Classifying Scrap Metal on the Edge

2019 December 10th
W251 Final Project
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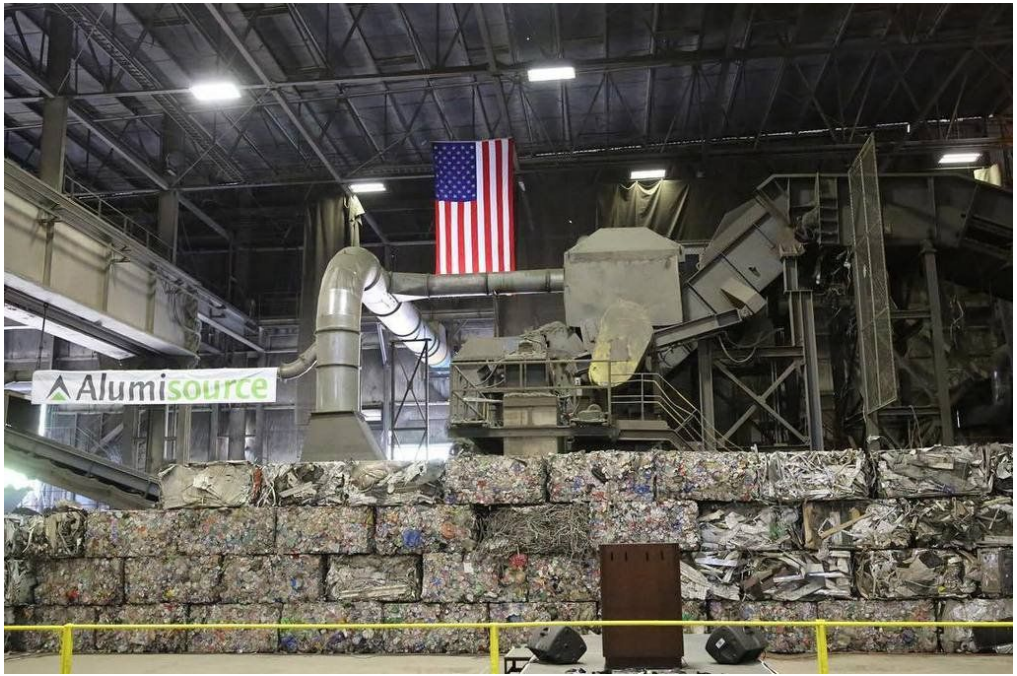
Alumisource



- Based near Pittsburg, PA.
- Specializes in metal shredding and processing.
- Transforms scrap metal from junkyards into raw materials for metal producers.
- Looking to improve accuracy of metal sorting at mass scale.

Existing Solutions

Tradeoffs

- Cost
- Speed
- Accuracy

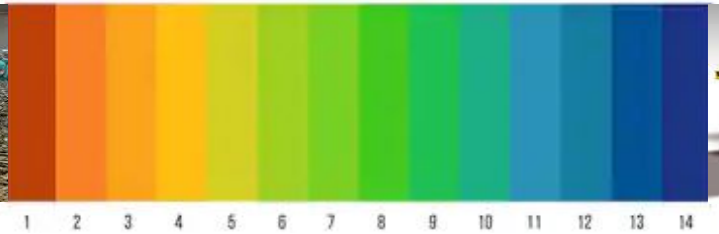
Manual/Slow

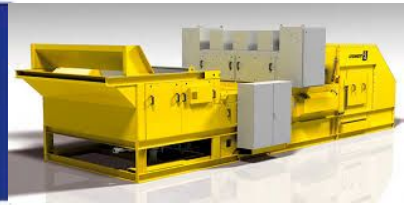
Automated/Expensive

New Solution

Tradeoffs

- Cost
- Speed
- Accuracy





- Lower-cost cameras, compared to costly sensors (e.g., lasers, xray)
- Edge computing, to keep pace with conveyor belt

