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# MODELING AND WEIGHT ESTIMATION OF AGRICULTURE PRODUCT USING IMAGE BASE FEATURES: AN EFFICIENT AUTOMATION

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**ABSTRACT**
According to the recent Indian horticulture report, there is a notable abundance in potato production within India, yet the volume exported remains minimal. The advent of image-based systems presents a novel technological avenue facilitating the broadening of agricultural operations, thereby aiding in the comprehensive automation of agricultural product processing. Integration of image-based systems promises substantial benefits to the agricultural sector, notably in time efficiency and the provision of precise estimations concerning product weight.
In the current research, we have integrated image-based feature extraction alongside the correlation of multiple parameters employing the DA model. Our experimental findings indicate that the DA model outperforms Artificial Neural Networks (ANN), Random Forest, and regression models. Notably, no existing image-based algorithm has been specifically designed for weight estimation, marking a novelty in our work. Furthermore, by integrating DA with Convolutional Neural Networks (CNN), we also extract additional features such as surface defects, damage, color, etc.

**Keywords:**
Image processing, modeling, regression, weight estimation

## 1. INTRODUCTION

### 1.1 Indian Government Horticultural report

India is a significant player in the global horticulture market, producing a wide variety of fruits, vegetables, flowers, spices, and medicinal plants. The Indian government periodically releases reports and updates on the status of horticulture in the country, detailing production, export policies, and other relevant information.
India's horticulture production is influenced by various factors such as climate, soil conditions, technological advancements, government policies, and market demand. The country produces a diverse range of horticultural products throughout the year due to its varied agro-climatic zones.
The export policy for Indian horticultural products is governed by the Directorate General of Foreign Trade (DGFT), which periodically revises and updates the export-import policies based on market conditions, international trade agreements, and domestic requirements. The export policy aims to promote the export of high-quality horticultural products while ensuring food safety standards and compliance with international regulations.
Production trends: Reports provide insights into the production trends of various horticultural crops such as fruits, vegetables, spices, flowers, and plantation crops. This includes data on production volumes, acreage under cultivation, yield per hectare, and regional distribution

Export promotion scheme: The Indian government often introduces export promotion schemes and incentives to boost horticultural exports. These schemes may include financial assistance, subsidies, market development assistance, quality certification support, and infrastructure development.
Market access: Export policies address market access issues by negotiating trade agreements, resolving trade barriers, and improving market infrastructure. Efforts are made to expand market access for Indian horticultural products in key importing countries.
Quality standards and certification: Compliance with international quality standards and phytosanitary regulations is essential for accessing export markets. The government focuses on improving quality control measures, implementing good agricultural practices (GAP), and providing certification support to growers and exporters
The Indian horticulture sector is dynamic and evolving, with the government playing a crucial role in facilitating production growth, market access, and export promotion. Keeping abreast of the latest reports and updates from government agencies such as the Ministry of Agriculture and Farmers Welfare, DGFT, and Agricultural and Processed Food Products Export Development Authority (APEDA) is essential for stakeholders involved in the horticulture value chain.
India's horticulture sector continues to thrive, contributing significantly to the country's agricultural economy. With a diverse range of fruits, vegetables, spices, flowers, and plantation crops cultivated across the nation, horticulture plays a pivotal role in ensuring food security, generating employment, and boosting export earnings.

**Production Highlights:**

- Total horticulture production in 2020-21 reached a record 334.60 million tonnes, marking a notable increase of 4.4% compared to the previous year
- Potato production surged to a record 56.17 million tonnes, witnessing an impressive increase of 7.61 million tonnes over the previous year's output
- Onion production remained robust at 26.64 million tonnes, maintaining a steady growth trajectory
- Tomato production also saw a positive trend, reaching 21.18 million tonnes in 2020-21

**A Global Staple**

- According to the ICAR-Central Potato Research Institute, potato is among the world's most crucial non-cereal, high-yielding horticultural food crops
- Globally, potato ranks third in terms of human consumption, following rice and wheat
- Despite occupying only 1.32% of cultivable land, potato contributes significantly to agricultural GDP, with a current share of 2.86%

**Economic Contribution**

- Agriculture, including allied activities, contributed 13.9% to the GDP in 2013-14, with the sector employing 54.6% of the total workforce
- While rice and wheat dominate in terms of cultivable area, potato's contribution to agricultural GDP per unit of cultivable land surpasses that of both rice and wheat combined, indicating its economic significance
- During the triennium 2014-17, India produced an average of 45.87 million tonnes of potato annually, contributing substantially to the Gross Value Added (GVA), amounting to ₹57,512 crore annually at current prices

The Indian horticulture sector's resilience and growth trajectory underscore its pivotal role in the agricultural landscape and the broader economy. With consistent efforts to enhance productivity, improve quality, and explore export opportunities, India continues to strengthen its position as a leading player in the global horticultural market.

### 1.2 Current market and Export policy

According to Indian horticulture report Both potato and onion are major agricultural crops in India. Potato is grown in almost all states throughout the year, while onion cultivation is more concentrated in certain states like Maharashtra, Karnataka, Gujarat, and Madhya Pradesh.

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Export policies for potatoes and onions can vary based on market conditions and domestic requirements. While potato exports are relatively stable and less influenced by government interventions, onion exports are more susceptible to policy changes due to the commodity's price sensitivity and its significance in the domestic market. The potato market in India is relatively more stable compared to onions. India is a major producer of potatoes, and the crop is grown in almost all states throughout the year. Potatoes are consumed widely in various forms and are also exported to other countries. While potato prices may fluctuate based on factors like production levels and demand, they tend to be less volatile compared to onions.

Potatoes are a vital cool-season vegetable, considered as important as wheat and rice in the global diet, with over one billion people consuming them worldwide. They're specialized underground storage stems known as "tubers" and boast a higher biological value of protein compared to cereals and milk. In India alone, they feature in over 100 recipes and are processed into various products like chips, flour, and starch, contributing to their widespread utilization

Planting seasons vary based on region and climate, with the optimal temperature ranging between 15 to 22 degrees Celsius. Propagated by tubers, healthy and disease-free specimens are crucial for maximum yields, with seed rates varying based on tuber size. Improved seeds yield better results, with enhanced soil coverage and reduced virus susceptibility. Exports in the last three years is tabulated in table 1,2, and 3 respectively.

