Leaf geometric properties measurement using computer vision system based on camera parameters

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Leaf Geometric Properties Measurement Using Computer Vision System Based on Camera Parameters

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Abstract. Leaf geometric properties play an important role in plat study. This paper aims to propose a method to measure leaf geometric properties, including area, perimeter, length, and width, using a computer vision system. The proposed method measured the properties by capturing leaf image from the top view using a calibrated camera. The captured image was processed to produce a binary image. The properties were extracted from the binary image based on camera parameters. The camera parameters were used to convert the unit of the properties from pixel to cm. Thirty leaf samples from three types of leaf were used to validate the proposed method in an experiment. The experiment result shows that the leaf measurement result using the proposed method has good accuracy with average absolute relative error less than or equal 2.27% and has strong linear relationship with manual measurement indicated by the coefficient of determination greater than 0.999.

Keywords: leaf geometric properties, measurement, computer vision, camera parameters

INTRODUCTION

Leaves are the organ of plant that have an important role in converting solar energy into chemical energy in the form of carbohydrates through photosynthesis [1]. Carbohydrates are used as the source of energy for plant growth [2]. The amount of solar energy absorbed by plant depends on the total area of leaves which is the sum of each individual leaf area in the plant [3]. In general, area and other geometric properties of leaf, including length, width, and perimeter, are used as agronomic parameters in determining the potential of yield from a plant [4]. In addition, such properties are also used to measure plant growth rate [5] and the effects of stress on plant [6].

Manually, leaf area measurement can be done using the grid counting method or the paper weighing method. In the grid counting method, the measured leaf is attached to a millimeter block paper, and then the number of small square-shaped grids covered by the leaf is calculated. Leaf area is obtained by multiplying the number of girds and the area of one grid. Whereas in the paper weighing method, the region on the millimeter block paper covered by the leaf is cut and then weighed. Leaf area is obtained from the weight of paper covered by leave divided by the weight of a millimeter block paper with an area of 1 cm^2. For length, width, and perimeter, the manual measurement is performed using a ruler or vernier caliper. The manual method is time-consuming, and its accuracy depends on the expertise of the user. In addition, this method is also difficult to measure the geometric properties of leaf with a non-simple edge, such as on hibiscus leaf (*Hibiscus rosa-sinensis L.*) [7–11]

Several alternative methods have been proposed to measure the geometric properties of leaf both semiautomatically and fully automatic. The semiautomatic methods for leaf area prediction have been proposed in [11] and [13]. The length and width of the leaf were measured manually and then used to predict area linier

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regression [11] and fuzzy inference system [13] by utilizing a computer program. Although the methods achieved a high coefficient of determination, their accuracy depends on the accuracy of the measurement of length and width of the leaf obtained by manual measurement.

Several computer vision systems based on digital image processing techniques have been proposed to measure leaf area as reported in [7–9,11,14]. The image of leaf was captured together with a reference object during measurement. Leaf area was approximated by the ratio of leaf area and reference object area (in pixels) in captured image multiplied by the actual area of reference object. Although the proposed systems produced small errors when compared to manual measurement, the using of reference object on the systems could lead to a problem during segmentation process and had an effect to the accuracy of measurement. In addition, if the position of reference object is not parallel to the position of leaf and camera, then the accuracy can also be decreased. Furthermore, almost all the proposed systems could not measure the others leaf geometric properties, such as perimeter, length, and width, except the system proposed in [11].

To avoid problems caused by the reference object, Siswantoro et al. [15] have proposed image based leaf area measurement method using an artificial neural network (ANN). For features, including length, width, perimeter, and area, were extracted from the image of leaf and were then inputted to ANN for leaf area prediction. The proposed system achieved good accuracy and did not need a reference object during image acquisition. However, the accuracy of ANN prediction will be decreased if the position and the orientation of the camera relative to the leaf change.

Another strategy to avoid the use of reference object is by employing camera parameters in transforming the unit of measurement from pixel to cm. In computer vision, camera parameters are used to transform the coordinate of a point in the real-world coordinate system to the image coordinate system and vice versa [16]. By using camera parameters, some points in the image coordinate system can be re-projected to the real-world coordinate system based on the method proposed in [17]. As a result, the distance between the points both in the real-world coordinate system and the image coordinate system can be obtained. This paper proposes a method for measuring the geometric properties of leaf, including area, perimeter, length, and width, using a computer vision system. The system employs the ratio of the distance between the points in the real-world coordinate system and the image coordinate system to convert the unit of length and area.

