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Granular computing in model based abdominal organs detection

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ABSTRACT

Detection of region specific voxel is a true challenge in many segmentation procedures. In this study a concept of implementing granular computing in the detection of anatomical structures in abdominal computed tomography (CT) scans is introduced. After proving the usefulness of the information granules to identify voxels that mark certain organs, an automatic model-based approach has been developed. A three-parameter granule that combines the interval and density distribution of voxels has been introduced and employed to identify organ specific voxels of the liver, spleen and kidneys. The specificity of the information granules varies between 90 and 99% for the liver and spleen and over 85% for the kidneys.

1. Introduction

Many segmentation approaches have been developed [1,2], yet most of them suffer from a requirement of a manual detection of initial points or seed points, or the boundary of organs to be delineated [3]. The analysis becomes very time consuming when the interaction is required at each slice of a 3D study [4,5]. The most prominent method already suggested to detect seed points and support the segmentation process is based on models [6,7]. Single probabilistic atlas as well as multi-atlas approaches [8] have been used in the segmentation of various regions [7]. In the current study an approach based on granular computing [9] is introduced. The concept, although extensively explored [10–13], has not been widely employed in image analysis.

First attempts have been made in 2005 by Pal et al. [14], who have defined a measure called "rough entropy of image". The composition of rough sets [15] and granular computing has been demonstrated for object extraction from gray scale image. The threshold level of segmented objects has been determined by optimization of the image rough entropy measure. The same method – with some modifications – has been used to detect moving objects in video sequences [16]. Moreover, in [17] the authors proposed a new algorithm based on granular multilevel rough entropy evolutionary thresholding.

Although medical image segmentation is a problem widely described in the literature [4], granular computing based methods are not common and limited to brain MRI scans, which are characterized by greater range of available soft tissue contrast than CT images. In [18] a hybrid method is proposed, consisting of a segmentation of the brain, with the granular rough set approach, and separation of brain white matter, with fuzzy thresholding. The results have been compared with the mean shift algorithm [19] with the following coefficients: Jaccard, Dice Similarity, Tanimoto, and Volume Similarity [20].

Yang et al. [21] introduced the rough fuzzy set model and performed an analysis of selecting an optimal threshold level, that minimizes some defined type of rough entropy of the image. The authors demonstrated results of the structure segmentation in a MR brain and a skull X-ray image.

The ultimate objective of this study is to introduce a concept of implementing granular computing in the detection of anatomical structures in 3D abdomen images. In brief, given a set of voxel, that forms a clinical image, a representative information granule is formed. It reflects the nature of an organ and differentiates it from its background and the neighboring structures. The information granule has been employed to a model based organ extraction procedure in order to evaluate the robustness of the process and the applicability of the granular computing concept to an automated image analysis methodology.

The paper is structured as follows. Section 2 introduces two approaches. The first one, based on a manual extraction of the initial region of selected anatomical structures, evaluates the robustness of granular computing and its applicability to the problem of extracting an information granule for each organ. The second approach introduces a model employed to automatically extract

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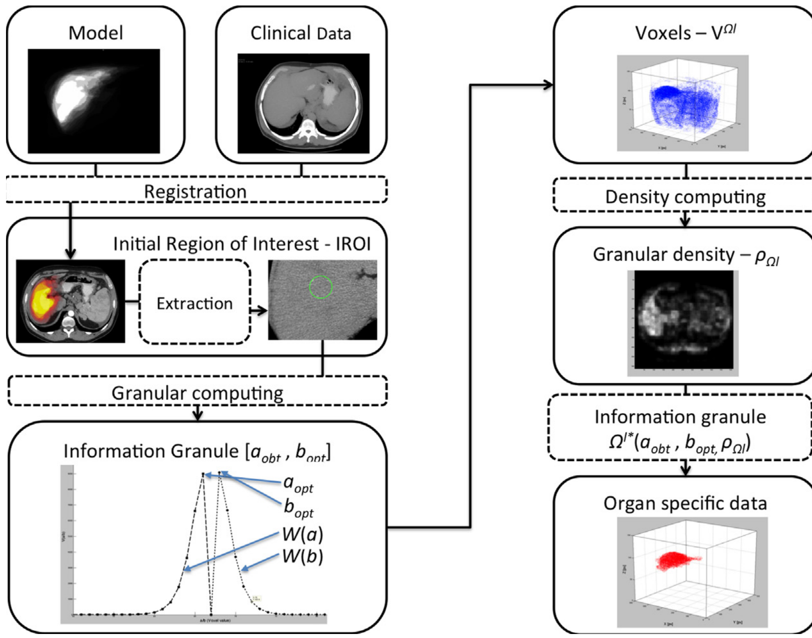

Fig. 1. Workflow of the presented method.

the initial region and subject it to the granular computing analysis. Section 3 describes the experiments and presents the results. Section 4 concludes the study.

