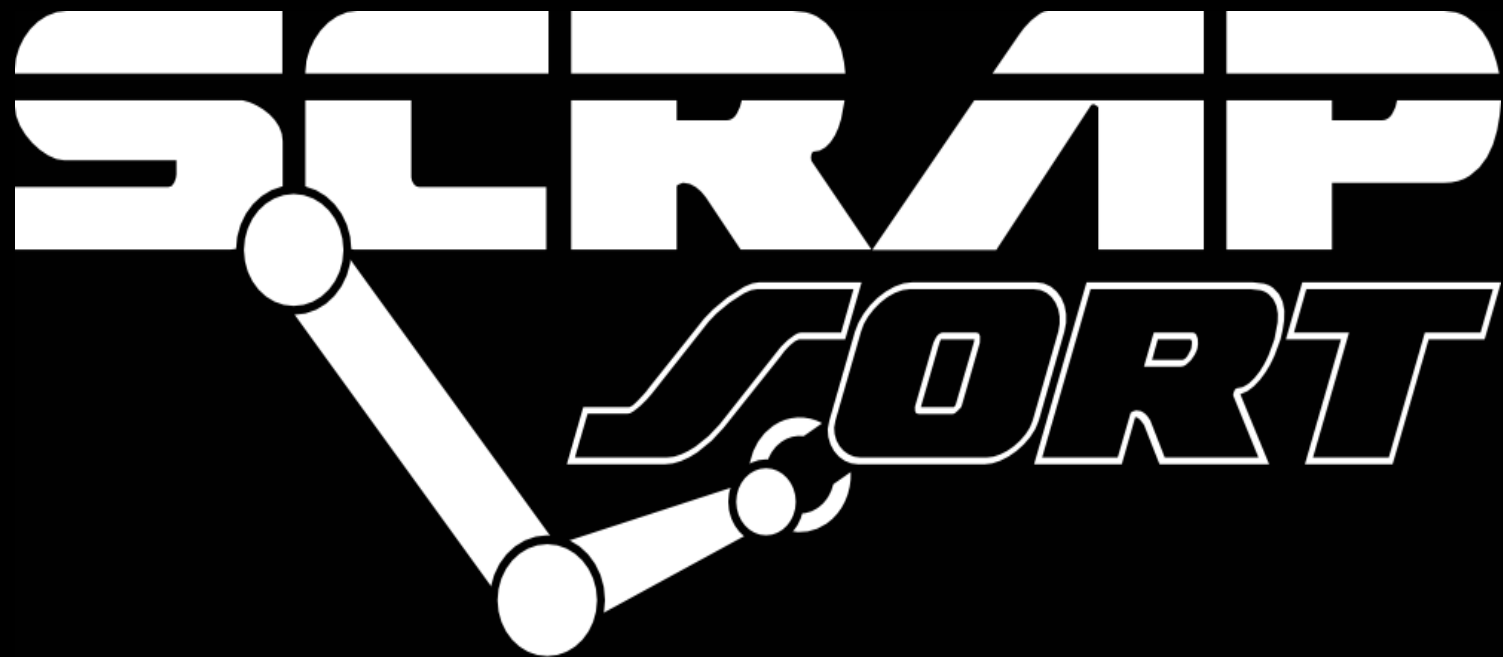


SERAP SORT

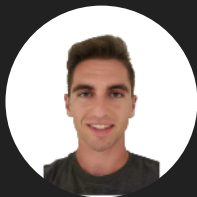
The logo consists of the word "SERAP" in a large, bold, white, sans-serif font with rounded terminals. Below it, the word "SORT" is written in a smaller, white, italicized, sans-serif font with a double-line outline. A stylized white robotic arm is integrated into the design, starting from the left side of the "SERAP" text, extending downwards and to the right, and ending with a gripper mechanism positioned over the "SORT" text.

An Autonomous System for Sorting Objects at the Edge

Meet the Team

Geffen Cooper

- Machine Learning



Bethany Long

- Embedded Systems



Tyler Ekaireb

- Embedded Systems



Vincent Benenati

- Control Systems



Kat Copeland

- Embedded Systems



Problem Formulation

The Problem

- Single-stream recycling have several issues:
 - Difficult classification
 - Contaminated recycling streams
 - Transportation cost and carbon-footprint
- Multi-stream recycling have complicated rules
- This results in:
 - Less than a third of recyclable waste is actually recycled[1]
 - Millions of tons of waste end up in landfills and the ocean



Remember the four basic guidelines:

