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Determination of Symmetrical Object Volume with Distance Parameter Using Linear Regression Method

Jatmiko Endro Suseno [a,1,*], Agus Setyawan [b,2] and Isnain Gunadi [c,3]

[a] Department of Physics, Faculty of Science and Mathematics, Diponegoro University, Semarang, Indonesia
[b] Department of Physics, Faculty of Science and Mathematics, Diponegoro University, Semarang, Indonesia
[c] Department of Physics, Faculty of Science and Mathematics, Diponegoro University, Semarang, Indonesia
[1]jatmiko@fisika.fsm.undip.ac.id*, [2]asetyawan@gmail.com,[3]gunadinung@gmail.com
* corresponding author

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ABSTRACT

The volume of objects is a consideration to the determination of the quality of goods such as eggs, fruit, piles of rice, or sand. This study aims to obtain a system for real-time measuring the volume of an object symmetrically using the linear regression method, which is faster, more effective, and more enjoyable. There are 2 inputs from the system, namely digital image capture from the camera and the distance of the object from the camera. This study uses segmentation and linear regression methods to determine the volume of an object's symmetrical. These objects are a pile of rice and eggs that are symmetrical in shape. The shape of the symmetry of each object is a cone for a pile of rice and an oval for an egg. The results of this research are a system for determining the volume of symmetrical objects using the linear regression method with an accuracy score of 96.48% for a pile of rice and 97.84% for an egg.

1. Introduction

The development of information technology has experienced rapid growth, one of which is in the field of instrumentation. Instrumentation is a tool used to measure and control a process [1]. So far, volume measurements have been carried out using instrumentation tools such as graduated cylinders, vessels, volumetric flasks, pipettes, and burettes [2-6]. Information technology, especially image processing, can be used to make volume instrumentation faster, more effective, and more enjoyable[7-8].

Several researchers have carried out research on the use of image processing to determine the volume value of egg bodies. including Zhou et al., 2009 who used machine vision [9], Siswantoro J., 2012 who used the numerical method calculation of Simpson's rule [10], Sapkal et al., 2017 who used the Montecarlo method [11] and Okinda et al., 2020 who used addition infrared (IR) measurement [12]. However, the previous method for determination of volume and the object's distance to the camera is fixed.

In this study, segmentation methods in image processing and linear regression are used to determine the volume of a symmetrical object. The object used in this study is a pile of rice and eggs. The symmetry shape of each object is a cone for a pile of rice and an oval for an egg. The linear regression method can be a volume calculation solution because it can be applied to more diverse symmetrical shapes. Oval and conical shapes were used in this study.

2. Method

2.1. Research Procedure

The research implementation of the system for determining the volume of symmetrical objects using the linear regression method is divided into several stages as shown in Fig. 1. The first stage begins with the design of the system build by preparing the tools and materials then designing the system using visual studio and programming code with the Python language.

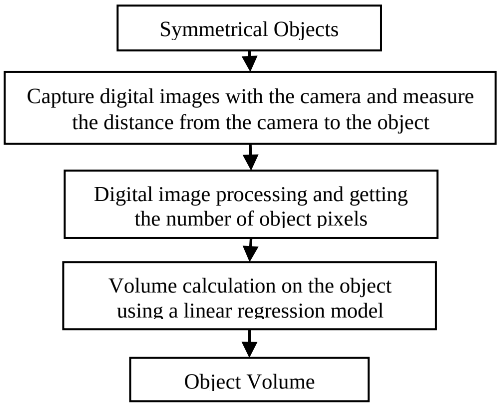

Fig. 1. System process stages

2.2. Hardware System

The system for determining the volume of symmetrical objects using the linear regression method consists of several components, including mobile phones, tripods, holders, and measuring cylinders. The system is shown in Fig. 2.

