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Tomato Grading with Respect to Maturity Levels Using CNN

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I. ABSTRACT

Food is a basic requirement for every living being to survive. It provides us with energy to perform our daily routine, being one of the basic requirements a majority of the population doesn't have the access to quality food. Due to improper food management over1.6 billion tons of food waste was generated in the year 2022.
In order to tackle this problem we need to reach the root of the problem. The root of the problem lies during the harvesting of fruits vegetable, grains, pulses etc... Were due to improper segregation and management of waste the quality of food being produced as the end product. In the wastage being produced this paper focuses on the agricultural wastes being generated. In India over 350 million tonnes of agricultural waste every year. This waste generated can be regulated by performing a precise harvesting. This project was carried out with a future sight of use age of robots while harvesting and so to expand the domain of deep learning in the field of agriculture i.e, towards harvesting. The solution proposed for the above problem statement was developed by taking tomato as an example and pre-grading to the vegetable unlike the traditional post grading methodology that is by grading the tomato into three grades with respect to the six ripening stages of a tomato and an additional classification the unfit category is added to promote waste management during harvest.
As working proof for the above idea a CNN model was developed by using tomatoes an example and the grading scale and the waste management system is developed on the basis of the six ripening stages of a tomato. Out of which the three distinguishable stages namely the mature green, turning stage, red ripe were used as the classification part and in order to perform waste management and additional classification called the unit called unfit was used (contains data on stem, leaves, flowers, dry twigs, sepals). A dataset of around 1838 images where each classification contains around 450 to 470 images. A CNN model with an accuracy of around 91.4% was developed.

Keywords:
Fruit/vegetable grading, Deep learning, Image processing, Food waste management, AI in harvesting, CNN.

II. INTRODUCTION

Fruit/Vegetable grading:

Grading fruits and vegetables after harvesting is an essential step in post-harvest management. Grading of fruits and vegetables based on physical characteristics like weight, size, color, shape, specific gravity, and freedom from diseases, depending upon agro climatic conditions. The known methods of grading fruits and vegetables are manual grading, size grading,
Grading fruits and vegetables in the fresh form for quality is essential, as people be com equality conscious day by day. Further, upon arrival of fruits and vegetables at the processing centers, they should be graded strictly for quality. The immature, properly mature, and over-mature fruits and vegetables should be sorted out for the best attributes.
Grading is sorting vegetables and fruits into different grades according to the size, shape, color, and volume to fetching high prices in the market. Or, the Arrangement of fruits into different groups by separating from a fruit lot is called grading. Grading depends on:

- Appearance
- Cultivar
- Size

- Color
- Quality

For the international market, there are 3 general grades which are as follows:

- Extra class.
- Class I.
- Class II.

Extra Class:
The extra class is of superior quality possess the shape size and color of the variety, and is likely to affect the inherent texture and flavor without internal defect. A 5%tolerance is allowed for errors. It must be carefully presented, considering the uniformity of the produces in size color, condition arrangement of the produce in the package quality, and appearances of the packing or pre-packing material.

Class I:
Almost having a same quality is like the Extra Class except that a 10% tolerance is allowed. Individual fruit is allowed a slight defect in shape, colour and miner skin defect which do not affect the general appearance for keeping qualities. In packing the size range may be wider and product need not always be arranged in the package.

Class II:
This class product may exhibit some external or internal defects provided they are fit for consumption while fresh. This class is best fitted for local or short distance market. This category will satisfy the needs of customers who are not too demanding and for whom price is more important than quality.

III. INTERNATIONAL GRADING STANDARDS USED FOR TOMATO GRADING

Definition of produce:

This standard applies to tomatoes of varieties (cultivars) grown from Solanum lycopersicum L. to be supplied fresh to the consumer, tomatoes for industrial processing being excluded. Tomatoes may be classified into the following commercial types:

- Round
- Ribbed
- Oblong or “elongated
- Cherry

Ribbed tomatoes have well differentiated ribs around the stalk end. The shape of the tomato will depend on variety. For the same variety, the shape of the tomato may change from the beginning to the end of the season. Therefore, the ribs may be more or less pronounced. Oblong (or elongated) tomatoes of ovoid or ellipsoid shape are more or less elongated, showing a smooth surface or slight ribs Cherry/cocktail tomatoes (miniature varieties) of all shapes.

Provisions concerning quality:
The purpose of the standard is to define the quality requirements for tomatoes after preparation and packaging. However, if applied at stages following export, products may show in relation to the requirements of the standard:

- A slight lack of freshness and turgidity;
- Other than extra Class

The products graded in classes other than the “Extra” Class, a slight deterioration due to their development and their tendency to perish. The holder/seller of products may not display such products or offer them for sale, or deliver or market them in any manner other than in conformity with this standard. The holder/seller shall be responsible for observing such conformity.

Special provisions for each class and the tolerances allowed:

- Intact
- Sound, produce affected by rotting or deterioration such as to make it unfit for consumption is excluded.

Intact:
The tomatoes must not have any damage or injury affecting the integrity of the produce.

Produce affected by rotting or deterioration:
Tomatoes must be free from disease or deterioration which appreciably affects its appearance, edibility or keeping quality. In particular, tomatoes affected by rotting, even if the signs are very slight, but liable to make the produce unfit for consumption upon arrival at its destination, are to be excluded.

Tomatoes, showing the following defects are therefore excluded:

- Marked bruises (soft patches) damaging the flesh due to rough handling and/or too tight packaging
- Fresh cracks due to rough handling
- Unhealed cracks (concentric or radial) caused by growth phenomena
- Unhealed damage caused by hail, showing deep pitting or corky roughness
- Damage caused by diseases
- Damage caused by low temperatures.

