herd, identify potential health risks to the cows, predict future fertility and milk production levels, and control the volume of pesticides sprayed on the crops. These innovative smart farming practices created a significant impact on agricultural development on farms. Lee [6] developed a smart monitoring system and integrated IoT technology and machine learning algorithms. An IoT Node based on a 3-axis accelerometer, and an IoT-based server designed to assess the movements and behaviors to determine the estrus activities of cows on the farm. By implementing three machine learning algorithms, the system is able to effectively identify estrus periods, monitor the movements in real-time, and send notifications immediately. Meanwhile, Chen [7] proposed a monitoring system based on the Narrow-band Internet of Things (NB-IoT) and OpenCV.

The system achieved low power consumption and improved estrus detection through temperature monitoring and image recognition capabilities. In [8], the researchers also proposed a smart surveillance system capable of analyzing animal behaviors. The system included body conditions scoring, heat detection method, and calving process monitoring. These subsystems improved the analysis of behavior and health status of the cows, assessed the significance of human to animal interactions in milk production, and performed accurate detection of in-heat signatures of cows. Ultimately, Barriuso et al. [9] presented multi-agent architecture based on virtual organizations to analyze various parameters such as physical activity, temperature, and estrus cycle. The combinational system provided tele-monitoring services, analyzed the movements for estrus detection, read temperature for health monitoring, and volume of feeds of the cow subjects for food control. The farmers remotely monitor and analyze the livestock.

Pratima et al [10], the collected data from sensors like temperature, heart rate and axial sensors is stored. This is used as datasets for the classifier using Support Vector Machine (SVM) algorithm and Decision Tree (DT). The health classifications are normal, less normal, and abnormal. The axial sensors inputs are classified to: standing, lying down and eating. The monitoring of real-time and classification is done by sending data to the prediction application through IoT dashboard in the web application. Bovo et al. [11], the system integrated specific sensor networks that allows the acquisition of big data time series about the physical and environmental conditions for both indoor and outdoor environmental features. This enabled a smart control of the facility, diagnosis of the operating conditions and early alerts in case of anomalies. The system is developed to work on several environmental situations and is able to make the data remotely available in real time in cloud.

Taneja et al. [12], through the long-range pedometer (LPR) and medical band are used as predictors for lame, transitioning to lame and non-lame. The 3 behavioral activities used are step count, lying time and swaps (from lying to going up). Clustering technique is used in forming cow profiles. It is assumed that all animals in each herd behave the same way. The three clusters are active, normal and dormant. The clustering model is based on the observation that there were some animals in the herd whose activity levels (step count, lying time and swaps) were always greater than the mean activity value of the herd (active) and then there were some animals in the herd whose activity levels were always less than the mean activity value of the herd (dormant), and then there were others who traced the herd mean (normal).

Table 1 shows comparison framework of related studies in this paper. In contradiction to most of the abovementioned studies, the automated estrus detection system presented utilizes three Pan-tilt-zoom cameras for navigation and remote monitoring capabilities, network video recorder (NVR) for playback and surveillance storage. Arduino microcontrollers is used for immediate call alert service, and routers for securing data transmission through a prepaid internet connection. The data gathered by the system is transmitted to the cloud database, visualized, and reflected in the developed web application. The web application helped farmers and researchers with data organization, data analysis, and decision-making.

Table 1 - Comparison framework of the related works

Authors	Materials and methods			
	Sensors	**Microcontroller**	**Application**	**Utility**
Lan, Quigley, and Masouras [5]	Digital bracelet; GPS sensor	-	Local Server	Behavioral pattern recognition; Notification alerts
Lee [6]	3-axis accelerometer	T.I. MSP 430	Local Server	Behavioral pattern recognition; Estrus Detection; Notification alerts
P. Chen [7]	3-axis accelerometer; camera	STM32L431; BC95-HB	Android App	Health monitoring; Estrus Detection
Zin, Kobayashi, Tin, and Hama [8]	Camera	-	Local Server	Behavioral Pattern Recognition; Body condition score evaluation
Barriuso et al. [9]	Accelerometer; GPS sensors; solar collar; thermometer; ultrasonic sensor	ATMega microcontroller	Web App; Android App; TV App	Estrus Detection; Notification alerts; Geolocation; Temperature monitoring
Pratama et al. [10]	Gyroscope, motion sensor, Accelerometer	Wemos D1 Mini	Local Server, Web Application	Body Temperature, Heart Rate, Behavioral Monitoring
Bovo et al. [11]	Temperature sensor, wind velocity, Humidity, Pressure	ATMega microcontroller	Local Server, Web Application	Environmental Monitoring, Increase herd productivity
Taneja et al. [12]	Long Range Pedometer (LPR), Medical band	None	Fog Node Enabled IoT, Message Queue Telemetry Transport (MQTT)	Lameness Detection, Behavioral Monitoring

3. Methodology

3.1 Research Locale - Barn

In this study, the estrus detection system is deployed in a small-scale commercial farm in the province of San Ildefonso, Bulacan, in the Philippines. The barn houses 17 Holstein-Friesian and Sahiwal crosses, a bull, and a water buffalo. According to Porto et al., the panoramic top-viewed images of the barn are crucial in to capture image frames which shows the cow's body contour [13]. To capture the panoramic top-view images, three DH-SD22404T-GN 4 Megapixel PTZ (Pan-Tilt-Zoom) Network Cameras were installed at a height of 3.78m. Each camera monitors an area for about 4.87 m x 3.97 m with a separation distance of approximately 2.98 m apart atop the cowshed, as shown in Figure 1.

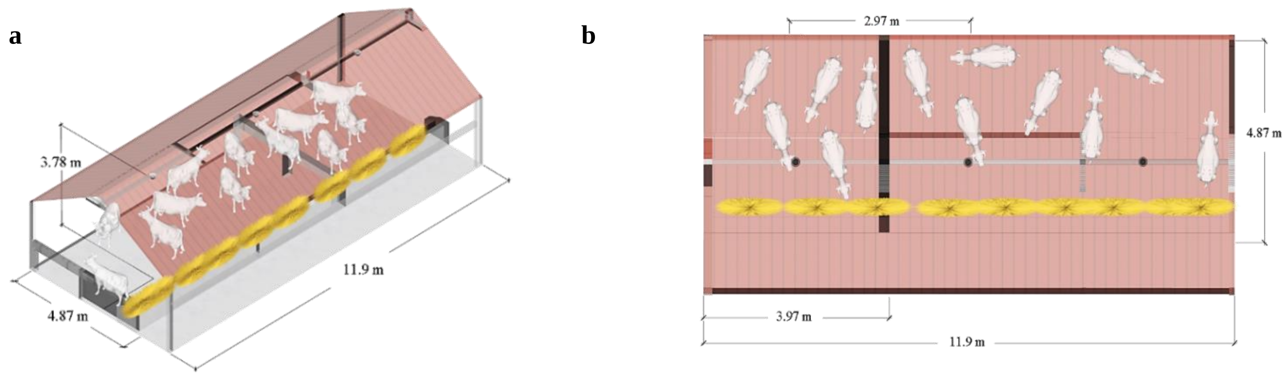

Fig. 1 - (a) The Isometric view of the setup; (b) The Top view of the setup

3.2 System Design

The system focuses on automatically detecting the estrus behavior of cows for farmers through the Internet of Things and notifying farmers of the detected instances for inseminations. The system detects the standing heat/mounting behavior of cows, a primary sign of estrus. It also follows an estrus detection rule developed by Tsai et al. [14].

