Machine learning-based Acoustic Repellent System for Protecting Crops against Wild Animal Attacks

Devsmit Ranparia
Department of Mechanical Engineering
Indian Institute of Technology Ropar
Rupnagar, India
2017meb1202@iitrpr.ac.in

Gunjeet Singh
Department of Mechanical Engineering
Indian Institute of Technology Ropar
Rupnagar, India
2017meb1207@iitrpr.ac.in

Anmol Rattan
Department of Mechanical Engineering
Indian Institute of Technology Ropar
Rupnagar, India
2017meb1193@iitrpr.ac.in

Dr Harpreet Singh
Department of Mechanical Engineering
Indian Institute of Technology Ropar
Rupnagar, India
harpreetsingh@iitrpr.ac.in

Dr Nitin Auluck
Department of Computer Science & Engineering
Indian Institute of Technology Ropar
Rupnagar, India
nitin@iitrpr.ac.in

2020 IEEE 15th International Conference on Industrial and Information Systems (ICIIS) | 978-1-7281-8524-8/20/$31.00 ©2020 IEEE | DOI: 10.1109/ICIIS51140.2020.9342713

***Abstract* — In this paper, we present some insights on the issue of crop destruction by wild animals. This is a serious concern for the affected farmers throughout the world and leads to significant social and financial distress among them. In order to understand the background of this problem, a survey of Katli village, Rupnagar, (India) was conducted. The main aim of the current work is to develop a device to protect crops from damage by wild animals by diverting them from the farms, without harming them physically. In this context, an Acoustic Repellent System has been designed which uses a convolutional neural network (CNN) based machine learning model and an IR camera to identify target animals, such as wild boar, nilgai, and deer. A Raspberry Pi (Rpi) module has been integrated with a camera and a frequency generator to recognise different animals and produce corresponding frequencies that keep them away from the farms of interest. Moreover, the architectural aspects of the proposed solution have also been detailed. Lastly, the potential impact of the proposed solution has been discussed.**

Keywords—Crop Destruction, Crop-Raiding, Wild Animals, Human-Wildlife conflict, ML, CNN, Acoustic, Repellent, IoT, Rpi.

I. INTRODUCTION

Agriculture is the primary occupation of three-quarters of the population in India. It is the lifeline for the Indian economy. Any major problem in this field can have a devastating impact on the country. Irregular rain patterns, unfavorable weather conditions, and excessive exploitation of fertile soil are a few prominent problems stalling the progress of agriculture in the country. Moreover, crop damage by wildlife is aggravating the situation. Burgeoning deforestation due to the ever-increasing population is resulting in the loss of animal habitats. This is coercing the wildlife to trespass human-populated areas, specifically the agricultural fields in search of food and habitat. India has a huge forest cover and agricultural fields on its fringe are at a greater risk of wild animal attacks. This is becoming a major concern nowadays in many parts of the world. In Tanzania for instance [1], the annual loss due to crop damage for the villages on the forest boundaries is around 250% of the loss incurred by other villages away from protected forest areas. Wild animals like elephant, deer, nilgai (blue bull), tiger, fox, etc. are frequently sighted in the agricultural lands in many parts of the country [2]. These animals pose major threats to the crops and lives of the farmers, even jeopardizing their own lives. To tackle this problem, we have proposed a robust and safe solution in the paper.

This paper is an outcome of the research and survey that we conducted in the village Katli, Punjab, India. This village shares its boundary with a forest due to which farmers bear heavy losses from crop damage by wild animals, notably nilgai, deer, and wild boar. These animals destroy up to 50% of their crops every season. This not only occurs in Punjab [3] but in other parts of India too, especially in the Southern and Northeastern region. For instance, a study conducted in the Trichur District, Kerala [4] reported that the Asian elephant inflicted the highest damage (Rs.17, 35,625/- per annum), followed by wild pig (Rs. 3,736/- per hectare per annum) and Indian crested porcupine (Rs. 615.47/- per hectare per annum). Moreover, in the gram panchayats of a few districts, there was around 50% crop destruction by animals coming from protected forests.


