Importance of Sampling Frequency in the Dynamic Speckle Analysis

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Abstract

In this article, we show as the variation of sampling frequency, in a dynamic speckle analysis, affect the value of some dynamic speckle index, in this case: the absolute value of the differences (AVD) index, the temporal speckle standard deviation index and the temporal speckle mean index. we show that the dynamic speckle index value decrease your maximum excursion with the grow of sampling frequency because this affect directly the time integration (exposition time) of camera.

Keywords: Frequency sampling, Dynamic speckle index, Dynamic speckle index, Dynamic speckle analysis

1. Introduction

Dynamic laser speckle is a phenomenon that is

2. System description

2.1. Exposure time of the camera

The acquisition time, frame per seconds (fps) or sampling frequency (F_s), in the camera Marlin F-033 will be calculated in the Table 1, where we can see, the shutter register value ($Shutter$), time base register value ($Base$), exposure

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time ($Exposure$), exposure time offset ($Offset$) and effective exposure time (E); so that

$$Exposure = Shutter \times Base, \tag{1}$$

$$\frac{1}{F_s} = E = Exposure + Offset. \tag{2}$$

Where, F_s is calculated in relation to the E; being that, the $Exposure$ represent the photography integration time and E the effective time between photographs.

$Shutter$	$Base\ [\mu s]$	$Offset\ [\mu s]$	$E\ [ms]$	$F_s\ [fps]$
3332	20	12	66.652	15.003
1665	20	12	33.312	30.019
1110	20	12	22.212	45.021
832	20	12	16.652	60.053

Table 1: Exposition time and sampling frequency

2.2. Data packages in the ink drying process

This data package analyze a drying ink process, where images data packages are taken at the times {0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10} min. In each time, the package has 512 images of 147 pixels of height and 166 pixels of width. They were use 4 different sampling frequency to the images in each package, being these frequencies 15, 30, 45 and 60 hz.

2.3. Data package of the activity analysis in corn seed

This data package analyze the activity of a corn seed with 3 days of germination. In this point, They are taken 4 image data packages with different sampling frequencies to each package, being these frequencies 15, 30, 45 and 60 hz. Each package has 512 images of 29 pixels of height and 31 pixels of width.

2.4. Test 1: ink drying process

The Fig. 1 represents the data analysis method, acquired at a sampling frequency of F_s, with the characteristic seen in the Section 2.2, where, $P(t)$

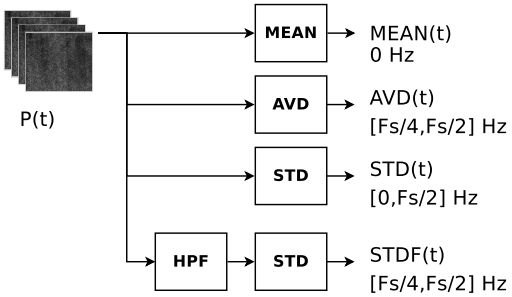


Figure 1: Data analysis of the ink drying process test.

is an image data package at the time t minutes. The $MEAN$ block represent the calculus of a temporal speckle mean index from the package $P(t)$, returning the value $MEAN(t)$, as exposed in the Section 3.1. The AVD block represent the calculus of a absolute values of the differences index from the package $P(t)$, returning the value $AVD(t)$, as exposed in the Section 3.2. The STD block represent the calculus of a temporal speckle standard deviation index from the package $P(t)$, returning the value $STD(t)$, as exposed in the Section 3.3. And finally, the block HPF represents a digital finite impulse response "high-pass filter" with order 40 and cut-off at $0.25F_s$ that causes to have the at end of path the $STDF(t)$ index value, a frequency filtered version of $STD(t)$. According the information of the data packages, we will have indexes values, for each minutes during 10 minutes.

2.5. Test 2: Activity analysis in corn seed

The activity analysis of a corn seed, uses the information of data package seen in the Section 2.2. We analyze this information of similar way to the seen in the Section 2.4, with the difference that is taken an data package at the time t (3 days of germination).

3. Theoretical definitions

3.1. temporal speckle mean index

3.2. Absolute Values of the Differences (AVD)

Frequency composition from $F_s/4$ until $F_s/2$ Hz like as HPF of first order.

3.3. Temporal speckle standard deviation index

Frequency composition from 0 until $F_s/2$ Hz like as HPF of first order.

