R&D SH@WCASE 2023

SCARP: 3D Shape Completion in ARbitrary Poses for Improved Grasping

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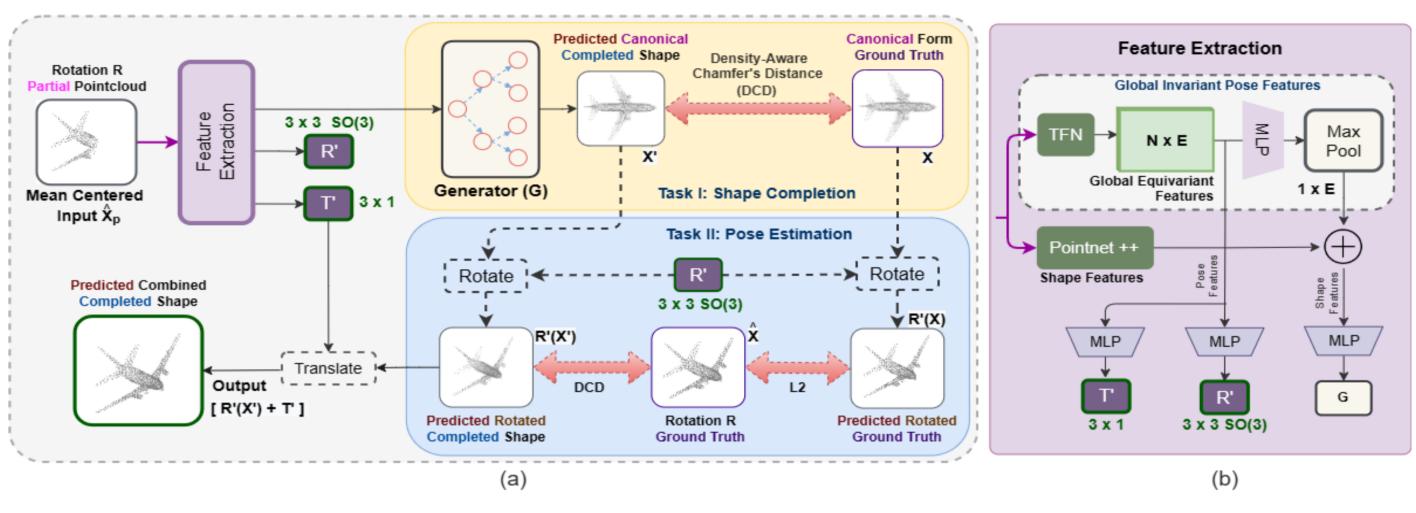
ABSTRACT

Recovering full 3D shapes from partial observations is a challenging task that has been extensively addressed in the computer vision community. Many deep learning methods tackle this problem by training 3D shape generation networks to learn a prior over the full 3D shapes. In this training regime, the methods expect the inputs to be in a fixed canonical form, without which they fail to learn a valid prior over the 3D shapes. We propose SCARP, a model that performs Shape Completion in ARbitrary Poses. Given a partial pointcloud of an object, SCARP learns a disentangled feature representation of pose and shape by relying on rotationally equivariant pose features and geometric shape features trained using a multi-tasking objective. Unlike existing methods that depend on an external canonicalization, SCARP performs canonicalization, pose estimation, and shape completion in a single network.

METHODOLOGY

Our multi-tasking objective is formulated to (1) complete the partial pointcloud X in a fixed canonical frame and (2) estimate the pose transformation from the canonical frame to the original pose {R, T}. In this pipeline, the two components (1) pose and (2) shape are predicted separately using two different output heads. To estimate the input's shape, we compute global geometric shape features, p, using Pointnet++. To estimate the pose of the input, we adapt TFNs to compute a global equivariant feature. The input to our shape completion network is a nonlinear combination of p and a global invariant embedding, F. We train the first head of our model to predict a full canonicalized pointcloud X' directly from X. Shape completion enables our model to learn a prior over the global shape of a category (a typical chair would have four legs and a backrest) enabling our network to directly canonicalize the partial inputs accurately, while predicting R' and T' on the second head of our model.