Wild animals give Punjab farmers sleepless nights
Aman Sood
Tribune News Service

Patiala, November 23
Just as Punjab farmers were beginning to recover from damage caused by unseasonal rains in September, marauding wild animals are giving them sleepless nights.

Standing crops on many acres have been destroyed by animals in search for food. Invasion by blue bulls and wild boars is most common. The Punjab Government allows culling of wild boars but other animals can neither be killed nor hurt.

To counter the wild threat, Gurdeep Singh of Chaunta Khurd village, Rupnagar, has taken to guarding his fields and pins hopes on some local hunters too for the job.

Fig.1: Newsletter excerpt from the Tribune, dated 23 Nov 2014

II. Related work

Till date, there have been a few contributions to solve this issue. There has been some research in IoT-based solutions for preventing animal intrusion into the fields. One approach employs ultrasonic repellers after identification of animals using a PIR (Passive Infrared) sensor [5]. Upon identifying the animal, it activates the driver which spontaneously produces ultrasounds within *20 - 40 kHz* of frequency to petrify them back to forests. However, this PIR sensor can't differentiate between different animals at the same time and thus the system always produces the predefined frequency for the target animal, which can prove to be disturbing and shocking in case of domestic animals and humans. Another proposed solution used a WSN (Wireless Sensor Network) system placed in nodes at strategic locations around the field [6]. An array of lasers and sensors (including photo detector cameras) continuously scans the perimeter of the field to detect any intrusion. The animals are then deflected using a combination of flashers and buzzers. This system's capability to reduce crop destruction was no more than 5%. Another study used ultrasonic sensors and the ORB algorithm to detect the animals and to scare them away [7].

Each study herein was performed with different objectives and optimized parameters according to its requirements hence, the functional efficiency and effectiveness of each of them varies. Recent advancements in Machine Learning (ML) and especially in deep learning, a subfield of ML, have broadened the scope of automation in various fields. Agriculture is without wonder, one of them. Since the outstanding performance in ImageNet [8], Large Scale Visual Recognition Challenge in 2012, convolutional neural networks (CNNs) have been widely utilized in computer vision technology. Numerous CNN models have been proposed which aim to solve complex image recognition problems with greater accuracy and faster performance, as compared to traditional computer vision techniques. We used CNN due to the same reason. An RPi microcontroller module, which gives much better performance than Arduino and has more memory, has been utilized in our solution. We have also designed our system to produce frequencies corresponding to each animal for higher effectiveness, and to ensure that domestic animals and humans aren't alarmed.

III. Survey

A. *Method of Survey and Data Collection*

We obtained the basic data about Katli village from the panchayat committee and CENSUS 2011 [9] data. We visited specific strategic locations to take a closer look at the problem. We contacted the villagers to compile the ground report of the village and get clear, detailed insights about the issue. Our survey included interaction with more than 70% farming-based families, questioning them about the losses they endure every year due to wild animals. We also enquired regarding the efficacy of their traditional methods to repel animals, relevant government policies and how these address their problem.

B. *Key Findings*

Post survey, we realized that the problem of crop destruction by wild animals is very prominent in and around the Katli village. Katli is a village in Rupnagar district in the state of Punjab, India. It is located 6 km north of Rupnagar and 43 km from the state capital Chandigarh. A terrain view of the village is shown in Fig. 2. The village right next to Katli, Sadabarat is facing the same problem. Annually, wild animals like barasingha, wild boar, nilgai, deer, etc. destroy almost 50% of the crops. Barasingha, nilgai (blue bull), and deer majorly destroy potato, sugarcane, rice, whereas wild boars devour all types of crops. In our geographical survey of the village, we found that animals usually enter the village from the Sadabarat village (where the fence is broken due to poor maintenance). As depicted in the map in Fig. 2, the animals can make inroads into the fields through a number of points as the forest is not completely fenced from all sides. One of these points is the open area besides St. Carmel School.