3.4. Filtered temporal speckle standard deviation index

Frequency composition from 0 until $F_s/2$ Hz like as HPF of first order.

4. Numerical results

4.1. Result of test 1

This test shows the analyze result of an ink drying process, across 10 minutes, with the sampling frequency: 15, 30, 45 and 60Hz.

The Figure 2 analyze the $MEAN(t)$ index, in the test showed in the Section 2.4, to each time t for 4 sampling frequencies. It easy to see as the value of

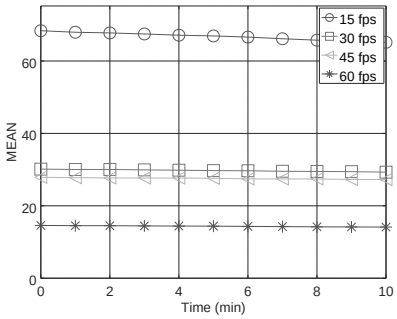
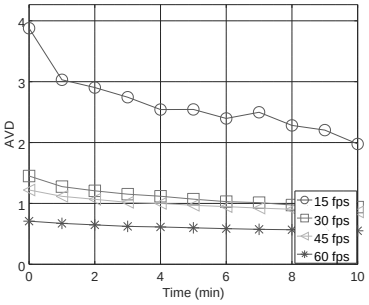


Figure 2: $MEAN$ index value.

index has a monotonous behavior over time. By other side the values in the curves decreases in proportion with the grow of sampling frequency.

(a) AVD index value.



(b) Normalized AVD index value.

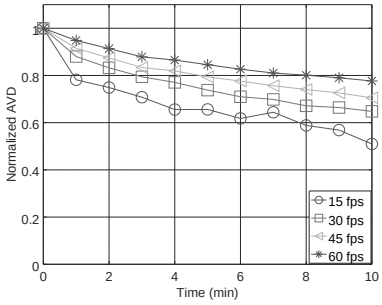


Figure 3: AVD index anaysis.

The Figure 3 shows the result of analysis explained in the Section 2.4 about the $AVD(t)$ index. The Figure 3a shows the $AVD(t)$ index, in each time t, to 4 sampling frequencies, showing a different behavior across time in each sampling frequency, so that, the value of the index in all the curve decreases in proportion with the grow of sampling frequency. By other side, the Figure 3b shows a normalized version of $AVD(t)$ index, so that the maximum value of curves have an unit value; thus, It is easy to see that the maximum excursion of the curve is greater when decrease the sampling frequency. Remembering that this index use information in a frequency band between $F_s/4$ until $F_s/2$ Hz, as seen in Section 3.2.

The Figure 4 analyze the $STD(t)$ index in the test showed in the Section 2.4. The Figure 4a shows the behavior of $STD(t)$ index, in each time t, to 4 different sampling frequencies. Remembering that this index uses information in a frequency band between 0 until $F_s/2$ Hz, as seen in Section 3.3. This index shows a different behavior across time to each sampling frequency, so that, the value of the index in each time of curve decreases in proportion with the grow of sampling frequency. By other side, the Figure 4b shows a normalized version of $STD(t)$ index; being the unit, the maximum value of curves; thus, It is easy to see that exist a small difference between the maximum excursion of the curves

(a) STD index value. (b) Normalized STD index value.

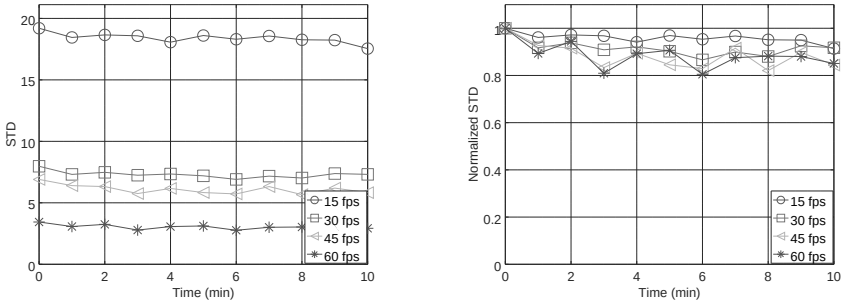


Figure 4: STD index anaysis.

with different sampling frequency; even so, It is possible to observe a decrease of the maximum excursion in the curve with the grow of the sampling frequency.

