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Research Article

Smart Agriculture Applications and Data Analysis with Industry 4.0

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ABSTRACT

The world's food demand is predicted to exceed its food supply significantly in the coming periods. Many physical factors, such as climate change in access to water, change the production amount and food prices. Efficient resource utilization can be achieved by developing smart agricultural applications using the IoT and image processing techniques. For this purpose, in the proposed study, a smart agriculture application was developed using IoT technology with image processing. In the proposed image processing algorithm, the crops' images were processed, weight estimates were made, and their numbers were taken. The data we collect instantly can be uploaded to the cloud, and the data collected on the cloud side can be analyzed over the mobile application. Thanks to data analysis with the mobile application we have developed, we can see the current status of the crops and make instant decisions, and it also plays a role in determining market prices. With all these studies, it has been seen that agriculture can be digitalized with the technologies we use, and thus, productivity in agriculture can increase significantly.

1. Introduction

Agriculture is the centuries-old culture of humanity and the technique of raising plants and animals, which is necessary for the basic need of humankind to feed and sustain its life. It comes first among the physical demands of people. It is essential for the continuation of life. According to a study by the United Nations in 2015, the world population is expected to be 9.7 billion in 2050 and 11.2 billion in 2100. The increase in the population of humanity requires further improvement of agricultural activities due to factors that negatively affect agriculture, such as environmental factors such as climate change, global warming, and drought. Information technologies are needed to ensure that the food supply can be sufficient in the future. Agriculture has developed continuously from the past to the present, and the processes in this development have been called versioning in the industry [1].

Industry 4.0, the Internet of Things (IoT), big data, cloud systems, sensors, etc., is the new version of the production system created by using technologies in communication. Large countries such as Germany, China, Japan, and America are investing to switch to this technology. Many countries have established research units for this purpose. In our country, research in this field continues.

One of the primary purposes of Industry 4.0 is to prevent waste by making maximum use of technology. For this reason, it aims to increase efficiency by establishing automation systems and following all production stages with correct planning and timely intervention. As with Industry 4.0, the development of agriculture has not stopped and has passed through specific steps. These stages have existed since the existence of humanity. Various factors, such as the development of technology and the increase in the human population, have influenced the

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development of the stages. These phases continue as follows;

Agriculture 1.0 – A farming method using only human and animal power. We can say that it is the most primitive form of agriculture used for centuries.

Agriculture 2.0 – Using pesticides and synthetic fertilizers and pesticides is the beginning of mechanization in agriculture.

Agriculture 3.0 – Use of GPS and computer software for data processing in agriculture.
Agriculture 4.0 – We can also call it smart agriculture. Using unmanned aerial vehicles and image processing techniques.

It aims to develop a smart agriculture system and strategy with the integrated operation of technologies such as the developing IoT, cloud computing, image processing, sensors, and big data. Also, it aims to integrate the industry in a way that provides maximum benefit from informatics, increases production efficiency, prevents wastage, and thus prevents various global crises.

It is possible to prevent the food crisis by integrating the same technologies into all agriculture processes. In particular, price fluctuations, which are frequently experienced today, affect the market negatively. It can be used to stabilize the food market due to the integration of information technologies and agriculture. Thus, our resources will be used as needed.

We can express the aim of the study as using Industry 4.0 technologies in agriculture to ensure planned production as needed. It is among our goals to minimize the effects of the food crisis that will occur in agriculture due to climate change, global warming, drought, and other problems affecting productivity in agriculture by making maximum use of technology.

The literature on smart agriculture has also developed in parallel with technology. The Israeli-based CROPX application has developed a solution that enables agricultural enterprises to consume fewer chemicals, energy, and water by collecting data from sensors and software and mapping the terrain from the satellite, guiding the user by giving advice. Isaac Bentwich, the founder of the CROPX company, stated that the farmers who installed this system achieved 25 percent savings in water and energy [2, 3].