Clean practically free of any visible foreign matter:
Tomatoes must be practically free of visible soil, dust, chemical residue or other foreign matter. The presence of visible foreign matter can detract from commercial presentation and acceptance of the tomatoes. Therefore, the acceptable limit for "practically free" would be - in all classes - traces of foreign matter. Excessive dust, soiling or visible chemical residues would lead to the rejection of the produce.

Fresh in appearance:
Tomatoes must not show any sign of withering or loss of firmness. Degradation in freshness is allowed at stages following dispatch.

Practically free from pests:
The presence of pests can detract from the commercial presentation and acceptance of the tomatoes. Therefore, the acceptable limit for “practically free” would be - in all classes - the occasional insect, mite or other pest; any colonies would lead to the rejection of the produce.
Free from damage caused by pests affecting the flesh:
Pest damage affecting the flesh makes the produce unfit for consumption. Any pest damage, affecting the skin only, is allowable within the limits allowed for skin damage in the respective classes.

Free of abnormal external moisture:
This provision applies to excessive moisture, for example, free water lying inside the package, but does not include condensation on produce following release from cool storage or refrigerated vehicle.

Free of any foreign smell and/or taste:
This provision applies to tomatoes stored or transported under poor conditions, which have consequently resulted in their absorbing abnormal smells and/or tastes, in particular through the proximity of other produce which gives off volatile odors.
3.3 Classification:
Tomatoes are classified in three classes, as defined below:
(i) “Extra” Class
Tomatoes in this class must be of superior quality. They must be firm and characteristic of the variety. They must be free from greenbacks and other defects, with the exception of very slight superficial defects, provided these do not affect the general appearance of the produce, the quality, the keeping quality and presentation in the package
(ii) Class I
Tomatoes in this class must be of good quality. They must be reasonably firm and characteristic of the variety. Tomatoes should have reasonably firm flesh, i.e. a very slight mark may be visible on the fruit after normal finger pressure has been applied. They must be free of cracks and visible greenbacks.

The following slight defects, however, may be allowed provided these do not affect the general appearance of the produce, the quality, the keeping quality and presentation in the package:

A slight defect in shape and development;
A slight hollowness due to insufficient pollination or nutrient deficiencies is allowed. Ribbed or some oblong varieties are allowed to be more irregular than round varieties
Slight defects in coloring:
A slight color defect due to insufficient ripening or nutrient deficiencies is allowed. Ribbed or some oblong varieties are allowed to be more irregular than round varieties.

Slight skin defects:
Slight skin defects such as scorching due to sun or chemical treatmet, hail damage or slight damage caused by pests or disease are allowed provided the defects due to disease are not progressive.
Very slight bruises:
Very slight bruises caused by rough handling are allowed provided they cause no more than slight damage to the flesh and are unlikely to develop further.

Furthermore, “ribbed” tomatoes may show:
- healed cracks not more than 1 cm long
- no excessive protuberances
- small umbilicus, but no suberization
- suberization of the stigma up to 1 cm²
- fine blossom scar in elongated form (like a seam), but not longer than two-thirds of
- The greatest diameter of the fruit.

(iii)Class II:
This class includes tomatoes that do not qualify for inclusion in the higher classes but satisfy the minimum requirements specified above. Tomatoes in this class must be of reasonable quality and suitable for human consumption. They must be reasonably firm (but may be slightly less firm than in Class I) and must not show
Unhealed cracks. The flesh of the fruit must be reasonably firm, i.e. the fruit may be distinguishably marked after normal pressure by the fingers but is not actually damaged. The following defects may be allowed, provided the tomatoes retain their essential characteristics as regards the quality, the keeping quality and presentation:

Defects in shape and development:
Ribbed or some oblong varieties are allowed to be more irregular than round varieties.

Defects in coloring:
A slight more color defect than class I category due to insufficient ripening or nutrient deficiencies is allowed. Ribbed

or some oblong varieties are allowed to be more irregular than round varieties.

Skin defects or bruises, provided the fruit is not seriously affected:
Skin defects such as scorching due to sun or chemical treatment, hail damage or slight damage caused by pests or disease are allowed, provided the fruit is not seriously affected and the defects due to disease are not progressive.
Bruises caused by rough handling are allowed provided they cause a not too serious damage to the flesh and are unlikely to develop further.
Healed cracks not more than 3 cm in length for round, ribbed or oblong tomatoes.
Some crops and varieties grown under special weather conditions may be particularly susceptible to the formation of "greenbacks". Lots which are graded at an early stage of ripeness and suspected of containing a large number of fruits with "green backs" not yet visible should only be graded Class II. "Green backs" and "yellow backs" which should not extend over the shoulder of the fruit are allowed. The "greenback" consists of a greenish, the yellow back of a yellowish ring around the stalk cavity being the visible sign of a hard, inedible part of the flesh.

Furthermore, "ribbed" tomatoes may show:

- more pronounced protuberances than allowed under Class I, but without being misshapen
- an umbilicus
- suberization of the stigma up to 2 cm^2;
- Fine blossom scar in elongated form (like a seam).

IV. GRADING SCALE USED IN THE PROPOSED MODEL

Stages of Ripening of a tomato:

Stage1: Mature Green Stage

In this stage, tomatoes reach their mature green stage. Usually, seeds are fully developed inside fruits in this point, and jellylike materials settle in locules. Besides red color slightly develops inside fruits but doesn't appear on the fruit surface. Some commercial or store-bought tomatoes may pick up in this stage to ripen during the long way of shipping.

