Activity assessment of fruits using the methods of inertia moment and absolute value of the differences

Md Zaheer Ansari[1,a] and A.K. Nirala[2,b]
[1,2]Biomedical Optics Laboratory, Department of Applied Physics,
Indian School of Mines Dhanbad, Jharkhand-826004, India
[a]mohamedzaheer1@gmail.com, [b]aknirala@yahoo.com

Article Info

Received: 5th October 2011
Accepted: 1st December 2012
Published online: 1st March 2012

ISSN: 2231-8860

ABSTRACT

This work presents a study of a technology applied in quality assessment of fruits. Evaluations were performed using a nondestructive and noninvasive method based on the interpretation of an optical phenomenon that occurs when the fruits are illuminated with coherent light, referred as biospeckle. A numerical analysis of the time history of speckle pattern (THSP) has been carried out by means of a co-occurrence matrix (COM) that assembles the intensity distributions of speckle pattern of the specimen with regard to time. Experiments have been performed to implement inertia moment (IM) and absolute value of the differences (AVD) methods on the biospeckle COMs. In the present work, we have used two different Indian fruits namely apple and tomato for the study of bio-activities using above methods for the first time. The variation of IM and AVD with frequency is found to increase for the fruits but apple has relatively higher rate of increase of IM and AVDs in comparison to tomato. In addition, the value IM for the fruits is found to decrease with the aging of the sample but apple has relatively lower rate of decrease of IM in comparison to tomato.

***Keywords*: Biospeckle, co-occurrence matrix, Inertia moment, absolute value of the differences.**

1. Introduction

There is need to evaluate the quality of fruits and vegetables at different stages of pre and post-harvest technology in order to provide product of the best quality to consumers (Abbott, 1999). Recently, a few interesting optical techniques and devices have been developed and successfully used for nondestructive evaluation of fruits and vegetables: Vis/NIR spectrophotometry (Zude-Sasse et al., 2002), time-resolved reflectance spectroscopy (Zerbini et al., 2003), hyperspectral backscattering imaging (Peng and Lu, 2008; Firtha et al., 2008), laser-induced light backscattering (Qing et al.,2007; Baranyai and Zude 2009) or chlorophyll fluorescence (Herppich, 2001; Herppich et al., 2001; Bauriegel et al., 2011). Nikolai et al. (Nicolai et al., 2007) have reviewed most of the above techniques, collectively naming them NIR spectroscopy, and have shown their feasibility and areas where more research are still needed.

Biospeckle is another optical technique that was introduced for nondestructive evaluation of activities of biological materials. In the method, coherent laser light illuminates an object of interest. The backscattered light interferes and a speckle pattern is created in an observation plane. If the sample does not show activity, the speckle pattern is stable in time. However in the case of biological samples, the speckle pattern consists of two components: the static one from stationary elements of the tissue and the variable one from moving particles of the tissue.

The variable in time speckle pattern is characteristic for biological tissue and has been called as the biospeckle (Xu et al., 1995; Zhao et al., 1997).

Bragga et al. (2009) have summarized that processes related with movement of the scattering centers in the tissue, such as cytoplasmic streaming, organelle movement, cell growth and division during fruits maturation and biochemical reactions, are responsible for a certain biospeckle activity. Brownian motions should be considered as a source of biospeckle activity too (Zhao et al., 1997). The knowledge about biospeckle in relation to fruits and vegetables is still limited. In general, it has been shown that biospeckle activity changes with an age or with some surface properties, for example an infection of a biological object. On the other hand there is lack of consistent biological interpretation of the phenomena.

So far, attempts to apply biospeckle methods in biological studies include measurements of blood flow in blood vessels (Briers and Fercher, 1982), viability of seeds (Braga et al., 2003; Sendra, 2005), activity of parasites in living tissues (Pomarico e al., 2004; Braga et al., 2005), analysis of maturation and bruising of fruits and vegetables (Pajuelo et al., 2003; Rabelo et al., 2005). These studies showed that decaying of a tissue conditions caused by age, illness/infection or damage, relates with lower biospeckle activity.