MATERIALS AND METHOD

Materials

The proposed method was implemented in a computer vision system consisted of software and hardware. The software was developed in Microsoft Visual C++ 2010 with open-source library for computer vision OpenCV 231 [18]. The hardware consisted of a camera, a computer, and a white background, as shown in Fig. 1. A Logitech HD Webcam C270h was used to capture the image of measured leaf. The camera was connected to a 2.20GHz Intel Core 2, RAM 4GB personal computer with Windows 7 operating system using USB cable. The computer was used to control the camera, process the captured image, and approximate the geometric properties of leaf. The computer vision system used the fluorescence lamps located on the ceiling of room as illumination source.

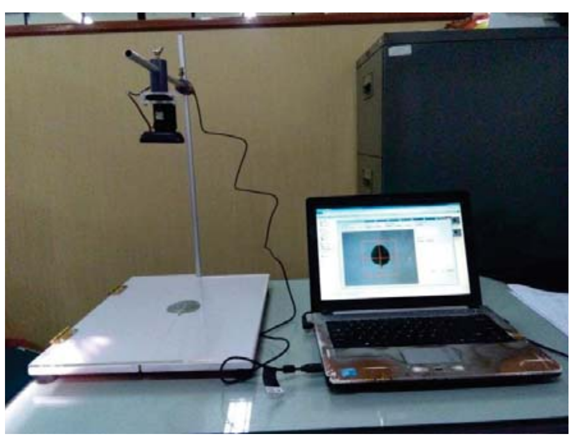


FIGURE 1. The hardware for the proposed computer vision system.

The proposed method was validated using three types of leaf, including ipecac (*Cephaelis ipecacuanha*), kailan (*Brassica oleracea Alboglabra Group*), and wild betel (*Piper sarmentosum Roxb. Ex Hunter*). Ten samples from each type of leaf were randomly chosen from each plant around the University of Surabaya campus. The geometric properties of every sample were manually measured to obtain the exact value of length (l_E), width (w_E), perimeter (P_E), and area (A_E). Figure 2 shows the example of leaves used to validate the proposed.

(a) (b) (c)

FIGURE 2. The example of leaves used to validate the proposed method (a) ipecac, (b) kailan, and (c) wild betel.

All samples were then measured using the proposed method to obtain the approximation of length (l_{App}), width (w_{App}), perimeter (P_{App}), and area (A_{App}). The accuracy of the proposed method was measured using absolute relative error (ARE), as in equation (1),

$$ARE = \left|\frac{M_{App} - M_E}{M_E}\right| \times 100\% \quad (1)$$

where M_E and M_{App} are exact and approximation measurement results, respectively.

Method

The proposed leaf geometric properties measurement method consisted of several steps, including camera calibration, image acquisition, pre-processing, segmentation, rotation, and geometric properties approximation. The details for every step are explained as follows.

1. Camera calibration. Camera calibration is a step to obtain the intrinsic and extrinsic camera parameters. The intrinsic camera parameter is used to transform a point in the camera coordinate system into a point in the image plane. On the other hand, the extrinsic camera parameter is used to transform a point in the real-world coordinate system to a pont in the camera coordinate system. The proposed method used a calibration technique proposed by Zhang [19]. The calibration step was performed using a 9×6 corners flat chessboard pattern as a calibration object, as shown in Fig 3. In this step, the location of the measured leaf during image acquisition was assumed located on plane $z = 0$ in the real-world coordinate system. This step was only performed once as long as the orientation and the position of the camera does not change. The camera parameters were then stored in xml files and used to determine the scaling factor in geometric properties approximation step.

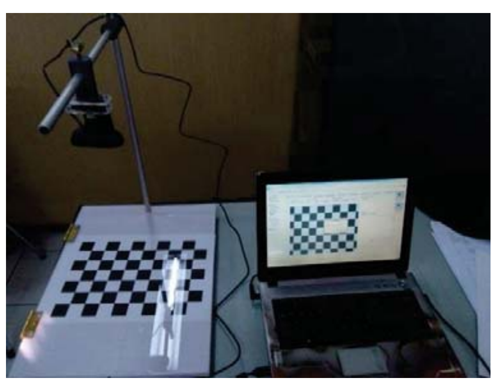


FIGURE 3. Camera calibration step.