1. Empty & clean
2. No liquids
3. No styrofoam
4. No tangles

Learn more at BARTHECART.COM

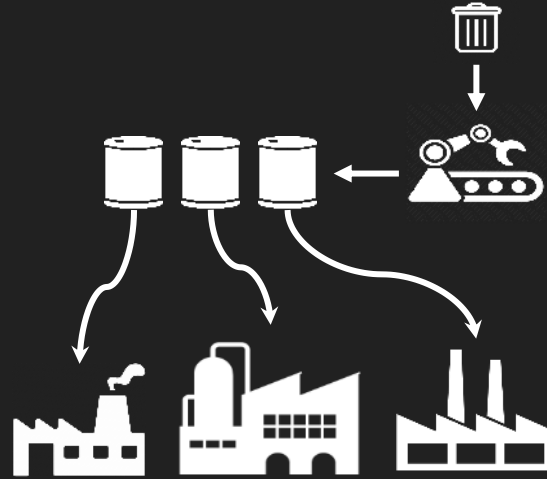
Yes	No
Paper and cardboard Cardboard (flattened) Food and drink packages - lids on preferred Mail, magazines, catalogs and newspapers Office and computer paper, gift boxes and gift wrap (metallic or glittered gift wrap is NOT recyclable)	Food-contaminated or greasy paper or cardboard Plastic-lined containers like ice cream and coffee cups
Plastics #1-5 and 7 (NOT #6) Food and drink packages - lids on preferred Toiletries, laundry and beauty aid packages - lids on preferred Rigid liner containers (2-gallon maximum)	Plastic bags and wrapping (text, dry cleaner and car air) Hot cup lids (#6) Styrofoam Packing peanuts Bubble wrap
Glass Jars and bottles - lids on preferred	Window glass, broken glass, stems or light bulbs
Aluminum and metal Cans with complete labels and top	Tangles
Miscellaneous NOs Batteries Food Herbicide containers Insecticide containers Hazardous chemical containers Hoses Household garbage Motor oil Paint and paint thinners All plant containers and flats Single-use plastic straws and utensils Textiles Tires Yard waste Over-sized items Many of these "No" items can be recycled nearby. For more information, download the Recycle LIFE app. Search "Recycle LIFE" in the app store.	

Search items to learn about local recycling or refuse options.
Processing contaminated recycling is costly. Please only recycle appropriate materials.

[1] <https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials#NationalPicture>

Our Solution

- Trash is sorted autonomously & inexpensively on-site
 - Train for specific waste types
 - Prevents contamination
- Sorted waste is sent to specialized facilities



Requirements:

- Recognize different recycling streams
- Sort into bins
- Operate at the edge self-sufficiently with limited space/power/cost/communication



