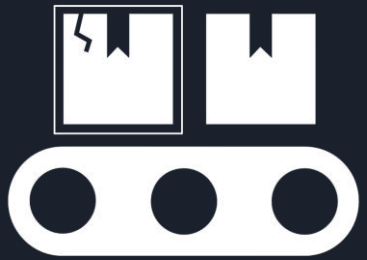


Defect Detect

Low Cost Quality Control Solution at the Edge

Team

Ryan Mosalem

Project Lead

Anthony Pella

Data Synthesis and Software Flow

Joshua Kim

Machine Learning

Limin Ding

Camera/Display

Shaunak Kale

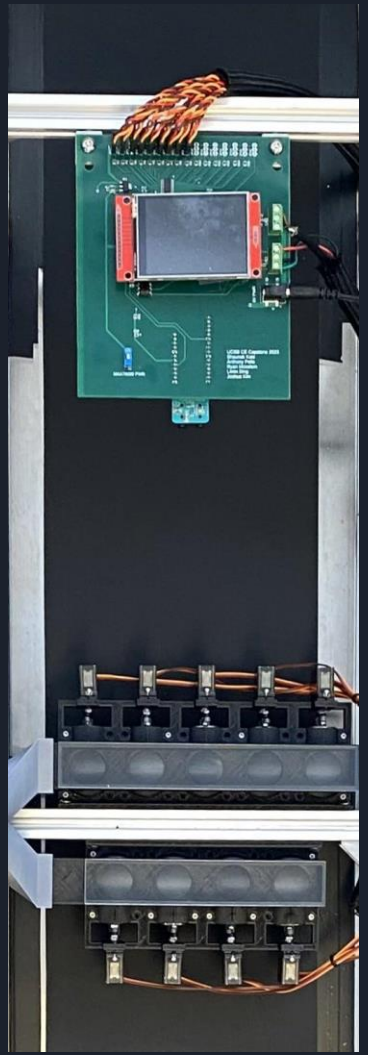
Hardware Design

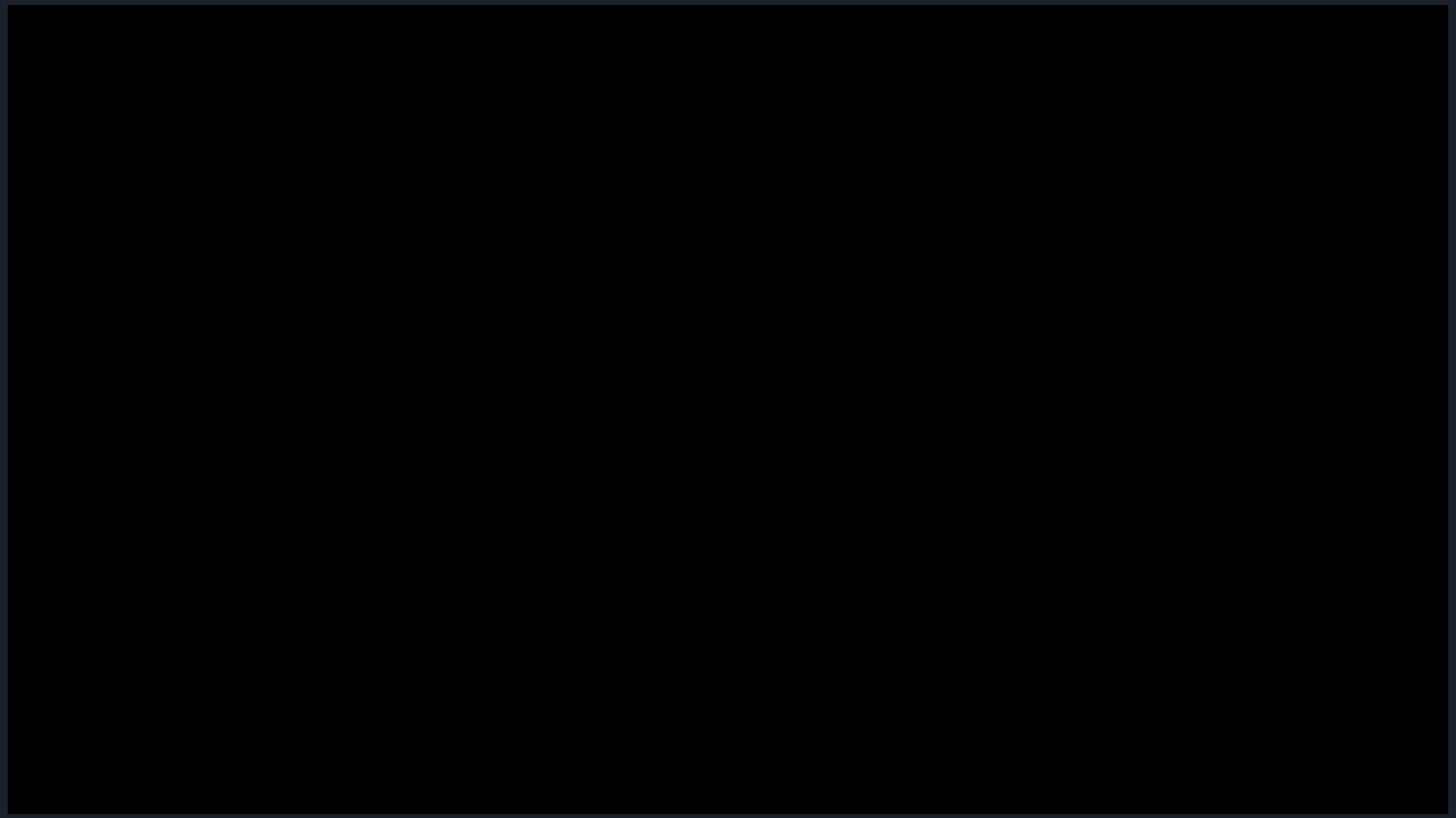
Motivation

- Current anomaly removal systems on the market are either expensive and inefficient or highly specialized
- Replace legacy embedded microcontroller solutions with similar cost AI powered systems