Fig. 2: Terrain view of Katli village, surrounding forest and infringements by wild animals

Through our surveys, we also obtained some insights on the steps taken by the villagers to tackle this wild animal problem. Some of the methods that have been put into practice by them are as follows:

1) *Agricultural Fences*

Fencing is a popular and effective practice that can last for many years, for protection from wild animals. However, erecting fences as a tool for protection is often regulated by the authorities. Some local and state entities may restrict or limit the use of certain types of fences. Therefore, before deciding on a suitable fence, it's important to check regulations entailed in the law. The quality of the fence depends on its material.

These fences may not even work for some animals, as a Barasingha for example, can jump up to 2 meters. In such cases, it may not be economical and feasible to erect fences at such heights. In addition, fences are likely to be damaged by animals or by natural causes, and hence, may not guarantee protection. A damaged fence is shown in Fig. 3, which was broken by animals two years ago, but the villagers did not have sufficient funds to repair it. During our survey, we also found that even an electric fence proved to be fatal for animals, as well as for humans.

Part No: CFP2058A-ART; ISBN No:978-1-7281-8524-8/20

Fig.3: Broken fence on the forest boundaries near Katli

2) Natural Repellents

Farmers also use various natural repellents like smoke, fish or garlic emulsion, beehive fence, and some egg-based repellents, but none of them works up to the mark as a long-term solution. Moreover, each of these solutions has side effects in one form or the other.

3) Hiring Watchmen

As can be seen in Fig. 4, many villagers have built hut-like structures in the midst of the farm. These are used for guarding fields at night. This is a feasible solution for rich farmers, however, poor farmers can't afford a watchman and the conditions are very hostile and chilly in winters for watchmen. Even attacks by animals on watchmen are not out of the equation.

Fig.4: Watchman's stand in the middle of the farm

4) Shooting Animals with Government's Permission

Poaching at first seems to be the most plausible solution and thus the government permitted the farmers to hunt the animals which were invading their fields. According to this policy, one is allowed to hunt the animals only when they invade his field and he has a permit from the government. However, if someone kills them in their natural habitat, then this policy does not provide protection to the poacher. Moreover, the legal glitch is that the farmer needs a licensed weapon and the skills to operate it safely. There is always a looming risk of retaliation by animals, like wild boars, elephants, etc.

Currently, there are no economic and lasting solutions for this problem. Keeping all the above points in mind, we propose to solve the problem by creating a long-term effective solution, which not only saves the crops but also, doesn't harm the animals.

Firstly, the proposed system will detect the kind of animal that happens to be in its region of detection. This system will use an Infrared camera to sense its surroundings and process images using Computer Vision. By employing various Machine Learning algorithms, it will analyze the data and identify the particular animal that is present. The microcontroller (Raspberry-Pi) is used for coordination. If the target animal is identified, it sends a positive signal and then a frequency generator will emit the frequency waves (corresponding to that animal) that will scare away the animal. It won't be able to tolerate the high-pitched sound and would leave the coverage area of the sensor [5].

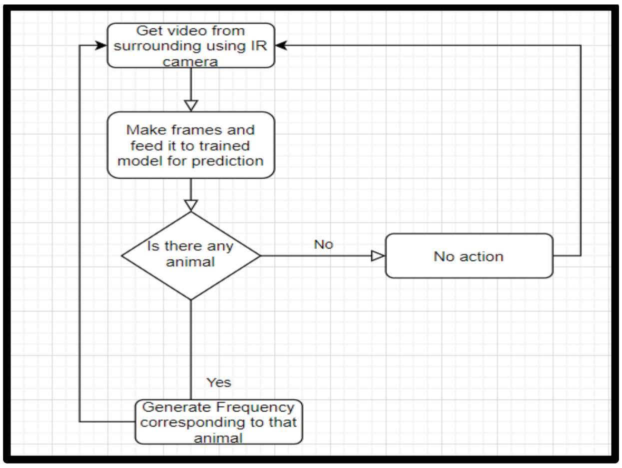


Fig.5: Network diagram of the proposed solution

IV. System Architecture

We now discuss our proposed system architecture. First, we list the various hardware components that will be a part of the proposed module.

