A System for Tomato Quality Assessment

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I. Background

Tomato grading is a process typically done through tedious laborious means and often subjective. This may lead to inconsistencies and variations in grading results which greatly increases the time consumption for grading verification to ensure consistency.

The goal of this project is to propose a system that can utilize image processing and machine learning technology to autonomously grade an image of a tomato just as illustrated by Fig. 1 based on predetermined grading parameters. This system would then theoretically be deployed in areas abundant with plantations, farms, or agricultural infrastructure to decrease the time consumption of the grading process.

Figure 1. Market sold tomatoes

II. Proposed System

The proposed system will be segregated into 2 parts, one is the conceptual version for individual use and the other is for corporate use namely industrial parties. For the individual use version, users upload tomato images through a user interface, which processes the images using normalization, segmentation, and auto-cropping techniques to autonomously prepare them for analysis. The system employs two models: a CNN model for assessing tomato freshness and an SVM model for evaluating physical characteristics like color uniformity, size, and circularity. The results from these models are presented as two separate grades where the former is for freshness and the latter for the physical attributes. Figure 2 illustrates the general workflow for the individual use case scenario. Thereafter, the second diagram represents an automated system tailored for large-scale tomato quality assessment in industrial settings. It integrates video processing, capturing footage of tomatoes moving on a conveyor belt, and extracts frames that are stored in an input directory. These frames are preprocessed using normalization, segmentation, auto-cropping, and video-to-image conversion. Subsequently, the system analyzes the preprocessed images using the same CNN and SVM models from the first system, producing freshness and physical quality grades. These grades are then summarized into an overall quality grade, and the images are renamed based on the results for easy organization. Figure 3 illustrates that the automated workflow makes this system efficient and better suited for real-time grading and large-scale operations in contrast to its counterpart.

