INTRODUCTION

Modern trends in pattern recognition and applications

Pattern recognition can be considered from different perspectives: historical, methodological, technological, and application-oriented. Literature sources give different date sequences of milestones in the development of pattern recognition theory. Some of them start from philosophical and psychological sources of the beginning of the 20th century. However, all the sources mark the period of 1930–1950 as forming the mathematical basis and raising the key ideas in cybernetics, facilitating the interest in pattern recognition in its simplest forms. It was understood that animals and humans could solve a lot of tasks due to processing a particular type of information (signals in a wide sense) or several types of information jointly. People started to ask themselves whether it was possible to realize some actions similarly to animals and humans by appropriate processing of analog and, later, digital signals. Due to joint efforts and the fast development of several areas of science, pattern recognition started to become a particular direction that manifested itself by the appearance of famous books of classic texts by Duda and Hart in 1973, Fukunaga in 1972, and some others (many of them were reissued later with the incorporation of new knowledge and achievements).

Any pattern recognition system has, first, to register and/or collect data from available sources and then carry out a certain feature extraction and, probably, their representation or preparation; after this, similarity detection is to be performed using a designed classifier. In the process of such a design, performance evaluation is a typical step. At each of these stages, there are numerous factors affecting how well the final pattern recognition goal is reached. Consider an urgent task of UAV or drone detection, localization, and classification. At least, there are four sources that can be potentially employed: vision, sound (acoustic signal), reflections of radar signals, and infrared (thermal) irradiation. Meanwhile, not all sources of information can be available simultaneously, infrared data are much more informative during nighttime, while visual observation is able to give more information during daytime, although in good weather conditions.

However, even if potential sources of information for pattern recognition are clear or can be established, the next stage task is to retrieve useful features and

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represent them properly. For the application mentioned above, this can be a drone image in visual or infrared bands (if resolution is appropriate), the object shape and color, the spectrum of acoustic signal, a radar portrait, or information on the object speed retrieved from radar reflection, etc. Then, the general feature extraction tasks divide into subtasks of finding the best features, selecting their number, providing real-time processing if necessary, combining the features of different origins, etc.

Similar problems often arise in other applications of pattern recognition. One good example is content-based image retrieval (CBIR) – the research topic that was popular about 30 years ago, the achievements of which were later realized in many modern browsers. At first sight, it is clear that shape, color, and texture features should be exploited. However, first, later it has occurred that image statistics can be useful, and, second, the tasks of finding the best feature representation, choosing their number, and the best aggregation strategy appear.

One more aspect is the rapid development of some scientific areas that, for a certain period, become a trend, seeming to be able to solve "earlier unsolvable" tasks. In the 90s of the previous centuries, it seemed that wavelets would throw other orthogonal transforms into the past and neural networks would replace all earlier designed classifiers. However, after one or two decades of accelerated development, the studies often slow down and attention is switched to other directions (methods, tools). At the moment, there are numerous classifiers, including not only neural network-based ones but also support vector machine, decision tree, and statistical classifiers.

Depending upon a situation at hand, different classifiers might occur as the best. This depends on a task to be solved, available a priori information, criteria of optimality or metrics used for performance evaluation, learning strategy, etc. A tendency of recent years is to employ convolutional neural networks (CNNs), the main advantages of which are the ability to learn better than conventional NNs due to better extraction of features. Numerous publications have appeared showing the applicability of approaches based on deep learning and artificial intelligence to solving various tasks in absolutely different areas (image processing, remote sensing, economics, agriculture, etc.). Some particular cases are studied in this monograph.

Three critical problems in deep learning-based data processing for pattern recognition and diagnostics are the following. First, one needs to have a database (dataset) or databases for learning with previously marked objects (classes). These datasets have to be large enough (e.g., contain hundreds or thousands of images with objects having different sizes, orientations, viewing conditions, and so on). This explains why numerous databases have appeared recently and continue to be designed (e.g., for infrared and underwater images). Second, there are many types and modifications of CNNs, and they continue to appear. Then, it is a problem to choose the best CNN for an application at hand or to retrain the already used CNN if conditions of its use have changed. Third, even for the best CNN trained well, it is always possible that the pattern recognition (classification) result is wrong. A question then is, what are the consequences of such wrong recognition, especially taking into account that it is becoming more and more popular to deliver decision making to artificial intelligence?

Summarizing the aforesaid, it is possible to state the following:

1) pattern recognition continues to develop, encapsulating new areas of its application;

2) it is possible to expect rapid development of machine learning and AI approaches for at least the next decade;

3) pattern recognition and diagnostic approaches become more motivated intuitively (based on assumptions and achievements of studies of human brain activity) rather than mathematically; due to this, learning is put into basis, and, thus, the creation of the corresponding databases becomes necessary as well as significant computations;

4) there is a caution that any trained CNN is able to produce quite reliable results only for conditions for which it was properly trained, while the outcomes for unexpected situations (conditions) can be wrong with high probability, and this can cause problems.