Applications of Deep Neural Networks in Agriculture

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Introduction

Due to increased internet usage, many changes are occurred in cultural, social, philosophical and economic relations. Agriculture science is evolved at high scale due to involvement of digital technologies. This impacted the production of goods, their distribution and consumption of agricultural goods and services, from the farmers to consumers. Modern agriculture needs to have high production efficiency combined with a high quality of obtained products. This applies to both crop and livestock production. To meet these requirements, advanced methods of data analysis are more and more frequently used, including those derived from artificial intelligence methods.

Emerging ICT technologies relevant to the understanding of agricultural ecosystems include remote sensing (Bastiaanssen et al., 2000), the Internet of Things (Weber and Weber, 2010), cloud computing (Hashem et al., 2015), and the analysis of big data (Chi et al., 2016;Kamilaris et al., 2017). Remote sensing provides large-scale snapshots of the agricultural environment by means of satellites, planes and unmanned aerial vehicles (UAVs, i.e. drones). When applied to agriculture it has several advantages, being a well-known, non-destructive method of gathering information on earth features. Remote sensing data can be collected on very large geographic areas, including inaccessible areas.

The IoT uses state-of - the-art sensor technology to measure various parameters in the field, while cloud computing is used to collect, store, pre-process and model huge amounts of data from different, heterogeneous sources. Eventually, big data processing is used in conjunction with cloud computing to analyze the data stored in the cloud on a large scale in real time (Waga and Rabah, 2014; Kamilaris et al., 2016).

A large sub-set of the data collected by remote sensing, and the IoT contains images. Images can provide a complete picture of agricultural fields and a number of problems could be solved through image analysis (Liaghat and Balasundram, 2010; Ozdogan et al., 2010). Therefore, image analysis is an important area of research in the agricultural domain and intelligent inspection techniques are used to identify / classify pictures, recognize abnormalities, etc., in different agricultural applications (Teke et al., 2013; Saxena and Armstrong, 2014).

Artificial neural networks (ANNs) are among the most common methods for predictive big-data analysis. They are commonly used to solve different classification and prediction problems, also in the broadly defined agricultural sector, for some time. They may

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be part of systems for precision farming and supporting decision making. Artificial neural networks can replace the classical modelling methods of many problems, and are one of the main alternatives to classical mathematical models. The scope of artificial neural networking implementations is very wide. For a long time now these methods have been used by researchers from all over the world to support agricultural production, making it more effective and providing the highest-quality products possible.

In spite of considerable development of several indirectly connected scientific fields as well as various research methods and techniques, ANNs mimic the work of man's nervous system only partially. Thus, the help of multifaceted tools, such as relevant computer programs, algorithms and other mathematical tools are needed when ANNs are used for analyses. Research has been carried out on various algorithms that can be applied in the analyses performed by ANNs (Graupe 2013). This approach allows the processes of network learning, and can make man's work easier, especially when dealing with complex tasks where traditional statistical methods cannot be applied.

There are two major learning paradigms when using the ANN analysis, each corresponding to a particular abstract learning task. These are: controlled instruction (with the so-called "teacher") and unsupervised (without "teacher") study. The first paradigm is used when the response provided by the network may be checked. In this scenario, the significance of the output vector, which is the exact answer to a given task, is calculated for each input vector (e.g. in agronomy, soil quality, nutrients, and crop year (Wieland and Mirschel 2008). When the answer is not known the second learning method is implemented.

Concepts and Definitions

ANNs are computer programs designed to represent just how information is interpreted by the human brain. That is to add, they are the digitized human brain models (Rosenblatt 1958, 1988). An initiation function characterizes the ANN models, which uses interrelated information processing units to transform input into output. Knowledge is acquired by detecting relationships and patterns in the data through neural networks. Raw input data is obtained by the neural network's first layer where it is analyzed, and then passed to the hidden layers. The hidden layer then transfers the knowledge to the final layer where it outputs the output. ANNs are trained through experience with suitable learning exemplars in like manner to human but not from programming. They learn from given information, with an identified outcome that optimizes its weights for a better prediction in circumstances where there is an unknown outcome.