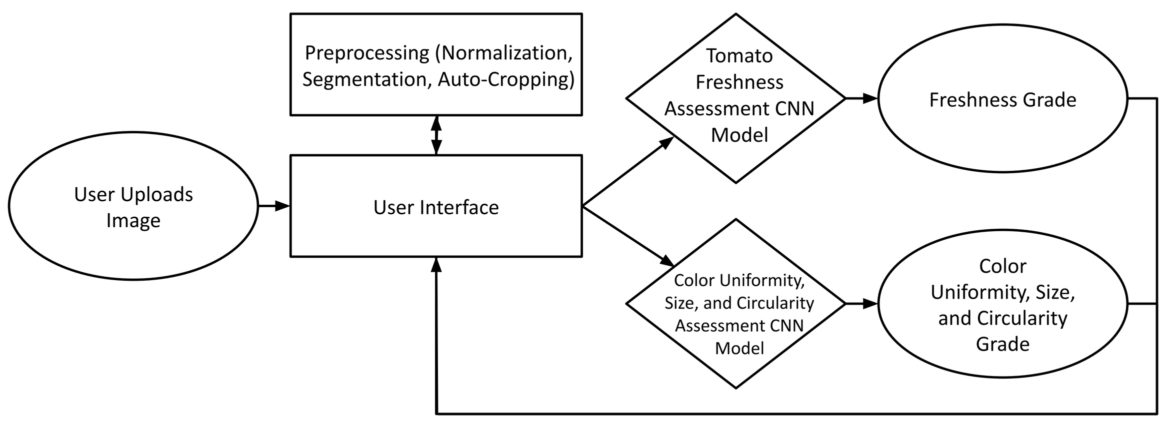

Figure 2. Proposed System Scenario for Individual Use

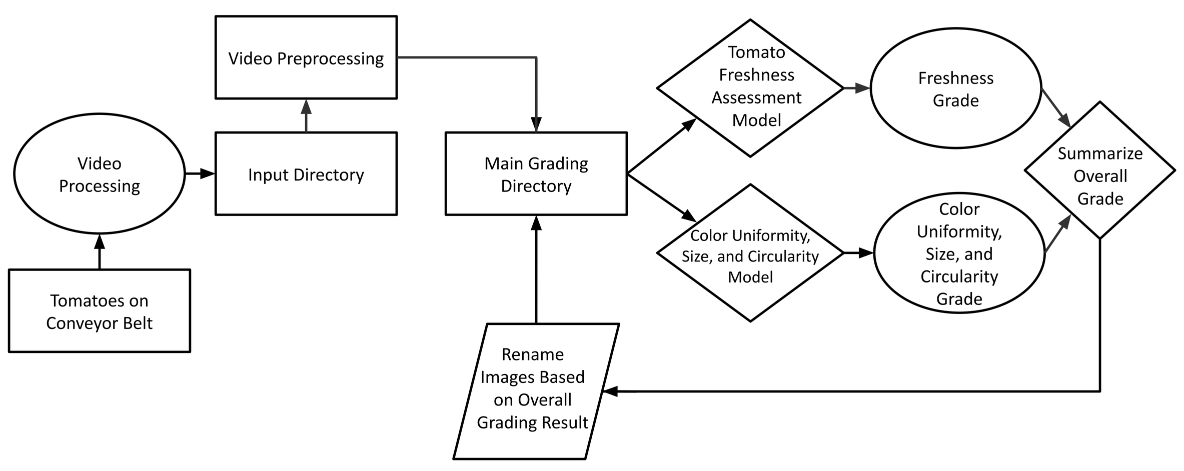

Figure 3. Proposed System Scenario for Corporate Use

III. Prototype Developed

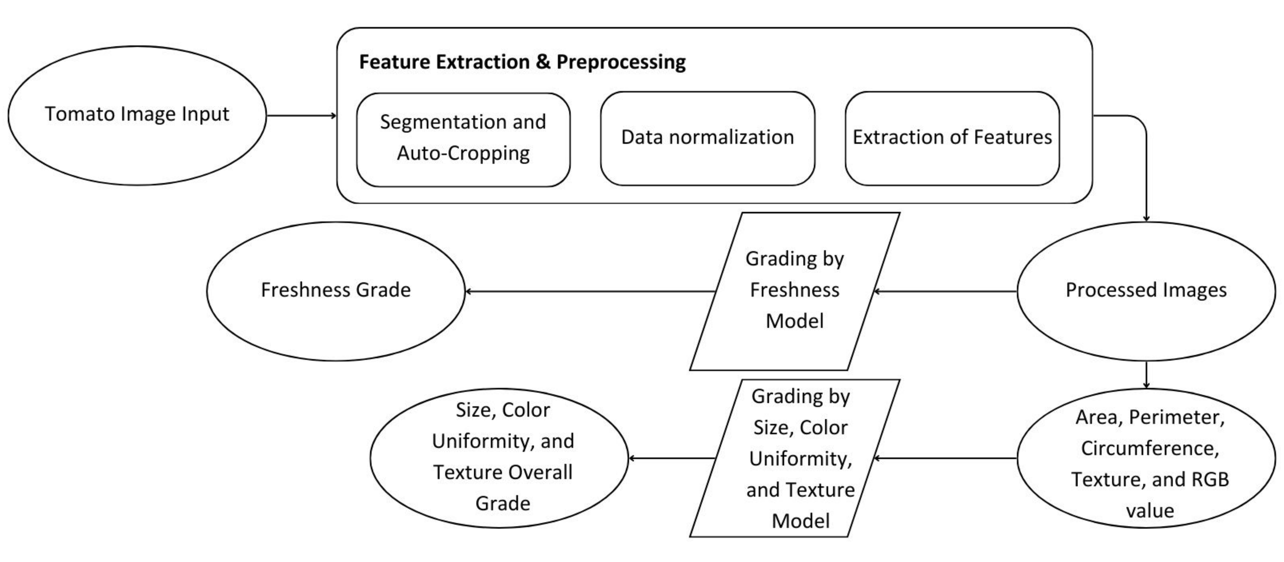

Figure 4. Overview of Developed System

We developed and worked on our system on the github repository our team created where we organized all the code, models, libraries, and data we used. Our system was developed using python and jupyter notebook which featured libraries which include openCV, PyTorch, pandas, NumPy, seaborn, matplotlib, os, glob, tensorflow, scikit, keras, and svm. The frameworks starts with NumPy, os, and glob as they are responsible for complicated calculations, handling, and operating files which are the most fundamental functions needed for our project. Seaborn, matplotlib, and pandas are used for handling data and we also used openCV for its image processing functions which are vital for our project. Lastly, we utilized tensorflow, scikit, keras, PyTorch and svm for the project's machine learning and performance metric analysis related matters. Moreover, our system utilizes models pre-trained using the VGG16 CNN architecture and a model developed from PyTorch which we finetune to enhance its performance as well as cater to our use cases better. To conduct our tests, we utilize our own virtual environment in our team's personal directories. Fig. 4 illustrates the overall workflow of our current developed system, the system starts when we acquire an image that we want to grade. Then, we preprocess the image through segmentation, auto-cropping, and data normalization to finally extract the features required to be read by our models. Once we've acquired the processed images and features, we can run our models to grade the tomato image we want to grade in which we'll eventually receive two grades (A-C and 1-4) based off our two models.

IV. Experiments

The training and validation data was taken from open source repositories on github titled "FGrade," and "Digital-Grading-of-Fruits," where they provided a total of 10061 unique data points of images of tomatoes with varying quality. The datasets provided were also prelabeled in each of their repositories. Subsequently, the testing data was collected by our members from Indonesia in the city of Surabaya and Sidoarjo, Jawa Timur, Indonesia. This procedure encompasses the surveying, collecting, and reporting of images of tomatoes over local markets, farms, and plantations. Lastly, we proceeded to conduct the labeling of the testing data manually by our team members and the overall data handling is represented by Table 1.