Data Collection

500 Samples (100 each)

- Aluminum
- Brass
- Copper
- Stainless Steel
- Zinc

Photography

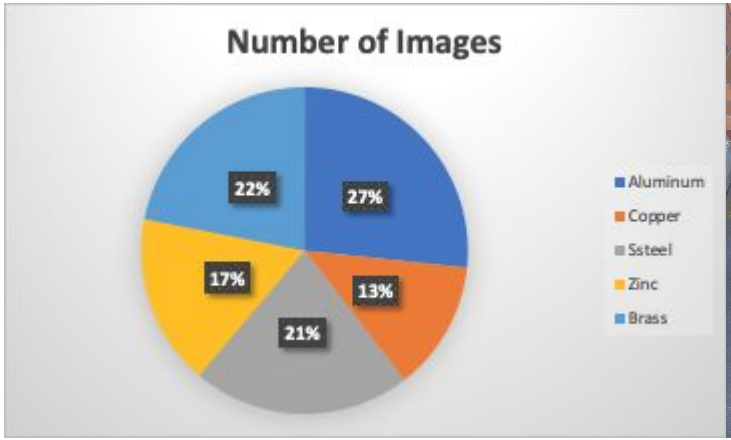
- Light Box
- Smartphone Camera

1383 Pictures

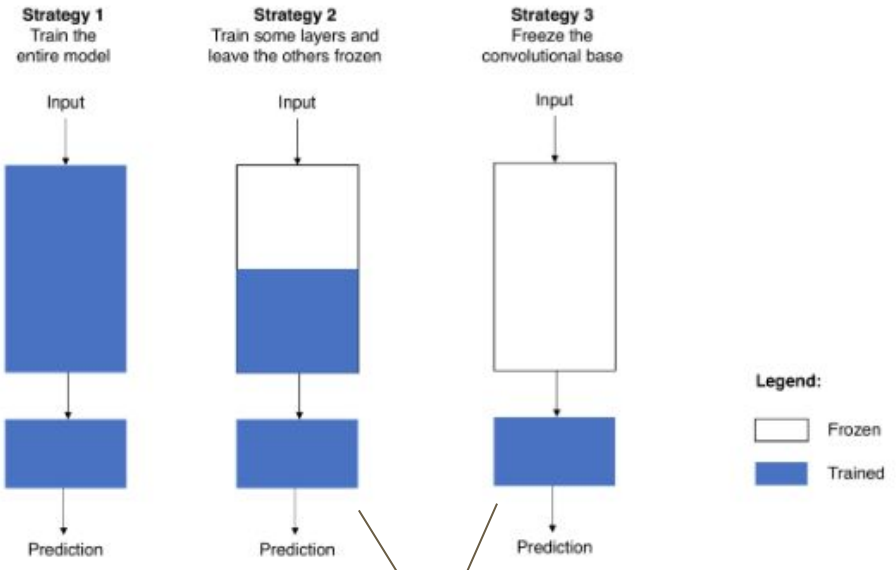
- Multiple angles taken per object

Models - Data Split

Metal	Number of Images	Training	Validation	Test
Aluminum	369	221	74	74
Copper	178	106	36	36
Stainless Steel	299	178	60	61
Zinc	234	140	47	47
Brass	303	181	61	61
Total Images		826	278	279



Models - Strategy



Training from Scratch

- CIFAR 10
- ResNet-20

Transfer Learning

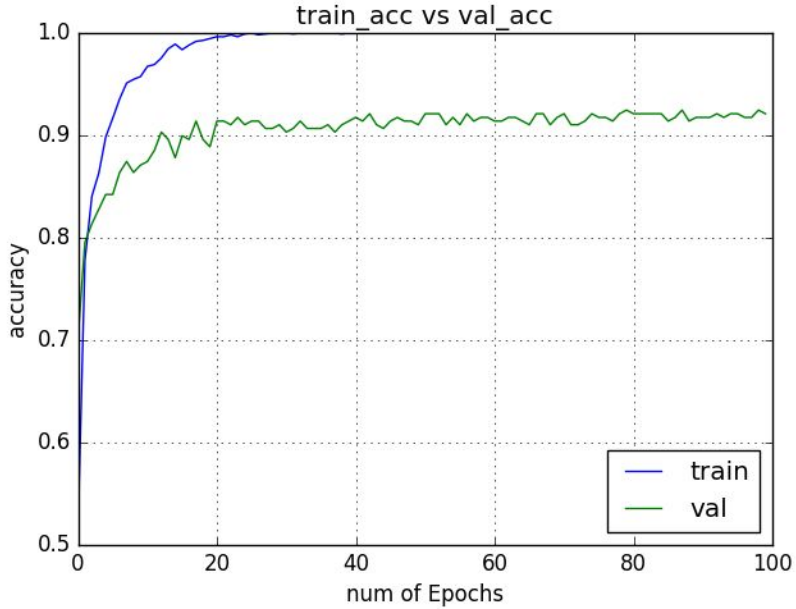
- ResNet-50
- ResNet-50 with fine tuning

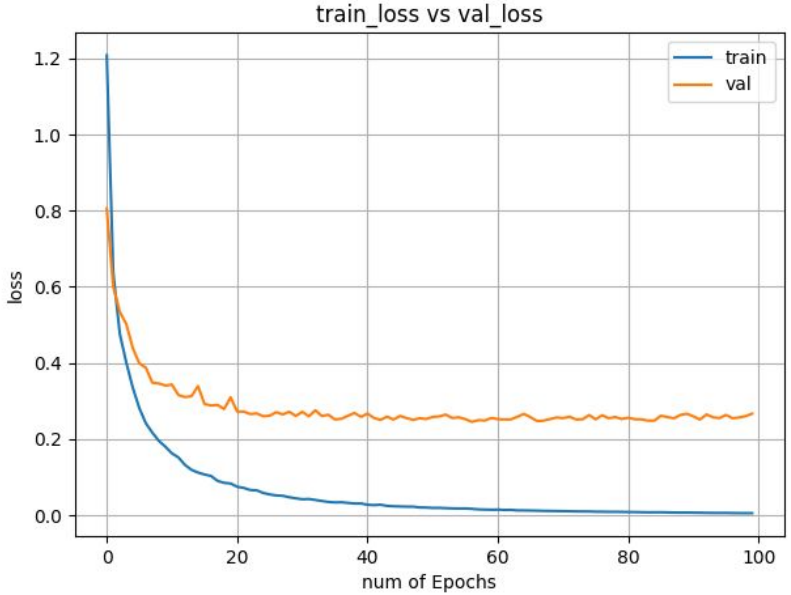
https://heartbeat.fritz.ai/pre-trained-machine-learning-models-vs-models-trained-from-scratch-63e079ed648f

