Smart Agriculture: A Review of IoT Technologies for Sustainable Farming

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Abstract—
The climate, topography, soil and biology are highly dependent on agriculture. In which land plays a significant role. Despite considerable progress in the service sector, agriculture remains India's primary source of employment and income, and price fluctuations in agricultural commodities have a significant impact on people's daily lives as well as agricultural inputs and outputs. In order to overcome all this, soil test values are used in the current study to classify several important soil characteristics, such as the Available Phosphorus (P), Potassium (K), Organic Carbon (OC) and Boron (B) village-wise soil fertility indices, as well as the Soil Reaction parameter (pH). We have addressed various algorithms related to data mining and machine learning (ML) classification techniques in this paper along with IOT hardware that used in agriculture. These algorithms are developed on a data set for yield prediction of crops that have been collected over the years. In addition, a comparative study is carried out to show which classification algorithm is better suited for classification techniques success prediction.

Keywords—machine learning classification, artificial neural network, soil analysis.
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1. INTRODUCTION

Agriculture is one of the primary industries in India, as 50 percent of the workforce is engaged in agricultural activities. In the Indian economy, the contribution of the agricultural sector is far higher than the world average (6.1 percent). However, due to the lack of technological development in the agricultural sector, traditional farms still have some of the lowest per capita output and incomes of farmers in India. Soil analysis is an important process since it offers nutrients such as pH, EC, temperature , humidity and NPK values that are present in the soil. Human efforts can be minimized by measuring soil quality using a soil sensor in automated soil testing. A suitable list of crops is forecast based on the values we get from our unit. In order to improve yield efficiency, crop prediction is also an important parameter. Thus, we estimate the appropriate crop along with the necessary fertilizers such as gypsum for alkali soils and lime for acidic soil on the basis of pH, moisture ,EC,temperature and NPK values.

Use of fertilisers and soil management techniques that are more efficient so as to increase agricultural output. Farmers can mitigate the disadvantage of the departing procedure. In India, various soil samples are gathered from agricultural land and delivered to labs, after which the farmers are tested and reported on. This is a laborious process that takes time. This procedure typically takes between seven and ten days, or more if the laboratory is remote. These labs take soil samples from different sites on the field, perform testing, and provide reports about the agricultural region. Will the research be accurate if a single sample is used? Use of fertilisers and soil management techniques that are more efficient so as to increase agricultural output. Farmers can mitigate the disadvantage of the departing procedure. In India, various soil samples are gathered from agricultural land and delivered to labs, after which the farmers are tested and reported on. This is a laborious process that takes time. This procedure typically takes between seven and ten days, or more if the laboratory is remote. These labs take soil samples from different sites on the field, perform testing, and provide reports about the agricultural region. Would the research be accurate if one sample is collected from rice-growing area and the other from land where vegetables are grown? If yes, then there is a high probability that the report created from the samples will vary solely from the rice-grown land report. It is impossible to create two studies for the same location due to the limited capacity of labs and their heavy research workload. If yes, then there is a high probability that the report created from the samples will vary solely from the rice-grown land report. It is impossible to create two studies for the same area due to a lack of resources and a heavy research workload in the labs.

ML methods are now successfully dealing with the problems of prediction and classification. In the field of agriculture, the exposure of ML methods certainly reduces challenges faced by domain experts. In the early days of
ML, the Levenberg-Marquardt based back-propagation technique in Artificial Neural Networks (ANNs) has been utilized to predict soil fertility.

The available water strength, clay loam,electrical conductivity (EC), silt loam and sandy loam soils, as well as soil organic carbon and bulk density have all been utilised in conjunction with partial least square regression in order to anticipate the fertility of the soil. Several research have made use of ML approaches in order to discover and address soil issues in agriculture. These problems include soil fertility prediction, delivery of needed nutrient levels, and water, amongst other things. Using phenotypic plant features as inputs, the J48, K closest neighbours (KNN), One-R, and Apriori classifier algorithms were used in order to classify and forecast wheat production. Wheat yield was broken down into three categories—low, medium, and high—through the use of supervised Kohonen and counter-propagation neural networks. Using theLogistic Regression, Naive Bayes (NB) classifier, Decision Tree (DT), the Random Forest (RF), Support Vector Machine (SVM) and AdaBoost decisions on the pesticide treatment for leaf roller pest monitoring on kiwifruit were made (LR). An unbiased linear predictor was used in order to determine the organic carbon content of the soil. By using the enhanced regression trees, the organic carbon on Sicilian soils was expected. The RF has been combined with the genetic algorithm approach of feature choice in order for predicting the organic carbon on eastern Australian soils.