Table 1. Overview of Data Handling

Number of Images Collected	Source	Labelling
6470	Github	Prelabeled
3591	Github	Prelabeled
300	Manually Acquired	Manually Labeled

To train the model required to develop our system, we created an open source github repository of our own where we fine-tune the pre-trained models provided from the same repositories we obtained our data from. Thematically, to test the model we utilized the validation dataset that we also obtained from the same repositories and then use a metric to measure how well the model performed.

Furthermore, to test the system, we provide an image of a tomato and test the model that we have trained on the image which will then output a grade based on the tomato's observed characteristics. To measure the competency of our model, we will utilize the F1 scoring metric and 5-fold cross validation technique. Therefore, we can summarize the models' performances as well as how they perform against their pre-trained version without any prior adjustments in Fig. 5 where the green colored bars are referring to our developed models.

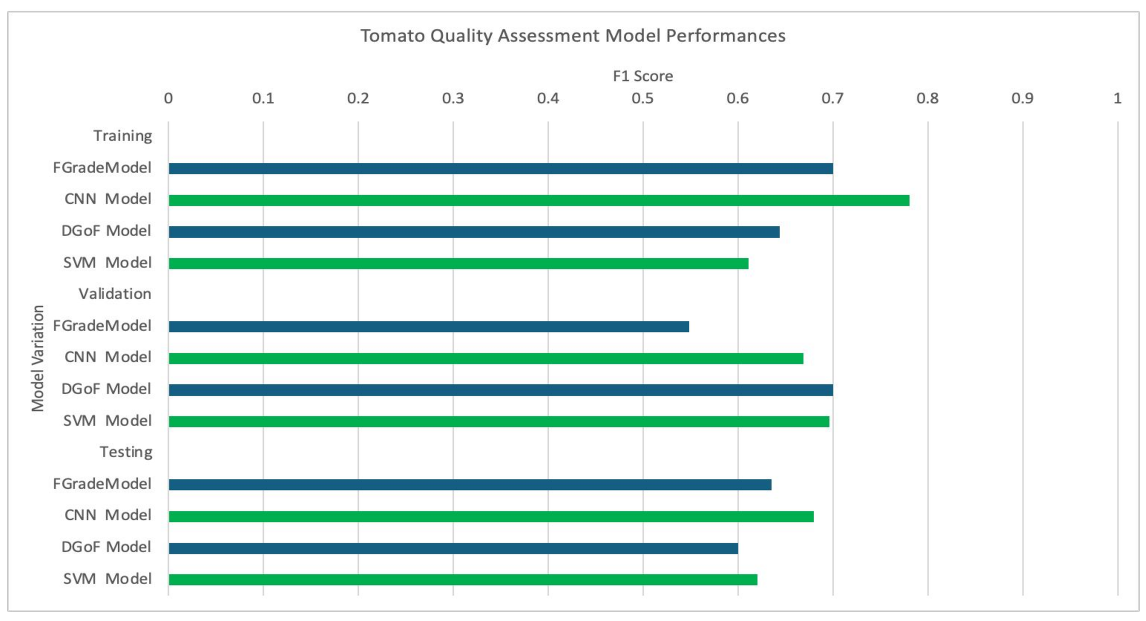

Figure 5. Summary of Relevant Model Performances

V. Conclusions

We were able to achieve our goal which was to utilize image processing and machine learning techniques to grade tomatoes into several different categories. We prototyped a system made up of 2 separate models that is able to grade tomatoes into several different categories based on their respective parameters. Furthermore, we managed to finetune 2 different models whilst utilizing over 10,000 unique data points and test them out on a dataset consisting of 300 real tomatoes of varying quality.

However, there were some limitations in our system which covers the class mapping of the freshness grading model. Although, the current model was able to minimize the bottleneck created by the amount of classes trained in the pre-trained model, the pre-trained model's accuracy is still reliant on the 10 class system which bottlenecks the model's accuracy. In this case, the project mainly focused on implementing 4 classes and due to the time constraints to train a whole new model from scratch for the freshness model, the current system relies on a mapping function from the pre-trained model to allow for larger margins of error. Moreover, there are areas that could use improvement for all of the classes in the system such as testing and comparing more pre-trained models, utilizing more classes that replicate real world grading, and future works could explore UI integration to improve user experience as the current system requires the user to have a certain degree of experience with coding to maneuver it.

Overall, we were able to successfully complete this project and learned ways to communicate with members in a more global setting similar to real world scenarios and projects. This project also taught us various frameworks and expectations for conducting a project in a professional setting.