Distributed Wild Bird Surveillance and Recognition System

Project Plan

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Introduction

Acknowledgements

SDMAY19-10 would like to thank the Department of Electrical and Computer Engineering for their continued support of student's professional and technical growth through the administration of this course. SMAY19-10 would also like to thank our client, Dr. Joe Zambreno, for the financial resources provided and his continued support of this project. We would also like to thank Craig Rupp, our advisor, for his guidance as we develop this project.

Problem Statement

Bird identification is a more complicated topic than one would think. As an example, can you identify the species of the four following birds?

Fig. 1: Four North American Birds

In the clockwise order from the top left, the birds are a male cardinal, female cardinal, another female cardinal, and a juvenile cardinal. Four seemingly different birds, but they all happen to be the same species. Now imagine these differences happening for all the birds across North America. Because of this, even for a hobbyist, bird identification can be challenging.

The task at hand to provide a solution to this problem is to create a self-contained system that can detect and classify bird species in realtime in our client's backyard. The current consumer products available are limited to nature cameras that are constrained by basic video streaming and photo capture capabilities that are not able to classify birds.

To do this, we will use an embedded GPU platform with a convolutional neural network for real time object detection and classification. Our model will be trained and tested with two already available North American bird datasets: NABirds V1 and Caltech-UCSD Birds 200.

As a result of this project, we will have delivered a well-documented HW/SW product to our client that will successfully identify North American birds in real time.

Project Deliverables and Specifications

The wild bird project has several key deliverables. Each one will be developed and tested over the course of two semesters. The core deliverables are: the hardware system, detection/classification system, data streaming/storage system, and frontend/user notification system.

Deliverables and Functional Requirements

Hardware

The hardware will facilitate data streaming and bird detection in real time. This system will consist of a Jetson board, SSD, 4k camera, and internet connection. The 4k camera will stream real time video from a bird feeder located in the clients yard. The system will be robust enough to withstand Iowa weather and provide a stable camera mount for a clear video stream.

Detection and Classification

The detection and classification systems will be running on the sourced hardware. This system will utilize neural network architectures such as YOLO to locate and identify birds in the field of view. The detection and classification will run in real time and be able to identify all of iowa's native bird species.

Data Streaming and Storage

Once the detection and classification system has identified a bird, the hardware system will store a video of that bird. The storage system will encompass cloud backup storage as well as local storage. These stored videos will be able to be streamed to a web client on request. In addition, the system will be able to stream live video from the bird feeder. The video playback and live streaming will be at least 1080p quality or higher.

User Notifications and Frontend

The final product will deliver a frontend web client and notification system. The frontend client will allow functionality to view previously identified birds as images and short video clips, receive notification upon new identification, provide a live video stream to the feeder, allow filtering for which birds are identified, and show statistics about bird identifications.

Non-Functional Requirements

The non-functional requirements revolve around the ease of use of the system for the client. The client should have no issues setting up the camera and moving the system's enclosure. The client should be able to seamlessly use the web interface provided to watch the streamed video, browse the captured photos and videos, and configure the notification system. In addition, it should also be under the project's budget of $1500.

Previous Work / Literature Review

Existing Solutions

Currently, there are no commercial solution that accomplish our task. There are a variety of wildlife cameras available on the market but, most existing solutions only take pictures when it detects motion in front of the camera. They do not attempt to detect actual objects in the frame, so they will be prone to false positives. Additionally, they do not attempt to perform any sort of classification for the objects in the picture.

We were able to find a similar hobbyist project by Kirk Kaiser. On his blog, Kaiser describes a bird detection and classification solution based around an Nvidia Jetson TX1 board. Kaiser runs machine learning models for object detection on the TX1, and whenever the models detect a bird, the camera saves 240 frames from the camera to an attached SSD. Where Kaisers solution lacks is classification. The models Kaiser is using are very broad will only apply the label “bird” to any birds in the image. We are looking for a solution to not only detect birds in an image, but also apply a label based on it’s species. Additionally, we aim to move storage requirements to a more accessible medium such as cloud based storage, rather than an on device SSD.

