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Adaptive Visual Target Identification and Tracking through Convolutional Neural Network (CNN) based Machine Learning and Computer Vision

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Abstract

The aim of this project is to identify a chosen object of interest at range using a camera feed and an image processing algorithm to assist in the detection, identification and tracking of the target.

This solution was then implemented as a rail-mounted tactical scope attachment for a Nerf Blaster. The attachment provides the user with real-time feedback on their aim using a side mounted screen.

The Team

- Alexis J. Renderos – Project Lead, Chief Engineer
- William Lavelle – Operations Director
- Ritvik Maripally – CAD Design and Data Collection
- Rolf Anderson – Software Development

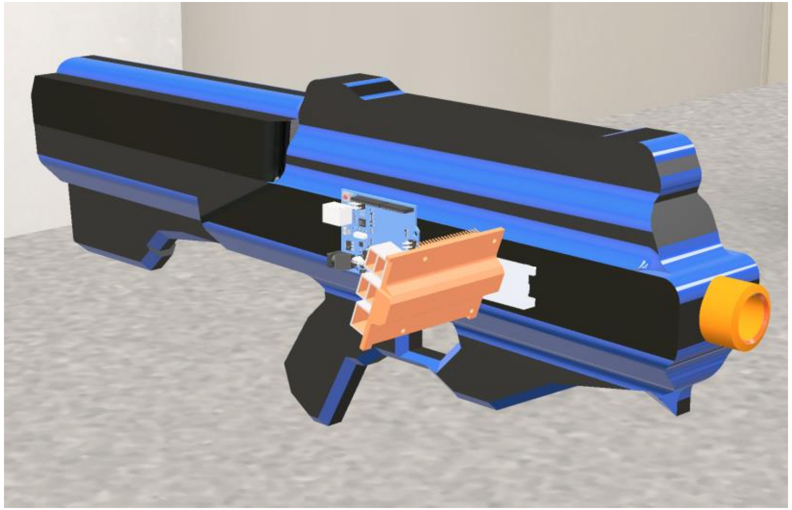
Collaboration and Communication

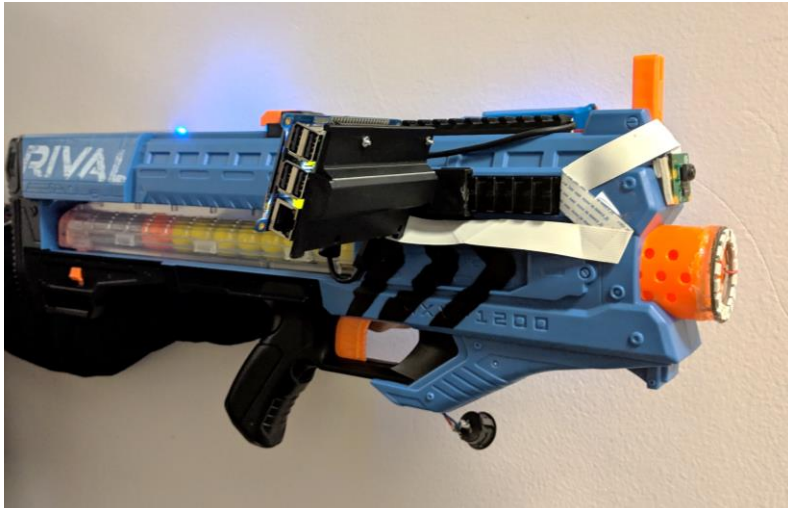
- GroupMe
  - We used this as the primary contact method between team members.
- GitHub Organization
  - We had two main repositories, one for code, and one for CAD. This allowed us to collaborate on different parts of the project easily and track contributions.
- Google Drive
  - Everything else that didn’t end up on one of the GitHub repositories ended up on a shared Google Drive. This was where most of our research and data went.
- Email
  - We used email as a more formal method of communicating with those outside of our project group, for example, Critical Tinkers Officers and our TA’s.