Models - Training

- Full training from scratch (CIFAR10 and ResNet-20)
  - Limited Inline Augmentation (No zoom/rotation/shear/vertical_flip)
    - 92% validation accuracy
  - Inline Augmentation
    - 83% validation accuracy on best model with resnet20
    - 76% test accuracy, model size of 4MB
- Transfer learning (vgg-16 and ResNet-50)
  - No Augmentation
    - 89% accuracy with ResNet-50
    - 92% accuracy with fine tuned ResNet-50
  - Inline Augmentation
    - 81.36% validation accuracy on best model with vanilla ResNet-50
    - 83.5% validation accuracy on best model with fine tuned ResNet-50
    - 71-74% test accuracy, model size of 99MB

Models - Metrics (Transfer Learning)





Transfer Learning - No Augmentation

Models - Confusion Matrix

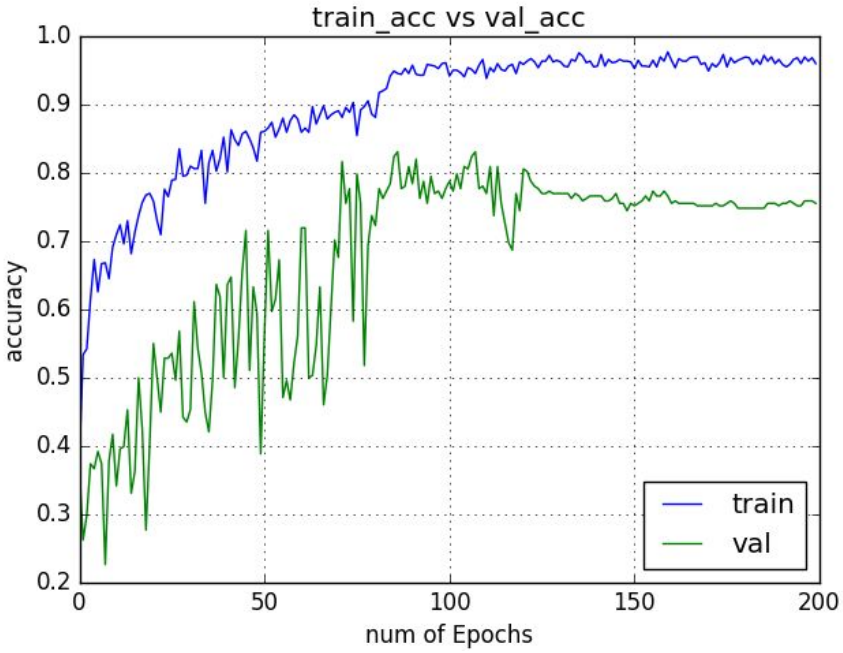
```
Confusion Matrix
[[56  0  0 10  1]
 [ 2 21  0 17  0]
 [ 5  0 29  2  0]
 [17  0  0 65  0]
 [ 0  9  0  5 39]]
Classification Report
              precision    recall  f1-score   support

        Zinc       0.70      0.84      0.76        67
       Steel       0.70      0.53      0.60        40
      Copper       1.00      0.81      0.89        36
       Brass       0.66      0.79      0.72        82
    Aluminum       0.97      0.74      0.84        53

    accuracy                           0.76       278
   macro avg       0.81      0.74      0.76       278
weighted avg       0.78      0.76      0.76       278
```

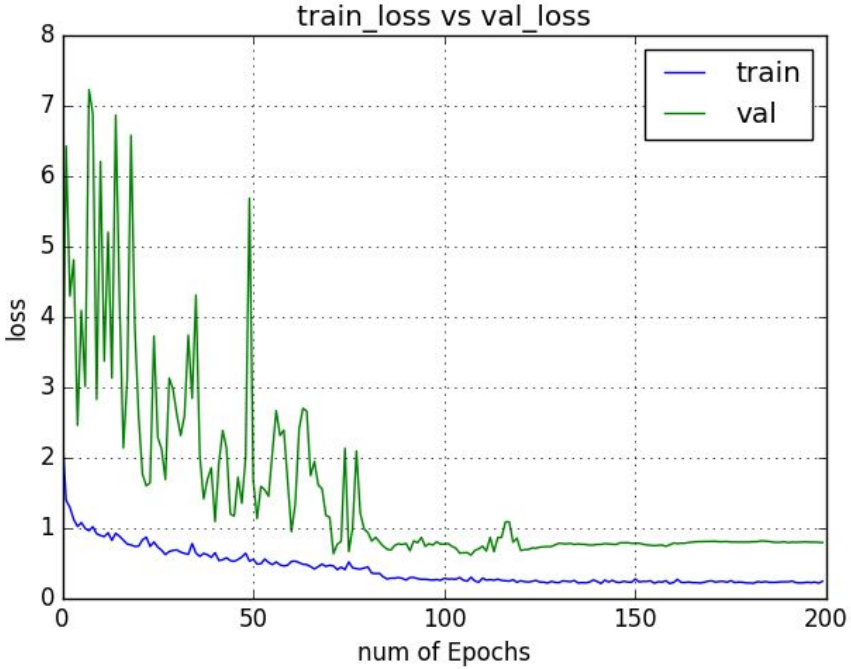
Training from Scratch
(with inline Augmentation)

```
Confusion Matrix
[[38  0  0  0  9]
 [ 3 17  0  1 39]
 [ 1  0 31  3  1]
 [ 1  1  1 39 19]
 [ 0  2  0  0 73]]
Classification Report
              precision    recall  f1-score   support

        Zinc       0.88      0.81      0.84        47
       Steel       0.85      0.28      0.42        60
      Copper       0.97      0.86      0.91        36
       Brass       0.91      0.64      0.75        61
    Aluminum       0.52      0.97      0.68        75

    accuracy                           0.71       279
   macro avg       0.83      0.71      0.72       279
weighted avg       0.79      0.71      0.70       279
```

