Using computer vision to augment safety in makerspaces

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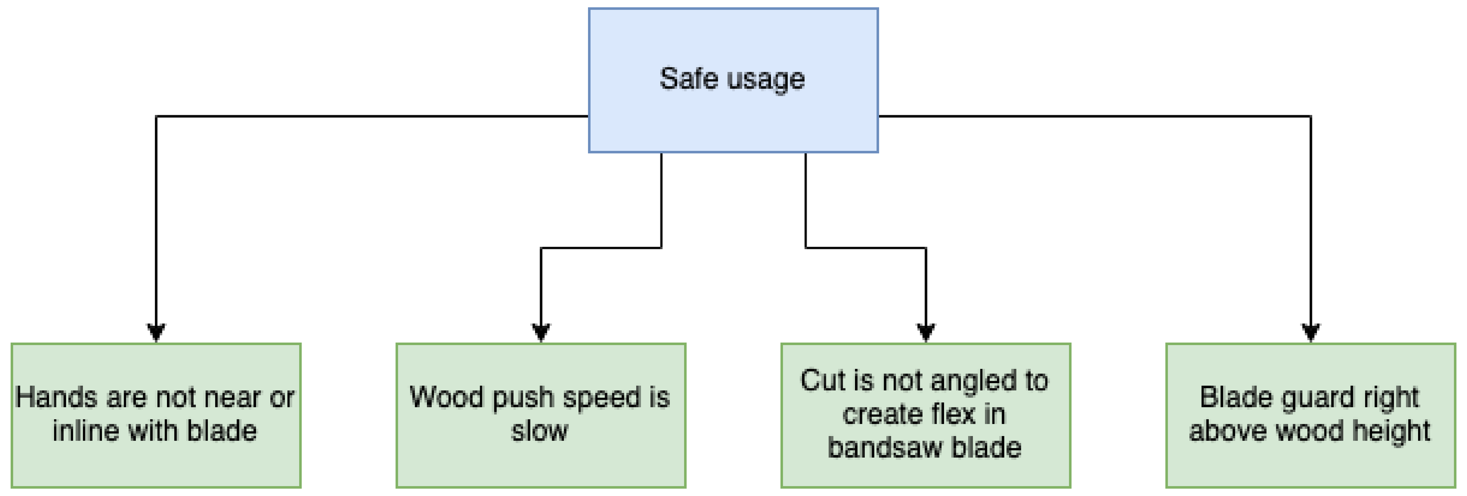
Background

Staff at makerspaces must balance training new members, monitoring the safety of members, and providing general maintenance to the makerspace studio during their shifts. When there are few users, this can be done effectively, however when small spaces become busy it can become difficult to have eyes on all the equipment to make sure it is correctly used. Instead of the staff keeping attention to all equipment, what if equipment was monitored autonomously?

Problem

To explore this idea, SMART^3 Makerspaces decided to implement a safety detection on the bandsaw inside the Invention Studio at Georgia Tech.

The band saw was chosen due to the simplicity of the machine and determination of 'safe' usage. Safe usage is defined as keeping hands out of the blade path when the machine is on, performing a cut at an appropriate speed and angle, and ensuring the blade guard is not higher than a small amount of the wood. The exact metrics of these attributes were qualitatively defined by on-duty staff at the makerspace when creating example data.



A chart designating the four ways to define 'safe' usage.

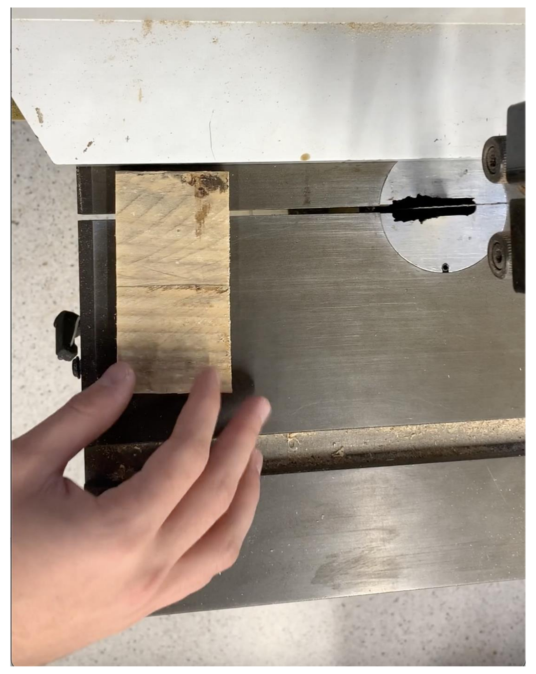
Unsafe usage, subsequently, was defined as any use of the bandsaw that did not comply with the rules above.