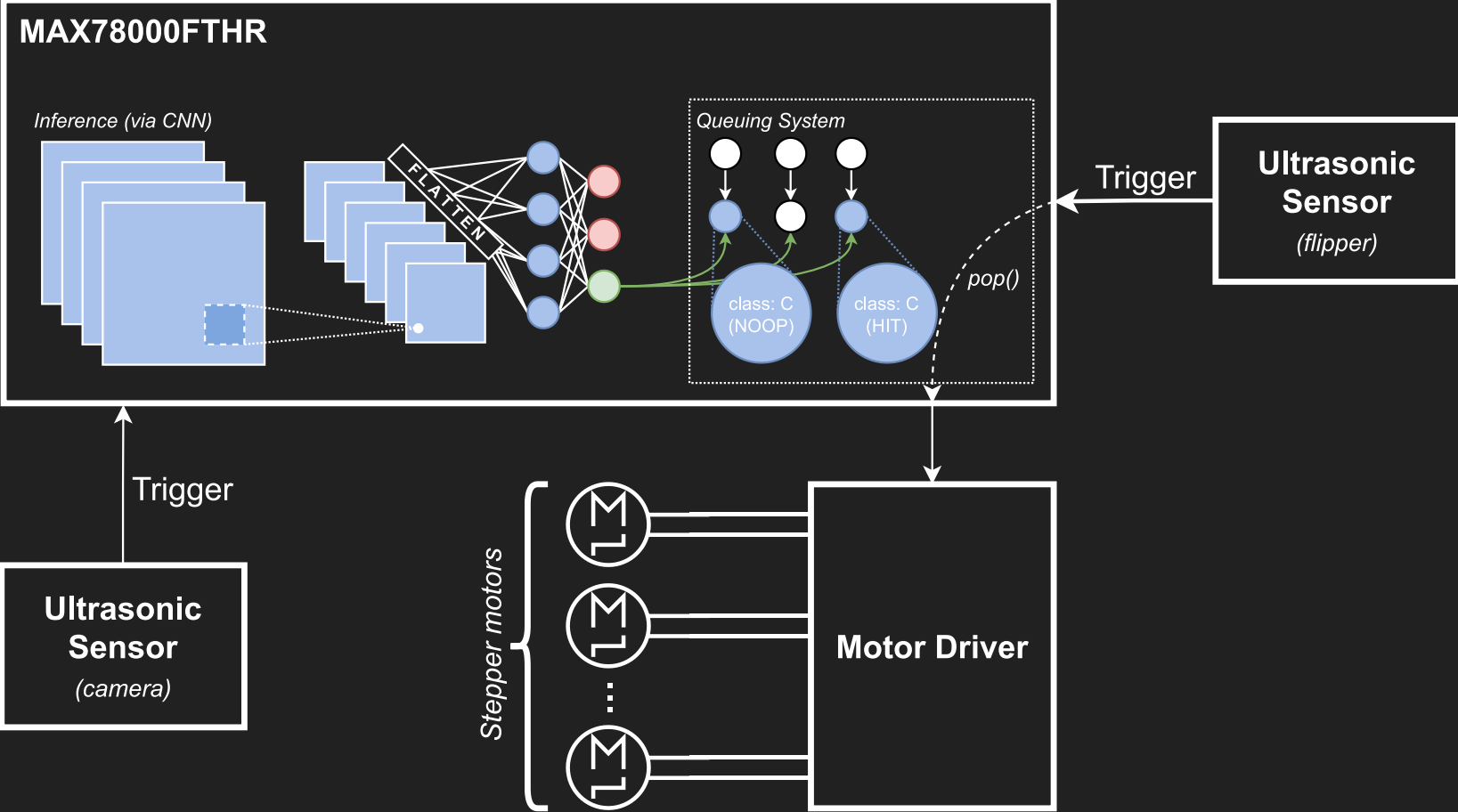
System Overview

Scrapsort

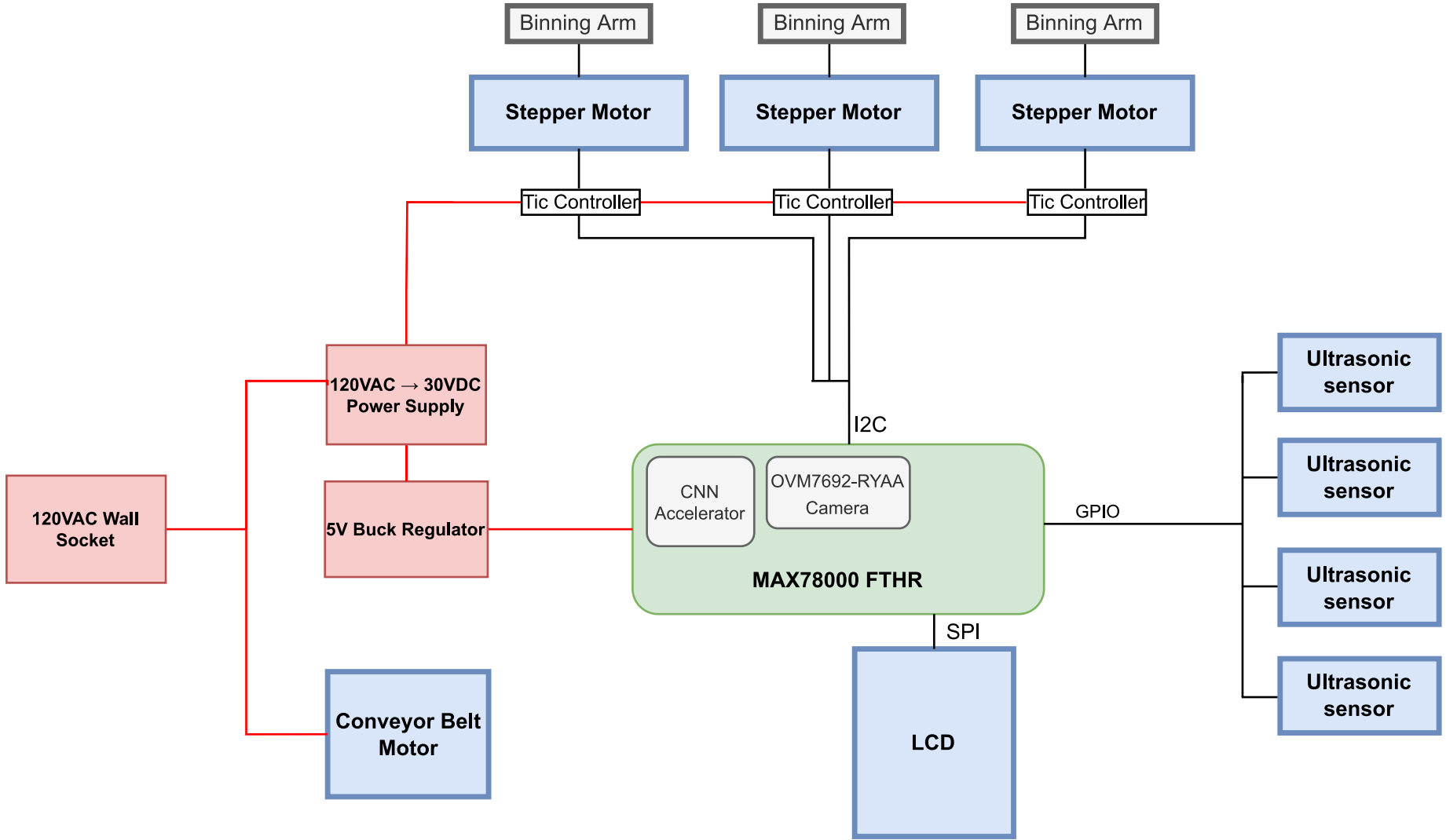
- Computer vision system to recognize trash on conveyor belt
 - Convolutional Neural Network (CNN) on microcontroller with hardware accelerator
- Ultrasonic sensors to trigger actions
- Lever arms to sort trash into bins