Dubbed the 'King of Vegetables', potatoes are a major food crop across more than 100 countries, with China, Russia, India, Poland, and the USA being major producers. Interestingly, less than half of global potato production is consumed fresh; the rest is processed into various food products, used as animal feed, or converted into industrial starch.

India, ranking second in global potato production after China, has seen a rise in per capita consumption from 12 to 17 kilograms per year since 1990. While potatoes aren't solely a rural staple in India, they serve as a significant cash crop, especially in the Indo-Gangetic plain during the short winter months from October to March, with some year-round production in higher altitude regions (Ref fig 1 and 2).


Fig. 1 - States producing potatoes in India

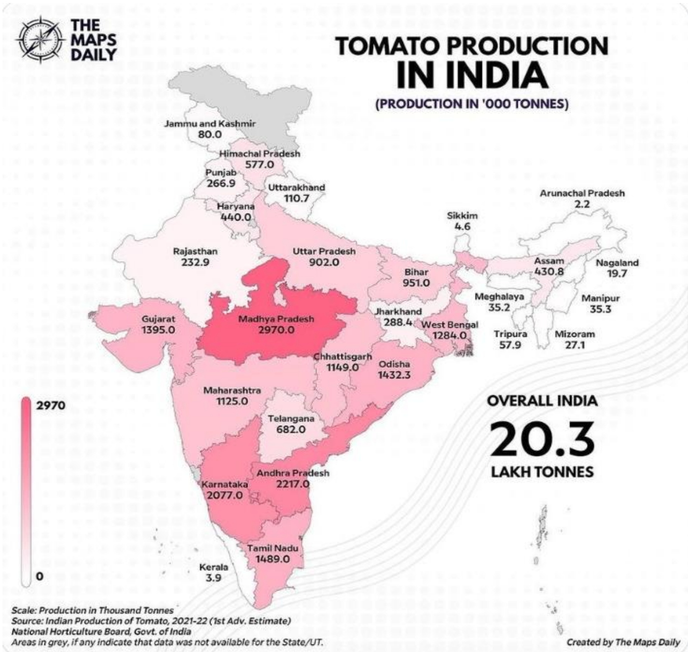


Fig. 2- States producing tomato's in India

Table 1: Monthly Export Of Potato

| Month/Year | Export | | | | | |
|---|---|---|---|---|---|---|
| | 2018 | | 2019 | | 2020' | |
| | Value in Rs. Crore | Qty in Tonnes | Value in Rs. Crore | Qty in Tonnes | Value in Rs. Crore | Qty in Tonnes |
| January | 31.79 | 35630 | 26.56 | 28530 | 36.42 | 26986 |
| February | 26.94 | 26981 | 25.87 | 24816 | 42.61 | 24392 |
| March | 25.74 | 22502 | 42.5 | 31000 | 46.92 | 24156 |
| April | 30.96 | 20114 | 41.25 | 29723 | 58.34 | 28074 |
| May | 28.43 | 18284 | 49.27 | 32670 | 42.98 | 23120 |
| June | 44.09 | 29955 | 56.88 | 39118 | 35.71 | 20281 |
| July | 39.1 | 29913 | 56.07 | 43368 | | |
| August | 48.32 | 37901 | 55.81 | 46384 | | |
| September | 42.83 | 38989 | 48.56 | 41156 | | |
| October | 39.17 | 41850 | 49.24 | 44003 | | |
| November | 33.6 | 31809 | 43.63 | 36623 | | |
| December | 41.87 | 41644 | 51.5 | 35504 | | |
| Total | 432.84 | 375572 | 547.14 | 432895 | 262.98 | 147009 |

Table 2: Monthly Export Of Onion

| Month/Year | Export |
|---|---|

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| | 2018 | | 2019 | | 2020 | |
|---|---|---|---|---|---|---|
| | Value in Rs. Crore | Qty in Tonnes | Value in Rs. Crore | Qty in Tonnes | Value in Rs. Crore | Qty in Tonnes |
| January | 289.82 | 55864 | 236 | 161501 | 0 | 0 |
| February | 209.14 | 102851 | 249.55 | 204063 | 24.85 | 3233 |
| March | 306.04 | 211337 | 272.07 | 197793 | 367.26 | 154612 |
| April | 312.52 | 246761 | 312.52 | 188948 | 526.88 | 233946 |
| May | 351.17 | 215582 | 239.83 | 163417 | 266.01 | 173272 |
| June | 199.14 | 152782 | 265.37 | 159614 | 370.64 | 240196 |
| July | 302.42 | 202860 | 265.36 | 160645 | | |
| August | 365.49 | 219786 | 245.48 | 126722 | | |
| September | 335.45 | 179504 | 423.18 | 104554 | | |
| October | 307.61 | 138815 | 105.22 | 17495 | | |
| November | 260.02 | 114867 | 41.38 | 5945.56 | | |
| December | 277.44 | 149452 | 4.83 | 633.3 | | |
| Total | 3,516.26 | 1990461 | 2660.79 | 1491331 | 1555.64 | 805259 |

Table 3 : Monthly Export Of Tomato

| Month/Year | Export | | | | | |
|---|---|---|---|---|---|---|
| | 2018 | | 2019 | | 2020 | |
| | Value in Crore | Qty in Tonnes | Value in Rs. Crore | Qty in Tonnes | Value in Crore | Qty in Ton nes |
| January | 5.32 | 3042 | 7.89 | 3095 | 19.24 | 9683 |
| February | 3.73 | 2330 | 4.45 | 1723 | 10.25 | 6379 |
| March | 4.25 | 2451 | 3.52 | 2593 | 6.36 | 4364 |
| April | 3.83 | 2747 | 2.61 | 2026 | 3.67 | 2837 |
| May | 4.11 | 2863 | 3.07 | 1764 | 2.04 | 756 |
| June | 6.18 | 2798 | 4.39 | 2216 | 7.73 | 2678 |
| July | 17.16 | 6134 | 16.18 | 6273 | | |
| August | 23.99 | 8973 | 18.8 | 7493 | | |
| September | 40.82 | 15922 | 28.26 | 11019 | | |
| October | 76.2 | 24163 | 21.93 | 8197 | | |
| November | 57.21 | 22835 | 53 | 17947 | | |
| December | 16.38 | 5954 | 37.97 | 15638 | | |
| Total | 259.18 | 100212 | 202.07 | 79984 | 49.29 | 26698 |

