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ORIGINAL ARTICLE

Intensity-Curvature Measurement Approaches for the Diagnosis of Magnetic Resonance Imaging Brain Tumors

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A B S T R A C T

This research presents signal-image post-processing techniques called Intensity-Curvature Measurement Approaches with application to the diagnosis of human brain tumors detected through Magnetic Resonance Imaging (MRI). Post-processing of the MRI of the human brain encompasses the following model functions: (i) bivariate cubic polynomial, (ii) bivariate cubic Lagrange polynomial, (iii) monovariate sinc, and (iv) bivariate linear. The following Intensity-Curvature Measurement Approaches were used: (i) classic-curvature, (ii) signal resilient to interpolation, (iii) intensity-curvature measure and (iv) intensity-curvature functional. The results revealed that the classic-curvature, the signal resilient to interpolation and the intensity-curvature functional are able to add additional information useful to the diagnosis carried out with MRI. The contribution to the MRI diagnosis of our study are: (i) the enhanced gray level scale of the tumor mass and the well-behaved representation of the tumor provided through the signal resilient to interpolation, and (ii) the *visually perceptible* third dimension perpendicular to the image plane provided through the classic-curvature and the intensity-curvature functional.

Introduction

The organization of the manuscript

The manuscript is organized as follows. The literature is addressed thoroughly in the introduction and discussion sections so as to relate it to the main research topic of the paper which is that one of proposing post-processing techniques (Intensity-Curvature Measurement Approaches) in order to collect from MRI complementary and/or additional

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information of the human brain tumor, and so to aid the diagnosis of the tumor. The mathematical formulation of the Intensity-Curvature Measurement Approaches is placed in the manuscript in the methodology section. The results are presented through images resulting from the Intensity-Curvature Measurement Approaches. There is immediate correlation between: (i) the concepts (Intensity-Curvature Measurement Approaches) treated by the paper in theoretical form (through the formulae given in the section titled: 'The mathematical formulation'), and (ii) the results presented through the images obtained from the application of the concepts. The discussion section places the emphasis on the significance of the results. The conclusion section is a stand alone paragraph which conveys to the reader what the paper reports.

The motivation of the literature review

The review of related work is preparatory to the statement of the working hypothesis which is given in the subsection titled: 'The contribution of the present works'. Therefore, the category of the literature reviewed is the one that focuses on MRI derived techniques which provide complementary and/or additional information to T1-weighted MRI. For instance, T2-weighted MRI is of help in the visualization of the human brain fat and water, which, if imaged with T1-weighted MRI, would not be seen as clearly when using T2-weighted MRI. Another example of collection of complementary and/or additional information is the use of the contrast agent in T1-weighted MRI. Thus, the paper reviews the literature while searching for evidence of MRI techniques based collectible information which is capable of complementing and adding to the information collected with T1-weighted MRI. Advantages, disadvantages and motivations to the use of the various and different MRI techniques are already known in the literature. Comparison between MRI techniques is beyond the scope of this manuscript. The scope of the present works is to present the signal-image post-processing techniques called Intensity-Curvature Measurement Approaches and to frame the techniques into the scientific literature as valuable methodology employable to collect complementary and/or additional information from T1-weighted MRI, T2-weighted MRI and Fluid Attenuated Inversion Recovery (FLAIR) imaging modalities.

The literature

Human brain tumor detection through the use of Magnetic Resonance Imaging (MRI) is a widespread technique for the diagnosis. MRI provides the information related to the anatomy of the pathology and such information is used in order to classify the tumor. The tumor embeds in its structure the key to the correct diagnosis and moreover embeds details that can be enhanced through the post-processing of the MRI images [1–3].

Human brain tumor detection can be performed and disease progression can be monitored by a variety of MR techniques [4] among which are here recalled: Diffusion Weighted Imaging (DWI), Diffusion Tensor Imaging (DTI), Proton MR Spectroscopic Imaging (MRS), Perfusion MR Imaging (PWI), and Dynamic Susceptibility Weighted Contrast-Enhanced (DSC) MR Imaging. However, enhanced T1-weighted Imaging is the most useful diagnostic technique and also the most used to monitor the progression (regression) of the disease [4]. Additionally, MR Imaging techniques have progressed to the level of being able to monitor molecule movements, the microvascular integrity and hemodynamic characteristics, and the chemical characteristics of some chemical compounds [5].

The literature reports a wide array of MR applications to the study and the diagnosis of human brain tumors. Distinction between radiation necrosis and brain metastasis was achieved with PET co-registered to MRI [6]. Another approach to the study of the human brain tumor is the one that makes use of T2-weighted images and maps of absolute regional cerebral blood flow (rCBF) derived from arterial spin labeling (ASL) [7]. The capability to make an accurate diagnosis of abscesses and cystic/necrotic brain tumors using Diffusion Weighted Imaging has been studied through research which made use of T1-weighted and T2-weighted MRI [8]. Within the context of the study of the assessment of an improved diagnosis of cerebral gliomas a study [9] reports the use of PET and MRI used with co-registration. Also, a recent study [10] used pre-contrast and post-contrast Susceptibility Weighted Imaging (SWI) in order to assess the diagnosis of brain neoplasms. Another study reports findings subsequent to the Magnetic Resonance Spectroscopy (MRS) study of a brain hemangioblastoma [11].

The literature shows that MRS is a source of additional information to the one collected through the use of T1-weighted MRI [12]. The information collected through MRS is on tumor malignancy and characteristic tumor metabolism [12]. However, it was argued that proton MRS alone is not comparable to MRI in the diagnosis of the brain tumor and thus it was proposed that pattern recognition of the biochemical information obtained with proton MRS can make an accurate diagnosis of the tumor [13]. As far as regards the use of computer based techniques for tumor type classification and grading is concerned, a study which uses pattern classification of data obtained through MRI and perfusion MRI was used and proved useful to the diagnosis of the tumor [14].

The use of contrast-enhanced computed tomography (CCT) for the diagnosis of brain metastases was investigated in comparison with MRI and the findings were in favor of the accuracy of the diagnosis through the use of MRI [15]. Another approach uses a comparison of MRI with Diffusion Weighted Imaging (DWI) while studying brain abscess and cystic or necrotic brain tumors, and finds that DWI, specifically to the results reported in the study, performs better than T1-weighted imaging [16]. T1-weighted imaging was also used in order to detect brain tumors and/or affections of the vascular system [17]. Insights into tumor pathogenesis were collected during a study that uses cancer stem cell (CSC) in mouse brains [18]. In order to assess both tumor cellularity and the grading of the gliomas, a study reports on a technique based on the use of diffusion-weighted Magnetic Resonance Imaging with echo-planar imaging (EPI) [19], which proves useful to the diagnosis and the characteristics of the gliomas. MRI has also been proven useful to fetal MRI [20].

The contribution of the present works

Recent studies have employed post-processing techniques in order to gain information from the human brain tumor MRI