Examples on Real-World Scans

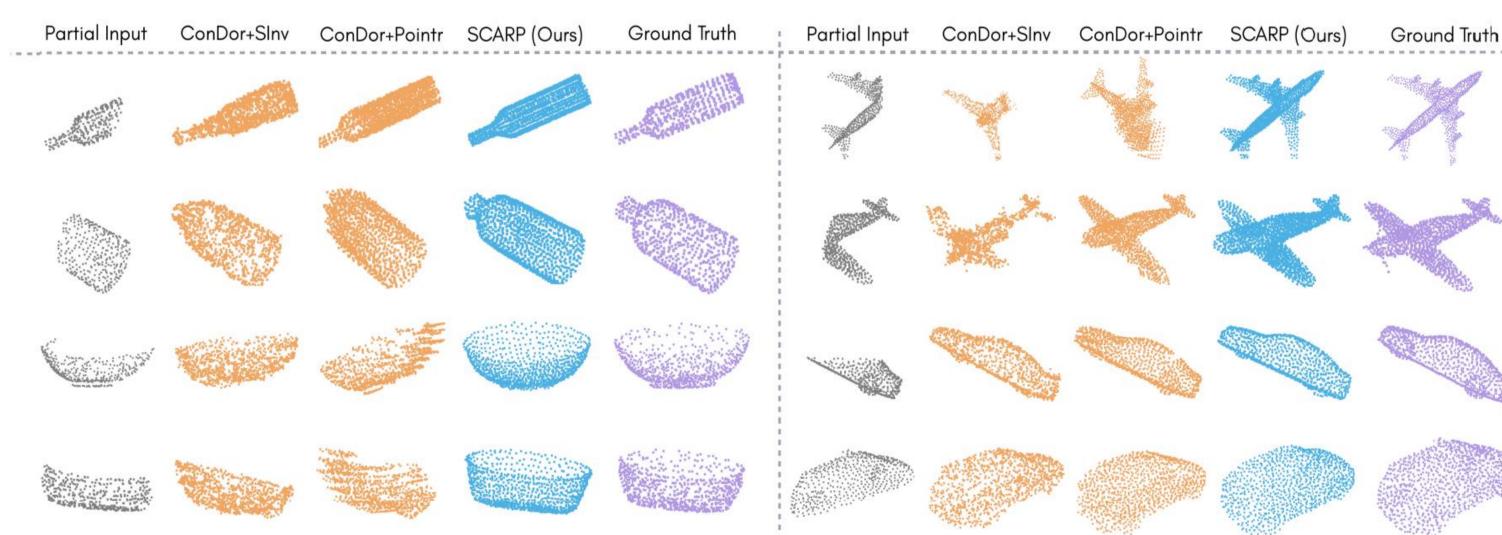


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RESULTS

To the best of our knowledge, we are the first to perform the task of shape completion in arbitrary poses. Therefore to have fair comparisons, we modify the existing shape completion networks by developing a multi-stage pipeline: (1) We use ConDor to first canonicalize the input partial pointclouds to a fixed canonical frame defined implicitly by ConDor. (2) We train and test the existing shape completion methods on ConDor's canonical frame. (3) Bring the completed pointcloud to the original orientation using a pose transform predicted by ConDor. We compare against (1) ConDor+Pointr, a SOTA pointcloud completion network that generates high-resolution completed pointclouds and (2) ConDor+Shape Inversion (SInv.).

SCARP outperforms existing multi-stage baselines, that rely on external canonicalization, on all the categories. Errors in the external canonicalization model propagate, giving a larger error in the output of the shape completion networks, as the input to the shape completion networks are not always in the exact canonical forms. This results in high inconsistencies and sub-optimal outputs.





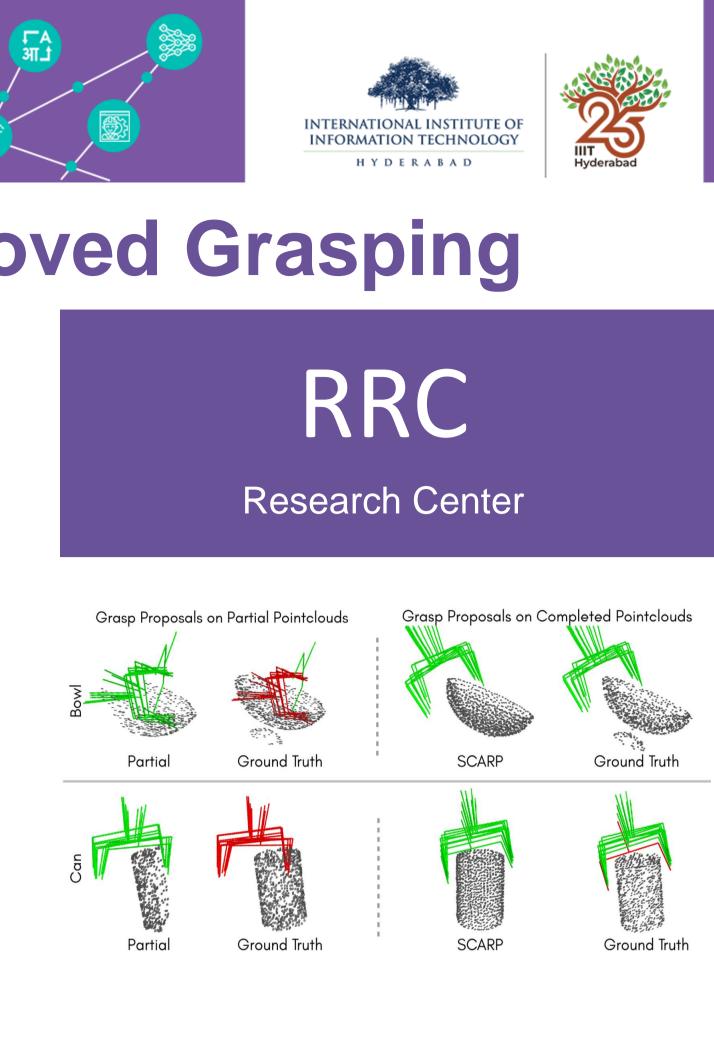


Partial Object



Shape Completion using SCARP

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