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Plant Identification Based on Artificial Intelligence

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Abstract. Species identification plays an important role in botanical research, but traditional identification tool, which mainly depends on reference books or identification keys, is often recognized as a difficult and frustrating task, especially for novices. In recent decades, many efforts have been made by taxonomists and programmers to ease the difficulty of species identification by developing a range of tools that increasingly involved the use of computers. In this paper, new advances of plant identification based on three main artificial intelligent technologies: expert system, artificial neural network, and machine vision are briefly introduced. Several trends of plant identification tools for non-expert users are also proposed in the last part.

Introduction

For a long time plant identification was a skill of survival necessity for all the people and it has been passed down from one generation to another. The proper knowledge and usage of plants has been one of the most important drive to the progress of human civilization. Now in modern society plant identification is no more a survival necessity, but it is still an important subject in education, horticulture and traditional medicine area. In addition, the development of precision-farming and growing number of plant fans also expand the demand for plant identification skills. However, plant identification, particularly for non-experts is a difficult and often frustrating task. Traditional plant identification mainly depends on the accumulation of people's own knowledge or the help of experts or books, which is either time consuming or unpractical. With the development of computer technology, many taxonomists or programmers are making their efforts in the development of tools aimed at easing the task of identification. Since 1960s to present, artificial intelligent technologies such as expert system, artificial neural network and machine vision have worked excellently in the development of non-expert plant identification tools.

Artificial intelligence (AI) with related technologies

AI is the study of computations that make it possible to perceive, reason, and act [1]. It was first proposed at a conference on the campus of Dartmouth College in the summer of 1956. By the end of the 20th century, many technologies such as Expert System (ES), Artificial Neural Network (ANN) and Machine Vision (MV) have been developed and applied in many fields.

ES is a branch of applied artificial intelligence (AI) developed in the early days of AI era. It was defined as "sophisticated computer programs that manipulate knowledge to solve problems efficiently and effectively in a problem area" [2]. An ES is often composed of four parts. They are the knowledge base (a collection of rules or other information structures derived from the human experts), the inference engine (the program at the core of the system which derives recommendations from the knowledge base and problem-specific data in working storage), the working memory (the data which is specific to a problem being solved) and the user interface (the means of communication between a user and the ES in problem-solving processes) (Fig. 1). When working with an ES, the computer obtains information via a question-answer dialogue as if the expert is obtaining information from clients. At the end of the dialogue, the system will produce a conclusion or a piece of advice.

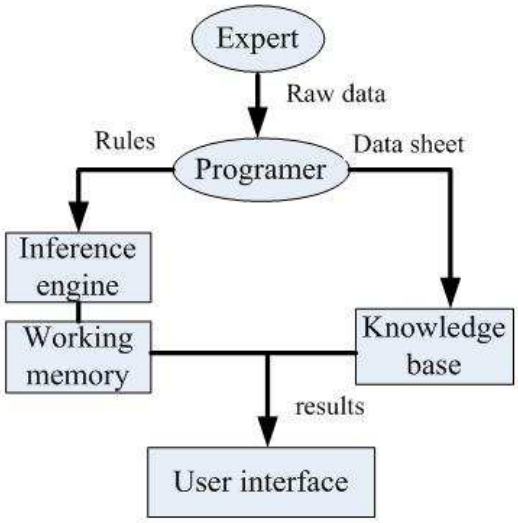

Fig. 1 The functional integration of components in an Expert System.

ANN is a powerful general-purpose tool applied to many tasks where data relationships have to be learned or, decision process and predictions have to be modelled from examples [3]. It was first developed early in 1958 by psychologist Rosenblatt [4] but was not widely used until 1980s. Generally an ANN consists of a pool of simple processing units (nodes or neurons), which are divided into three types of layers: one input layer (consists of input nodes), one or more hidden layers (consists of hidden nodes) and one output layer (consists of output nodes). When train an ANN, raw data is fed into network via input layer, processed in hidden layers, with results come out from output layer (Fig. 2).

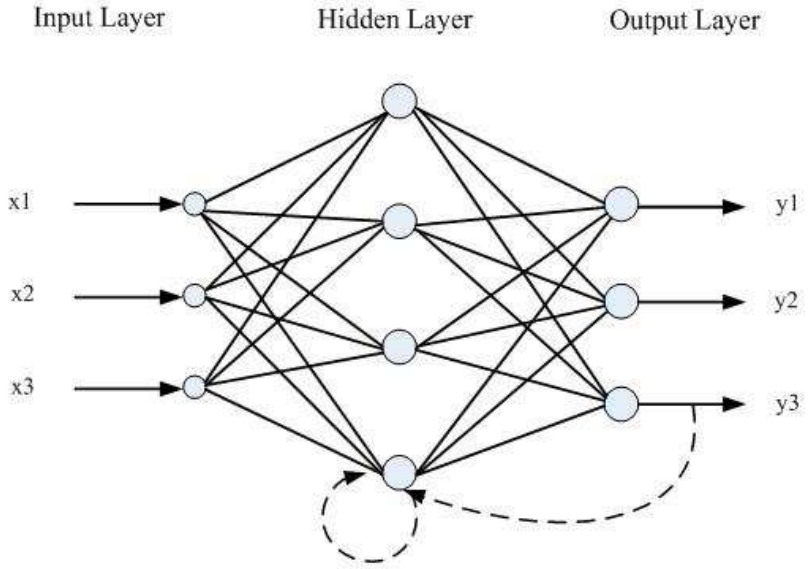

Fig. 2 Scheme of Artificial Neural Network (ANN).
(real line means Back Propagation ANN, dashed line means Recurrent ANN)

Machine Vision is a technology attempts to identify objects represented in digitized images provided by video cameras, thus enabling robots to "see" [5]. A complete MV system often consists of a sensor (for example a camera), which gathers the raw information, a feature extraction mechanism that computes numeric or symbolic data from the raw information, and a classification or description scheme (often called classifier) that does the actual job of classifying.

