Acquisition and segmentation images algorithm for the temporary study of the dynamic speckle phenomenon

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Abstract. Dynamic speckle is an interferometric phenomenon, which has been considered a sensitive way to monitor the weak changes in biological samples, and therefore it is a reliable tool that can be applied in many areas, from medicine to farming. Its use demanded the appearance of a series of methods to illuminate, process the images and provide their analysis. For this reason, for its implementation it requires systems of acquisition of images and algorithms of detection or identification of the biological material of the rest of the whole of the image. This work proposes an algorithm that allows the acquisition and segmentation of biological samples of plant origin. The algorithm developed requires the CMOS camera of a cell phone for the acquisition and transmission of the images of size 720x480 pixels, a computer for the management, reception and processing of the same, a wireless local area network, a He-Ne laser 633 nm with 10 mW of power as a coherent light source, an optical diffuser and an aluminum surface for the placement of biological samples. The study showed satisfactory results to acquire images and store them, allowing their subsequent segmentation.

1. Introduction
The speckle pattern arises when an optically rough surface is illuminated with light that has a high degree of coherence, such as that which comes from a laser, the scattered light has a particular intensity distribution, making the surface appear to be covered with a structure fine granular [1,2]. The images of this phenomenon can be used to measure the dynamic activity of seeds, fruit beats, parasitic activity, etc. [1,3-5].

The acquisition and segmentation of dynamic speckle images does not have a standard. Many algorithm proposals have emerged for this purpose. The acquisition has been proposed with dedicated CCD cameras for digital image processing [6,7]. In the same way, algorithms for the acquisition and processing of dynamic speckle images through web cameras, digital cameras and USB cameras have been developed [8-10]. The boom and the progressive improvements of the CMOS cameras have led to the study of its implementation in systems of dynamic speckle image acquisition [11]. Also, development on portable acquisition systems has been reported [6,12].

This research sought to develop an image acquisition and segmentation algorithm for the temporal study of the dynamic speckle phenomenon through the implementation of a wireless system based on a cell phone with Android operating system. This algorithm interacts with an application that acts as a server of images, controls the acquisition of images of 720x480 pixels, segments the images and detects the material under study (seeds). The study showed satisfactory results to acquire and segment
dynamic speckle images allowing to determine how many individuals or samples are exposed to the laser beam.

2. Materials and methods
The present work consists of an algorithm implemented in Matlab that controls the acquisition of dynamic speckle images in an optical assembly, and then segmented them to identify the material under study to facilitate processing. The algorithm developed requires a CMOS camera cell phone for the acquisition and transmission of the images of size 720x480 pixels, a computer for the management, reception and processing of the same, a wireless local area network, a He-Ne laser 633 nm with 10 mW of power as a coherent light source, an optical diffuser and an aluminum surface for the placement of biological samples. The requirements of the algorithm are shown in Figure 1. The beam of this laser impinges on a microscope objective in order to expand it. Then it goes through a diffuser producing the speckle pattern. This incident pattern illuminates on the samples. The Droidcam application creates a server in the local area network, which is accessed with the private ip address of the phone and a port number. The algorithm establishes a connection with the Droidcam mobile application wireless by the local area network and acquires an image under white light. It asks the user for two parameters: number of dynamic speckle images to acquire and acquisition frequency. Then, the system acquires the dynamic speckle images (under the laser beam and without white light), controlling the frequency of acquisition according the preference of the user. The phone is attached to the optical set up, using a base designed and printed in 3D.

Figure 1. The requirements of the algorithm.

Figure 2. Diagram of the algorithm.

The image of the illuminated samples is segmented under its own color. The script results in a segmentation mask. Then, it labels each group of pixels, identifies them as samples and calculates the
The system calculates, with the bwlabel command, the number of samples present in the image. This process generates a number of masks equal to the number of samples. Each mask contains a single group of pixels corresponding to the samples. Dynamic speckle images are converted to grayscale. Finally, each mask is segmented once again by obtaining a small mask to optimize the administration of RAM by the system. In the example that will be shown in this article, 30 samples were used. The small masks corresponding to each sample and segment the dynamic speckle images. Figure 2 shows a diagram of the algorithm.

