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Self-Learning IOT based Integrated Management for Improving the Quality of Yield in Pomegranate for Indian conditions

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Abstract
India is the largest producer of pomegranate in world. It produces five Lakh tones of total global production of ten Lakh tones, yet the export is only 5000 tones. The reason for shortfall in exports is its inadequacy to meet the global export standards. Various challenges like fertilizer & pest management, irrigation management etc. exist in production of high-quality fruits. Due to large scale geographical distribution of product with larger variations in climate, soil conditions it is very difficult to manage production using a general rule. The production management must be adapted to each specific field condition with a goal to achieve high quality of yield. This work proposes a self-learning data mining technique to learn the optimum conditions for higher quality yield and enforce the learnt rules using IOT based controller. The learning is done from a multidimensional view of irrigation, pest and fertilizer management to achieve optimum fruit quality.

Keywords: *India is the largest producer, IOT*

1. Introduction

India ranks second in product of horticulture crops and first in pomegranate production contributing 50% to global production of 10lakh tons per year. Even with highest production, the export is as low as 5000 tons compared to Spain which exports 75,000 tons of its total production of 1 Lakh tons. One of the important reasons for reduced share of exports is the lower quality. The quality degrades due to various causes of environment, irrigation, fertilizer and pests. Diseases such as Bacterial Blight, Fruit Spot, Fruit Rot and Leaf Spots etc.also affect the quality of production. Achieving a higher quality of yield is very challenging and single rule-based management of irrigation, fertilizer, pests is not possible in diverse area like India. The conditions of soil, irrigation, environment etc. are quire varying and it necessitates more specialization is integrated quality management solution. Internet of Things (IOT) is one of important technological transformation happening in Farming all over the world. It has made agriculture smart. In smart agriculture, sensors monitor the all production affecting factors in the field like humidity, temperature, soil moisture etc. and controls many systems like irrigation, fertilizer management etc. These system helps to optimize the resources water, fertilizer, pesticide usage so to achieve higher yield. IOT is used in various applications like Precision farming, monitoring of live stocks, greenhouse farming.

The current IOT methods for integrated management of irrigation, fertilizer, pesticide to achieve high quality involve human factors in decision making. The administrators of these system configure rules for operation of system time to time received form external inputs like research institutions. This work integrates a data mining based intelligent rule construction system for integrated management of irrigation, fertilizer, pesticide with IOT based control. IOT sensors collect various

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parameters from field and sends to decision control system. This system continuously learns the best practices depending on various factors like demographics, cropping patterns, environmental factors etc. and derives rules. The specialized rules are sent to IOT based controller to control irrigation, fertilizer and pest management with goal to improve the quality of yield for pomegranate.