Transfer Learning
(with inline Augmentation)

Models - Metrics (Training from Scratch)





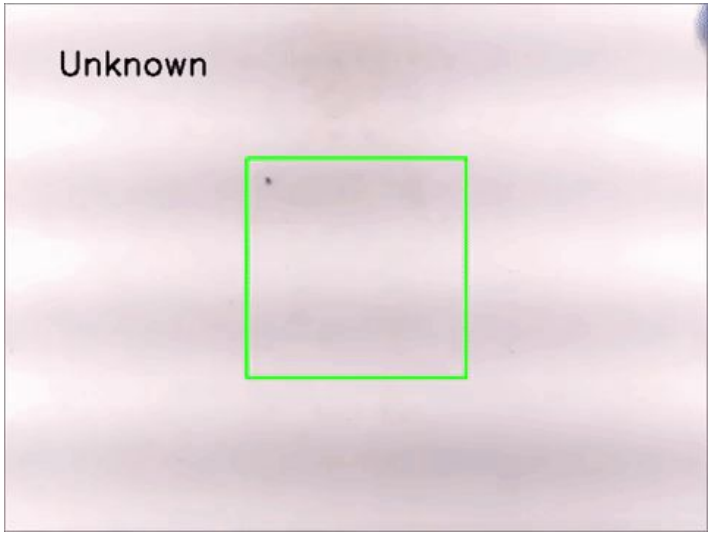
Train from Scratch with resnet20- With Inline Augmentation

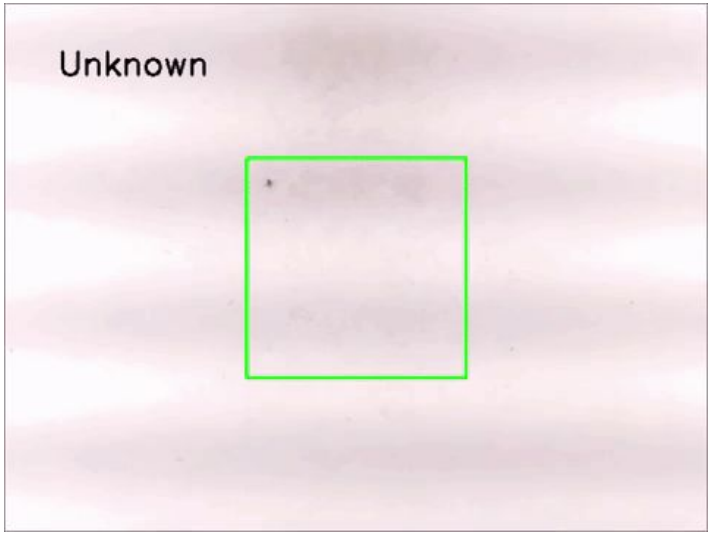
Webcam Testing

- Video Settings
  - Webcam (Logitech C920)
    - Auto/default settings
    - Exposure -8.0 (bright/white background)
  - Lights
    - 2 x LED, 100 watt, 1600 lumens
  - Classifier Input
    - Center crop (reduce banding influence)
  - Green “Centering” Box
    - Not a bounding box; video shot framing aide
  - “Unknown”
    - No negative samples
    - Heuristic: if prediction far too precise, display “Unknown”

