University of Zurich UZH | **ETH** zürich

ROBOTICS & PERCEPTION GROUP

Department of Informatics - Institute of Neuroinformatics

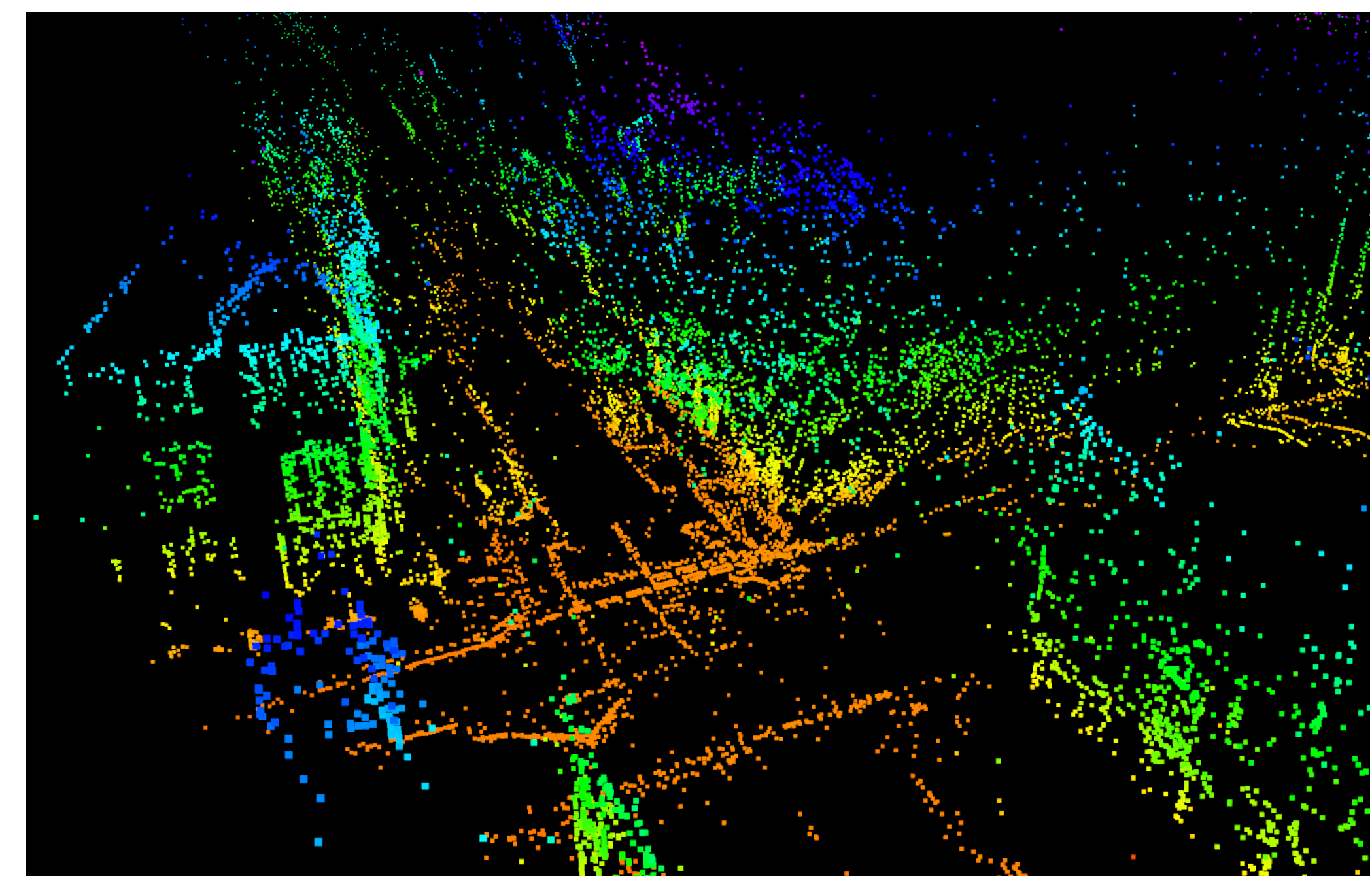# Place Recognition in Semi-Dense Maps: Geometric and Learning-Based Approaches

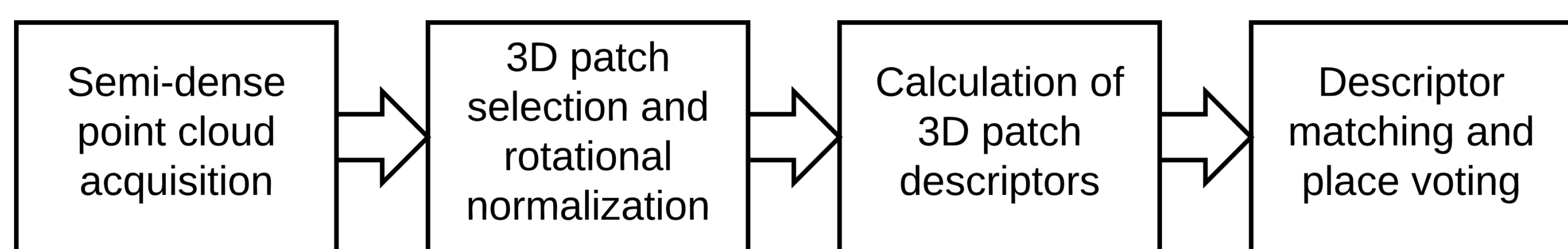Yawei Ye, Titus Cieslewski, Antonio Loquercio, Davide Scaramuzza