Figure 2 shows the system design of this research. Three IP PTZ Cameras serves as the sensor for this IoT system and capture the live video feeds inside the barn. The system unit takes the live video feeds from these cameras, converts it to frames, and performs image processing to identify standing heat/mounting behavior instances. This system unit, serves as an IoT server, runs a python program for image processing with a Faster Regional based Convolutional Neural Network (RCNN) Algorithm. If the estrus detection parameters are satisfied, it sends a signal to an Arduino microcontroller with GSM module to initiate a phone call as a notification for users/farmers. The IoT server also updates the cloud database on the web server through a Secure Shell (SSH) connection and shows the updated information on the web application. Then the server triggers a web-app push notification on the user's mobile devices and allows the end-users to remotely confirm estrus detection by controlling the PTZ cameras on the barn.

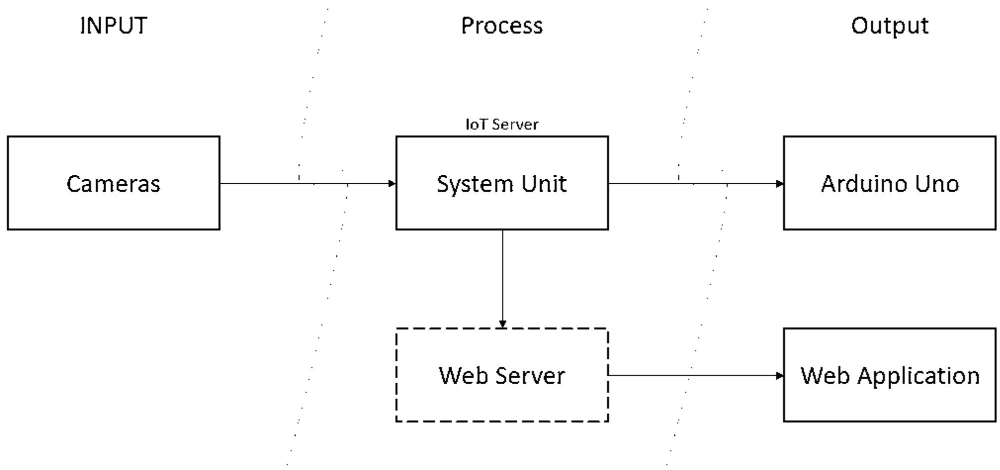

Fig. 2 - Simplified Input-Process-Output (IPO) diagram of the system

3.3 Hardware Setup

The study requires reliable devices to have an effective and accurate automated detection system. The items listed below are the devices incorporated in the smart system:

1. **IP Camera and NVR:** An Internet Protocol (IP) camera is a networked digital video camera that transmits data over a Fast Ethernet link. Users often used IP cameras, a digitized and networked version of closed-circuit television, for IP surveillance [15]. Now, this study utilizes the video analytics application of IoT and a typical IP Surveillance setup. Machine learning algorithms are applied to the video feeds, allowing the IP cameras to detect cows and their estrus behavior automatically. The PTZ Cameras and the DHI-NVR4108 Lite Network Video Recorder (NVR) are interconnected and installed to capture real-time activities at the barn and to record the feeds captured by the cameras that allow playbacks for the last 30 days, respectively. The NVR acts as a switch for the IP cameras and is also Power-over-Ethernet (PoE) enabled that permits power over Ethernet cable, and consequently provides electrical energy for the cameras and eliminates the usage of cables and adapters on the cameras.
2. **System Unit**: The system unit serves as the IoT server/image processing unit for the developed system. The IP cameras are connected to the same network as the Closed-Circuit Television (CCTV) using Unshielded Twisted Pair (UTP) cables. A python program that utilizes custom neural network models runs on the server for image processing. From here, the Universal Serial Bus (USB)-connected Arduino microcontroller sends call alerts as part of the notification system. A Hewlett Packard (HP) Elitebook 8470p Notebook PC is deployed at the barn to run and perform the estrus detection program that is also connected to the web server through an SSH connection.
3. **Arduino Modules:** Along with the system unit, the Arduino UNO R3 microcontroller and the SIM 800L module that receive the commands from the server and send short message service (SMS) call alerts to the users, respectively, are deployed in the barn. Arduino UNO is a microcontroller that has analog and digital inputs, a ceramic resonator, a power jack, a USB port, and a reset button; whereas the SIM 800L is a cellular module that has a wire antenna, a PCB antenna with a pigtail, and a SIM Card socket.
4. **Network Devices- Routers/Modems:** For network connectivity, an ASUS RT-N12 Wi-Fi Router with VPN capabilities to allow the utilization of network ports for the transmission of data, and a HUAWEI 4G Router B315 from Globe to provide prepaid internet services in the barn are used.

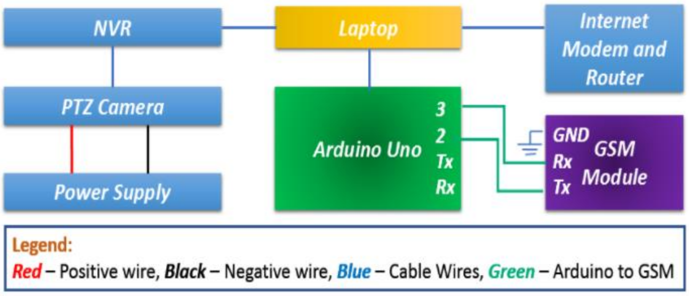

Fig. 3 - Schematic diagram of the system

Figure 3 is the schematic diagram that shows the interconnectivity of sensors, microcontrollers, module, and other equipment. The PTZ camera records the live video feed of cattle activity through coaxial cable getting its power from power supply. The data is transmitted from sensors to NVR via Ethernet cable. The transmitted data is accessed freely on database through an IoT-based web application from the system unit that runs the program for data accumulation and surveillance. The data is sent to Arduino Uno connected to GSM module. Then, Arduino microcontroller directly sends a call alert to end users using GSM Module. Through the internet, data results are transmitted cloud database. Since the overall system requires Internet accessibility, the unit is connected to an Internet Modem through Ethernet cables.