In the present work, the analysis of the activity in a speckle pattern is conveniently evaluated by a method known as “time history of speckle pattern” (THSP), which permits the evolution of one column in the speckle pattern during the time of observation. The numerical analysis of this THSP is carried out by means of a co-occurrence matrix (COM) that assembles the intensity distributions of a speckle pattern with regard to time. Experiments have been performed to implement “inertia moment” (IM) method on the biospeckle COMs which generates reliable information on the bio-activity of living tissue of the fruits. Also one of the most recently developed method known as “absolute value of the differences “(AVD) is being analyzed by handling it on biospeckle COM.

2. Methodology

2.1. Fundamentals of Biospeckle

Biospeckle is nondestructive optical technique based on the analysis of variations of laser light scattered from biological samples. Biospeckle activity reflects the state of the investigated object. It occurs when laser light is scattered by objects showing some type of activity present in fruits and other biological samples. It is due to changes in the phase of light produced by movements of the scatterers, changes in the refractive index etc. Contributions from different scatterers produce time variations in local intensity. The visual appearance of the pattern is similar to that of a boiling liquid, so it is sometimes called ‘boiling speckle’ or dynamic speckle.

2.2. Moment of inertia of co-occurrence matrix

A convenient way to show the time evolution of a speckle pattern is that proposed by Oulamara et al. (2011) For every state of the phenomenon being assessed; successive images of the dynamic speckle pattern are registered. A certain column (for example, the middle one) is selected in each of them. Then, a new image is constructed by setting, side by side, the chosen column extracted from the successive patterns. The resulting image is named 'time history of the speckle pattern (THSP)'. Its rows represent different points on the speckle pattern and the columns their intensity in a sequence of regularly spaced time steps. The activity of the sample appears as intensity changes in the horizontal direction, that is, along the rows.

When a phenomenon shows low activity, time variations of the speckle pattern are slow and the THSP shows a horizontally elongated shape. In the limit, when there is no activity, the THSP shows no variation in the horizontal direction. Conversely, when the phenomenon is very active, the THSP shows fast intensity variations that resemble an ordinary spatial speckle pattern. The THSP is assumed to be representative sample of the state of the phenomenon being assessed when it was registered. In the THSP, the time variations of the intensity are shown in one direction (horizontally) while the space variations are shown in the other (vertically). As the time and space statics of the phenomenon need not be the same, also the number of required data in the time direction need not be the same as in the space direction.

The THSP images are 8-bit gray-level matrices, and thus, there are 256 possibilities to represent pixel's values: from 0 (black) to 255 (white). A co-occurrence matrix (COM) expresses the number of transitions of each THSP pixel with respect to its immediate neighbor. In image processing, the COM is very useful to characterize the texture features in the images. In biospeckle analysis, the COM represents an intermediary step to obtain the inertia moment (IM) of a sample. $M_{CO} = [N_{ij}]$The co-occurrence matrix is defined as;M_{co}

$$M_{CO} = \left[N_{ij} \right] \quad (1)$$

where, the entries are the number **N** of occurrences of a certain intensity value *i*, that is immediately followed by an intensity value *j*. This is a particular case of the so called 'spatial grey level dependence matrices'. It is usually used to characterize texture in images (Oulamara et al.,1898; Zobrist and Thompson, 1975; Kruger et al., 1974). In the spatial case, its principal diagonal is related to homogeneous regions and the non-zero elements far from it represent high contrast occurrences.

In the present work, the variable of interest is time. Then the involved N values are the occurrences of a certain grey value *i* followed in the next time step by a value *j* in the THSP as described above.

When the intensity does not change, the only non-zero values of this matrix belong to the principal diagonal. As the sample shows activity, intensity values change in time, the number N outside the diagonal increases and the matrix resembles a cloud. Nevertheless, this matrix is sparse; it is mostly composed by zero values.

