

Automatic Identification of Footwear Class Characteristics

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Goal: To automatically identify class characteristics of footwear outsole images.

Background: In shoe print analysis, it is often useful to determine the frequency of a given shoe print (or features of the print) in a local population. Machine learning tools, such as neural networks, are an inexpensive and efficient way to automatically identify these features, which may inform about the prevalence of such features.

Footwear class characteristics include the size and shape of geometric design elements. Size, orientation, and position of geometric elements are capable of distinguishing most shoes collected in samples from the general population [1], and can be used to speed up database searches for candidate shoe models [2].



Table 1: Geometric Elements. Categories modified from [3]

An automated algorithm which can identify these features in shoe images could be used to assemble an open-access database of shoe models searchable by image upload or feature selection. Spatial relationships between geometric features could be added to further reduce the number of shoes with the same characteristics.

- A convolutional neural network (CNN) is a tool for deep learning that is well-suited to image analysis.
- Inspired by the brain, CNNs learn global patterns using a hierarchy of local feature detection and pooling
- VGG16 is a CNN [4] pre-trained on ImageNet, an image database with more than 14 million images spanning 20,000+ categories [5].

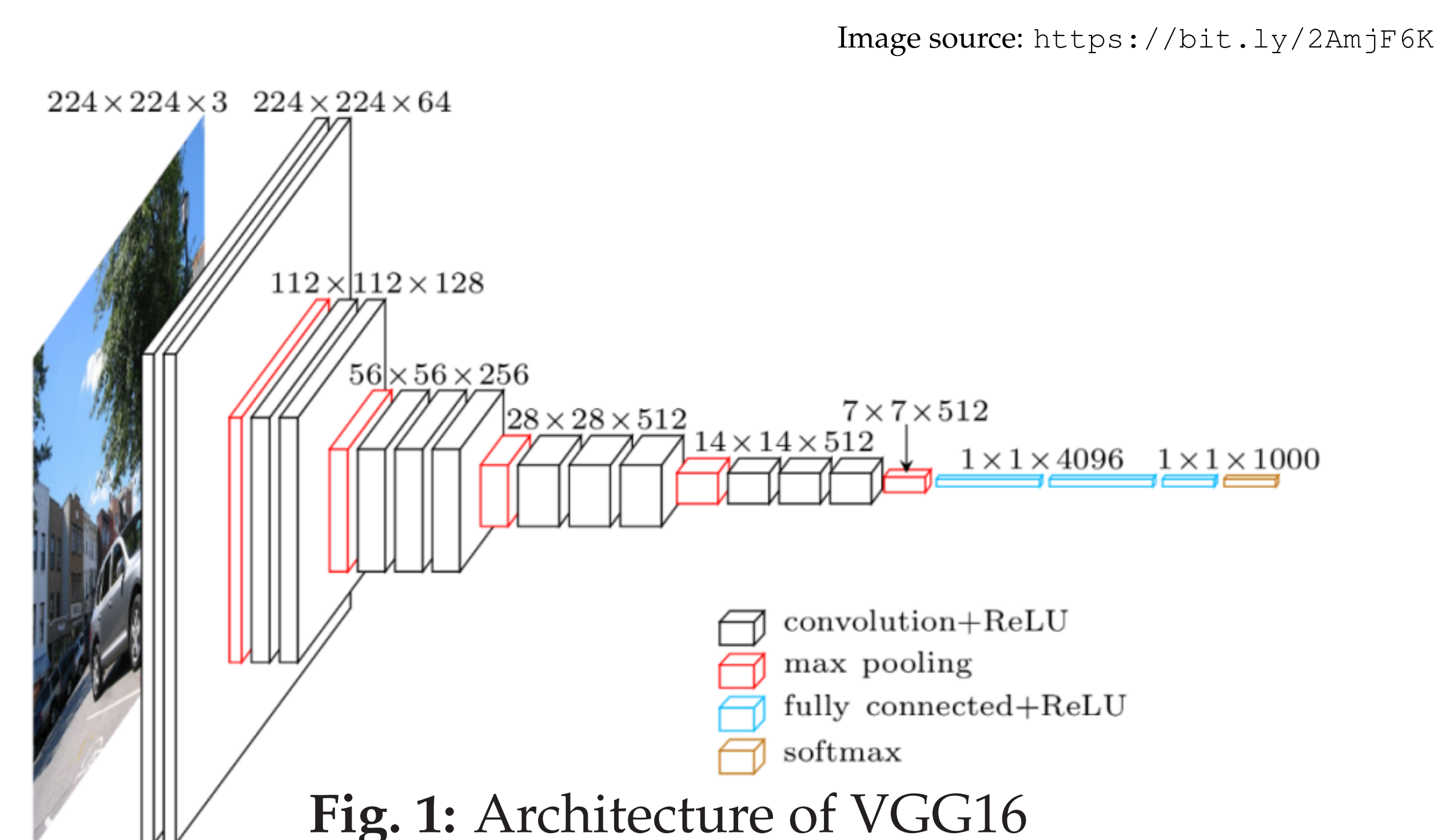


Fig. 1: Architecture of VGG16

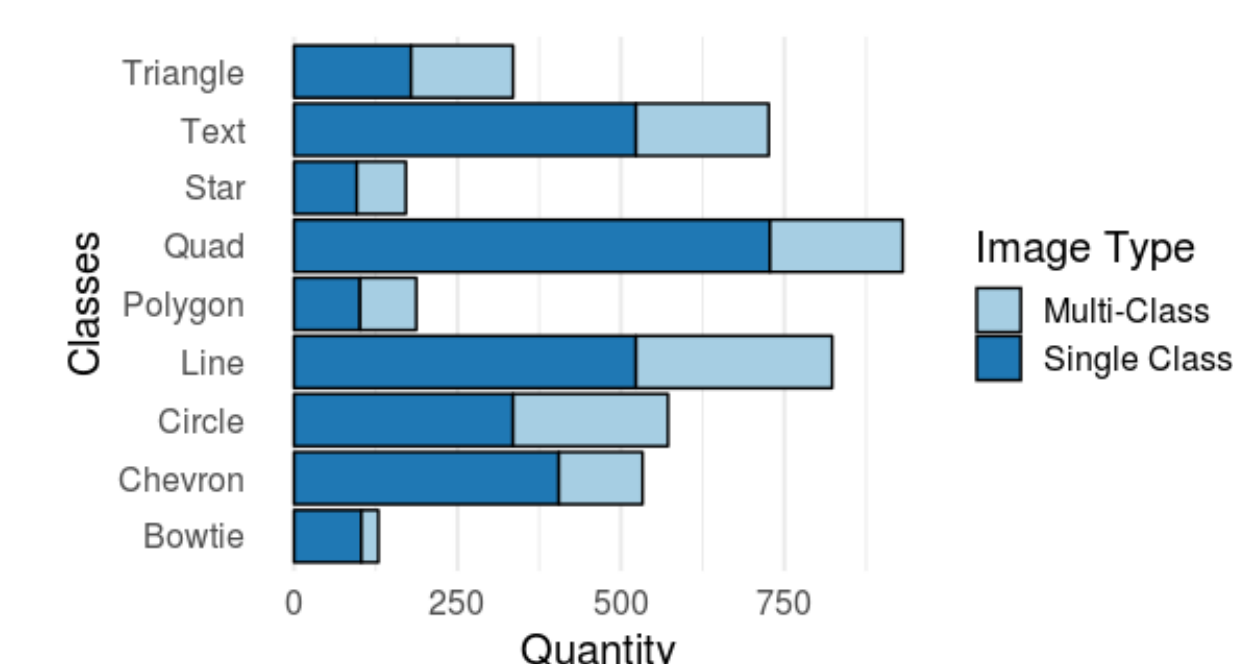


Fig. 2: Label Frequency

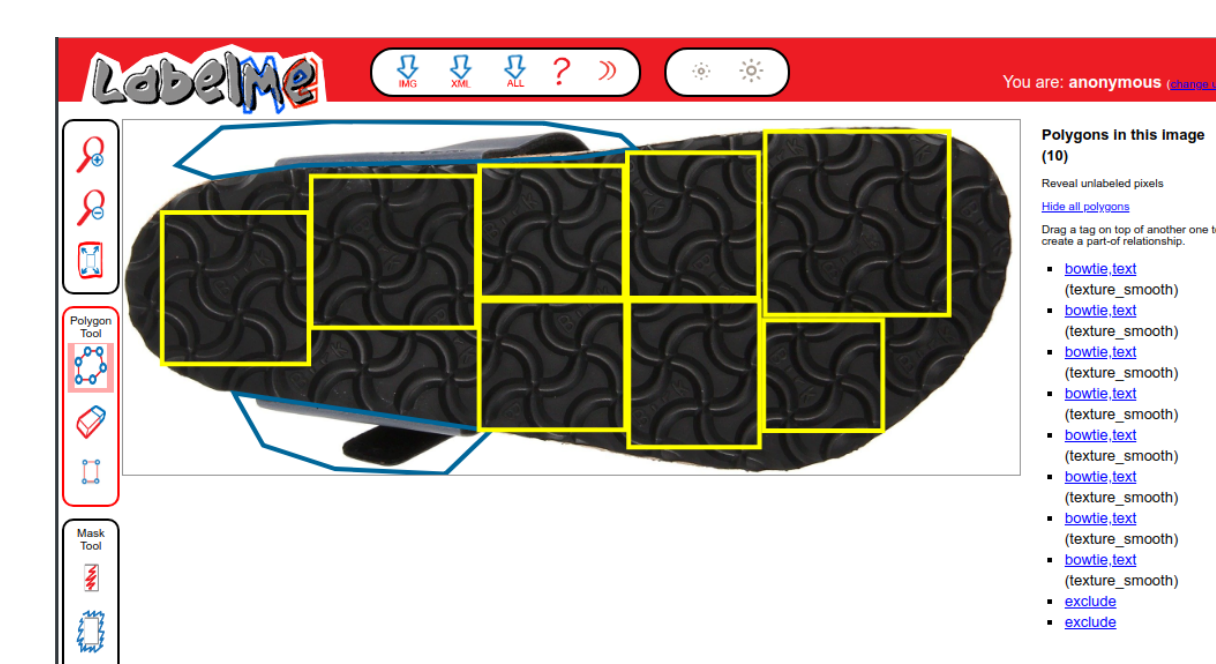


Fig. 3: LabelMe Tool [6]

- 24,000 multi-label images from 2,200 shoes
- Training set: 50%, downsampled to get approximately equal numbers of each label
- Validation set: 25%, used during training
- Test set: 25%, used after training

| Predictions | triangle | text | star | quad | polygon | line | circle | chevron | bowtie | Truth |
|-------------|----------|------|------|------|---------|------|--------|---------|--------|-------|
