Application of Machine Learning in Criminal Evidence Examination

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Abstract

With the development of artificial intelligence, machine learning has become more widely used in various fields. This paper briefly summarizes machine learning and its classification. Based on the specific research direction of forensic science, this paper analyzes its role in various aspects of test and identification, as well as its effect in application. At the same time, it sums up the problems and deficiencies in its application currently, and look ahead to its future development. In recent years, machine learning has been widely used in the field of forensic science, especially in the test and identification of criminal evidence. In this field, machine learning will be combined with multi-disciplinary knowledge to develop multi-layer integrated systems in the future, which will have even more application value.

Keywords

Machine learning; examination; neural network; individual identification.

1. Introduction

As one of the three main driving forces of artificial intelligence, machine learning has experienced development and breakthrough since its emergence. At present, it has the ability to solve many practical problems and the potential of wide application, which can get more results with less effort as combined with basic technology of other fields. As we all know, the application of machine learning in various industries is not uncommon to see, for example, sorting web pages based on machine learning can personalize the search results according to users' preferences. Because of its ability to actively "learn" data, machine learning help scholars collect, process, extract, and predict massive information in complex dimensions, many of them have introduced it into research and development of verification software systems in the field of criminal science and technology. This paper will briefly introduce machine learning and its classification, its application in different inspection and identification, and summarize problems need to be solved in future research as well as looking forward to its future development and application prospects, which lay a good foundation to make it play a more important role in forensic evidence examination and identification.

2. Machine learning and its introduction

2.1 Machine Learning

Machine Learning, which is based on massive data on the Internet and parallel computing power of computer systems, combined with multidisciplinary knowledge such as probability, statistics and brain science, enables machine autonomously simulate human learning data to make intelligent decisions and other behaviors1. Its development process has mainly gone through the following three stages.

2.1.1 Appearance and germination

Machine learning first appeared in the 1950s to the mid-1960s, while people mainly used software programming to enable computers to implement logical reasoning, computational processing, etc, but

these did not make the intelligence level of computers meet human expectation for machine learning. Researchers have found through further research that these intelligent functions require computer to "learn" a large amount of prior knowledge to gradually acquire it.

2.1.2.Calm and development stage

From the 1960s to the mid-1980s, people realized that existing theories and methods are far from satisfying the actual needs, so they try to extract general rules of their own thinking, then use programming algorithms to make computer have the decision-making ability. With ever-increasing information and data of the Internet, people have envisioned whether computers can learn a single or multiple concepts autonomously, realizing through logical structures or pre-processed images as internal descriptions in conjunction with neural networks.

2.1.3.Prosperous period

Machine learning has developed rapidly since the mid-1980s, and the advent of big data era has made machine learning break through the bottleneck constantly. Since then, machine learning has emerged from the field of artificial intelligence, while more powerful and complex algorithms have been developed, and machine learning combined with various neural networks has begun to be applied in various fields, such as pattern recognition and data mining.

2.2 Machine learning classification

Through the existing literature research on machine learning, author considers that machine learning can be divided into three categories, supervised learning, unsupervised learning, and semi-supervised learning.

2.2.1 Supervised learning

Supervised learning means that providing training samples and the category labels corresponding to them to the learning systems when training models. These tags include the category, attributes, and feature point locations of data, and are continually trained to correct the predicted results. Typical supervised learning methods include classification algorithms such as decision trees, support vector machines, supervised neural networks, and regression algorithms such as linear regression.

2.2.2 Unsupervised learning

Unsupervised learning introduces only samples without classified tags into the learning system during sample training. Machines can only infer predictions by estimating the distribution of large sample data or their relevance. Representative unsupervised learning methods include dimensionality learning methods such as cluster analysis and principal component analysis.

2.2.3 Semi-supervised learning

Semi-supervised learning, also known as reinforcement learning, predicts unlabeled samples by unlimited trial and error in the learning model to find potential links between tag samples and unlabeled samples. Compared with the first two kinds of learning, semi-supervised learning can combine some labeled samples and a large number of unlabeled samples to train model simultaneously, which not only improve learning performance, but also make prediction results more accurate. At present, semi-supervised learning mainly includes semi-supervised classification, semi-supervised clustering, semi-supervised regression, semi-supervised dimensionality reduction.