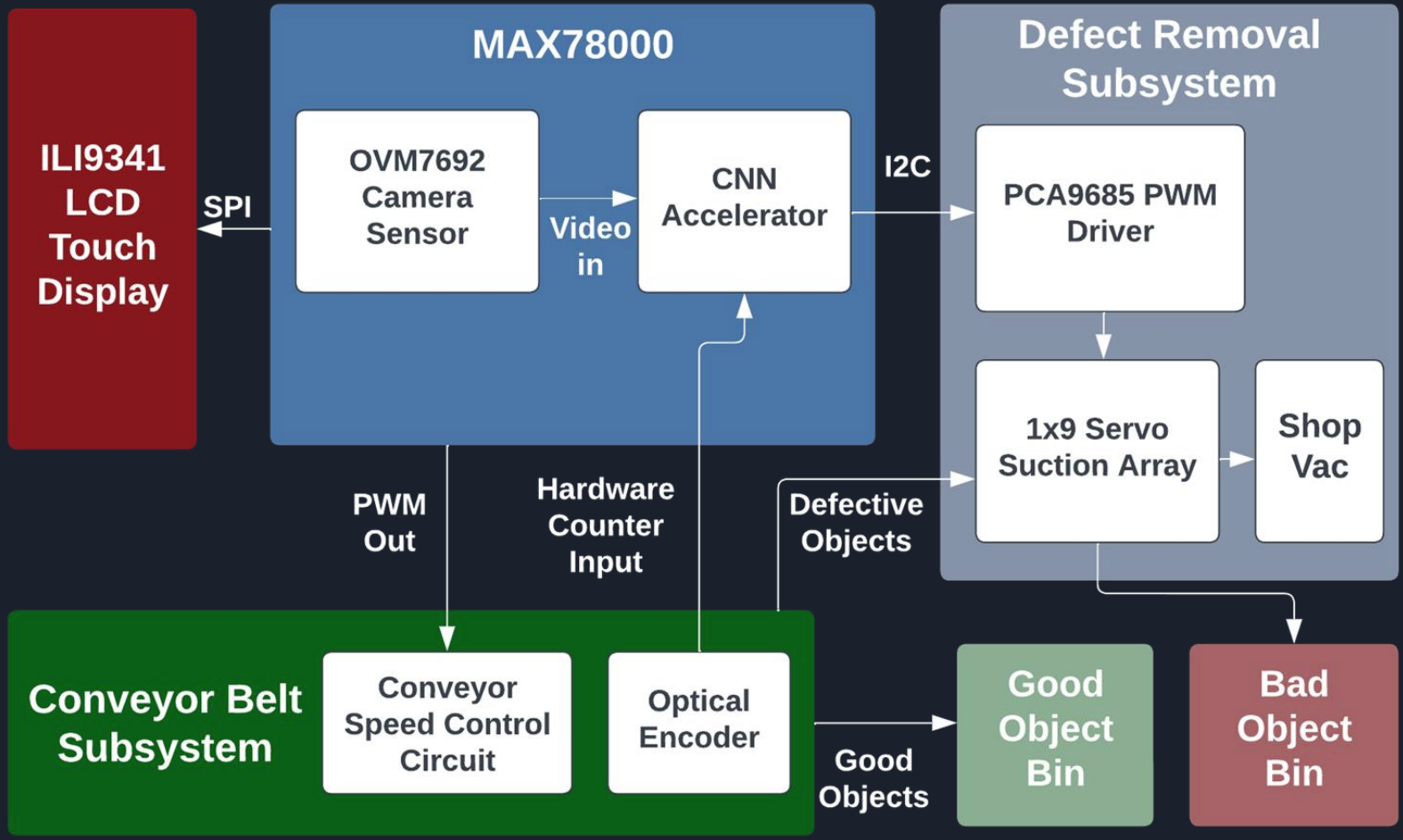
System Overview

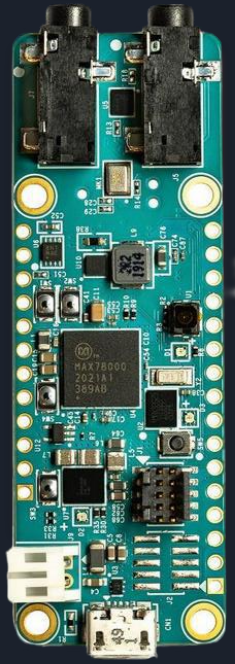
- Unfiltered pinto beans are placed on a conveyor belt
- Custom CNN Model detects defective objects
- Vacuum system removes defects further down the conveyor belt

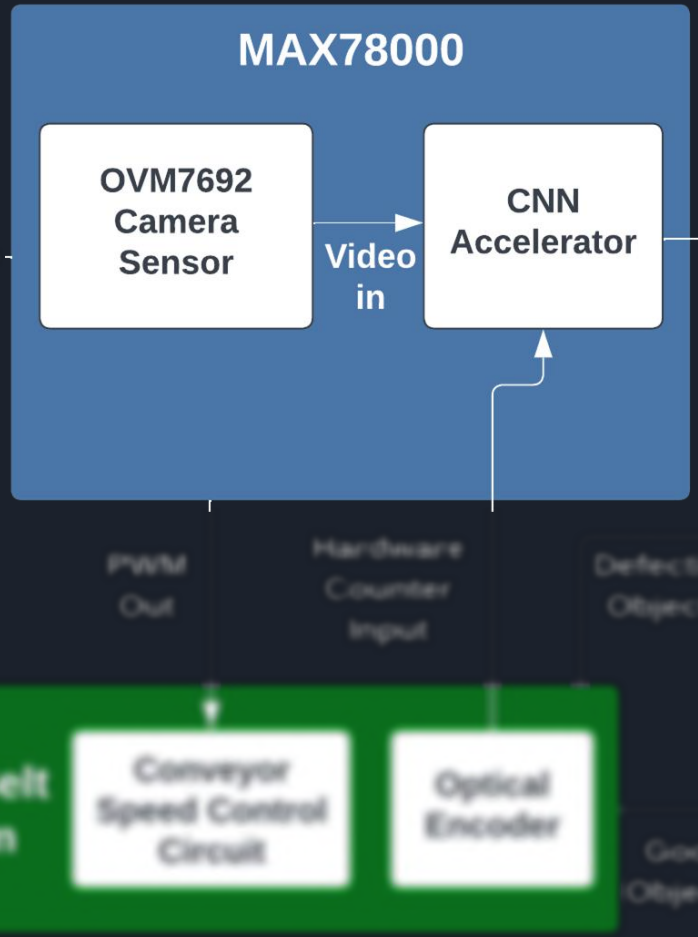




Block Diagram


ILI9341 LCD Touch Display
SPI
MAX78000
OVM7692 Camera Sensor
Video in
CNN Accelerator
I2C
Defect Removal Subsystem
PCA9685 PWM Driver
1x9 Servo Suction Array
Shop Vac
PWM Out
Hardware Counter Input
Defective Objects
Conveyor Belt Subsystem
Conveyor Speed Control Circuit
Optical Encoder
Good Objects
Good Object Bin
Bad Object Bin