Each individual neuron in the nervous system works independently, but as part of a network it transmits information obtained from prior neurons to further ones. In the case of artificial neural networks, this means that a given neuron sums up input signals with appropriate weight values obtained from prior neurons and creates a non-linear threshold function of the sum obtained, which is sent as input signal to other connected neurons. The rule functioning in ANN functions is based on an "all" or "nothing" rule, which is described by a function that can take two possible values, 0 or 1 (**McCulloch-Pitts model** (Osowski 2013)): the value 0 means that the excitation was lower than the activity threshold of the neuron, and the value 1 means that the excitation was higher than the activity threshold of neuron.

One of the first most known and well described examples of artificial neuron networks is the so called "**perceptron**" (a model of the nervous cell), which was proposed by F. Rosenblatt in 1958 (see Rosenblatt 1958, 1988). This net design had many advantages, but its effects were not fully satisfying. The greatest benefit of the net was the fact that it acted appropriately even though one of its elements was damaged. On the other hand, the neural net could not further complicate the task, and it is an indication of considerable susceptibility to the various changes, which were happened in process of learning (Tadeusiewicz 1993).

Until the eighties of the last century, research on neural networks had been neglected, and only the rapid development of Very-Large-Scale Integration (**VLSI**) technologies succeeded to instigate a renewed interest in methods of information processing, including neural networks (Osowski 2013). The work of Hopefield (1982) on ANNs was a milestone of research in this field, and was continued in an increasing number of scientific centers. Hopefield's works led to a substantial increase in scientific projects on ANNs, which not only resulted in new types of networks, but also added to the progress of practical implementations of this method. At the same time, rapid progress in informatics and computer systems resulted in the creation of innovative solutions and greater possibilities of exploring, learning and testing ANNs. Research on artificial neural networks is nowadays an increasingly popular domain of knowledge, being used in various scientific fields (Hashimoto 1997).

Chronological development in applications of neural networks in agriculture

In systems involving plant environments related to agriculture, in which sudden and quick changes of environmental conditions usually take place, the selection of an appropriate net is difficult. Such environments present non-linearity of variables in time, and are affected by many unknown factors. Therefore, it is difficult to assess complex relationships between the input and output signals founded on analytical methods.

In this study, areas in agricultural science have been identified are mentioned in fig.1.

Fig.1 Agriculture problems addressed using neural networks

There are many different methods currently used in agricultural and biological sciences (Kalra 1998; Benton and Jones 2001), but sometimes these are not efficient enough in analyses based on scores of obtained results. Thus, the use of ANNs has become increasingly popular in these domains of science, as for example in the study carried out by Kim and Gilley (2008) on the relationships between soil erosion and precipitations. The results of these simulations, performed using models derived from ANNs, indicated that the amount of soil erosion was positively correlated with the amount of precipitations and run-off.

Additionally, it was found that water erosion was the direct result of the detachment of soil particles by raindrops. Further, in this study it was concluded that ANNs could generate models that reflect the non-linearity in the nutrient medium of the plants derived from the **erosion of the soil**, due to the excess water. The later can also lead to uncontrolled nutrient leaking (Kim and Gilley 2008). In the above-mentioned research, the authors used the Neural Works Professional II/PLUS (NeuralWorks, Carnegie, Pennsylvania) Version 5.22 software for the construction of a multi-layer net; this package allowed the elaboration of their own model by providing selected net parameters and system control.

ANNs can be applied in studies on a great variety of topics, as it will be shown below. For example, studies on decreasing herbicide rates are important, since they are related to the negative effects of herbicides on the environment (i.e., pollution). In such a research, aiming the **optimization of the herbicide rates** (Moshou et al. 2001), the best results were obtained by using multi-layer perceptron BP trained, vector quantization and various methods based on self-organizing maps (SOM).