Another technology company, Phytech, uses sensor and cloud technologies in agriculture. It allows monitoring and planning based on the data directly received from the system with the help of sensors. It counts every drop of water the crop receives and records it as data. The rapidly developing drone technology has been used to automate and accelerate image processing procedures for smart agriculture [4, 5].

There are also applications such as Dronedeploy, one of the new drone-based internet services. These applications can generate datasets from their acquired images and quickly interpret the results. Even near real-time response is expected soon [5, 6].

England, Israel, and the Netherlands have become leading countries in the world with their investments and practices in smart agriculture. The UK established its first field crops analysis facility in 2015. The facility operates 24 hours a day and has a scanner that can scan an area of 1800 square meters with sensors and cameras on it. Thanks to the scanner, plant health and development can be followed.

According to the smart agriculture market research conducted by Huawei in 2017, the market value of the world smart agriculture market, which was 13.7 billion dollars in 2015, is expected to increase to 26.8 billion dollars in 2020. According to these data, the market will double in value within five years [7].

2. Smart Agricultural Technologies

In smart agriculture, several technologies can be used for each process. Before the production process, production planning can be done using technologies such as big data analytics and data warehouses. The fields to be produced can be addressed by the images taken from the satellite and the processing of these images. The production can be planned with the analysis by keeping the information on which crop can be grown in which fields. An extensive database open to any large farmer or producer can be developed with crop cards containing the characteristics of the crops to be produced. Since crops are physical objects, IoT can be used to retrieve data.

2.1. Internet of Things (IoT)

The IoT enables physical objects to transfer data to the network with the help of sensors, sensors, RFID, devices, and software. This concept allows automation systems to be created by digitizing data from physical objects. Since it is based on constantly receiving data from things, it needs Big Data and Cloud technologies so that the received data can be processed, made meaningful, and stored. There is no specific architecture in the literature, but many examples of architecture can be found. The architecture of the IoT system is shown in Figure 1.

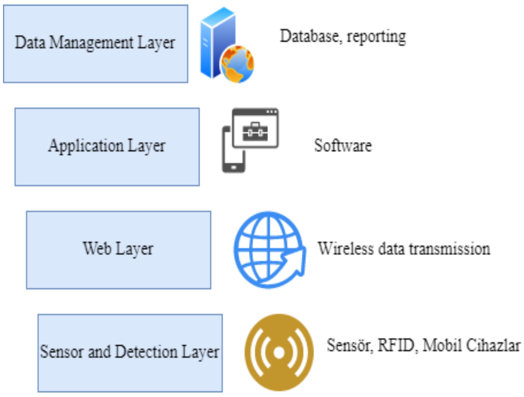

Figure 1. IoT architecture

Data collected from objects is sent to the cloud server. The size of the data is increasing due to the diversity of objects and the constant incoming data. Big Data technology is used to analyze and report this data. Big Data technologies enable us to draw meaningful assumptions from data. Many applications, such as smart cities and environments, have been developed, and more application areas are available. IoT technologies build the system's basis for developing smart farming applications. Environmental variables such as ambient temperature, humidity, and mineral content in the soil can be collected and processed through sensors and software, thus optimizing environmental factors such as humidity and temperature. Digitization and storing agricultural data are crucial to establishing a smart agriculture system. Instant data provides immediate response to environmental factors. If the moisture in the soil drops, the optimum moisture balance can be achieved by using drip irrigation technology. An example of a Crop Irrigation system with IoT is given in Figure 2.