System Control Flow



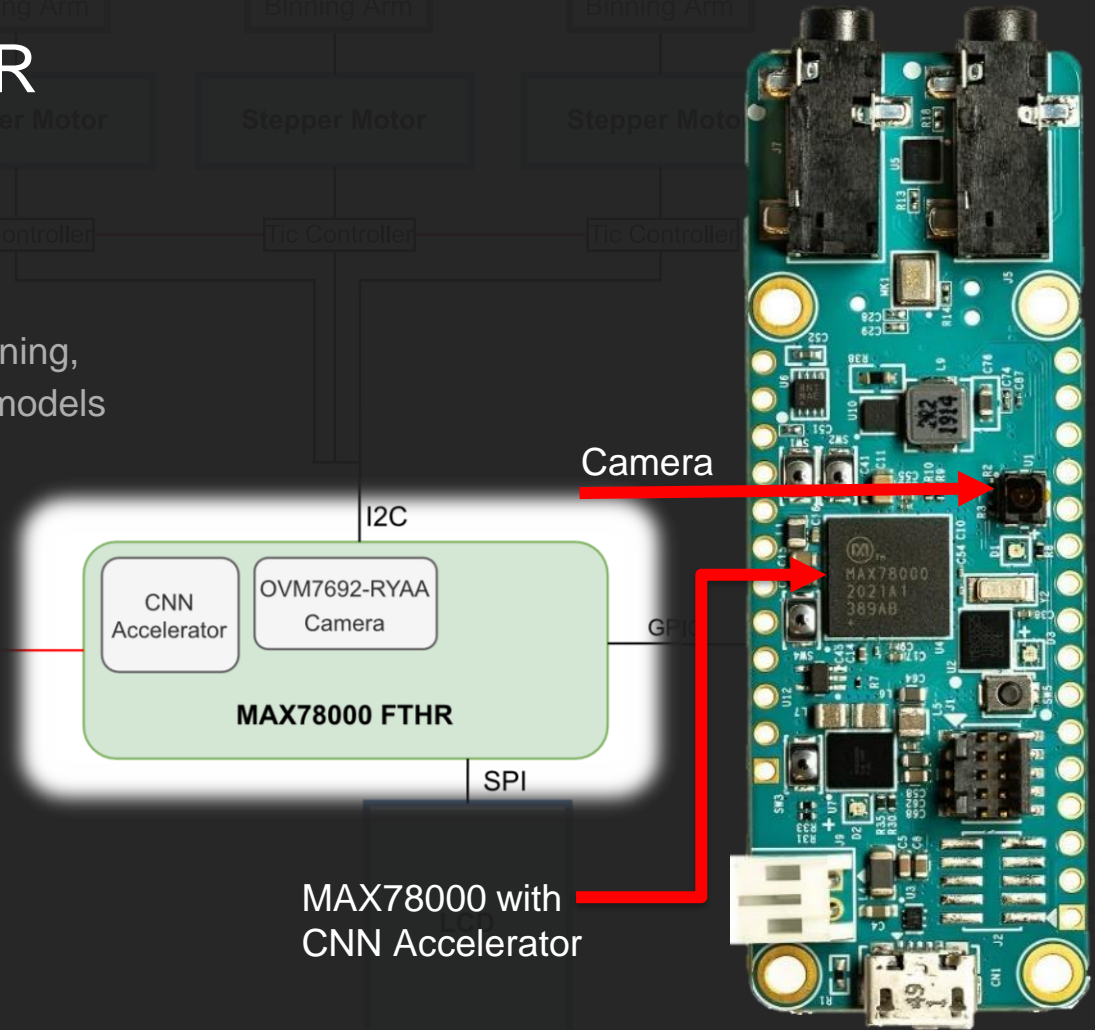
Hardware



Board: MAX7800FTHR

- Low power & low cost
- Small form factor
- CNN accelerator
 - Custom tools available for training, quantizing, and synthesizing models

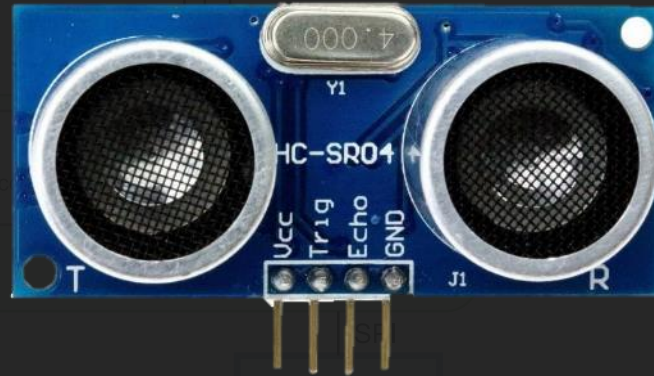
MAX78000 Specs	
Core	ARM Cortex-M4
Flash	512 KB
SRAM	128 KB
Core Clock Speed	Up to 100 MHz