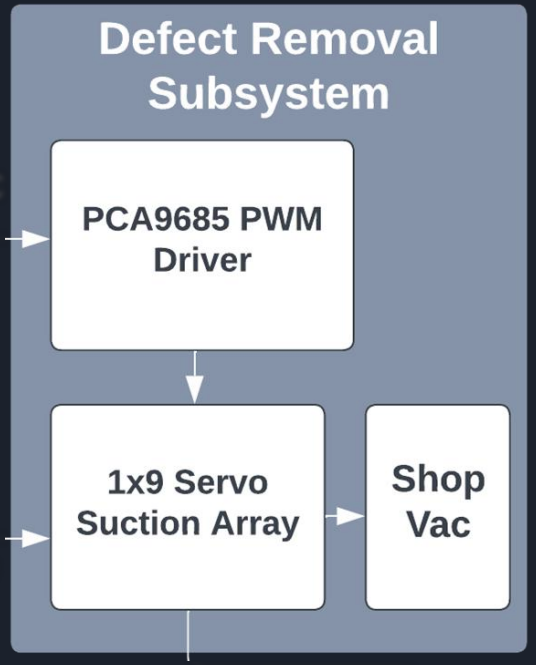
MAX78000 Featherboard

- Development Board with MAX78000 AI Microcontroller and VGA Camera Module
- Runs CNN Model and removal mechanism logic
- Streams frames and detections to LCD Display

MAX78000 SPECS	
Internal SRAM	128 KB
Core	ARM Cortex-M4F
Internal Flash	512 KB
Clock Max Speed	100 Mhz