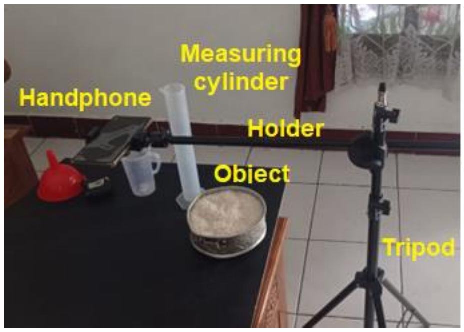

Fig. 2. Hardware System

2.3. Image Processing

The process of feature extraction from object images is carried out in visual studio code with the Python programming language and the OpenCV library. The feature extraction process results in the number of object pixels with a value of 255. The flowchart of the feature extraction process can be shown in Fig. 3.

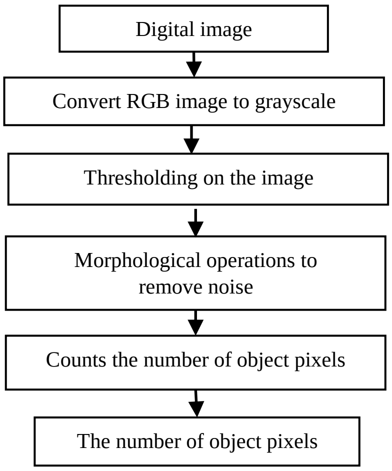

Fig. 3. Flow chart of image processing

First, the initial Red, Green, and Blue (RGB) color image is converted to a grayscale (black and white) image to facilitate object segmentation. The segmentation process itself uses a thresholding operation which will make the image a binary image that only has two-pixel values, namely 0 for black (background) and 255 for white (object) [13]. After the thresholding process, a morphological process is carried out using an opening algorithm to eliminate noise and continue to calculate the number of pixels with a value of 255 [14]

2.4. Linear Regression

Linear regression is an algorithm used to predict or visualize a relationship between two different features/variables. It is a regression model that uses a straight line to describe the relationship between the variables of the function f in the equation $\hat{y} = f(x)$, where $\hat{y}$ is the predicted result of each input x [15]. The general linear regression equation is written in (1).

$$f(x) = \beta + \sum_{i=1}^{n} \omega_i^T x_i \quad (1)$$

β is a bias, intercept, or constant. Meanwhile, $\omega^T{}_i$ is the weight or regression coefficient of variable i, and x_i is variable i [15].

The linear regression model in this research contains information on the volume ($\hat{y}$) of object measurements as a result of predictions as well as the number of pixels (x_1) and the distance of the object to the camera (x_2) as inputs.

The variable number of pixels (x_1) and the variable distance (x_1) have a comparator component with the volume variable ($\hat{y}$), namely the coefficient of the variable number of pixels ($\omega^T{}_1$), the coefficient of the variable distance ($\omega^T{}_2$) and the constant (β). The system that has been made is then tested, analyzed, and drawn conclusions. The flowchart of the linear regression can be shown in Fig. 4.

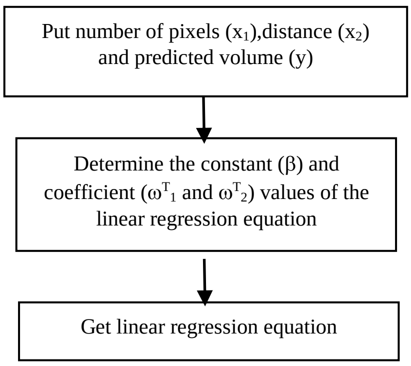

Fig. 4. Flow chart of linear regression method

3. Results and Discussion

The system interface consists of an input textbox to enter the distance, rice, and egg buttons to calculate the volume based on the object, a panel to display the binary image, and a label to display the volume value and the number of pixels. The system interface can be described in Fig. 5.