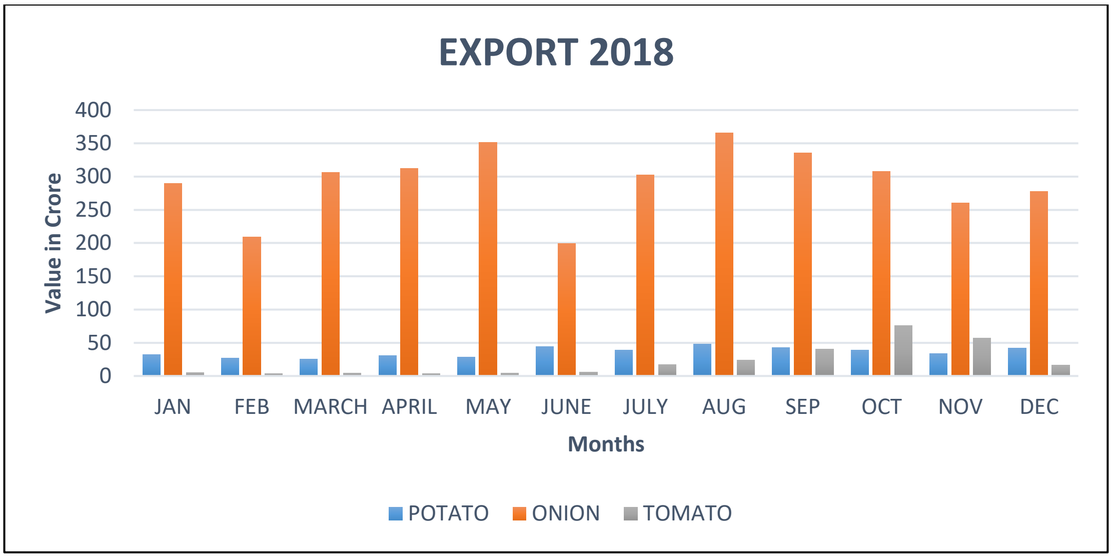


Fig 3: Export of important agricultural product in 2018

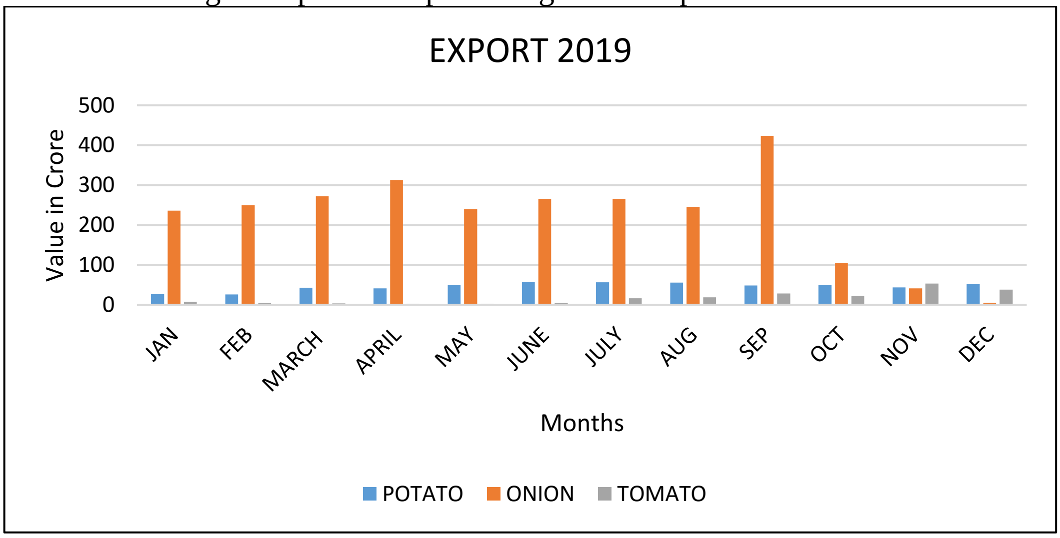


Fig 4: Export of important agricultural product in 2019

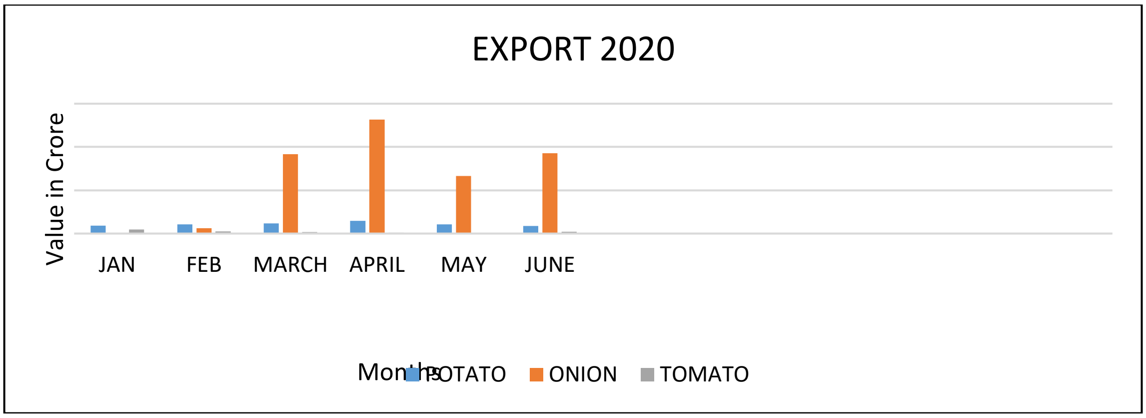


Fig 5: Export of important agricultural product in 2020

Indian export in the last three years is as show in fig 3,4 and 5. State wise exportation is tabulated in table 3,4,5 and 6.