In addition to the soil's pH and the Cation Exchange Potential (CEC) calculated from mid-infrared spectra, partial least squares are required for calculating the quantity of organic carbon in different soils. The Bayesian network was used to evaluate soil fertility, which includes identifying the pH value of the soil as well as the values of soil nutrients such as nitrogen, copper, phosphorus, potassium ,organic carbon, iron and zinc. To create wind speed, it was determined whether or not ML approaches are spatially transferable. The techniques of discrete time, radio frequency, SVM, Bayesian networks, and ANN were utilised to study the soil in areas directly involved in the production and processing of precision crops [1].There are several data mining techniques ways to build algorithms of formulations for different models in order to overcome the numerous issues and develop useful information and reports. Data mining came into the picture to assess the large amount of data and is also referred to as the KDD method. A method of linear regression that looks at how the response variable impacts how one interprets the interference variable. The act of making an educated guess as to the value of a response variable by basing that guess on the value of an explanatory variable is known as prediction.Yield forecasting is a critical agricultural issue. Every farmer wants to know how much he can expect in terms of his yield. In the previous century, yield predictions were made taking into account the specific field and crop knowledge of the farmer. Some ML actions require training data to be extracted from previous data, and the data collected has been used for training to learn how to categorize futureyield predictions.

The simple procedure of ML pipeline is show in FIg.1. The process starts with the collection of raw data and then preprocessing is performed to remove unnecessary data or to clean the data which will be further used for processing. The clean data is pass to feature extraction algorithm to get important features. After getting important features model training is performed on preprocess data and then fine tuning is done to improve the performance of system. After training testing is done with similar type of dataset and at the end performance metrics are calculated.

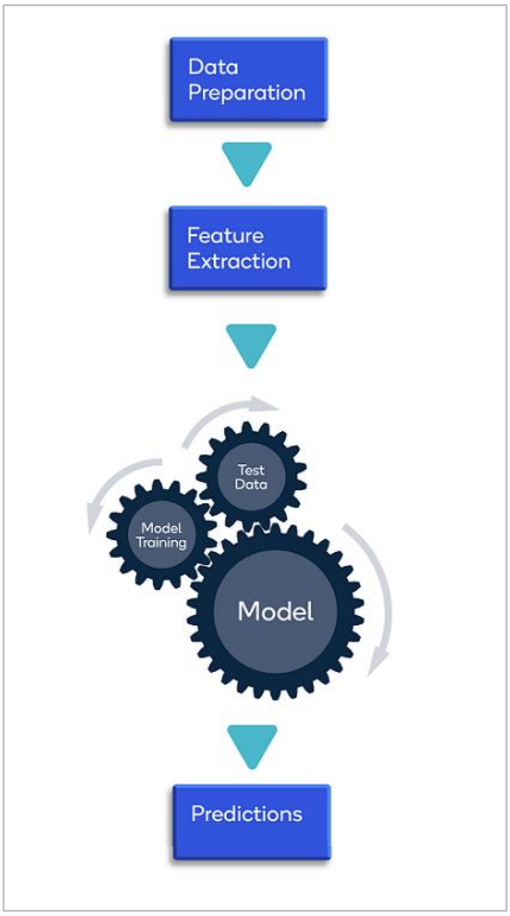


Fig. 1 ML pipeline architecture

The following sections are included in this paper: Section I explains the introduction. Section II also explains the literature review on data mining, machine learning techniques and methodologies for crop yield prediction in the literature review,Section 3 explains application, sensors used in Smart farming andpaper is conclude at last.

