Proposal of Prediction Model for Smart Agriculture Based on IoT Sensor Data

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Abstract **- Prediction is a mechanism to prevent and make changes in different sectors. Climate changes are affecting different sectors but the most damaged is the agriculture sector because it affects the quality and quantity of agricultural products. Farmers who produce grapes in recent years face many challenges due to climate change, this is evident also in our region Kosovo. Prizren region is known for grape products and many families depend on grape production. For this reason, in this paper, we are going to show recent research in this area and present the most appropriate algorithms used for the prediction of smart IoT sensor data for the prediction of the quality and quantity of agricultural products. In this paper, we propose a model for the prediction of the quantity and quality of grapes in order to recommend what is the right time to do grape processing and grape sterilization because those are the crucial fact that affects the quality and quantity of the grape.**

Keywords - Internet of Things; Artificial intelligence; data mining; IoT sensor data; smart agriculture;

I. INTRODUCTION

The quality and quantity of agricultural products nowadays are affected a lot because of climate change. Using IoT smart sensors to collect data and predict what will happen in the future to prevent possible damage to agricultural products. By using smart agriculture sensor data, we predict the temperature for next year in order to help farmers in grape cultivation by specifying the period of time when the grape harvest is to be done which has a direct impact on the quality and quantity of grapes.

Human history can be described through the history of agriculture. Agricultural landscapes represent the very essence of the agricultural and cultural heritage of the population living and working in it. Food, land, water, environment, and population growth are challenges to which governments and institutions must respond. In the past, the combination of measures and instruments was used to support agriculture that had insufficient results due to climate variability and market changes, but today with new technology we can have sustainable solutions.

The authors in this paper [1] elaborate on the term smart farming and show different examples of why it is important to use technology in order to improve the production of different agricultural products.

The objective of smart agriculture is to provide solutions that can be applied to all farmers, regardless of farm size, region, or sector, exploiting scale effects and keeping the cost of technology low. In this context, policies are needed to ensure high-speed data transmission and harmonized interoperability, the adoption of standards at the European level to promote connections in the rural area, and adequate infrastructure and data processing services.

So far, the expected benefits from the integration of technological processes in agriculture are high production efficiency and quality, cost reduction, optimization of inputs, minimization of medical impacts, also the creation of jobs for specialized personnel. Yet thanks to support for agriculture, policies and growing awareness of the economic and ecological benefits that new technologies in agriculture can produce real the potential to spark a process of radical transformation in the sector. According to analysts [2], the global smart agriculture market which was worth almost $ 10 billion in 2017, will reach $ 23 billion by the end of 2022.

Having a strategy for smart agriculture will help farmers to make a decision and improve food production [3]. FAO [3] estimated that if the present production and consumption rates continue, agricultural production should increase 60% by 2050 to meet the needs of food of the world's population. Because the climate has changed, it is important to integrate Information and communication technologies (ICT) to protect food production.

The main idea is to propose a model for predicting the grape yield and its quality based on weather conditions parameters and past year's grapes yield.

The aim of this paper is to analyze the existing research in this field and based on the analysis we will give information to farmers for a potential year what the quality of the grape will be and recommend when is the right time to do the grape processing and grape sterilization because these are crucial factors to the quality and quantity of the grape.

The following in the second section is related work on this particular topic compared to what we have done in this research. The third section defines what smart agriculture is and its relation to IoT. The fourth section describes the prediction model for Smart agriculture. Then in the fifth section, the fourth phase model for prediction in smart agriculture is presented. And last is the conclusion and future works.

II. RELATED WORK

Statistical models predict that the world's population will reach 8.5 billion by the end of 2030 [4]. This represents a real threat to our food security and puts the current food production system under pressure. Efficient use of Earth's natural resources is the only solution to facing future challenges such as global hunger. The implementation of precision agriculture using new technologies such as artificial intelligence, big data, IoT, and remote sensing is the first step toward this goal [5], [6].

S. S. Rathore et al. [7] proposed a prediction model for smart agriculture using IoT sensor data. The model incorporates machine learning algorithms and data analytics to predict crop yields, plant health, and soil moisture. The authors also discuss the importance of using IoT sensor data to optimize agricultural practices, reduce waste, and increase efficiency.

