

Determining camera parameters for round glassware measurements

F O Baldner^{1,2}, P B Costa^{1,2}, J F S Gomes², D M E S Filho² and F R Leta¹

¹ Universidade Federal Fluminense – UFF; Programa de Pós-Graduação em Engenharia Mecânica – Laboratório de Metrologia Dimensional e Computacional
Rua Passo da Pátria, 156 – Niterói – Rio de Janeiro – Brasil

² Instituto Nacional de Metrologia, Qualidade e Tecnologia - Inmetro
Av. Nossa Senhora das Graças, 50 – Xerém – Duque de Caxias – Rio de Janeiro – Brasil

E-mail: fbaldner@gmail.com

Abstract. Nowadays there are many types of accessible cameras, including digital single lens reflex ones. Although these cameras are not usually employed in machine vision applications, they can be an interesting choice. However, these cameras have many available parameters to be chosen by the user and it may be difficult to select the best of these in order to acquire images with the needed metrological quality. This paper proposes a methodology to select a set of parameters that will supply a machine vision system with the needed quality image, considering the measurement required of a laboratory glassware.

1. Introduction

Machine vision is a field in constant development. From the digital camera sensors' conception in the late 1960s to this day, their resolution has greatly increased, and it is not uncommon for cellphones to have a small sensor with a 5 MPixel resolution, or even greater.

However, traditionally, such cameras are hardly sought to be used on scientifically applied machine vision inspection or measurement systems. Are these cameras really improper for this kind of application? With digital photography equipment presenting increasing quality, one must wonder why these cameras may not be used.

Enabling users to have control over certain operational parameters (such as aperture, exposure, etc.) is a characteristic of the digital single-lens reflex (DSLR) cameras. With such control, there's a wide variety of parameters to determine in order to find the best conditions needed.

Machine vision systems in general can provide different types of measurements, direct or indirect, with the end result being a matter of choosing the correct combination of hardware (camera, lenses, lighting, etc.). Metrology is the science of measurement and is in constant evolution, and such systems may provide an interesting source of measurement results.

Ranging from dimensional measurements [1] to colorimetry [2], there are many possibilities for machine vision in metrology [3]. Fluids metrology in particular deals with a great amount of glassware in its day to day work. Devices such as viscometers require the measurement of certain dimensions to calculate the viscosity of the fluid flowing inside of it [4].



This paper has the objective of providing a methodology for choosing values for the parameters of aperture in a camera for the acquisition of glassware images that will, subsequently, be used to extract a concrete value of a dimension from.

2. Camera Definitions

This section defines important terms in the camera field that will be used throughout this paper.

2.1. Focal plane

In optics, when a light ray passes through a lens, parallel to its optical axis, it will converge to a point called the focus [5]. The focal plane is the plane which is perpendicular to the optical axes that contains this point. The objects in this plane will provide a sharp image behind the lens, as shown in figure 1 with the object to the right in the focal plane and the other two outside.

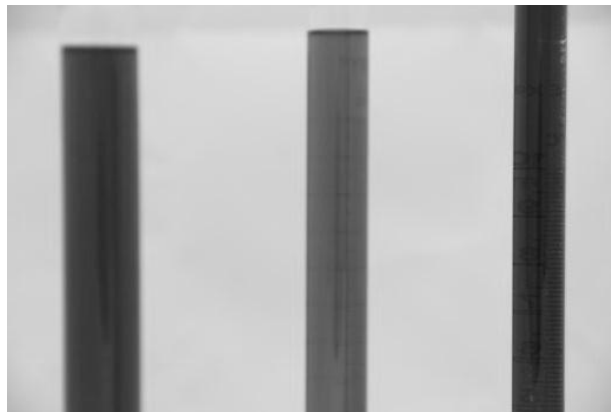


Figure 1. Focal plane example.

