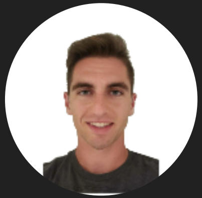
SCRAP SORT

An Autonomous System for Sorting Objects at the Edge

Meet the Team

Geffen Cooper

- ➢ Machine Learning



Bethany Long

- ➢ Embedded Systems

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- ➢ Embedded Systems

Vincent Benenati

- ➢ Control Systems

Kat Copeland

- ➢ Embedded Systems

Problem Formulation

The Problem

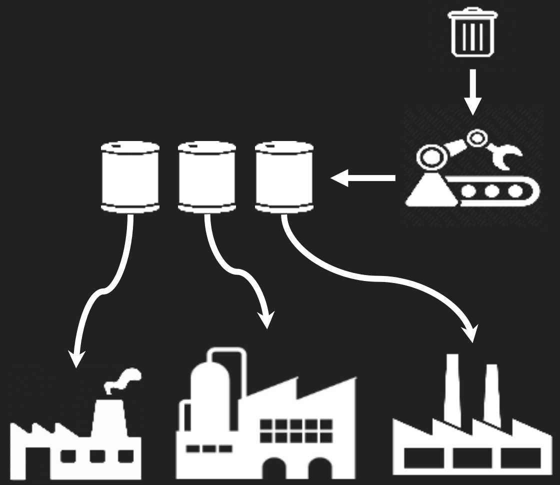
- Single-stream recycling have several issues:
  - Difficult classification
  - Contaminated recycling streams
  - Transportation cost and carbon-footprint

- Multi-steam 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

[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:

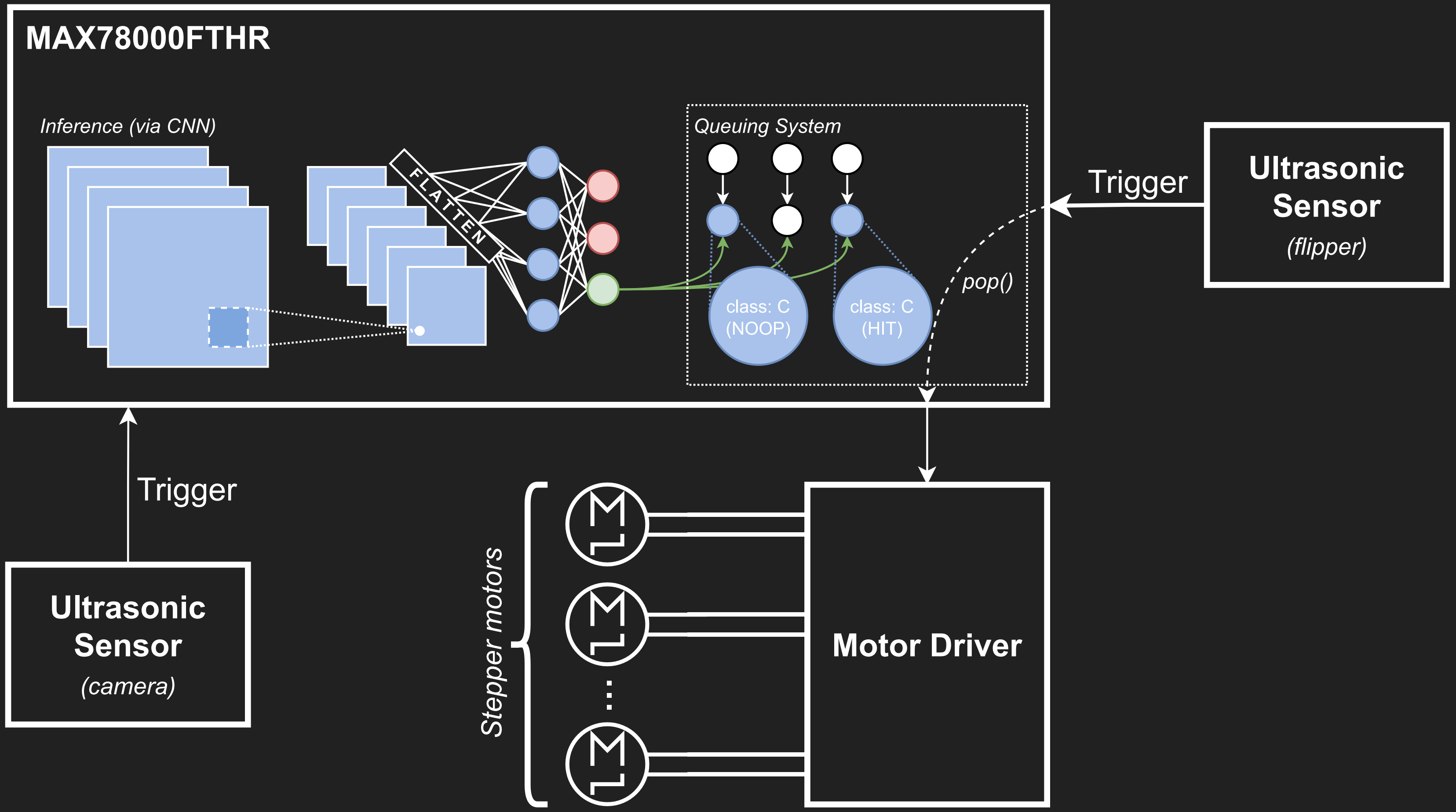
- Recognize different recycling streams
- Sort into bins
- Operate at the edge self-sufficiently with limited space/power/cost/communication