Stage2: The Breaker Stage

Once tomatoes start changing their color from the mature green stage to some other color is called the 'breaker stage.' In this stage, tomatoes definitely break the green color spell and jump to tannish-yellow, pink or red color up to 10% of the surface of the fruit. Tomatoes are in the breaker stage physiologically mature and develop the flavor fully or very close to it. In this stage, light pink or red color shows at the blossom end of your tomatoes. That indicates the fruits are producing ethylene gas internally, which encourages ripening.

So, once your tomatoes get to the breaker stage, they don't need any more nutrients from plants. Then you can pick them up and apply several indoor tomato ripening methods to ripen the. After one or two weeks, they will ripen thoroughly.

Some commercial growers prefer to pick their tomatoes at the breaker stage. However, it may depend on thegrowing season. Usually, tomatoes are in the winter season picked up earlier at the mature green stage. On the other side, summer season tomatoes are picked at the breaker stage.

Stage3: Turning Stage

Tomatoes in the turning stage are less firm than in the previous stages. If you pick your tomatoes at this stage, they will take less time to ripen than the tomatoes picked up from the breaker stage.

As you know that fruits harvested from a breaker or more advanced stages are considered vine-ripe tomatoes. In this stage, more than 10% but less than 30% of tomato fruit surface turns its color from green to tannish-yellow, pink, red, or a combination there of.

Stage4: Pink Stage

Tomatoes in the pink stage cover more than 30% but less than 60% of their fruit surface with pink or red color. They are less firm than the previous stages and ripen faster than turning tomatoes. Birds or other natural critters may attack your tomatoes in this stage or the advanced stages.

Stage5: Light Red Stage

This stage covers more than 60% but less than 90% of the tomato fruit surface with pinkish-red or red color. The light red tomatoes are softer than pink stage tomatoes and are a few days behind getting full ripe tomatoes.

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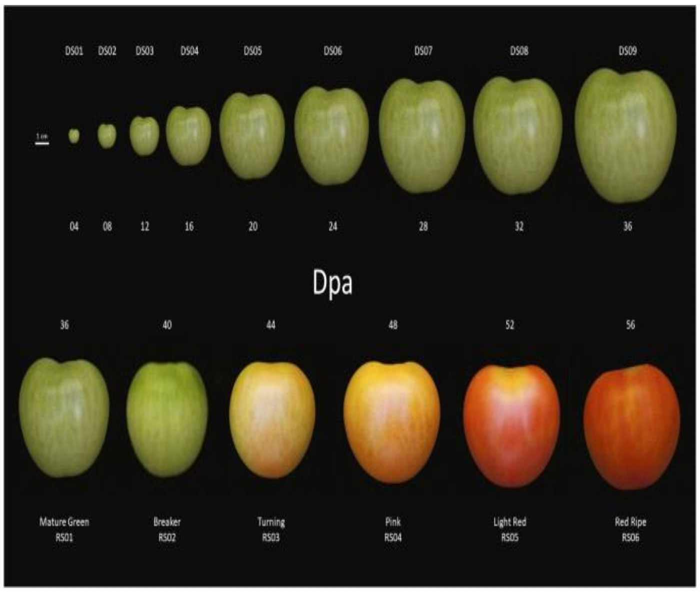
Stage6: Red and Final Stage

This is the ultimate ripening stage of tomatoes. In this stage, more than 90% of the fruit surface turns red color. Fruits are neither too hard nor too soft. Some folks believe that only red tomatoes get the real taste and flavor when they are picked off the vine. Red tomatoes are ready to eat instantly after picking them and need not ripen anymore.



V. PROPOSED MODEL.

The proposed is developed to perform pre-grading (that is performing grading of the vegetables during the harvest) unlike the traditional post-grading methodology (grading the vegetables after harvest) under an insight of ensuring precise and profitable harvesting, on the other hand also helping in food waste management. The project has developed a tomato grading software which can used with the AI based harvesters which are to be developed in the future. In the proposed model a CNN custom trained model was developed using the publication "Determination of developmental and ripening stages of whole tomato fruit using portable infrared spectroscopy and Chemo metrics" as reference to grade the tomatoes. A dataset of 1850 images with 4 classifications is used and an accuracy of around 91.4% was also achieved.

Dataset description:

A dataset with a total of 832 images is used with 2 categories (Used to develop the tomato detection model)

- Tomato: 364 images
- Unfit: 468 images

A dataset with a total of 1850 images is used with 4 categories (Used to develop the tomato grading model)

- Mature green: 460 images
- Red ripe: 460 images
- Turning: 460 images
- Leaves: 470 images

Datasetlink:
https://data.mendeley.com/datasets/9zyvdgp83m/1/files/96899488-f44d-48d4-8554-0e3593c7cdb7

VI. SELECTION OF PARAMETERS AND ITS DEFENITION

Model generation:

Tensor Flow:

Tensor Flow is a free an open-source software library for machine learning and artificial intelligence. It can be used across a range of tasks but has a particular focus on training and inference of deep neural networks.

Tensor Flow was developed by the Google Brain team for internal Google use in research and production. The initial version was released under the Apache License 2.0 in 2015.Google released the updated version of TensorFlow, named Tensor Flow 2.0, in September 2019.

Tensor Flow can be used in a wide variety of programming languages, including Python, JavaScript, C++, and Java. This flexibility lends itself to a range of applications in many different sectors.