2. LITERATURE REVIEW

The variations in the price of agricultural commodities have a significant effect on the everyday lives of individuals and on the inputs and the outputs of agricultural production. Therefore, accurate forecast of food prices, it is necessary if scientific decisions are to be taken by agricultural authorities. Yongli Zhang et al [1] suggested a new model selection method that involves time series characteristics and forecast horizons in order to forecast prices more adaptively. In order to identify agricultural product prices, twenty-nine features have been used, and the candidate forecast models are three smart models: ANN, support vector regression (SVR), and extreme learning machine (ELM). For learning the underlying relationship between the factors and output of the candidate models, both RF and SVM are implemented. In addition, for minimize feature redundancy and then for further enhancement the forecast accuracy, minimum redundancy and maximum relevance approach (MRMR) has been used.

Bellow et al. [2] compared a variety of methods and evaluated the use of numerous agricultural metrics to arrive at an estimate of production throughout the Canadian prairies. This research was carried out in three agro-climate meadows located in the Saskatchewan Census Agricultural District (CAR) and the Saskatchewan Rural Municipality (RM). The gross primary productivity (GPP) , vegetation indices and net primary productivity (NPP) that were calculated from MODIS were compared with the yields that were already available for barley, spring wheat and canola. In order to evaluate the connection between the metrics and the yield, multiple linear regressions were performed. The development of models has been achieved via the use of the leave-one-out cross validation method. According to their results, when crop growth is at its highest, vegetation indices become stronger predictors of yield than GPP or NPP, and EVI2 performs better than NDVI. This was the case regardless of the crop type. The seasonal maximum EVI2 can be estimated using CAR-level crop yields. Over the course of many decades, LOOCV provided evidence that the models were reliable; nonetheless, researchers discovered that the models' accuracy varied from decade to decade. Evaluations employing RM-level yields found drastically lower accuracy, with NSE values ranging from 0.37 to 0.66 and RRMSE values ranging from 18 to 28 percent. During the polygon stage of the Soil Landscapes of Canada (SLC) project, the yearly crop yields were mapped using the models that performed the best.

The force that maintains life on earth comes from the ground itself, which is often referred to as the Spirit of Endless Life. Agriculture is still India's primary source of both employment and revenue, despite the substantial progress that has been made in other areas of the economy, particularly the service sector. According to Onwuka, Brown, and others' [4] research, conducting soil testing would be a valuable method for assessing the nutrient status of both the available soil and helping to determine the correct amount of nutrients to be added to the soil as per the requirements of the crop. This is due to the fact that soil testing helps identify the optimum quantity of nutrients to put to the soil in order to preserve fertility. In the majority of instances throughout this investigation, soil test data were employed to determine several crucial soil features. Village-wise soil fertility indicators for (P), (K) , (OC)and (B) are among these features (pH). To reduce excessive spending on pesticide inputs, save time for experts in chemical soil analysis, increase profitability, improve soil health, and enhance environmental quality, village-specific soil metrics are categorised and forecasted. The features of the soil at the village level are categorised to decrease expenditures on unnecessary pesticide inputs, increase profitability, save time for chemical soil analysis experts, and enhance soil health and environmental quality. Extreme Learning Machine (ELM) is a classification approach for rapid learning that was used to solve these five classification tasks. ELM is a method that employs many activation functions, including Gaussian radial base, sine-squared, hyperbolic tangent, triangular base, and hard limit. The Gaussian radial base function achieves the highest performance for four of the five problems, which exceeds 80 percent in the majority of precision rate measurements for each problem, based on the monitoring of the ELMs' performance by various activation functions for these soil parameter classifications. The subsequent functions are hyperbolic tangent, hard bound, triangular base, and sine-square, in that order.On the other hand, their performance of the real classification issue, which is the pH classification, only results in a hyperbolic tangent with a Gaussian radial basis, moderate values, and optimal performance (almost 90 percent).

Khatri et al [5] present the design and validation for Precision Agriculture applications of a pH measurement IoT device. The framework is based on an IoT architecture consisting of: data acquisition and processing, information, user access and centralization. As well as its experimental validation process, the design process of each module is recorded. With a pH measurement slope of -0.058V and an RMSE of 0.037 for the calibration model, author demonstrated the system's ability to calculate at several points in large areas their The goal of this project is to devise a low-cost electronic system and its application that has the capability of monitoring and controlling the water quality to ensure that it remains within the specified parameters.

