Single Depth-image 3D Reflection Symmetry and Shape Prediction

Zhaoxuan Zhang, Bo Dong*, Tong Li, Felix Heide, Pieter Peers, Baocai Yin*, Xin Yang*

Abstract

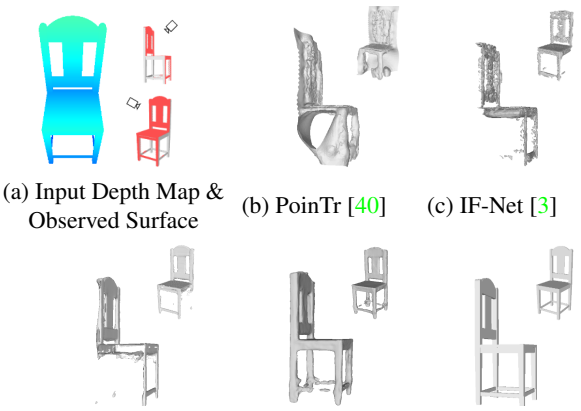
In this paper, we present Iterative Symmetry Completion Network (ISCNet), a single depth-image shape completion method that exploits reflective symmetry cues to obtain more detailed shapes. The efficacy of single depth-image shape completion methods is often sensitive to the accuracy of the symmetry plane. ISCNet therefore jointly estimates the symmetry plane and shape completion iteratively; more complete shapes contribute to more robust symmetry plane estimates and vice versa. Furthermore, our shape completion method operates in the image domain, enabling more efficient high-resolution, detailed geometry reconstruction. We perform the shape completion from pairs of viewpoints, reflected across the symmetry plane, predicted by a reinforcement learning agent to improve robustness and to simultaneously explicitly leverage symmetry. We demonstrate the effectiveness of ISCNet on a variety of object categories on both synthetic and real-scanned datasets.

1. Introduction

Symmetry is an intrinsic geometric property present in the vast majority of man-made and natural objects [12, 17], and which has been exploited to improve the efficacy of applications such as shape matching [12], segmentation [13], object retrieval [8], and robotic grasping [34].

In this paper, we aim to leverage symmetry as an aid for the completion of shapes from partial observations [23, 24, 28]. Recently, Yao *et al*. [39] presented Front2Back, a framework for 3D shape reconstruction from a single RGB image. A key observation in Front2Back is that a (nearly) complete 3D model can be effectively described by a pair of 2.5D visible surface images taken from opposite views (*i.e*., front and back views). Based on this observation, Front2Back completes a shape by synthesizing a back view using a global 3D reflective symmetry plane from a given front view. However, the reconstruction quality is significantly affected by the input front view angle (Figure 1(d)). Moreover, Front2Back assumes the availability of a 'perfect' symmetry plane, which in practice is challenging to obtain from partial observations [21, 22, 45].

*Co-corresponding authors.



(a) Input Depth Map & Observed Surface (b) PoinTr [40] (c) IF-Net [3]

(d) Front2Back [39] (e) Ours (f) Ground Truth

Figure 1. ISCNet more efficiently leverages symmetry cues for robust shape completion from a single depth image compared to prior methods.

We present ISCNet (Iterative Shape Completion Network), a single depth-image shape completion method that explicitly leverages symmetry cues. Our key insight is that symmetry detection and symmetry-based shape completion are complementary tasks that can provide constructive cues to the other task. Symmetry detection can help shape completion by providing object-centric information about missing geometrical features, and shape completion can provide more robust symmetry cues by filling in missing geometry. Departing from existing work [33] that assumes an ideal prediction of the symmetry plane, ISCNet iteratively refines the symmetry plane and the reconstructed shape jointly. Furthermore, unlike Front2Back [39], ISCNet does not rely on the initial input viewpoint to a-priori fix the synthetic back view camera position but instead leverages a trained reinforcement learning (RL) policy to select optimal pairs of reflection viewpoints at each iteration. We empirically found that predetermining the viewpoints is less effective than RL-based viewpoint selection which can more effectively deal with the dynamic shape of a partial point cloud during the refinement process.

Specifically, ISCNet takes as input a single depth image and reprojects it to an incomplete point cloud. Instead of explicitly detecting a symmetry plane, we estimate the pose [30] that aligns the symmetry plane to the X-Y plane. Based on the current estimate of the point cloud and symmetry aligning pose, an RL agent determines a pair of *re-*