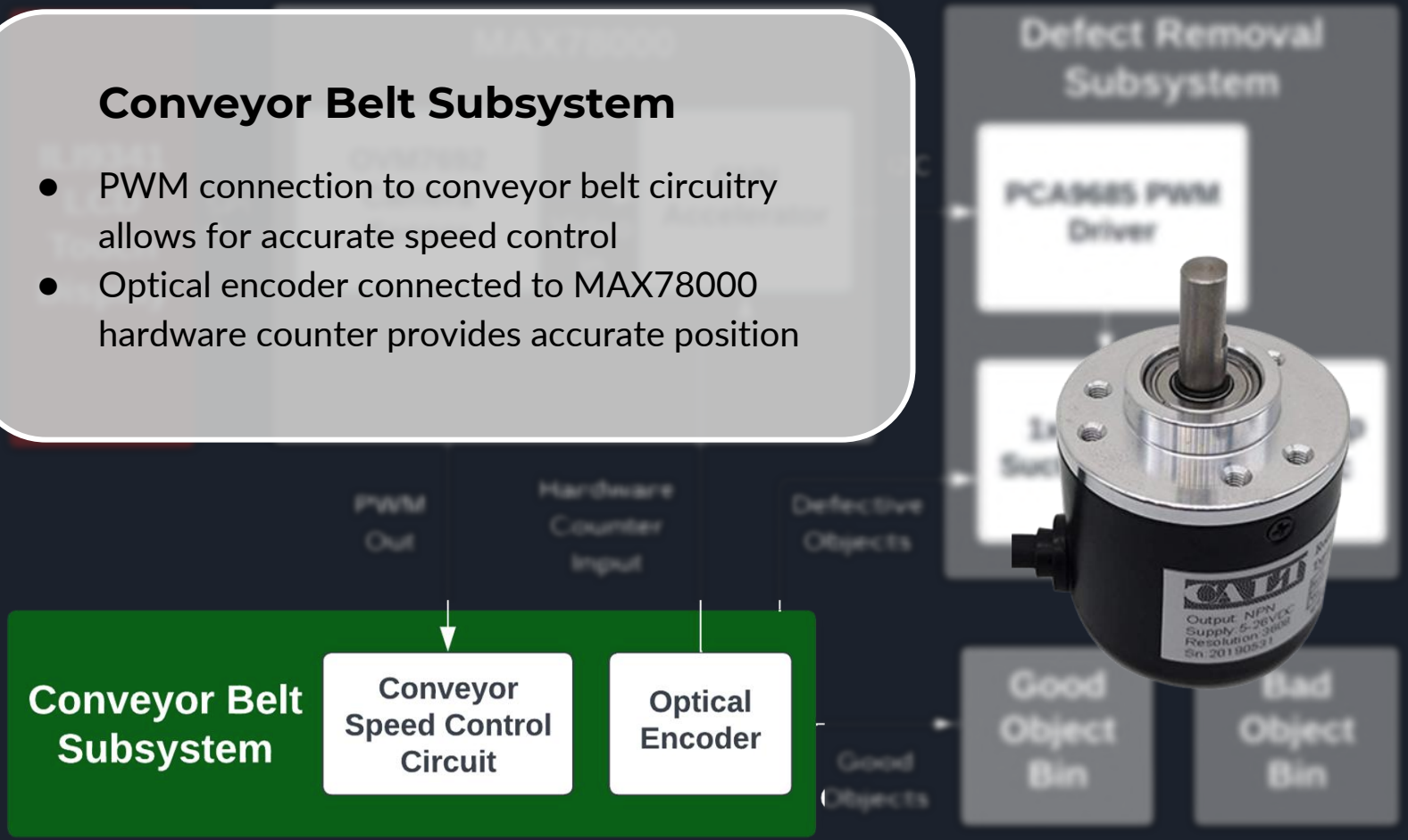
Defect Removal Subsystem

- Nine vacuum channels span the width of the belt
- I2C interfaced PWM driver operates servo-controlled ball valves
- Defective objects are sucked into the bad object bin