| triangle | 0.02 | 0.1 | 0.03 | 0.08 | 0.09 | 0.17 | 0.08 | 0.03 | 0.49 | |
| text | 0.06 | 0.06 | 0.14 | 0.04 | 0.03 | 0.09 | 0.03 | 0.64 | 0.09 | |
| star | 0.1 | 0.04 | 0.06 | 0.03 | 0.1 | 0.05 | 0.57 | 0.06 | 0.05 | |
| quad | 0.2 | 0.33 | 0.08 | 0.23 | 0.26 | 0.69 | 0.11 | 0.12 | 0.36 | |
| polygon | 0.02 | 0.03 | 0.05 | 0.02 | 0.54 | 0.09 | 0.11 | 0 | 0.07 | |
| line | 0.04 | 0.21 | 0.05 | 0.58 | 0.06 | 0.21 | 0.07 | 0.07 | 0.12 | |
| circle | 0.05 | 0.02 | 0.61 | 0.02 | 0.07 | 0.05 | 0.09 | 0.11 | 0.06 | |
| chevron | 0.05 | 0.64 | 0.02 | 0.08 | 0.05 | 0.12 | 0.05 | 0.03 | 0.1 | |
| bowtie | 0.69 | 0.06 | 0.03 | 0.02 | 0.06 | 0.06 | 0.12 | 0.01 | 0.08 | |

Fig. 4: Percent of test images identified as containing a class with probability ≥ 0.2 , after accounting for multiple labels

- Features for statistical models to assess match strength
- Speed up database searches
- Estimate frequency of class characteristics given information about local population

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