IPD-Net: SO(3) Invariant Analysis For Point Cloud Decomposition

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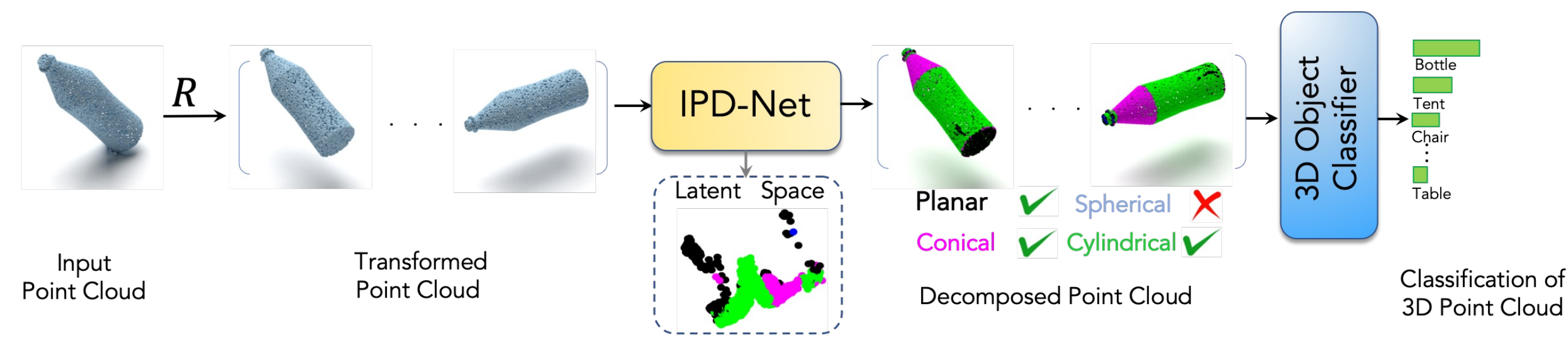
Introduction

- To imbibe human cognition system to identify and interpret familiar objects regardless to orientation in 3D Deep Learning and Vision.
- Understanding the point cloud by decomposing it into four primitive shapes (Planar, Cylinder, Cone, and Sphere) and use abstraction for classification of point clouds.