System Overview

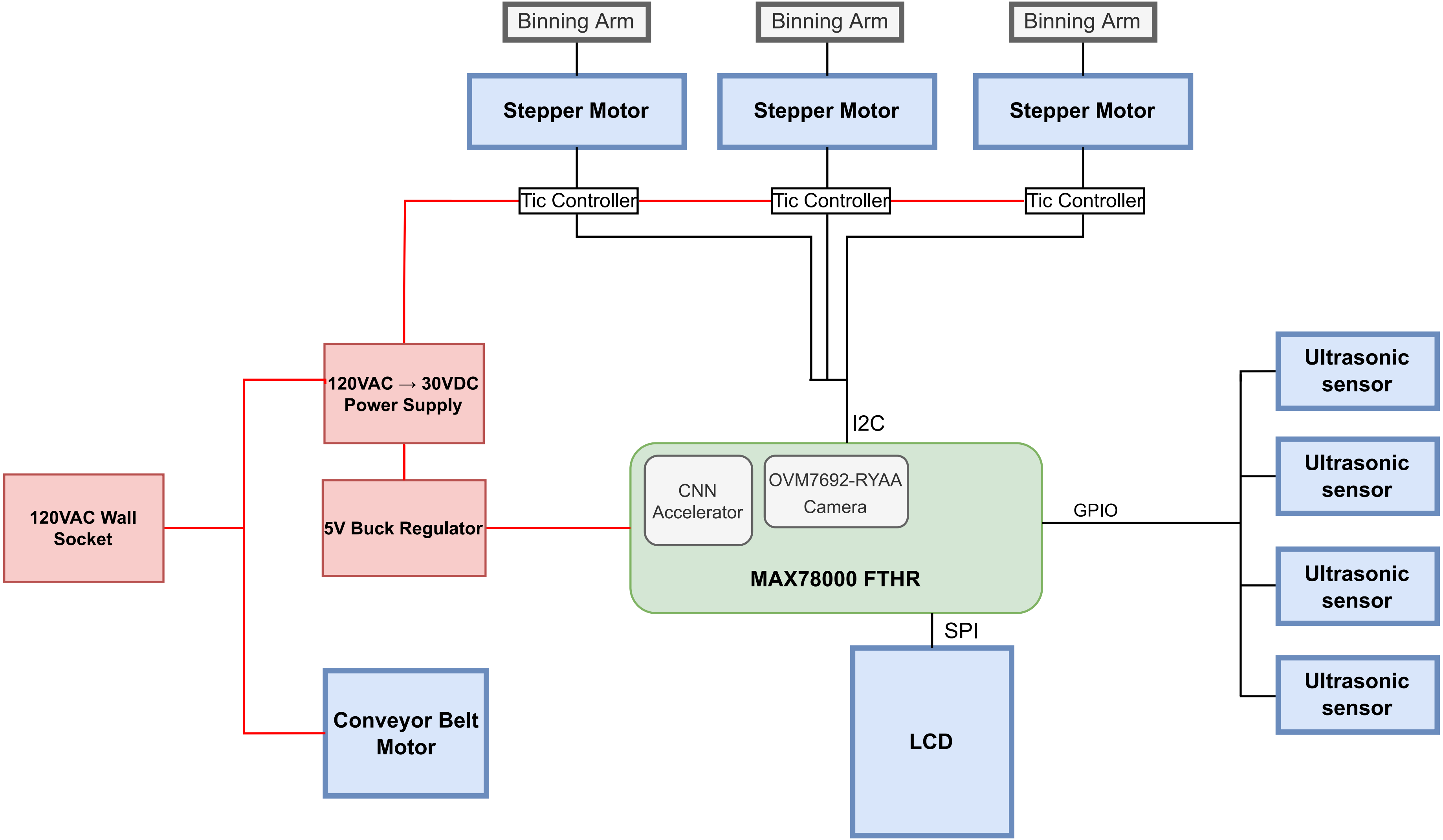
Scrapsort

- 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



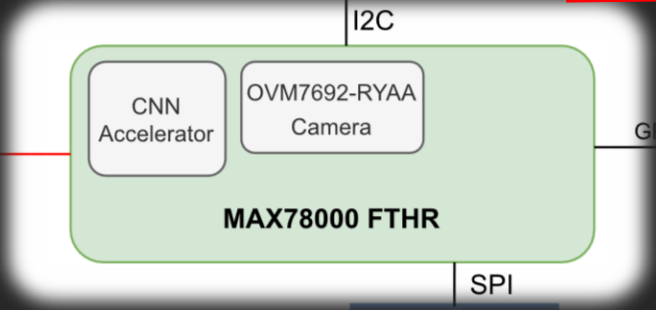
Hardware

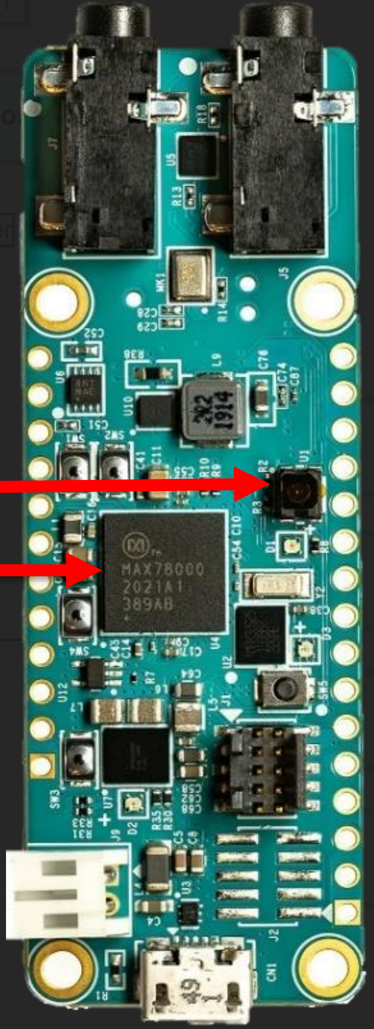

Binning Arm
Binning Arm
Binning Arm
Stepper Motor
Stepper Motor
Stepper Motor
Tic Controller
Tic Controller
Tic Controller
I2C
120VAC → 30VDC Power Supply
120VAC Wall Socket
5V Buck Regulator
CNN Accelerator
OVM7692-RYAA Camera
MAX78000 FTHR
GPIO
Ultrasonic sensor
Ultrasonic sensor
Ultrasonic sensor
Ultrasonic sensor
SPI
LCD
Conveyor Belt Motor