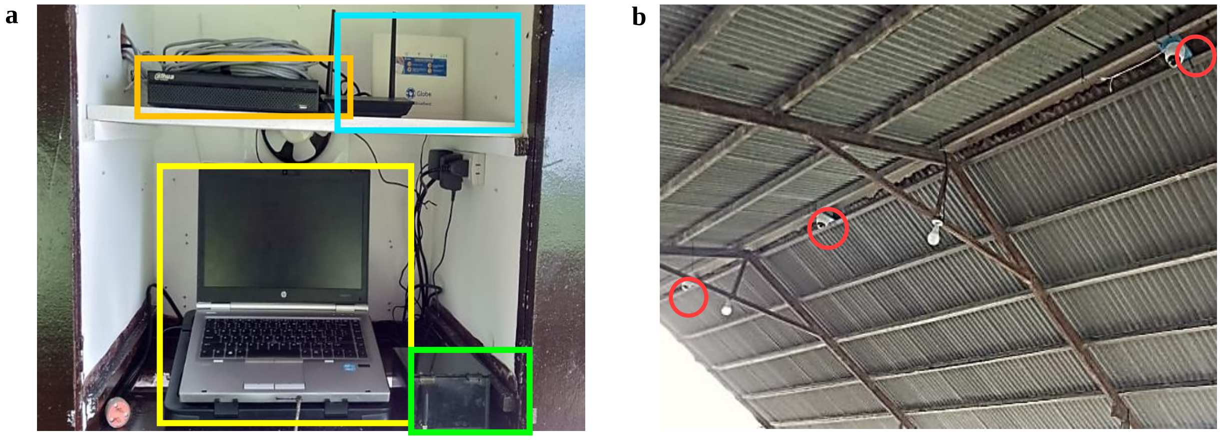

Fig. 4 - (a) Setup of devices – Network Video Recorder (orange), System Unit (yellow), Microcontroller (green), Routers (blue); (b) Setup of the IP PTZ Cameras (red)

Figure 4 shows the actual hardware setup in the barn. These are the components of the hardware as described at the hardware set up. The system is built and installed in a casing that encloses the NVR, the system unit, the modules, and the network devices (a), along with the IP Cameras (b) that were strategically placed in the barn.

a. Network Setup

A private network is set up for connectivity of modem, router, system unit, NVR, and IP cameras. Initially, the IP Cameras is connected to NVR using straight-through UTP cables, where the internal switch within the NVR is statically assigned IP addresses. Then, the NVR is connected directly to the Asus router, together with the System Unit or Server, where both IP addresses are statically assigned to the router. The router gets internet access from the modem provided by the ISP and uses a prepaid type connection, the Internet Service Provider (ISP) is Globe Telecommunications. It is wirelessly connected to the ISP using Long Term Evolution (LTE) under the Carrier Grade Network Address Translation (CGNAT) protocol.

The system is integrated with a virtual private network (VPN) subscription from Ivacy. By setting up the VPN client and its credentials on Asus router, all the devices are connected to the router can access the internet via a VPN. This connection allows the private network to obtain a static public IP address and configurable ports for port forwarding the ISP does not readily provide. These are necessary to gain remote access and allow data traffic to the equipment installed on the farm by opening specific ports through VPN providers. As this study is conducted on a remote farm, the internet access is not readily available. There are no postpaid internet connections services in the area. Due to that reason, a prepaid internet connection is used. Since ISPs blocked the port forwarding features, a VPN and a local IoT server is used, instead of a cloud-based server.

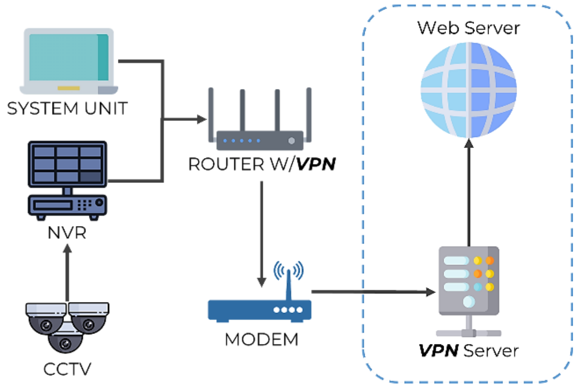

Fig. 5 - Network diagram

Figure 5 represents the network diagram of the system. The system unit or server takes the live feed from the camera through the Real Time Streaming Protocol (RTSP) protocol following the application programming interface (API) provided by the NVR vendor. The running program on the server performs estrus detection. Once the program successfully detects an estrus event, it sends the output data via SSH using the best routing protocol within the private network to the webserver. Outgoing packets sent by the server underwent encryption in the VPN-configured router before going out of the local network. These packets are decrypted on the remote VPN server provided by Ivacy and are forwarded to the web server. The web server is configured in a web hosting and cloud provider, Linode [15], to have its public website IP address. It is registered in a DNS server as www.eztect.xyz. The users of this project can access the app by going to www.eztect.xyz using a browser in any device on a cellular network. A feature of the app also allows the users to control the IP cameras on the barn.

b. Web Application

In this research, a web-application is developed through Flask, a Python-driven web development toolkit implemented with RESTful API, as in [16]. Flask is capable of scaling up to complex applications which began as a simple wrapper around Jinja and Werkzeug. It is categorized as a micro-framework possessing a simple but extensible core without lacking in functionality. Through Flask, it is easier to take advantage of the tools built for WSGI of a Python-based web interface [17]. Because of its flexibility and functionalities, the web application was efficiently designed to attain the following features:

1. Cattle Performance Report: This feature helps the user to keep track of automatic estrus detection and insemination instances and to easily assess pregnancy and calving rates through visualizations. A screenshot of the feature is illustrated in Figure 6.