Y. Liu et al. [8] developed a predictive model for precision agriculture using IoT sensor data. The authors used a decision tree algorithm to analyze data from soil moisture and temperature sensors and made predictions about crop growth and yield. The authors note that their model can be used to optimize irrigation and fertilization practices, leading to increased crop yields and reduced water usage.

M. Tariq et al. [9] proposed a crop yield prediction model for smart agriculture using IoT sensor data. The authors used data from various sensors, including temperature, humidity, and light sensors, to predict crop yields. The authors also discuss the potential benefits of using IoT sensor data for smart agriculture, including reduced labor costs and increased crop yields.

D. Kumar et al. [10] developed a predictive model for crop disease detection and prevention using IoT sensor data. The authors used machine learning algorithms to analyze data from soil moisture and temperature sensors, as well as image data from cameras, to identify crop diseases and make recommendations for prevention and treatment. The authors note that their model can help farmers reduce crop losses due to diseases and increase crop yields.

S. H. Jung et al. [11] proposed a prediction model for grape quality using IoT sensor data. The authors used data from various sensors, including temperature, humidity, and leaf wetness sensors, to predict grape quality. The authors also discuss the potential benefits of using IoT sensor data for smart agriculture, including improved crop quality and reduced labor costs.

These studies highlight the potential benefits of using IoT sensor data for smart agriculture, including increased efficiency, reduced labor costs, and improved crop yields and quality. The studies also demonstrate various predictive models that can be developed using IoT sensor data, including models for crop yield prediction, precision agriculture, crop disease detection and prevention, and grape quality prediction.

Agriculture has always been an area that has required a lot of work and frequent maintenance even for the smallest work. It also requires careful supervision so that the person is able to know when the plants are ready to be harvested, or even to see the diseases of the harvest as early as possible, and to definitely notice the insects in the plants because otherwise they are damaged. In a word, we can say that a lot of work is needed to increase productivity in this area, and here begins to include smart agriculture.

Based on the source [12] by 2050 the world's population will increase from 7.3 billion to 9.7 billion inhabitants on the planet, which means that food production must increase by 70%, where the only way to achieve growth is with the intervention of new technology.

In recent years, grape cultivation has become difficult for farmers due to frequent climate change. The goal of mining and predicting the grape quality and yield of grape is to help viticulture farmers to take decisions related to their farms and business. We have 5 years of data from weather hydrometeorological institution where the air pressure, air temperature, humidity, wind direction, and wind speed is measured which are very important parameters to be analyzed related to our topic. From IoT sensors for smart agriculture, we also collect data for land humidity where we are going to analyze how it affects the grape quality and yield.

The main idea is to propose a model for predicting the grape yield and its quality based on weather conditions parameters and past year’s grape yield.

Based on the analyses we will give information to farmers for the potential year on what the quality of the grape will be and recommend what is the right time to do the grape processing and grape sterilization because are crucial factors that affect the quality and quantity of the grape.

There are different studies in this field but no such study is done yet for our region.

III. SMART AGRICULTURE AND IOT

Human history can be described through the history of agriculture. Agricultural landscapes represent the very essence of the agricultural and cultural heritage of the population living and working in it. Food, land, water, environment, and population growth are challenges to which governments and institutions must respond. In the past, the combination of measures and instruments was used to support agriculture that had insufficient results due to climate variability and market changes, but today with new technology we can have sustainable solutions.

By smart agriculture [1], [13], [3] we mean the use of digital techniques to recreate, govern, and optimize production processes. Digital transformation encourages human intervention in agriculture and helps reduce the workload, carry out specific measures, to calibrate the use of chemical products of soils and crops, in addition to guaranteeing and increasing crops. It also helps manage all those processes that enable or support agricultural production, including economic administrative processes.

The authors in this paper [15] elaborate on the term of smart farming and show different examples of why is important to use technology to improve the production of different agricultural products.

The objective of smart agriculture is to provide solutions that can be applied to all farmers, regardless of farm size, region, or sector, exploiting scale effects and keeping the cost of technology low. In this context, policies are needed to ensure high-speed data transmission and harmonized interoperability, the adoption of standards at the European level to promote connections in the rural area, coupled with adequate infrastructure and data processing services.