Relevant Literature

The most relevant literature to our project is based around the classification solutions. Recently, there have been many breakthroughs in the field of image processing and classification. We are consulting various academic papers to design an appropriate model to accomplish the task of bird classification.

Proposed System / System / Solutions

We propose using a self-contained embedded platform that is equipped with several key features: online connectivity, internal storage for images and videos, high quality optics, and an onboard recognition system. A sample block diagram of the system can be seen below.

The system begins with a 4K image capture or stream from the e-CAM131_CUTX2 from E-Con Systems. The camera interfaces with the NVIDIA Platform through the Camera Serial Interface. Once the frame is on the board, we will apply some image pre-processing to reduce the image size for more efficient computing. Then, the image will be fed through our neural network architecture. This may be one or more neural networks for detection and classification. After, we will apply a image post-processing algorithm. From the board, these frames will be sent to the cloud for storage over the client's home network.

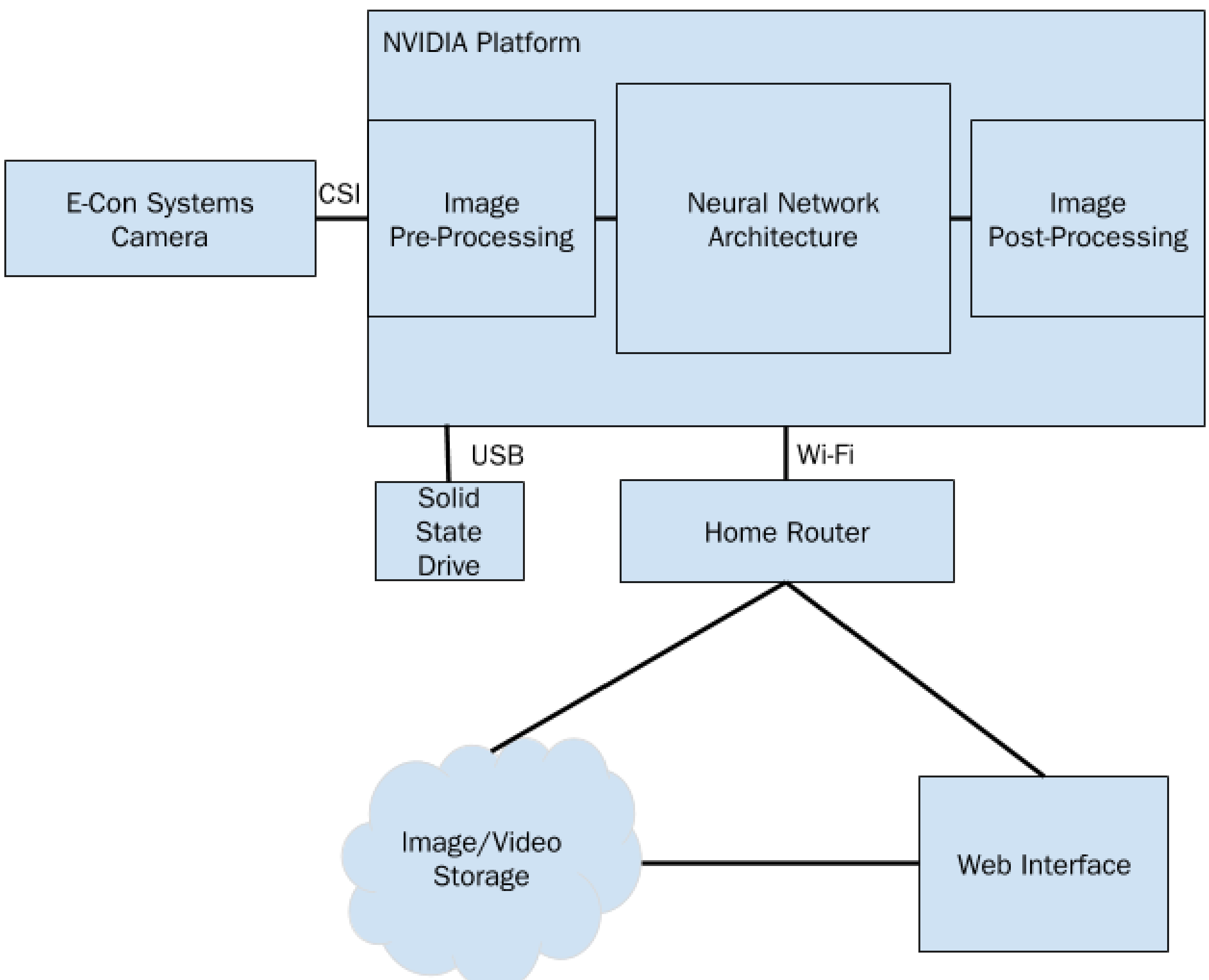

Fig. 2: Block Diagram

Hardware

E-Con Systems provides a Linux camera driver (V4L2) for the 13.0 MP MIPI CSI-2 camera. This will allow us to interface the board with the camera. On top of that, the board is also compatible with Gstreamer-1.0 for video recording and network streaming. We are also having a solid state drive connected to the board over USB to have easy access to the captured images from local storage.

Detection and Classification

We are considering using a cascading style neural network architecture. The first neural network will be solely for bird detection. The second will be a convolutional neural network for the bird classification. We are splitting these two up because it is much faster to detect a bird than to classify one.

Data Streaming and Storage

Out storage solution will be based in the cloud. The jetson board will connect to an endpoint for a cloud application and stream picture data as well as classification/detection data to the cloud service. The cloud service will backup the data, and make it available to the frontend.

