

A Field Model for Repairing 3D Shapes*

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Abstract

This paper proposes a field model for repairing 3D shapes constructed from multi-view RGB data. Specifically, we represent a 3D shape in a Markov random field (MRF) in which the geometric information is encoded by random binary variables and the appearance information is retrieved from a set of RGB images captured at multiple viewpoints. The local priors in the MRF model capture the local structures of object shapes and are learnt from 3D shape templates using a convolutional deep belief network. Repairing a 3D shape is formulated as the maximum a posteriori (MAP) estimation in the corresponding MRF. Variational mean field approximation technique is adopted for the MAP estimation. The proposed method was evaluated on both artificial data and real data obtained from reconstruction of practical scenes. Experimental results have shown the robustness and efficiency of the proposed method in repairing noisy and incomplete 3D shapes.

1. Introduction

Suppose we are given a set of RGB/RGB-D images of an object captured at multiple viewpoints. The object in the real world (i.e. 3D space) is then re-constructed using some 3D reconstruction algorithm. Ideally, if an object can be observed in RGB/RGB-D images, it can be well reconstructed. However, in reality we have found that the reconstruction often fails even if the RGB/RGB-D data is complete. This is because the matching of the RGB data in structure-from-motion based reconstruction methods (e.g. [14]) could not be done accurately, specially for objects of uniform colours. For reconstruction methods using depth (e.g. [39, 4]), the missing of depth could also cause the incompleteness. We illustrate several cases of this situation in Fig. 1.

Recent advances of 3D acquisition devices and 3D scene reconstruction research [28, 38, 39, 40, 4] have enabled large-scale acquisition of 3D scene data and this has raised

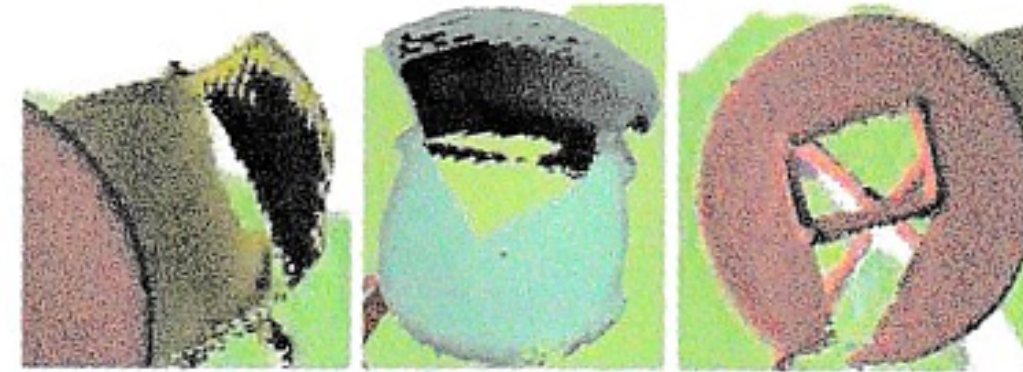


Figure 1. Examples of incomplete shapes after reconstruction using [4].

a demand on 3D data analysis. However, it often happens that the 3D data cannot be obtained at high quality (as shown in Fig. 1), even by recent reconstruction methods, e.g. [4]. Specifically, the 3D surfaces are missing and/or broken and this phenomenon causes difficulties for many sequential tasks such as 3D object detection and recognition [30, 36], shape analysis [20, 19], and scene understanding [32, 12]. Repairing missing and broken surfaces thus plays a critical role and deserves in-depth study. In this paper, we focus on repairing incomplete 3D shapes. This problem can be also referred to as shape completion. We assume objects are not occluded, i.e. they can be fully observed in RGB/RGB-D images. However, this assumption does not mean that objects can be completely reconstructed.

1.1. Related Work

Existing shape completion approaches make use of geometric information represented at either low-level or high-level. Low-level geometry describes local structures, e.g. local smoothness, and can be used to fill small holes on broken surfaces. For example, Curless and Levoy [5] proposed to extract surfaces by examining the boundary of unseen and empty voxels. However, this method requires additional range images to carve away redundant surfaces. In [7], Davis et al. filled gaps and holes on broken surfaces by performing a convolution on the signed distance values. This process was repeated until a new implicit surface could be defined at the gaps. In [16], a broken object was represented in an octree grid on which inner and outer grid points were determined. The broken object was then constructed by contouring the grid points. In [29], holes on a broken

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