So far, the expected benefits from the integration of technological processes in agriculture are high production efficiency and quality, cost reduction, optimization of inputs and minimization of medical impacts, and also the creation of jobs for specialized personnel. Yet thanks to support for agriculture, policies and growing awareness of the economic and ecological benefits that new technologies in agriculture can produce really have the potential to spark a process of radical transformation in the sector.

IV. A Prediction Model of Smart Agriculture Based on IoT sensor Data

Smart agriculture in recent years is a very interesting area to research and are doing a lot of studies in this area. A prediction is a tool for decision-making for farmers before they predict the yield of certain crops through their own practice and observed weather parameters. For prediction, the main field of research is Data Mining because it can predict crop yield by discovering unseen information from the influence of the existing climatic dataset [14].

Here we are going to show the researches which uses prediction algorithms to analyze data collected from IoT sensors.

The aim of this paper [15] is to show the impact that has climate changes on the cultivation of grapes in northeast Italy. The paper aims to verify if the grape yield and quality are affected by planting options and climate conditions. Six weather stations are placed in the study area in Italy where a new dataset is created and data as a mean of daily rainfall, temperature, and relative humidity among the six stations are collected. They analyzed 10-year data where weather conditions are analyzed. Also, geo-data are analyzed to see how the land position affects the quality and quantity of grapes. They measured sugar concentration and tartaric acid. There was a positive linear regression between climate conditions and the quality and quantity of grapes.

The authors [12] in this study propose a prediction model of Apple disease in the apple orchards of Kashmir valley using data analytics and Machine learning in IoT systems. To collect data a survey is conducted with local farmers in order to know if technologies will help them in decision-making. The paper also shows the challenges that are faced when technologies for smart agriculture are incorporated into the traditional environment. The paper proposes a prediction model based on linear regression and data analyses.

The other study [17] also proposed a model for smart agriculture based on mobile which integrates IoT and cloud-based big data analytics. The aim of the proposed model is to predict the crop yield and decide the better crop sequence based on the previous crop sequence in the same farmland with the soil nutrient current information. The proposed model estimates also the total production and for crop region-wise estimates the total fertilization required. This will help farmers to manage the costs of agricultural products.

The authors in this paper [14] present a model for classifying the data of sugarcane yield by implementing various decision tree algorithms where the classes are categorized as low, moderate, and high. They use Hadoop and Elasticsearch for Big Data mining. The proposed model is divided into three phases: Relief feature selection where training data are given as input after that is attribute ranking and then the filtering of the attribute is done. The second phase is called classification model implementation where is done MapReduce decision tree classification and comparison of C4.5, C5.0, and random forest decision tree is done. Last is the third phase named accuracy prediction where is done computation of classification accuracy. Comparison of these three algorithms C4.5, C5.0, and Random Forest is done by some form of measurement [14] as Accuracy, Error, Precision, Sensitivity, and Specificity. The result of this study shows that there is a correlation between climate conditions and sugarcane productivity. They propose MapReduce-based classification algorithms for classifying the sugarcane yield classes from accessible observed climatic parameters [14].

The authors in this paper [17] show a model for finding the correlation between weather conditions and Grape berry quality. The study is conducted in Portugal. They measured the temperature as average, min, and max for three months Jun, July, and August, and how the temperature affects the grape berry quality and quantity. They found that high temperature decreases berry weight, titratable acidity, anthocyanins, and TPI, and increases pH and potential alcohol. They use different algorithms such as correlation analysis, Pearson product-moment correlation coefficients, Student’s t-test, and ANOVA analysis.

The authors in this paper [18] present the impact of climate change on viticultural products in Europe. They found that Increased future warming and dryness will probably result in an eventual overall loss of viticultural suitability in the Mediterranean-like climatic areas of southern Europe, while in central and northern Europe, warming conditions will potentially benefit grapevine cultivation.

The authors [19] in this paper propose a model for grape quality prediction by combining open-source AutoML techniques and Normalized Difference Vegetation Index (NDVI) data for vineyards obtained from four different platforms-two proximal vehicle-mounted canopy reflectance sensors, orthomosaics from UAV images and Sentinel-2 remote sensing imagery-during the 2019 and 2020 growing seasons. The author of this paper investigates the application of open-source AutoML and multi-platform multi-temporal NDVI data for the evaluation of quality attributes of grapes. They compare it with the method proposed before [20].