Board: MAX78000FTHR

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

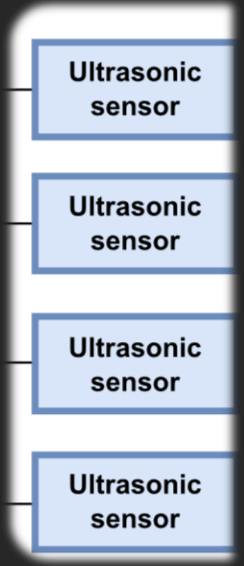
MAX78000 Specs	
Core	ARM Cortex-M4
Flash	512 KB
SRAM	128 KB
Core Clock Speed	Up to 100 MHz

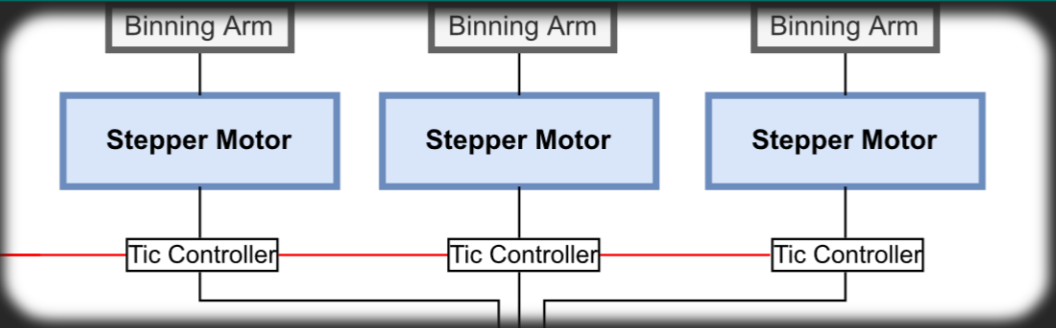




Ultrasonic Sensors

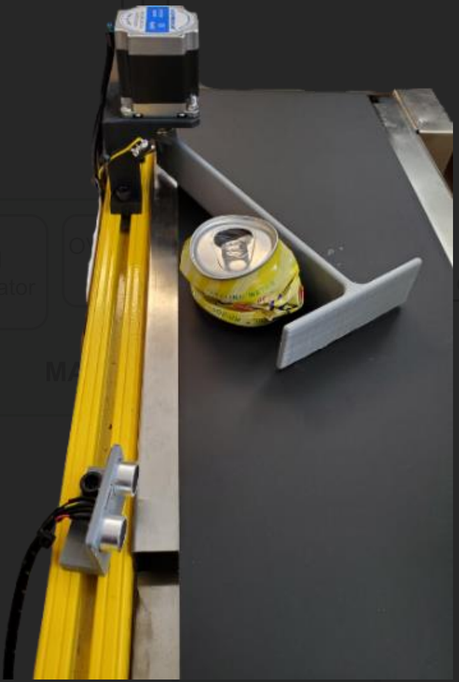
- Simple and flexible interface to trigger interrupts for capturing images and activating stepper motors