There are also some scholars who divide machine learning into mechanical learning, teaching learning, deductive learning, analog learning, and inductive learning according to machine learning strategies[2].

3. Application of Machine Learning in Forensic Evidence Examination and Identification

As a technical means of criminal investigation, forensic science plays an important role in criminal investigation. However, traditional methods of inspection and identification cannot meet technical needs of all cases in the era of big data and high-tech crimes, especially when the number of evidence in major cases is huge, the information is cumbersome, or the police force is particularly serious.

Therefore, many scholars apply machine learning to the field of forensic science, helping technicians to better carry out the work of forensic evidence identification and case analysis. Artificial intelligence has become a development trend in the field of technology and the use of it instead of subjective discrimination is an important goal of evidence examination and individual identification.

3.1 Application in document examination

Document examination mainly includes handwriting examination, seal printing examination, printing document examination, etc., and now machine learning is mainly applied to handwriting examination and identification. Online handwriting examination has become mature, but related research of offline handwriting examination is still going on because of its difficulty. .

As early as 2003, Chen Guoming[3] researched and developed a recognition system for handwriting examination through pre-processing of handwriting images to form texture image, and then using Gabor filter to extract features from spectrum analysis, and finally achieve individual recognition. In 2004, he[4]proposed using a support vector machine instead of the traditional distance vector classifier to identify handwriting features. In the same year, Xiao Guohua[5] improved the multi-class support vector machine model and handwriting image preprocessing algorithm, the proposed method achieved good recognition results in text-independent handwriting identification system. During the same period, Huang Yaping[6] used independent component analysis to extract handwriting texture features, and then used neural network to find the optimal feature parameters to form personal handwriting texture labels, of which the experimental results were good.

A few years later, Cheng Lin[7] proposed a recognition method based on multi-scale wavelet texture analysis, fractal dimension and self-organizing neural network classifier for text-independent handwriting recognition, which achieved good results. In the following year, Zhai Yuxin[8] proposed a semi-supervised local dimension reduction algorithm based on measuring geodesic distance for handwriting identification, replacing the Euclidean distance that cannot reflect data manifold structure with the geodesic distance, and proved superiority of this algorithm by comparison.

For feature extraction classification, Zhu RuoXi[9] extracted the text direction line feature of the character outline to form feature space, and then used principal component analysis method to reduce dimension, as well as selected appropriate fuzzy membership function and feature fusion to classify features. Liang Xilu [10]introduced deep neural network into iterative training of sample data to reduce the error rate, and tried to use it to identify imitation signatures, which improved the rigor of machine learning handwriting examination.

3.2 Application in microscale evidence examination

The application of machine learning in microscale evidence is still not extensive. There are many foreign studies, and domestic research in this area is relatively weak., especially in the field of forensic science, which is worthwhile for researchers to explore in more detail. The following highlights some combination of machine learning and microscale evidence examination and identification at the current stage in China for future reference.

In the fiber evidence examination, Yao Ming[11] designed an image automatic processing algorithm for parameters included in fiber edge and section cracks, extracted and evaluated the fiber profile and crack characteristics, and used the multilayer perceptual neural network to learn sample data, which effectively improved accuracy. Min Zhao et al [12] also combined artificial neural network and classification vector machine to classify four carbon fiber fabrics, in which the multi-layer feedforward network has the best classification performance.

In the micro-paint paint examination, Hao Yuyuan [13] used the Fourier transform infrared spectroscopy of trace paint evidence as research object, applied the pattern recognition method SIMCA method and BP artificial neural network algorithm suitable for high-dimensional chemical measurement and data processing to trace paint identification. In this paper, an ANN model for infrared spectral pattern recognition of paint samples was established, with the recognition accuracy rate up to 97%. Zheng Ying [14]et al. established a paint evidence comparison system based on the established paint sample

database of accident vehicle physical information and spectral information, in which we can find the vehicle corresponding to the paint piece extracted on site, that is, the nearest suspect vehicle of the criminal scene, providing the basis for cracking traffic accidents and escaping cases.