A more in-depth understanding of the soil water content (SWC) of the crop irrigation soil wetting layer will make it possible to develop irrigation plans that are more in line with reality and will result in a more effective use of water for irrigation purposes in agricultural settings. To better forecast the effects of climate change at several depths, Hirich et al. [6] suggested a SALTMED model. Model inputs included gridding and transforming continuous meteorological and SWC data, followed by feature extraction and implementation of high-dimensional spatial and time series features using a meta-learner. This model was created to better forecast SWC at many depths.

The Internet of Things (IoT) technology is being utilised for contemporary agricultural development to enhance the efficient growth of agriculture. This is happening as a result of the construction of a smart agricultural system by Jinyu Chen1 and Ao Yang et al [7]. Data visualisation and cluster analysis are two methods that are often used in the context of smart farming to determine the primary technologies that have the potential to effectively increase production efficiency and assure the quality of agricultural goods. Data visualisation and cluster analysis are two methods that are often used in the context of smart farming to determine the primary technologies that have the potential to effectively increase production efficiency and assure the quality of agricultural goods. In the context of smart farming, data visualisation analysis and cluster analysis are also used to find important technologies that may effectively boost production efficiency and assure the quality of agricultural goods. In the field of agriculture, the IOT is used for a variety of purposes, including induction, identification, monitoring, and feedback, as well as the recognition of important changes in the phase of smart, technical, and efficient application. The research of the aquaculture industry's grasp of front-end induction and IoT intelligence has some reference value as well.

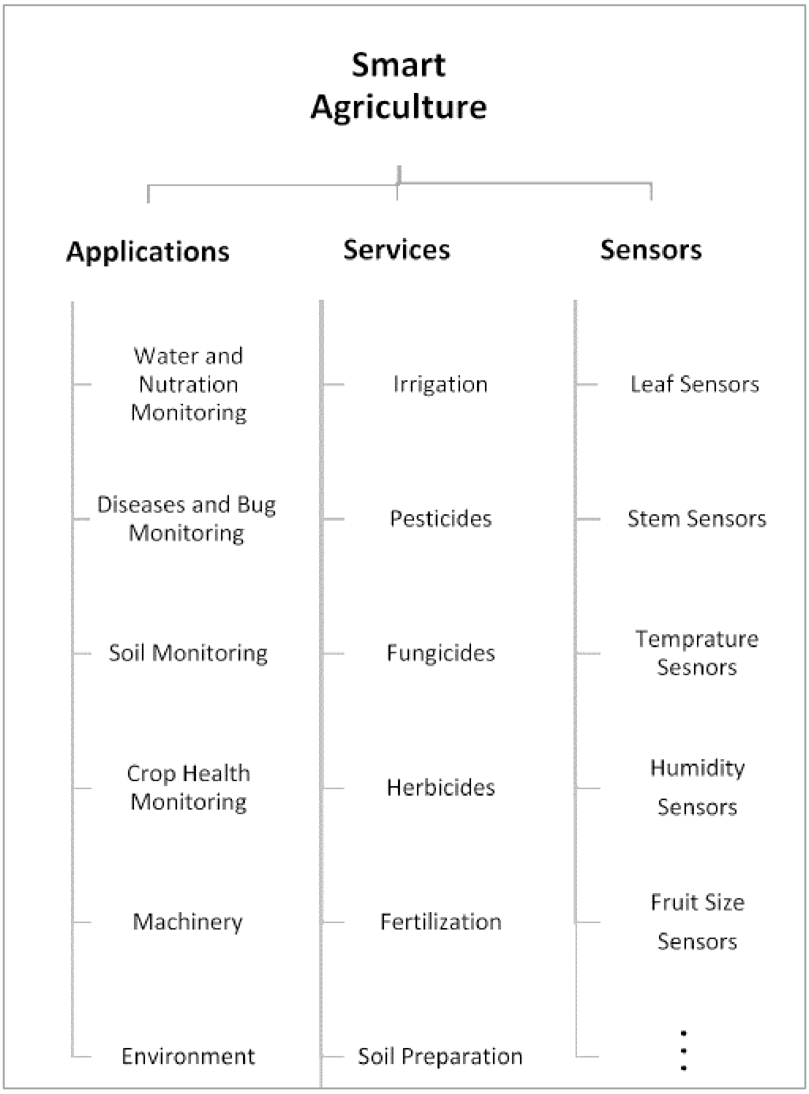
Hochreiter and Schmidhuber developed the LSTM network by basing it on the RNN at position [9]. This was done in order to solve the issue of gradient disappearance or explosion, which can take place due to the long-range memory of the original RNN. In addition, they added a data-updating gate mechanism to the network. Nevertheless, LSTM can only learn forward features and does not have any backward learning characteristics. The bi-directional LSTM (BiLSTM) network may make greater use of contextual semantic data by merging forward and backward LSTMs [10].