MAX78000 with CNN Accelerator

Ultrasonic Sensors

- Simple and flexible interface to trigger interrupts for capturing images and activating stepper motors



Ultrasonic sensor

Ultrasonic sensor

Ultrasonic sensor

Ultrasonic sensor

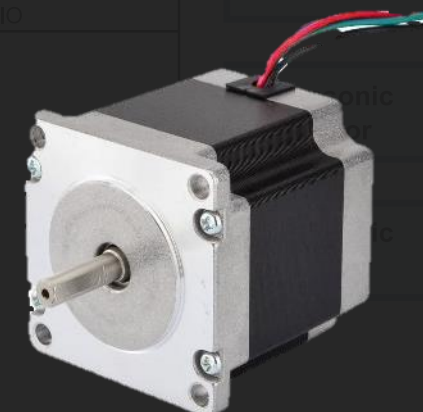
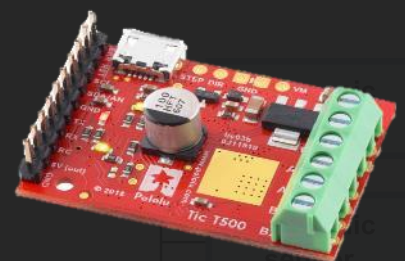
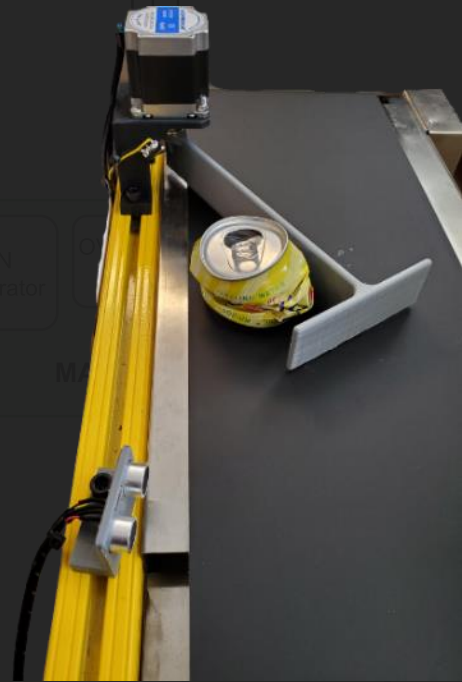
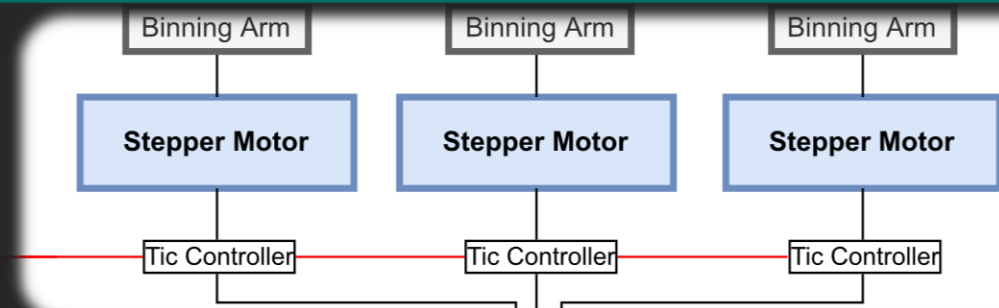
Lever arm

- Pros

- Simple, robust design
- Fast
 - NEMA 23 Stepper Motor move quickly
 - Good response time
- Easily upgradable

