Nature Photography Robot

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Use Case

- Problem: Animal photography is time consuming and mundane. Remote controlled photography robots do little to fix this problem. Photo editing is necessary, but similarly human-capital intensive.
- Goal: Produce a stationary nature photography robot, which can locate, track and photograph animals. The system should also perform automated image editing.
- ECE Areas:
  - Signals and Systems - Image Processing and Control Systems
  - Software Systems - Embedded System Programming

Quantitative Requirements

- Detection Ability
  - Requirement: The system must detect half visible animals within 25 meters with a recall of 75%
  - Reasoning:
    - Animals less than half visible are likely not worth photographing
    - Recall is a more important metric than precision or accuracy, because animal appearances are sparse and removing irrelevant photos is a quick process.
    - Humans certainly do not reach 100% recall on this task, though there is little data. An autonomous system with 75% recall would photograph as many animals as a perfect human in just 33% more time. We believe this is a reasonable tradeoff for the reduction in human labor.
    - 25 meters is the necessary distance to photograph birds in nearby trees
- Detection Speed
  - Requirement: The system must detect animals within 15 seconds.
  - Reasoning: Animals rarely stay in the same position for a long period of time. A walking animal moves approximately 2m/s and could walk the entire search diameter in 25 seconds.

Quantitative Requirements Cont.

- Tracking Ability
  - Requirement: The system must be able to follow and photograph an animal moving 2 m/s.
  - Reasoning: Photographing a running animal or flying bird is too difficult even for many humans, but the system should be able to follow and photograph a walking animal.
- Photo Quality
  - Requirement: The photo should be 12MP and have quality indistinguishable from a human shot and edited photograph. Human testers should not do better than guessing (50% accuracy) when labeling photos as robot or human pictures.
  - Reasoning: The most common and accessible form of photography is phone photography, so our system should reach this level of quality. Most modern phones have 12MP cameras and in-app editing software. In addition to the technical capabilities, this measure tests the robots ability to center and focus the photograph like a human would.

Technical Challenges

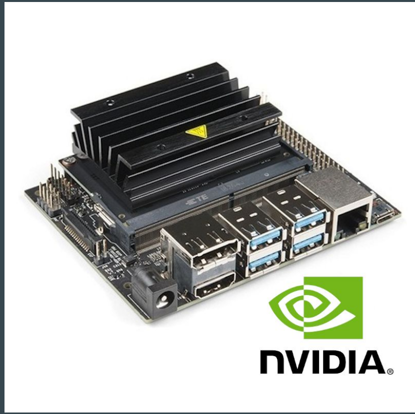
- Robot Mobility
- Camera Quality and Capability
- Speed/Accuracy Tradeoff in Detection
- Zoom/Tracking Tradeoff
- Computing Power on Embedded System
- Photo Quality after Editing

Technical Challenges - Risk Mitigation

- Accuracy before speed
  - A system that misses stationary animals but operates quickly is useless
- Investing in proper hardware instead of using complicated software hacks
  - 2 Camera system
  - 12MP Camera with zoom control
  - Buying premade Pan/Tilt system
- Have a simple starting point
  - Detection: Pretrained CNN
  - Tracking and Shooting: 2 camera approach with inverse compositional alignment
  - Editing: Basic brightness, color balance, contrast, zoom and focus rules

Solution Approach - Hardware

- Jetson Nano 2GB Developer Kit
  - Provides computing power for neural networks and image processing on an embedded systems
- 2 x Arducam 12MP Pan Tilt Zoom Camera with Metal Base and 2 Digital Servos
  - Cameras connect through MIPI and USB
  - Motors connect through GPIO pins



Solution Approach - Software

- Search and Detection
  - Initial:
    - Uniform scan at various speeds
    - Pre-trained animal detection CNN (EfficientNet w/ Kaggle Animal Detection Image Dataset)
  - Goal: Strategic search with bayesian optimization
- Tracking and Shooting
  - Initial:
    - Camera 1: Inverse compositional alignment at low speeds for nearby targets
    - Camera 2: Adequate zoom/focus
  - Goal: Optimized tracking of distant targets at high speeds
- Editing
  - Initial:
    - Implement a set of image processing algorithms (sharpening, color correction, smoothing, ect.)
    - Apply using research defined heuristic methods
  - Goal: Deep Neural Network trained for applying image processing algorithms

Testing, Verification, and Metrics

- To test the robot's recognition capabilities, a set of animal pictures may be placed in its environment under different lighting conditions and levels of occlusion
    - Locate new animals in 15 secs
    - Targets 5m, 15m, and 25m away
- Human testers will be shown pairs of photos and asked to distinguish robot photos from professional photos
- Animal tracking to be tested at 3 different speeds and 3 different distances
    - Slow(0-1 m/s), medium (1-3 m/s), and fast (3+ m/s)
    - Consistent tracking for up to 5s