2.2. Exposure time

Exposure time is the amount of time in which the lens' shutter will be opened in order to expose the image sensor to the light from the object [6]. The image of an object photographed under an exposure of 1/2 s is shown in figure 2, contrasting with the object in figure 3, whose exposition was 1/8000 s.



Figure 2. Object under high exposure.

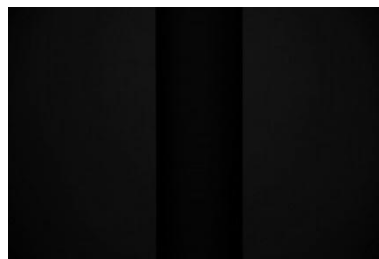


Figure 3. Object under low exposure.

2.3. Aperture

Aperture is the area of the shutter in which light will pass through. The aperture size is measured in a ratio of the focal distance of the lens and the shutter's opened diameter [6], shown in figure 4. For example, an aperture of $f/2$ means that the shutter's opened diameter is half the focal distance of the lens.

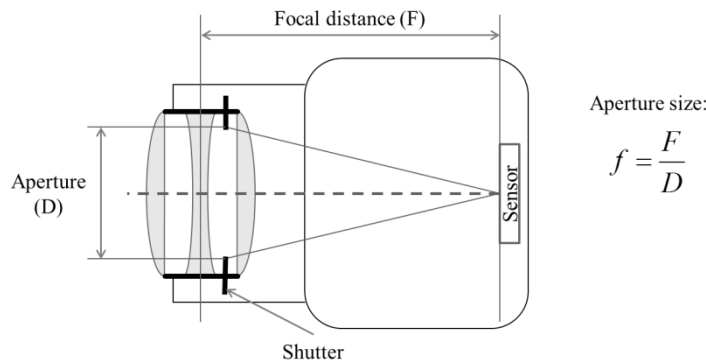


Figure 4. Schematic showing the quantities involved in the aperture size determination.

2.4. ISO value

It is a system for measuring film (or sensor, in digital cameras) sensitivity. Increasing the ISO value allows for a faster shutter speed, given the same aperture size, to photograph a certain object in a darker environment [6]. This sensibility enhancement, however, creates grainy areas especially in areas of the image in which the sensor did not receive much light [7].

2.5. Exposure value (EV)

The exposure time combined with the lens aperture, in a certain object with a certain lighting condition provides the exposure value (EV) which defines the luminance (quantity of light) of the image [6]. By changing both exposure and aperture (increasing the aperture size and lowering the shutter speed, or vice-versa) the EV is kept, meaning that the same amount of light will reach the sensor, as shown by the histograms in figure 5.

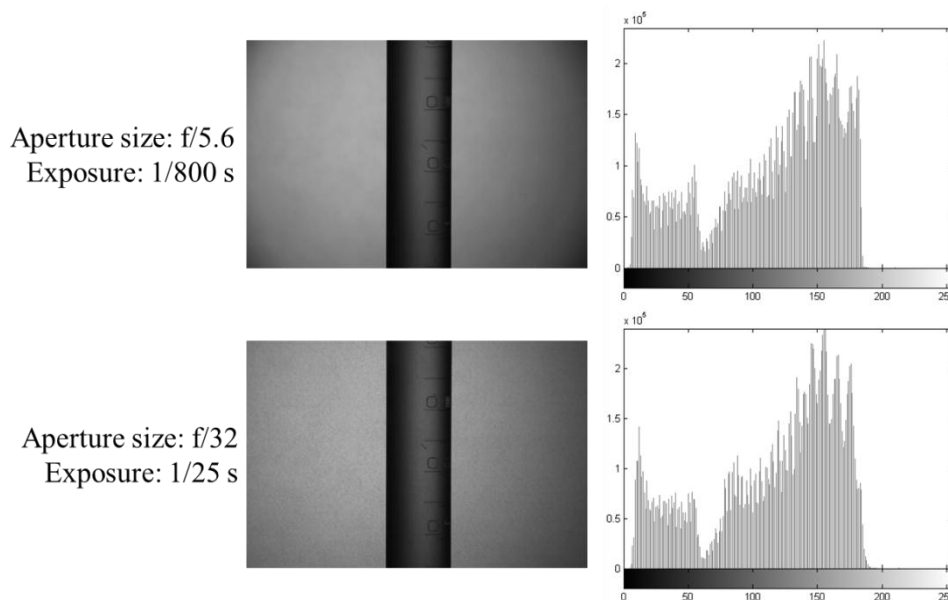


Figure 5. Two images with the same EV but different parameters.