A. Hardware Components

- Rpi Infrared Camera
- Ultrasonic Frequency generator
- Raspberry Pi 3B
- LiPo batteries
- Network Connectivity Module
- Module Casing

B. Detection of Animals

The movement and images of the approaching animal would be detected by a high-resolution Infrared Night Vision camera. Even in the absence of humans, this will ensure security during night, harsh weather, and low visibility. The camera will capture the video continuously, and the video will be fed directly to the Raspberry Pi (Rpi 3B), a microcontroller that acts as the coordinator and the brain of the entire module. The Rpi will spontaneously capture frames after certain predefined intervals. The frames will be captured and processed using the OpenCV library in python language.

The captured frames will then be fed to the Machine Learning model, which will predict the appropriate animal with a significant probability of being accurate.

The challenge is how to fix the gap between two frames which need to be captured. If we try to capture every frame, then the data will be huge and the computational cost will be exorbitant. Also, doing so is unnecessary, since the animal will definitely be shot for a couple of seconds in the video (if it comes in the camera's visibility range). On the other hand, if we keep a huge gap, then the animals may get away without detection. After studying the motion of wild animals and some brainstorming, we concluded that a frame capture rate between 1 frame every second to 1 frame every 10 seconds would suffice. The appropriate choice would be to capture a frame every 5 seconds.

C. Machine Learning Model for Animal Prediction

The frames obtained will be used to predict whether there is any wild animal in the area, and if so, which one. The prediction will be done using a Machine Learning (ML) model, which is based on the Convolutional Neural Network (CNN) framework. The CNN framework is a deep learning algorithm generally used in image recognition.

Convolutional Neural Networks follow the strategy of extracting simple patterns from the image in every layer and later, combining those patterns to identify complex features of the image. In each layer, we apply convolution on the image by operating it with a filter matrix. Then pooling is done, where the particular value is extracted from a specified sub-part of the image which represents the whole subpart. In turn, the features become coarse but the dimension reduces considerably for easy computation and avoiding overfitting in the model. To decide weights of neurons of each layer, an activation function is used, which through forward and backward propagations tries to minimize the error in the training dataset by adjusting the weight of each neuron. The total number of layers, number of neurons in each layer, size of filter matrix, type of activation function, pooling layer shape are the hyper parameters whose values are chosen based on the applications, input parameters and on the basis of the experience of the programmer [10].

We trained the ML model based on CNN (refer to Fig. 6) in Jupyter Notebook. The training dataset was obtained from Google Images, Shutterstock [11], and the Kaggle database [12]. The dataset contained more than 10,000 images of certain animals such as blue bulls, hens, boars, dogs, etc. The dataset was also divided into a training set comprising 80% of all images. The remaining 20% were stored under testing dataset. The training dataset was then renamed using a python script, since each image must have the information on which animal it represents. That data is then represented in the form of a categorical matrix. Before feeding the dataset to the model, images were filtered out by removing duplicates and the images containing watermarks. Next, the dataset was formatted and split into the training set and the testing set. The model has 4 Convolutional layers with the Rectified Linear Unit as an activation function and max-pooling done by a 2 x 2 pooling layer. It has 1 dense layer with Rectified Linear Unit as an activation function and the output is a layer with 'Softmax' activation function. The model was compiled with 'Binary Cross entropy' as the loss function and 'Adam' as the optimizer.