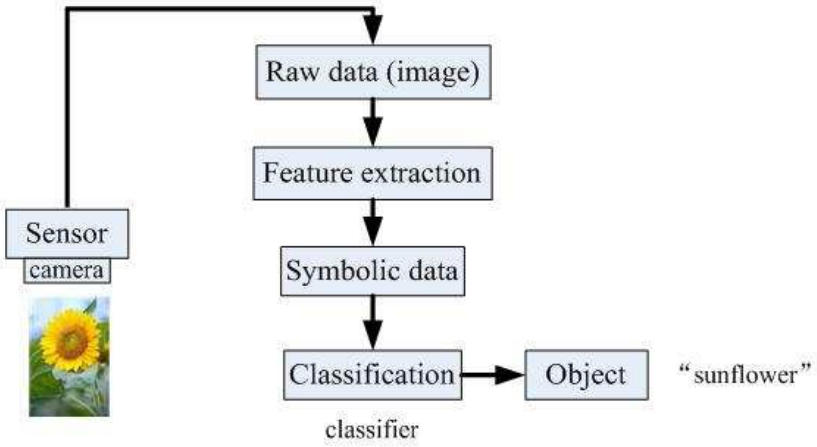

Fig. 3 Scheme of Pattern Recognition.

Application of AI technologies in plant identification

It has been a long time since AI technologies were used to plant identification. ES started to be implemented in plant identification in 1980s [6]. Early systems were more of trials on methodologies such as forward-reasoning [7], back-propagation [8] or Fuzzy ES [9]. In recent years, more attention were paid to the practicality and convenience of systems, such as online plant identification aid systems [10]or crop disease diagnosis systems [11]. Lopez-Morales (2008) developed an integral intelligent system for the diagnosis and control of tomatoes diseases and pests in hydroponic greenhouses [12], Gonzalez-Andujar (2009) developed an expert system for pests, diseases and weeds identification in olive crops [13]. These researches have opened a new application of computer-aided plant identification in an important field called precision farming. There are also identification systems specified for a small area. For example, Cai et al. (2007) developed an Expert system for the identification, classification and verification of plants in Tian Mu Mountain, China [14].

The application of MV in plant identification also started in 1980s. Guyer et al. (1986) analysed some parameters, such as length, width，density of leaves from eight plants and proposed the possibility of applying Machine Vision to plant identification [15]. Not long after that, Franz reported having built a plant identification system using shape descriptions from digital images [16]. Woebbecke used color indices for weed identification under various soil, residue and lighting conditions [17]. Although these researches were mostly based on simple parameters from images and used statistical method or low-level rule base as classifiers, partly restricted by the hardware and software situation at that time, their success excited more tries and important progress in this field. Tang et al. (2003) used gabor wavelets and neural network for real-time selective herbicide application [18]. Wang et al. (2007) built a real-time, embeded, weed-detection system for the identification of weeds in wheat fields [19].

ANN started to be used in plant identification in 1990s. Clark & Warvick (1998) used a multilayer perceptron neural network to generize artificial keys for plant identification [20]. One year after that, Mancuso and Nicese developed a Back Propagation Neural Network (BPNN) to distinguish 10 olive (*Olea europaea* L.) cultivars [21]. Compared with a simple ANN, BPNN has a back propagation algorithm thus can generate a much better accuracy. This has been proved in identification systems of Rollinia (*Annonaceae*) species [22], grape (*Vitis vinifera* L.) genotypes [23] and rice varieties [24]. One weak point of these ANN is their morphological characters (features) were mainly collected manually. In some cases, raw data should even be collected by experiments [25]. As the development of image processing softwares, automated feature extraction became possible. Plant identification system based on image, especially leaf image, seemed more promising. Du et al. (2006) developed a plant species identification based on leaf shape matching technique [26],

Bruno et al. (2008) used Fractal dimension for the process of feature extraction. Features extracted from leaf image can be shape, color, margin or texture [27]. Wu et al. (2007) developed a leaf recognition algorithm for plant identification using probabilistic neural network [28]. Mugnai et al. (2008) used an ANN based on phyllometric and fractal parameters for the identification of *Camellia japonica* L. genotypes [29], Wu et al. (2009) identified weed/corn with BPNN based on wavelet features and fractal dimension [30], Qi and Yang (2003) used sawtooth feature of leaves for plant identification [31].

The development trends of plant identification tools

Till now, most identification systems are based on 2D image data, which is often mixed with data from non-target plants and lead to a lot of work in denoising process. 3D stereo data may overcome this problem fine. But identification systems based on 3D tereo data requires a high running speed of computer. This is still a bottleneck at present, but it will surely not a problem in the future.

As the development of internet, the communication between people and experts is becoming more simple and convenient especially when internet interactive with cellphones and every phone has a camera embed. In the future, there will be some service websites or even companies working for plant identification. When the user is interested in an unknown plant, he can take its image with his cellphone and send the image to the website, where some experts are on line and may reply the query immediately.

In recent years, the development of data mining gives plant identification another choice. Ten years ago, we would not imagine getting a mass of information by inputting a single word according to a search engine such as Google. Now it has become as common as eating a cake. The shortage of this technology is we can only search by words till now. If in the next ten years we can search by inputting an image and get its name or some other information, that would be a new reform of plant identification.

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