W2 Statistical Learning Algorithms for Forensic Scientists

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Learning Overview: The goals of this workshop are to: (1) introduce attendees to the basics of supervised learning algorithms in the context of forensic applications, including firearms and footwear examination and trace evidence, while placing emphasis on classification trees, random forests, and, time permitting, neural networks; (2) introduce the concept of a similarity score to quantify the similarity between two items; (3) show how learning algorithms can be trained to classify objects into pre-determined classes; (4) discuss limitations of Machine Learning (ML) algorithms and introduce methods for assessing their performance; and (5) discuss the concept of a Score-based Likelihood Ratio (SLR): computation, advantages, and limitations.

Impact on the Forensic Science Community: The use of learning algorithms will increase as measurement of features in various types of evidence improve. This is particularly true in the case of pattern evidence. Forensic scientists will greatly benefit from understanding the basic ideas that underpin statistical learning since these types of methods have already been proposed for firearms examination, fingerprints, glass comparison, and shoe print evidence.[1,2] Most quantitative training for forensic scientists emphasize classical statistical ideas, so a workshop in which forensic practitioners are exposed to learning algorithms is novel and timely.

When a task consists of deciding whether two items are similar enough to suggest that they could have a common source, an alternative approach is to use statistical or machine learning. Machine learning is the term used to refer to a family of statistical methods and computer algorithms that find patterns in data and has been around for decades.[3] There are many different types of algorithms, but a basic taxonomy is to distinguish between *supervised learning* algorithms and *unsupervised learning* algorithms.[4] The focus of this presentation is on supervised learning methods.

Supervised algorithms rely on training data, for which ground truth is known, and on test data, on which the performance of the algorithm can be tested. In a simple example, several bullets are fired from a large number of guns. To train an algorithm to recognize whether a pair of bullets was fired from the same or from a different gun, one might begin by creating all possible pairs of bullets, and compute, for example, the difference in the average striation depth for each pair. This difference is a feature, and perhaps it takes on low values when two bullets were fired from the same gun and high values otherwise. Presented with the value of the feature for pairs of bullets known to have been fired from the same or from different guns, the algorithm then "learns" that same-gun bullets tend to exhibit values of the feature in a certain range that is different for different-gun bullets. With this knowledge, the algorithm can then classify other pairs of bullets for which it does not know in advance whether the bullets were shot from the same or from a different gun.[5]

In real applications, the number of features can be very large, and the number of classes can also be large. In classification examples, the response variable—or class—is discrete, but algorithms can also be used when the response is continuous; in this case, the problem is to predict the value of a variable given information on a large number of features.

Reference(s):

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2. Park, Soyoung, and Alicia Carriquiry. Comparing 2D images using SURF and graph theory. Submitted.
3. Burkov, Anatoliy. *The Hundred-Page Machine Learning Book*. Self-published, 2019.
4. Efron, Bradley, and Hastie, Trevor. *Computer Age Statistical Inference: Algorithms, Evidence and Data Science*. New York: Cambridge University Press. 2016.
5. Hare, Eric, Heike Hofmann, and Alicia Carriquiry. Automatic matching of bullet land engraving. *The Annals of Applied Statistics*. 11 (2017): 2332–2344.

Machine Learning, Algorithms, Similarity Score