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A COMPREHENSIVE STUDY ON MACHINE LEARNING IN AGRICULTURE

Dr.D.B.Lokhande[1], Dr.T.A.Chavan[2],Prof.D.P.Patil[3]

[1]Assistant Professor, [2] Principal & Professor,[3]Assistant Professor

[1,2] Department of Computer Science & Engineering,[3]Electronics and Telecommunication Engg.

Shree Siddheshwar Women's College of Engineering, Solapur (MS), India.

Abstract: Agriculture has undergone a digital transformation that has transformed various management functions into artificially intelligent systems in an effort to extract value from the growing amount of data coming from various sources. Machine learning, a branch of artificial intelligence, has a great deal of potential to address many difficulties in the development of knowledge-based farming systems fully reviewing recent scholarly literature using the keywords machine learning" along with crop management, water management, soil management, and livestock management," and current study aims to shed light on machine learning in agriculture. Only journal articles that were released between 2018 and 2020 were deemed eligible. The findings showed that this topic is relevant to various disciplines that support global convergence research. Furthermore, it was noted that crop management was the main focus. There were many different machine learning algorithms used, with artificial neural network-based algorithms being the most effective. Additionally, the most extensively studied crops and animals were wheat and maize, along with cattle and sheep. In order to obtain trustworthy input data for the data analyses, a variety of sensors mounted on satellites and unmanned ground and aerial vehicles have been used.

Keywords: Machine learning; water management; soil management; livestock management; artificial intelligence; crop management;

1. INTRODUCTION

a. General Context -Machine Learning in Agriculture

Modern agriculture has to cope with several challenges, including the increasing call for food, as a consequence of the global explosion of earth's population, climate changes, natural resources depletion , alteration of dietary choices, as well as safety and health concerns [1]. As a means of addressing the above issues, placing pressure on the agricultural sector, there exists an urgent necessity for optimizing the effectiveness of agricultural practices by, simultaneously, lessening the environmental burden. In particular, these two essentials have driven the transformation of agriculture into precision agriculture. This modernization of farming has a great potential to assure sustainability, maximal productivity, and a safe environment. In general, smart farming is based on four key pillars in order to deal with the increasing needs; (a) optimal natural resources' management, (b) conservation of the ecosystem, (c) development of adequate services, and (d) utilization of modern technologies.[2] An essential prerequisite of modern agriculture is, definitely, the adoption of Information and Communication Technology (ICT), which is promoted by policy-makers around the world. ICT can indicatively include farm management information systems, humidity and soil sensors, accelerometers, wireless sensor networks, cameras, drones, low-cost satellites, online services, and automated guided vehicles [3-6].

The large volume of data, which is produced by digital technologies and usually referred to as "big data", needs large storage capabilities in addition to editing, analyzing, and interpreting. The latter has a considerable potential to add value for society, environment, and decision-makers. Nevertheless, big data encompass challenges on account of their so-called "5-V" requirements; (a) Volume, (b) Variety, (c) Velocity, (d) Veracity, and (e) Value. The conventional data processing techniques are incapable of meeting the constantly growing demands in the new era of smart farming, which is an important obstacle for extracting valuable information from field data. To that end, Machine Learning (ML) has emerged, which is a subset of artificial intelligence, by taking advantage of the exponential computational power capacity growth. [7-9]

There is a plethora of applications of ML in agriculture. According to the recent literature survey , regarding the time period of 2004 to 2018, four generic categories were identified (Figure 1). These categories refer to crop, water, soil, and livestock management [1]. In particular, as far as crop management is concerned, it represented the majority of the articles amongst all categories (61% of the total articles) and was further sub-divided into: [10]

_ Yield prediction;

_ Disease detection;

_ Weed detection;

_ Crop recognition;

_ Crop quality.

