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Image-based parameters: Bayesian Model in banana fruit mass prediction

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ABSTRACT

The emergence of contagious diseases has intensified the need for the adoption of technologies that minimize human contact with potentially contaminated surfaces and objects. Due to the manual nature of fruit weighing within Zimbabwean supermarkets, there is frequent human-mass scale contact. Hence, manually operated mass scales are on the long list of prospective disease spreading surfaces. This study proposes the assessment of the feasibility of banana fruit mass modelling based on image analysis, as a way of eliminating human-mass scale contact during the manual weighing process. The banana fruit image-based parameters considered in this study are filled image, minor axis length, equivalent diameter, perimeter, stalk length and major axis length. The Bayes Linear Regression model has been utilized in identifying image-based parameters that are of significance to the mass determination model. The major axis length of the banana has been identified as the most significant mass prediction image-based parameter. Using the Mean Absolute Percentage Error (MAPE), the major axis length-based model accuracy has been assessed. The model has an accuracy of 96.61 %. Since, the accuracy value lies within the upper quartile region, the formulated model is accurate enough to be used for banana mass prediction. Based on the paired t-test results, the difference between the average of predicted value minus actual value is not big enough to be statistically significant. The system has an acceptable response time of four seconds.

Keywords: Image-based, banana fruit, mass prediction, Bayesian model.

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1. INTRODUCTION

Due to them being an outstanding source of potassium, bananas are highly consumed in Zimbabwe. This high demand for the golden fruit has resulted in high human traffic on fruit mass balances in supermarkets in Zimbabwe. Because of most diseases being spread through human contact with contaminated surfaces, there is need to device mass determination methods that are contactless. The image-processing based technique has previously been successfully implemented to characterize fruit physical parameters, albeit on fruits other than bananas. This study is an assessment of the feasibility of the image-based technique in characterizing banana mass.

Omid et. al. (2010) utilized the image processing-based technique in determining citrus fruits volume and mass. The fruits considered in the study are oranges, tangerines, limes and lemons. The response variable in the study is the product volume, while the individual elliptical frustum volumes of the individual fruits are the control parameters. An algorithm to determine the product volume has been developed and its accuracy determined by the coefficient of determination (R^2). The algorithm-based results are in harmony with water displacement-based volume. Hence, the image-based characterization technique is reliable and can be utilized. In a separate study, Ponce et. al. (2019) classified olive fruit varieties using image process processing-based parameters and convolution neural networks. Using image techniques, fruit images have been obtained and used to train convolution neural networks. The trained model could classify olive fruits with an accuracy level of 95.91 %. Based on the results, it has been concluded that the image-based technique is an effective way of classifying fruits in general.

Vivek et. al. (2017) characterized the mass of Sohiong fruit using the fruit's physical and mechanical properties as the control variables, while the mass is the response variable. The generated model could predict the fruit mass with high accuracy. It has been concluded that a scientific base has been enriched by the study results. The shape and size of the 'Moro' Blood Orange and 'Valencia' Sweet Orange cultivar have been determined using image processing technique (Sayinci, et al., 2012). Machine vision techniques have been successfully utilized in automatic counting and mass estimation of olive fruits. The model could predict fruit mass with a relative error not more than 1.16 %. This is an exhibition of the model's high prediction power. Hence the technique can be reliably used. Numerous other researchers have successfully utilized the technique (Shahir, et al., 2018; A'Bidin, et al., 2020).

According to a review by Kodagali (2012), has been extensively utilized in automatic fruit recognition systems. This has been necessitated by need for accurate, swift and reliable fruit attributes determination. It has been highlighted that appearance plays a vital role in fruit-based decision making. Among the vast sea of fruit attributes are mass, size, ripeness, and disease classification. Despite the success of the machine vision in fruit identification, the uptake of the technology is still low. Based on the reviewed literature, it can be comfortably concluded that image analysis of fruits is a reliable characterization technique for fruits. The study paper layout is as follows: image analysis process steps, experimental setup, experimental results, predictor impact assessment using Bayes' model and model accuracy assessment. The process variables used in fruit mass determination are also outlined.

2. BANANA IMAGE PROCESSING

Image-based techniques utilize a computer for image analysis for the purposes of enhancing object feature visibility and hence aid in decision making. During the processing stage, as much attributes as possible are acquired before a decision is made about which ones have the greatest impact for decision making. The process flow chart for image processing is presented in Figure 1.