2. Related Work

In [1] authors proposed a smart agricultural model to decide the higher productive crop sequence. It is decided based on past crop sequence on the farmland. The agricultural model uses big data analytics to find the best crop sequence and fertilizer requirement for achieving better production. Authors in [2] proposed a smart agriculture-based solution for water management. The system proposed a low power and low-cost solution to monitor temperature, soil moisture, rain, water level and control irrigation. In [3] a machine learning model-based irrigation level prediction is proposed. The irrigation requirements are predicted based on parameters like temperature, humidity, soil moisture and weather forecast data. The system has a provision for a closed loop control for irrigation. A support vector regression model is trained to predict the irrigation level based on temperature, humidity, ultra violet radiationand weather forecast. Authors in [4] proposed image processing-based irrigation control system. The gray scale image of agricultural field is analyzed to estimate the ratio between wetness and dryness portions of the soil. The ratio between wet and dry area of soil is used to control the irrigation level. In [5] a machine learning based irrigation recommendation is proposed with support of past knowledge of experienced agrarians. Regression based on Gradient Boosted Regression Trees is used for prediction of irrigation plan. Authors in [6] proposed a thermal imaging based intelligent irrigation monitoring system. A drone fitted with thermal imaging camera captured thermal images. These thermal images are used to analyze water requirements, leaf water potential and non-uniform irrigation. The irrigation policy is fine tuned based on the information collected from thermal images. A fuzzy logic-based decision support system for irrigation scheduling is proposed in [7]. The experiences of the farmer and best practices are expressed as fuzzy rule sets. These rules along with results from soil and crop models are used to construct an optimized irrigation schedule. Authors in [8] proposed a fertilization and irrigation management system using wireless sensors technology, machine learning and decision support systems. The parameters used for decision making are temperature, humidity, soil properties, seasonand nutrients. Precision irrigation with IOT based smart management of water is proposedin [9]. Big data analytics is proposed for large scale scalability and context dependent processing.An infection model for predicting strawberry crop disease is proposed in [10]. General Infection Model proposed in this work predicts infection risks. The infection modelling is based on weather conditions as input. Historical weather conditions affecting the quality of strawberries is used to build the infection model. A machine learning model for pomegranate disease diagnosis is proposed in [11]. Neural network is trained with GLCM features extracted from diseased and healthy fruits. The proposed system is able to predict many of diseases affecting pomegranate quality.Randomized Block Design based experiment was done on 4-year-old pomegranate orchard to analyze the correlation between the nutrients and yield. Similar to [11], a correlation analysis between the nutrients and fruit quality is analyzed in [12]. The quality of fruit is measured is terms of average fruit weight, average fruit length and diameter. Authors in [13] assessed fruit quality assessment using data mining methods. The work analyzed many methods and found gray correlation analysis is found to perform better for gray correlation analysis.All these methods used multiple quality metrics to evaluate the fruit quality.In [14] authors applied backscattering and multispectral imaging techniques to detect the quality of fruits. They applied this work for tomato fruit. Image processing based features are extracted to train an artificial neural network to predict the fruit quality. An automatic fruit classification system for orange based on image features and machine learning is proposed in [15]. The orange fruit is segmented from camera image. From the segmented fruit, fractal and textural features are extracted. Multiple machine learning algorithms are trained to classify the fruit to three categories of good, defective and moderate.