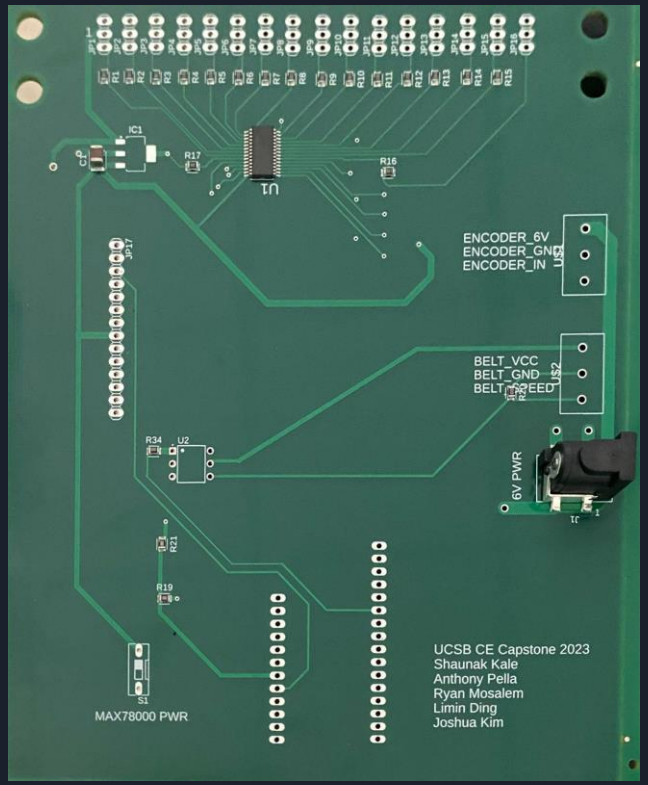


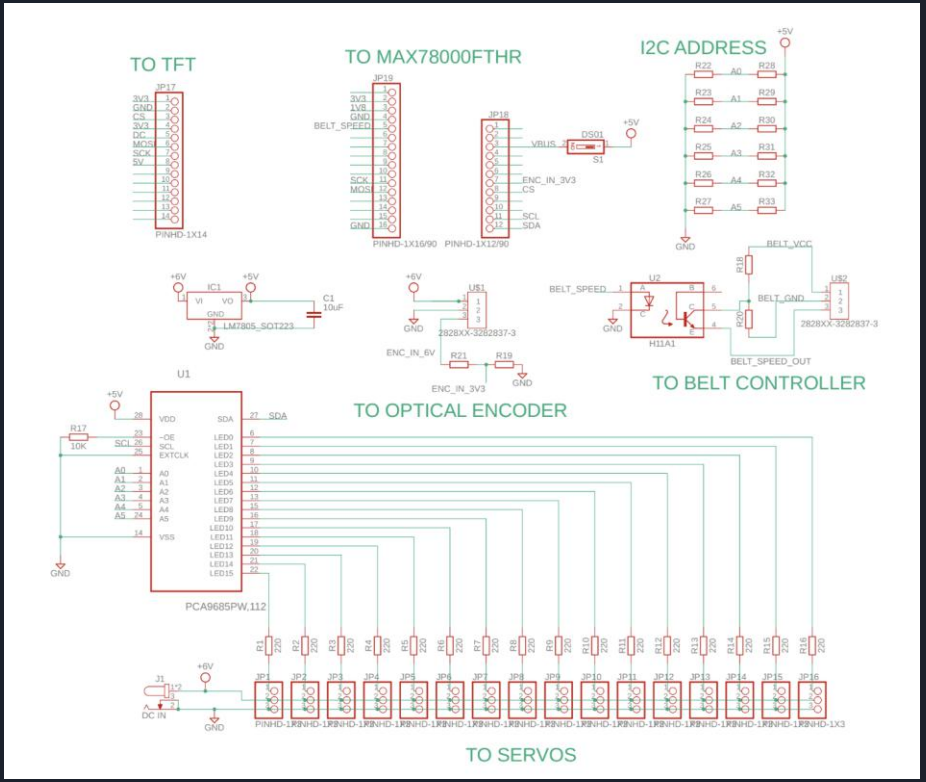
Conveyor Belt Subsystem

- PWM connection to conveyor belt circuitry allows for accurate speed control
- Optical encoder connected to MAX78000 hardware counter provides accurate position



Custom PCB


ENCODER_6V
ENCODER_GND
ENCODER_IN
BELT_VCC
