High Speed Coin Sorting With Convolutional Neural Networks

Paul Krush
https://github.com/GemHunt/CoinSorter

Introduction:

The goal of this project is to physically sort pennies by date very quickly with low cost open source hardware & software.

Motivation:

To learn about machine vision and get experience with the full life cycle of a machine vision product. To gain experience with the current crop of deep learning tools and their use of NVidia GPUs.

So the tail wags the dog… The field of high speed coin classification was chosen because of current GPU computational efficiency over CPUs and more importantly future GPU computational scalability.

Hardware & Software Mechanics:

At this point the system is just a quick proof of concept to show physical coin sorting. It sorts about 2 pennies a second, continuously. One solenoid and 2 physical bins are currently set up. It uses C#, OpenCV for image preprocessing, a cheap microscope webcam, an Arduino for solenoid control, SQLite, and local classification with Caffe complied on Windows 10.

Model training is done on a Linux server, either local or AWS, with Caffe & DIGITS.

Coins are metered by an off-the-shelf coin hopper. Conveyor hardware is 3D printed ABS. Conveyor belting is undergarment strapping. (0.15mm "TPU Tape")
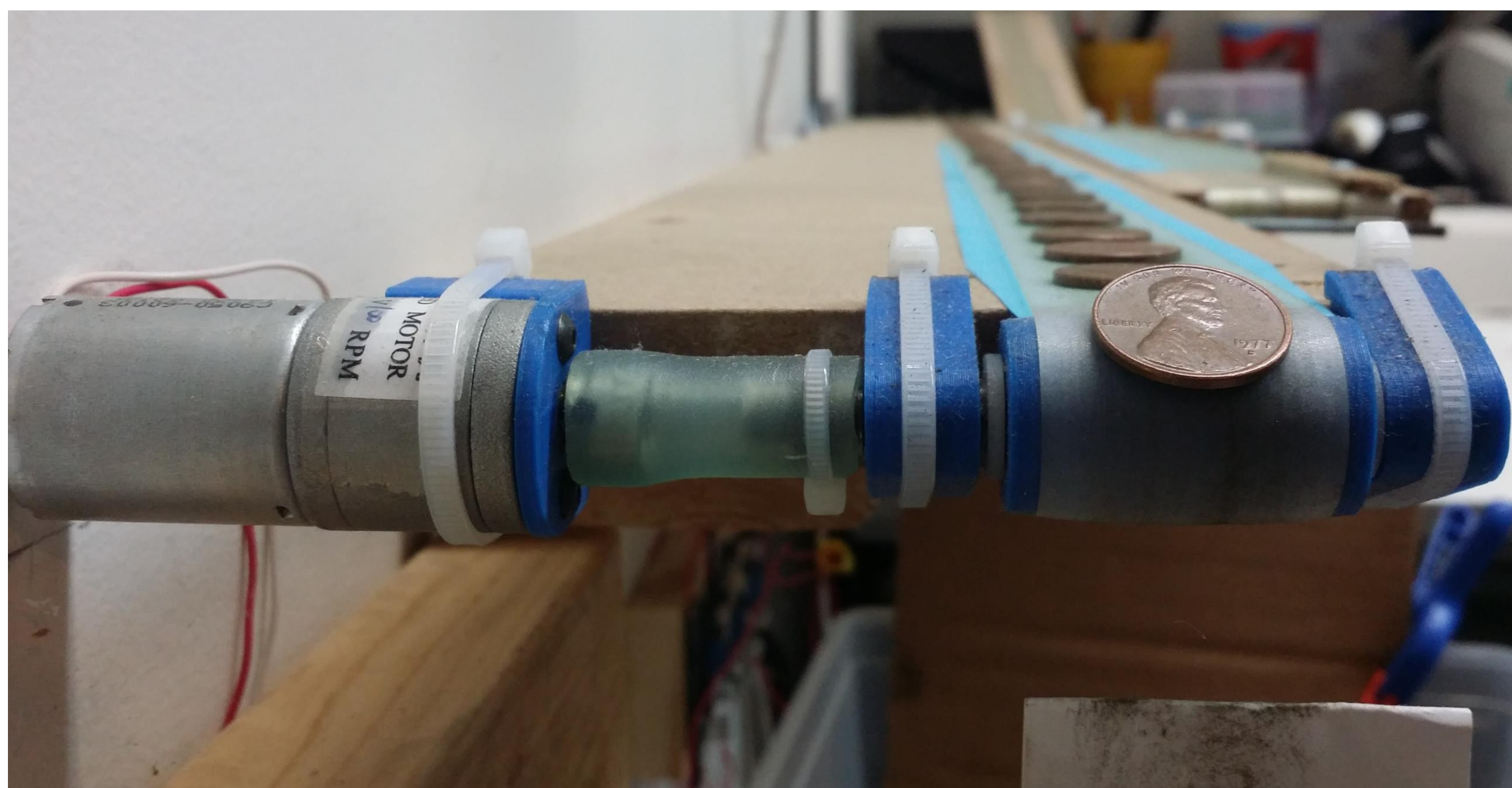
Image Processing Pipeline:

OpenCV: Image captured from webcam, triggered by IR sensor from Arduino

OpenCV: Removal of skew (caused by coin moving at high speed)

OpenCV: Threshold in Cr component of the YCbCr space

OpenCV: Coin image crop from contour detection

Caffe CNN: Detection of the 5% poorly cropped coins with a stock cifar10 network, 32x32 color

Caffe CNN: Coin design classification (Heads vs Tails vs Other…) LeNet with an additional set of conv & pooling layers. 2x output, 60x60 gray, 12x rotational augmentation

Caffe CNN: Coin orientation classification (images rotated to create 360 different categories) LeNet with an additional set of conv & pooling layers, 2x output, 64x64 gray

Caffe CNN: Coin date classification, a stock cifar10 network, 32x32 color

Results:

Start to finish preliminary accuracy is around 70 percent. Expected accuracy is much higher. Most of the error at this point is due to using a very small training set. Simple improvements can be made throughout the pipeline.

Next Steps:

Camera & lighting needs to be fixtured and standardized. Four different lighting and camera setups have been used so far. Accuracy drops drastically after the camera type, position, lens, or lighting changes. Cropping issues need to be fixed and matched to the possible new camera.

Conclusion:

So far accuracy is higher than expected which is great. Unfortunately the project is taking a lot longer than expected. Computational requirements are much lower than expected, which ironically does not fulfill the stated goal of needing a GPU for classification! Of course this is a good problem to have and leaves the door wide open for more complex work in the future.

Future Work:

One of the holy grails of modern numismatics is to discover new types of coin varieties and mint-made errors. Automatically correlating coin regions and features by date and mint mark is the next logical milestone to archive this. Capturing both sides of the coin will be a requirement to do this.