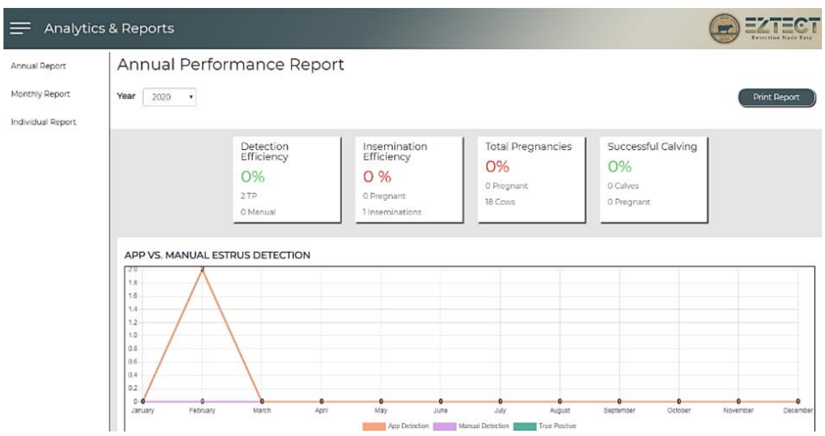

Fig. 6 - Screenshot of the cattle performance report

2. Cattle Inventory: This feature lets the user view his or her livestock and the corresponding IDs, Breed, Gender/Status, and recent estrus record of the cows. A screenshot of the feature is illustrated in Figure 7.

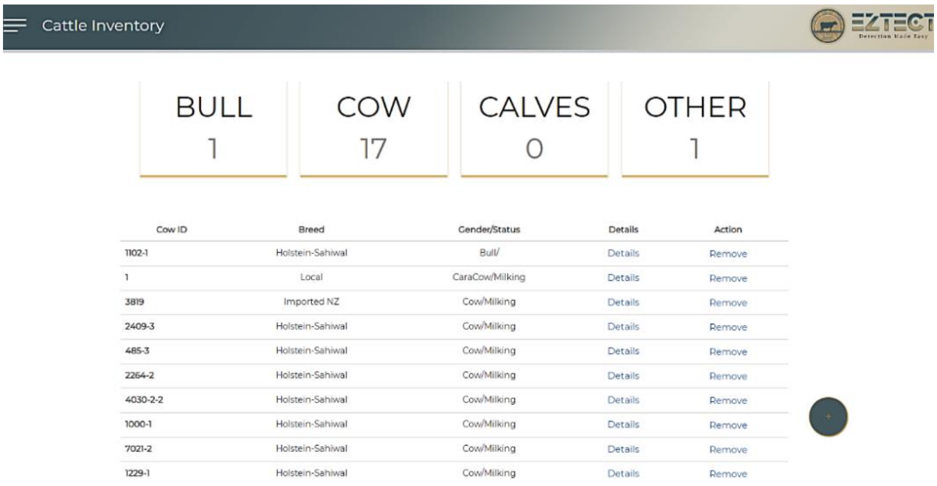

Fig. 7 - Screenshot of the cattle inventory

3. Dashboard: This feature allows the user to see the 8-hour Countdown Timer, the Estrus Logs, and the interactive events, and the prediction of future signs as well. A screenshot of the feature is illustrated in Figure 8.

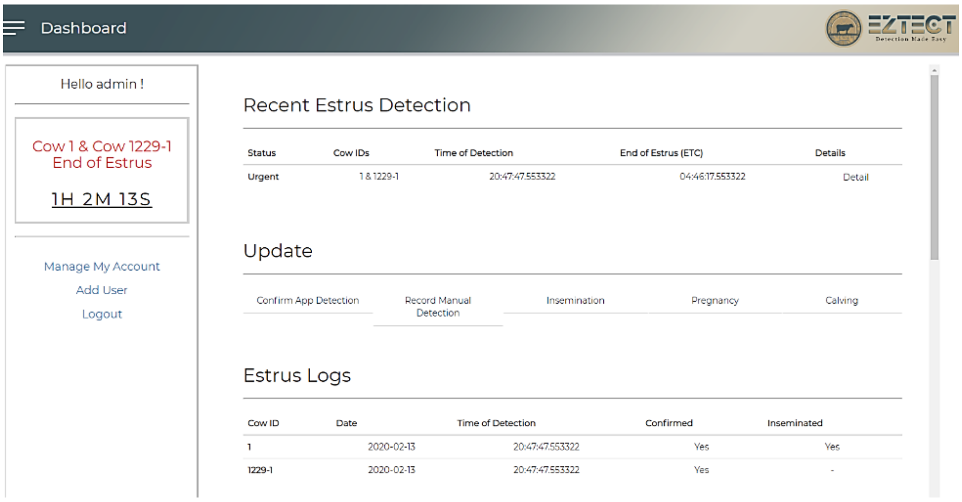

Fig. 8 - Screenshot of the dashboard

4. Locator: This feature informs the user of the estimated travel time between the current location and the farm, ensuring the arrival within the 8-hour effective insemination period through the Google Map API [18]. A screenshot of the feature is illustrated in Figure 9.

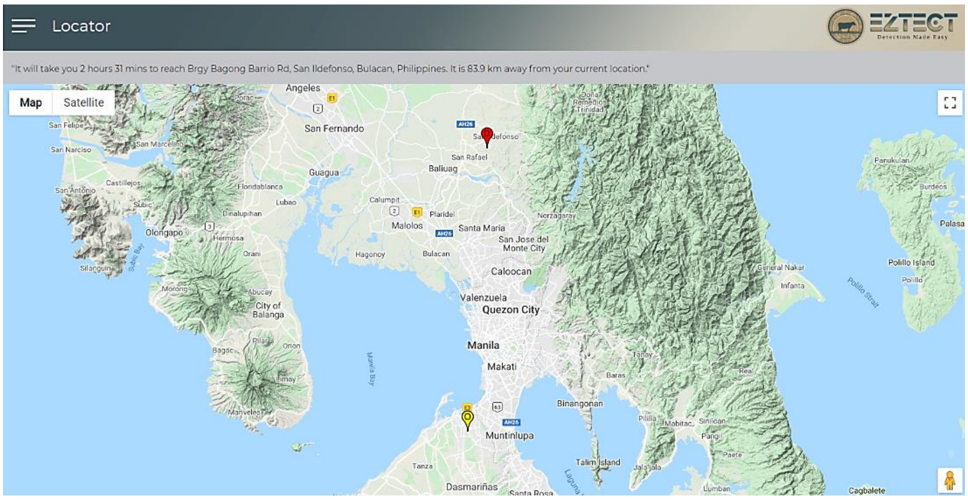

Fig. 9 - Screenshot of the locator

5. Report Generation: This feature allows the user to download PDF-generated annual, monthly, or individual cattle estrus reports containing relevant information about the cows in the barn. A screenshot of the feature is illustrated in Figure 10.