| Table 3: State-Wise Potato Production In The Country | | | |
|---|---|---|---|
| STATE/UTs | Five year Average (2014-15 to 2018-19) | 2018-19 | 2019-20 ($Y^d$ Ad. Est.) |

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| | Production | Share | Production | Share | Production | |
|---|---|---|---|---|---|---|
| UTTAR PRADESH | 15030.64 | 31.11 | 15323.55 | 30.53 | 14004.93 | 27.54 |
| WEST BENGAL | 11057.82 | 22.89 | 11000 | 21.92 | 13160 | 25.88 |
| BIHAR | 6992.7 | 14.48 | 8153.91 | 16.25 | 7710 | 15.16 |
| GUJARAT | 3564.85 | 7.38 | 3706 | 7.39 | 3616.46 | 7.11 |
| MADHYA PRADESH | 3225.95 | 6.68 | 3315 | 6.6 | 3457.32 | 6.8 |
| PUNJAB | 2473.23 | 5.12 | 2724.44 | 5.43 | 2870 | 5.64 |
| HARYANA | 853.75 | 1.77 | 897.85 | 1.79 | 626.09 | 123 |
| ASSAM | 1003.12 | 2.08 | 773.48 | 1.54 | 1139.84 | 2.24 |
| TOTAL OF ABOVE STATES | 44202.05 | 91.5 | 45893.23 | 91.44 | 46584.64 | 91.6 |
| OTHER STATES | 4105.56 | 8.5 | 4296.29 | 8.56 | 4272.57 | 8.4 |
| ALL INDIA | 48307.6 | 100 | 50189.52 | 100 | 50856.21 | 100 |

Table 5: State-Wise Onion Production In The Country

| STATE/UTs | Five year Average (2014-15 to 2018-19) | | 2018-19 | | 2019-20 | |
|---|---|---|---|---|---|---|
| | Production | % Share | Production | % Share | Production | % Share |
| MAHARASHTRA | 7105.23 | 32.78 | 8047 | 35.26 | 11363 | 43.31 |
| MADHYA PRADESH | 3356.93 | 15.49 | 3672 | 16.09 | 4082.9 | 15.2 |
| KARNATAKA | 2903.42 | 13.4 | 2558 | 11.21 | 2275 | 8.47 |
| RAJASTHAN | 1107.84 | 5.11 | 997.26 | 4.37 | 1557 | 5.8 |
| GUJARAT | 1085.96 | 5.01 | | 4.87 | 1243 | 4.63 |
| BIHAR | 1259.13 | 5.81 | 1311.45 | 5.75 | 1313.16 | 4.89 |
| ANDHRA PRADESH | 854.76 | 3.94 | 980.66 | 4.3 | 980.61 | 3.65 |
| HARYANA | 702.12 | 3.24 | 780.15 | 3.42 | 609.65 | 2.27 |
| UTTAR PRADESH | 428.67 | I .98 | 440.38 | 1 .93 | 454.03 | 1.69 |
| TAMIL NADU | 398.68 | 1.84 | 301 | 1.32 | 434.58 | 1.62 |
| TELANGANA | 376.95 | 1.74 | 309.29 | 1.36 | 163.34 | 0.61 |

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| | | | | | | |
|---|---|---|---|---|---|---|
| TOTAL OF ABOVE STATES | 19579.69 | 90.34 | 20508.29 | 89.87 | 24476.27 | 91.14 |
| OTHER STATES | 2093.91 | 9.66 | 2311.14 | 10.13 | 2379.66 | 8.86 |
| All India | 21673.6 | 100 | 22819.43 | 100 | 26855.93 | 100 |

Table 6: State-Wise Tomato Production In The Country

| STATE/UTs | Five year Average (2014-15 to 201819) | | 2018-19 | | 2019-20 (Y[d] Ad. Est.) | |
|---|---|---|---|---|---|---|
| | Production | Share | Production | Share | Production | Share |
| Andhra Pradesh | 2687.78 | 14.21 | 2503.49 | 13.17 | 2667.43 | 12.96 |
| Madhya Pradesh | 2423.57 | 12.81 | 2516.08 | 13.24 | 2655.29 | 12.91 |
| Karnataka | 2021.8 | 10.69 | 2030.04 | 10.68 | 2163 | 10.51 |
| Odisha | 1318.68 | 6.97 | 1304.18 | 6.86 | 1306 | 6.35 |
| Gujarat | 1342.81 | 7.1 | 1367.57 | 7.19 | 1378.78 | 6.7 |
| West Bengal | 1224.09 | 6.47 | 1268.57 | 6.67 | 1271.35 | 6.18 |
| Bihar | 992.62 | 5.25 | 964..48 | 5.07 | 964.2 | 4.69 |
| Maharashtra | 962.19 | 5.09 | 860.75 | 4.53 | 1040 | 5.06 |
| Telangana | 1027.85 | 5.43 | 891.69 | 4.69 | 820.62 | 3.99 |
| Haryana | 677.98 | 3.58 | 650.63 | 3.42 | 494.53 | 2.4 |
| Uttar Pradesh | 750.07 | 3.96 | 844.43 | 4.44 | 880.76 | 4.28 |
| Tamil Nadu | 660.91 | 3.49 | 814.43 | 4.28 | 1592.31 | 7.74 |
| Total Of Above States | 16090.3 | 85.05 | 16014.48 | 84.25 | 17234.27 | 83.77 |
| Other States | 2828.04 | 14.95 | 2992.76 | 15.75 | 3338.24 | 16.23 |
| All India | 18918.39 | 100 | 19007.24 | 100 | 20572.51 | 100 |