2. Image acquisition. During image acquisition, the measured leaf was placed in the bellow of the camera at a distance of 30 cm with the orientation of the image plane parallel to the leaf. The measured leaf was located between the background and a transparent acrylic plate to flatten the leaf surface. The image of measured leaf was acquired with a white background in RGB (red, green, blue) color space with a size of 640×480 pixels. The acquired image was stored in PNG file for further steps and analysis. Figure 4(a) shows the example of the acquired image.
3. Pre-processing. In this step, the RGB image was first converted to a grayscale image with intensity fall in the range $[0,255]$. A Gaussian smoothing [20] with a kernel size of 3×3 was then employed to the converted image to reduce noise generated by the camera during image acquisition. Figure 4(b) shows the result of pre-processing step.
4. Segmentation. This step aimed to separate leaf object in the grayscale image from its background to produce a binary image. An automatic thresholding technique based on Otsu method [21] was used to divide pixels in the image into two clusters, object and background. The method produced a threshold value T that minimize intra-cluster intensity variance and maximize inter-cluster intensity variance. A grayscale pixel with intensity greater than T was clustered as a background pixel with binary value 0 (black pixel), otherwise as an object pixel with binary value 1 (white value). To improve the result of the segmentation step, two morphological operators, opening and closing [20], were employed to remove mis-segmented pixels. Figure 4(c) shows the example of a binary image produced in this step.
5. Rotation. To facilitate measurement step, the binary image was rotated such that the major and minor axis of the leaf are parallel to the coordinate axis of the image coordinate system. The magnitude of rotation angle was obtained by calculating the angle between the eigenvector of the covariance matrix of the binary image and the closest coordinate axis of the image coordinate system. Figure 4(d) shows the result of the rotation step.

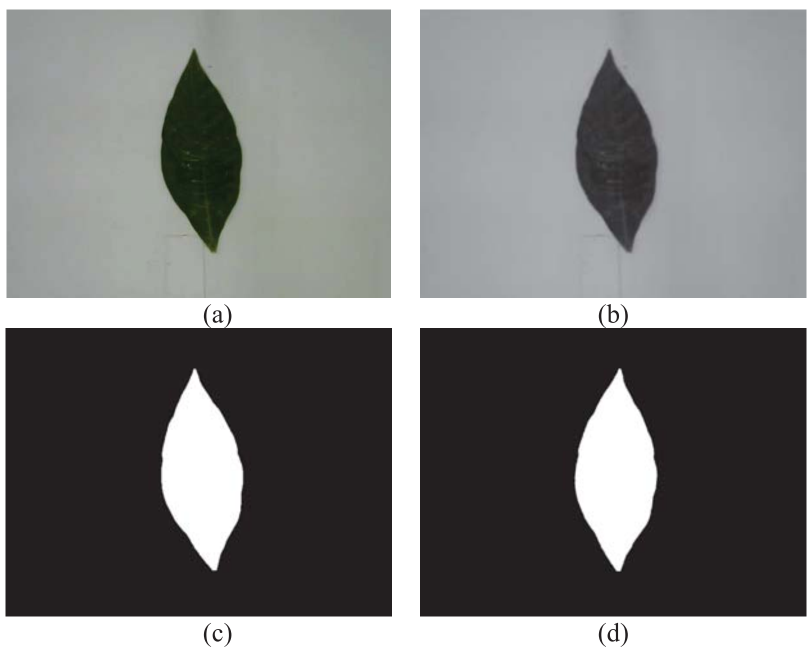


FIGURE 4. The example of (a) captured image, (b) grayscale image, (c) binary image, and (d) rotated image.