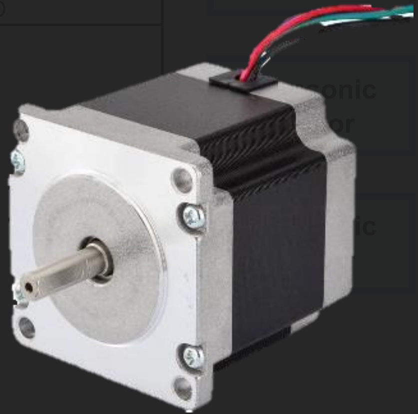




Lever arm

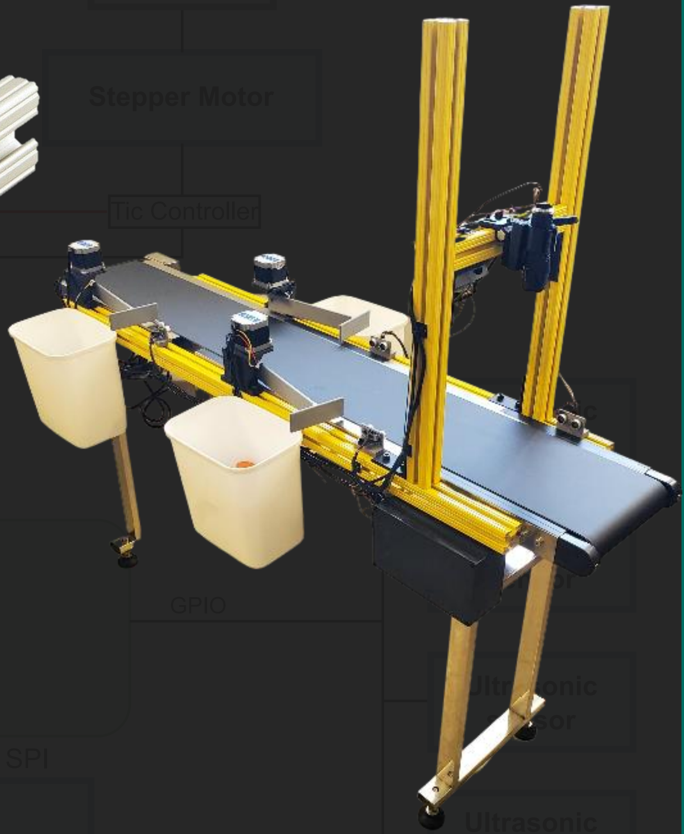
- Pros
  - Simple, robust design
  - Fast
    - NEMA 23 Stepper Motor move quickly
    - Good response time
  - Easily upgradable
- Cons
  - Requires a lot of space between items

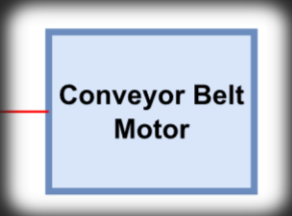




Conveyor Belt

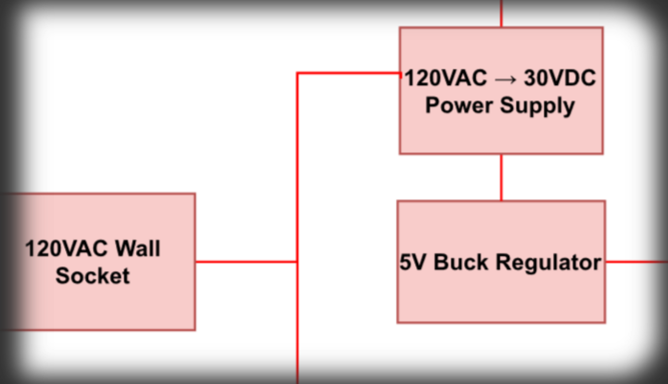
- Adjustable speed
- Adjustable custom 80/20 guardrails and camera mount
- Length: 59”
    - Long enough to partition sections for classification and sorting