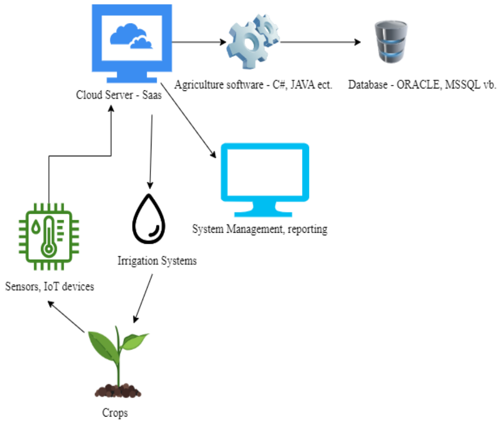

Figure 2. Crop irrigation system with IoT

2.2. Image processing

Image processing is analyzing the image data in the digital environment within the framework of algorithms determined according to the purpose of use in the digital environment. For example, the fields in the digitally transferred image data taken from the air by Unmanned Aerial Vehicles (UAVs) or drones can be shown by an algorithm that recognizes the uncultivated areas by color, painting them with red or the desired color. Even the percentile of the uncultivated areas from the image can be extracted with the algorithm.

This image-processing technology is also used in agriculture. In his article, Nan Xu [8] showed that image processing technology is mainly used in agriculture in the following five directions. These are monitoring crop growth, diagnosing diseases and pests, diagnosing diseases and pests, monitoring maturity, and recognizing crop color. In addition, the study obtained results that positively affect the agricultural development of image-processing technology.

Images from the field are transferred to the cloud system for image processing technology using camera drones and UAVs. By analyzing the image data processed with specific algorithms, the actions that need to be taken in the digital environment can be shown to the user, and their automation can be provided. An image processing system in agriculture is given in Figure 3.

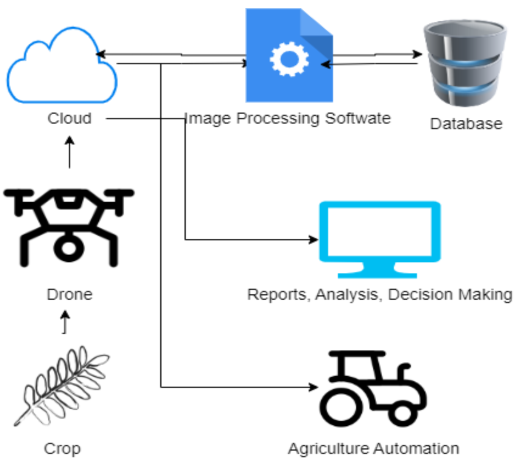

Figure 3. Image processing in agriculture

2.3. Big data

Data emerged with the concept of computer technologies and consisted of digits (0,1) combined. Raw data doesn't mean anything by itself. It becomes information if it is processed. Today, with the increase in data collecting and smart devices, the amount of data collected is increasing exponentially. Data sets that are incrementally obtained in this way are called big data. Big data has three elements: volume, velocity, and diversity. Volume (V) is the size of the data; velocity is the rate at which data is acted upon. Since the data obtained with the IoT is real-time, the speed of writing to the memory is also important. Variety refers to the type of data. Data such as video and audio are expressed as unstructured data types, while data held in relational databases are expressed as structured.

The data collected in agriculture and the fields managed with smart agriculture applications will increase over the years. Big data technologies will be needed to analyze and make sense of these data. Since IoT technologies in smart agriculture are mandatory, technologies such as data mining and data science, which cannot be considered independently of big data technologies, should work in an integrated manner. In addition, due to the increasing data over the years, an agricultural memory will be formed. Agricultural activities in the following years will be planned more easily, and market stability will be ensured. Farmers across the country are often confused when deciding on the type of crop to plant. If the analysis of the data collected from a single center is provided, necessary guidance will be provided.

3. Smart Farming Application with Image Processing

Images were taken by taking photos in our application. A black background is used to make the image easy to process. It is possible to take and process images outside the black background, but it is desired to be affected by noise in the least way. This application can take and process images instantly with a drone camera. However, efforts have been made to make the application work primarily in its basic form. The overall flow chart and layers of the Smart Agriculture Image Processing Application are shown in Figure 4.

