J Real-Time Image Proc
DOI 10.1007/s11554-013-0343-4

ORIGINAL RESEARCH PAPER

Real-time speckle image processing

Elías Todorovich · Ana Lucia Dai Pra · Lucia Isabel Passoni · Martín Vázquez · Ezequiel Cozzolino · Fernando Ferrara · Gery Bioul

Received: 25 October 2012 / Accepted: 22 March 2013

Abstract The laser dynamic speckle is an optical phenomenon produced when a laser light is reflected from an illuminated surface undergoing some kind of activity. It allows a non-destructive process for the detection of activities that are not easily observable, such as seed viability, paint drying, bacterial activities, corrosion processes, food decomposition, fruit bruising, etc. The analysis of these processes in real time makes it possible to develop important practical applications of commercial, biological and technological interest. This paper presents a new digital system based on granular computing algorithms to characterize speckle dynamics within the time domain. The selected platform to evaluate the system is Field Programmable Gate Array (FPGA) technology. The obtained minimum clock periods and latencies enable speckle image processing with real-time constraints with a maximum throughput of about thousand 512 × 512 fps.

Keywords Dynamic speckle · Granular computing · Programmable logic · Real-time processing · Rough-fuzzy sets

E. Todorovich · M. Vázquez · E. Cozzolino · F. Ferrara · G. Bioul
Faculty of Engineering, FASTA University, Mar del Plata, Argentina
e-mail: gbioul@ufasta.edu.ar

E. Todorovich (✉) · M. Vázquez
Universidad Nacional del Centro de la Provincia de Buenos Aires, Campus Universitario, B7001BBO Tandil, Argentina
e-mail: etodorov@exa.unicen.edu.ar

A. L. Dai Pra · L. I. Passoni
Faculty of Engineering, Universidad Nacional de Mar del Plata, Mar del Plata, Argentina
e-mail: daipra@fi.mdp.edu.ar

1 Introduction

The laser speckle is an optical phenomenon that occurs when a reflected laser light from a lighted surface is shown as a granular pattern of high contrast. When there is some activity in the illuminated surface this speckle pattern evolves in time. The dynamics of the observed physical phenomenon can be assessed by one of the behaviors of interest called "boiling", because of its appearance, where the speckles disappear and reappear without any significant displacement. This behavior can be observed in different types of phenomena like biological (seed viability [4], bacterial activity [20], fruit bruising [14], etc.) or non-biological processes (drying of paints [7, 12], corrosion [9], etc.); the activity is given by the change of the sample properties due to diverse physical phenomena.

Captured sequences of laser speckle images must be processed offline via a general purpose computer to characterize the phenomena, using ad hoc-designed descriptors that analyze the behavior of every pixel across the sequence. A wide set of these descriptors can be found in [18]; many of them carry out processes in the time domain, such as the descriptor of Fujii [10], Generalized Differences [1], Fuzzy Granular Descriptor (FGD) [5], among others. Other descriptors carry out this task using frequency domain tools, like the High to Low Frequency ratio (HLR) [11], and Frequency Band Decomposition [19]. Others deal with the frequency–time domain, such as the Wavelet Entropy Descriptor [16].

These descriptors perform differently depending on the type of application. Cases belonging to the so-called biospeckle phenomena are quite difficult to characterize, particularly when it comes to detecting regions of interest in living specimens, such as regions of bruising in apples,

Published online: 11 April 2013