2.6. Depth of field

In a camera lens, there is a range of values in which the light will produced a focused image of an object. This represents the depth of field, where any objects inside this range will appear in focus, and everything else out of focus. This is controlled by the focal distance, the focus point and the aperture. By setting the first two values the aperture will determine the depth of field. The greater the aperture

(smallest f number), the shallowest the depth of field is [6], as seen in the example of figure 6, where, in the picture with an aperture of $f/5.6$ the depth of field did not encompass the two objects to the left, and with the aperture of $f/9$ the middle object is inside the depth of field with the rightmost one.

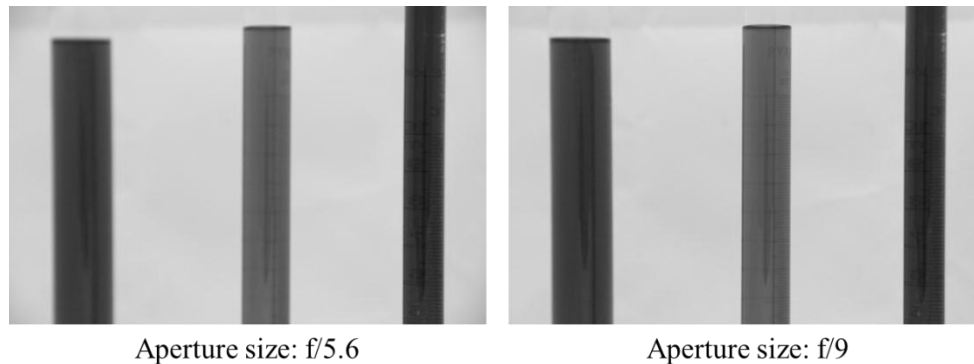


Figure 6. Depth of field in different apertures.

3. Materials and Methods

This section details the equipment and materials used for this experiment, as well as the methodology employed.

3.1. Materials

For this experiment, the image acquisition device used was a DSLR camera (Canon 60D) with an 18-135 mm lens connected to the computer and controlled by Canon's software (EOS Utility).

The object used was a beaker filled with red dyed water, to provide a contrast with the background. A diffuser was built with tracing paper to reduce the reflection from the light source [8]. The object and the light source (an incandescent lamp with a color correlated temperature of approximately 2700 K) were placed inside a dark box to avoid interaction with other light sources. The entire setup is shown in figure 7.

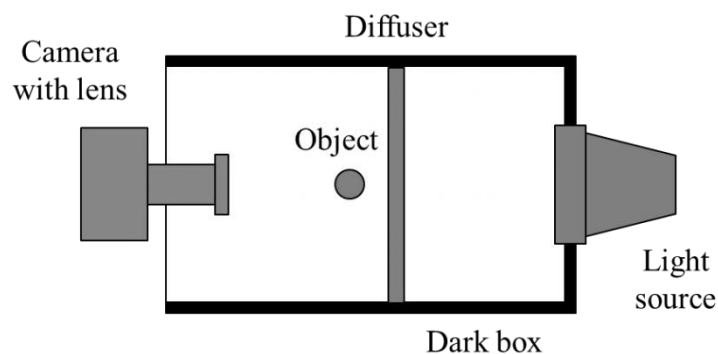


Figure 7. Image acquisition setup.