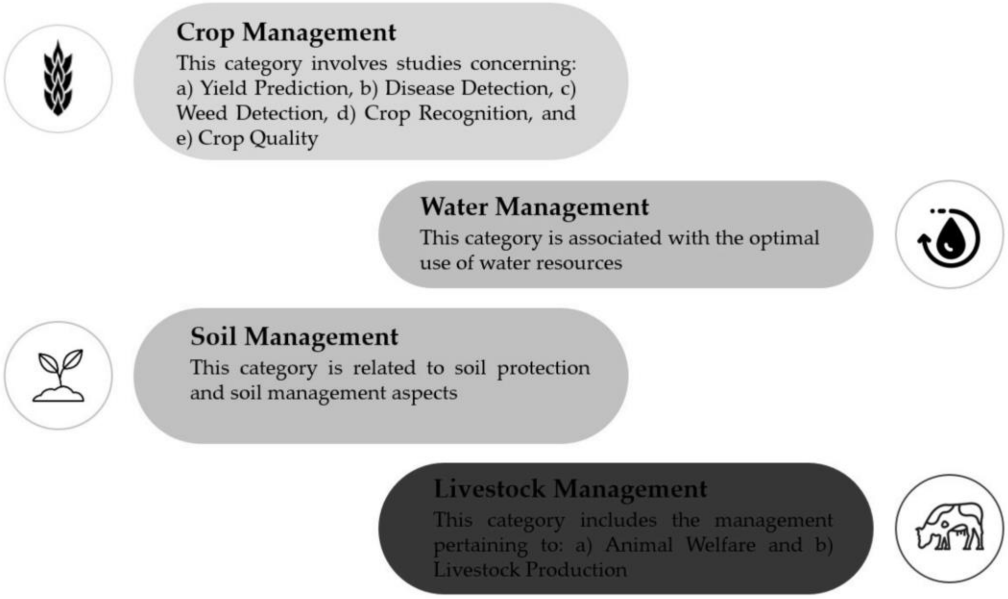

Figure 1. The four generic categories in agriculture exploiting machine learning techniques,

b. Open Problems Associated with Machine Learning in Agriculture

Due to the broad range of applications of ML in agriculture, several reviews have been published in this research field. The majority of these review studies have been dedicated to crop disease detection, weed detection, yield prediction, crop recognition, water management, animal welfare, and livestock production. Furthermore, other studies were concerned with the implementation of ML methods regarding the main grain crops by investigating different aspects including quality and disease detection[11] . Finally, focus has been paid on big data analysis using ML, aiming at finding out real-life problems that originated from smart farming , or dealing with methods to analyze hyperspectral and multispectral data. [12]

Although ML in agriculture has made considerable progress, several open problems remain, which have some common points of reference, despite the fact that the topic covers a variety of sub-fields. According to, the main problems are associated with the implementation of sensors on farms for numerous reasons, including high costs of ICT, traditional practices, and lack of information[13-15]. In addition, the majority of the available datasets do not reflect realistic cases, since they are normally generated by a few people getting images or specimens in a short time period and from a limited area.[16-20]

c. Aim of the Our Study

As pointed out above, because of the multiple applications of ML in agriculture, several review studies have been published recently. However, these studies usually concentrate purely on one sub-field of agricultural production. Motivated by the current tremendous progress in ML, the increasing interest worldwide, and its impact in various do-mains of agriculture, a systematic bibliographic survey is presented on the range of the categories [22], which were summarized in Figure 1. In particular, we focus on reviewing the relevant literature of the last three years (2018–2020) for the intention of providing an updated view of ML applications in agricultural systems.[24-27]

2. LITERATURE REVIEW

In general, the objective of ML algorithms is to optimize the performance of a task, via exploiting examples or past experience. In particular, ML can generate efficient relationships regarding data inputs and reconstruct a knowledge scheme[28]. In this data-driven methodology, the more data are used, the better ML works. This is similar to how well a human being performs a particular task by gaining more experience. The central outcome of ML is a measure of generalizability; the degree to which the ML algorithm has the ability to provide correct predictions, when new data are presented, on the basis of learned rules originated from preceding exposure to similar data[29].

More specifically, data involve a set of examples, which are described by a group of characteristics, usually called features. Broadly speaking, ML systems operate at two processes, namely the learning (used for training) and testing. In order to facilitate the former process, these features commonly form a feature vector that can be binary, numeric, ordinal, or nominal[30]. This vector is utilized as an input within the learning phase. In brief, by relying on training data, within the learning phase, the machine learns to perform the task from experience. Once the learning performance reaches a satisfactory point (expressed through mathematical and statistical relationships), it ends. Subsequently, the model that was developed through the training process can be used to classify, cluster, or predict.[32]

