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Dynamic tracking with simultaneous edge enhancement

Daniel Sierra-Sosa [a,b,*], Mariano Isaza-Monsalve [b], Luciano Angel-Toro [c], Myrian Tebaldi [d]

[a] *Department of Computer Engineering and Computer Science, Duthie Center for Engineering University of Louisville, Louisville, KY, United States*
[b] *Grupo de Modelado Matemático (GRIMMAT) Escuela Ciencias, Departamento de Ciencias Matemáticas, Universidad EAFIT, Medellín, Colombia*
[c] *Grupo de Óptica Aplicada, Escuela de Ciencias, Departamento de Ciencias Físicas, Universidad EAFIT, Medellín, Colombia*
[d] *Centro de Investigaciones Ópticas, CIOp (CONICET, CIC) and OPTIMO (Dpto. Ciencias Básicas, Facultad Ingeniería, UNLP), P. O. Box 3, 1897 M.B. Gonnet, Argentina*

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ABSTRACT

Due to the isotropic edge enhancement, the vortex phase filters are of commonly used in spatial filtering. In general, these filters employ a spiral phase mask on the Fourier plane, the square modulo from this convolution is the edge enhanced image. Nonetheless, several digital filtering applications based on vortex phase filters leave aside the complex-valued information. This complex-valued field is obtained from the Laguerre-Gauss transform application over static or dynamic events, namely single images or frames in a video. We propose the usage of complex field to locate and track phase singularities in dynamic events. In this sense, not only each object edges in a given scene are enhanced, but also phase singularities related to each object. This imprints a characteristic marker given by the assignation of optical vortex to objects with unique core structure properties, allowing for tracking a particular object in dynamic events.

1. Introduction

In recent years' numerous contributions dedicated to image filtering techniques have aroused, the growing interest is supported by the novel emergent applications for smartphones, computer vision, machine learning, among others. There exists several and powerful image filtering techniques oriented to different purposes [1], and in this context the edge detection techniques have a proven relevance by making possible the identification and isolation from a particular object in a given scene. From optics field, the spiral phase filtering is a well-known technique, which allows for the enhancement of object edges in an image, this may be performed with orientation selectiveness and high noise tolerance [2–5].

The edge enhancement is a must-have operation between the image processing tools. This operation is useful in a wide range of applications from cosmological to microscopy imaging [6,7], because large amount of information can be learned from images, by the sharp edge identification from objects in a scene; the recovered data will depend on the processed information nature. The edge enhancement process can be accomplished by the usage of different filtering techniques.

* Corresponding author at: Department of Computer Engineering and Computer Science, Duthie Center for Engineering University of Louisville, Louisville, KY, United States.
E-mail address: d.sierrasosa@louisville.edu (D. Sierra-Sosa).

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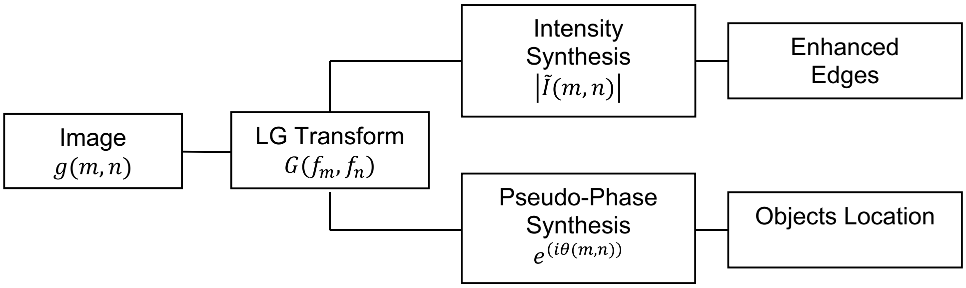

Fig. 1. Procedure scheme for both edge enhancement and object sub-pixel location.

By means of a converging lens it is possible to obtain the Fourier transform from information. Taking into advantage this fact, there exists an architecture formed by two converging lenses: one located a focal length apart from an image, the other two focal lengths apart from the latter; then in the plane located at the focal length of this last lens an image is formed, depending on the employed filtering mask on the first lens focal plane, the obtained image output will be modified (filtered). This architecture is commonly known as 4f architecture, and by selecting the adequate filter, the edges may be enhanced with directional selectiveness or in an isotropic manner [8]. An experimental implementation of the latter is presented in [9], where the authors employ a Laguerre-Gauss filter in the 4f architecture to enhance the object edges.

The digital implementation of this filtering technique for edge enhancement can be performed by using the Laguerre-Gauss transform. When using this transform it is possible to obtain a complex valued function from filtered images, even in low signal to noise ratio recordings [10]. With the complex information it is possible not only to find edges from a given object in a scene, but also to relate phase singularities to each object. A phase singularity will occur in those places where the real and imaginary parts are null. These singularities give each particular object a characteristic mark, which can be followed between different images or frames within a video or animation. The related phase singularities are used as image markers, giving the possibility to track several objects from different scenes or recordings, by matching the core structure properties from each of them [11].

In this paper, we propose the usage of complex fields obtained when filtering, allowing for synthesizing both the location and edges from objects in a given scene. In Section 2 we describe the process to synthesize the complex-valued information obtained by performing a Laguerre-Gauss transform from frames in a dynamic event. In Section 3 we present the results by using the procedure described in Section 2. First we present the processing of MRI images by using Laguerre-Gauss transform as stated in literature [2–5], second we present the complex field synthesis for video frames in a real video of an expanded polystyrene ball in a vibrating surface and in a simulated orbital movement of four particles. In the expanded polystyrene ball case, we tracked the phase singularities from pseudo-phase maps by matching its core structure properties. In the last example, we identify each object in a given scene by using simultaneously the intensity and pseudo-phase map information. Finally, each object trajectory can be determined.

2. Edge enhancement and tracking procedure description

The filtering and tracking process is accomplished by transforming the image of discrete spatial coordinate's m and n with Laguerre-Gauss transform, the output of this operation is a complex field related to the real-valued function from the image. Those complex fields can be interpreted as intensity and pseudo-phase maps, the field intensity will determine the objects edges within a scene, and pseudo-phase map synthesis in the context of phase singularities will determine the object location. This process is schematized in Fig. 1, and is conducted for each frame into dynamic events allowing for identify and track the motion of a given object in a scene.

To achieve this, for a given real valued function $g(m,n)$ its Fourier Transform $G(f_m, f_n)$ is obtained. It is possible to relate an analytic complex signal $\tilde{I}(x,y)$ by using a linear integral transform, where a Laguerre-Gauss filter $LG(f_m, f_n)$ is employed, the transform and the filter are described by [12]:

$$\tilde{I}(x,y) = \iint_{-\infty}^{\infty} LG(f_m, f_n)\, G(f_m, f_n)\, e^{2\pi(f_m x, f_n y)} df_m, df_n \quad (1)$$

$$LG(f_m, f_n) = (f_m + if_n)\, e^{-(f_m^2+f_n^2)/\omega} = \rho e^{-(\rho^2/\omega^2)} e^{i\beta} \quad (2)$$

where $\rho = \sqrt{f_m^2 + f_n^2}$ and $\beta \equiv arctan\left(f_n/f_m\right)$ are the polar coordinates in the frequency domain and ω allows for controlling the bandwidth of the Laguerre-Gauss function. This transform can be applied over images and video frames as well, by defining the transform as the convolution from image with the inverse Fourier transform from filter. This provides a powerful tool to analyze and synthesize the information by relating a particular complex signal to each record, and in this manner obtain the intensity and pseudo-phase map in each case.