V. Proposed model for Smart Agriculture Sensor Data

The recommendations that emerge from the model will depend on the specific predictions made by the algorithm. For example, if the model predicts that grapes will be of low quality due to high humidity, a recommendation might be to apply protective measures to prevent mold or other diseases that could affect grape quality. Alternatively, if the model predicts that grapes will be of high quality due to favorable weather conditions, a recommendation may be to increase vine irrigation to ensure optimal growth and yield.

Overall, the model focuses on predicting the quality and quantity of grapes based on environmental factors, and the resulting recommendations depend on the specific predictions made by the algorithm.

The proposed model now predicts the weather temperature, and humidity based on the data collected from IoT sensor data and the hydrometeorological institute based on it we analyze the data for grape yield for the last five year and we analyze the time frame when the grape sterilization is done.

Prediction of the quality and quantity of grapes is

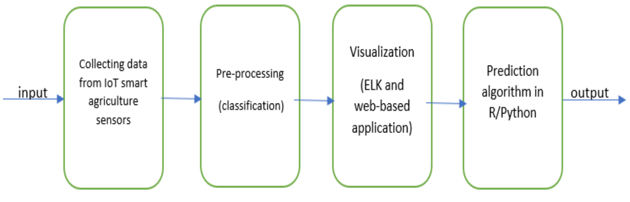

Figure 1. Proposed model for prediction of temperature

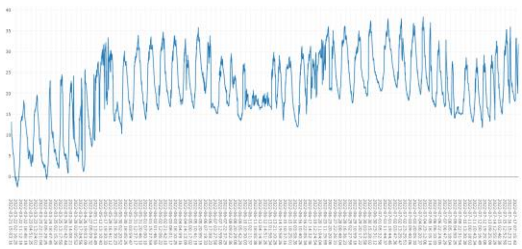

Figure 2. Temperature data collected from IoT smart agriculture sensors

based on four essential elements:

- IoT sensor data which are used for training the model
- Data collected by interviews with farmers on how to cultivate grape
- Data from the Kosovo Hydrometeorological Institute and Institute of viticulture
- One or more prediction algorithms.

A four-phase framework is proposed, consisting of IoT sensor data collection in real-time, preprocessing of data, real-time visualization of data, and at last prediction of quality and quantity of grapes. The proposed model is shown in figure 1.

The first step is to install IoT smart city and smart agriculture sensors and configure them to collect data in real-time and send them to Mashlium server where automatically the data are saved then in MySQL. The data are collected by sensors and sent throw a Wi-Fi connection to the main server where a MySQL database is installed. Is important to mention that the sensors can be located at a distance of 5 km from the center where the data are saved. Libelium sensors that we use are Smart City Pro and Smart Agriculture. The programing language for configuring them is like Arduino, based on C and C++. Table 1 below presents the data that are collected from Libelium IoT SmartAgriculture and SmartCity sensors. There are six parameters collected every minute (the time can be defined by us). The data are registered every five minutes and we have a dataset from march 2022 that continues. The second phase is pre-processing of data, the data are seasonal time-series data as shown in figure 2 below.

This phase includes the classification of data and removing unnecessary data. Here we use classification methods to remove unnecessary data and prepare them for visualization.

The third phase is visualization of data by ELK [21] and analyzing them in real time. ELK is composed from Elasticsearch, Kibana and Logstash where we have configured the data from the datacenter where we collect IoT data automatically in real time to send to ELK and visualize there. In Logstash we can configure and do pre-processing of data before visualizing them in Kibana. Kibana offer the possibility of visualization and also analyzing and the possibility of adding additional algorithms for visualization and prediction of data. Also, we have developed a web-based platform for monitoring the data collected from IoT sensors mentioned above.