An example of the blade guard on the band saw being too high. This presents the problem of the user or a passerby to accidentally catch something in the blade.

Methods

To classify a frame from a recording of a cut on the band saw 'safe' or 'unsafe', SMART^3 decided to use Convolutional Neural Networks due to prior experience with this technology. In total, there was a need to determine an effective manner to generate the dataset, preprocess each frame, and build an effective neural network.

Recording each cut was done from a top-down view using a phone mount. Multiple cuts of mixed safe and unsafe usage were recorded and manually labelled frame by frame whether the action in the current frame was safe or unsafe.



The left picture shows the mounted phone camera set up on the bandsaw. On the right is a sample image of the perspective generated by this mounted set up. Notice the raised blade guard, which shows the current action is unsafe.

After recording over 30 different cuts, 79% of frames were determined as safe and 21% of frames were determined as unsafe.

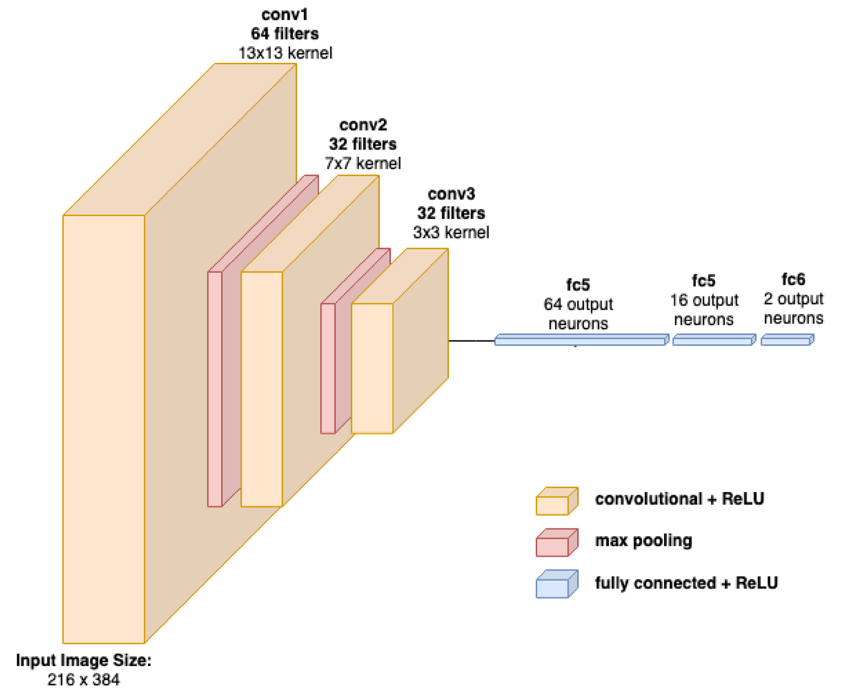
To allow for manageable training on our available machines and highlight key features of the image, preprocessing of each image was required. Preprocessing of each frame was done in the following manner, with an example before and after image on the right.

1. Decrease the resolution to 0.2 of original size
2. Increase the contrast of the image using Histogram Equalization of Lightness in the image's LAB form
3. Grayscale the image

Overall, this decreased the the data points for each image by over 98% while, by inspection, keeping relevant details to image intact.

Methods (cont.)

The Convolutional Neural Network was built using TensorFlow, and it utilized Adam as the optimizer and binary cross entropy as the loss function. The safe and unsafe training class weights are calculated based on the percentage that they compose the dataset.



A visualization of the Convolutional Neural network used for classification.

Results

The model was tested on a reserved set of data amounting to 20% of the total frames that exist in all recordings. The test set was composed a random selection of frames from all of the cuts made. The model was able to reach ~80-85% accuracy on the testing set. if the model had guessed randomly and accounting for proportionality of classes, the accuracy would be expected to be ~67%. This shows that model did learn against the dataset provided.

However, the model failed to generalize to new cuts. In practice, the model simply classified every single frame as safe, likely based on proportionality.

Conclusion and Future Work

All in all, the ability to detect safe usage of the band saw autonomously was successful in the test bed but failed in practice.

SMART^3 Makerspace is currently working on improving the detection algorithm by utilizing the YOLO computer vision technique to gain information about the location of objects, particularly the blade, blade guard, and hands, and performing manual logic in determining whether a frame is safe or unsafe.

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