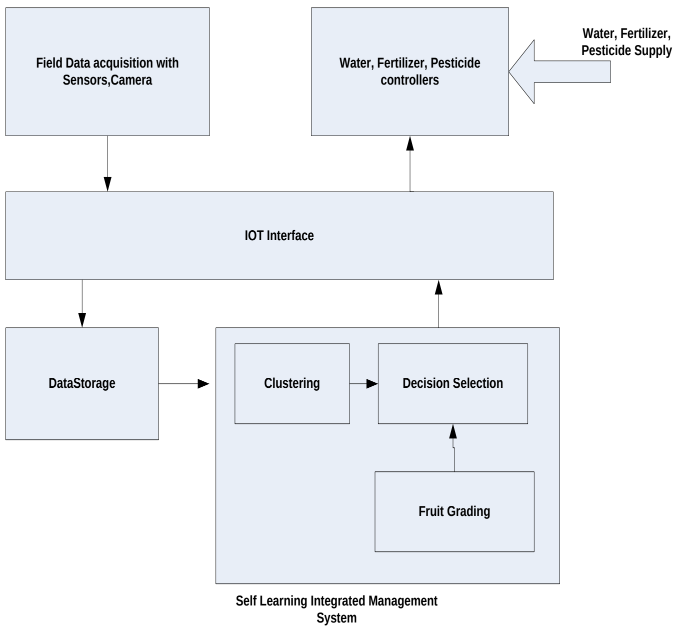

Figure 1: Architecture

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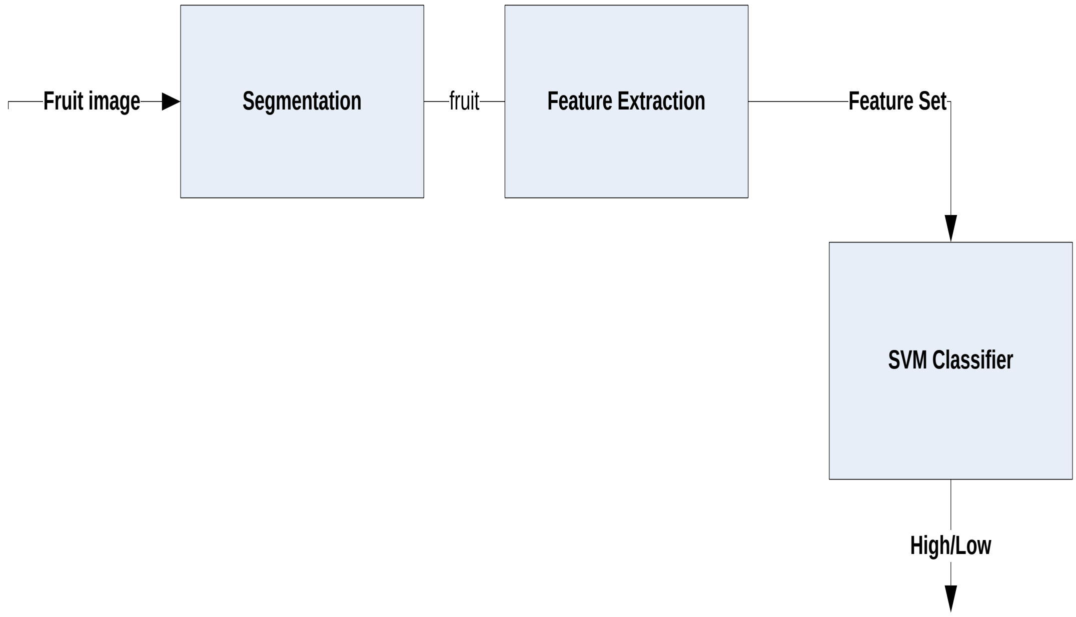

Figure 2: Fruit Grading System

3. Self Learning Iot Based Integrated Management

The architecture of self-learning IOT based integrated management is given in Figure 1.

Sensors are fixed in fields to collect various environmental factors prevalent in the field. Sensors to monitor temperature, humidity, water level and rain are installed in fields to collect the data. Camera is fixed to collect the fruit image. The sensed data and fruit images are sent via IOT interface to a Self-learning integrated management system. These data are stored in the storage repository. Self-learning integrated management system mines the stored data and detects optimized integrated management decision to achieve higher quality of yield. Based on the decision selected, rules are created and send via IOT interface to the controller in Farm. These controllers use the rules to trigger irrigation, pest and fertilizer control valves. Through controller, the irrigation quantity, fertilizer quantity and pesticide quantity to be given to the plant is controlled. Each field is assigned with ID and configured with soil type and location in the self-learning integrated management system. The camera collects the image of fruit image samples. The data collected over every sampling time (configurable) is sent via IOT interface and saved in the storage repository indexed using the field ID.

A fruit grading system using image processing and machine learning is trained in the self-learning integrated management system to classify the fruit images acquired from field to two grades of high and low.The fruit grading system architecture is given in figure 2. An SVM classifier with radial bias kernel is trained with following features of fruit image

1. Texture based statistical features
2. HSV histogram features
3. Color auto correlogram
4. Color moments
5. Wavelet moments

The input image is first preprocessed to segment the fruit region from the camera image. Image processing is done to extract features. The extracted features are given to SVM to grade the fruit to high or low quality. For fruits of low quality, best decision for improving the quality by mining in the storage repository is made by the self-learning integrated management system

The fields configured in the management system are hieratically clustered based on location, soil type, average temperature, average rainfall and average humidity. Bottom up Hierarchical agglomerative clustering is done with K levels.

Each cluster is split to two partitions with fields having higher grade fruits in one group and fields having low grade fruits in another category.