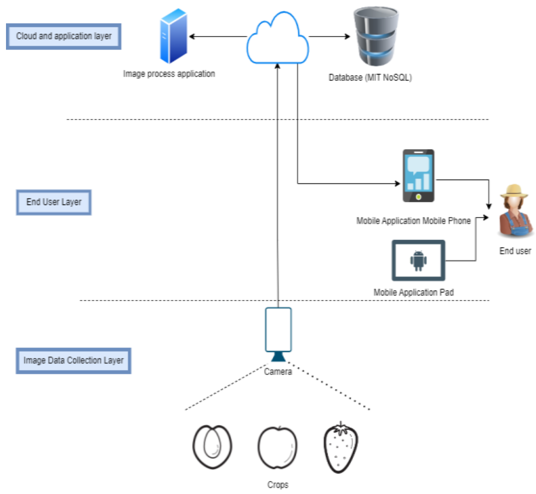

Figure 4. Smart agriculture image processing application

3.1. Image processing

Then, the file path of the image we will process into the project is taken. The image is scaled for easier processing. At this stage, a matrix equal to the picture's dimensions is created, and the value of each pixel of the picture is assigned to this matrix. Since our picture is colored, a third dimension comes with RGB. The scaled version of the image we want to process is seen in Figure 5. As seen in the picture, there is 1 TL and one lemon.

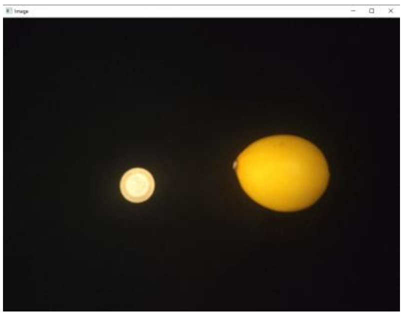

Figure 5. Scaled image to be processed

In the next step of the algorithm, we make our image black and white for easy processing. The cvtColor function of OpenCV is used to create a black-white image. As in Figure 6, the image has become black and white.

Figure 6. Black and white state of the image

In the image, the three dimensions that came from RGB are dispersed. In the next step of the algorithm, the threshold function from OpenCV is used. This function converts the image to a binary image. In this way, the borders are now easier to draw. The format of the image in this step of the algorithm is given in Figure 7.

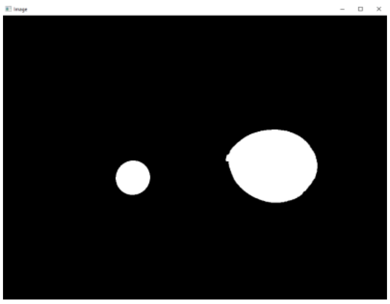

Figure 7. Binary format of the image

With the histogram function of the matplotlib library, histogram graphics of the picture in black and white and binary format, as in Figure 8, are produced. When the graphs are examined, the threshold function used will facilitate the calculation of contours, which is the next step of the algorithm.

When the histogram graphs are examined, it is observed that the black and white picture can take more than one value between 0 and 50, while the histogram graph of the binary image can only take 0 and 255 values. In the image on the double base, the borders have become well-defined, and the picture has now been prepared to be passed to the contour drawing stage.

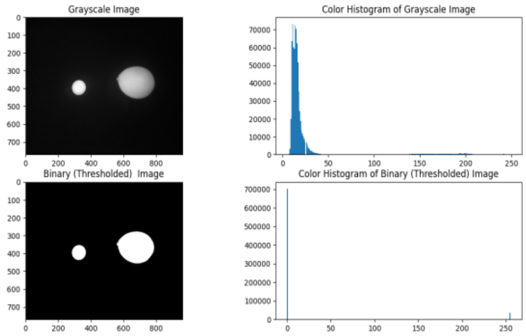

Figure 8. Color histogram charts of image gray and binary formats

The next step of the algorithm is drawing contours by going over the image on the binary base. The drawContours function, which is in the OpenCV library's functions, is used for contour drawing. When this function is used, the objects in the picture are detected one by one. Then, the objects are sorted from the smallest to the largest. Since there are two objects in our painting, two objects are detected only for contour drawing.