For video streaming, the cloud service will establish a connection between the board and front end. Establishing a direct connection between the board and the user will help reduce overheard from cloud processing, and reduce cloud costs. The user can then choose if they would like to save certain clips from the stream in our cloud storage solution.

User Notifications and Frontend

The frontend solution will be implemented using AWS. The website will allow users to view previously identified birds, a live stream of the bird feeder, and change notification settings. Each previously identified bird will have an associated video or image, and statical information about the detection/classification. The user can select which birds to be notified for and modify the threshold at which to notify. The notification system will be an RSS feed. Clients will use a RSS client to subscribe to notification from the bird watching application.

Assessment of Proposed Solution

Hardware

Strengths

- E-Con Systems cameras are supported by the Nvidia Jetson and had high frame rates at 4k video resolution.
- The Nvidia Jetson board is widely used in embedded solutions for image recognition, and is a good form factor for our outdoor application.

Weaknesses

- E-Con Systems cameras are not widely used in the consumer market and not many examples of implementation are around.

Detection and Classification

Strengths

- Convolutional neural networks are widely used today for image recognition, and are highly expandable to different image domains.

Weaknesses

- Most of the available training datasets consist of high quality images of birds, whereas the images our system will be using will be noisier leading to lower classification accuracy.

Data Streaming and Storage

Strengths

- Cloud storage will be expandable and will not have to work about hardware limitation or hardware reliability for storage and web interface.

Weaknesses

- 4k images take a lot for storage and could use a significant amount of our clients internet bandwidth.

Trade-Offs

- We will be sacrificing some video resolution during video streaming to ensure that the stream will not be choppy.

User Notifications and Frontend

Strengths

- Will provide a clean interface for notifications and viewing of birds
- Notifications can be customized to interests of certain kinds of birds

Weaknesses

- The website will be hosted in the cloud and will have recurring costs.