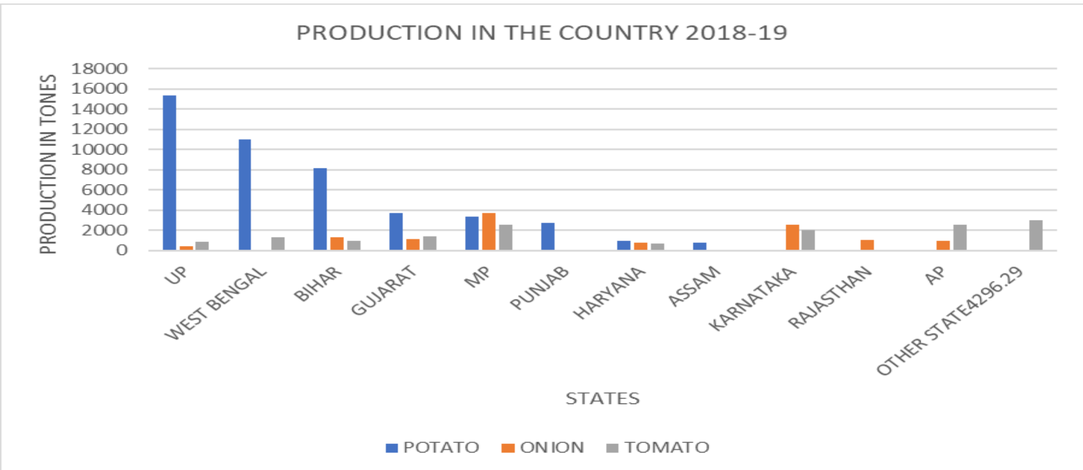


Fig 6: Production in 2018-19

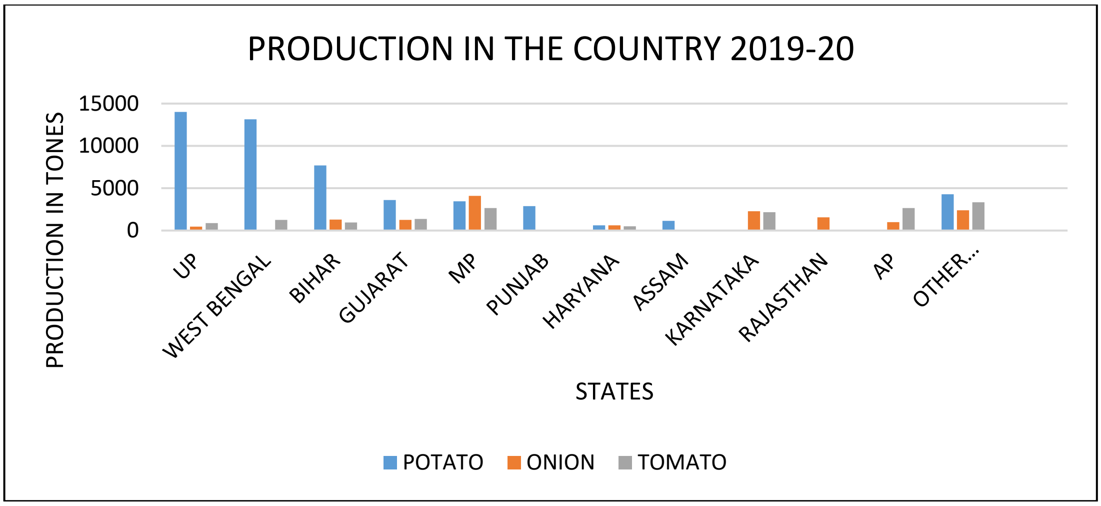


Fig 7: Production in 2019-20

According to Indian horticulture report Both potato and onion are major agricultural crops in India. Potato is grown in almost all states throughout the year, while onion cultivation is more concentrated in certain states like Maharashtra, Karnataka, Gujarat, and Madhya Pradesh. (ref fig 6 and 7)

Export policies for potatoes and onions can vary based on market conditions and domestic requirements. While potato exports are relatively stable and less influenced by government interventions, onion exports are more susceptible to policy changes due to the commodity's price sensitivity and its significance in the domestic market. The potato market in India is relatively more stable compared to onions. India is a major producer of potatoes, and the crop is grown in almost all states throughout the year. Potatoes are consumed widely in various forms and are also exported to other countries. While potato prices may fluctuate based on factors like production levels and demand, they tend to be less volatile compared to onions.

**1.3 Industrial need**

In India, agriculture being the major occupation and hence the economic growth of country is hugely dependent on agricultural sector. Demand of good quality fruits is increasing with the rise in population. GDP of the many countries rely upon its export. Major part of GDP of India depends on its fruit export business. the need for efficient sorting and quality control systems in fruit processing to meet the increasing demand and to enhance economic growth. Using machine-controlled sorting systems with image processing technology indeed offers promising solutions to improve fruit quality, increase productivity, and reduce labour-intensive processes. Integrating machine vision technology, especially depth cameras for defect detection, can significantly enhance the accuracy and efficiency of sorting operations. By investing in such advanced technologies, India can potentially boost its fruit export business, which plays a crucial role in the country's GDP. Additionally, improving the quality and sorting efficiency can contribute to better market competitiveness and meet the rising demands both domestically and internationally.

Automatic potato grading systems leverage cutting-edge technology like computer vision and machine learning to precisely sort potatoes based on size, shape, and quality, ensuring consistent and error-free grading. They streamline the grading process, significantly reducing time and labor compared to manual methods, leading to cost savings and higher throughput. By standardizing grading and identifying defective potatoes, these systems maintain consistent quality and reduce waste, optimizing distribution channels and maximizing profitability. Equipped with data analysis capabilities, they enable informed decision-making and continuous improvement in potato production processes. Moreover, by automating grading tasks, they save on labor costs and allow workers to focus on other aspects of potato production. Overall, automatic grading systems enhance efficiency, quality control, and profitability in potato production, benefiting producers and consumers alike

**1.4 Current System available for grading**

India does not have a standardized national grading system for potatoes. However, there are general guidelines followed by farmers, wholesalers, and retailers to determine the quality of potatoes. These guidelines often include factors such as size, shape, skin appearance, and overall quality.(Ref. fig 8). In India, potatoes are commonly graded based on:

**Size**: Potatoes are often categorized into different size grades, such as small, medium, large, and extra-large. This classification is usually based on weight or count per unit (e.g., per kilogram or per sack

**Shape**: Uniformity in shape is preferred, with round or oval shapes being typical. Irregularly shaped or deformed potatoes may be considered lower in grade

**Skin Appearance**: The skin should be smooth, free from cuts, bruises, and blemishes. Uniformity in skin color is also desirable

**Costs and Complexity**: Implementing and maintaining grading systems can be costly and complex, particularly for smaller-scale producers or regions with limited resources. Compliance with grading standards may require additional infrastructure, training, and administrative efforts.