Aji et al. (2013) applied an ANN in their study concerning palm oil. There are many diseases which can attack palms, which result in a substantial decrease in oil production. Detection of any pathogen at early development stages is difficult, thus the authors used in their study a specific technology designated to produce an **early diagnosis and classification of the disease**; they also proposed an appropriate treatment of this disease. The ANN was trained in image processing, and was able to diagnose three threatening palm diseases. A special method, called 'the complex linearity method' was designed to shorten the time needed for disease recognition by using mobile devices in investigations. It was based on visual analyses performed by means of image processing in a specially designed spatial system in an ANN. The optimal number of ANN layers selected by the authors was 6 (Aji et al. 2013). In this way, by using the classification model in the learning process, 87.75% of diseases were identified in the palm leaves under investigation.

Qiao et al. (2010) analyzed **water uptake in the soil** environment, by taking into consideration that water absorption by roots is reliant on the density and humidity of the soil around growing roots. Water uptake by plant roots is an important process in the hydrological cycle. It is not only crucial for plant growth, but also plays an indispensable role in determining microorganism communities, as well as by influencing the physical and biochemical properties of the soil. Root capability to extract water from soil depends on both soil and plant properties. Determination of volume, conformation and distribution of the roots in soil poses a lot of difficulties to scientists, since non-invasive methods for explicit description of the whole plant root system have not yet been elaborated. Thus, the authors proposed an alternative method (still being tested) based on ANN analyses of data on plant water uptake. The absorption rate was estimated based on direct measurements of mass balance, the evaluation of soil moisture following Darcy's law (Brinkman 1949), and the assessment of water content in soil derived from calculation of capillary potential at 100 cm depth.

Another important subject of study is the **water deficit** (e.g., during drought), which is one of the most important environmental factors limiting sustainable yields, and needs a reliable tool for its quantification. Measurement of the chlorophyll a prompt fluorescence (PF), simultaneously with that of delayed fluorescence (DF) and reflectance at 820 nm (MR), allowed the analysis of changes in the performance of the photosynthetic machinery in bean leaves submitted gradually to drought conditions compared to a control (Goltsev et al. 2012).

Likewise, many different studies have been conducted with the use of ANNs in agricultural research. The majority of those involve **forecasting** (Jiang et al. 2004; Uno et al. 2005; Savin et al. 2007). Jiang et al. (2004) described an ANN model with backward propagation. Savin et al. (2007) used information obtained from the **SPOT VEGETATION satellite to forecast** the winter wheat **yield**. The algorithm, which they were developed is the connective utilization of ANNs - fuzzy sets, fuzzy neural networks (FNNs) and granulated neural networks (GNNs). Uno et al. (2005) elaborated models for yield prediction in corn using statistical and ANN methods based on various data on plant vegetation obtained from airborne digital imaging systems. They obtained greater prediction accuracy with an ANN model by comparison with the three conventional empirical models, which were used in this study, too. Soares et al. (2013) attempted to foresee the cultivation efficiency of fields distributed throughout Russia.

Scope for further study

Despite all of the above opportunities, the use of ANNs in the field of agricultural sciences is still very limited, but it is highly expected that ANNs will soon become one of the major research tools in these fields. The reason behind that is the huge demand for understanding and predicting any system's behavior based on different physiological processes. The rapid development of electronic devices and testing instruments would allow more and more researchers to collect tremendous amounts of data even within a short period of time (i.e., less than a second). Only ANNs will be able to handle these vast amounts of data to highlight human behaviours and common responses and behaviours. It can be used to forecast, for example, the impact of abiotic and biotic stressors on living organisms, and will enable us to consider practical solutions for plant growth and to avoid huge financial losses, e.g. in the region of mineral fertilization.

Conclusions

Neural networks are in a real sense one of the best solutions to a few agriculture problems. Undeniably, the implementation of ANN to precision agriculture plays a crucial role in potential assessment of the idea of precision farming as a viable way of fulfilling the food demands of the planet. Nonetheless, in order to ensure viability of future food demands, farmers welfare and economic growth, more work on the impacts of ANN on agricultural problems has to be carried out.

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