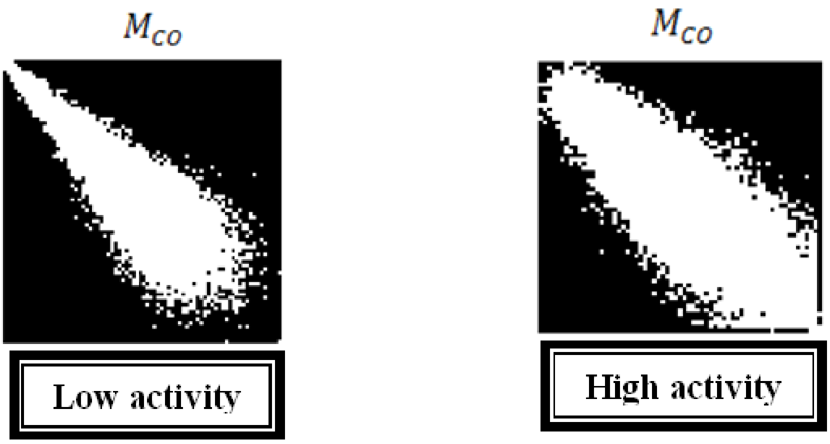

Fig.1. Co-occurrence matrix M_{CO} for low and high activity biological sample

2.3. Generation of inertia moment (IM) of the COM

The IM of the co-occurrence matrix is a usual texture descriptor that has been used as a measure of biospeckle activity in some applications (Xu et al., 1995; Allam et al., 1997; Arizaga et al., 1999. In order to obtain a quantitative measure from this matrix, it is necessary first to normalize it. This is done by dividing each row of the matrix by the number of times that the first grey level appeared. The sum of the components then equals to;

$$M_{ij} = \frac{N_{ij}}{\sum_j N_{ij}} \tag{2}$$

This is obtained in a way such that low variations of pixel intensity will add low values to the final IM value, while high variations will contribute more to the IM value. For example, if a pixel intensity changes from 0 (the most dark intensity possible) to 255 (white), this will add $(0 - 255)^2 = (-255)^2 = 65025$ to the final IM value. However, if the change was from 50 to 45, this will add $(50 - 45)^2 = 5^2 = 25$ to the final IM value. In this way, if the phenomenon being observed changes its state in a dynamic way, then this will be registered as a variation in the pixel intensity. Nevertheless, if the phenomenon presents small changes in the speckle patterns, then the IM will add less value to quantify it. A measurement of the spread of the IM values around the principal diagonal can be constructed as the sum of the matrix values times its squared row distance to the principal diagonal. This is a particular second-order moment called the moment of inertia $\boldsymbol{M_I}$ of the matrix with respect to that diagonal in the row direction and is given by

$$M_I = \sum_{ij} M_{ij} \left(i - j\right)^2 \tag{3}$$

2.4. Generation of absolute value of the differences (AVD) of COM

The AVD is a first statistic moment order, which is an alternative to the routine IM method [32]. It is based on the principle that the summation of differences is the main information searched, and that the square operation carried out in the IM method can amplify the variations in the time history in a distorted way.

$$AVD = \sum_{ij} \left\{ M_{ij} \left| i - j \right| \right\} \tag{4}$$

3. Description of Experiment

For the study of biospeckle temporal properties of the fruits, a 2 mW He-Ne laser at 632.8 nm wavelength were expanded and spatially filtered and then is allowed to fall on the specimen. The diffused reflected light from the specimen forms a speckle field in space.The speckle intensity is recorded by a CCD camera with a lens and so the subjective speckle field is recorded.

For the experiment apple and tomato were taken as fresh as possible and stored in a cool place. The observation area was marked on each of them. 225 images were taken at an interval of 1 sec to find the IM and AVD values against its activity values. Also 200 images were taken at an interval of 1min to find the variation of IM and AVD value against time. Successive images were registered, digitized to 8 bits (256 grey levels) and stored. Very low illuminating intensity was used to minimize the effect of the irradiation on the sample activity.

Measurements were performed on the same places of the samples. For the co-occurrence matrix analysis, a column of the free propagation speckle pattern was read every 1sec for the first result and every 1 min for the second result and then, a composite image of 225 by 225 pixels was formed by stacking consecutive columns. Finally, this image was retrieved and the second-order moments of its co-occurrence matrix were calculated. The speckle images were then registered, the THSP was constructed and the IM was calculated. The whole set of reading was repeated three times and for each of them IM and AVD were calculated.

Two types of Indian fruits namely apple and tomato (treated as fruit) have been selected. We have taken a series of observations for the fruits and repeated these observations three times almost in identical situation with temperature in the range of 20 -25° C and humidity in the range of 55- 60% . We are presenting the representative typical graphs for the fruits.