BELT_GND
BELT_SPEED
6V PWR
MAX78000 PWR
UCSB CE Capstone 2023
Shaunak Kale
Anthony Pella
Ryan Mosalem
Limin Ding
Joshua Kim


TO TFT
TO MAX78000FTHR
I2C ADDRESS
TO BELT CONTROLLER
TO OPTICAL ENCODER
PCA9685PW,112
TO SERVOS

Embedded Software Flow

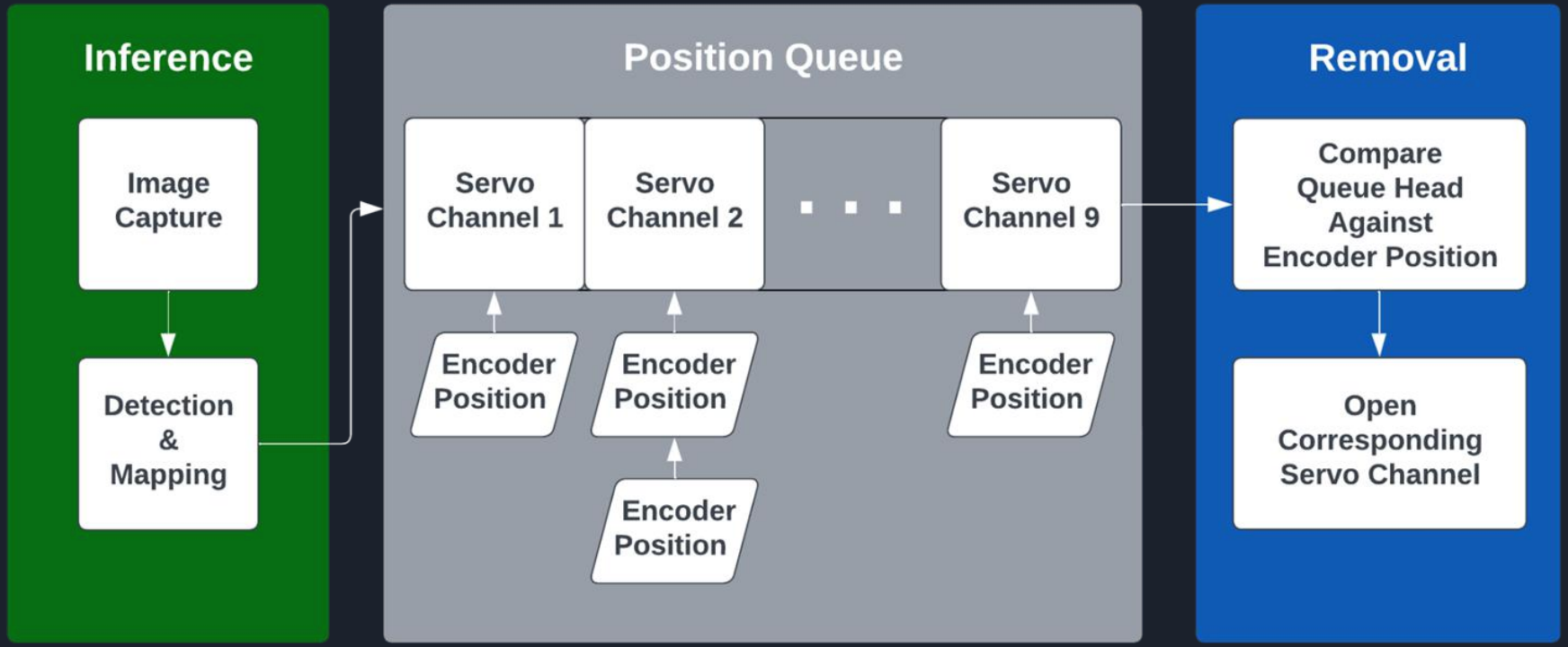
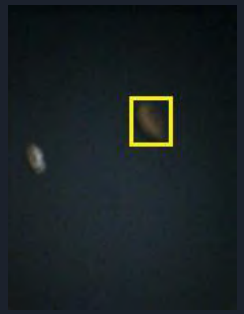