Fig. 8 - Potato grader machine

**2. Literature Review**

Sung-Hyuk Jang et. al. [1] This research paper deals with the development of object tracking, counting, and sorting of the potatoes using YOLOv5 and DeepSORT algorithms. In addition to this, mass and volume estimation was done with over an average error of 13% of individual and total error on measured mass of about 9%. The paper concludes that there is a need of using regression models and improvisation in calibration and validation of dataset and there is an additional study required for visualization of yield information. This yield monitoring system can be possibly applied to other underground crops.Ali H. Alharbi et. al. [2] This research paper deals with the development of automatic Fruit classification and recognition along with fusion-based feature extraction performed by Enhanced Tunicate Swarm Algorithm hyperparameter optimizer. DenseNet, ResNet and Inceptionv3 models were used. In this study XGBoost model was used for Fruit classification. The fruits considered in this study were Cashew, Kiwi, Orange, Plum, Watermelon and Nectarine. Over 3000 samples were considered in total. The technique presented here can be used for the real-time application of fruit classification and recognition. Shantilata Palei et al. [3] All the papers published during 2010-2021 related to diseases and fruit grading systems and techniques for citrus has been reviewed in this research paper. The paper also has provided an overview symptomatic information of citrus diseases. After studying and analysing the past research papers of the same, this paper has suggested a framework for ML and DL approach. The suggested framework includes CNN models, classification based on SVM, KNN, ANN. It has also analysed the major challenges in disease detection and fruit grading of citrus based on machine vision which includes flaw detection, measurement, identification, etc. This paper has concluded that the using of Hybrid approach (ML & DL) might prove effective in this domain for further research.S. K. Chakraborty et. al [4] This research paper has aimed to develop a light weight DCNN model which can be used for real time vision based citrus fruit sorting system. Goals achieved in this study includes development of a less complex CNN model named as SortNet, automatic fruit grader and development of robust algorithm comprising of DCNN based architecture. This study further concludes that the SortNet functioned way better than state of the art models which were relatively more complex and had higher response time when used with low-cost appliances. Anand Kumar Pothula et al. [5] The aim of this research was to investigate the rotational behaviour and imaging of apples using a new Singulating and Rotating Mechanism (SRM) for in-field quality grading at 3 different conveyor speeds. As a result, the rotational function of SRM has been successful in presenting individual apples for quality grading. This in-field sorting system can be well suited for automatic in-field quality grading of apples at a faster rate. TheOo Mon [6] Volume estimation from 2D images of mangoes using an image processing algorithm has been proposed in this research paper. Over 150 mango samples were tested using the algorithm and this performance data was then compared with the traditional volume measuring methods. This algorithm has given good approximation for thickness and volumes of the mangoes to the traditional methods. P.U. Patil et. al. [7] In this research, ML algorithms such as ANN, CNN and SVM have been used to detect and sort the Dragon fruits using its features. Features of the Dragon fruit which were mainly considered for identification of quality of the fruit were size, shape, weight and colour of sample and type of disease. Based on the number of iterations, it has been observed that the accuracy of feature detection varies. it was also observed that the convolution function increased the speed of operation and gives better effective outputs when compared to ANN and SVM. T. R. Christian Konfo et. al. [8] This study has been done to provide a short review of the recent advances in the use of digital technology in Agri-food processing. This study has concluded that the use of modern digital technologies in this field have provided significant number of advantages. In addition to this the cost of these technologies can be huge and implementation can be complex but will be promising. This research provided an efficient and simple model for weight and volume estimation (chopped pyramid method) of Japanese sweet potatoes grown in Vietnam. The accuracy obtained for volume and weight respectively are 96 and 95 percent. This model has achieved a speed of 45 samples per second with hardware consisting of a single camera to take top view images of the sample. This method concluded that camera calibration and subtraction of background are the most important parameters in estimating the volume. To increase accuracy one may use ML, ANN models. S. Bayano-Tejero et. Al. [10] This research has been carried out to design and develop trailer models, (i) trailer for sorting and transporting (TST) & (ii) trailer for reception cleaning and sorting (TRCS). The prototype of both the trailer models were tested and validates using Artificial Olives and Real Infield Olives. The algorithm created for the trailers was successful in sorting of 3 different fruit ripening stages. The cleaning system, fruit maturity sorting system and the grading machine obtained 100, 83 and 98 percent accuracy. This was achieved using PLCs, cameras, Raspberry Pi, GPS, etc. Vishal Meshram et.al. [11] This study was conducted to prepare a Dry Fruit image dataset using Mobile rear camera. The .heic photos of 3024 x 4032 were converted to 512 x 512 with .jpg using Python script. The photos were taken in Natural and Artificial Backgrounds on different surfaces. Kristyna Simkova et. al. [12] This study dealt with the chemical properties and further processing separation of two grades of strawberry. The quality parameters of strawberry were tested for two cultivars. Using chemical testing, it was found that the smaller strawberries had higher anthocyanins content and the larger ones had higher ascorbic acid and sugar contents. This making small ones suitable for puree and other further processing. This study has provided a preliminary basis for further research for processing of small-sized strawberries.

**2.1 Research Gap**

Research investigating the estimation of potato weight through image analysis has not been undertaken thus far. Additionally, the practice of grading potatoes according to their size, shape, and gravimetric properties has not been implemented. Moreover, a fully automated system for these purposes has not been observed within this context. Furthermore, no model has been developed to effectively correlate multiple parameters in potato evaluation. Importantly, existing research has failed to emphasize the necessity and significance of potato exportation.

**2.2 Scope of work**

- Extraction of features from images.
- Formulation of a Dimensional Analysis (DA) model for data analysis.
- Implementation of a DA classifier for performance calculation.
- Development of automation techniques for systems previously reliant on manual operation.
- Integration of Dimensional Analysis (DA) with Convolutional Neural Networks (CNN) for enhanced data analysis and classification.