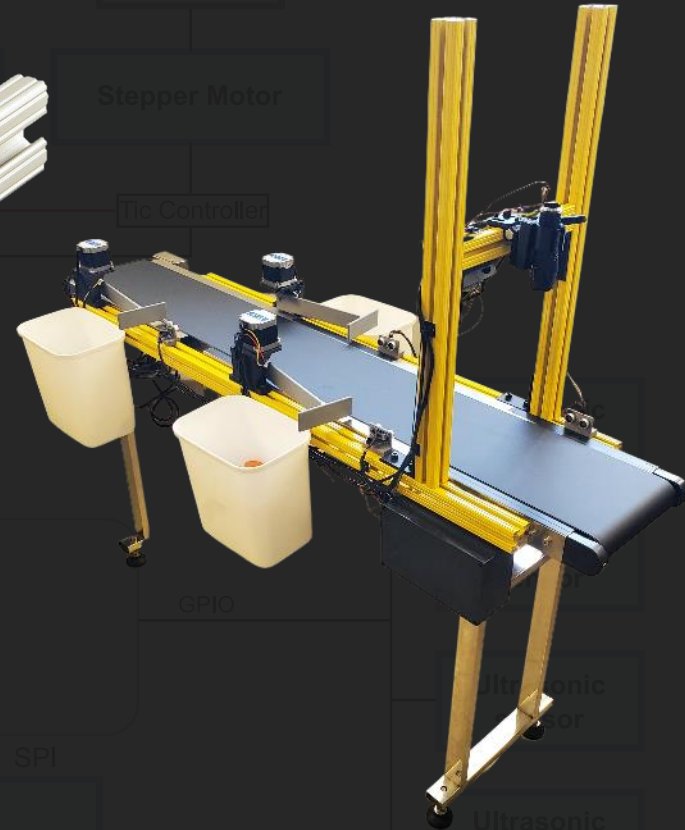
- Cons

- Requires a lot of space between items



Conveyor Belt

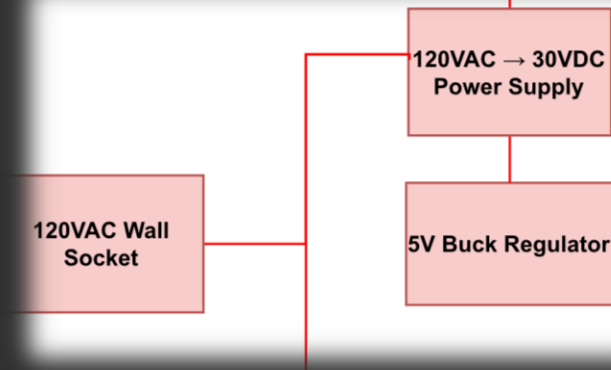
- Adjustable speed
- Adjustable custom 80/20 guardrails and camera mount
- Length: 59"
 - Long enough to partition sections for classification and sorting



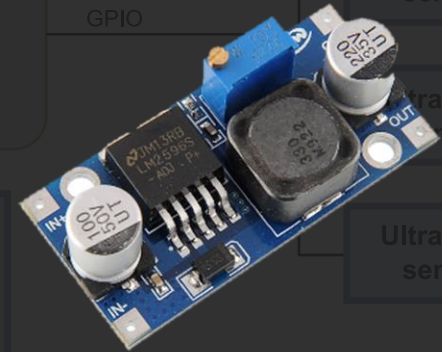
Conveyor Belt
Motor

Power Supply

- 120VAC Switching Power Supply outputs 30VDC for the stepper motors



- Buck Converter drops 30VDC to 5VDC for ultrasonic sensors, microcontroller, & flashlight



Machine Learning

Machine Learning

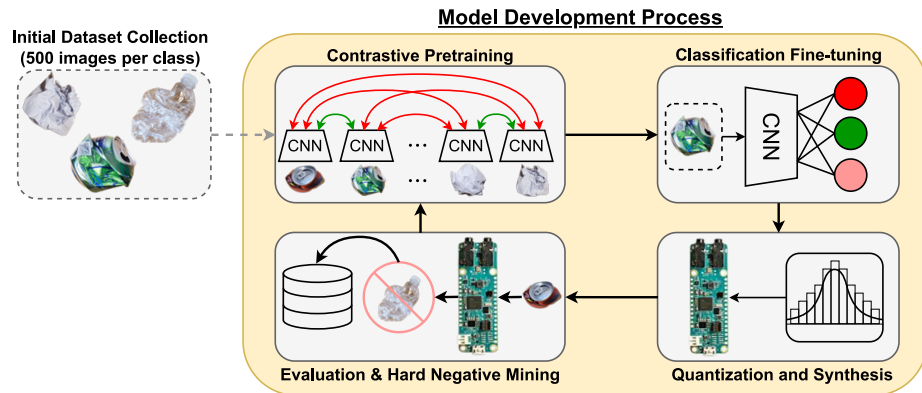
CNN Accelerator

- On-chip memory mapped peripheral
- Tools for quantization aware training
- Limited to basic operations: 3x3 kernels, ReLU activation, batch normalization

