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Rotational Projection Statistics for 3D Local Surface Description and Object Recognition

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Abstract Recognizing 3D objects in the presence of noise, varying mesh resolution, occlusion and clutter is a very challenging task. This paper presents a novel method named Rotational Projection Statistics (RoPS). It has three major modules: local reference frame (LRF) definition, RoPS feature description and 3D object recognition. We propose a novel technique to define the LRF by calculating the scatter matrix of all points lying on the local surface. RoPS feature descriptors are obtained by rotationally projecting the neighboring points of a feature point onto 2D planes and calculating a set of statistics (including low-order central moments and entropy) of the distribution of these projected points. Using the proposed LRF and RoPS descriptor, we present a hierarchical 3D object recognition algorithm. The performance of the proposed LRF, RoPS descriptor and object recognition algorithm was rigorously tested on a number of popular and publicly available datasets. Our proposed techniques exhibited superior performance compared to existing techniques. We also showed that our method is robust with respect to noise and varying mesh resolution. Our RoPS based algorithm achieved recognition rates of 100, 98.9, 95.4 and 96.0 % respectively when tested on the Bologna, UWA, Queen's and Ca' Foscari Venezia Datasets.

Keywords Surface descriptor · Local feature · Local reference frame · 3D representation · Feature matching · 3D object recognition

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1 Introduction

Object recognition is an active research area in computer vision with numerous applications including navigation, surveillance, automation, biometrics, surgery and education (Guo et al. 2013c; Johnson and Hebert 1999; Lei et al. 2013; Tombari et al. 2010). The aim of object recognition is to correctly identify the objects that are present in a scene and recover their poses (i.e., position and orientation) (Mian et al. 2006b). Beyond object recognition from 2D images (Brown and Lowe 2003; Lowe 2004; Mikolajczyk and Schmid 2004), 3D object recognition has been extensively investigated during the last two decades due to the availability of low cost scanners and high speed computing devices (Mamic and Bennamoun 2002). However, recognizing objects from range images in the presence of noise, varying mesh resolution, occlusion and clutter is still a challenging task.

Existing algorithms for 3D object recognition can broadly be classified into two categories, i.e., global feature based and local feature based algorithms (Bayramoglu and Alatan 2010; Castellani et al. 2008). The global feature based algorithms construct a set of features which encode the geometric properties of the entire 3D object. Examples of these algorithms include the geometric 3D moments (Paquet et al. 2000), shape distribution (Osada et al. 2002) and spherical harmonics (Funkhouser et al. 2003). However, these algorithms require complete 3D models and are therefore sensitive to occlusion and clutter (Bayramoglu and Alatan 2010). In contrast, the local feature based algorithms define a set of features which encode the characteristics of the local neighborhood of feature points. The local feature based algorithms are robust to occlusion and clutter. They are therefore even suitable to recognize partially visible objects in a cluttered scene (Petrelli and Di Stefano 2011).