3. MACHINE LEARNING METHOD

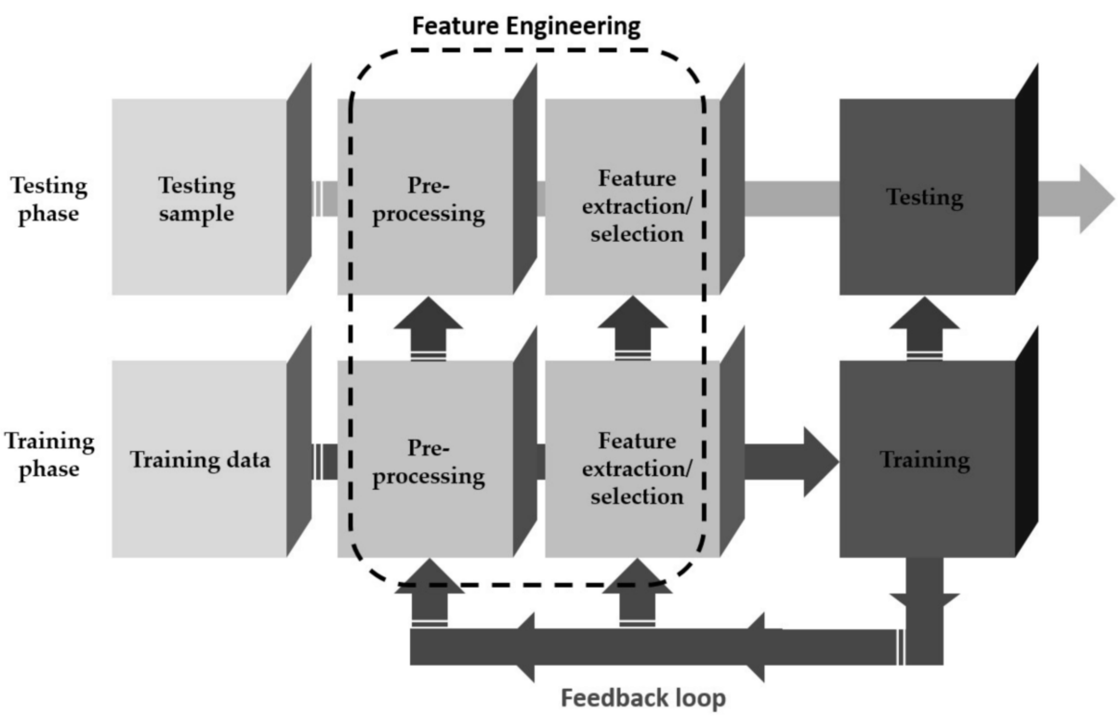

Figure 2. A graphical illustration of a typical machine learning system.

Based on the learning type, ML [33] can be classified according to the relative literature as:

_ Supervised learning: The input and output are known and the machine tries to find the optimal way to reach an output given an input;

_ Unsupervised learning: No labels are provided, leaving the learning algorithm itself to generate structure within its input;

_ Semi-supervised learning: Input data constitute a mixture of labeled and non-labeled data;

_ Reinforcement learning: Decisions are made towards finding out actions that can lead to the more positive outcome, while it is solely determined by trial and error method and delayed outcome[35,36].

Nowadays, ML is used in facilitating several management aspects in agriculture and in a plethora of other applications, such as image recognition , speech recognition, autonomous driving, credit card fraud detection , stock market forecasting, fluid mechanics, email, spam and malware filtering , medical diagnosis, contamination detection in urban water networks, and activity recognition, to mention but a few.[38-40]

4. DISCUSSION-

Confusion matrix constitutes one of the most intuitive metrics towards finding the correctness of a model. It is used for classification problems, where the result can be of at least two types of classes. Let us consider a simple example, by giving a label to a target variable: for example, “1” when a plant has been infected with a disease and “0” otherwise. In this simplified case, the confusion matrix (Figure 3) is a 2 x 2 table having two dimensions, namely “Actual” and “Predicted”, while its dimensions have the outcome of the comparison between the predictions with the actual class label. Concerning the above simplified example, this outcome can acquire the following values:

_ True Positive (TP): The plant has a disease (1) and the model classifies this case as diseased (1);

_ True Negative (TN): The plant does not have a disease (0) and the model classifies this case as a healthy plant (0);

_ False Positive (FP): The plant does not have a disease (0), but the model classifies this case as diseased (1); False Negative (FN): The plant has a disease (1), but the model classifies this case as a healthy plant (0).

Predicted \ Actual	1	0
1	TP	FP
0	FN	TN

Figure 3. Representative illustration of a simplified confusion matrix.