TABLE I. DATA COLLECTED FROM IOT LIBELIUM SENSOR DATA FOR SMARTAGRICULTURE AND SMARTCITY

id	*id_wasp*	*id_secret*	*frame_type*	*Frame number*	*sensor*	*Value*	*timestamp*	*sync*	*raw*	*parser_type*	*MeshliumID*
8049	SmartCityPro	3E381CE819623C3D	134	0	CO2	-1	6/8/2021 14:55	0	noraw	1	2.11E+13
8050	SmartCityPro	3E381CE819623C3D	134	0	PRES	96821.63	6/8/2021 14:55	0	noraw	1	2.11E+13
8051	SmartCityPro	3E381CE819623C3D	134	0	HUM	41.6	6/8/2021 14:55	0	noraw	1	2.11E+13
8052	SmartCityPro	3E381CE819623C3D	134	0	TC	27.23	6/8/2021 14:55	0	noraw	1	2.11E+13
8053	SmartCityPro	3E381CE819623C3D	134	0	US	270	6/8/2021 14:55	0	noraw	1	2.11E+13

Last is the prediction phase. In this phase different algorithms are compared and chosen the best one or more to be used for the prediction of the quality and quantity of grapes, the data mining techniques will be used in this phase. Algorithms that have been used to predict temperature are NeuralProphet [22], Random Forest Regression [23], SARIMA[24], and ANN by KERAS[25].

Samples (which from now on we are going to refer to as datasets) contain hourly temperature values from the 1st of January 2017 up to the 31st of December 2021. Using these values, we are going to try and predict temperatures for the whole of 2022 year. There are some periods during which sensors haven't been measuring temperature. Those values have been replaced with a specific value that doesn't leave holes in our dataset.

Forecasting temperature is done in a straightforward way based on assumption. There are many factors affecting air temperatures, such as pressure, humidity, wind speed, and direction, but seasonality allows us to predict daily temperature with a small margin of error. Since temperatures are seasonal (going from winter into summer, temperatures start to get higher, and vice versa from summer into winter), today's predicted temperature will be based on yesterday's temperature, and yesterday's temperature will be based on the day before yesterday, and so on.

Grabbing and formatting our datasets is going to be handled by Pandas, a Python library that can read and manipulate CSV Files. Plotly [26], another Python library, will be used to show plots and visualize our datasets and predicted values.

VI. CONCLUSION AND FUTURE WORKS

Smart Agriculture is a fairly new term and most farmers are not aware of what exactly lies behind it. The term smart agriculture refers to the use of technologies such as the Internet of Things, sensors, location systems, robots, and artificial intelligence on farms [1], [6]. The ultimate goal is to increase the quality and quantity of the harvest.

Some examples of technology used in smart agriculture are:

- Precise watering and proper nutrition of plants;
- Management and control of temperature in the greenhouse;
- Sensors for soil, water, light, humidity, and temperature management;
- Software platform;
- Location systems – GPS, satellites, etc.;
- Communication systems – based on mobile connection;
- Robots;
- Analytics and optimization platforms.

The connection between all these things is the Internet of Things, which is a mechanism for the connection between sensors and machines resulting in a complex system that manages the farm based on the received data. Thanks to this system, farmers can monitor the processes on their farms and make strategic decisions remotely - tablet, phone, or any other mobile device without being present in the fields.

This paper proposes a model for the prediction of the quality and quantity of grapes based on IoT sensor data from agriculture. This proposal will help farmers to take decisions and improve the process of grape processing and grape sterilization.

Because the world is facing climate change on one side and population growth on the other side [5], [6] is very important to use data mining techniques in agriculture to predict the quality and quantity of agriproducts. We use sensor data for the past five years as temperature, air humidity, air pressure, and land humidity which is a very important factors related to grape quality and based on them the proposed model will be able to recommend an adequate period for grape processing and grape sterilization. The quality and quantity for the past five years will be analyzed and based on them we do predictions for next year.

The proposed prediction model in this paper is focused on predicting grape quality and quantity based on environmental factors, and the recommendations that arise depend on the specific predictions made by the algorithm.

The next step of our research is a selection of the prediction models and algorithms used by other authors, and to compare them and select the best to compose the new model which is better than the existing one.

Also, a web-based platform for visualizing the data in real-time will be proposed in the future where the farmers will be able in real-time to monitor the weather parameters such as temperature, air humidity, air pressure, and land humidity.

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