Note: predictions are rounded to 4 places in videos

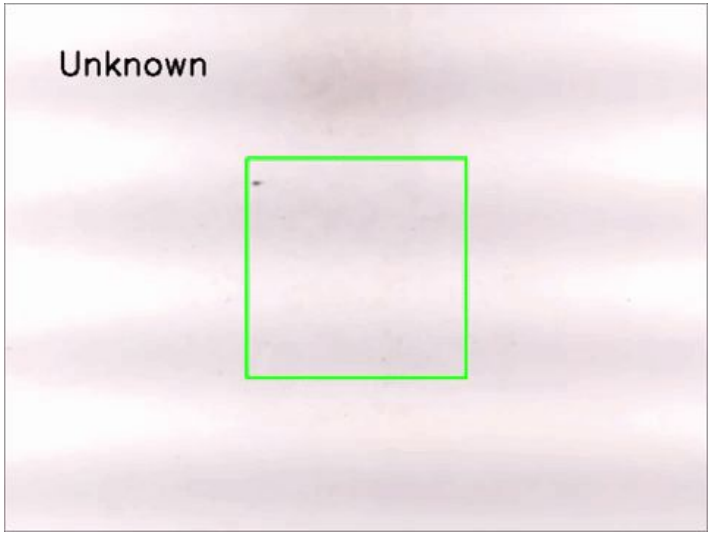
Webcam Testing

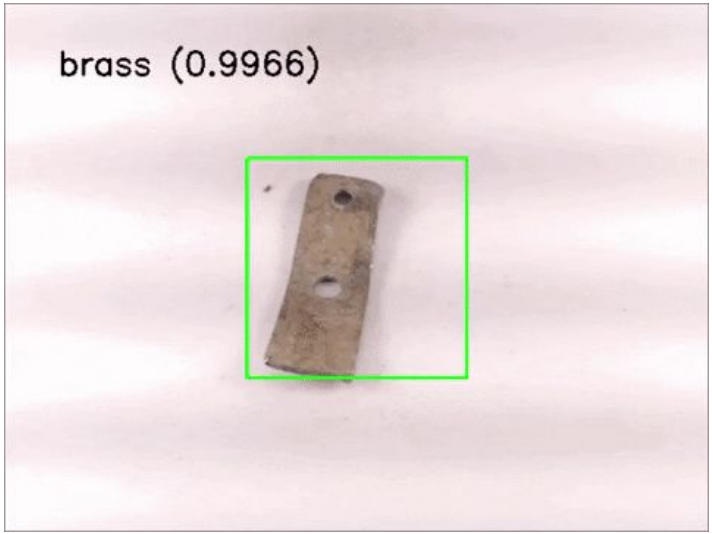




True Class: Aluminum

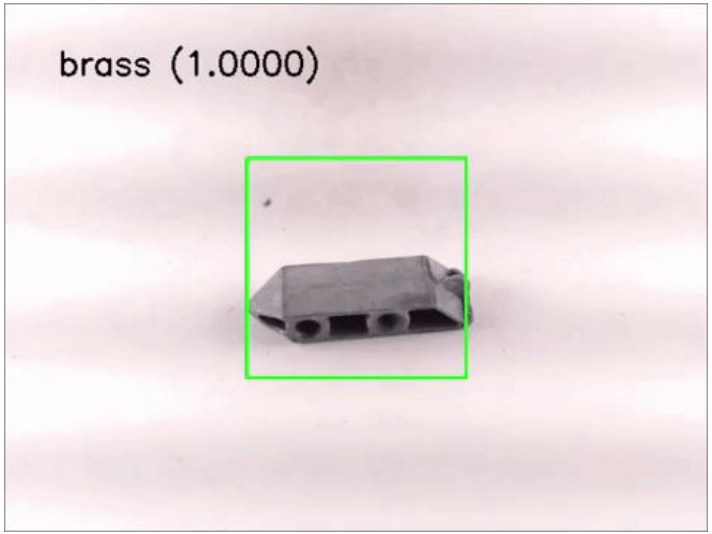
Webcam Testing

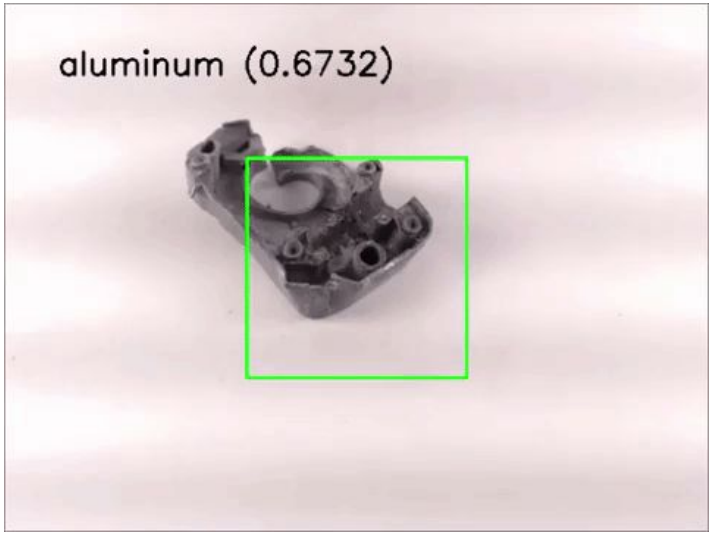




True Class: Brass

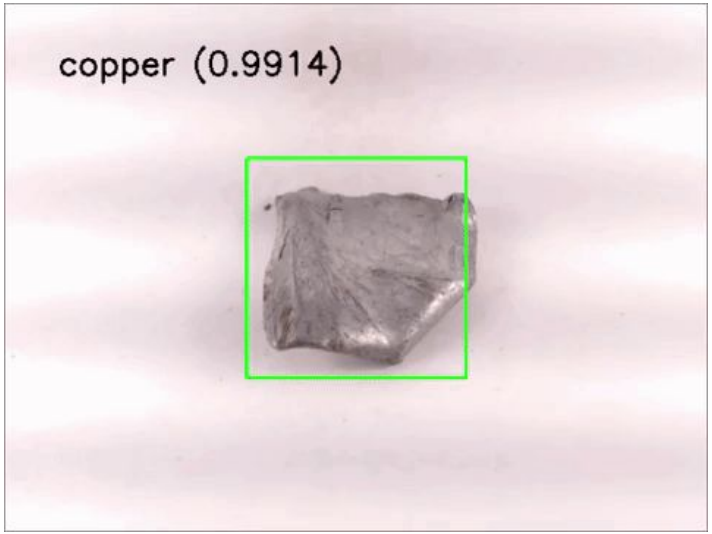
Models - Webcam Testing