Contributions

- Extracting Implicit Invariant Features (IIF) towards achieving invariance in decomposition using centric distance field and normals.
- Extracting global signature of the point cloud through Spatial Rectification Unit (SRU) using canonical representation for rotation invariant signature.
- Generalizability of IPD-Net as plugin for classification of point clouds on benchmark dataset (ModelNet40)
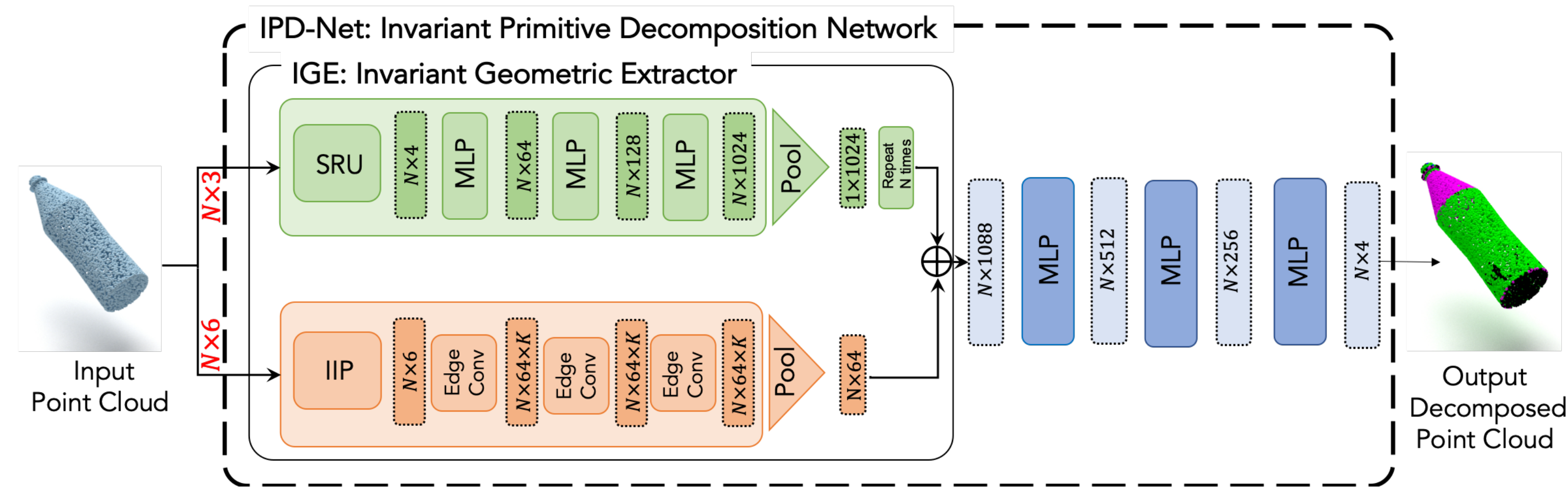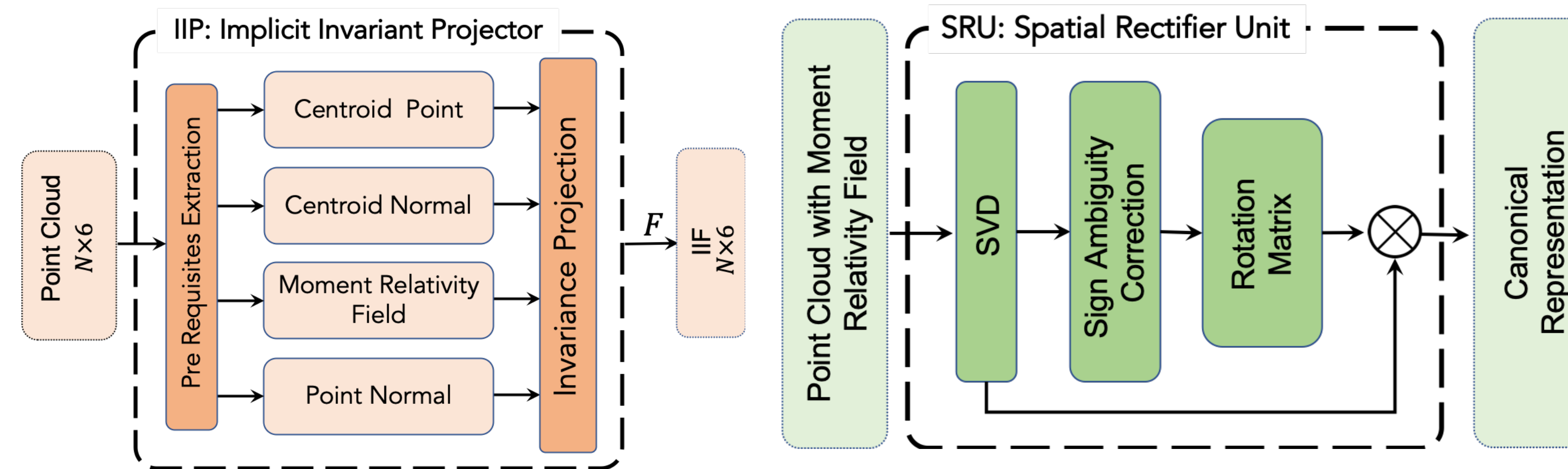

Methodology

- Introduce a novel Moment Relativity Field denoted by Ψ.
- $\|\Psi\|$ being a scalar descriptor facilities in understanding the underlying relative typologies of point cloud with-respect-to to centroid.
- Using Moment relativity field, normal and centroid, derive novel Implicit Invariant Features F to incorporate a range of factors given by,

$$F = [\, \|\,\Psi\,\|, \Psi \cdot N, \Psi \cdot N_\mu, N \cdot N_\mu, u(N) \cdot u(N_\mu), v(N) \cdot v(N_\mu)]$$

$$\text{where, } u(x) = \Psi \times x \text{ and } v(x) = u(x) \times x$$

- Employ Singular Value Decomposition (SVD) on point cloud point cloud containing (x, y, z) along with Moment-Relativity Field $\|\Psi\|$.
- With the the spatial information and distance value for each instance present the orthogonal matrix projects the point cloud into 4-dimensional canonical space.
- Ambiguity in the rotation matrix is fixed by resolving sign ambiguity in U and V^T

Results

- The decomposition accuracy of proposed methodology on TraceParts dataset in comparison with state-of-the-art method ABD-Net.

Model Name	Z/Z	Z/SO(3)	SO(3)/SO(3)
ABD-Net	93.22	26.75	91.33
IPD-Net	90.51	**90.51**	90.51

Results

- The classification accuracy of our proposed invariant features with PointNet and PCT in comparison with state-of-the-art methods on ModelNet40 with 1024 point density.

Model Name	Z/Z	Z/SO(3)	SO(3)/SO(3)
PointNet	89.5	19.2	75.5
PointNet ++	91.8	18.4	77.4
DGCNN	92.2	20.6	81.1
PCT	92.1	20.2	85.3
IPD-Net + PointNet	88.7	**88.7**	88.7
IPD-Net + PCT	90.2	**90.2**	90.2

- Comparison of IPD-Net with ABD-Net Decomposition results on ModelNet40.
  - The planar screen of the Laptop
  - The cylindrical bodies of the Airplane and Rocket

Rocket   Laptop   Airplane   Stool