3.3 Application in trace examination

3.3.1 Fingerprint examination

Machine learning is focused on fingerprint recognition in the application of trace examination. Foreign scholar Nagaty studied the application of neural network to fingerprint recognition in 2001[15] and 2003[16]. In 2001, he used a three-layer feedback network to classify fingerprints, and this system correctly classified more than 95% of 1500 clear fingerprints. In 2003, he added secondary neural network in it with self-organizing feature maps, which greatly improved classification accuracy and strongthen its anti-noise ability, used for discriminant analysis of fuzzy fingerprints.

In 2005, Zhao Bo et al[17] proposed a new algorithm for fingerprint enhancement, which avoids problems such as loss of true detail points and extraction of pseudo-detail points. The following year, he[18] proposed a fingerprint recognition algorithm based on global direction information, improved the model and related parameters of model-based direction information calculation, as well as the fingerprint recognition accuracy. Ma Baofeng et al[19] used the hyperplane-based support vector machine for learning training and comparison and the results show that the binary vector machine works well. Mao Keming et al[20] also proposed a new algorithm for determining the core point location of fingerprint and calculating the point's direction by SVM, which can effectively improve recognition rate.

4. Tool trace examination

In terms of tool traces examination, Pan Nan et al[21] studied the line traces commonly found in high-speed cable wire-cutting cases, combined with dynamic time warping algorithm based on wavelet features to achieve the matching similarity of trace features, he designed a wavelet domain feature fast traceability algorithm nonlinearity for non-linear line traces to quickly infer or eliminate criminal tool, which has strong applicability.

Some scholars have applied machine learning into other studies. Kingston22 discussed the application of neural network in forensic traces and pattern recognition as early as 1992. The research of Banno23 shows that machine learning can be used for classification and identification of bullet trace, including forgery scenes, deformation trace.

Application in image and video

1. Image video examination

The application of machine learning in this aspect is endless. In the aspect of license plate recognition, Yang Dali etc24 proposed a video license plate character recognition method based on self-organizing neural network And experimental results show that the method is fast, efficient and accurate. While for digital image identification, Dong Jing25 proposed a splicing tampering forensics algorithm based on noise characteristics, and a model that combines a plurality of image features and aggregates machine learning training sample data to detect image tampering..

2.Audio examination

In 2014, Zeng Jinhua et al26 analyzed and summarized current progress and achievements of machine learning in the authenticity study of digital recording. At present, machine learning at home and abroad is mainly applied in the classification and identification of recording equipment microphones, digital recording tampering and recording similarity in equipment identification. In the same year, they 27studied the key feature extraction and integration algorithm of recording equipment, and based on this they did many researches using SVM on separability of recording equipment.

Abdel-Hamid et al 28、29combined with Hidden Markov to establish a model of convolutional neural network for recognizing voice, and conducted experiments on a standard TIMIT voice database. The results show that the error rate of this model is 10% lower than conventional neural

network model with the same hidden layer number and weight, indicating that convolutional neural network model can improve voice recognition accuracy.

3.Face recognition

The earliest face recognition method in literature is the geometric feature-based method proposed by Bledsoe30, which uses the nearest neighbor method to identify the distance ratio between facial points. However, this method is semi-automatic, the feature points must be manually positioned and illuminated and insensitive to light and posture.

Many scholars have proposed a model-based recognition method, which introduces active shape model, Hidden Markov model, active representation model, eigenface method, Bayesian face recognition method, independent component analysis and other methods into face recognition research, optimizing and improving the segmentation extraction, similarity comparison and calculation of facial features, , and gradually improved recognition accuracy and speed. Yang Mei 31proposed an illumination compensation algorithm and improved model based on anisotropic pulse coupled neural network for changing illumination, and verified its practicability and validity in real-time face recognition system through experiments.