Keras:

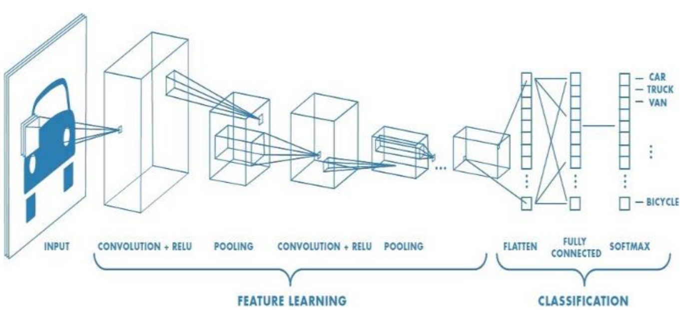
Keras is an open-source software library that provides a Python interface for artificial neural networks.

Keras acts as an interface for the TensorFlow library. Keras contains numerous implementations of commonly used neural-network building blocks such as layers, objectives, activation functions, optimizers, and a host of tools to make working with image and text data easier to simplify the coding necessary for writing deep neural network code.

The code is hosted on GitHub, and community support forums include the GitHub issues page, and a Slack channel. Keras allows users to productize deep models on smartphones (iOS and Android), on the web, or on the Java Virtual Machine. It also allows use of distributed training of deep-learning models on clusters of Graphics processing units (GPU) and tensor processing units (TPU).

CNN architecture:

Convolution Neural Network:
CNN stands for Convolutional Neural Network. In Deep Learning, a CNN (Convolutional Neural Network) is a type of ANN (artificial neural network) that is usually for image, text, object recognition, and classification. Deep Learning recognizes objects in an image/text by using a CNN (Convolutional Neural Network). CNN (Convolutional Neural Network) also called as convnets or CNN (Convolutional Neural Network), is a well-known method in Machine vision applications. The class of deep neural networks that are used to analyze visual imagery. This type of architecture is analyzed to recognize objects from image and video data. It is used in applications like video or image or recognition, NLP (neural language processing).
In the initial stages of the project there were three deep learning architectures were available (most commonly used to develop models in the food classification domain.) ANN (Artificial Neural Networks), CNN (Convolutional Neural Networks),Transfer learning. In ANN a maximum accuracy of over 57-60% was only achieved, in order to get a higher accuracy with the limited dataset CNN was used and an accuracy of 91.4% was achieved, since the satisfiable accuracy was obtained using CNN, transfer learning was not used.



Stride Convolutions:
Stride is a component of convolutional neural networks, or neural networks tuned for the compression of images and video data. Stride is a parameter of the neural network's filter that modifies the amount of movement over the image or video. For example, if a neural network's stride is set to 1, the filter will move one pixel, or unit, at a time.

Padding:
Padding in a CNN is set to zero, then every pixel value that is added will be of value zero. If, however, the zero padding is set to one, there will be a one pixel border added to the image with a pixel value of zero.

Pooling Layer:
In order to down sample images while preserving information, we use pooling layers, we have two types of pooling layers which are max-pooling and average pooling.

Up sampling layer:

In order to up sample or make your image large you use these types of layers, it often sometimes blurs your image or other disadvantages.

Max pooling:
Pooling is a feature commonly imbibed into Convolutional Neural Network (CNN) architectures. The main idea behind a pooling layer is to “accumulate” features from maps generated by convolving a filter over an image. Formally, its function is to progressively reduce the spatial size of the representation to reduce the amount of parameters and computation in the network. The most common form of pooling is max pooling.

Max pooling is done to in part to help over-fitting by providing an abstracted form of the representation. As well, it reduces the computational cost by reducing the number of parameters to learn and provides basic translation invariance to the internal representation. Max pooling is done by applying a max filter to (usually) non-overlapping sub regions of the initial representation. The other forms of pooling are: average, general.

Max pooling was used in developing the model as it filters out the features by selecting only the features with the maximum value and considerably reduces the size of the feature map, makes computation of the data much faster and reduces overlapping of the sub regions.

Activation functions:

An activation function is a function used in artificial neural networks which outputs a small value for small inputs, and a larger value if its inputs exceed a threshold. If the inputs are large enough, the activation function "fires", otherwise it does nothing. In other words, an activation function is like a gate that checks that an incoming value is greater than a critical number.

Activation functions are useful because they add non-linearities into neural networks, allowing the neural networks to learn powerful operations. If the activation functions were to be removed from a feedforward neural network, the entire network could be re-factored to a simple linear operation or matrix transformation on its input, and it would no longer be capable of performing complex tasks such as image recognition.

Well-known activation functions used in data science include the rectified linear unit (ReLU) function, and the family of sigmoid functions such as the logistic sigmoid function, the hyperbolic tangent, and the arctangent function.

Types of activation function:

- Step function
- Tanh function
- Sigmoid function
- ReLu function
- SoftMax function
- Exponential

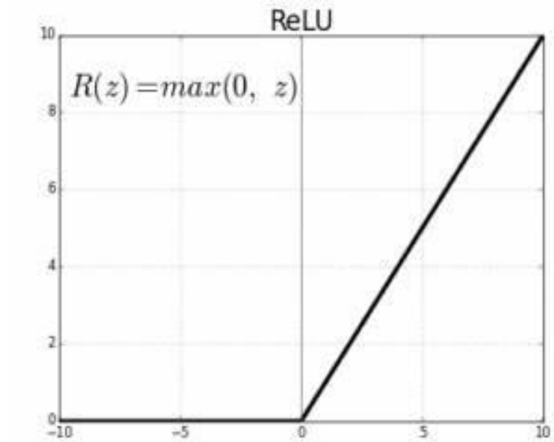
Relu activation function:
The rectified linear activation function or ReLU is a non-linear function or piecewise linear function that will output the input directly if it is positive, otherwise, it will output zero. It is the most used activation function in neural networks, especially in Convolutional Neural Networks (CNNs) & Multilayer perceptrons.