A wide range of ML algorithms was implemented in the selected studies. The ML algorithms that were used by each study as well as those that provided the best output. These algorithms can be classified into the eight broad families of ML models, which are summarized in Table A10. Figure 4 focuses on the best performed ML models as a means of capturing a broad picture of the current situation and demonstrating advancement, As can be demonstrated in Figure 4, the most frequent ML model providing the best output was, by far, Artificial Neural Networks (ANNs), which appeared in almost half of the reviewed studies (namely, 51.8%). More specifically, ANN models provided the best results in the majority of the studies concerning all sub-categories. ANNs have been inspired by the biological neural networks that comprise human brains , while they allow for learning via examples from representative data describing a physical phenomenon. A distinct characteristic of ANNs is that they can develop relationships between dependent and independent variables, and thus extract useful information from representative datasets.

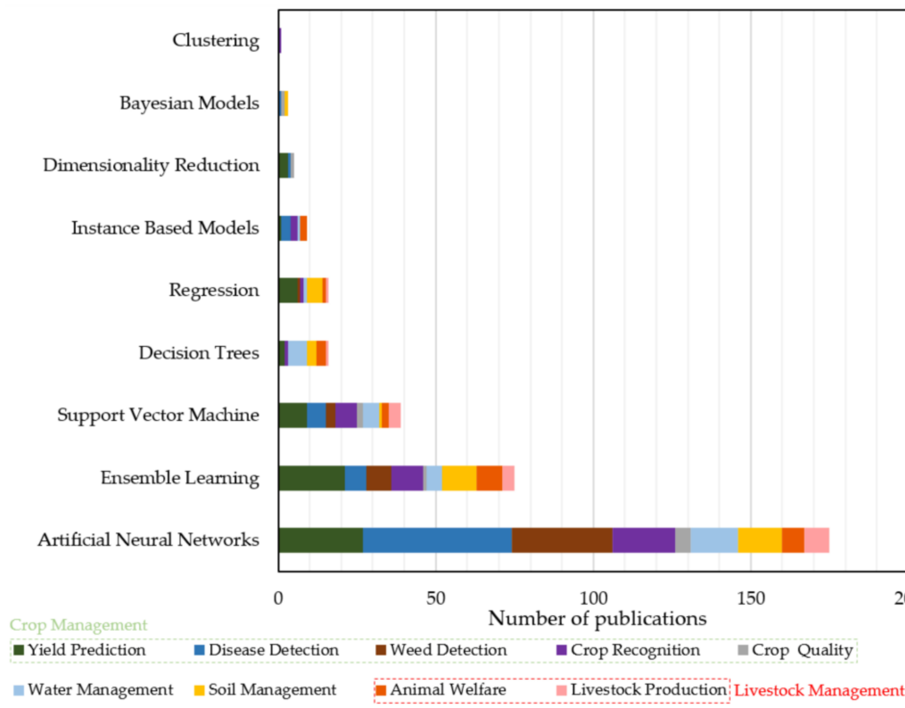

Figure 4. Machine Learning models giving the best output.

5. CONCLUSION-

To that end, a comprehensive analysis of the present status was conducted concerning the four generic categories that had been identified. These categories pertain to crop, water, soil, and livestock management. Thus, by reviewing the relative literature of the last three years (2018–2020), several aspects were analyzed on the basis of an integrated approach. In summary, the following main conclusions can be drawn:_ The majority of the journal papers focused on crop management, whereas the other three generic categories contributed almost with equal percentage. Considering the as a reference study, it can be deduced that the above picture remains, more or less, the same, with the only difference being the decrease of the percentage of the articles regarding livestock from 19% to 12% in favor of those referring to crop management. Nonetheless, this reveals just one side of the coin. Taking into account the tremendous increase in the number of relative papers published within the last three years (in particular, 40 articles comparing to the 338 of the present literature survey), approximately 400% more publications were found on livestock management. Another important finding was the increasing research interest on crop recognition.

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BIOGRAPHIES:-

1)

Dr.Dheeraj Bhimrao Lokhande is Assistant Professor (Computer Science and Engineering) in Shree Siddheshwar Women’s college of Engineering, Solapur, Maharashtra, INDIA. He is having Ph.D. in Computer Science and Engineering. He has 13 years of teaching Experience. He has qualified in GATE Examination.

2)

Dr.T.A.Chavan is Principal and Professor (Computer Science and Engg.) in Shree Siddheshwar Women’s college of Engineering, Solapur, Maharashtra, INDIA. He is having Ph.D. in Computer Science and Engineering. He has 20 years of teaching Experience.

3)

Prof.Dhananjay Padmakarrao Patil is Assistant Professor (Electronics and Telecommunication Engg.) in Shree Siddheshwar Women’s College of Engineering, Solapur, Maharashtra, INDIA. He has having 17 years of teaching experience and 6 years of industry experience.