The Targets

- 3 Popular Drink Cans
  - Arizona Green Tea
  - Razzleberry Peace Tea
  - Monster Mango Loco Juice
- Distinct colors
- Easy to find in stores
- They taste great, too!

The Design





The Design

The Design

- Nerf Rival Zeus
  - The blaster!
- Raspberry Pi
  - Processes image data and displays feedback on aim
- Arduino
  - Controls the NeoPixel light ring
- NeoPixel Light Ring
  - Provides additional light to the subject if needed

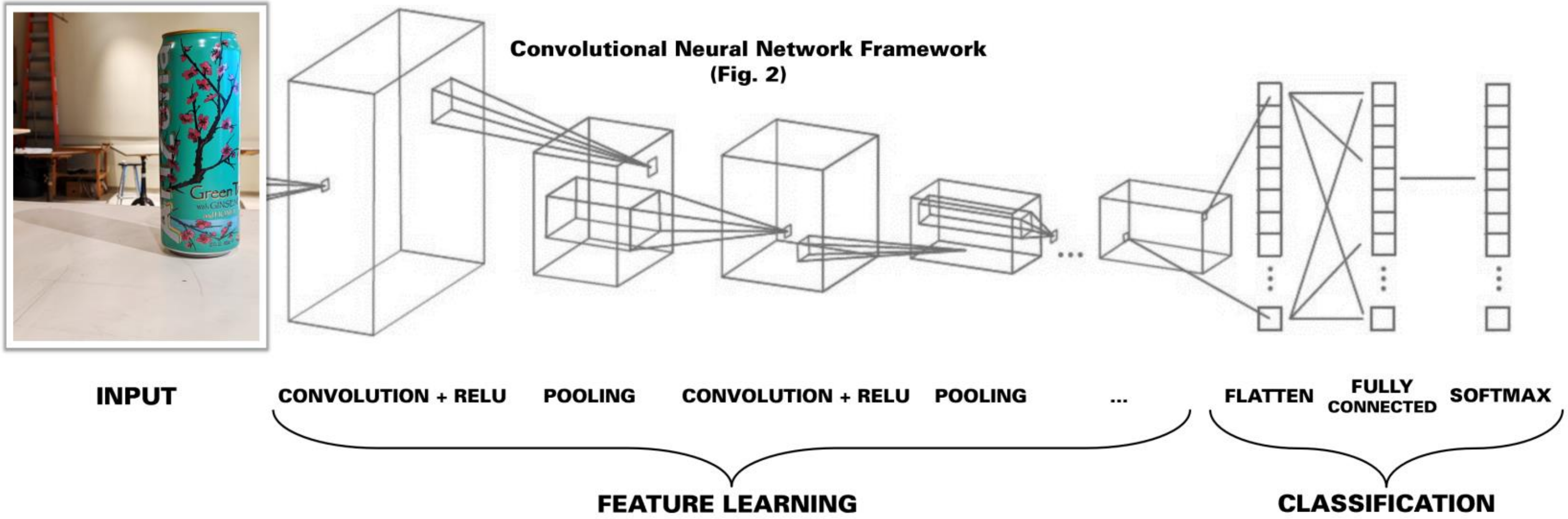
Hardware Features

- 40-50 Foot Effective Range
- Light Ring
  - Provides extra light to user and camera in low light conditions
- Side mounted LCD
  - Used to display camera feed and algorithm output to user
- Fully portable
  - Powered through a network of batteries mounted on the blaster
- Sounds like an angry lawnmower