3.2. Methods

The first step in the experiment is to determine a value for the aperture size. After setting up the equipment, the lens' focal distance must be chosen so that the object will fill the image as most as possible while still being sharp around its diameter (since it's a round object). For this, the focus point must be set to the lowest possible value and then fine adjusted using the software to avoid moving the equipment.

After this, the aperture is set to the smallest value possible and the exposure is chosen so that the image is neither over-exposed (too much light) nor under-exposed (too little light). This can be achieved by looking at the image histogram, where it shouldn't be concentrated on either extremity.

This process is then repeated by decreasing the aperture size and increasing the exposition time by one step each. With this, all the images have the same EV. The images are then segmented using Otsu's algorithm [9] and everything but the center object was removed from the image. For each segmented image an average diameter is calculated and then, for the collection of images, a sample average diameter is calculated, along with the standard deviation. This is all described by the flowchart in figure 8. By analyzing these results along with each image, a proper aperture size can be chosen.

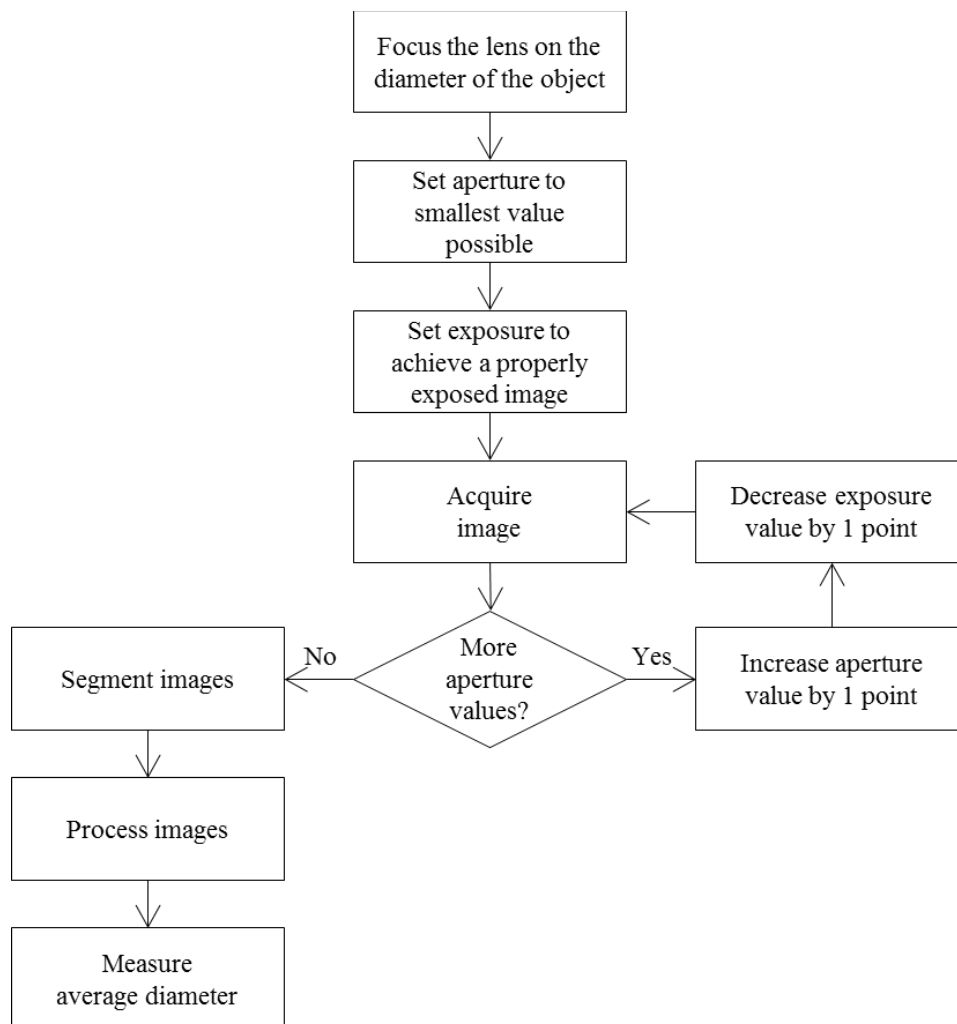


Figure 8. Flowchart for the methodology of picture processing and analyzing.