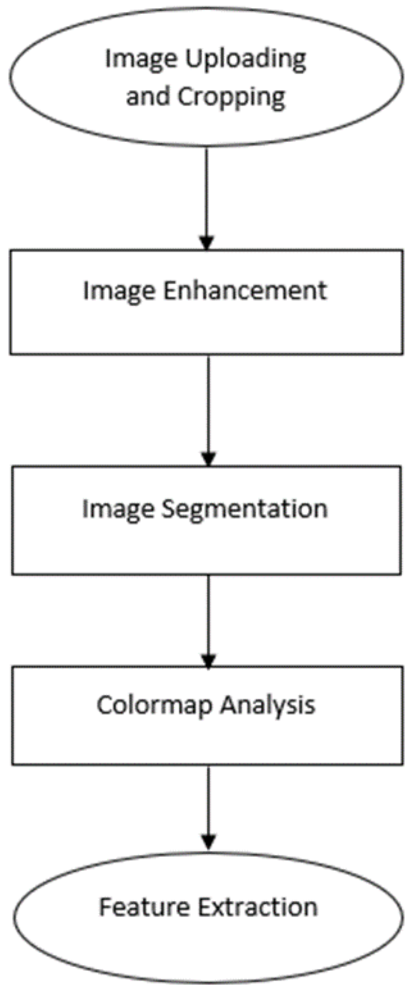

Figure 1. Image Processing Flow Chart

3. MATERIALS AND METHODS

The fruit images were captured using a Samsung Galaxy Note 4 auto focus camera with a rear facing resolution of 16 Mega pixels and Smart OIS front facing 3.7 Mega pixel camera with f1.9. Twelve data sets of fruit images have been captured in the study. A total of six fruit image-based features have been acquired. The features are filled area (U), minor axis length (V), equivalent diameter (W), perimeter (X), stalk length (Y) and major axis length (Z). The image processing procedure has been performed in MATLAB and the impact of each parameter in mass prediction has been accomplished using the Bayes' model. Figure 2 is a presentation of image acquisition and mass measurement setups. The mass has been measured using a Denver instruments scale. Some samples of banana images before feature acquisition are presented in Figure 3.