Recognition based on neural network has also developed earlier, Kohonen32 introduced self-organizing map neural network into recognition system in 1994, and Lawrence and Giles 33 added convolutional neural network for identification, which improved recognition performance. Domestic scholar Jiang Yanxia 34 also designed a new face tracking recognition method based on adaptive feature subspace, and applied robust statistical technique and path similarity measurement in the robust local reservation mapping method, which can complete tracking and identification at the same time, as improving the recognition accuracy.

In the design of identification system, multi-classifier integration has become reality needs. Gutta et al35 combined integrated RBF with decision tree to improve recognition accuracy. Huang et al36used neural network integration and realized automatic judgment and recognition of multi-view faces. Liu Yang37combines wavelet analysis with neural network to effectively improve recognition efficiency and accuracy. Zhao Yiru[38]has improved the face recognition method based on self-training interval neighbors several times, achieving higher recognition with small samples. Yin Ruoxuan[39]studied and improved face super-resolution reconstruction algorithm based on weighted sparse representation, and introduced machine learning to solve the face recovery problem in actual surveillance video. A set of face recovery method based on poisson image editing was proposed with good results.

At present, face recognition is still a hot research topic in machine learning. More and more scholars are proposing new algorithms and system optimization designs to improve feature extraction algorithms and recognition system.

4.1 Application in examination of physical and chemical evidence

Casamento et al[40]introduced machine learning into condition optimization for the separation of explosive components by capillary electrophoresis. Casale[41] uses self-organizing neural network to identify characteristics of cocaine gas chromatographs. The results show that the method is more accurate and sensitive than cluster analysis and correlation analysis. Waddel et al[42]also used neural networks to study a large number of hallucinogen data, and experiments show that it has stronger data classification ability and higher value than principal component analysis and hierarchical clustering.

In residue analysis, Tana et al[43]used gas chromatography-mass spectrometry as well as multivariate pattern recognition method to detect and distinguish the combustion improver of petroleum products, using principal component analysis with similarity analysis to study the classification of combustion improver and the relationship between the sample and carbon size.

In the explosive examination, Chen Tao et al[44]used the fuzzy clustering analysis method to establish a standard terahertz absorption spectrum model database, which realized the effective classification and identification of elemental explosives, mixed explosives and confusing substances. In the following year, he[45] used the THz spectrum of biomolecules as the data feature, combination of principal component analysis and fuzzy pattern recognition to form a standard THz spectral model

database, which improved THz spectral recognition accuracy of biomolecules and realized biological automatic identification of molecular THz spectra. At the same time, he also proposed a THz-TDS technology combined with chemometrics to achieve non-destructive and non-destructive quantitative analysis of multi-component mixture, and introduced multiple characteristic spectral region screening algorithms into the THz spectra quantitative analysis of multi-component mixtures. In this way, the quantitative analysis accuracy of multi-component mixture with THz spectrum model is effectively improved, and the model complexity is reduced, as the quantitative content detection of multi-component mixture is fast, efficient and non-destructive, which have a broad development prospects and application value in the field of biological, physical and chemical evidence examination .

4.2 Application in forensic examination

4.2.1 Forensic pathology

Bocaz-Beneventi et al46used capillary electrophoresis combined with neural network to study the relationship between sodium, potassium components in the vitreous humor and death time of 61 cadaveric bodies at different time points after death, and the results showed that neural network can improve the accuracy of speculative PMI, and show the correlation between different components and death time. Boulle et al47applied neural networks into the analysis and prediction of specific death causes, as the results showed that the sensitivity and specificity of it were good.

4.2.2 Forensic anthropology

In 2004, Femandes48used spiral CT to scan the skull to obtain the size, volume and shape of maxillary sinus, applied neural network into racial and gender analysis, resulting in 90% and 79% correct rates. Verma et al49adopted deep neural network to carry out hair individual recognition research, using 5/21 hair morphological features to achieve 83% classification rate, which is more accurate and reliable than traditional methods. In gait individual identification, Xia Wei50improved footprint segmentation algorithm for the collection and analysis of plantar pressure image, introduced the switch median filtering algorithm to eliminate impulse noise, and realized block division by density clustering. Based on the ground reaction force (GRF) gait recognition, the spatiotemporal HOG feature is constructed, realizing gait recognition by the SVM based on RBF kernel function as classifier. The study also established a particle filter-based footprint tracking model for multiple pedestrians, and conducted classified experiments of abnormal gait detection.