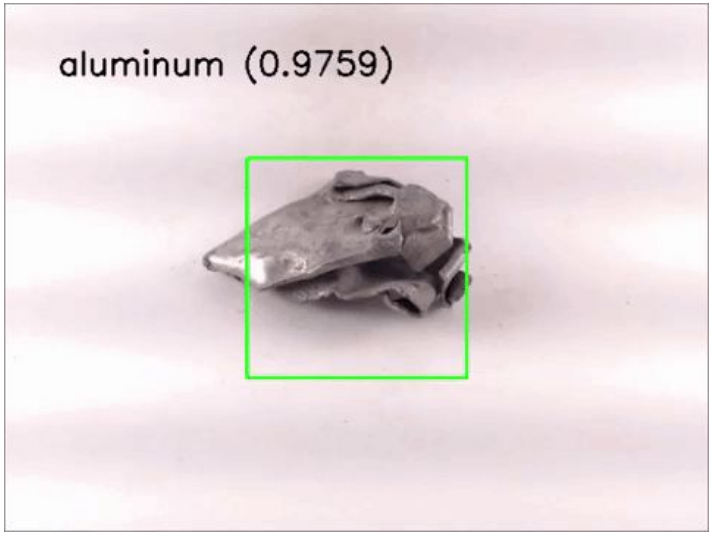




True Class: Zinc

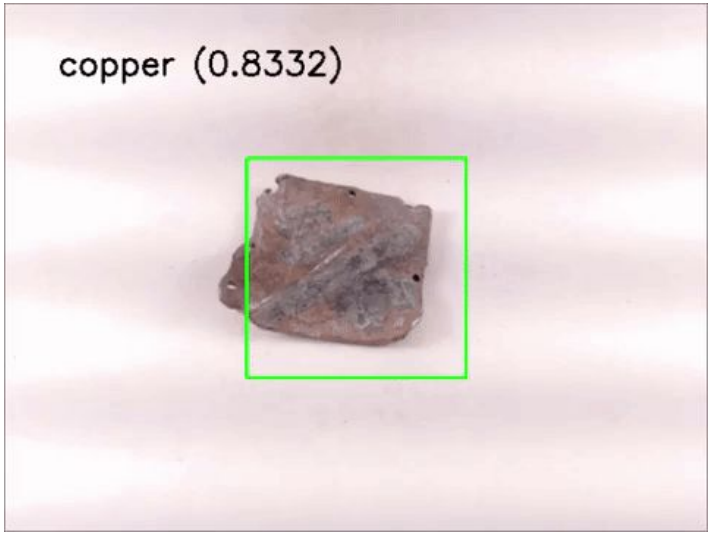
Models - Webcam Testing

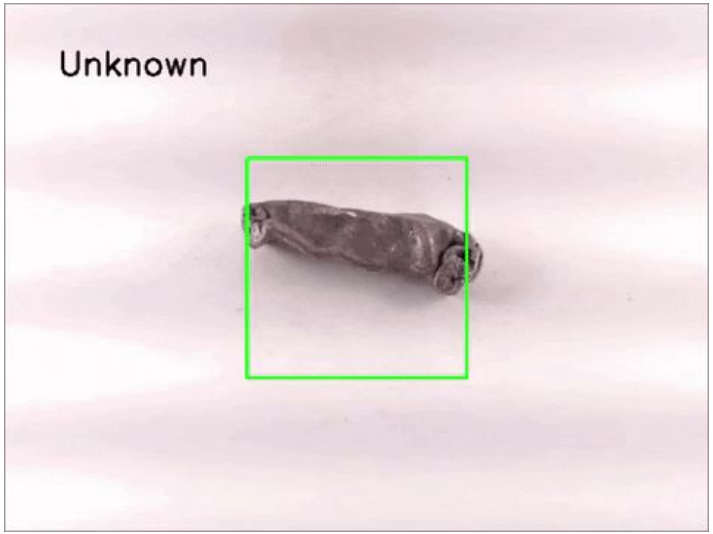




True Class: Stainless Steel

Models - Webcam Testing



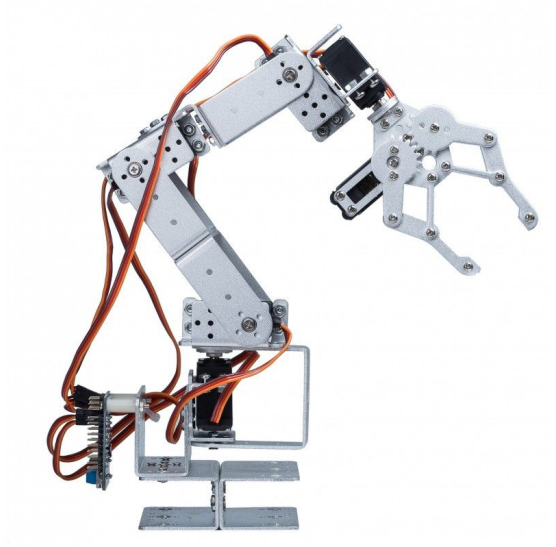


True Class: Copper

Future Work

- Enable object detection, to function for actual working conditions.