Starting from the lowest level till K levels, best models for irrigation, fertilizer and pest management is constructed for the fields with higher quality fruit. At each level, the data collected about sensor reading, irrigation quantity, fertilizer dosages, pesticide dosages from the higher quality fields are collected from the storage repository. The problem of finding the optimum value for irrigation quantity, fertilizer dosage and pesticide dosage for input variables of sensor reading (temperature, humidity, soil moisture, rain) is solved as multioutput regression problem.

A multioutput regressor is constructed at every level in the cluster to model the relationship between the irrigation quantity, fertilizer dosage and pesticide dosage. This multioutput regressor is frequently reconstructed on periodic interval like 1 week by mining the data from the storage repository. If cluster does not sufficient number of entries (in terms of fields), then no model is created for that cluster.

The multioutput regression model is constructed using support vector regression. Support vector machines are usually used with single output variable. It constructs a relation between the input vector X and single output y_i from a given training set D. It finds the regressor $w\epsilon\, R^{m\times 1}$ and the bias term $b\epsilon R$ which minimize

$$\frac{1}{2}\,||w||^2 + C\sum_{i=1}^{N} L(y^{(l)} - (\emptyset(x^{(l)})^T w + b))$$

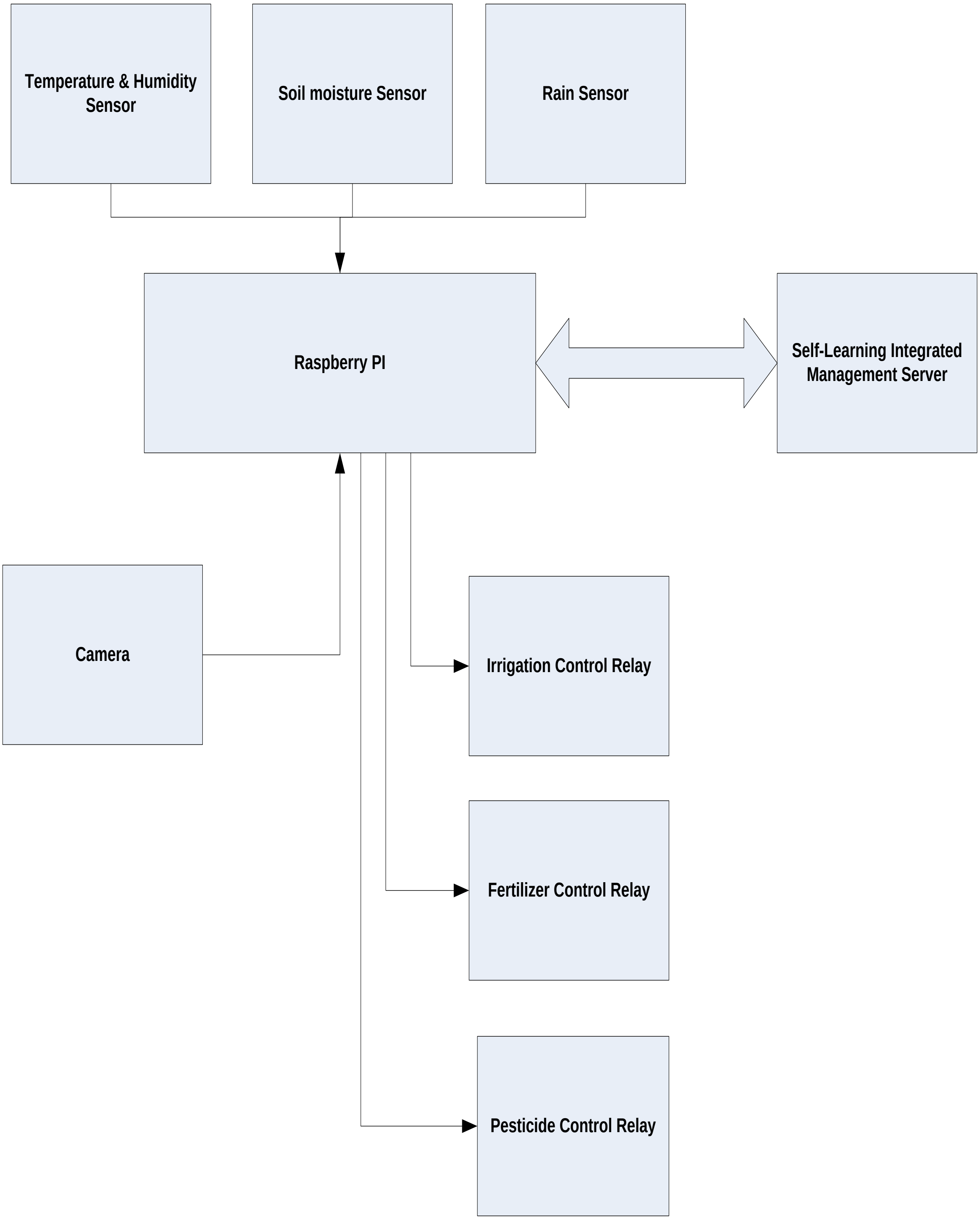

Figure 3: Proof of Concept

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Where $\emptyset$ is the non linear transformation to a higher dimensional Hilbert space H and C is the tradeoff parameter between regularization and error reduction. L is the Vapnick loss function. The solution w , b is induced by linear combination of training set in the transformed space with an absolute error. For the case of multiple output variables, single output SVR can be easily applied independently to each output. But, since this does not consider the possible correlations between the output, traditional SVR needs to be extended by adapting the minimization method as