5. The development prospect of machine learning in forensic evidence examination

In recent decades, machine learning has become more and more widely used in criminal evidence examination and identification work at home and abroad, which has been successfully applied to speech recognition, face recognition, gait recognition, handwriting recognition, etc. These applications have effectively solved difficulties in the actual work of technicians, saved a lot of time and energy of manual extraction of features and subjective discriminant analysis, avoiding disadvantages accumulated by technicians' own operation errors. This development trend that artificial intelligence and traditional technology are combined and promoted not only promotes the development of artificial intelligence itself, but also facilitates the maturity of technology in the field of forensic science. However, at this stage, these technologies cannot be applied to technical work in comprehensive or whole process, and still faces some challenges in various aspects, such as the lack of mathematical theory, the solution of deep neural network training. From current development research trends in this field, the next stage of machine learning mainly has the following aspects of development.

5.1 Unlabeled data learning

At present, machine learning in forensic evidence examination and identification still uses a supervised learning method on a large scale. Although the final recognition rate is high, the previous sample processing and learning training take a long time. In order to popularize it more widely and

more rapidly in the grassroots police, the next stage needs to research and develop more advanced algorithms or adopt new models for unsupervised or semi-supervised learning, while accumulating theoretical knowledge to select reasonable parameters such as regularization intensity, effectively shortening training time and improving efficiency of examination and identification.

5.2 Convenient application of small model technology

The convenience of machine learning applications in forensic science work has always been pursued by criminal technicians. However, due to the limitations of existing models and algorithms, this goal has always been limited in practical applications and research. Therefore, in future research, the application of large models needs to be simplified continuously, and the development of small model technology should be focused at the same time. Designing mobile portable devices or software such as APP can enable technicians to quickly and accurately complete the examination work, which make them widely used in site survey, species identification, individual identification, etc.

5.3 Complex dynamic decision-making task application

The application of the existing machine learning model is mainly for the processing of static tasks in forensic evidence examination, such as fingerprint recognition, handwriting recognition, fiber recognition, etc. Some of the dynamic tasks such as gait tracking and video recognition still have some difficulties. The application of machine learning in the field of forensic science and technology will focus on the research of dynamic identification and decision making, further broadening the application scope of new technologies and improving the efficiency along with the quality of multiple identification work, which will truly make machine learning become a good helper for criminal technicians.

6. Conclusion

In summary, the application of machine learning in the field of criminal science and technology is very extensive, and the future development prospects should not be underestimated. Information of forensic science work is complex and susceptible to many factors, which require technicians to spend a lot of time and energy to distinguish between right and wrong, to balance the weight and usually part of work is subject to factors and experience of technicians. Machine learning can automatically process information, which can reduce or even avoid the impact of technicians themselves on test identification results, making it more accurate and objective. More importantly, machine learning can "learn" multi-disciplinary information knowledge of forensic science, form a multidisciplinary neural network or a comprehensive examination and identification system, and improve efficiency and quality of them.

Of course, there are still some shortcomings in machine learning, thus further research and improvement are needed. For example, there is no standardized training and parameter control method when conducting sample training or the existing algorithms cannot meet the needs in the face of multidisciplinary data processing. These problems require researchers' past experience and practical work requirement to adjust and explore. In addition, researchers cannot fully explain the parameters obtained after sample training, so this method cannot replace traditional identification method, can only being used as auxiliary means of existing work.

No means is perfect. Machine learning has solved many problems for technicians in practical work of forensic evidence. It is worth noting that with the deepening and maturity of future research, machine learning will play an increasingly important role in this field, and the scope of application will become wider and wider.

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