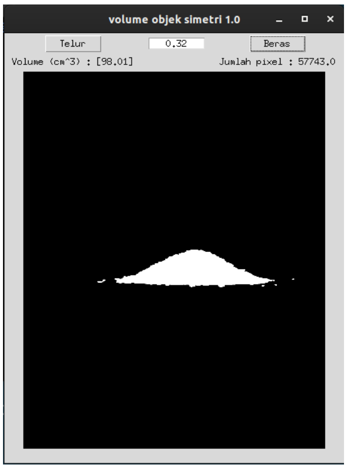

Fig. 5. System interface

This system has two independent variables, namely the object of piles of rice and eggs (number of pixels and distance), then the equation becomes from (1) to (2).

$$y = \beta + \omega_1^T x_1 + \omega_2^T x_2 \qquad (2)$$

In order for the system to be solved using the linear regression equation, it is necessary to prove that the predicted volume (y) has a linear relationship with the inputs, both the number of pixels (x_1) and the distance (x_2). The linear relationships in a pile of rice are the volume prediction graph (y) to the number of pixels (x_1) in Fig. 6 and to the distance (x_2) in Fig. 7.

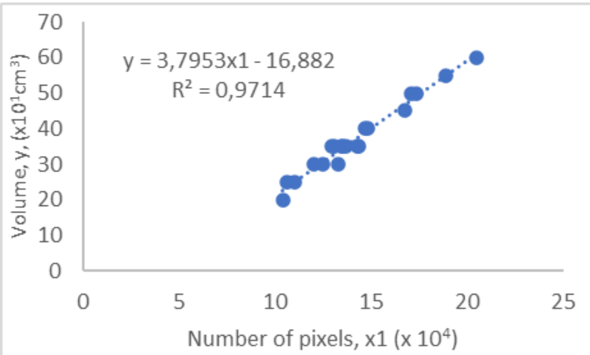

Fig 6. Graph of correlation of volume (y) and number of pixels (x_1) for a pile of rice

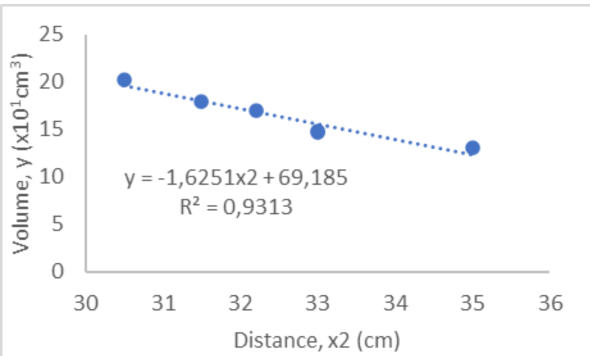

Fig. 7. Graph of predicted volume (y) and distance (x_1) for a pile of rice

And the linear relationship graphs for an egg are in Fig. 8 for the graph of x_1-y and in Fig. 9 for the graph of x_2-y.

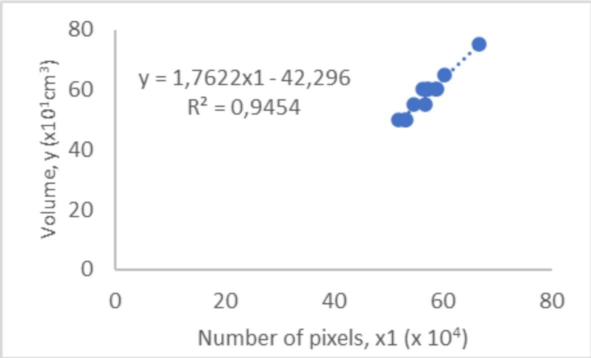

Fig. 8. Graph of correlation of volume (y) and number of pixels (x_1) for an egg

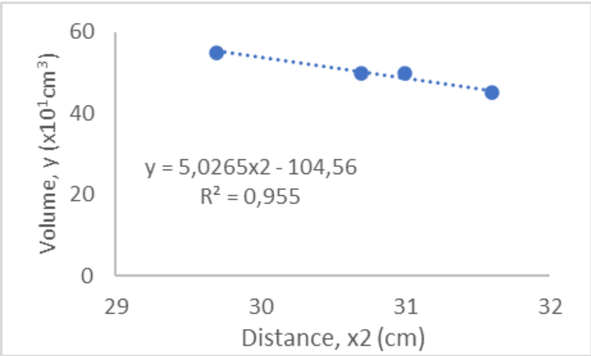

Fig. 9. Graph of correlation of volume (y) and distance (x_1) for an egg

Testing the linearity of the data shows that the input-input relationship, namely the number of pixels (x_1) and the distance (x_2) to the output volume (y) shows a linear graph for both the object of a pile of rice and an egg. So that the settlement using linear regression can be done.