4. Results

4.1 Variation of co-occurrence matrix for the fruits:

Figures from 2 to 3 show the co-occurrence matrices of apple and tomato for different days respectively for which we can consider it to have high, intermediate and low activities respectively. It can be seen that the points in the main diagonal represent no change of intensity while the spread of points out of the diagonal represents time intensity changes. So, if the activity of the biological tissue is low, intensity changes are slow and the only appreciable values of the matrix appear near to the diagonal .Conversely, if activity is high, the fast intensity changes produce high values far away the principal diagonal of the matrix. Hence it is found that the activity goes on decreasing with time.

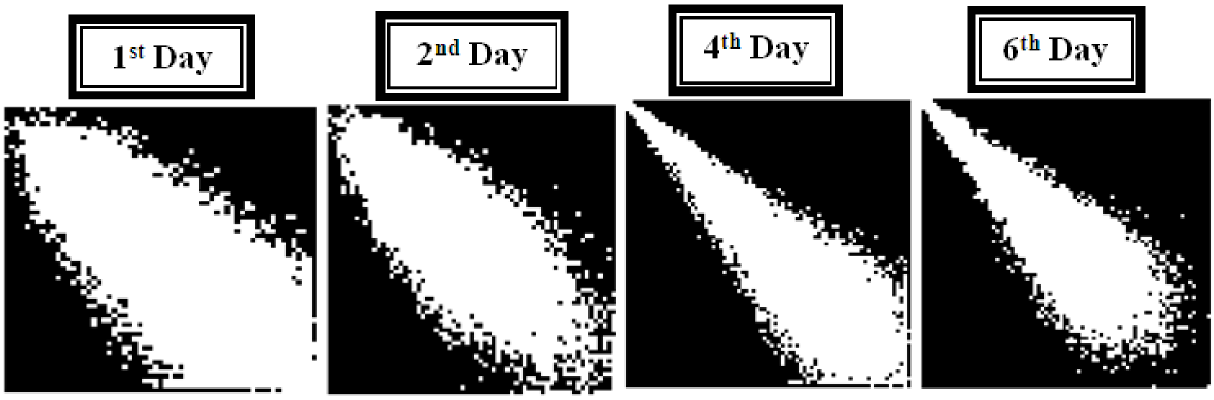

Fig.2. Co-occurrence matrix M_{CO} for 1st, 2nd, 4th and 6th day of Apple

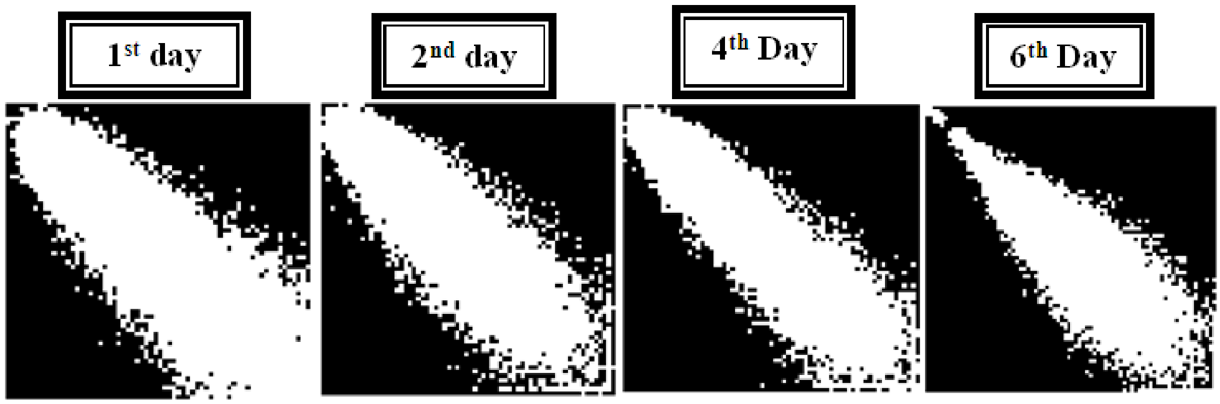

Fig.3. Co-occurrence matrix M_{CO} for 1st, 2nd, 4th and 6th day of Tomato

4.2. Variation of IM and AVD with activity:

On the first day when the sample was fresh IM value increases rapidly which gives the variation of pixel or intensity value but when the activity of biological sample goes on decreasing with time the IM value decreases. The influence of the higher changes in the activity, represented by the abrupt changes in the THSP pixels is decreased in the AVD approach as shown in the figs.4b-5b. This is an important achievement of the AVD because it could represent the same phenomenon of IM method with a new contribution to the results, in addition to a reduced number of operations.