Software

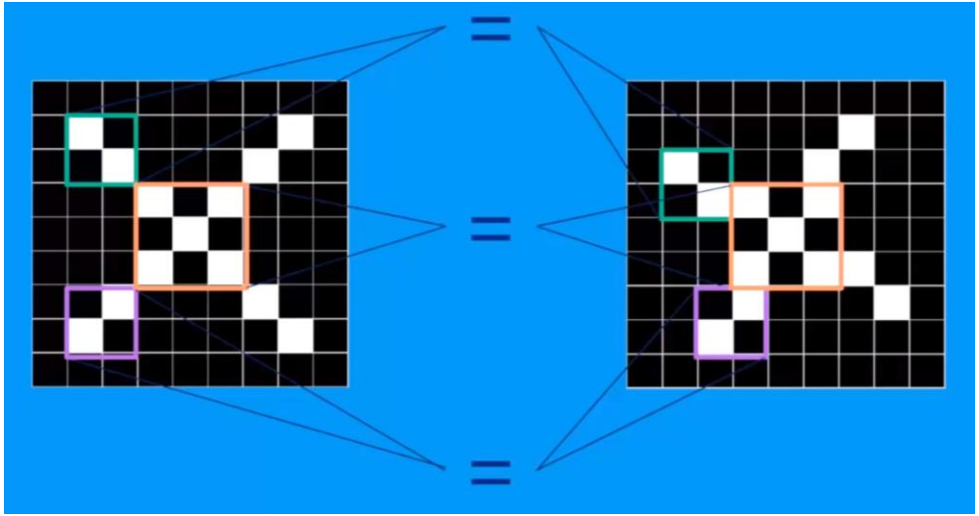
- Written all in Python
- OpenCV
  - A software library dedicated to real-time computer vision
- Tensorflow
  - A symbolic math library that is also used for machine learning applications
- Keras
  - An open-source neural-network library that runs on top of Tensorflow
- Plus a *little* C for the Arduino

Convolutional Neural Networks



Convolutional Neural Networks

- Also known as ConvNets
- Look for patterns in images



Convolutional Neural Networks

- Filtering
  - Takes image data and tries to find a feature it knows
- Built on what are called Convolutional Layers
  - Convolution
    - Repeated filtering across the entire image, produces a new "filtered image" that indicates to us where the feature lies on the image.
  - Pooling
    - Create a new, smaller image that further indicates the prevalence of a pattern.
  - ReLU (Rectified Linear Units)
    - Take any negative values and make them zero.

Convolutional Neural Networks

- Fully Connected Layer
  - Now the ConvNet tries to connect the dots and determine what it is looking at.
  - It will use the “images” produced by the convolution layers to vote on what the current image is.
  - This layer dynamically changes through gradient descent, which is essentially the changing the voting weight based on the ConvNet’s error.
- These layers all get stacked on top of each other
  - Like, *really, really* stacked

Convolutional Neural Networks

- In the end, the ConvNet should be able to:
  - Look through an image
  - Find any targets
  - Approximate their position
  - Analyze which target is in the field of view

KCF Tracking Algorithm

- Tracks a set of pixels
- Analyzes how it changes over time
    - Determines if that change is too drastic (tracking failure) or if that change is acceptable (tracking success).
- Computationally Efficient – Fast runtime
- Surprisingly accurate
- Handles target occlusion well