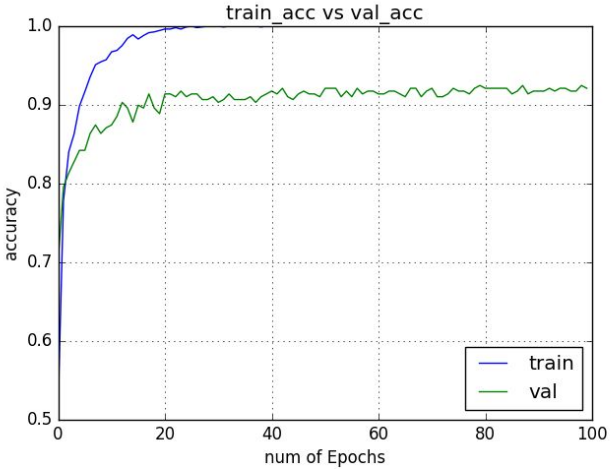
- Link object detection to robotic arm for “hand-picking” scrap metal.



Conclusion


Al
Brass
Cu
SS
Zn


NVIDIA JETSON TX2

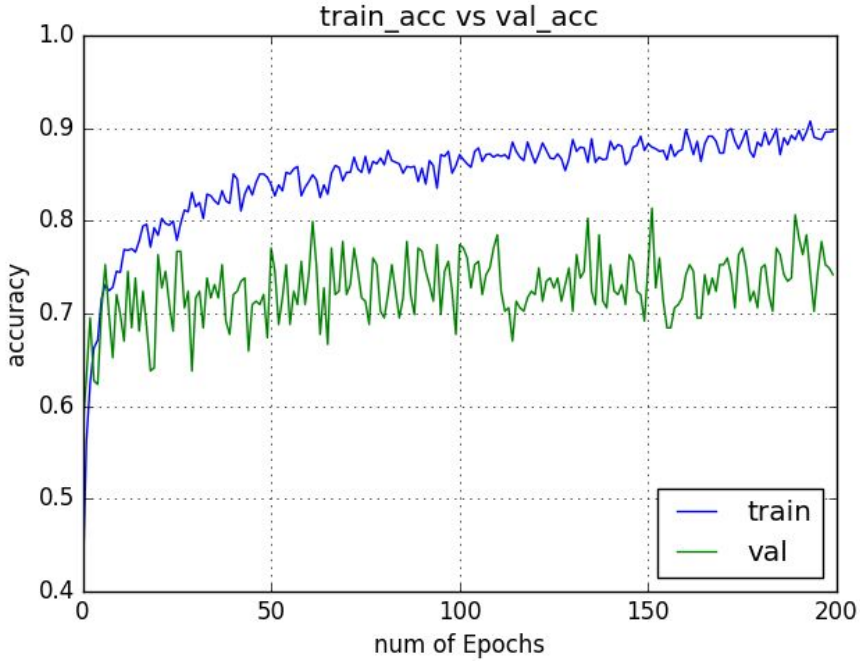

train_acc vs val_acc
1.0
0.9
0.8
0.7
0.6
0.5
accuracy
0
20
40
60
80
100
num of Epochs
train
val