Model: "model"

Layer (type)	Output Shape	Param #
input_1 (InputLayer)	[(None, 75, 75, 3)]	0
conv2d (Conv2D)	(None, 73, 73, 16)	448
max_pooling2d (MaxPooling2D)	(None, 36, 36, 16)	0
conv2d_1 (Conv2D)	(None, 34, 34, 32)	4640
max_pooling2d_1 (MaxPooling2	(None, 17, 17, 32)	0
conv2d_2 (Conv2D)	(None, 15, 15, 64)	18496
max_pooling2d_2 (MaxPooling2	(None, 7, 7, 64)	0
conv2d_3 (Conv2D)	(None, 5, 5, 128)	73856
max_pooling2d_3 (MaxPooling2	(None, 2, 2, 128)	0
flatten (Flatten)	(None, 512)	0
dense (Dense)	(None, 512)	262656
dense_1 (Dense)	(None, 2)	1026

Total params: 361,122
Trainable params: 361,122
Non-trainable params: 0

Fig. 6: Summary of the Machine Learning model

D. Acoustic Repelling of detected animal

Based on the animal that our model has predicted, the Raspberry Pi will send a signal to the Ultrasonic Frequency generator. The ultrasonic repellent we would use can produce frequencies ranging from 15 to 65 kHz. It has a satisfactory audible range of 10 - 15 meters with the span of 110 degrees. To further increase that audible range, we would use an amplifier for better effectiveness. Upon prediction of a particular animal, the Rpi will send a command to generate a particular range of frequencies corresponding to the predicted animal. According to our literature study, wild animals have evolved to be sensitive to hearing ultrasonic sound frequencies along with developing considerable acoustic diversity [13]. Thus, roughly each animal has a specific range of frequencies that it can hear and a frequency range that is irritating to them, most of which are well beyond the hearing capacity of humans. The hearing frequencies range for the target animals are:-

- Nilgai (blue bull) and deer: 33 Hz – 50 KHz [7].
- Wild Boar *(Sus Scrofa)*: 250Hz – 40 KHz [14]

E. Cloud Networking

The animal recognition module will share the data over the cloud regularly through a Wi-Fi connection. The cloud setup will consist of an Amazon/Microsoft cloud instance running on a machine. The data shared will be used to analyze the patterns and responses of wild animals. We can visualize the errors if any, resolve them, and achieve better results.

F. Mechanical design of the whole module

Based on the standard size and shape of all the hardware components, we designed the outer casing/box that could hold all the hardware and provide protection from outside disturbances. For better understanding, we made a CAD model of the casing to get more clarity on the assembly (refer to Fig. 7).

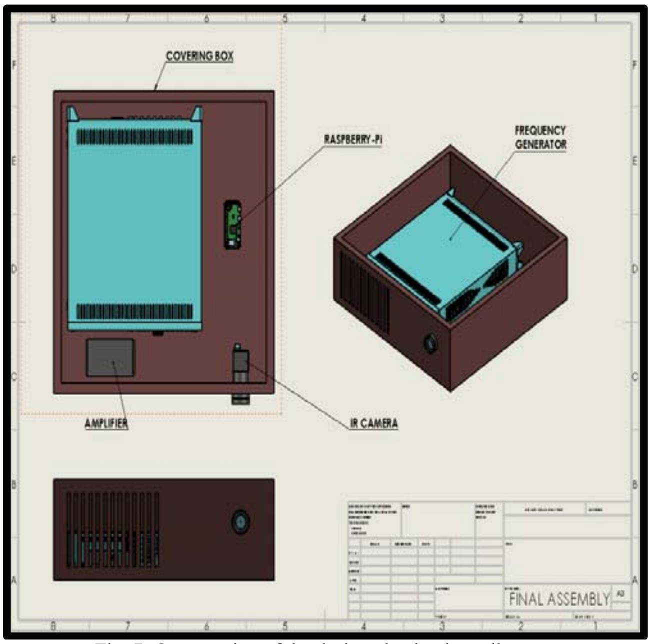
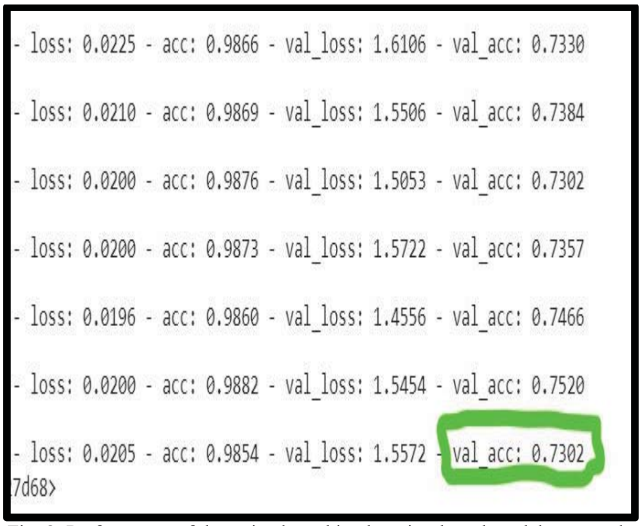