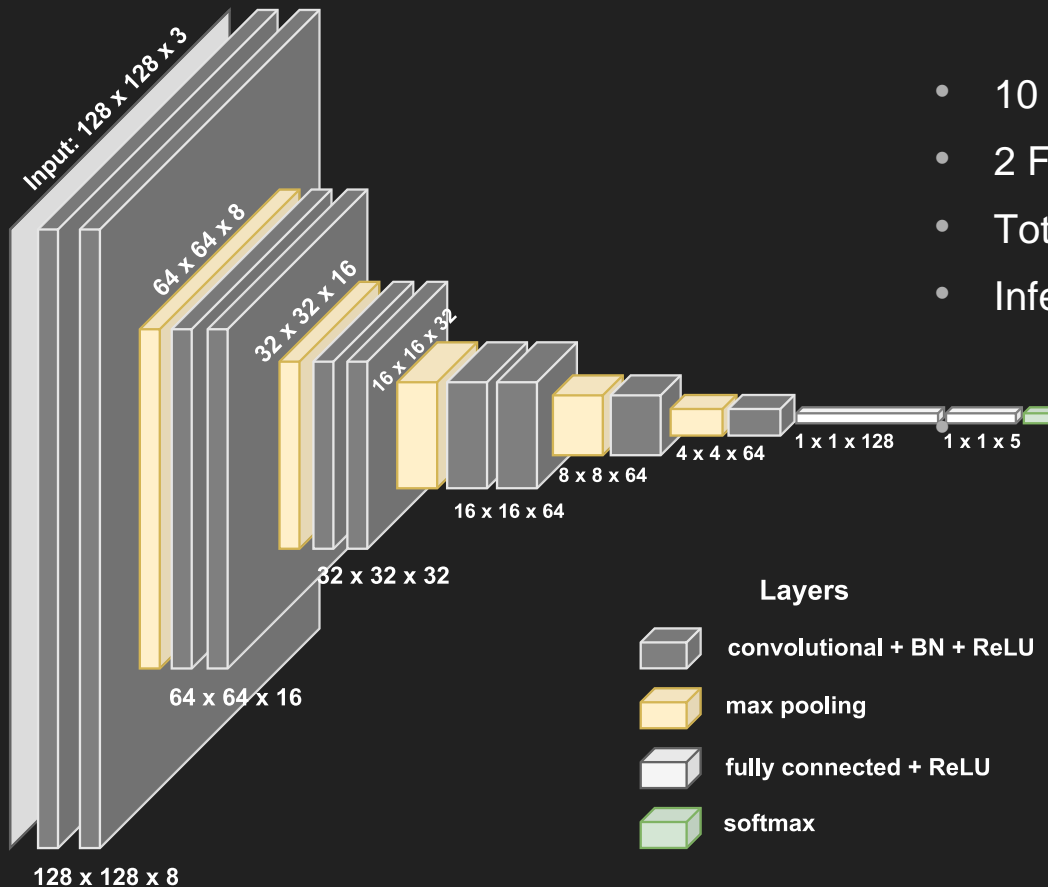
Model Development Process

1. Collect Data
2. Train multiple classification models
3. Quantization and Synthesis of model
4. On-board evaluation
5. Repeat

Accelerator Specs	
Weight Memory	432 KiB
Data Memory	512 KiB (32 KiB x 16)
Clock Speed	50 MHz
Max Input Resolution	91 x 90 (without streaming)



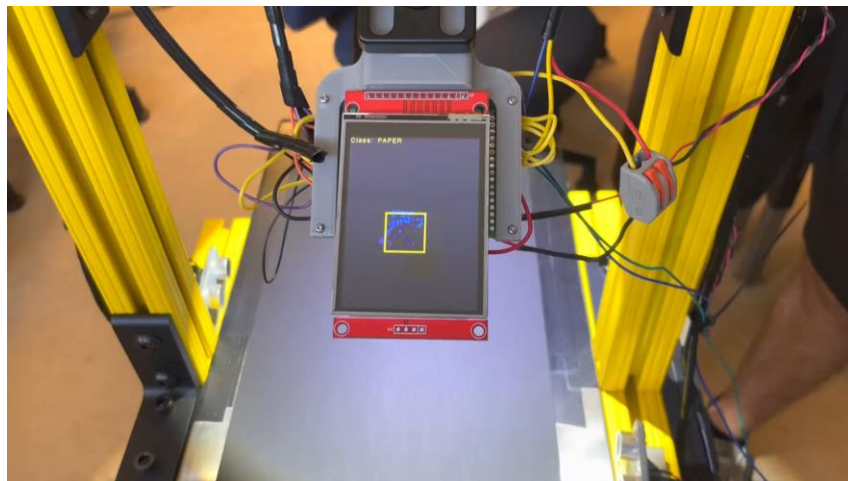
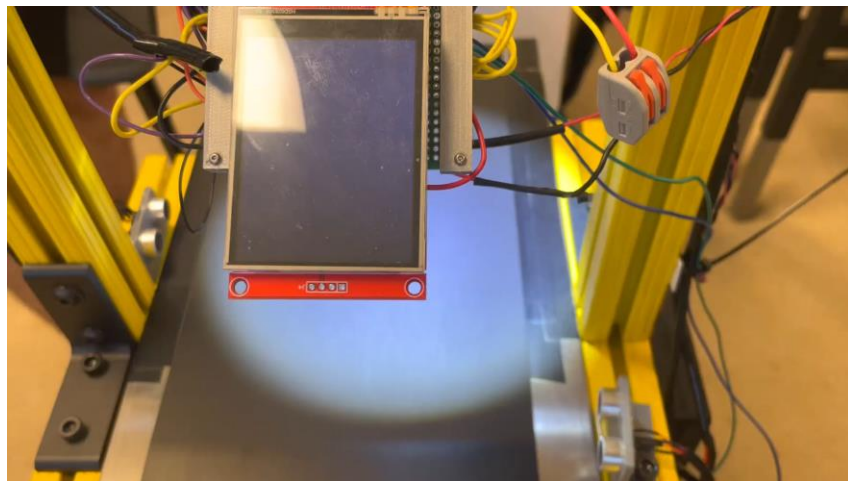
Current CNN Architecture (Classification)