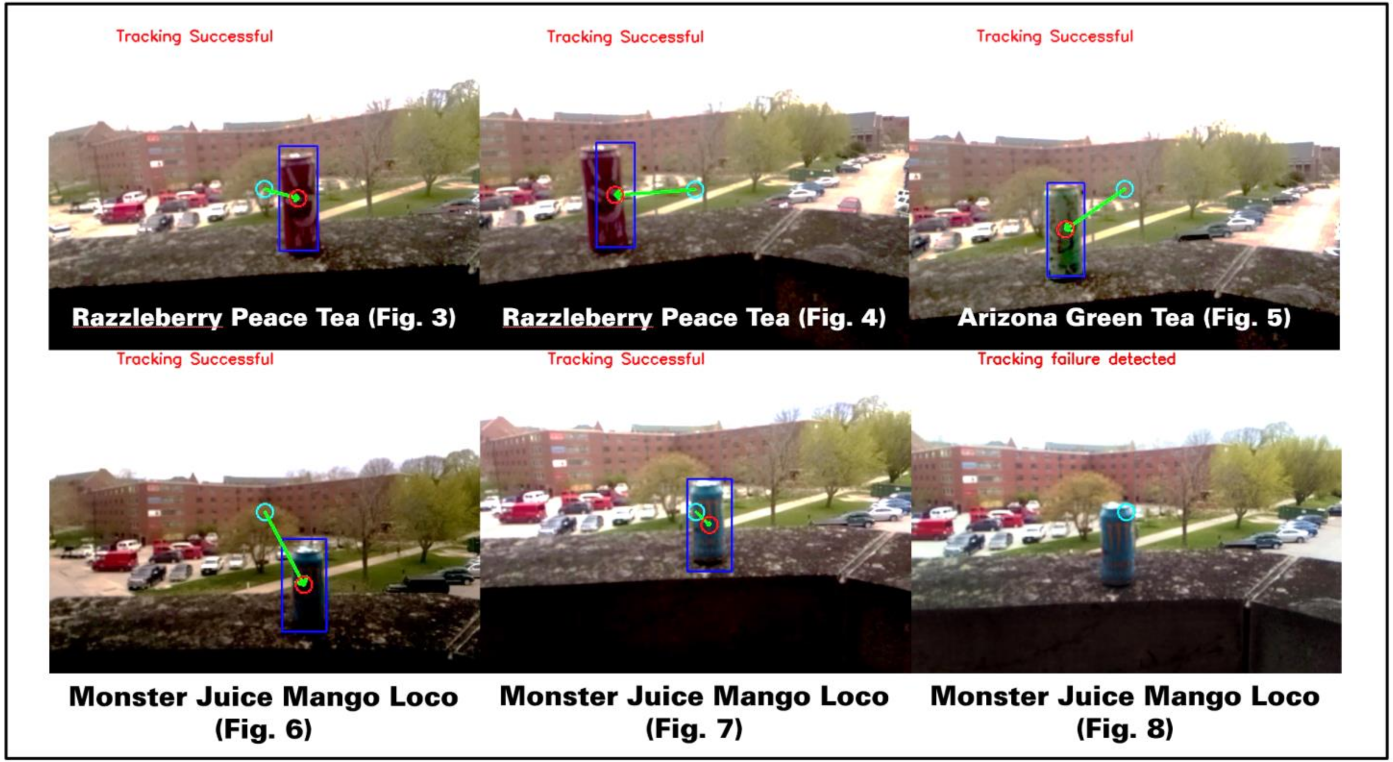
Software Flow

- ConvNet provides the initial location of the target to the KCF Tracker once a target is found
- KCF Tracker continues to find the location of the target until it fails
- Once the KCF Tracker fails, the ConvNet takes over again to repeat the process.

User Feedback

- Mounted on the Nerf Blaster is a screen that displays the current camera feed to the user.
- Gun Reticule: Light Blue Circle
- Target Center: Red Circle
- Target Location: Dark Blue Rectangle
- Error Feedback: Green Arrow

User Feedback



Conclusion and Analysis

- The CNN sucked.
  - Overall, target was too low of a resolution to be meaningful to the CNN, and thus performance suffered
  - CNN was trained twice, once with high-resolution target images, and once with low-resolution target images
  - The high-resolution model excelled with high-resolution targets (as expected)
  - Low-resolution model did well, but was easily thrown off by false positives
- The KCF Tracker slaps.
  - Fast, accurate, and recovered well from target occlusion.
  - 10/10

Conclusion and Analysis - Potential Applications

- The CNN relies on three major circumstances:
  - One, the target is visible (little to no occlusion)
  - Two, the target is consistent (all targets look the same and are predictable)
  - Three, the target has been previously analyzed (thousands of photos)
- With these in mind:
  - The potential military applications are slim—targets are not always consistent and have rarely been analyzed as much as the ConvNet demands.
  - A major retailer could use this to assist in a shipping warehouse—it could help workers/robots find the correct product.
  - This sort of technology is actually already in use in the Amazon app—you can scan a product (not necessarily the barcode) and it will show you listings for it.