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Abstract

This paper presents a new set of three-dimensional rotation invariant texture descriptors based on the well-known local binary patterns (LBP). In the approach proposed here, we extend an existing three-dimensional LBP based on the region growing algorithm using existing features developed exquisitely for two-dimensional LBPs (pixel intensities and differences). We have conducted experiments on a synthetic dataset of three-dimensional randomly rotated texture images in order to evaluate the discriminatory power and the rotation invariant properties of our descriptors as well as those of other two-dimensional and three-dimensional texture descriptors. Our results demonstrate the effectiveness of the extended LBPs and improvements against other state-of-the-art hand-crafted three-dimensional texture descriptors on this dataset. Furthermore, we prove that the extended LBPs can be used in medical datasets to discriminate between MR images of oxygenated and non-oxygenated brain tissues of newborn babies.

Keywords: Local binary patterns (LBP), Three-dimensions, Rotation invariance, Texture classification

1. Introduction

1.1. Context

Texture analysis is a key topic in image processing and computer vision, playing an important role in medical and industrial applications. Texture is a fundamental property of physical objects that, when captured on image, may suffer from noise, illumination changes, occlusions, viewpoints or scale variations. Producing high discriminant descriptors invariant with respect to grey-scale changes as well as to rotation is essential in order to solve many real-world problems. With the advent of three-dimensional images, textures have become more complex and full of information leading to extremely interesting applications. Although two-dimensional texture analysis methods have become very powerful, in three-dimension, these approaches may result in the loss of important information with consequent non-optimal results. An appropriate characterisation of textures in three-dimensions is therefore crucial for the development of state-of-the-art systems as for cases such as the analysis of MR images (Kovalev et al., 2001) or modelling and recognition of 3D biomedical textures (Depeursinge et al., 2014; Majtner and Svoboda, 2014). Among the most popular two-dimensional texture methods, the local binary patterns (LBP) have gained a great deal of attention in many applications and research studies in the last decade (Ahonen et al., 2006; Liu et al., 2012; Ojala et al., 2002; Sorensen et al., 2010). In contrast, the three-dimensional implementations of local binary patterns are very few and often do not fully match the necessary requirements. Zhao and Pietikäinen (2006, 2007b,a) introduce for the first time the concept of three-dimensional local binary pattern by proposing two novel approaches to analyse dynamic textures. The first method ($VLBP$) consists of stacking multiple classic LBP operators on top of each other forming a spiral whereas the second method ($LBP-TOP$) consists in placing three descriptors in an orthogonal fashion. Paulhac et al. (2008) propose a three-dimensional fully rotation invariant LBP descriptor based on a region growing algorithm and the so called uniform patterns. Fehr and Burkhardt (2008) attempted to classify 3D volume data exploiting the LBP method and the spherical harmonics (SH). In a similar way, Banerjee et al. (2013) propose a descriptor by exploiting the spherical harmonics but unlike Fehr and Burkhardt (2008) the rotation invariance is obtained without searching for the minimum correlation over all angles. Another interesting method is proposed by Liu et al. (2011) who developed a novel three-dimensional fully rotation invariant LBP based on unique rotation, reflection and translation invariant patterns. This method is based on the extraction in advance of all possible congruent patterns which are then clustered in order to identify all the unique shapes defining a texture.

In addition to these papers, there is a considerable number of publications related to local binary patterns and the work we present here. Majtner and Svoboda (2014) present a comparison of 2D and 3D texture descriptors on biological data. The volume LBP $VLBP$ and the $LBP-TOP$, as well as four variants of non-rotation invariant 3D LBP built from four Platonic solids frames are investigated in their paper. The

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