Mathematically, it is expressed as:

RELU(x) = max(0,x)

$$RELU(x) = \begin{cases} 0 \ if \ x < 0 \\ x \ if \ x >= 0 \end{cases}$$

Graph of relu activation function:



$$\sigma(x) = \frac{1}{1 + e^{-x}}$$

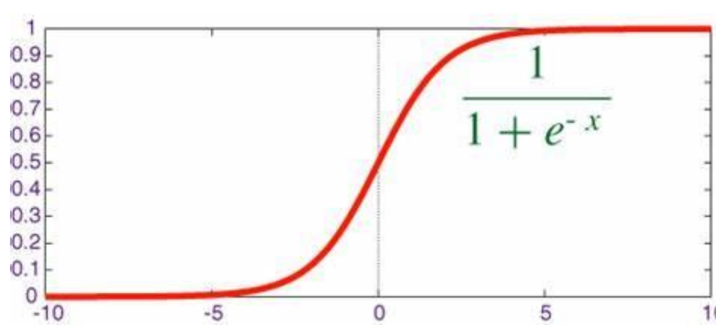
Sigmoid activation function:

A sigmoid unit in a neural network. When the activation function for a neuron is a sigmoid function, it is a guarantee that the output of this unit will always be between 0 and 1. Also, as the sigmoid is a non-linear function, the output of this unit would be a non-linear function of the weighted sum of inputs.

The formula of the sigmoid activation function is:

F (x) = σ (x) = 1 ⁄ (1 + e-x)

Graph of sigmoid activation function:



In the model developed only ReLu and sigmoid activation functions were used as the input to the CNN /dense layer will be ranging from negative to positive infinity, when the values passes through ReLu activation function the range is shortened to a range of zero to a positive threshold vlaue, when the value from Relu to sigmoid it is further shortened to a range zero to one, more smaller the range of value of the output of a activation will be, more better will be the prediction accuracy of the model.

Dropout layer:
The Dropout layer is a mask that nullifies the contribution of some neurons towards the next layer and leaves unmodified all others. We can apply a Dropout layer to the input vector, in which case it nullifies some of its features; but we can also apply it to a hidden layer, in which case it nullifies some hidden neurons.

Dropout layers are important in training CNNs because they prevent overfitting on the training data. If they aren't present, the first batch of training samples influences the learning in a disproportionately high manner. This, in turn, would prevent the learning of features that appear only in later samples or batches.

Dropout layer is used to nullify the excessive neurons from the convolutional layer there by also helping in reducing the loss occurring while training the model.

Flatten layer:
The flattening layer is to converts data into 1-dimentional array for feeding next layer. We flatted output of convolutional layer into single long feature vector. Which is connected to final classification model, called fully connected layer. let's suppose we've [5,5,5] pooled feature map are flattened into 1x125 single vector.

If you do not use Flatten, the way the input tensor is mapped onto the first hidden layer would be ambiguous. Flattening is converting the data into a 1-dimensional array for inputting it to the next layer. We flatten the output of the convolutional layers to create a single long feature vector.

Flatten layer is used to convert the 2D matrix output obtained from the dropout layer as a 1D matrix, making it ready to be fed to the dense layer.

Dense layer:
In any neural network, a dense layer is a layer that is deeply connected with its preceding layer which means the neurons of the layer are connected to every neuron of its preceding layer. This layer is the most commonly used layer in artificial neural network networks. Dense Layer is used to classify image based on output from convolutional layers. Each Layer in the Neural Network contains neurons, which compute the weighted average of its input and this weighted average is passed through a non-linear function, called as an "activation function". It also helps in the learning process in the model.

This is the layer where the final prediction of the input images are done and the image is finally classified.

Model compilation:
Model compilation is an activity performed after writing the statements in a model and before training starts. It checks for format errors, and defines the loss function, the optimizer or learning rate, and the metrics. A compiled model is needed for training but not necessary for predicting.

Optimization:

An optimizer is a method or algorithm to update the various parameters that can reduce the loss in much less effort. It is an algorithm or function that adapts the neural network's attributes, like learning rate and weights.

Types of optimizers:
- Gradient Descent
- Stochastic Gradient Descent
- Adagrad
- Adadelta
- RMSprop
- Adam

Adam optimizer:
Optimizer that implements the Adam algorithm. Adam optimization is a stochastic gradient descent method that is based on adaptive estimation of first-order and second-order moments. According to Kingma et al., 2014, the method is " computationally efficient, has little memory requirement, invariant to diagonal rescaling of gradients.

Adam algorithm:

Adam is an alternative optimization algorithm that provides more efficient neural network weights by running repeated cycles of "adaptive moment estimation." Adam extends on stochastic gradient descent to solve non-convex problems faster while using fewer resources than many other optimization programs.

Adam optimizer is used as it is comparatively faster than other optimizers and also helps in significantly reducing overfitting of data.

Cross entropy:
Cross-entropy can be used to define a loss function in machine learning and optimization.