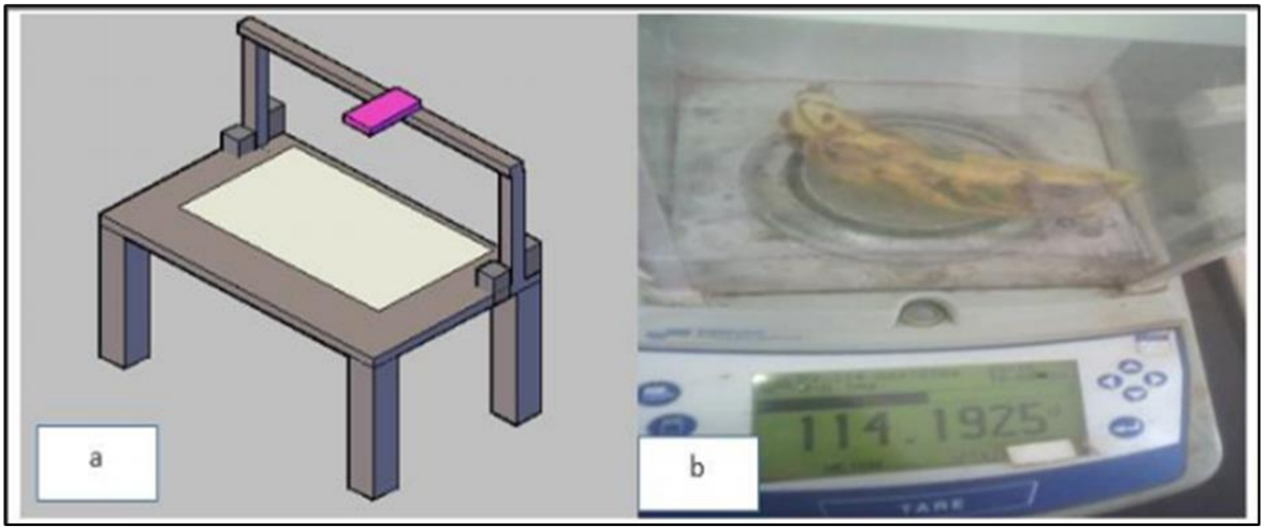

Figure 2. (a) Image Acquisition Experiment Setup and (b) Mass Measurement Setup

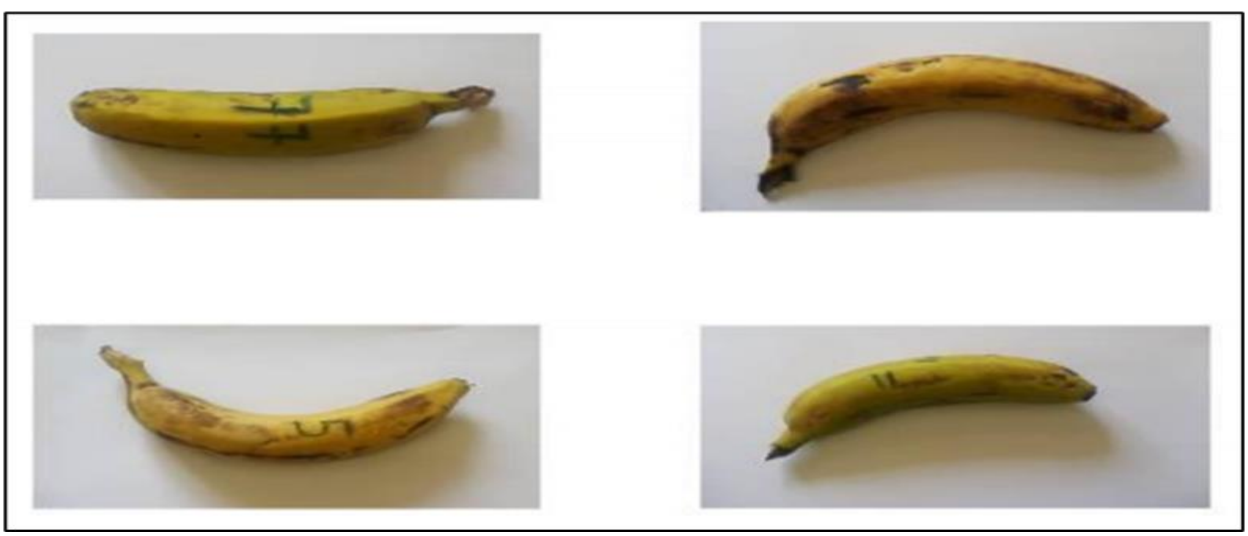

Figure 3. Unprocessed Banana Images

4. RESULTS AND DISCUSSION

The following image-based banana features have been acquired and tabulated: filled area (U), minor axis length (V), equivalent diameter (W), perimeter (X), stalk length (Y) and major axis length (Z) (Table 1). The model with the greatest significance on banana mass has been ascertained by the Bayes' model. The results presented in Table 2 show that the model containing only major axis length (Z) as the predictor has the greatest significance. This is indicated by the high posterior probability of Z in column three. A regression model in terms of Z has been formulated and presented by (1).

Table 1: Image-Based Banana Features

Exp. No.	U	V	W	X	Y	Z	Mass
1	38379	158.41	220.72	1131.6	58.16	427.89	151.18
2	52155	211.51	257.69	1404.8	85.69	480.71	185.4
3	31841	153.88	201.35	1031	50.93	367.58	104.9
4	31924	132.35	201.61	898.75	34.99	374.04	116.25
5	34238	126.11	208.79	916.49	34.04	391.3	123.74
6	31867	139.32	201.43	879.35	37.23	356.29	110.26
7	28451	108.08	190.33	846.91	68.55	358.66	116.42
8	29273	117.65	193.06	890.43	20.49	349	110.59
9	39757	187.19	228.99	1279.7	77.39	440.98	150.75
10	32577	150.18	203.66	1000.5	35.38	365.16	114.17
11	46726	189.63	243.91	1390.5	68.6	485.28	174.91
12	43522	146.41	235.4	1212	55.46	513.71	197.2

Table 2. Model Significance Table

Models	P(M)	P(M|data)	BF_M	BF_{10}	R^2
Z	0.024	0.793	156.848	1.000	0.0972
V+Z	0.010	0.028	3.045	0.090	0.0973
U+Z	0.010	0.028	3.036	0.089	0.0973
X+Z	0.010	0.028	3.028	0.089	0.0973
Y+Z	0.010	0.026	2.730	0.081	0.0973
W+Z	0.010	0.025	2.702	0.080	0.0973
U+V+Z	0.007	0.010	1.438	0.043	0.983
V+W+Z	0.007	0.008	1.127	0.034	0.982
U+W+Z	0.007	0.006	0.817	0.025	0.980
U+X+Z	0.007	0.005	0.690	0.021	0.979