2. Method

The overall method contains two phases. First, an interactive method has been introduced in order to prove the hypothesis, that granular computing may be applicable in the image analysis field. Second, a model based fully automatic approach has been introduced (Fig. 1). Its goal is to extract certain anatomical regions that exhibit a significant level of specificity. In this study the liver, the spleen, and the kidneys are considered.

2.1. *Granular computing in the extraction of abdominal organs*

In the image analysis systems the segmentation phase is a crucial element. We anticipate, that the area to be extracted reflects the experimental data with as minimal over-detection as possible [22]. Thus, the system should exhibit a significant level of specificity [23]. In terms of granular computing approach this means, that we would like to have a very compact information granule. The

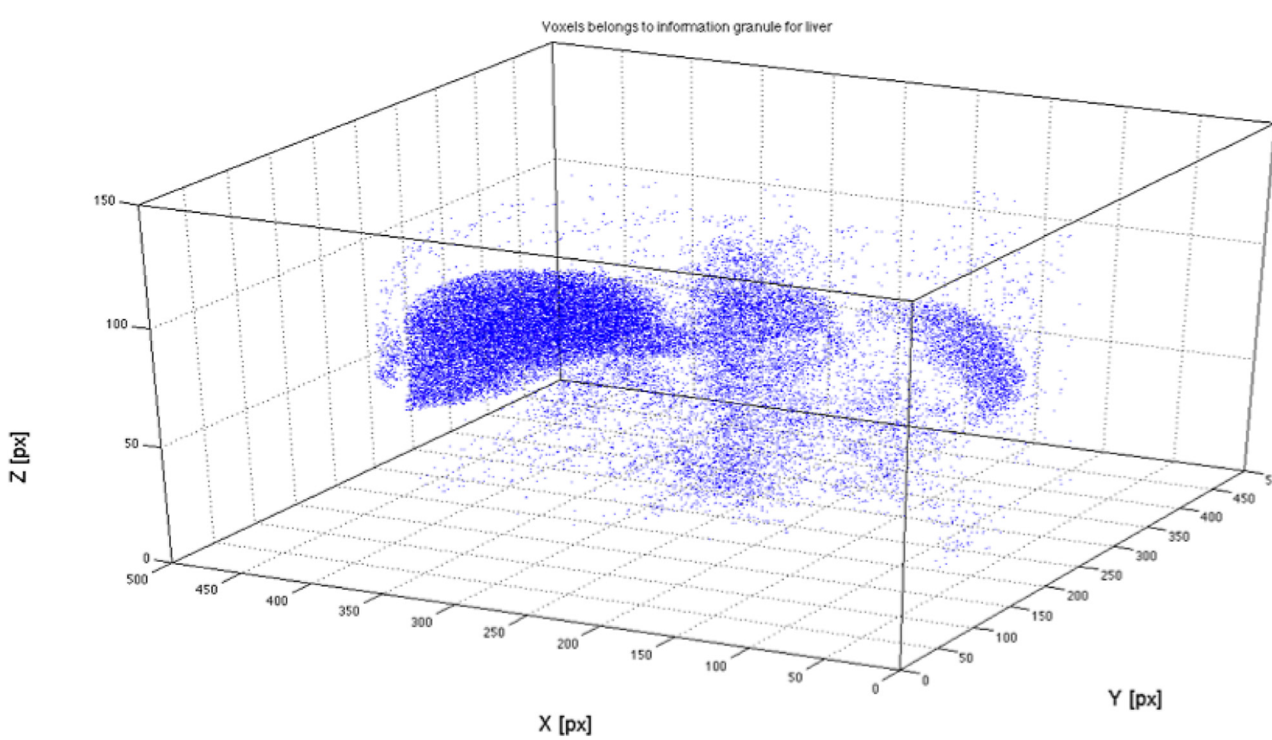

Fig. 2. Distribution of liver voxels determined by the granular information.