Fig. 7: Outer casing of the designed animal repellent system

V. Performance Evaluation

After compiling the model for 20 epochs and with batch size of 64, we achieved a training accuracy of 98.54% and validation accuracy of 73.02% (see Fig. 8). The model was trained for Nilgai, dogs, and hens. This accuracy is enough to provide substantial advantage to the farmers.



```
- loss: 0.0225 - acc: 0.9866 - val_loss: 1.6106 - val_acc: 0.7330
- loss: 0.0210 - acc: 0.9869 - val_loss: 1.5506 - val_acc: 0.7384
- loss: 0.0200 - acc: 0.9876 - val_loss: 1.5053 - val_acc: 0.7302
- loss: 0.0200 - acc: 0.9873 - val_loss: 1.5722 - val_acc: 0.7357
- loss: 0.0196 - acc: 0.9860 - val_loss: 1.4556 - val_acc: 0.7466
- loss: 0.0200 - acc: 0.9882 - val_loss: 1.5454 - val_acc: 0.7520
- loss: 0.0205 - acc: 0.9854 - val_loss: 1.5572 - val_acc: 0.7302
7d68>
```

Fig. 8: Performance of the trained machine learning-based model proposed for the animal repellent system

VI. Possible Impact

Our work adds value to different stakeholders by protecting the fields and balancing the ecosystem.

Increase in overall crop production - There will be an appreciable drop in crop damage by wild animals. This will directly increase the per capita income of the farmers leading to better living conditions. With more money in their hands, they can opt for better technology for their farms and can augment their profit. Thus, a small step can rekindle a process which would uplift the economy of the country.

Promote quality of life - Our proposed model will not only solve the problem of crop destruction, but will also reduce the attacks by wild animals on the local people of the village, and thus ensure the safety and security of the people. It will lessen the human workload, as its working requires almost zero human intervention unlike the traditional practices. The reckless poaching of wild animals in the name of safety and protection of human interests will be curtailed. The government can prune the expenses that are allotted to wildlife protection. This will ensure the harmless treatment of animals leading to ecological stability and balance. We feel that these efforts can pave the path towards sustainable development.

Mapping to Large scale - If this solution works out to be practically successful, it will not only solve the issue for the Katli village, but will prove to be helpful in other parts of the country as well. Once the system is deployed far and wide across the country, we can have an exchange of data between different places to increase the efficiency of the system.