Validation and Acceptance Test

In order to test our project design, we would need to test each individual component:

- The housing will be tested for weather-proofness, without any equipment in it. This way, we can validate the integrity of the structure without damaging any critical hardware. Once we verify that the housing is appropriately resilient, we can insert dummy hardware to check that the structure is not compromised before installing the real components.
- The camera images will have to be inspected by hand, for quality and sharpness. This will be done after encoding and uploading.
- The web interface will be evaluated by Dr. Zambreno and by other members of the team to ensure its design is user-friendly.
  - The testing will be included to ensure that setup and usage can be done in a reasonable amount of time
- The detection model will be tested against real-world conditions provided via video from the client’s backyard. We are aiming for at least a 90% true positive accuracy on detection in good conditions, and less than 10% false positive accuracy, both measured frame-by-frame.
- The recognition model will be tested both against sample images from our dataset, as well as against the real-world conditions described above. We are aiming for at least an 90% correct classification under ideal weather conditions.

Project Timeline

First Semester Goals:

- Preliminary prototype available for the client to take home over winter break
  - Clear convolutional neural network architecture
    - 90% on with training images
    - 60% accuracy on real data from board
  - This will include a camera and a Jetson board interfacing properly
    - Image capture
    - Video streaming
  - Detection of birds working on jetson
    - SSD configured for local storage
    - Local storage of video feed on SSD for testing different neural network
  - Offboard features including basic cloud storage and user interface
    - Cloud storage setup for detected birds
    - Basic video stream to user interface
    - Basic detection feed with time and bird identity

Goals by Spring Break:

- Fully-functional prototype for field testing

End of Second Semester

- Greatest realtime bird detection and classification system in the world, or a box that doesn't do anything

Challenges: Risks / Feasibility

Feasibility and Challenges

There are various challenges we will need to overcome throughout the course of this project. To successfully complete our project we will need to be able to detect and classify birds in real time, store images and video clips, and finally notify and make the data available to our end user. We believe that there are tools and procedures that can be used to mitigate these challenges.

First and foremost, we must find a way to efficiently classify birds. Currently, machine learning models are often run in resource rich environments. For our application, we will need our models to run in a very limited embedded environment. We believe that we can deal with this issue through a variety of machine learning techniques such as pruning our output classes, and reducing the overall size of our model. These changes may then impact the accuracy of our classification, and we will need to find a balance between accuracy and speed that meets our requirements.

Second, there exists a risk that optimizations in one subsystem will result in a loss in functionality or performance in another. We will have to take great care to ensure that we consider the health of the entire system in every change we make. To accomplish this we will develop various integration tests to test the health of the overall system. These tests should function as a means of ensuring that changes are localized, and do not have unforeseen consequences in other subsystems.

The next challenge after identification will be transmitting the images from the board over to the user. Given the high quality optics that are being used, the board will need to dedicate a significant amount of time to video encoding and data storage. This is require a balance of cpu resources dedicated to video streaming/storage and bird detection/classification. This problem is a resource optimization problems which can be realistically solved if we dedicate enough time to testing our streaming and classification systems.

Risks

There are two primary risks and security concerns we must consider when designing our system. They include an unauthorized individual viewing the video stream from the base station, and an attacker gaining control over the base station. The probability of either of these events is very low, but they must still be considered when designing our system. We will have to make sure that we use appropriate authentication measures and limit access to the TX1 board outside of our use case.

Standards

We will have to take several standards into consideration when exploring our options on case design or purchase. As an outdoor product, this project must be able to withstand some amount of dust and moisture exposure.

First, the IP code, for ingress protection, is an international standard that measures “Degrees of protection against the penetration of solid bodies, the penetration of water, and the access of personnel to live parts.” IP codes are formatted as IP##, where the first numeral measures its protection against dust and the second numeral measures protection against moisture.

It would be appropriate for the enclosure to have an IP code of IP43. This corresponds to “Protected against the penetration of solid objects having a diameter greater than or equal to 1 mm” and “Protected against rain at an angle of up to 60 degrees.”

Test Plan

Conclusions

Neural Networks + Nvidia Jetson → Success
Q.E.D.

Figures and Tables

Fig. 1: Four North American Birds
Fig. 2: Block Diagram

References

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