The primary pre-trained CNNs leveraged as first-stage classifiers are VGG VeryDeep-19, VGG VeryDeep-16, and VGG S. The second-stage classifier is trained using the validation data set based on the 1000 class scores from each of the best 3 CNNs as the feature vector (i.e., 3000 element feature vector). The correct label used for training is from the validation data set. The second-stage Random Forest classifier is trained using 1000 trees. This method reports the single label from the second-stage classifier for each top 5 guess, and therefore should be interpreted with respect to top-1 error rate.

**Method 3: Color Space Fusion (Results Not Submitted)**

- Experimentation has shown that the input image’s color space has an influence in classification result [6]
- Objective was to train CNNs from scratch for specific color spaces (RGB, HSV, CIE LAB) and fuse labels/scores using methods similar to Method 1 and Method 2
- Accomplished by creating copies of the ImageNet data set for each color space
- Used Caffe for training GoogLeNet CNNs to accompany RGB pre-trained CNNs

**Conclusions**

- Novelty of approach is the use of multiple best-of-breed CNNs as input to a second stage classifier, as opposed to simple averaging of their decisions. We envision that applying this method with multiple of the best submissions from this year’s competition could offer improved performance.
- Presented approaches are amenable to applications with limited computing resources or quick turn-around times, as training a second-stage classifier is trivial.
- Also tried:
  - Multiple second-stage classifiers (SVM, Gentle Boost, MP-PiNv, GMM)
  - Hyperparameter search to identify effective neural networks quickly and with minimal manual effort for new data sets
  - Trained our own VGG and GoogLeNet CNNs
- Recommend that top-1 results also be released as part of ILSVRC
- A combination of MatConvNet and Caffe were used for this work

**References**