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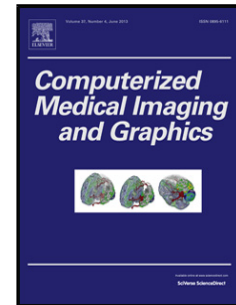Please cite this article as: Pawel Badura, Virtual bacterium colony in 3D image segmentation, <![CDATA[*Computerized Medical Imaging and Graphics]]>* (2017), http://dx.doi.org/10.1016/j.compmedimag.2017.04.004

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Virtual bacterium colony in 3D image segmentation

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Abstract

Several heuristic, biologically inspired strategies have been discovered in recent decades, including swarm intelligence algorithms. So far, their application to volumetric imaging data mining is, however, limited. This paper presents a new flexible swarm intelligence optimization technique for segmentation of various structures in three- or two-dimensional images. The agents of a self-organizing colony explore their host, use stigmergy to communicate themselves, and mark regions of interest leading to the object extraction. Detailed specification of the bacterium colony segmentation (BCS) technique in terms of both individual and social behavior is described in this paper. The method is illustrated and evaluated using several experiments involving synthetic data, computed tomography studies, and ultrasonography images. The obtained results and observations are discussed in terms of parameter settings and potential application of the method in various segmentation tasks.

Keywords: artificial intelligence, multiagent systems, swarm intelligence, image segmentation, computer-aided diagnosis

1. Introduction

Image processing and analysis is a widely developed and used engineering activity nowadays. On one hand, civilization of the first decades of the 21st century is a more picture-based civilization than ever, mainly due to globalization mechanisms and expansion of social networks. On the other hand, the rapid and symbiotic growth of medicine and technique produces terabytes of imaging data of various modalities, like computed tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET), or ultrasonography (US). Such huge amount of diverse image data – traditional images, medical imaging 3D volumes or movies – involves wide interest in dedicated information technologies: image processing and analysis. Although available tools become still more efficient in terms of storage space or CPU speed, the chase continues and remains challenging. Image segmentation stands for one of the basic tasks in the above field of interest as a foundation for further cognitive analysis. It groups the image points into separate regions corresponding to some logically connected objects within the image [1]. Many techniques being rather image processing tools have been employed into segmentation including mathematical morphology and watershed [2, 3], hard or fuzzy clustering [4, 5, 6], fuzzy connectedness [7, 8, 9], level sets [10, 11], deformable models [12], or intelligent scissors [3, 13]. Segmentation techniques can be organized into several families: region- or edge-based, interactive, semi-, or fully-automated, operating on 2D or multidimensional images [14,

15, 16]. It is, however, hard to define a universal segmentation approach. Mostly, the algorithm is highly problem-dependent in terms of image source and dimensionality, type of organ, and its appearance within the image. The algorithm designed for computer-aided diagnosis (CAD) has to be able to provide a reliable outcome in a reasonable time [17]. In some cases such a requirement precludes techniques, whose complexity might be acceptable in case of the 2D images, from being adapted into volumetric or space-time analysis.

One of the ideas, well known, yet perhaps still not explored enough in the discussed area, is to handle such problems by means of heuristic tools. They offer an attractive trade-off: a shorter computational time for uncertainty of solution. Obviously, the level of certainty have to be high enough to accept the result, being the key in the development of heuristic, biocybernetic algorithms, often classified as artificial intelligence (AI) [18]. The designer collects specific knowledge by observing the real world, living organisms, natural information systems, social behaviour of human or animal communities and then tries to model and imitate them in the computer system.

The AI branch most widely used in the area of image segmentation is probably the fuzzy logic, sets an systems; several fuzzy tools have already been mentioned in this paper. Also, the artificial neural networks (ANN) are willingly employed here [19]. In general, CAD often involves intelligent expert systems, based on some knowledge acquired during experiments and collected as a rule base [20, 21]. A different look at the system intelligence emerges from the evolutionary and multiagent systems.

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