The number of objects detected here shows that the algorithm has worked correctly up to this stage. Figure 9 shows the contour drawing where the borders of the coin and lemon are drawn. With the contour drawing, the borders of the objects are now determined, and we can now calculate how many pixels there are within the borders.

In the next stage of the algorithm, the pixel numbers in the area within the contours of the codes are calculated as the values taken from the screen output in Table 1 from the console screen of the application.

Figure 9. Drawing the contours of the objects detected in the image

Table 1. Pixel counts calculated in the app

Image	Pixel Counts Calculated
1 TL	5520
Lemon	30470

According to the pixel numbers obtained from the function, the areas of each pixel actually calculated in square centimeters are shown in Table 2. Knowing the area of the coin helped when calculating the actual area of the pixel. By dividing the coin's area by the number of pixels, the actual area of 1 pixel was calculated as in the screen output written next to the 1-pixel parameter. The actual area of the lemon in the picture was estimated by establishing the proportion.

Table 2. Actual area conversion of pixel counts calculated in the application

	Actual area (cm^2)
1-Pixel	0.00097295821
Lemon	29.6460368612

In part, up to this algorithm stage, we calculated the crop area in the photo, whose weight we wanted to calculate in square centimeters. After this stage, weight estimation will be made depending on the crop type. A unique calculation method for the crop will be used so that our algorithm will work correctly. As seen in Table 3, as a result of the quantitative measurements, the parameters of the randomly selected crops were as in the table.

Table 3. Density calculations of crops

Crop	Mass (gram)	Volume cm^3	Density Mass ($gram/cm^3$)
LEMON1	85.4	90	0.9488
LEMON2	121.2	125	0.9696
MANDARIN1	48.1	55	0.8745
MANDARIN 2	77.7	90	0.8633

The selected crops' images are processed using our application's algorithm in the next step. As a result, the values shown in Table 4 were obtained. The averages of the area/mass values we obtained from our image processing calculated from these values were taken. The estimated weight of the crop is calculated using the values we get from here.

Table 4. Values of crops obtained from image processing

Crop	Calculated with image processing (cm^2)	Calculated Area / Mass
LEMON1	29.64	0.3470
LEMON2	38.12	0.3145
MANDARIN1	21.83	0.4538
MANDARIN2	33.04	0.4252

The averages of the collected data were calculated in Table 4.5. We will use these averages when calculating the mass from the image we are processing. As can be seen, the area/mass value used for each type of crop is different, and the average values should be calculated using the necessary physical measurements.

In the next step of our algorithm, the system weight estimation software was calculated as 89,6200 grams with the Area / Mass parameter specific to our crop.

Table 5. Density calculations of crops

Crop	Average Calculated Area / Mass
LEMON	0.3307
MANDARIN1	0.4395

The same algorithm was tested with the same crop type and with a different crop type. The results and error rates table is shown in Table 6.

Our algorithm worked and obtained weight estimates with a nominal error rate. The total error rates are shown in Table 7. Our algorithm made predictions for all measurements with an average error of 4.13%.

Table 6. Comparison of the actual mass of crops and their calculated mass by image processing

Crop	Mass (gram)	Calculated with image processing (gram)	Error Rate
LEMON1	85.4	89.62	4.94%
LEMON2	121.2	115.25	5%
MANDARIN1	48.1	49.68	3.28%
MANDARIN2	77.7	75.17	3.3%

Table 7. Total error rate table

Parameter	Value
Total mass (gram)	332.4
Mass Calculated by Image Processing (gram)	329.72
Average Error Rate	4.13%

3.2. IoT application

The proposed IoT architecture starts with the acquisition of data with the help of a camera. The collected data is first processed in our running application in the cloud and transferred wirelessly to our Firebase Cloud Platform. Our Mobile application, which we developed on the MIT platform, also allows data analysis by pulling data from the Firebase Cloud Platform. The whole system works in integration with each other. The architecture of our IoT application is shown in Figure 10.

