On generalized differences for Biospeckle image analysis

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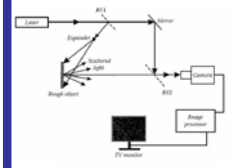
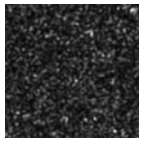
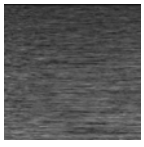
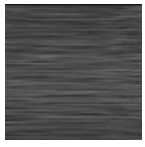
INTRODUCTION

Biospeckle is a technique whose purpose is to observe and study the underlying activity of some material. The technique has its roots on optical physics, and its first step is an image acquisition process that produces a video sequence whose characteristics allow researchers to have an interpretation of the activity of the observed material by an analysis of the video content. The recent literature on this subject presents several different measurements for analyzing the video sequence. One of the most popular measurement is the Generalized Difference (**GD**). The computation of the **GD** has an asymptotic complexity of O(n*n). In this paper we propose: (i) an alternative O(n) algorithm for the computation of the **GD**, and (ii) an alternative measurement, that we call **GD*.** We discuss the qualitative similarities between the **GD** and the **GD***. We conclude that the **GD*** is an alternative generalized difference measurement, and thus it can replace the **GD** in many applications. We show that the **GD*** is a function of the variance, and it can be computed in O(n). Finally, if the **GD** itself is desired as measurement, it can now be computed in O(n) by the novel algorithm presented.









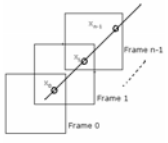


Fig.1: experimental set up.
Fig.2: one frame of video sequence.
Fig.3: temporal history of a speckle pattern of a material in high activty.
Fig.4: same as Fig.3 with low activity.
Fig.5: one pixel activity evolution. The activity of pixel p at frame i (i-0,1,2,.. n-1) is represented as xi. Evolution ➔ sequence sp=[x0,x1,....,xn-1]

MATERIAL and METHODS

$$GD(s) = \sum_{i=0}^{n-1} \sum_{j=i+1}^{n-1} |x_i - x_j|$$

GD: Generalized difference
Complexity : O(n*n)

Fast computation of GD: $GD(s) = \frac{1}{2} \sum_{i=0}^{n-1} \sum_{i=0}^{m-1} |x_i - j| g_j$

$$GD(s) = \frac{1}{2} \sum_{i=0}^{m-1} \left(\sum_{j=0}^{m-1} |i-j| g_j \right) g_i \qquad P_i = \sum_{j=i+1}^{m-1} |i-j|\, g_j$$

$$GD(s) = \sum_{i=0}^{m-1} P_i\, g_i \qquad S_i = \sum_{j=i}^{m-1} g_j$$

$$P_1 = P_0 - \sum_{j=1}^{m-1} g_j \qquad P_{i+1} = P_i - S_{i+1}$$

$$P_2 = P_1 - \sum_{j=2}^{m-1} g_j \qquad G_{k+1}(s) = GD_k(s) + P_{k+1}\, g_{k+1}$$

Mathematical induction:
(i) Initial condition: (ii) Inductive step : (iii) Stop condition

$$S_0 = n \qquad S_{k+1} = S_k - g_k \qquad k = m-1$$
$$P_0 = \sum_{j=1}^{m-1} j\, g_j \qquad P_{k+1} = P_k - S_{k+1}$$
$$G_0(s) = P_o\, g_0 \qquad GD_{k+1}(s) = GD_k(s) + P_{k+1}\, g_{k+1}$$

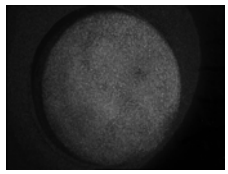
Alternative generalized difference GD*:

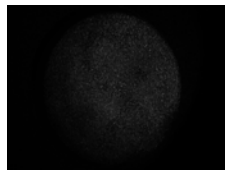
$$GD^*(s) = \sum_{i=0}^{n-1} \sum_{j=i+1}^{n-1} (x_i - x_j)^2$$

GD* as a function of the variance:

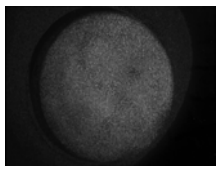
$$GD^*(s) = n^2\, \sigma^2(s)$$

RESULTS





Fgi.6 (a),(b): Comparison between GD (a) and GD* (b).



Fig,7 (a), (b): Comparison between GD (a) and WD (w=5).

CONCLUSIONS

runtime GD for a typical bispecke: 2 h , alternative GD: 26min
Runtime of WGD: 16h. (w=5).
Future work: extention of WG with the presented alternative algorithm and comparison with Fuji method.

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Apoio: CNPq, Fapemig