### 2.3 Research Objectives

1. **Domain Identification and Industry Survey:**

- We initiated our research endeavor by delving into the domain of agricultural product quality assessment, embarking on an initial exploration to gain a comprehensive understanding.
- Subsequently, we meticulously conducted an industry survey, seeking to glean insights into prevailing practices, challenges, and technological advancements within the field.

2. **Literature Review and Objectives Finalization:**

- A meticulous literature review was undertaken, aimed at identifying pertinent studies, methodologies, and critical gaps in existing research.
- Leveraging the insights garnered from the literature review and industry survey, we finalized our research objectives, meticulously tailoring them to address identified gaps and contribute novel insights to the field.

3. **Fabrication of Experiment Setup & Experimentation:**

- With a clear vision in mind, we proceeded to design and fabricate an experimental setup meticulously engineered to capture detailed images of agricultural products and extract pertinent features.
- Subsequent experimentation endeavors involved utilizing the developed setup to capture images of diverse agricultural products, meticulously collecting corresponding data on attributes such as size, shape, and color.

4. **Mathematical Model Training & Testing:**

- Employing advanced methodologies, we embarked on the training of mathematical models, predominantly leveraging state-of-the-art machine learning algorithms.
- Rigorous testing of the trained models ensued, wherein a subset of our meticulously curated dataset was utilized to assess model performance, facilitating the fine-tuning of model parameters as deemed necessary.

5. **Testing Model for Multiple Agricultural Products:**

- Our testing endeavors were broadened to encompass an array of agricultural products, aimed at evaluating the versatility and robustness of our developed models.
- Extensive data collection efforts were undertaken, enabling comprehensive assessment of model performance across varying product types and characteristics.

6. **Analysis and Result Discussion:**

- Thorough analysis of the results gleaned from model testing and experimentation ensued, enabling the identification of correlations between input features and agricultural product weight and volume.
- Subsequent discussions centered on the implications of our findings vis-à-vis our research objectives, elucidating key insights, limitations, and avenues for future exploration.
- A comprehensive comparison of results with existing literature and industry practices was undertaken, fostering a holistic understanding of the research outcomes.

Through the meticulous execution of this research methodology, we have systematically addressed our research objectives, from inception to culmination, effectively contributing valuable insights to the field of agricultural product quality assessment. The image based weight estimation system is as shown in fig 9.

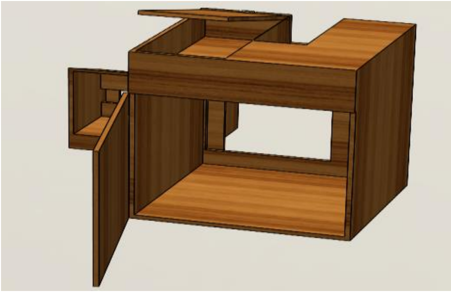

Fig 9 : Design image capturing unit.

**3. Result and Discussion**

Following is the block diagram (Fig 10) of the code:

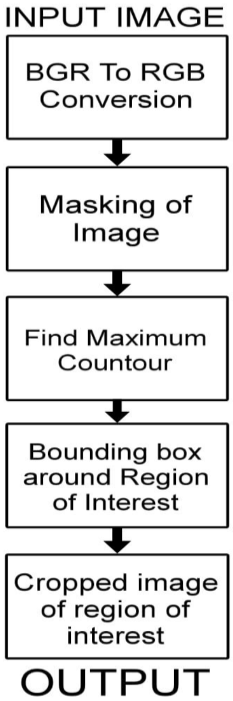


Fig. 10 - Block diagram of image converter algorithm

● Input:
This is first step where we give input as our images.

● BGR To RGB Conversion:
This is first process for feature extraction from image. The format of image is changed from BGR(Blue Green Red) to RGB(Red Green Blue) in this step. This is step on which all the next processes are depend.

● Masking of Image:
Masking is the process which is done on the image by using python program. This is step needed for feature extraction.

● Find Maximum Contour:
This is following step after image is masked. In this we find the maximum contours of the image using program. This is important step in feature extraction.

● Bounding box around Region of interest:
In this step based on previous steps we draw bounding rectangle or box around the region of interest which the required object we want. The output dimensions are based on this bounding box or we can say those are the dimensions of this box

● Cropped image of region of interest:

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The output is shown along with the cropped image from the original image. This image is just the of bounding box we previously made. Based on this our required dimensions are given as output.

● Output:

Output we get as length and breadth which are the required features.

**Output Explanation:**

In output we get length and breadth of the region of interest along with the how processing of image is done.

Following is the flow of image (Fig 11) processing for feature extraction:

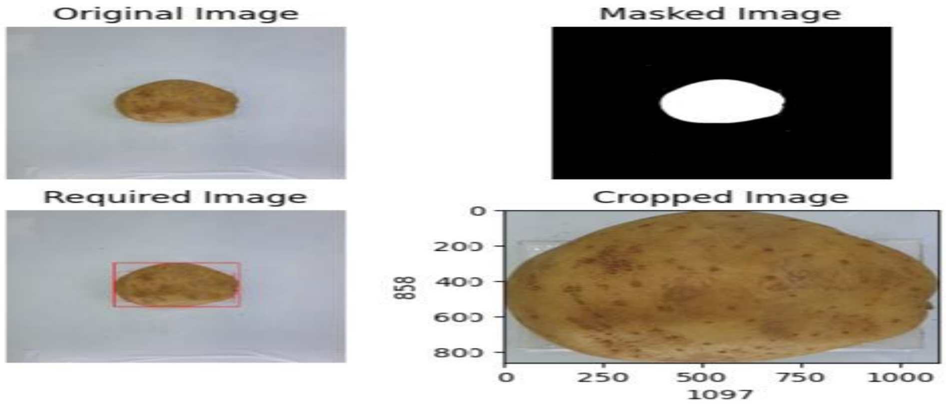


Fig. 11- Flow of Image Processing

Length: 1097 pixels

Breadth: 858 pixels

The Weight models has been prepared based on captured image length, width and thickness and tabulated in table 7 and 8 respectively.