Rajshekhar Borate et al. [11] first identifies the information for the list of procedures that were employed and then discusses the information. The cultivation of agricultural crops and other types of crops may be accomplished in a number of ways in India. It is dependent on a variety of different factors, including the weather. The economy, research, and even the geographical elements that are at play are all important. It is possible to obtain details or information that can help farmers and government agencies make good choices and better rules to help increase demand for data mining techniques that are used to extract information from agricultural records and to estimate better crop yield for main crops. Such methodologies and techniques are based on the historical production of miscellaneous trees.

Srilakshmi et al [12] presents a comparative study on the IoT and its applications in smart agriculture. The IoT has emerged as a promising technology for improving agricultural practices and increasing crop yields. This study examines the features and advantages of IoT-based agriculture systems and compares them with traditional farming methods. The paper highlights the challenges of implementing IoT in agriculture and proposes solutions to overcome these challenges. Additionally, the study presents a detailed analysis of various IoT-based applications in agriculture, such as smart irrigation, crop monitoring, and livestock management. The paper also reviews some case studies of IoT-based agriculture systems and their impact on the agricultural industry. The study concludes that IoT-based agriculture systems have significant potential to improve productivity, reduce resource consumption, and enhance the quality of agricultural products.

3. IOT APPLICATIONS, SENSORS AND SERVICES IN SMART AGRICULTURE

Adaptive agricultural techniques provide answers to problems that need to be solved, such as the effects of a warming climate on weather and soil conditions, the need to reduce waste, and the proliferation of environmentally friendly housing. A wide variety of sensors, self-driving cars, control systems, and robots are included in the IOT. These are the several phases of prediction in agriculture, from the farm to the fork, which are shown below [12]. The hierarchy of the many applications, services, and sensors that might be used in smart agriculture is shown in Figure 2.



A. APPLICATION OF SMART FARMING

1) Monitoring soil, climate conditions, and plants

Large-scale climatic changes and natural calamities significantly reduce crop yields and plant viability. Several sensors can record a variety of environmental variables, which may then be reported on by the IOT in the form of integrated and heterogeneous data.

Soil and nutrient concentrations, together with moisture, temperature, and electrical conductivity, may all be monitored with the use of sensors. Databases are then used to keep track of this data. Based on the soil profile, the appropriate amount of fertiliser will be applied.Farmers and people who work in agriculture need to download mobile apps and sign up with the cloud through MobileApp. The weather, soil conditions, irrigation levels, plant growth, and damage are all kept track of in the cloud. It also keeps information about farmers, marketing agents, agro vendors, service providers, and government programmes for the agriculture sector, such as loans for farmers and discounts on seed and/or fertilisers. Samples of soil and the environment are taken periodically, and sensors collect and update the data. This data is used to control the smart farms. IOT is a key part of keeping an eye on plants to find bugs and diseases that are slowing their growth. Through sensors, alarms and alerts can be sent to farmers to tell them to take action if the level of pest control goes above the range that was set. Farmers and agriculturists can also find out through a cloud database when the best time is to plant crops, control pests and plant diseases, and harvest.

2) Irrigation of Water and Less Waste

By monitoring tank levels and setting irrigation times, the IOT makes it possible to control how much water is used so that plants can grow as well as possible. It is also important to keep an eye on any unwanted leaks. Enterprise cloud hosting makes it possible to access all of them through web and mobile applications. In the agricultural sector, IoT technologies aid in the reduction of waste and the maximisation of productivity. It's a way to cultivate crops that allows for more precision and control. Temperature, pressure, humidity, and light are all factors that might affect the condition of grains stored in silos and grain elevators.

3) Keeping an eye on animals

Farmers and people who work in agriculture collect information about where their cattle are, how healthy they are, and when they should be fed. IoT-based sensors are also used to find the sick animal in a herd before it spreads disease to the rest of the animals. This will greatly reduce livestock losses and costs by keeping an eye on them all the time and getting the others back.