Types of cross entropy:

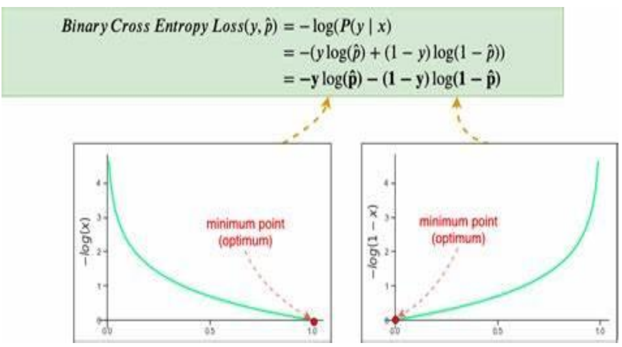
- binary cross entropy
- categorical cross entropy
- sparse categorical cross-entropy

Binary cross entropy:

Binary cross-entropy can be used to define a loss function in machine learning and optimization.

Binary cross entropy formula is given as:

L n = − [y n · log σ (x n) + (1 − y n) · log (1 − σ (x n))]



Binary cross entropy is used as multiple classification and labeling has to be performed over a single image in order to obtain the final output.

Accuracy metrics:

Accuracy is the easiest metric to understand. It’s simply the number of correct predictions on a dataset. Given a test dataset of 1,000 images for example, in order to compute the accuracy, you’ll just have to make a prediction for each image and then count the proportion of correct answers among the whole dataset

There are some loopholes in the accuracy performance metric:

1. Imbalanced Data the example discussed above is having an equal proportion of the data points of both the classes. This type of dataset, where data points are approximately equal for both the classes, is called a balanced dataset.

Data Augmentation:

Data augmentation is a set of techniques to artificially increase the amount of data by generating new data points from existing data. This includes making small changes to data or using deep learning models to generate new data points.

Data augmentation is performed in order generate many more images using the limited dataset available, by doing so we can reduce the disk space occupied by the actually used data while training the model(augmented images are stored directly on the server), we will also be able to reduce under/overfitting of data.

Types of data augmentation:

- Adversarial training/Adversarial machine learning:
  It generates adversarial examples which disrupt a machine learning model and injects them into a dataset to train.

- Generative adversarial networks (GANs):
  GAN algorithms can learn patterns from input datasets and automatically create new examples which resemble training data.

- Neural style transfer:
  Neural style_transfer models can blend content image and style image and separate style from content.

- Reinforcement learning:
  Reinforcement learning models train software agents to attain their goals and make decisions in a virtual environment.
- Popular open-source python packages for data augmentation in computer vision are Keras ImageDataGenerator, Skimage and OpeCV.

Image Data generator:

The Image Data Generator is a tool that allows you to create images from scratch using TensorFlow. You can use this tool to create images of any size, shape, or colour, and you can even control the level of detail in the image. This makes it possible to create images that are very realistic, or to create images that are completely abstract.

OpenCV:

OpenCV is a library of programming functions mainly for real-time computer vision. Originally developed by Intel, it was later supported by Willow Garage, then Itseez. The library is cross-platform and licensed as free and open-source software under Apache License. What is OpenCV and why it is used? OpenCV (Open Source Computer Vision Library) is an open source computer vision and machine learning software library. OpenCV was built to provide a common infrastructure for computer vision applications and to accelerate the use of machine perception in the commercial products..

Scikit-image:

Scikit-image is an open-source image processing library for the Python programming language. It includes algorithms for segmentation, geometric transformations, color space manipulation, analysis, filtering, morphology, feature detection, and more. Scikit-image, or skimage, is an open source Python package designed for image preprocessing. If you have previously worked with sklearn, getting started with skimage will be a piece of cake. Even if you are completely new to Python, skimage is fairly easy to learn and use.

Prediction:

There are two types of predictive models. They are Classification models, that predict class membership, and Regression models that predict a number. These models are then made up of algorithms. The algorithms perform the data mining and statistical analysis, determining trends and patterns in data. Predictive modeling is a commonly used statistical technique to predict future behavior. Predictive modeling solutions are a form of data-mining technology that works by analyzing historical and current data and generating a model to help predict future outcomes.

Probability model:

Probabilistic modeling is a statistical technique used to take into account the impact of random events or actions in predicting the potential occurrence of future outcomes. Probabilistic deep learning is deep learning that accounts for uncertainty, both model uncertainty and data uncertainty. It is based on the use of probabilistic models and deep neural networks. We distinguish two approaches to probabilistic deep learning: probabilistic neural networks and deep probabilistic models.

Metrics function:

A metric is a function that is used to judge the performance of your model. Metric functions are similar to loss functions, except that the results from evaluating a metric are not used when training the model.

Types of evaluation metrics:

- Accuracy
- confusion matrix
- log-loss
- AUC-ROC

Accuracy metrics:

Accuracy is a metric that generally describes how the model performs across all classes. It is useful when all classes are of equal importance. It is calculated as the ratio between the numbers of correct predictions to the total number of predictions.

The formula for accuracy metrics is given as:

Accuracy = (TP+TN)/(TP+FP+FN+TN)

Confusion matrix:

A confusion matrix is a table that is used to define the performance of a classification algorithm. A confusion matrix visualizes and summarizes the performance of a classification algorithm.

- True positive: A true positive is an outcome where the model correctly predicts the positive class.
- True negative: A true negative is an outcome where the model correctly predicts the negative class.
- False positive: A false positive is an outcome where the model incorrectly predicts the positive class.
- False negative: A false positive is an outcome where the model incorrectly predicts the negative class.