$$\frac{1}{2}\sum_{i=1}^{d} ||w_i||^2 + C\sum_{i=1}^{N} L(y^{(l)} - (\emptyset(x^{(l)})^T w + b))$$

Where w is m×d matrix $w = (w_1, w_2 \dots . w_d)$ and $b = (b_1, b_2, \dots b_d)^T$

When a field fruit is detected to be of low quality, the lowest cluster in which the field is present is found and it is checked if that cluster has the multioutput regressor model. If there is model for that cluster, then input for the model is constructed from the sensor reading collected from field and fed to the model to get the output prediction in terms of irrigation quantity, fertilizer dosage and pesticide dosage. When there is no model in that cluster, the next highest cluster with model is selected for regression to predict the irrigation quantity, fertilizer dosage and pesticide dosage.

The advantage in the solution is its ability to self-learn the optimum parameters for achieving higher quality from the historical information mined from storage repository. Due to use of clustering, the best practices followed for achieving higher quality in similar field conditions and neighborhood is brought to fields with lower quality fruits.

4. Results

A proof of concept of the proposed solution was implemented. The architecturediagram of the proof of concept system is given in figure 3. The system was simulated for 100 nodes with random distribution around a 100 km radius. Each node generated sensor reading in correlation to the geographical area of deployment. Randomly 20 nodes were made to send images of good quality fruits and rest of nodes were made to send image of bad quality. Following are the good quality and bad quality fruit images used for testing.