$$Mass = -88.483149 + 0.553409\,Z \tag{1}$$

Table 3. Model Prediction Results

Z	**Mass**	**Predicted Mass**	**Absolute Percentage Error**
427.89	151.18	148.31	1.89
480.71	185.4	177.54	4.23
367.58	104.9	114.93	9.56
374.04	116.25	118.51	1.94
391.3	123.74	128.06	3.49
356.29	110.26	108.69	1.42
358.66	116.42	110.00	5.51
349	110.59	104.65	5.37
440.98	150.75	155.55	3.18
365.16	114.17	113.59	0.50
485.28	174.91	180.07	2.95
513.71	197.2	195.80	0.70
Mean Absolute Percentage Error (MAPE)			**3.39**
Prediction Accuracy			**96.61**

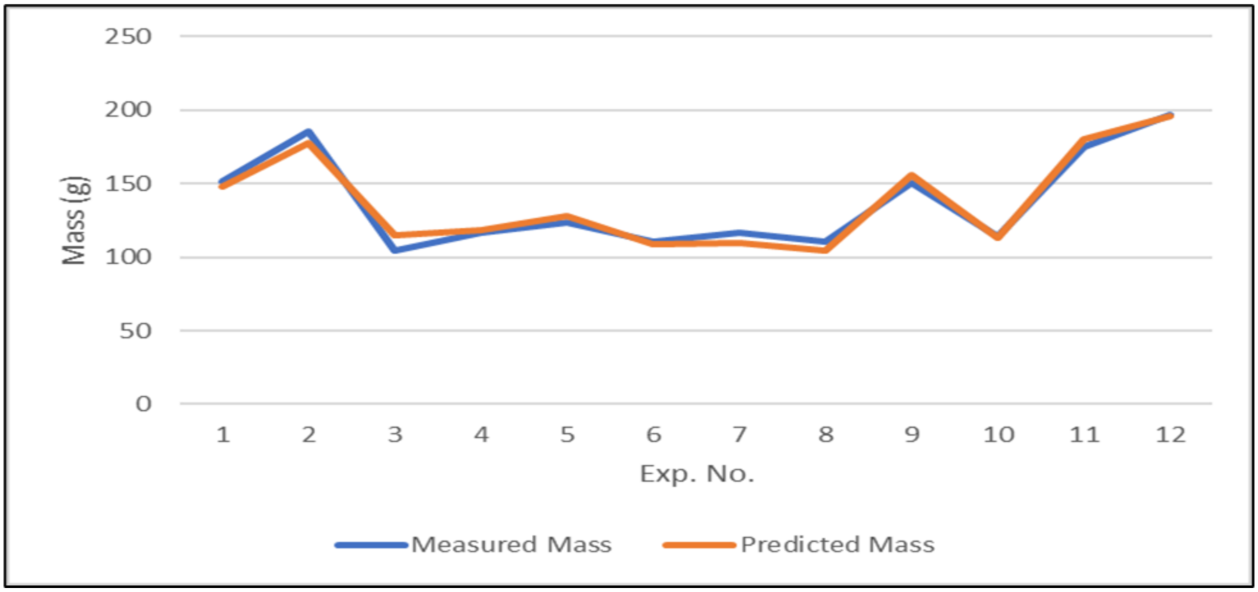

Figure 1. Plot of Measured and Predicted Banana Mass Against Experiment Number.

Model prediction results with their associated accuracies are presented in Table 3. The model has a Mean Absolute Percentage error of 3.39% or a prediction accuracy of 96.61%.

Paired t-test using t-distribution at α (0.05) significant level yields a p-value of 0.8024. Since p-value > α, H_0 cannot be rejected. The average of Predicted Value minus Actual Value's population is assumed to be equal to the μ_0. In other words, the difference between the average of Predicted value minus actual value and the μ_0 is not big enough to be statistically significant.

5. CONCLUSION

The accuracy of a mass predicting model formulated using the Bayesian model has been evaluated in this study. The model has a prediction accuracy of 96.61 %. Since the prediction accuracy lies within the upper quartile region, the model is accurate enough to be trusted and used in banana mass prediction. Furthermore, the significance of the difference between manually measured banana mass and model-based mass has been assessed. The difference has been found to be not big enough to be significant. Among the chosen banana mass determination parameters, major axis length has been discovered to be the most significant. Based on the study results, the formulated model may be reliably utilized in banana mass characterization. This technique may also be incorporated in automatic mass determination of bananas, leading to the reduction of human contact with manual mass determination balances in use in most supermarkets in Zimbabwe.

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