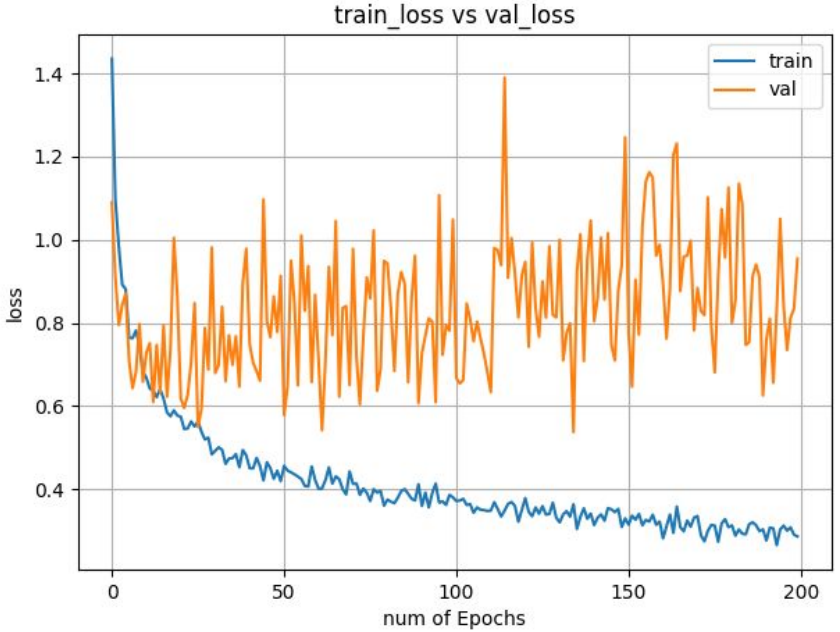
Backup

Outline

1. Alumisource
2. Existing Solutions
3. New Solution
4. Data Collection
5. Models
6. Future Work
7. Conclusion

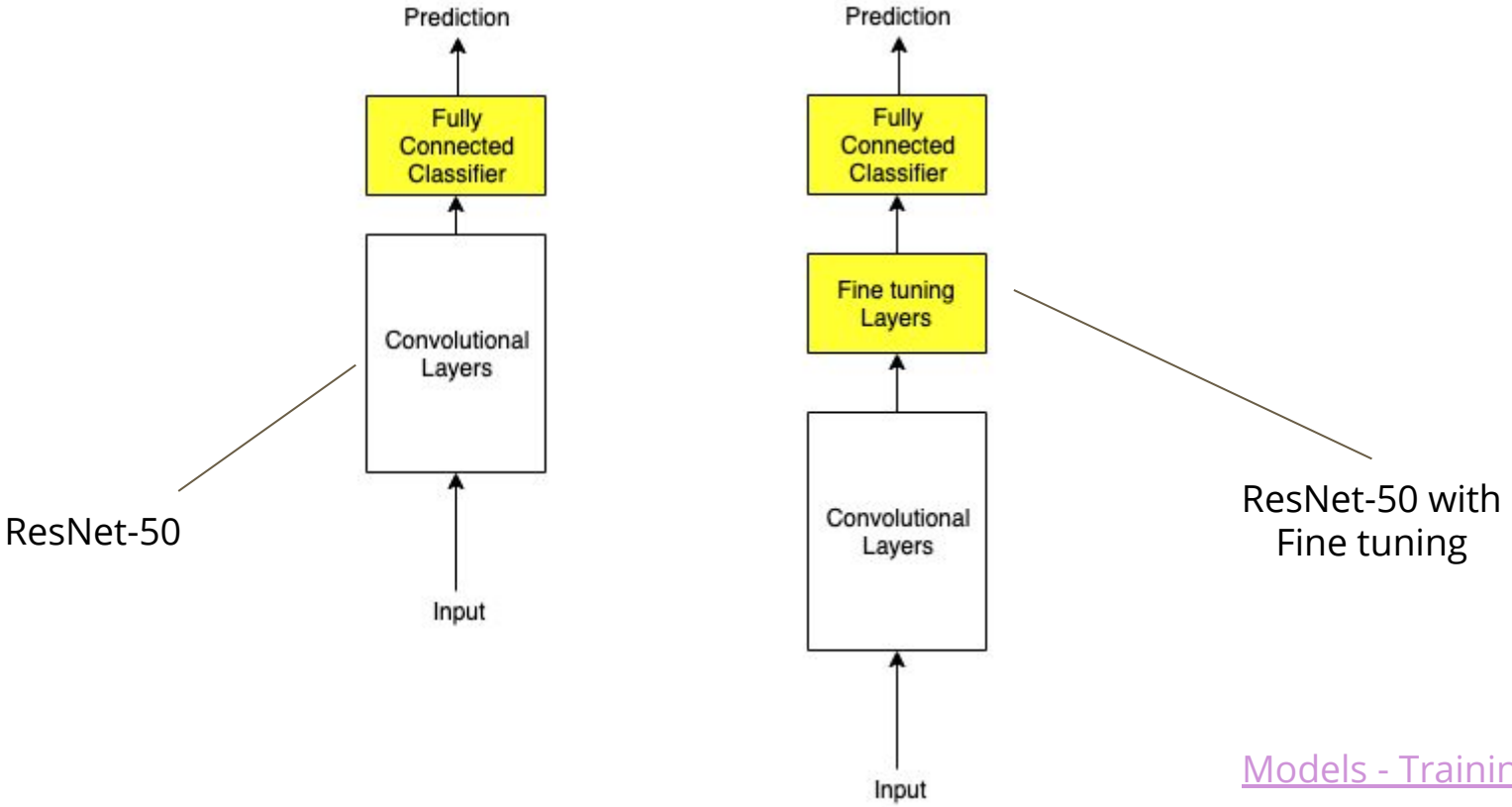
Models - Metrics





Transfer Learning - With Inline Augmentation

Transfer Learning - Strategies



Models - Training

Model Performance

Model	ResNet50	ResNet50 Fine Tuned	ResNet20
Best Val Accuracy	0.81	0.84	0.83
Test Accuracy	0.74	0.71	0.76
Loss	0.95	1.51	0.85
Model Size (MB)	90	99	4

Pre-Trained Model	VGG-16	ResNet-50
Val Accuracy	0.68	0.89
Loss	1.1	0.39
Model Size	300MB	92MB

Models - Training