4. Experiment With Aperture

Using the methodology proposed in 3.2, the camera focal distance was set to 135 mm and the focus was adjusted via software. For the highest possible aperture for this lens' focal distance (F/5.6) the exposure that would produce a proper image is 1/800 s, generating the image shown in figure 9, alongside its histogram, in figure 10. Segmentation using Otsu's algorithm [9] produces the image shown in figure 11.



Figure 9. Acquired image.

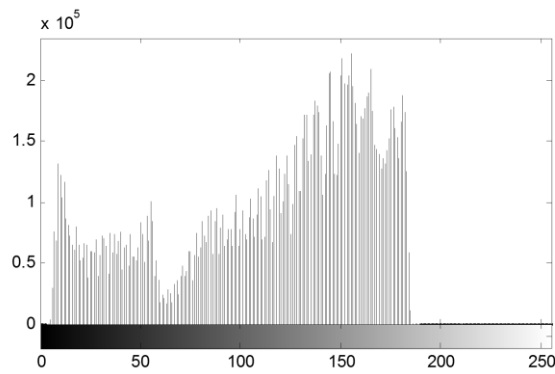


Figure 10. Image histogram.

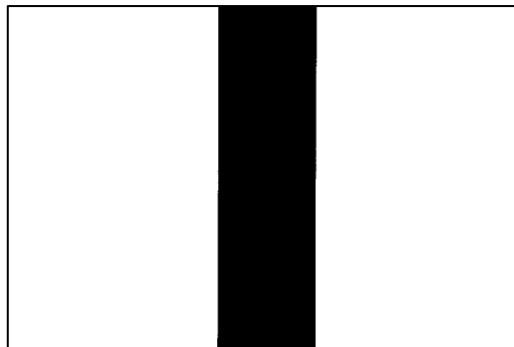


Figure 11. Segmented image.

This process was then repeated, decreasing the aperture by one step, decreasing the exposure time by one step and acquiring an image. The resulting images would produce the exact same histogram as previously seen in figure 10. As seen in table 1, the smallest aperture possible was F/32, which had an exposure of 1/25 s. This process generated 16 images with the same EV but different aperture sizes.

Table 1. Aperture and exposure values for each image.

Image	Aperture	Exposure [s]	Image	Aperture	Exposure [s]
1	F/5.6	1/800	9	F/14	1/125
2	F/6.3	1/640	10	F/16	1/100
3	F/7.1	1/500	11	F/18	1/80
4	F/8.0	1/400	12	F/20	1/60
5	F/9.0	1/320	13	F/22	1/50
6	F/10	1/250	14	F/25	1/40
7	F/11	1/200	15	F/29	1/30
8	F/13	1/160	16	F/32	1/25

5. Results

After acquiring and processing each image, an average diameter in pixel is calculated for each image. In order to determine this diameter in millimeters, the length of the pixel must be calculated. By measuring the diameter of the beaker with a caliper, the length of the pixel is calculated using equation (1). With the length of the pixel calculated, the millimeter values for each image were then calculated with equation (2).

$$l_p = \frac{d_{\text{caliper}}}{\frac{1}{n} \sum_{i=1}^n d_{\text{pixel}(i)}} \quad (1)$$

$$d_{\text{mm}(i)} = d_{\text{pixel}(i)} \cdot l_p \quad (2)$$

These results are shown in the graph of figure 12, with lines marking the largest and smallest values. It can be observed that the amplitude of these measurements is of 0,04 mm.