- **Length (LN)**

Table 7: Correlation of length with weight

| Length | | | | |
|---|---|---|---|---|
| Linear equation | **Quadratic equation** | **Cubic equation** | **$4^{th}$ degree equation** | **$5^{th}$ degree equation** |
| Y=(5.074*X)-242.5 | Y=0.01633*X^2+2.042*X-111.9 | Y=-0.0004449 * X^ 3 +0.1458 * X^ 2 - 9.867 * X+231.8 | Y=0.000006481*X^4-0.003044*X^3+0.5216*X^2-32.9*X+740 | Y=0.00000007102*X^5-0.00002948*X^4+0.003998*X^3-0.1438*X^2-2.706*X+210.1 |
| $R^2$= 0.939584534 | $R^2$= 0.943344128 | $R^2$= 0.9456752 | $R^2$= 0.946178073 | $R^2$= **0.9462332** **(Best fitted Model)** |

- **Width (WD)**

Table 8: Correlation of width with weight

| Width | | | | |
|---|---|---|---|---|
| Linear equation | **Quadratic equation** | **Cubic equation** | **$4^{th}$ degree equation** | **$5^{th}$ degree equation** |

| | | | | |
|---|---|---|---|---|
| Y=8.215*X-335.6 | Y=0.0915*X^2-4.005*X + 51.2 | Y=-0.00128*X^3 +0.3537*X^2-21.3*X + 416.6 | Y=-0.00000006625*X^4 -0.001261*X^3+ 0.3518*X^2-21.22*X+415.3 | Y=0.000002249*X^5 -0.0007864*X^4 + 0.1061*X^3-6.781*X^2+209.9*X-2496 |
| $R^2$= 0.937185363 | $R^2$= **0.985295473 (Best fitted Model)** | $R^2$= 0.9520455 | $R^2$= 0.95204547 | $R^2$= 0.95235121 |

- **Thickness (TH)**

Table 9: Correlation of Thickness with weight

| Thickness | | | | |
|---|---|---|---|---|
| Linear equation | **Quadratic equation** | **Cubic equation** | **4th degree equation** | **5th degree equation** |
| Y=11.45*X-377.9 | Y=0.08292*X^2+2.776*X-160.5 | Y=-0.007684*X^3 +1.316*X^2-61.15*X+907 | Y=0.0001669*X^4-0.04369*X^3 +4.151*X^2-157.6*X+2102 | Y==0.0000204*X^5-0.005323*X^4+0.534*X^3-25.54*X^2+586.9*X-5180 |
| $R^2$= 0.905962269 | $R^2$= 0.90949661 | $R^2$= 0.915383054 | $R^2$= 0.9158854 | $R^2$= **0.91706225 (Best fitted Model)** |

➢ **Input 2: (Geometric Features or Size based Input features of Potato's)**

**One Dimensional Features (1D)**

- **Arithmetic Mean Diameter (AMD)**

Table 10: Correlation of Arithmetic Mean Diameter with weight

| Arithmetic Mean Diameter (AMD) | | | | |
|---|---|---|---|---|
| Linear equation | **Quadratic equation** | **Cubic equation** | **4th degree equation** | **5th degree equation** |
| Y=8.049*x-345.4 | Y=0.1043*x^2-6.481*x+133.4 | Y=0.00002494*X^3 +0.09898*X^2-6.111*X+125.2 | Y=-0.00000706*X^4 +0.002328*X^3-0.1491*X^2+5.427*X-69.87 | =-0.00000002672*B5^5 +0.000002114*B5^4 +0.0008794*B5^3-0.04612*B5^2 +1.56*B5-21.56 |
| $R^2$= 0.972645554 | $R^2$= 0.99343015 | $R^2$= **0.9934305 (Best fitted Model)** | $R^2$= 0.9933073 | $R^2$= 0.99337687 |

- **Geometric Mean Diameter (GMD)**

Table 11: Correlation of Geometric Mean Diameter with weight

| Geometric Mean Diameter (GMD) |
|---|

| Linear equation | **Quadratic equation** | **Cubic equation** | **4th degree equation** | **5th degree equation** |
|---|---|---|---|---|
| Y=271.7*X -1387 | Y=173.2*X^2 - 1753*X+4491 | Y=48.6*X^3-688.3*X^2+3290*X-5308 | Y=-4.241*X^4 +149.1*X^3-1574*X^2+6757*X-10300 | Y=-11.27*X^5 +329.8*X^4-3802*X^3+21730*X^2-61760*X+69990 |
| $R^2$= 0.954460132 | $R^2$= 0.992779396 | $R^2$= 0.9932182 | $R^2$= **0.9934412 (Best fitted Model)** | $R^2$= 0.9933941 |

- **Equivalent Diameter (ED)**

Table 3.8: Correlation of Equivalent Diameter with weight

| Equivalent Diameter (ED) | | |
|---|---|---|
| Linear equation | **Quadratic equation** | **Cubic equation** |
| Y=8.411*X-357.8 | Y=0.1225*X^2-8.22*X+177.6 | Y=0.0004055*X^3+0.03789*X^2-2.523*X+54.49 |
| $R^2$= 0.970879878 | $R^2$= 0.99415216 | $R^2$= **0.9942227 (Best fitted Model)** |

**Conclusion**

From the presented work,we can summarize that above models works more efficiently and accurately for weight estimation and for classification. The models shows the potential of it to beat existential advance machine learning models like regression, random forest and artificial neural network.

As other models work flexibly with other advance deep learning models such as Recurrent neural networks (RNNs), Convolutional neural networks (CNNs), Transformer, Multilayer perceptrons (MLPs), Long Short Term Memory Networks (LSTMs) models etc. We can also make DA classifier more flexible and capable to perform functions along with advance models. This models are more adaptable, programmable and flexible with advanced machine learning and deep learning models. In the present work, the models presented are more compatible with Convolutional neural network (CNN) for image processing to classify it on the basis of Color, Surface defects and Texture. We develop an algorithm which will give results of the best models along with estimated weight and class of product using Regression, Random forest and Artificial neural network, also in result we will get to know the class of product for color, surface defects and texture using CNN. This is the extension for developed model using deep learning model. For current work we have taken quality product but in future by using CNN we can take any product and classify them according to our requirements using CNN.

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