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Radial snakes: Comparison of segmentation methods in synthetic noisy images

Jéssyca Almeida Bessa [a,*], Paulo César Cortez [b], John Hebert da Silva Félix [c], Ajalmar Rêgo da Rocha Neto [a], Auzuir Ripardo de Alexandria [a]

[a] *Instituto Federal de Educação, Ciência e Tecnologia do Ceará, Brazil*
[b] *Universidade Federal do Ceará, Brazil*
[c] *Universidade da Integração Internacional da Lusofonia Afro-Brasileira, Brazil*

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A B S T R A C T

There has been a growing use of digital image processing since the 90's. To process an image it must be transformed successively in order to extract information more easily. The first steps in an image analysis are the acquisition followed by the preprocessing to prepare the image for the next step. This step is called image segmentation which is the process of separating different regions of the image according to their properties. The segmentation process is fundamental for all image analyses, as the final result is essentially dependent on the quality of the segmentation. Highlighted among these techniques are the active contour systems, known as snakes. The active contour methods can be subdivided in two main groups: two-dimensional search (traditional) and one-dimensional search (radial). The radial active contours were developed in order to obtain a smaller computational cost. The aim of this work was to study, evaluate and compare algorithms of radial active contours in synthetic noisy images and thus identify the advantages and disadvantages of each method in order to point out the most appropriate method for a given application. This work makes a quantitative and qualitative comparison of three methods: Traditional Radial Snakes, Hilbert Radial Snakes and pSnakes. The results of this research are suitable for academic research as they show that the recently developed pSnakes method is effective in image segmentation with noise. This paper also considered the processing time of the different methods.

1. Introduction

Biological vision is one of the main ways for humans to explore the world, performing complex functions naturally, such as: analysis, interpretation and recognition and pattern classification. Thus, many researchers attempt to produce artificial vision systems with the same efficiency as the biological system.

Computer Vision Systems are defined as computer systems capable of acquiring, processing and interpreting correspondent images of real scenes (Brigger, Hoeg, & Unser, 2000). The first step in a vision system is the image acquisition. Generally the image is submitted for pre-processing after the acquisition. This step involves noise filtering and correction of geometric distortions introduced by the sensor. The pre-processing is necessary before submitting the image to segmentation (Malassiotis & Strintzis, 1999). Appropriate methods of segmentation, an essential step of image analysis, are required for a Computer Vision System (Gonzalez & Woods, 2010).

Image segmentation is a process in which the image is divided into homogeneous regions or parts that may represent one or more objects of interest, according to some uniformity criterion (Melo-Pinto et al., 2013; Shan, He, & Wang, 2014). However this task is still highly complex for computational systems, especially to overcome two of most apparent problems: quantification and qualification of information represented by many different ways such as gray-level intensity, edges, contours and texture. These features are naturally sought by the human visual system when the evaluated signal is an image (Jain, Duin, & Mao, 2000). The goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze. The choice of a particular technique depends on the type of image and the expected result (Harangi & Hajdu, 2014). The analysis of which method has higher accuracy depending on the image geometry is of utmost importance.The active contours is a methods have been that is applied with success to several problems of

* Corresponding author.
E-mail addresses: bessajessyca@gmail.com (J.A. Bessa), cortez@lesc.ufc.br (P.C. Cortez), jhsfelix@gmail.com (J.H. da Silva Félix), ajalmar@gmail.com (A.R. da Rocha Neto), auzuir@gmail.com (A.R. de Alexandria).

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image processing and Computer Vision, such as edge detection and object tracking, among others.

Active contours or snakes were introduced by Kass, Witkin, and Terzopoulos (1987). This technique allows images to be segmented using edge detection. The result of image segmentation is a set of segments that collectively cover the entire image, or a set of contours extracted from the image (Hafiane, Vieyres, & Delbos, 2014). This method has been successfully applied to many problems of image processing and Computer Vision even under low signal/noise ratio situations.

However, it cannot be applied to all cases of image segmentation due to problems such as inappropriate runtime, requirements for the automatic selection of initial contours, non-convergence in situations of low sharpness, poorly defined edges or no edges. Therefore other approaches have been proposed in some papers, such as Self-Organizing Active Contour model for image segmentation (Abdelsamea, Gnecco, & Gaber, 2014), Novel Adaptive Balloon Active Contour Method (Filho, Cortez, da Silva Barros, & de Albuquerque, 2014), Fusing multiple active contours (Harangi & Hajdu, 2014), Aided geodesic active contours (Shan et al., 2014), Size-adapted segmentation (Arikidis et al., 2008), Active contour model based on fuzzy speed function (Chen, Li, fang Tian, bo Zhu, & han Bao, 2014; Tran, Pham, & Shyu, 2014), Active contours based on IIR filtering (Delibasis, Asvestas, Kechriniotis, & Matsopoulos, 2014), hybrid active contour model with structured feature (Ge, Li, Shao, & Li, 2015), Active contour model driven by local and global intensity fitting energies (Jiang, Li, Wang, & Chen, 2014; Mandal, Chatterjee, & Maitra, 2014) and Radial active contours (Chen, Huang, & Rui, 2001).