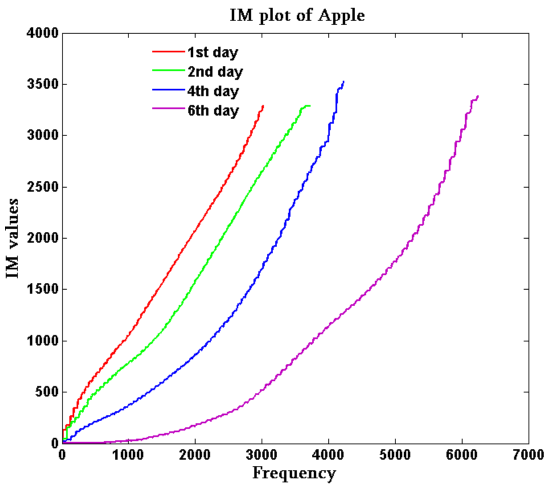

Fig.4a. Variation of IM with frequency for Apple

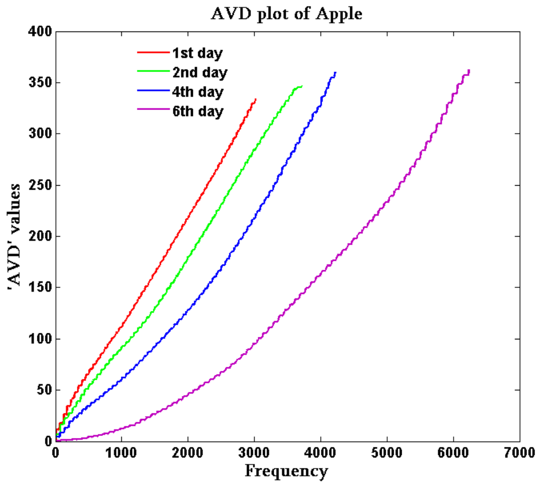

Fig.4b. Variation of AVD with frequency for Apple

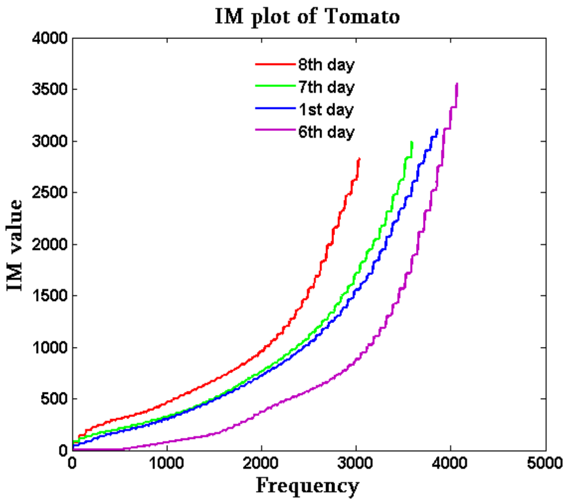

Fig.5a. Variation of IM with frequency for Tomato

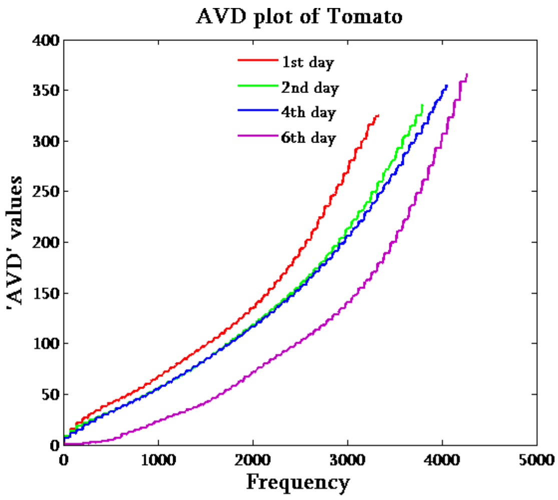

Fig.5b. Variation of AVD with frequency for Tomato

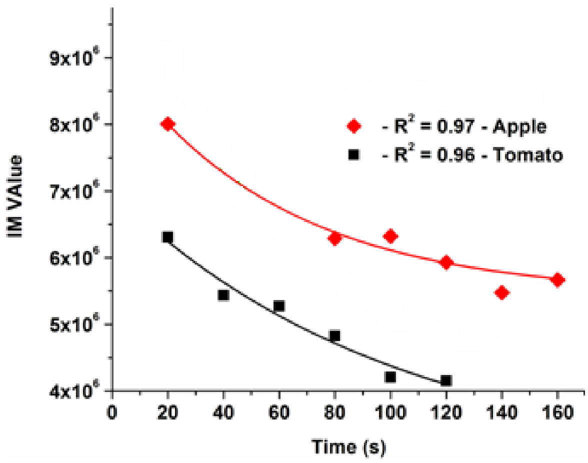

Fig.6. Variation of Inertia Moments with Time (s) for different

5. Conclusion

The COM created is found to be a very useful tool to characterize the texture features of different images of biological specimen. The formalism of IM algorithm represents the activity by a nondimensional number, where the high activity is presented by higher values and lower activity by lower values. From the results, we observe the following

a. 1. From the images of COM for apple and tomato, it was found that due to high activity of apple the fast intensity changes produce high values far away from the principal diagonal of the matrix in comparison to the tomato.
b. 2. The variation of IM and AVD with frequency is found to increase for the samples but apple has relatively higher rate of increase in comparison to tomato.
c. The value IM for the samples is found to decrease with the aging of sample but apple has relatively lower rate of decrease in comparison to tomato as shown in Fig. 6.
d. It is evident from graphs 4 to 5 that AVD is an alternative to the IM method because the sum of the square of differences in the IM method can amplify the variations in the THSP in a distorted way.

Acknowledgement

We are sincerely thankful to DST, New Delhi for giving financial assistance of Rs. 39.902 lakhs as sponsored project no. "*SR/S2/LOP-07/2005 dated 24/10/2007"* without which it would not have been possible to perform this works at all.