6. Geometric properties measurement. Let W and H be the width and high of the binary image, respectively. To determine the scaling factor S_f (cm/pixel), four points on the binary image at a distance of 50 pixels from the center of the image plane both in vertical and horizontal directions, which point $A\left(\frac{W}{2}, \frac{H}{2}-50\right)$, point $B\left(\frac{W}{2}, \frac{H}{2}+50\right)$, point $C\left(\frac{W}{2}-50, \frac{H}{2}\right)$, and point $D\left(\frac{W}{2}+50, \frac{H}{2}\right)$ were re-projected into plane $z=0$ in the real-world coordinate system by using the method proposed in [17] based on the camera parameters, as illustrated in Fig. 5. The value of S_f was obtained using the formula in equation (2),

$$S_f = \frac{1}{200}\left(\sqrt{(x_a - x_b)^2 + (y_a - y_b)^2} + \sqrt{(x_c - x_d)^2 + (y_c - y_d)^2}\right) \quad (2)$$

where $A'(x_a, y_a, 0), B'(x_b, y_b, 0), C'(x_c, y_c, 0)$, and $D'(x_d, y_d, 0)$ are the coordinate of the re-projection of A, B, C, and D, respectively, in the real-world coordinate system.

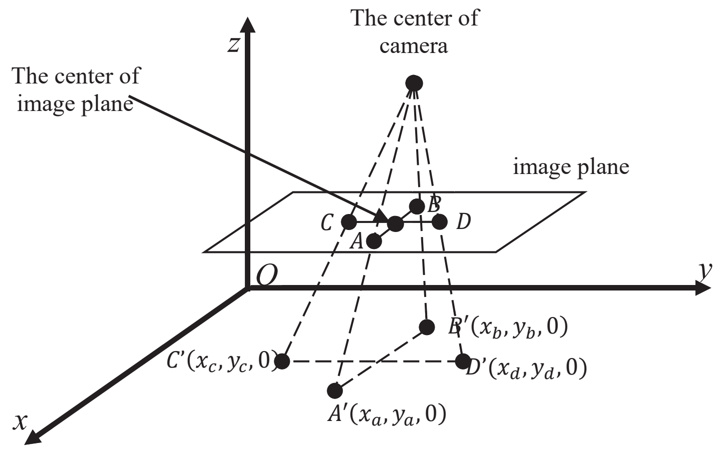


FIGURE 5. The illustration of scale factor determination.

Let N_L and N_P be the number of leaf pixels (white pixels) in the binary image and the number of pixels in the leaf contour obtained from the binary image, respectively, as shown in Fig. 6(a). The approximation of area A_{App} and perimeter P_{App} of the measured leaf were approximated by using the formulas in equation (3) and (4), respectively.

$$A_{App} = S_f^2 N_L \quad (3)$$

$$P_{App} = S_f N_P \quad (4)$$

7. To determine the approximation of length l_{App} and width w_{App} of the measured leaf, the minimum bounding rectangle of leaf contour that parallel to the coordinate axis of the image coordinate system was determined first, as shown in Fig. 6(b). Let N_l and N_w be the length and width of the bounding box in pixels. The length and width of the measured leaf were approximated by using the formulas in equation (5) and (6), respectively.

$$l_{App} = S_f N_l \quad (5)$$

$$w_{App} = S_f N_w \quad (6)$$

(a) (b)

FIGURE 6. The example of (a) leaf contour and (b) minimum bounding rectangle of leaf contour.

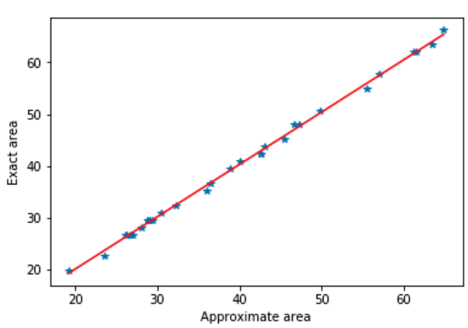
RESULTS AND DISCUSSION

The results of geometric properties measurement for 30 leaf samples using the manual method and the proposed method together with absolute relative errors are summarized in Table 1. It can be observed from Table 1 that, on average, the geometric properties of leaf samples measured using the proposed method were very close to the exact values. Most of area, length, and width values obtained using the proposed method were slightly smaller than the exact values. In contrary, most perimeter values obtained using the proposed method were greater than the exact values. Average AREs for all geometric properties were between 1.39% and 2.27%. The highest average ARE of 2.27% accrued in measuring perimeter. This condition might be occurred due to inaccuracy in the manual measurement of perimeter. For other geometric properties, the proposed method produced approximation with average ARE less than 1.50%. The small average AREs for all geometric properties indicate that the proposed measurement method has good accuracy in measuring area, perimeter, length, and width of leaf.