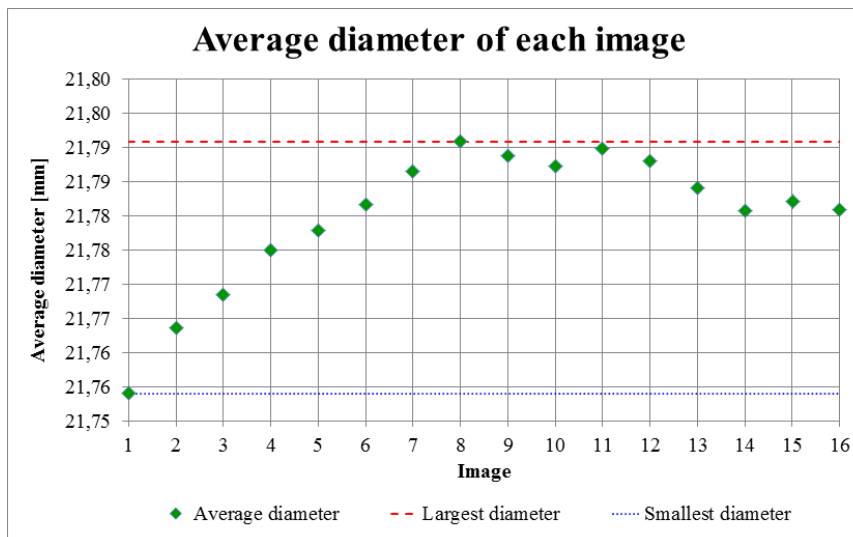


Figure 12. Average diameters for each image, alongside the maximum and minimum diameters.

6. Conclusion

Taking the average as the real value, we have a percentage error of 0,05% and -0,14%. For certain applications (for example, in Ubbelohde viscometers, the diameter needs to be within 2% of a nominal value in millimeters [10]) this can be an acceptable result.

However, how well is the average diameter a good representation of the real value? This discussion often reflects back on the application of the user.

Further analysis of the gathered data needs to be done in order to understand the influences of things such as lighting, lens' sphericity, or even the unevenness of the glassware. Future works on these subjects must concentrate on studying these error sources. Another important analysis that must be done is studying the influences for the calculation of the measurement uncertainty.

Acknowledgements

The authors would like to acknowledge FAPERJ (under grants E-26/103.591/2012, E-26/103.618/2012 and E-26/171.362/2001) for its financial support.

The authors would also like to acknowledge their colleagues from UFF and Inmetro for the support while conducting the experiments.

References

- [1] Feliciano F F, de Souza I L and Leta F R 2005 Visão computacional aplicada à metrologia dimensional automatizada: considerações sobre sua exatidão *ENGEVISTA* **7** 38-50
- [2] Gomes J F S 2013 Padronização de metodologia para caracterização de cor por imagem aplicada à seleção de frutas *Doctoral Thesis from Universidade Federal Fluminense*
- [3] Gomes J F S and Leta F R 2012 Applications of computer vision techniques in the agriculture and food industry: a review *Eur. Food Res. Technol.* **235** 989-1000
- [4] Baldner F O, Leta F R, Costa P B, Tortelote A S, Santo Filho D M E, Rodrigues C R C and Barbosa A P F 2011 Measurement of dimensional parameters in ubbelohde type viscometers using digital images *2º Cong. Int. de Metrologia Mec*
- [5] Tipler P A and Mosca G 2007 *Física para Cientistas e Engenheiros* vol 2 (Rio de Janeiro: LTC)
- [6] Hedgecoe J 2005 *O Novo Manual de Fotografia* (São Paulo: Editora Senac São Paulo)
- [7] Trigo T 2010 *Equipamento Fotográfico* (São Paulo: Editora Senac São Paulo)
- [8] Hunter F, Biver S and Fuqua P 2007 *Light Science & Magic* (Burlington, MA: Focal Press)
- [9] Otsu N, A threshold selection method from gray-level histograms 1979 *IEEE Trans. Sys. Man and Cyber.* **SMC-9** 62-6
- [10] ISO 3105: Glass capillary kinematic viscometers - Specifications and operating instructions 1994