The motivation to compare the Radial active contour method is related to the lack of a tool capable of solving all kinds of analyses due to the peculiar attributes of each type of image in real-time. Thus, the main aim of this work is to carry out a comparative study of methods based on the radial active contour methods, such as Traditional Radial Snakes, radial snakes with Hilbert energy, and, finally, analyze a new method called pSnakes (de Alexandria et al., 2014). The concept of radial active contours is relatively new. Radial active contours were developed in order to decrease the computational complexity of the active contour methods and consequently real-time applications (Gemignani, Faita, Ghiadoni, Poggianti, & Demi, 2007). The energy calculation and its minimization are performed in one dimension (1D) (polar coordinates), thus making them faster. These methods were applied and evaluated in the segmentation of synthetic noisy images that can reproduce failures and noise in real images.

The paper is organized as follows: In Section 2, we provide a brief literature review of the algorithms for active contours and a review of the major works of radial snakes.

2. A brief literature review of active contours

2.1. Active contours (snakes)

This model is one of the techniques for image segmentation that was introduced by Kass et al. (1987) to segment images by edge detection. This method is applied with success to several problems of image processing and Computer Vision, such as edge detection and object tracking, among others. There is no perfect solution for all cases, because the uniqueness of each problem is characterized by specific images. However, the snakes technique was able to solve problems in which edge detection by gradient did not succeed because of low contrast contours, the presence of noise, and other reasons.

This method consists of drawing curves, starting outside or inside the object of interest. This curve is molded, and deformed by some different forces like a snakes that and moves like a snake until it finds the edges of the object in question. This edge approach is performed through successive minimization iterations of a previously specified energy (Maksimovic, Stankovic, & Milovanovic, 2000). These forces are related to the functions that rule the contour. According to Filho et al. (2014) the curve behaves like an elastic band that once around an object it shrinks to get closer to the contours of the object. Traditional active contours were have been applied in several areas such as: Medical Engineering (de Alexandria et al., 2014; Harangi & Hajdu, 2014; Hafiane et al., 2014), Pattern Recognition (Shan et al., 2014) and Mechanical Engineering.

However, the control points of these curves must be initialized close to the contour of interest to ensure convergence in non-iterative models (Kass et al., 1987). The curve also has difficulties to converge in concave regions because the parameterization of the internal energy of its own contour hinder the geometric flexibility due to opposing horizontal force vectors that annul themselves, blocking the evolution of the curve (Davatzikos & Prince, 1995; Xu & Prince, 1998).

In order to overcome the limitations of the traditional method of active contours (two-dimensional) and looking for a lower computational cost, radial models were developed (Denzler & Niemann, 1996).

2.2. Radial active contours

The traditional active contours method is based on Variational Methods. The goal is to minimize a function representing the snake energy. These methods use Cartesian coordinates. The radial active contour methods uses polar coordinates instead of Cartesian coordinates to locate the control points (nodes) (Chen et al., 2001). This method is less computationally complex than the traditional active contour methods because the energy minimization calculations are performed in one dimension. Thus this method is faster and has more uses for real time applications (Liang, Ding, & Wu, 2008).

The initial concept of edge detection in digital image processing by radial beams was not directly used in the active contours methods. Buda et al. (1983) anticipated the need to use polar coordinates to effect the edge detection of the object of interest from the center of the object. In this work, spaced rays at a certain angle depart from the object center and are used to detect edges, transforming the two-dimensional problem to a one dimensional problem.

One of the most well-known and relevant radial snakes is called Active Rays. The technique was developed by Denzler and Niemann (1996) and is applied to trace the outlines of objects in real time. The idea is to define a point of origin inside the boundary

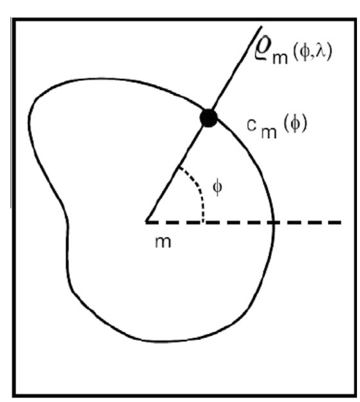

Fig. 1. Representation of Active Rays (Denzler & Niemann, 1996).