References

Abbott, J. A. (1999). Quality measurement of fruits and vegetables. Postharvest Biol. Technol. 15, 207-225.

Zude-Sasse, Z., Truppel, I., and Herold, B. (2002). An approach to non-destructive apple fruit chlorophyll determination. Postharvest Biol. Technol. 25, 123-133.

Zerbini, P. E., Grassi, M., Cubeddu, R., Pifferi, A., and Torricelli, A. (2003). Time-resolved reflectance spectroscopy can detect internal defects in pears. Acta Horticul. 599, 359-365.

Peng, Y., and Lu, R. (2008). Analysis of spatially resolved hyperspectral scattering images for assessing apple fruit firmness and soluble solids content. Postharvest Biol. Technol. 48, 52-62.

Firtha, F., Fekete, A., Kaszab, T., Gillay, B., Nogula-Nagy, M., Kovács, Z., and Kantor, D.B. (2008). Methods for improving image quality and reducing data load of NIR hyperspectral images. Sensors. 8, 3287-3298.

Qing, Z., Ji, B., and Zude, M. (2007). Predicting soluble solid content and firmness in apple fruit by means of laser light backscattering image analysis. J. Food Eng. 82, 58-67.

Baranyai, L., and Zude, M. (2009). Analysis of laser light propagation in kiwifruit using backscattering imaging and Monte Carlo simulation. Comput. Electron Agr. 69, 33-39.

Herppich, W. B. (2001). Application Potential of Chlorophyll Fluorescence Imaging Analysis in Horticultural Research. In Proceedings of the 6th International

Symposium: Fruit, Nut and Vegetable Production Engineering, Potsdam, Germany, 11–19 September. 609-614.

Bauriegel, E., Giebel, A., and Herppich, W. B. (2011). Hyperspectral and chlorophyll fluorescence imaging to analyse the impact of Fusarium culmorum on the photosynthetic integrity of infected wheat ears. Sensors. 11, 3765-3779.