The Figure 5, analyze the $STDF(t)$ index, in the test showed in the Section 2.4. The Figure 5a shows the behavior $STDF(t)$ index, in each time t, to

(a) $STDF$ index value. (b) Normalized $STDF$ index value.

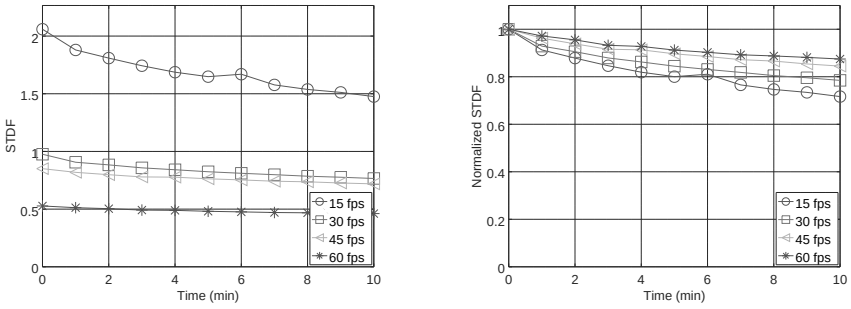


Figure 5: $STDF$ index anaysis.

4 different sampling frequencies. Remembering that this index uses filtered information of datapack, so that your frequency band is between $F_s/4$ and $F_s/2$ Hz, of similar way of $AVD(t)$ index but with different order filter, as seen in

Section 3.4. This index shows monotone decreasing behavior in time, where we observe a different behavior across time to each different sampling frequency; so that, the value of the index in each time of curve decreases in proportion with the grow of sampling frequency. By other side, the Figure 5b shows a normalized version of $STDF(t)$ index; being the unit, the maximum value of curves; thus, It is easy to see that exist a considerable difference between the maximum excursion of the curves with the use of sampling frequency; so, It is possible to observe a grow of the maximum excursion with the grow of the sampling frequency.

4.2. Result of test 2

5. Analysis results

5.1. Analysis of results: test 1

In the results of ink drying process test, seen in Section 4.1, we can observe in the Figure 2, that the index shows a relation between the value of curve and the sampling frequency of datapack. How is known [**?**], the temporal speckle mean index is related to the observed illumination level in the surface of study material. Thus, we can conclude that the level of illumination perceived by the camera decrease with the increment of sampling frequency. This is because that the exposition time is modified, see Section 2.1, with the alteration of sampling frequency, so that less lighting is used to take the picture and consequently the temporal speckle mean index decrease in your value. The modification of exposition time also affect other indexes, how can it be seen in the Figures 3, 4 and 5, where these indexes decrease your values in concordance with the decrease of exposition time. Other way in that the sampling frequency affect the values of indexes, It is that it limits the band of signal frequency analyzed; for example, a sampling frequency F_s causes that the analyzed signal frequency band will be between $0Hz$ and $F_s/2\ Hz$. Thus, in this context we have an index as $MEAN(t)$ that use information at $0\ Hz$ only, the index $STD(t)$ that use information between $\langle 0, F_s/2]\, Hz$, and be other side we have indexes as

the $AVD(t)$ and the $STDF(t)$ index, that use information of half frequency band, this is between $[F_s/4, F_s/2]\,Hz$. In the comparison between $STD(t)$ vs $\{\ STDF(t)$ and $AVD(t)\ \}$, we can observe how the half part use of frequency band causes the decrease of curves values, but considerably good values in the maximum excursion of the curve. By other side, in the case of ink drying process, the use of complete frequency band, It returns low values of maximum excursion in the curves. The importance of excursion in this test, It is due the necessity of to have significant differences en the values of two states, when the sample start or end the ink drying process.

6. Conclusion

In this work were presented comparisons of behavior of three dynamic speckle indexes subject to different values of sampling frequency, thus we concluded that: It is important to know to choose an appropriate sampling frequency, being recommendable to use the minimal sampling frequency possible to get an acceptable maximum excursion, so that the phenomenon under study to be in the analyzed frequency band. Finally, we show that the digitization of speckle signal imply a restriction of frequency band of signal and consequently this affect the result of an speckle analysis.

7. Acknowledgment

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8. Bibliography