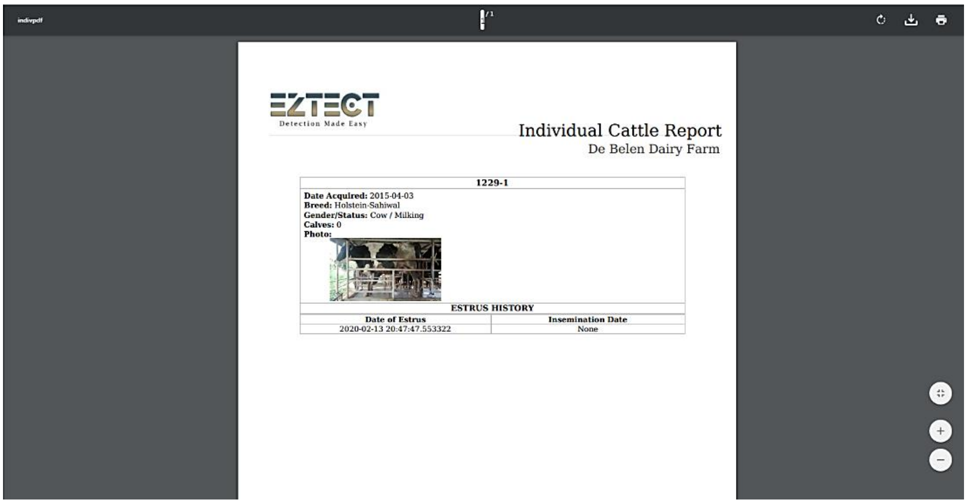

Fig. 10 - Screenshot of the downloadable report

6. 'Moonitor' Live View: This feature lets the user access and control the surveillance cameras at ease through pan, tilt, and zoom capabilities of the cameras to get a better view of the barn. A screenshot of the feature is illustrated in Figure 11.

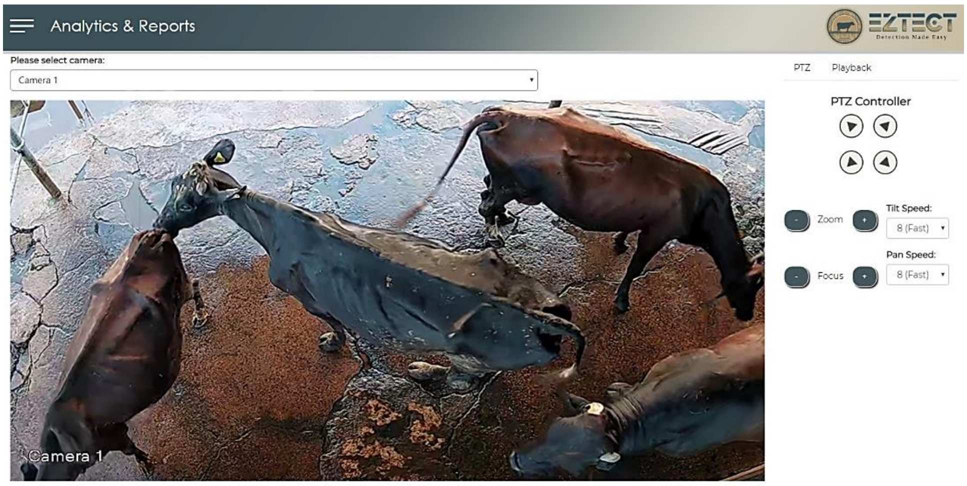

Fig. 11 - Screenshot of the "Moonitor" live view

7. Web Push Notification: This feature notifies the user of the detected standing-heat activity through the push notification services provided by the OneSignal platform.

c. Overall System Structure

The overall system architecture is shown in Figure 12. It consists of connections between devices from the input to the output. The system consists of three major parts: input devices, detection system, and output system. The PTZ cameras serves as input devices are connected to the NVR. From this, a wired connection is established between NVR and main processing unit. The unit executes automatic detection program. Once estrus is detected, all results are stored locally and wirelessly, respectively, by database and cloud storage. The data is sent to the cloud server, which is accessed through the IoT-based web application.

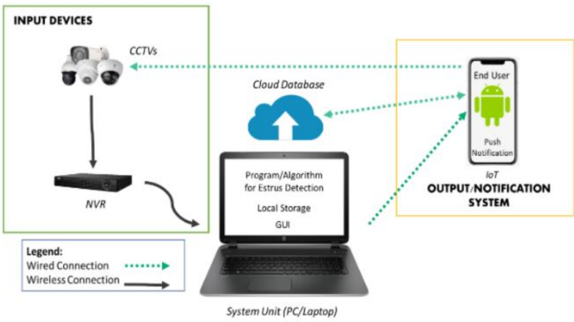

Fig. 12 - The over-all system architecture

The program workflow of the system is shown in Figure 13. The program primarily loads necessary packages, label map, and frozen inference graph that is generated and trained through TensorFlow [19]. Afterward, the program runs an SSH connection through Paramiko and RSA key authentication. Consequently, the camera processes the image frames through OpenCV. In the image processing section, the first object detector will visualize "COW" predictions and identify object overlapping activities through bounding box corner analysis, as in [21]. The program generates various data frames [21] to contain information such as the Cow Name, ID, box coordinates and angles, and date and time of detection, considering one class for prediction.

If conditions are met, the last object detector acquires the image frame for processing. Once the detection criteria are satisfied, the program declares an estrus activity otherwise, the program continues to visualize bounding boxes on the image frame. Next, the program locally saves and remotely upload the comma-separated-value (CSV) files that contains the aforementioned data. It initializes the remote database to align the data to the web application routes. While the program restarts the Estrus counter, it continues to perform object detection. The web application performs data visualization, forecasts the next possible estrus activity, and activates the 8hr-countdown timer. At the same time, the program sends in a call-alert to the end-user. It will deliver push notifications on the app-subscribed network devices.