3.3. Data analysis

Data analysis was performed by using Python's Pandas library. Methods in the Pandas library were used to analyze the data collected from the environment.

Figure 10. IoT system architecture

The size of our data will grow a lot later in the implementation. Pandas library has been preferred in our application because of its efficient speed performance in extensive data analysis. Due to the application, the number and estimated weight data can be collected while the crops are in the field. Due to these data, we can perform predictions for the future. The collected data can be compared with previous years and used in production planning.

Example screenshots of bar, column, and line graphics used in our mobile application by performing data analysis are given in Figure 11 and Figure 12, respectively.

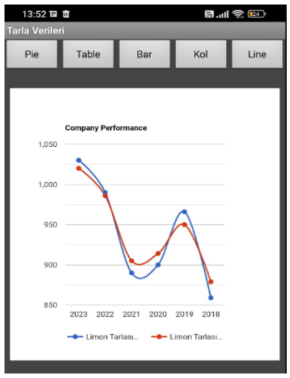

Figure 11. Line chart data analysis

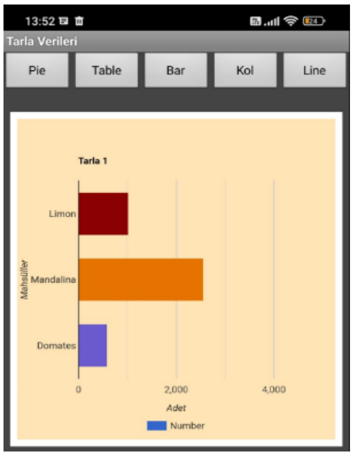

Figure 12. Bar chart data analysis

4. Discussion and Conclusion

As a result of the research, it is seen that due to factors such as increasing population rate, drought, and climate change, humanity needs to use agricultural resources correctly to survive. It is seen that the way to manage these resources correctly is through the digitalization of agriculture by integrating agriculture with the Internet of Things, image processing, and big data technologies.

Governments are investing in this issue, which has also been studied worldwide. Although Türkiye's climate and soils are suitable for agriculture, it is still at risk of a serious food crisis. Countries such as the Netherlands, England, and Israel have made applications that increase productivity in agriculture with their technological studies. It is necessary to increase the applications of similar models in our country.

In our application, the OpenCV image processing library is used in Python. Visual Studio Code was used on the code side as a development environment, and Colab was used as an online alternative. On the database side, the NoSQL database structure was used in the Firebase environment. Instantly, the images of the crops were processed with our algorithm, the data were kept in the database, and successful results were obtained with a low error rate by making weight estimations. In the study, it is seen that the use of technology in agriculture increases productivity.

In addition, the image processing project we have done also contributes to this. The positive results we have obtained from our work show that the project can produce even more successful results by maturing as the technologies develop. Based on these positive results, investments should also increase in agriculture, which is a very important area. In our country, whose soils and climate are highly suitable for agriculture, incentives should support efforts. Due to the importance of agriculture, as technological developments continue, the scope of the study has the infrastructure that can mature over time.

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Authors' Contribution

The authors contributed equally to the study.

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The Declaration of Ethics Committee Approval

This study does not require ethics committee permission or any special permission.

The Declaration of Research and Publication Ethics

The authors of the paper declare that they comply with the scientific, ethical, and quotation rules of SAUJS in all processes of the paper and that they do not make any falsification of the data collected. In addition, they declare that Sakarya University Journal of Science and its editorial board have no responsibility for any ethical violations that may be encountered and that this study has not been evaluated in any academic publication environment other than Sakarya University Journal of Science.

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