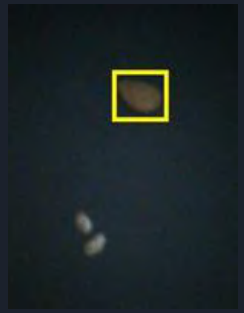
Image Capture

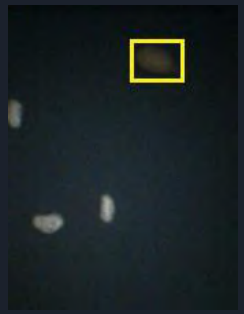
- Input size for CNN model: 224 x 168
- One image can only cover half of the conveyor belt
  - Use two images to cover the whole width of conveyor belt
  - Only store one image to save memory

Machine Learning Development Process



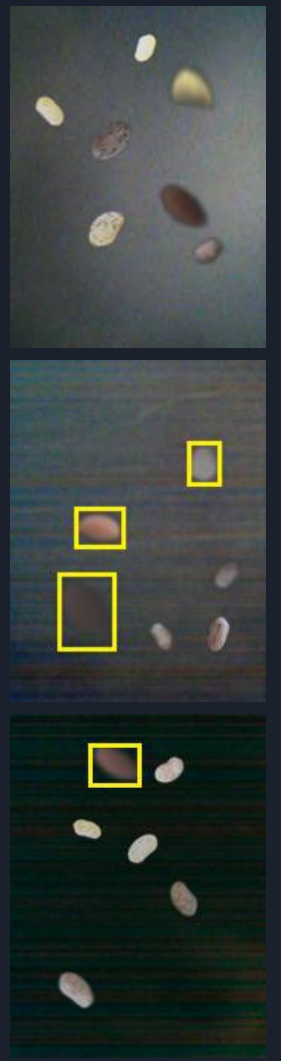
- Generate artificial data
- Train classification model using PyTorch to detect defects and ignore non-defects as the background
- Quantization and synthesis of model
- Test on MAX78000 and repeat the process