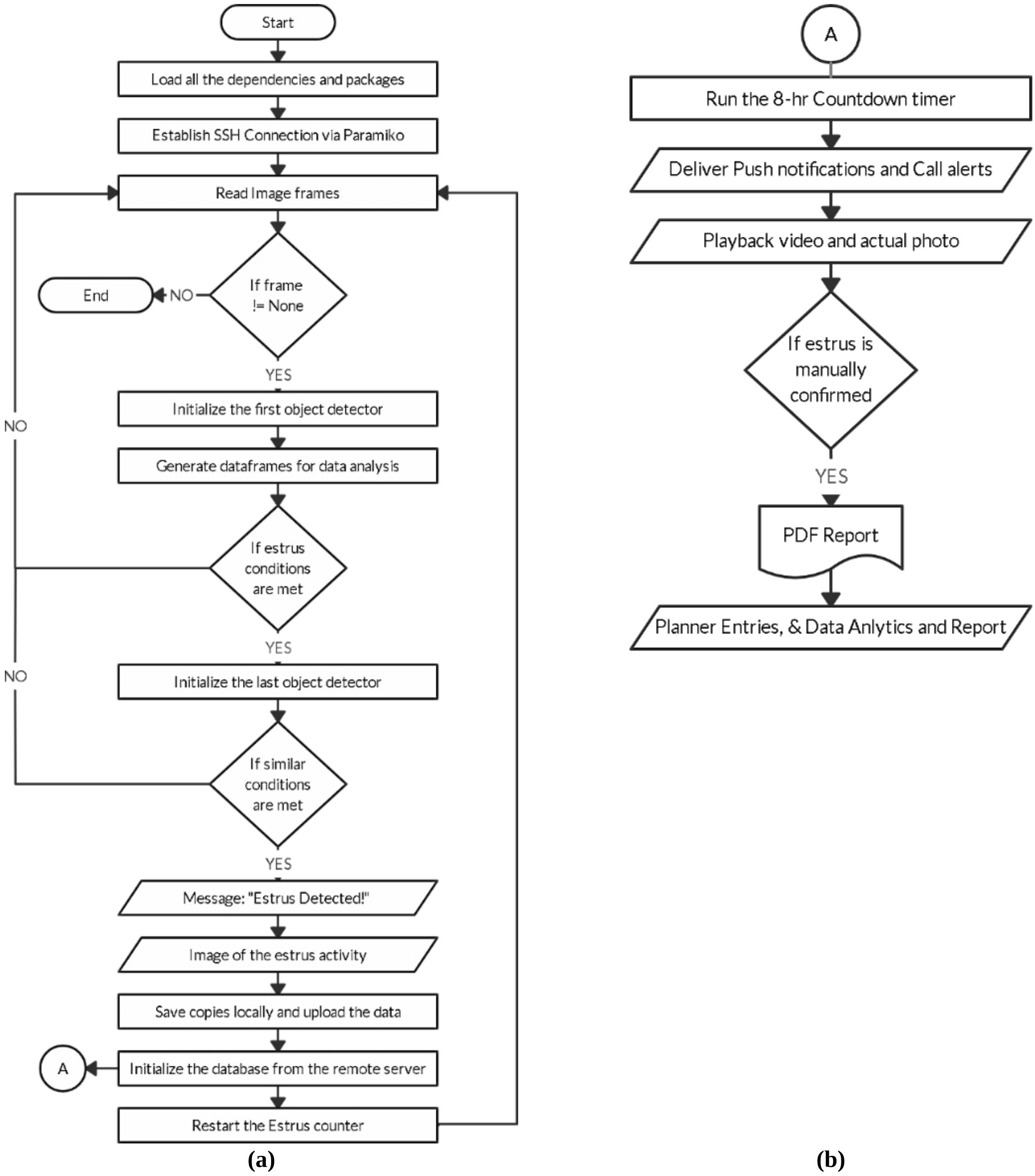

Fig. 13 - (a) Flowchart of the Detection system; (b) Flowchart of the Remote Database subsystem

4. Results and Discussion

This study is a non-invasive and non-contact estrus detection system using image processing, artificial intelligence, and Internet of Things technology to detect standing heat behaviors. The detection system comprises of classification, detection, and notification sub-systems.

Two custom neural network models developed through the TensorFlow Object Detection API classify and detect the dairy cows and their estrus behaviors using machine learning. In the pre-training phase, the Faster R-CNN model integrates about 1400 images for each class, but the Single Shot Detector (SSD) model utilizes a total of 21912 cow images. In the pre-processing phase, the Faster R-CNN and SSD models train the images through data augmentation techniques such as autoaugment_image, random_horizontal, random_vertical, random_adjust_brightness, and random_rotate_90. The over-all training for both models took approximately 387 hours.

In the detection stage, the program captures video frames from three strategically installed PTZ cameras, visualizes bounding box predictions based on models' inference to detect the cows, and declares standing-heat activities based on

the overlapping of the predicted boxes. Whenever the simulation projects the mounting behavior of the cows, the program locally and remotely stores the image of that instance and the record containing vital information of the cows.
The IoT-based Web Application provides access to standing-heat records and other relevant information about the cows, remote monitoring through the Pan-Tilt-Zoom Cameras, and assistance on estimating travel time between the user's current location and the farm. Once the program declares a standing-heat activity, it automatically sends an SMS call to the registered number through an Android-compatible GSM Module and simultaneously notifies the application to deliver push notification alerts to the user's computer or smartphone.

a. Database Results

The deployed system executed the program in the barn for 4 months, with 10 hours of daylight and artificial light exposure. As shown in Figure 14, the web application reported a total of 4 app-detections of standing-heat, 4 manually detected standing-heat signs, and 2 "True Positive" and "False Positive" detections of the EZTECT.

As shown in Figure 14, there are a total of 4 app-detections of standing-heat, 4 manually detected standing-heat signs, and 2 "True Positive" and "False Positive" detections of the system. As represented in Table 2, the end-user stated "FALSE" due to the incorrect detection of the system with "COW N" and "COW P" as in-heat cows, which instead should be the "BULL" and "COW Q". Nevertheless, the system initially and correctly detected 4 standing-heat signs, but with 2 false predictions and identifications leading to 2 "True Positive" and 2 "False Positive" results, attaining a 50% detection efficiency. The experiment involved 1 bull, 1 caracow and 17 cows. Table 3 shows the legend of the cow ID and cow code used in the experiment.

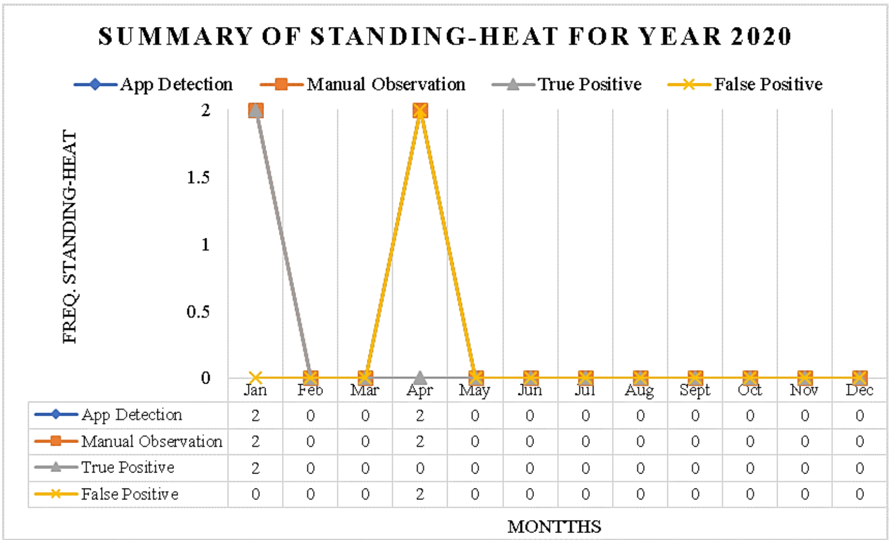

Fig. 14 - Graphical Representation of Database Result for the Frequency of standing-heat