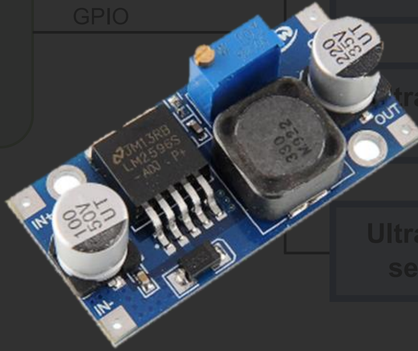


Power Supply

- 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

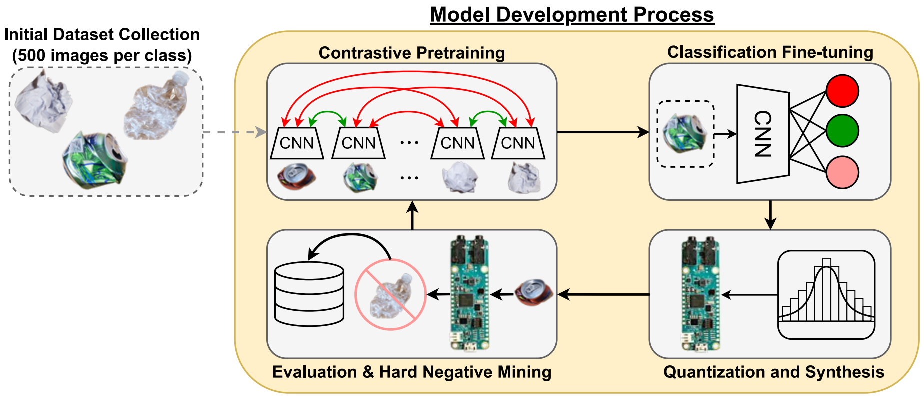
CNN Accelerator

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

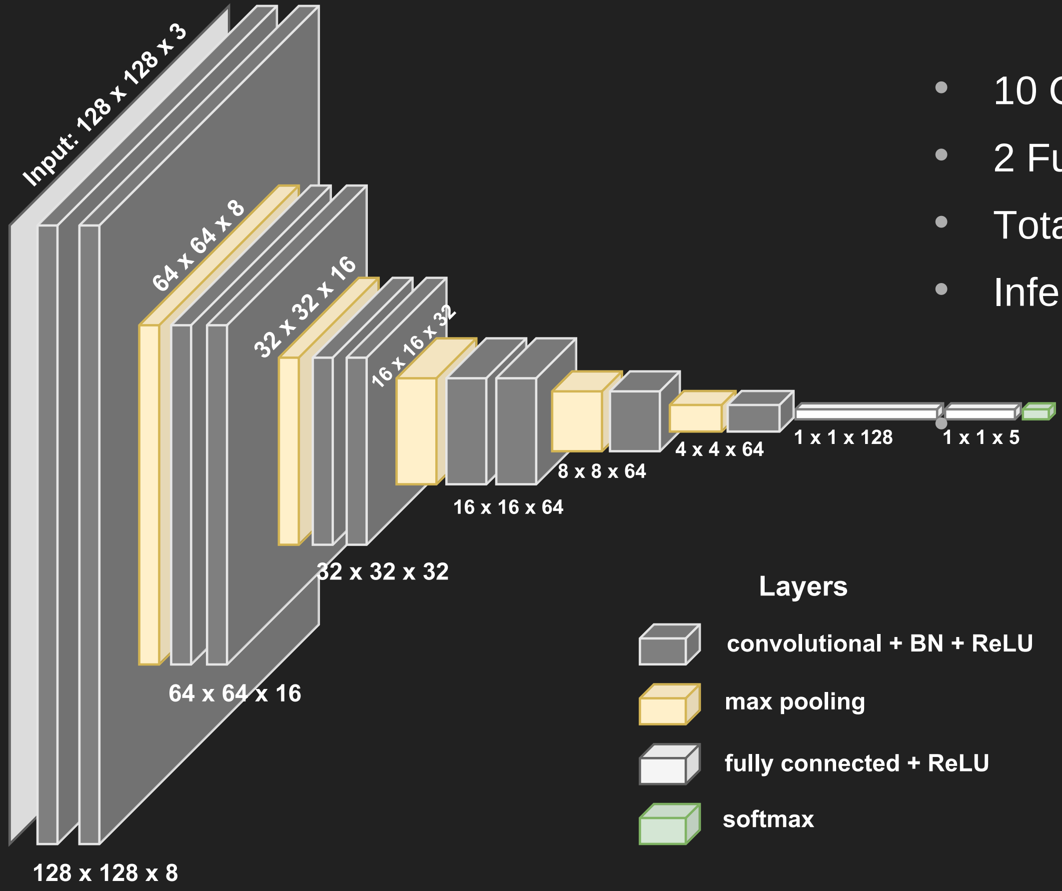
Model Development Process

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)



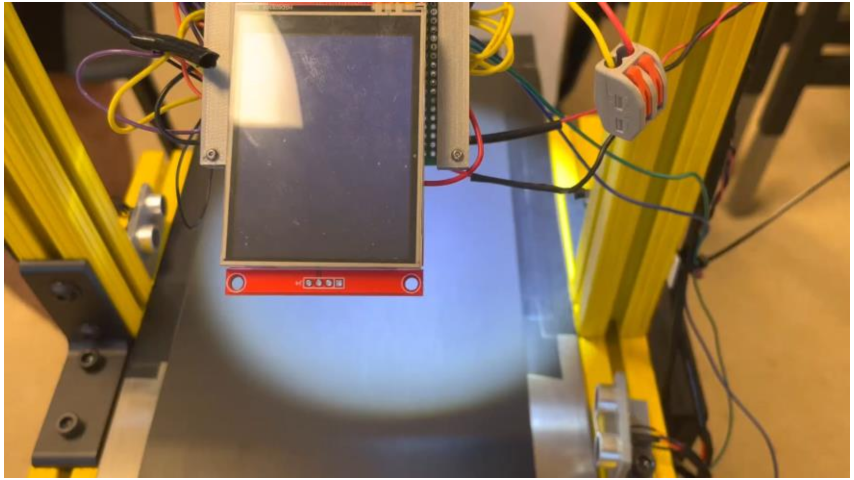
