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Detection of Curvilinear Structure via Recursive Anisotropic Diffusion

Authors : Sardorbek Numonov, Hyohun Kim, Dongwha Shin, Yeonseok Kim, Ji-Su Ahn, Dongeun Choi, Byung-Woo Hong

Abstract : The detection of curvilinear structures often plays an important role in the analysis of images. In particular, it is considered as a crucial step for the diagnosis of chronic respiratory diseases to localize the fissures in chest CT imagery where the lung is divided into five lobes by the fissures that are characterized by linear features in appearance. However, the characteristic linear features for the fissures are often shown to be subtle due to the high intensity variability, pathological deformation or image noise involved in the imaging procedure, which leads to the uncertainty in the quantification of anatomical or functional properties of the lung. Thus, it is desired to enhance the linear features present in the chest CT images so that the distinctiveness in the delineation of the lobe is improved. We propose a recursive diffusion process that prefers coherent features based on the analysis of structure tensor in an anisotropic manner. The local image features associated with certain scales and directions can be characterized by the eigenanalysis of the structure tensor that is often regularized via isotropic diffusion filters. However, the isotropic diffusion filters involved in the computation of the structure tensor generally blur geometrically significant structure of the features leading to the degradation of the characteristic power in the feature space. Thus, it is required to take into consideration of local structure of the feature in scale and direction when computing the structure tensor. We apply an anisotropic diffusion in consideration of scale and direction of the features in the computation of the structure tensor that subsequently provides the geometrical structure of the features by its eigenanalysis that determines the shape of the anisotropic diffusion kernel. The recursive application of the anisotropic diffusion with the kernel the shape of which is derived from the structure tensor leading to the anisotropic scale-space where the geometrical features are preserved via the eigenanalysis of the structure tensor computed from the diffused image. The recursive interaction between the anisotropic diffusion based on the geometry-driven kernels and the computation of the structure tensor that determines the shape of the diffusion kernels yields a scale-space where geometrical properties of the image structure are effectively characterized. We apply our recursive anisotropic diffusion algorithm to the detection of curvilinear structure in the chest CT imagery where the fissures present curvilinear features and define the boundary of lobes. It is shown that our algorithm yields precise detection of the fissures while overcoming the subtlety in defining the characteristic linear features. The quantitative evaluation demonstrates the robustness and effectiveness of the proposed algorithm for the detection of fissures in the chest CT in terms of the false positive and the true positive measures. The receiver operating characteristic curves indicate the potential of our algorithm as a segmentation tool in the clinical environment. This work was supported by the MISP(Ministry of Science and ICT), Korea, under the National Program for Excellence in SW (20170001000011001) supervised by the IITP(Institute for Information and Communications Technology Promotion).

Keywords : anisotropic diffusion, chest CT imagery, chronic respiratory disease, curvilinear structure, fissure detection, structure tensor

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