Table 2 - Database Results for the Verification of the Project Testing

Cow ID	Date	Time	Validity	Inseminated
1	January 11, 2020	2:37:22 PM	TRUE	NO
1229-1	January 11, 2020	2:37:22 PM	TRUE	YES
257-2b	April 2, 2020	6:24:13 PM	FALSE	NO
67	April 2, 2020	6:24:13 PM	FALSE	NO

Table 3 - Legend for the Cow ID

COW CODE	COW ID	COW CODE	COW ID
BULL	1102-1	COW I	0739-1
CARACOW	1	COW J	4062-1
COW A	3819	COW K	3897
COW B	2409-3	COW L	2264-1
COW C	485-3	COW M	2534
COW D	2264-2	COW N	257-2b
COW E	4030-2-2	COW O	516-3
COW F	1000-1	COW P	67
COW G	7021-2	COW Q	3220
COW H	1229-1		

b. Notification Results

A screenshot of the recorded call alerts obtained from the program through the Arduino and the GSM module during the experimentation and trial phase of the system is shown in Figure 15.

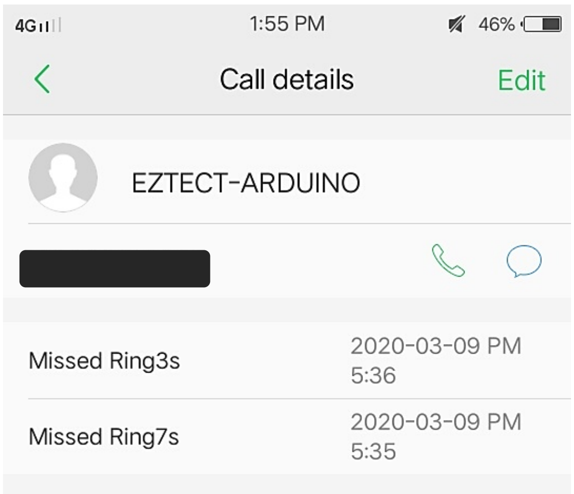

Fig. 15 - Screenshot of the call alerts

c. Qualitative Review Comparison of Related Works

Table 4 - Summary of findings

Authors	Problem to be Solved	Outcome
Lan, Quigley, and Masouras [5]	Development of an intelligent agricultural management system	Various implementation of electronic sensors provided significant results in cattle monitoring and crop management.
Lee [6]	Development of an estrus detection and health monitoring system based on three-machine learning algorithms	The CNN-based program performed effectively in recognizing early, peak, and late estrus activities, and predicted estimated calving dates of breeding cattle.
P. Chen [7]	Development of an estrus detection system based on NB-IoT communications	The system successfully detected mounting behaviors and monitored temperature readings of cows while achieving low power consumption.
Zin, Kobayashi, Tin, and Hama [8]	Development of a video-based monitoring system for analyzing cow behaviors and patterns	The system can perform heat detection of cows at a high accuracy rate with the body conditioning scores.
Barriuso *et al.* [9]	Development of a remote monitoring system for dairy cattle using multi-agents and wireless sensor networks	The combinational system provided real-time data visualizations which allowed the farmers to immediately analyze the results through the developed applications and perform insemination and verification of findings once a notification alert is sent.
Pratima et al. [10]	Development of Smart Collar for reading body temperature, heart rate, Gyroscope, Motion Sensor and accelerometer for Behavior Monitoring using IoT	The collected data from sensors are stored and classified using machine learning to produce Normal, less Normal, and Abnormal health classification outputs. Based from the axis sensor produce a graphical output to find out the cows are standing, lying down and eating.
Bovo et al. [11]	Development of Smart Monitoring System which are networks of sensors used for environmental monitoring for the animal welfare	The acquisition of big data time series about the physical and environmental conditions of the facilities hosting cow herds for both indoor and outdoor environmental features. This enables smart control, diagnosis of conditions and alerts anomalies.
Taneja et al. [12]	Development of Fog Enabled IoT for Lameness Detection and Behavior Analytics	The utilization of fog computing to extend cloud computing services to the edge of the network through fog node to enable computation closer to the source of data.
Proposed work	Development of an automated estrus detection system based on neural networks with surveillance and notification systems via the Internet of Things (IoT)	The developed system successfully identified estrus events at a 50% detection efficiency and effectively performed data visualizations, remote monitoring, geolocation, and notification delivery.

Table 4 represents the summary of findings between the proposed SDF and detection system, and other relevant research. As abovementioned, this study deals with the development of an automated estrus detection system based on neural networks with surveillance and notification systems through the Internet of Things. In comparison with the papers [5] and [6], the proponents utilized the intersection of predicted bounding boxes through IP PTZ cameras instead of accelerometers to analyze the step readings, lameness, and active states of the cows. Moreover, the proponents programmed a web application that can receive image detection results, represent the data in a graphical format, and deliver web push notifications to subscribed network or cellular devices. The web application developed in this study is closely similar to one of the systems constructed by Barriuso *et al.* [9]. However, their application does not include remote monitoring and control capabilities to view certain areas of the barn through the "Moonitor" Live view section and estrus countdown timer to predict the next possible estrus events through the calendar and dashboard sections.

5. Conclusion and Recommendation

Based on the findings and results of the study, the following conclusions are drawn out. Firstly, the cost-effective smart system consisted of Pan-tilt-zoom (PTZ) cameras, a Network Video Recorder (NVR), a high-processing laptop, and an Arduino Uno and GSM Module proved to be interoperable and beneficial in providing local and remote monitoring of the cows in the barn; giving access to high quality recorded video footages for security and validation purposes; managing cattle records, detection results, and other relevant information through the web application; and notifying the proprietors of the De Belen Dairy Farm of any detected estrus activities in the barn. Secondly, the custom neural network models such as - the Faster R-CNN; and the Single Shot Detector (SSD) models proved to be effective in visualizing bounding boxes for the detection of cows and identifying its standing-heat behaviors through supervised learning and bounding box corner analysis in comparison with combination of Scale Invariant Feature Transform (SIFT), HAAR Cascade Classifier, and Random Forest (RF), K-Nearest Neighbor (KNN), or Support Vector Machine (SVM) algorithms. Next, the IoT-based Web Application ("EZTECT App") proved to be capable of data visualization and report generation of relevant cow information, remote camera control for monitoring, and notification alerts. The App was also able to generate a countdown timer and a calendar-planner for forecasting and preparations and a locator map for minimizing decisions. Finally, the results gathered in the study are initially verified by one of the farm caretakers, wherein the system only performed 50% in detection efficiency.