		Actual Values	
		Positive (1)	Negative (0)
Predicted Values	Positive (1)	TP	FP
	Negative (0)	FN	TN

VII. WORKING

The proposed model is implemented using a combination of two custom trained deep learning-CNN models which all together consist of 22 layers where the first 11 layers are used to detect the presence of the tomato and the next 11 layers is used for grading the detected tomato. The grade of the detected tomato is shown alongside the image of the tomato.

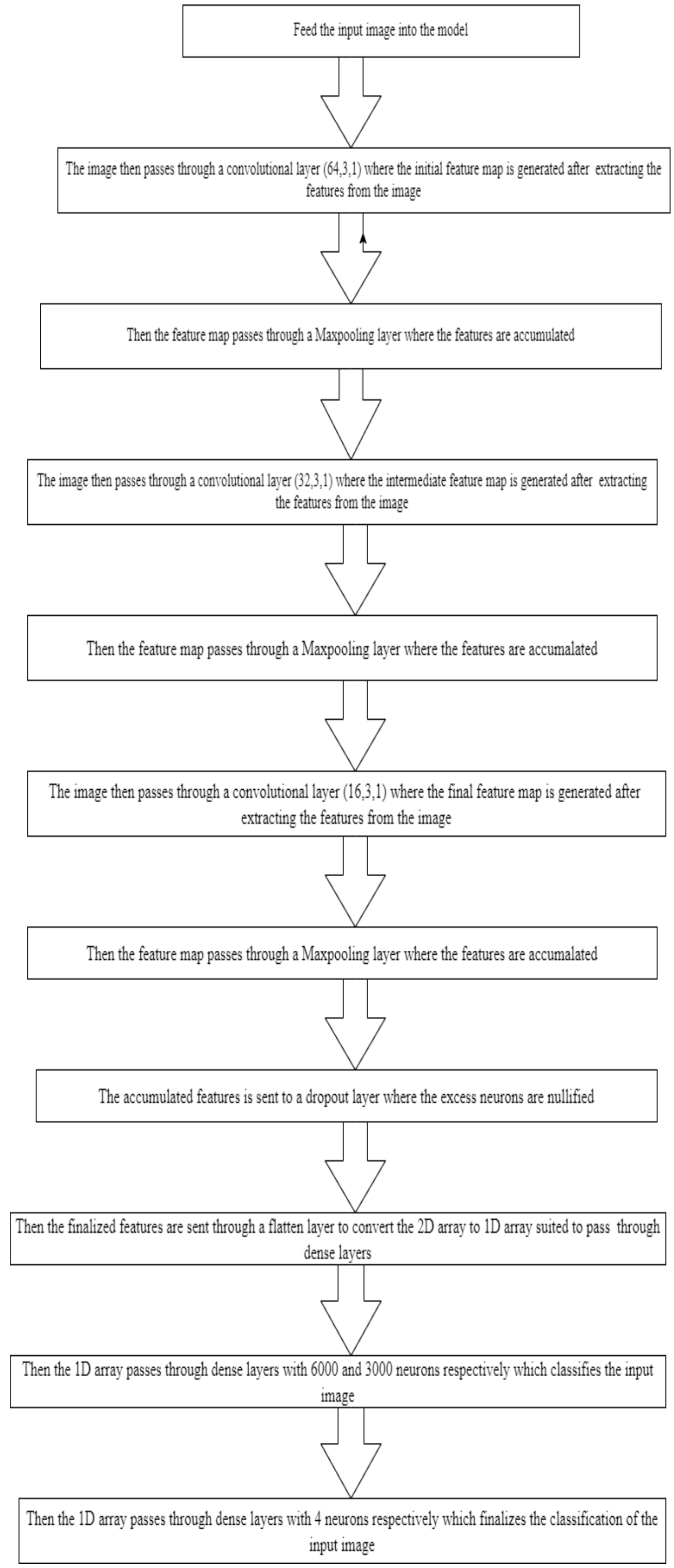
The general working of the proposed model is given below as follows:

- The image of the tomato to be graded is fed into the tomato detection model.
- Once the presence of tomato is confirmed the tomato in the image graded accordingly.

  Where the image is passed through the following layers:

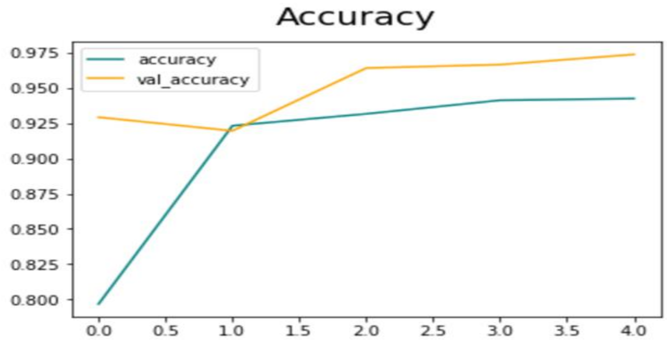
- Passes through 2D convolution layer (64, 3, 1) With reLu activation function.(This layer extracts the features rom the input image)
- Max pooling layer(This layer accumulates the features so as to reduce the amount of parameters and computation in the network)