3. Results and discussion
The connection to the camera is fast but the frame transmission rate depends on the state of the channel, co-channel interference, traffic in the local area network and its respective CSMA/CA medium access control protocol. On average, transmission rates of 30 frames per second are obtained, with minimum and maximum rate of 7 to 40 frames per second respectively.

The acquisition under white light can be seen in Figure 3. This image is taken as a basis to perform the color segmentation of the samples, obtaining the image shown in Figure 4. In this stage, the algorithm counts the pixel groups and establishes the number of samples. Subsequently, the algorithm extracts each individual from the sample to its own image, as can be seen in Figure 5 that we show as an example. Each extracted image (One per sample) is processed to select the area of interest of each one (See Figure 6). The dynamic speckle images are converted to gray scale. The masks obtained for each element of the sample are applied to each of the gray scale images. This stage leaves the images ready for statistical digital processing. In the example, used in this article, it means that the product of the quantity of seeds was created by the quantity of images (30x500 images), 15000 images in total to analyze the total of seeds independently each one.
4. Conclusions
This algorithm proved to be efficient and effective to acquire maximum one image every 100 ms, without compromising its performance or delays. Under ideal conditions of exclusive access to the local area wireless network, you can make acquisitions every 25 ms. The proposed system segments and detects the samples, counting them, and preprocesses dynamic speckle images to prepare them for analysis. This algorithm allows the individualized analysis of the elements of the sample. Which opens new perspectives for the study of dynamic speckle images. Likewise, this script reduces the computational load, leading to its use in computers with few computer resources. Finally, it was possible to develop an algorithm that operates hardware wirelessly and that may have applications in microbiology, in the historical analysis of microorganism populations, in addition to the proposed use in the phenomenon of dynamic speckle.

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References
[1] Rabal J and Braga R 2009 Dynamic laser speckle and applications (London: CRC Press)
[2] Dainty J 1984 Laser speckle and related phenomena (New York: Springer Verlag)
[3] Patiño M, Pencue E and Vargas R 2016 Biotecnología en el Sector Agropecuario y Agroindustrial 14 2
[4] Patiño M, Vásquez J, Andrade C, Arizaga R, Rabal H and Trivi M 2011 Determination of coagulation time of human blood by biospeckle technique Proc. SPIE 22nd Congress of the International Commission for Optics: Light for the Development of the World (Puebla) vol 8011 (Mexico: International Commission for Optics) pp 80118S 1-5
[5] Koshoji N, Bussadori S, Bortoletto C, Prates R, Oliveira M and Deana A 2015 PLoS ONE 10(2) e0118429 1-9
[6] Pérez A, González-Peña R, Braga R, Perles Â, Pérez-Marín E and García-Diego F 2018 Sensors 18(1) 190 1-13
[7] Dai A, Meschino G, Guzmán M, Scandurra A, González M, Weber C, Trivi M, Rabal H and Passoni L 2016 Journal of Optics 18(8) 085606 1-11
[8] Richards L, Kazmi S, Davis J, Olin K and Dunn A 2013 Biomedical Optic Express 4(10) 2269-2283
[9] Vannoni M, Trivi M, Arizaga R, Rabal H and Molesini G 2008 European Journal of Physics 29(5) 967-975
[10] Vega F and Torres C 2015 Journal of Physics: Conference Series 582 012025 1-9
[11] Aguanno V, Lakestani F and Connelly M 2004 Speckle interferometry using a CMOS-DSP camera for static and dynamic deformation measurements ICEM12 - 12th International Conference on Experimental Mechanics (Bari) vol 1 (Italy: Politecnico di Bari) pp 1-8
[12] Genet R 2013 Journal of Astronomical Instrumentation 2(2) 1340008 1-7