Herppich, W. B., Linke, M., Landahl, S., and Gzik, A. (2001) Preharvest and postharvest responses of radish to reduced water supply during growth. Acta Horticult. 553, 89-90.

Nicolai, B. M., Beullens, K., Bobelyn, E., Peirs, A., Saeys, W., Theron, K. I. and Lammertyna, J. (2007). Nondestructive measurement of fruit and vegetable quality by means of NIR spectroscopy: A review. Postharvest Biol. Technol. 46, 99-118.

Xu, Z., Joenathan, C., and Khorana, B. M. (1995) Temporal and spatial properties of the time-varying speckles of botanical specimens. Opt. Eng. 34, 1487-1502.

Zhao, Y., Wang, J., Wu, X., Williams, F. W., and Schmidt, R. J. (1997). Point-wise and whole-field laser speckle intensity fluctuation measurements applied to botanical specimens. Opt. Lasers Eng. 28, 443-456.

Braga, R. A., Dupuy, L., Pasqual, M., and Cardosos, R. R. (2009). Live biospeckle laser imaging of root tissues. Eur. Biophys. J. 38, 679-686.

Briers, J. D., and Fercher, A. F. (1982). Retinal blood-flow visualization by means of laser speckle photography. Investig. Ophthalmol. Vis. Sci. 22, 255-259.

Braga, R. A., Dal Fabbro, I. M., Borem, F. M., Rabelo, G., Arizaga, R., Rabal, H. J., and Trivi, M. (2003). Assessment of seed viability by laser speckle techniques. Biosyst. Eng. 86, 287-294.

Sendra, G. H., Arizaga, R., Rabal, H. J., and Trivi, M. (2005). Decomposition of biospeckle images in temporary spectral bands. Opt. Lett. 30, 1641-1643.

Pomarico, J. A., DiRocco, H. O., Alvarez, L., Lanusse, C., Mottier, L., Saumell, C., Arizaga, R., Rabal, H., and Trivi, M. (2004). Speckle interferometry applied to pharmacodynamic studies: Evaluation of parasite motility. Eur. Biophys. J. 33, 694-699.

Braga, R. A., Rabelo, G. F., Granato, L. R., Santos, E. F., Machado, J. C., Arizaga, R., Rabal, H. J., and Trivi, M. (2005). Detection of fungi in beans by the laser biospeckle technique. Biosyst. Eng. 91, 465-469.

Pajuelo, M., Baldwin, G., Rabal, H., Cap, N., Arizaga, R., and Trivi, M. (2003). Biospeckle assessment of bruising in fruits. Opt. Lasers Eng. 40, 13-24.

Rabelo, G. F., Braga, Jr. R. A., Fabbro, I. M. D., Arizaga, R., Rabal, H. J., and Trivi, M. R. (2005). Laser speckle techniques applied to study quality of fruits. Revista Brasileira de Engenharia Agricola e Ambiental. 9, 570-575.

Braga, R. A., Nobre, C. M. B., Costa, A. G., Safadi, T., and da. Costa, F. M. (2011). Evaluation of activity through dynamic laser speckle using the absolute value of the differences. Optics Communications. 284, 646-650.

Oulamara, A., Tribillon, G., and Duvernoy, J. (1989). Biological activity measurements on botanical specimen surfaces using a temporal decorrelation effect of laser speckle. J Mod Opt. 36, 165±79.

Zobrist, A., and Thompson, W. (1975). Building a distance function for gestalt grouping. IEEE Trans Comput. 718±728.

Kruger, R., Thompson, W., and Franklin A. (1974). Turner, Computer diagnosis of pneumoconiosis. IEEE Trans Systems Man Cybernetics. 40±49.

Allam, S., M. Adel P. ReÂ freÂgier. (1997). Fast algorithm for texture discrimination by use a separable orthonormal decomposition of the co-occurrence matrix. Appl Opt 36, 8313±21.

Arizaga, R. Trivi, M., and Rabal, H. J. (1999). Speckle time evolution characterization byco-occurrence matrix analysis. Optics and Laser Technology, 31, 163-169.

Xu, Z., Joenathan, C., and Khorana, B. M. (1995). Temporal and spatial properties of the time-varying speckles of botanical specimens. Opt Eng. 34, 1487–1502.