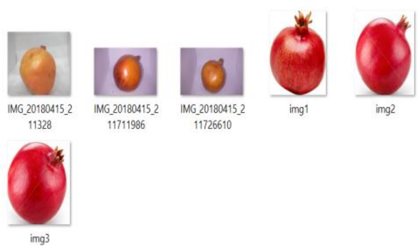

Figure 4: Good Quality Fruits

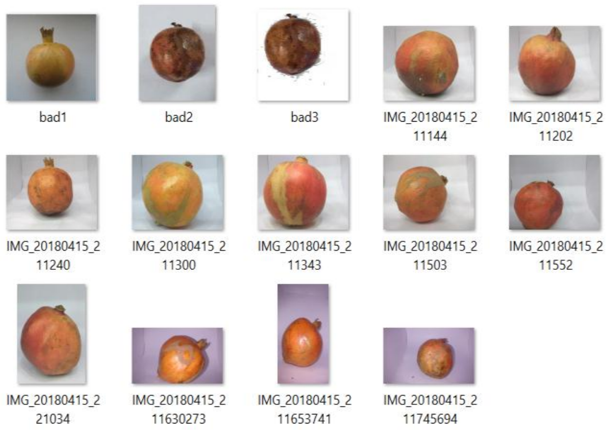

Figure 5: Bad quality fruits

Sensor reading were sent at rate of 1 reading per minute. The performance of the Fruit grading system is measured in terms of accuracy against following SVM kernels for kernel parameter.

1. Radial Bias Network (RBF)
2. Mexican-Hat
3. Morlet

The accuracy is measured for three& tenfold cross validation and the result is below

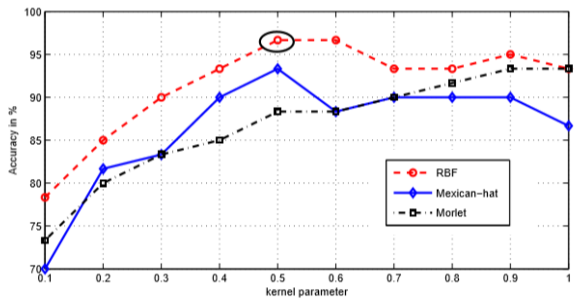

Figure 6: Accuracy for 3-fold cross validation

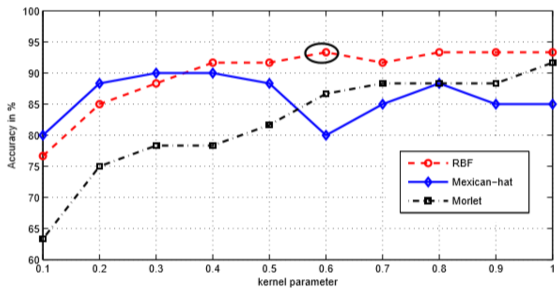

Figure 7: Accuracy for 10-fold cross validation

From the results, RBF kernel is found to provide higher accuracy in food grading of about 96% at kernel parameter of 0.5.

We also measured the difference is prediction accuracy of Multi output SVR regression in terms of Mean Square Error (MSE) for different prediction outputs of irrigation volume, fertilizer volume and pesticide volume and the result are below. The result is compared against linear regression.

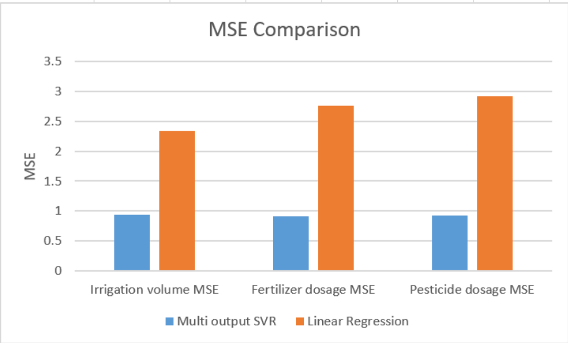

Figure 8: MSE Comparison

Table 1: MSE Comparison

MSE	Multi output SVR	Linear Regression
Irrigation volume	0.94	2.34
Fertilizer dosage	0.91	2.76
Pesticide dosage	0.93	2.91

From the results, it can be seen that multi output regression has lower MSE and gives the optimum dosages to achieve better quality.

5. Conclusion

This work proposed self-learning IOT based integrated management system for improving the quality of pomegranates. Based on sensor reading and fruit images from the field, a self-learning multi output regression model is created to predict the optimum value of irrigation volume, fertilizer dosage and pesticide dosage due to be used to achieve higher quality fruits. A proof of concept of the proposed system was implemented and accuracy of fruit grading process and the dosage prediction process is measured. The system is found to have higher accuracy. As a next step, the system will be implemented on fields and live tested for fruit quality.

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