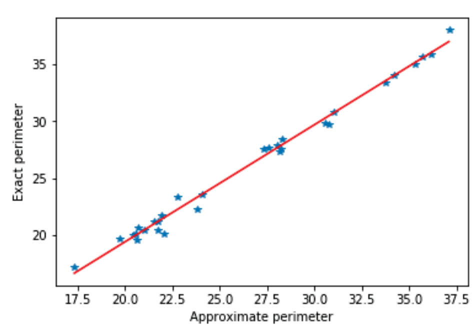
TABLE 1. The summaries of geometric properties measurement for leaf 30 samples

Sample	Average Exact				Average Approximation				Average ARE(%)			
	$A(\text{cm}^2)$	$P(\text{cm})$	$l(\text{cm})$	$w(\text{cm})$	$A(\text{cm}^2)$	$P(\text{cm})$	$l(\text{cm})$	$w(\text{cm})$	A	P	l	w
Ipecac	52.81	32.89	14.15	5.86	52.31	33.03	13.92	5.77	1.15	1.00	**1.64**	**1.86**
Kailan	30.00	20.57	7.05	5.76	29.59	21.37	6.95	5.74	1.91	3.85	1.43	1.15
Wild betel	36.90	24.51	8.97	5.88	36.92	24.86	8.85	5.82	1.38	1.96	1.31	1.15
All	39.90	25.99	10.06	5.83	39.61	26.42	9.91	5.78	1.48	2.27	1.46	1.39

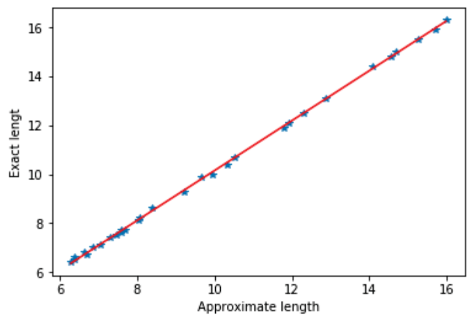
To support the analysis using ARE, the coefficient of determination R^2 was used to measure the linear relationship between the results of geometric properties measurement using the proposed method and the manual method. Figure 7 shows the linear relationship between the results of geometric properties measurement using the proposed method and the manual measurement. As can be seen in Fig. 7, the relationship between the results of geometric properties measurement using the proposed method and manual measurement closed to a straight line. For all samples, the coefficient of determination for area, perimeter, length, and width were 0.9998, 0.9995, 0.9999, and 0.9996, respectively. This fact indicates that the results of geometric properties measurement using the proposed method have a strong linear relationship with the manual measurement. In addition, since all values of R^2 were greater than 0.999 then it means that more than 99.9% variation in the result of manual leaf geometric properties measurement can be explained using a linear relationship by the results of leaf geometric properties measurement using the proposed method.



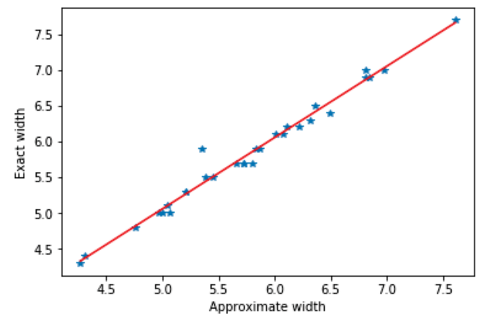
(a)



(b)



(c)



(d)

FIGURE 7. The **l**inear relationship between approximate value and exact value for: (a) area, (b) perimeter, (c) length, and (d) width.

In term of computational time, the proposed method only required less than 0.05 second to measure the area, perimeter, length, and width of a leaf together. On the other hand, manual measurement took more than 600 seconds to measure the area, perimeter, length, and width of a leaf. This result is faster when compared to manual measurement.

CONCLUSION

This paper proposes a method to measure the geometric properties of leaf, including area, perimeter, length, and width, using computer vision system. To perform measurement process, the proposed method captured the image of leaf using a calibrated camera from top view with the orientation of image plane parallel to the leaf. The image was then processed to obtain area, perimeter, length, and width of the leaf, in pixel^2 or pixel. All values were then converted to cm^2 or cm using a scaling factor determined from camera parameter obtained during calibration step. The experiment results show that the proposed method could achieve a good measurement result compared to manual measurement. Furthermore, the proposed method only needed less than 0.05 seconds to measure area, perimeter, length, and width together. For future research, the using of different scaling factor of each geometric properties and different distance between the camera and the measured leaf to be investigated to improve the measurement results.