- Passes through 2D convolution layer (32, 3, 1) With reLu activation function.(This layer extracts the features rom the input image
- Max pooling layer(This layer accumulates the features so as to reduce the amount of parameters and computation in the network)
- Passes through 2D convolution layer (16, 3, 1) With reLu activation function.(This layer extracts the features rom the input image)
- Max pooling layer(This layer accumulates the features so as to reduce the amount of parameters and computation in the network)
- Dropout Layer (The Dropout layer is a mask that nullifies the contribution of some neurons towards the next layer and leaves unmodified all others)
- Flatten layer (The flattening layer is to converts data into 1-dimentional array for feeding next layer.)
- Two dense layers with 6000 and3000 neurons respectively with reLu activation function (Dense Layer is used to classify image based on output from convolutional layers.)
- Dense layer with 4 neurons and a sigmoid activation function. (Performs the final major classification of the image according to the provided labels)
- The output obtained after this layer is given to a prediction function, in our model probabilistic prediction function of is used which gives the probability of prediction of all four classes as a numpy array.
- From the obtained numpy array the maximum probability is extracted using the argmax() function and the class corresponding to the output of the argmax() function is shown as the output
- Hence the output is displayed with the predicted class alongside the input image.

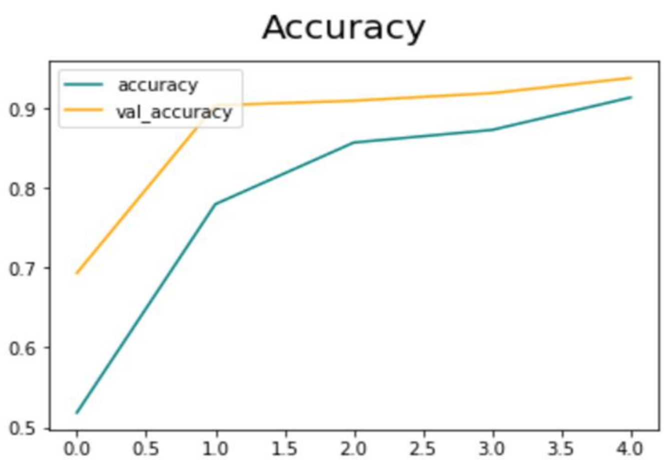


VIII. ACCURACY (TRAINING VS VALIDATION)

(TOMATO DETECTION MODEL)

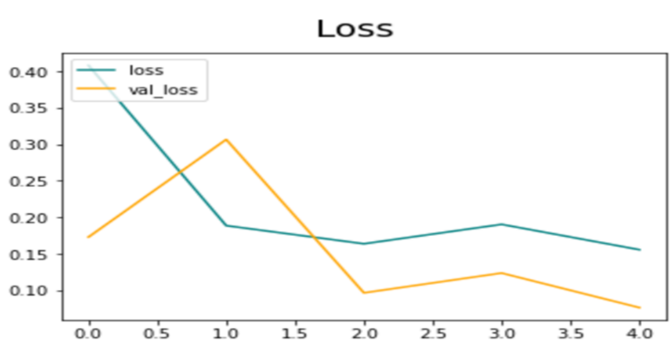


(TOMATO GRADING MODEL)

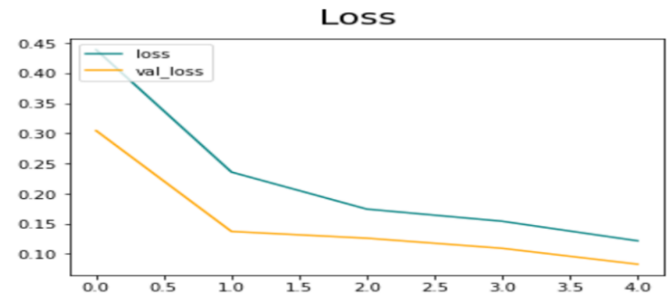


IX. LOSS (TRAINING VS VALIDATION)

(TOMATO DETECTION MODEL)

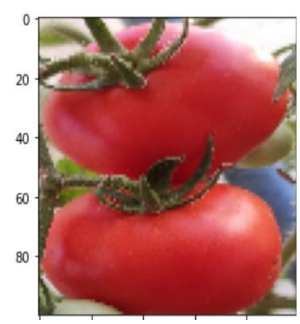


(TOMATO GRADING MODEL)

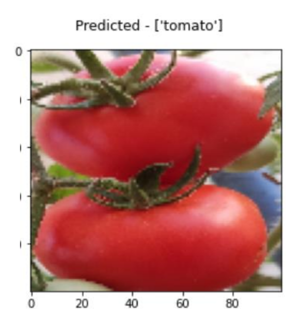


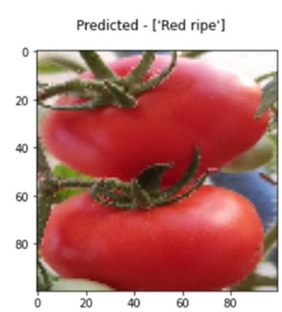
X. OUTPUT

INPUT IMAGE:



OUTPUT IMAGES:





XI. CONCLUSION

The post grading scale is the currently**,** widely used grading technology at present days, but technology is evolving at a rapid rate such that the industrial processes have now become remotely controlled using IoT (Internet of Things)**.** Similarly in the field of agriculture and food technology several processes like crop monitoring, pest control, irrigation, temperature and other physical parameters control etc…are performed using artificial intelligence and machine learning models. This project is developed in an attempt of expanding the domain of deep learning in the field of agriculture by developing a deep learning based image classification model which classifies tomato on the basis of its maturity level, which can be used as a pre – grading technology that can be used while harvesting a tomato crop, this model can also help in the development of crop harvesting robots which are to be developed in the near future.

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