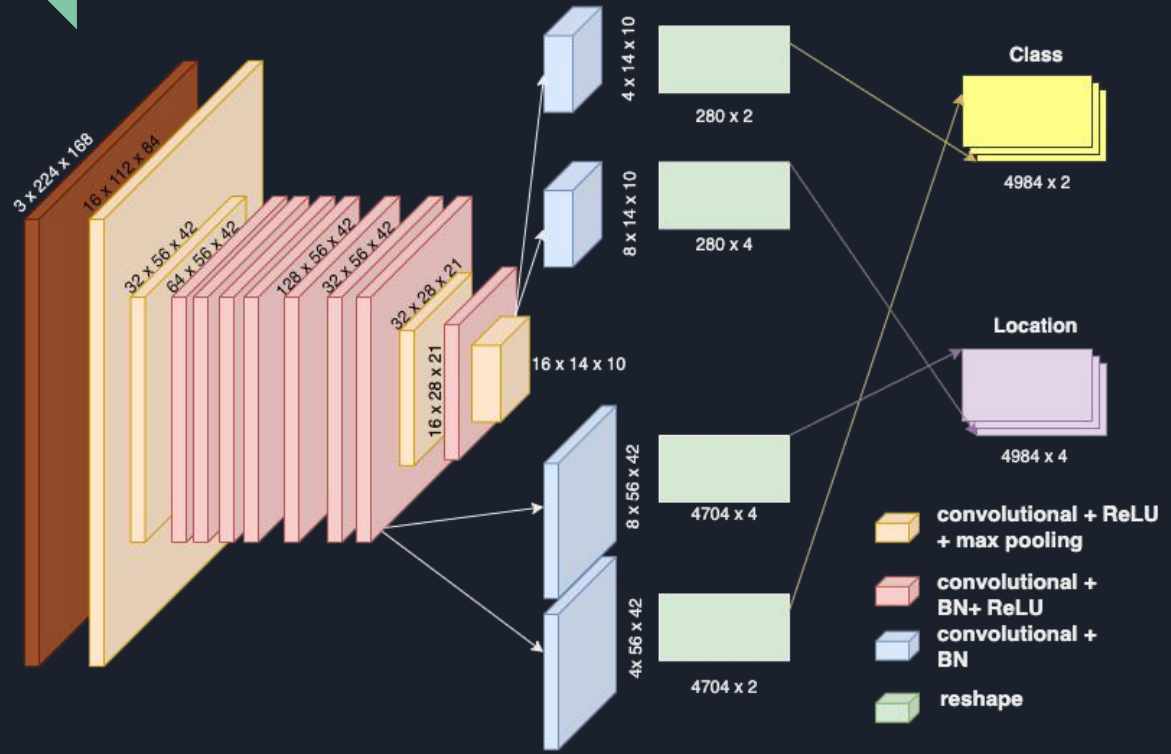


Data Synthesis

- Uses OpenCV for object processing and creation
- Captured hundreds of camera images and used contour detection to crop out individual objects
- Composited objects on varying backgrounds + Random background + Automatic annotation
- Fast prototyping and model building



CNN Architecture



- Weight memory: 260,568 bytes out of 442,368 bytes (58.9%)
- Inference Time: 49.9 ms
- 16 convolutional layers

Challenges

- Sensitivity to external light
- Can only capture 3 frames per second
- Multiple removal system hardware redesigns
- Data collection and annotation
- Creating realistic synthetic images

Good Bin

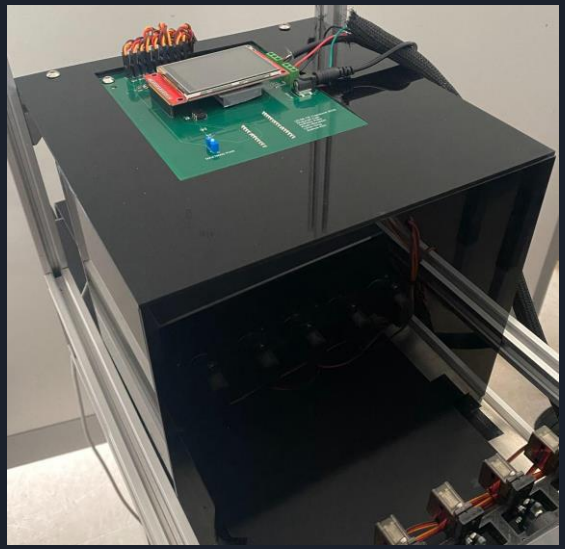
Defect Bin

Synthetic

Real

Improvements

- Enclosure to control for external light
- Manually set sensor gain & exposure time
- Increased the frames per second from ~3 to ~7 by enabling camera sleeping between frames and using DMA to transfer images to the TFT display
- Train ~100 epochs with dataset size of 40000+ images
    - Mean Average Precision: 0.93
- Fine tuned compositing algorithm and added sparsity constraint for synthetic images
- Created a highly accurate model, suitable for industrial settings

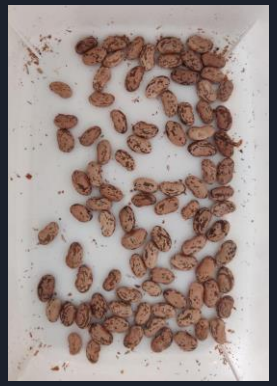


Results

Good Bin

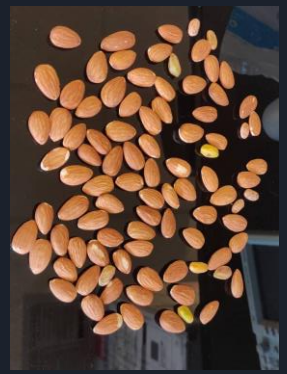
April

May



June

Defect Bin



Acknowledgements

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  - Alex Lai - TA
  - Jimmy Kraemer - TA

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ANALOG DEVICES

Questions?