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REFERENCES

1. H. Sabouri, S. J. Sajadi, M. R. Jafarzadeh, M. Rezaei, S. Ghaffari, and S. Bakhtiari, "Image processing and prediction of leaf area in cereals: A comparison of artificial neural networks, an adaptive neuro-fuzzy inference system, and regression methods," Crop Sci. **61**(2), 1013–1029 (2021).
2. L. Taiz and E. Zeiger, "Plant Physiology, Sinauer Associates," (2002).
3. J. B. Reece, L. A. Urry, M. L. Cain, S. A. Wasserman, P. V Minorsky, and R. B. Jackson, *Campbell Biology* (Pearson Boston, 2011), **9**.
4. S. Yoshida, *Fundamentals of Rice Crop Science* (Int. Rice Res. Inst., 1981).
5. L. M. Dwyer and D. W. Stewart, "Leaf Area Development in Field-Grown Maize 1," Agron. J. **78**(2), 334–343 (1986).
6. S. Cha-um, T. Trakulyingcharoen, P. Smitamana, and C. Kirdmanee, "Salt tolerance in two rice cultivars differing salt tolerant abilities in responses to iso-osmotic stress," Aust. J. Crop Sci. **3**(4), 221 (2009).
7. C. Lü, H. Ren, Y. Zhang, and Y. Shen, "Leaf Area Measurement Based on Image Processing," in *2010 International Conference on Measuring Technology and Mechatronics Automation* (2010), **2**, pp. 580–582.

8. S. B. Patil and S. K. Bodhe, "Betel leaf area measurement using image processing," Int. J. Comput. Sci. Eng. **3**(7), 2656–2660 (2011).
9. M. H. Radzali, N. A. M. Kamal, and N. M. Diah, "Measuring Leaf Area using Otsu Segmentation Method (LAMOS)," Indian J. Sci. Technol. **9**(48), 1–6 (2016).
10. S. K. Pandey and H. Singh, "A Simple, Cost-Effective Method for Leaf Area Estimation," J. Bot. **2011**, 6 (2011).
11. H. Liu, X. Ma, M. Tao, R. Deng, K. Bangura, X. Deng, C. Liu, and L. Qi, "A plant leaf geometric parameter measurement system based on the android platform," Sensors **19**(8), 1872 (2019).
12. J. I. Córcoles, A. Domínguez, M. A. Moreno, J. F. Ortega, and J. A. de Juan, "A non-destructive method for estimating onion leaf area," Irish J. Agric. Food Res. **54**(1), 17 (2015).
13. M. J. Amiri and A. Shabani, "Application of an Adaptive Neural-Based Fuzzy Inference System Model for Predicting Leaf Area," Commun. Soil Sci. Plant Anal. **48**(14), 1669–1683 (2017).
14. A. Gong, X. Wu, Z. Qiu, and Y. He, "A handheld device for leaf area measurement," Comput. Electron. Agric. **98**, 74–80 (2013).
15. J. Siswantoro and I. B. Made Artadana, "Image Based Leaf Area Measurement Method Using Artificial Neural Network," 2019 Int. Conf. Artif. Intell. Inf. Technol. 288–292 (2019).
16. J. Siswantoro, A. S. Prabuwono, and A. Abdullah, "Volume measurement algorithm for food product with irregular shape using computer vision based on Monte Carlo method," J. ICT Res. Appl. **8**(1), (2014).
17. J. Siswantoro, A. S. Prabuwono, and A. Abdullah, *Real World Coordinate from Image Coordinate Using Single Calibrated Camera Based on Analytic Geometry* (2013), **378 CCIS**.
18. G. Bradski, "The opencv library," Dr Dobb's J. Softw. Tools **25**, 120–125 (2000).
19. Z. Zhang, "A flexible new technique for camera calibration," IEEE Trans. Pattern Anal. Mach. Intell. **22**, 1330–1334 (2000).
20. R. C. Gonzalez, *Digital Image Processing*, 4th ed. (Prentice Hall, 2017).
21. N. Otsu, "A Threshold Selection Method from Gray-Level Histograms," Syst. Man Cybern. IEEE Trans. **9**(1), 62–66 (1979).

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