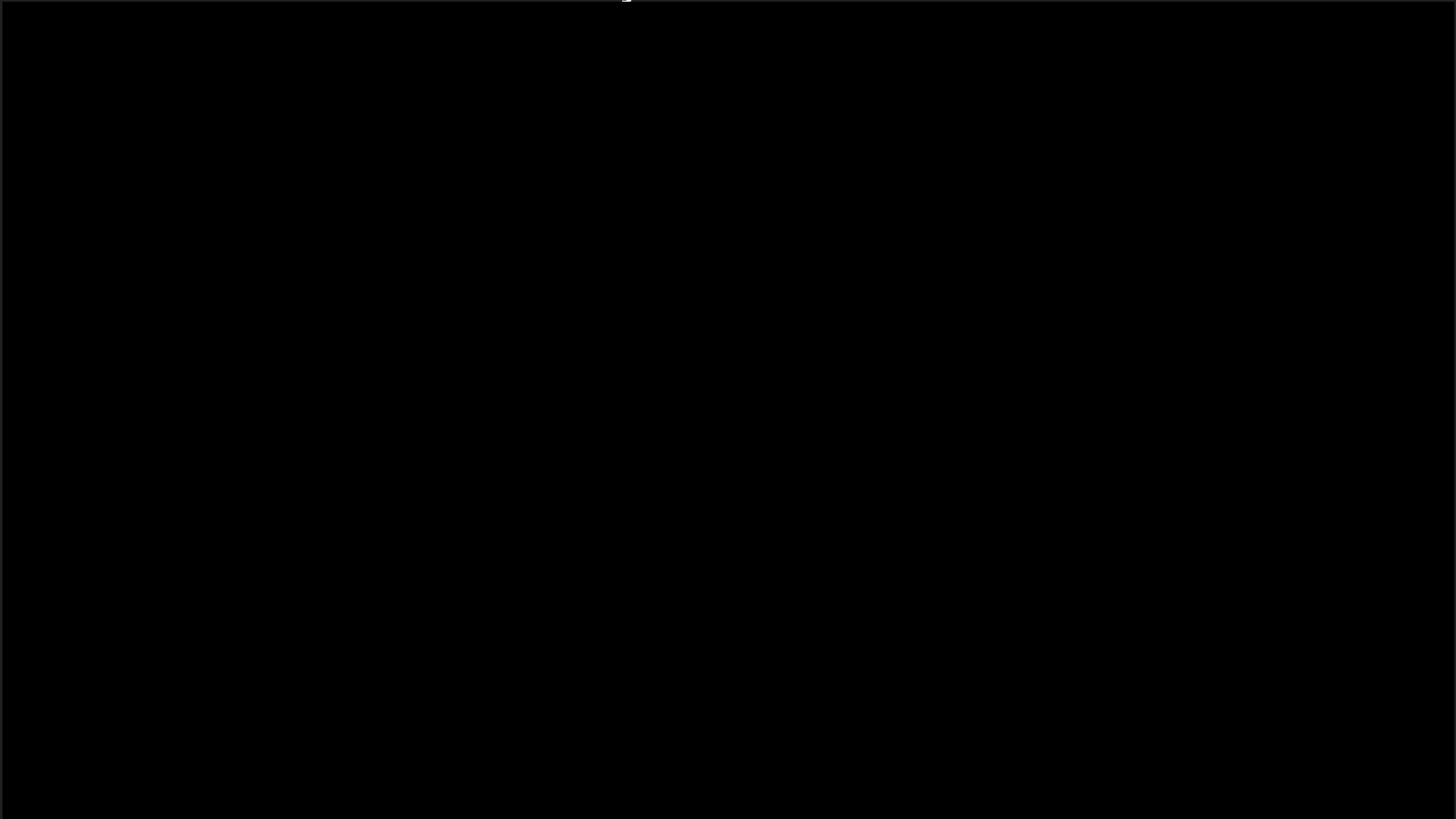
- 10 Convolution Layers (147,096 weights)
- 2 Fully Connected Layers (131,712 weights)
- Total: 278 KB ~ 63% weight memory
- Inference Time: 13.5 ms

Classification and Detection

- Under stable lighting, classification and detection work well
- Adjusted camera settings to account for lighting/distortion
 - Disable automatic exposure control
 - Decreased exposure time
- Dataset:
 - ~4k images for classification (1k per class)
 - ~1.5k images for detection (500 per class)



Full System in Action



Acknowledgements

Analog Devices:

- Brian Rush



UCSB:

- Professor Yogananda Isukapalli
- Professor B.S. Manjunath
- Christopher Cheney
- Brycen Westgarth
- Satish Kumar

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