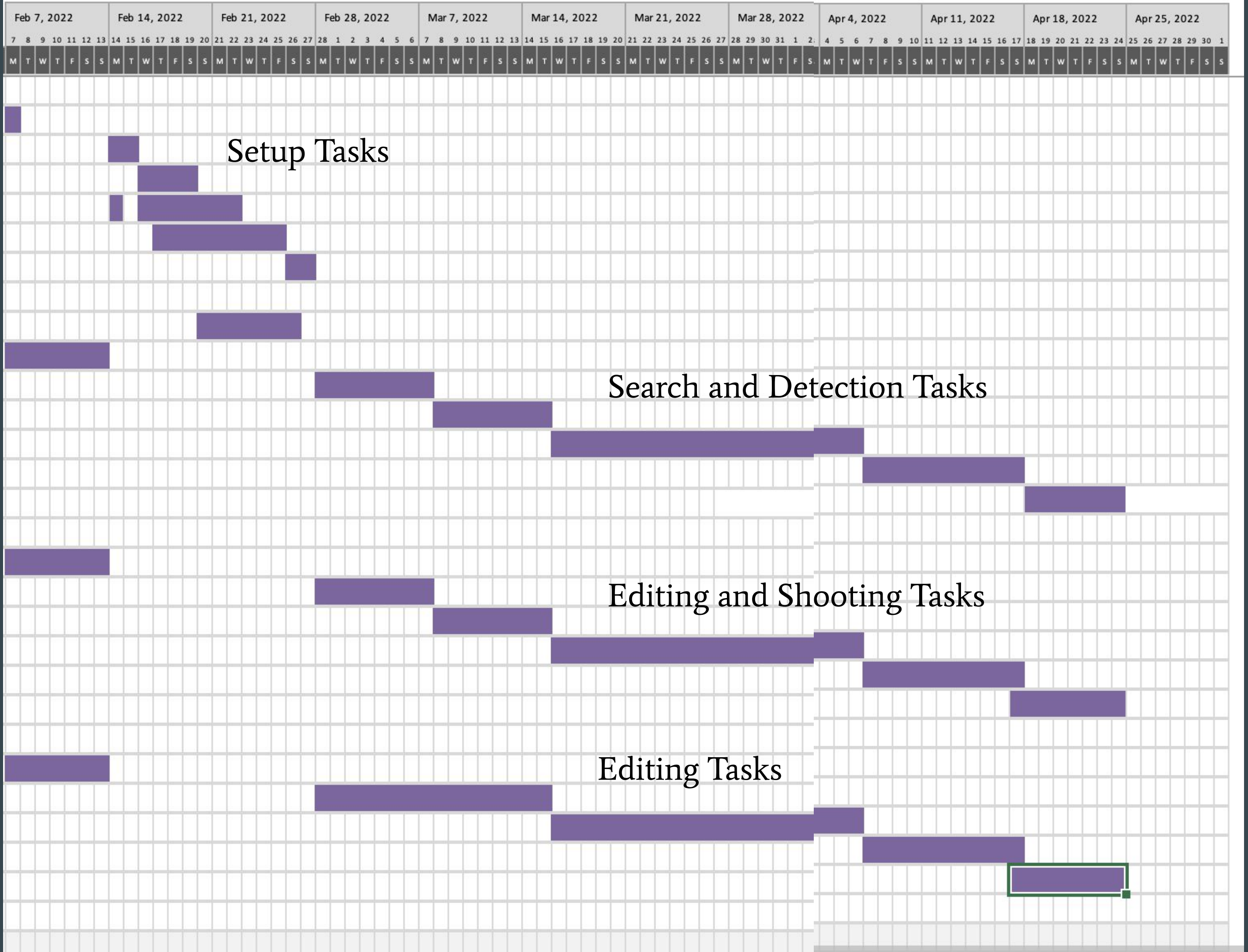
Tasks and Division of Labor

- Justin
  - Physical Setup
  - Image editing lead
- Sid
  - Electronics Setup
  - Detection and search lead
- Fernando
  - Pretrained CNN Setup
  - Tracking and photography lead

Schedule

- We split our work into 4 major sections:
  - Physical Setup
  - Detecting
  - Tracking
  - Editing
- Two major testing rounds will be used
  - All components will be tested in these evaluations
  - We will redistribute efforts based on success of first testing round

TASK	PROGRESS	START	END
Setup			
Order Parts		2/6/22	2/7/22
Wiring		2/14/22	2/15/22
Getting Video to Jetson		2/16/22	2/19/22
Physical Setup		2/15/22	2/22/22
Controlling the Setup		2/17/22	2/25/22
Setup Slack		2/26/22	2/28/22
Detection			
Get CNN Operating		2/20/22	2/27/22
Initial Search Algorithm (Simple Scan)		2/6/22	2/13/22
Test Initial Search Algorithm		2/28/22	3/7/22
Planning Updates		3/8/22	3/15/22
Implementing Updates		3/16/22	4/6/22
Final Testing and Decision Making		4/7/22	4/17/22
Detection Slack		4/17/22	4/24/22
Tracking			
Baseline Tracking Algorithm (HMM)		2/6/22	2/13/22
Test Baseline Tracking Algorithm		2/28/22	3/7/22
Planning Updates		3/8/22	3/15/22
Implementing Updates		3/16/22	4/6/22
Final Testing and Decision Making		4/7/22	4/17/22
Tracking Slack		4/17/22	4/24/22
Editing			
Implementing Image Processing Algorithm		2/6/22	2/13/22
Implement & Research Hueristic Editing Rules		2/28/22	3/15/22
Explore Neural Network Approaches		3/16/22	4/6/22
Final Testing and Decision Making		4/7/22	4/17/22
Editing Slack		4/17/22	4/24/22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Feb 14, 2022
Feb 21, 2022
Feb 28, 2022
Mar 7, 2022
Mar 14, 2022
Mar 21, 2022
Mar 28, 2022
Apr 4, 2022
Apr 11, 2022
Apr 18, 2022
Apr 25, 2022
Setup Tasks
Search and Detection Tasks
Editing and Shooting Tasks
Editing Tasks