Completion of the linear regression method on a system with 2 input variables according to (2), requires three linear equations, in other words, it requires a variation of the input and output relationship of 3 variations. Data were collected for 3 variables, for the object of a pile of rice the data is obtained in Table 1.

Table 1. Experimental data on a pile of rice

Input		Output
Number of pixels, x_1 ($x10^4$)	Distance, x_2 (cm)	Volume, y ($x10^1$ cm^3)
45	35	15
40	32	17
35	33	13

The three linear equations can be solved if the digits are the same so that the constants and coefficients can be determined, in this case, it is 2 digits regardless of the order of the multiplier. Then to apply to the actual volume calculation, the variable value must be multiplied by the multiplier order.

The solution of the linear equation from the data in Table 1 uses substitution, the result is that the constant β is 45, while the coefficients ω^T_1 is 0.5 and ω^T_2 is -1.5. Therefore the linear equation for determining the volume of a pile of rice is (3).

$$y = 0.5x_1 - 1.5x_2 + 45 \tag{3}$$

In the same way, solving linear equations is also applied to the case of determining the volume of an egg object. Experimental data collection on an egg is in Table 2.

Table 2. Experimental data on an egg

Input		Output
Number of pixels, x_1 ($x10^4$)	Distance, x_2 (cm)	Volume, y ($x10^1$ cm^3)
52	32	45
55	31	55
56	30	60

The solution uses substitution for Table 2, the result is gotten that the constant β is -103.5, while the coefficients $\omega^T{}_1$ is 3.75 and $\omega^T{}_2$ is -1.25. The linear equation for determining the volume of an egg is (4).

$$y = 3.75x_1 - 1.25x_2 - 103.5 \quad (4)$$

Testing the linear equations above is done by taking the distance from the camera to the object and the size of the object at random, the test results for an object of a pile of rice and an egg are obtained in Table 3 and Table 4, respectively.

Table 3. Testing data on a pile of rice

Input		Output	Predicted volume ($x10^1$ cm^3)	Error (%)
Number of pixels, x_1 ($x10^4$)	Distance, x_2 (cm)	Volume, y ($x10^1$ cm^3)		
50.00	30.50	23.34	24.25	3.91
45.00	35.00	14.54	15.00	3.16
35.00	33.00	13.50	13.00	3.73
40.00	31.50	17.60	17.75	0.85
35.00	32.20	15.10	14.20	5.94
			Average error	3.52

Table 4. Testing data on an egg

Input		Output	Predicted volume ($x10^1$ cm^3)	Error (%)
Number of pixels, x_1 ($x10^4$)	Distance, x_2 (cm)	Volume, y ($x10^1$ cm^3)		
51.34	30.7	50.15	51.78	3.24
54.49	31.6	61.87	62.84	1.56
55.79	31.6	65.64	64.60	1.58
52.31	31.0	55.72	54.29	2.57
49.73	29.7	45.18	46.01	1.84
			Average error	2.16

The results obtained from this model have an accuracy rate of 96.48% for piles of rice and 97.84% for an egg. In addition to real-time, this system is also scalable when compared to the two previous studies. The linear regression model in this system can be continuously trained to increase its level of accuracy and reduce limitations.

4. Conclusion

This system is a smart instrument that can determine the volume of a symmetrical object using the linear regression method in real-time, faster, more effective, and more enjoyable. The symmetrical objects in this testing are a pile of rice and an egg. The testing results are an accuracy score of 96.48% for piles of rice and 97.84% for an egg.

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