Current CNN Architecture (Classification)

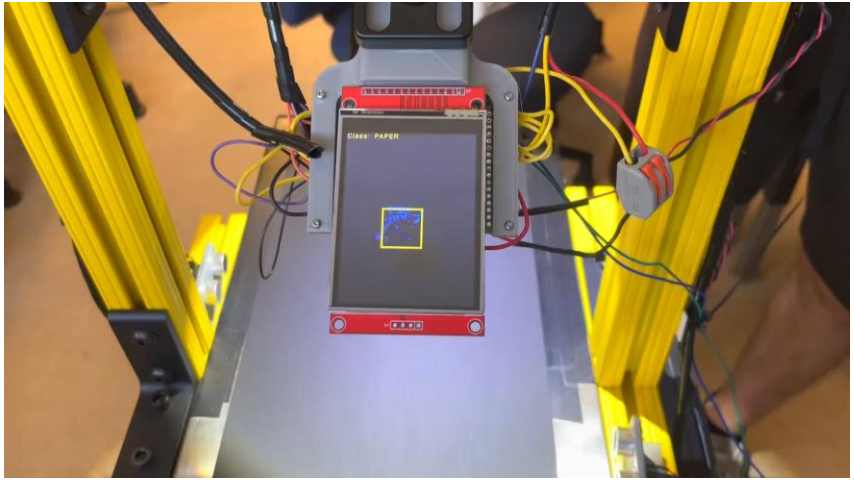


- 10 Convolution Layers (147,096 weights)
- 2 Fully Connected Layers (131,712 weights)
- Total: 278 KB ~ 63% weight memory
- Inference Time: 13.5 ms

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

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- Brycen Westgarth
- Satish Kumar

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