VII. Conclusion

The problem of wild animals attacking agricultural fields has persisted for decades, but neither the locals nor the government have been able to solve the problem satisfactorily, which is forcing many farmers to abandon farming. In this paper, we have presented an integrated approach in the field of Internet of Things for Smart Agriculture based on low power devices and open source systems. The goal of this work is to provide a repelling and monitoring system for crop protection against animal attacks. Our theoretical model with detailed system architecture has been elucidated, which has an accuracy of more than 73%. In our future work, we will extend the current functionalities of our system and investigate the on-ground accuracy. We will then utilize the feedback to develop a more robust product. The product is slated to have a huge impact on the lives of affected farmers in terms of economic and social benefits.

VIII. Future work

The work on the assembly of the module and its integration with the hardware is in progress to make the system ready to be deployed. Subsequently, this system will be implemented in the agricultural fields of Katli village after initial checks to verify the hypothesis and accuracy of our proposed solution. With time, we will use the accumulated data to optimize our CNN model and hence, improve its accuracy.

IX. Acknowledgment

The survey of the village would not have been possible without the continuous guidance and enthusiasm of Dr Devaraj. P. (Asst. Prof., IIT Ropar). We are also indebted to Ashank, Jatin Garg (B. Tech students, IIT Ropar) and Mansi (PhD student, IIT Ropar), without whom, it would be difficult to complete our survey.

X. References

[1] M. Angela, N. Julius, N. Janemary, and R. Eivin, "The impact of crop raiding by wild animals in communities surrounding the Serengeti National Park, Tanzania," International Journal of Biodiversity and Conservation, vol. 6, no. 9, pp. 637–646, 2014.

[2] A. Veeramani, E. A. Jayson, "A survey of crop damage by Wild Animals in Kerala", *The Indian Forester* 1995.

[3] A. Sood, "Wild animals give Punjab farmers sleepless nights," The Tribune, Nov. 24, 2014.

[4] Jayson, E. A., "Assessment of crop damage by wild animals in Trichur District, Kerala." No. 491, KFRI Research Report, 2012.

[5] S. Giordano, I. Seitanidis, M. Ojo, D. Adami, and F. Vignoli, "IoT solutions for crop protection against wild animal attacks," *2018 IEEE International Conference on Environmental Engineering (EE)*, 2018.

[6] M. B. H., D. Janeera, and A. K. A.g, "Internet of Things based Wild Animal Infringement Identification, Diversion and Alert System," *2020 International Conference on Inventive Computation Technologies (ICICT)*, 2020.

[7] A. Sharma, T. Chaudhary and N. R. Chauhan, "Design and Simulation of Automated Sound System to Protect the Agriculture Farms", *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, 2017.

[8] L. Fei-Fei, J. Deng, and K. Li, "ImageNet: Constructing a large-scale image database," *Journal of Vision*, vol. 9, no. 8, pp. 1037–1037, 2010.

[9] "Katli Population - Rupnagar, Punjab," *Katli Village Population - Rup Nagar - Rupnagar, Punjab*. [Online]. Available: https://www.census2011.co.in/data/village/38644-katli-punjab.html. [Accessed: 10-May-2019].

[10] P. Simard, D. Steinkraus, and J. Platt, "Best practices for convolutional neural networks applied to visual document analysis," *Seventh International Conference on Document Analysis and Recognition, 2003. Proceedings.*

[11] *Nilgai Images*, Shutterstock.com, March 2020 [Online]. Available: https://www.shutterstock.com/search/nilgai

[12] *Animals-10 dataset*, Kaggle.com (Google Images) - Corrado Alessio, March 2020. [Online]. Available: https://www.kaggle.com/alessiocorrado99/animals10.

[13] B. D. Charlton, M. A. Owen, and R. R. Swaisgood, "Coevolution of vocal signal characteristics and hearing sensitivity in forest mammals," *Nature Communications*, vol. 10, no. 1, 2019.

[14] R. S. Heffner and H. E. Heffner, "Hearing in domestic pigs (Sus scrofa) and goats (Capra hircus)," *Hearing Research*, vol. 48, no. 3, pp. 231–240, 1990.