This research aims to provide insights for other researchers to construct a smart monitoring system that can effectively aid and minimize the management loads of the farmers while being able to detect estrus activities of cattle livestock. Due to the 50% detection efficiency of the system, the proponents recommend to: (1) improve the estrus detection of the system to provide more accurate results; (2) use cloud messaging services to send messages to end-users rather than call alerts and push notifications from the application; and (3) find alternative ways of sending data from a remote location to the cloud server.

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References

[1] P. Vate-U-Lan, D. Quigley and P. Masouras, "Internet of Things in agriculture: a case study of smart dairy farming in Ontario, Canada", *The 15th International Conference on Developing Real-Life Learning Experience Smart Education for Sustainable Development*, DRLE 2017

[2] M. O. Akbar, M. S. S. Khan, M. J. Ali, A. Hussain, G. Qaiser, M. Pasha, U. Pasha, M. S. Missen and N. Akhtar, "IoT for Development of Smart Dairy Farming," *Journal of Food Quality*, vol. 2020, pp. 1-8, 2019.

[3] R.C. DeLaval, "Smart Livestock Farming Market to Eyewitness Massive Growth", *BouMatic Robotics*, Fullwood, Lely, 14 October 2020. [Online]. Available: https://rejerusalem.com/85723/smart-livestock-farming-market-to-eyewitness-massive-growth-by-2028-delaval-boumatic-robotics-fullwood-lely/.

[4] L. G. S. Bersales, "Philippine Statistics Authority," 1 July 2020. [Online]. Available: http://www.psa.gov.ph/content/cattle-situation-report-january-march-2020-0. [Accessed 15 October 2020].

[5] P. Vate-U-Lan, D. Quigley and P. Masouras, "Smart Dairy Farming through Internet of Things (Iot)," *Asian International Journal of Social Sciences*, vol. 17, no. 3, pp. 23-26, 2016.

[6] M. Lee, "IoT Livestock Estrus Monitoring System based on Machine Learning," *Asia-Pacific Journal of Convergent Research Interchange*, vol. 4, no. 3, pp. 119-128, 2018.

[7] P. Chen, "Dairy Cow Health Monitoring System Based on NB-IoT Communication," in *2019 International Conference on Electronic Engineering and Informatics*, Nanjing, China, 2019.

[8] T. T. Zin, I. Kobayashi, P. Tin and H. Hama, "A General Video Surveillance Framework for Animal Behavior Analysis," in *2016 Third International Conference on Computing Measurement Control and Sensor Network (CMCSN)*, Matsue, Japan, 2016.

[9] A. L. Barriuso, G. V. González, J. F. D. Paz, Á. Lozano and J. Bajo, "Combination of Multi-Agent Systems and Wireless Sensor Networks for the Monitoring of Cattle," *Sensors*, vol. 18, no. 1, pp. 1-27, 2018.

[10] Y. P. Pratima, D.K. Basuki, S Sukaridhoto, A.A. Yusuf, Faruq, B. Putra, "Designing of a Smart Collar for Dairy Cow Behavior Monitoring with Application Monitoring in Microservices and Internet of Things-Based Systems", *2019 International Electronics Symposium (IES)*, Surabaya, Indonesia, pp. 527-533, 2019.

[11] M. Bovo, S. Benni, E. Santolini, M. Agrusti and P. Tassman, "A Smart Monitoring System for a Future Smarter Dairy Farming", *2020 IEEE International Workshop on Metrology for Agriculture and Forestry (MetroAgriFor)*, pp. 165 – 169, 2020.

[12] M. Taneja, N. Jalodia, P. Malone, J. Byabazaire, A. Davy and C. Olariu, “Connected Cows: Utilizing Fog and Cloud Analytics Toward Data-driven Decisions for Smart Dairy Farming”, *IEEE Internet of Things Magazine*, December 2019, pp. 32-37

[13] Porto, S. MC, C. Arcidiacono, U. Anguzza and G. Cascone, "A computer vision-based system for the automatic detection of lying behaviour of dairy cows in free-stall barns," *Biosystems Engineering,* vol. 115, pp. 184-194, 2013.

[14] D.-M. Tsai and C.-Y. Huang, "A Motion and Image Analysis Method for Automatic Detection of Estrus and Mating Behavior in Cattle," *Computers and Electronics in Agriculture* , vol. 104, pp. 25-31, 2014.

[15] A. Massry, A. Courdavault, A. Mohammed, A. Sauber, C. Kenney, W. Smith, J. Frederickson, R. Myers, M. Queue and C. Cravens, "Linode," 2015. [Online]. Available: https://github.com/linode/. [Accessed 2019].

[16] C. Xianjun, Z. Ji, Y. Fan and Y. Zhan, "Restful API Architecture Based on Laravel Framework," *Journal of Physics: Conference Series,* vol. 910, no. 1, 2017.

[17] P. Vogel, T. Klooster, V. Andrikopoulos and M. Lungu, "A Low-Effort Analytics Platform for Visualizing Evolving Flask-Based Python Web Services," in *2017 IEEE Working Conference on Software Visualization (VISSOFT)*, Shanghai, China, 2017.

[18] C. Fu, Y. Wang, Y. Xu and Q. Li, "The logistics network system based on the Google Maps API," in *2010 International Conference on Logistics Systems and Intelligent Management (ICLSIM)*, Harbin, China, 2010.

[19] J. Huang, V. Rathod, R. Votel, D. Chow, C. Sun, M. Zhu, A. Fathi and Z. Lu, "GitHub," 15 June 2017. [Online]. Available: https://github.com/tensorflow/models/tree/master/research/object_detection. [Accessed 27 April 2020].

[20] Y. He, C. Zhu, J. Wang, M. Savvides and X. Zhang, "Bounding box regression with uncertainty for accurate object detection," *2019 IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR),* pp. 2883-2892, 2019.

[21] V. Porcu, Python for Data Mining Quick Syntax Reference, New York City: Appress, 2018.