4) Smart Greenhouses

IoT sensors that are powered by the sun will be used to build modern, healthy, and affordable green houses. The sensors tell us about the temperature, pressure, humidity, and amount of light. Sensors keep an eye on these environmental factors, and control can be done either automatically or by hand. Water is also used to water plants with smart sprinklers. All of these things are linked together using IoT. A cloud server accesses the data and gives farmers solutions that don't cost too much.

B. SENSORS [3]

Out of all the smart farming tools that are currently on the market, wireless sensors are the most important and play a key role in gathering information about the crops and other things. Wireless sensors are used wherever they are needed on their own, and they can also be added to almost every part of modern agricultural tools and heavy machinery, depending on the application. In the next section, we'll talk about the main types of sensors, how they work, what they're used for, and what benefits they offer.

1) Acoustic Sensors

Acoustic sensors can be used for a variety of things on a farm, like tilling the soil, pulling weeds, picking fruit, etc. The best thing about this technology is that it can solve problems quickly and cheaply, especially when it comes to portable equipment. It works by measuring how the noise level changes when the tool comes into contact with other things, like soil particles.

2) Field-Programmable Gate Array (FPGA)-Based Sensors

FPGA-based sensors are now being used in agriculture because they can be set up in different ways. The main ways these can be used are to measure plant water loss, humidity, and irrigation in real time. Their use in agriculture is still in its early stages, though, because of their size, cost, and need for a lot of power. These sensors need more power, so they can't be used for continuous monitoring. They are also expensive and don't work as well as other sensors.

3) Optical Sensors

These sensors use the way light reflects off of things to measure things like the organic matter in the soil, the soil's moisture and colour, the presence of minerals and what they are made of, the clay content, etc. Different parts of the electromagnetic spectrum are used to test how well the soil can reflect light. Changes in the way waves reflect help to show changes in the density of the soil and other parameters. Optical sensors based on fluorescence are used to get a general idea of how a plant is doing, especially to watch the ripening of the fruit.

4) Ultrasonic Ranging Sensors

People think these kinds of sensors are a good choice because they are inexpensive, can work in a wide range of situations, are easy to use and can be adjusted in ways like the sampling rate. Tank monitoring, spray distance measurement (e.g., controlling the height and width of the boom so that the spray coverage is even, detecting objects, and avoiding collisions), and crop canopy monitoring are all common uses. When these sensors are used with a camera, they can be used to find weeds.

5) Airflow Sensors

These sensors can measure how much air can get through the soil, how much water is in the soil, and the structure of the soil to tell the difference between different types of soil. Measuring can be done in one place or while the device is moving. For example, it can be used in a fixed position or in mobile mode.

6) Electrochemical Sensors

Most of the time, these are used to figure out the levels of nutrients in the soil by measuring things like pH. Chemical soil analysis is usually expensive and takes a lot of time. These sensors can easily be used instead. To be more specific, these sensors are used to measure the soil's macro and micro nutrients, as well as its salinity and pH.

7) MECHANICAL SENSORS

The different levels of compaction are shown by mechanical sensors that measure the soil's mechanical resistance (compaction). The mechanical sensors are put into the ground or cut into it. Strain gauges or load cells measure the force and record it.

8) ass Flow Sensors

Some of these sensors are used to measure the flow of grain, such as when the grain goes through a combine harvester. This gives information about the yield. Sensing the flow of a lot of grain to figure out the crop yield has been done for the last 20 years.

9) Remote Sensing

This group of sensors is used to collect and store geographic data, as well as to analyse, change, manage, and display all kinds of spatial or geographical data.

4. CONCLUSION

Smart Agriculture through the integration of IoT technologies has shown great potential to revolutionize the farming industry and improve its sustainability. The adoption of these technologies can enhance productivity, optimize resource utilization, reduce environmental impact and promote efficient management practices. The review of various IoT technologies such as sensors, drones, and precision agriculture systems highlighted their benefits and limitations in the context of sustainable farming. It is important for farmers to carefully consider their specific needs and limitations before investing in any IoT technology. Nevertheless, the implementation of IoT technologies in agriculture can ultimately lead to a more efficient, sustainable and profitable future for the industry.

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