February

October
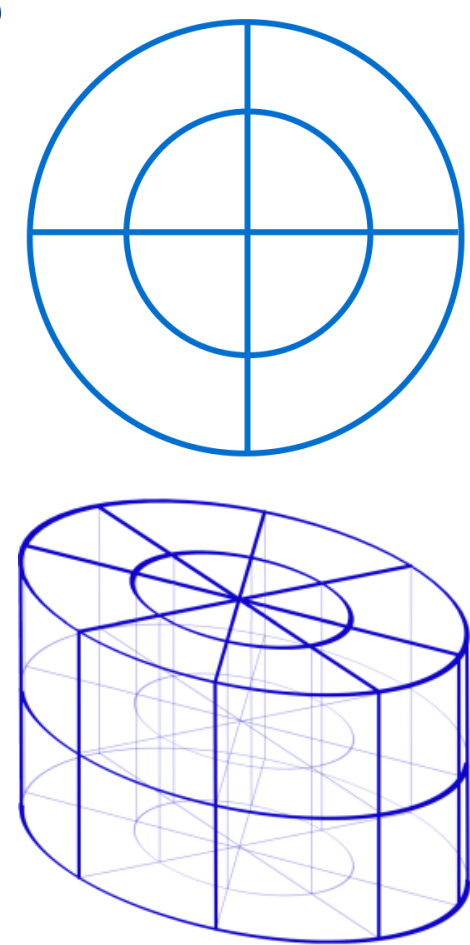
Semi-Dense point cloud from DSO

Photometric appearance changes due to many factors, but the geometry stays the same. Can we exploit this for place recognition?

The Overall Approach

Semi-dense point cloud acquisition → 3D patch selection and rotational normalization → Calculation of 3D patch descriptors → Descriptor matching and place voting
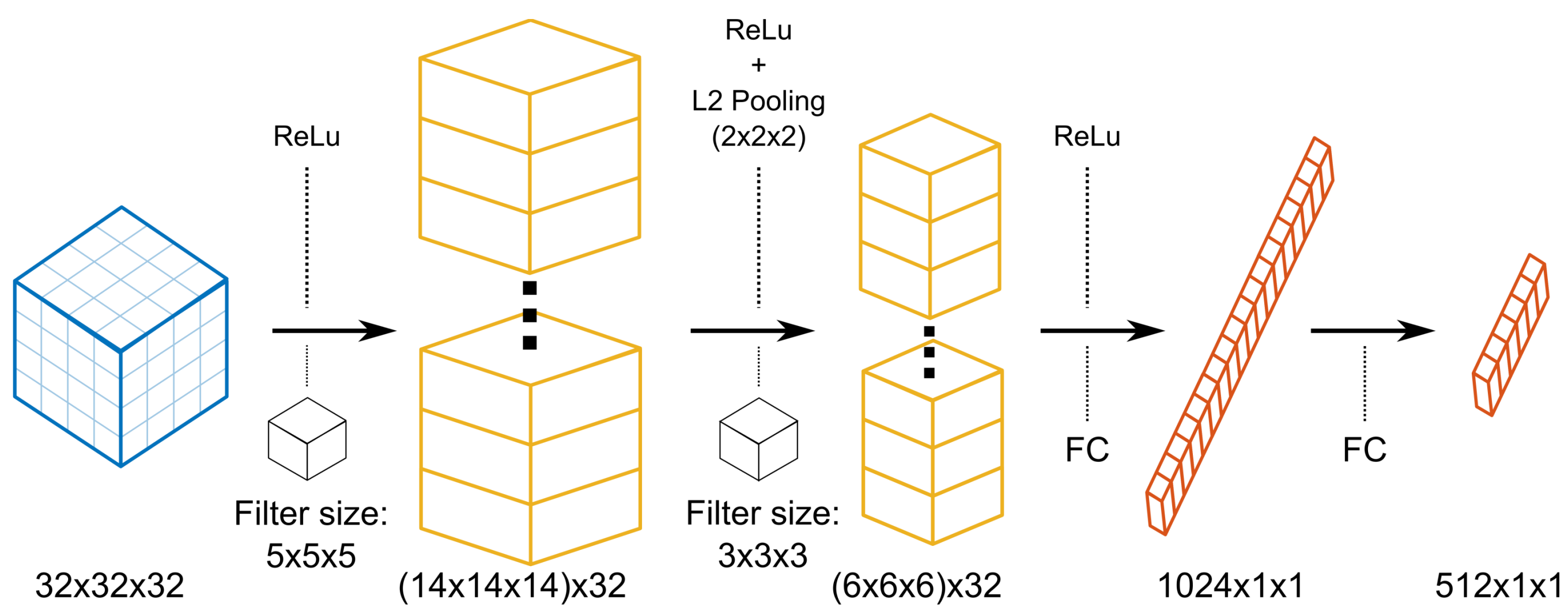
Hand-crafted Descriptors

- Describe **local point clouds**
- Used descriptors: NBLD, M2DP
- Need to be **agnostic to surface normals**
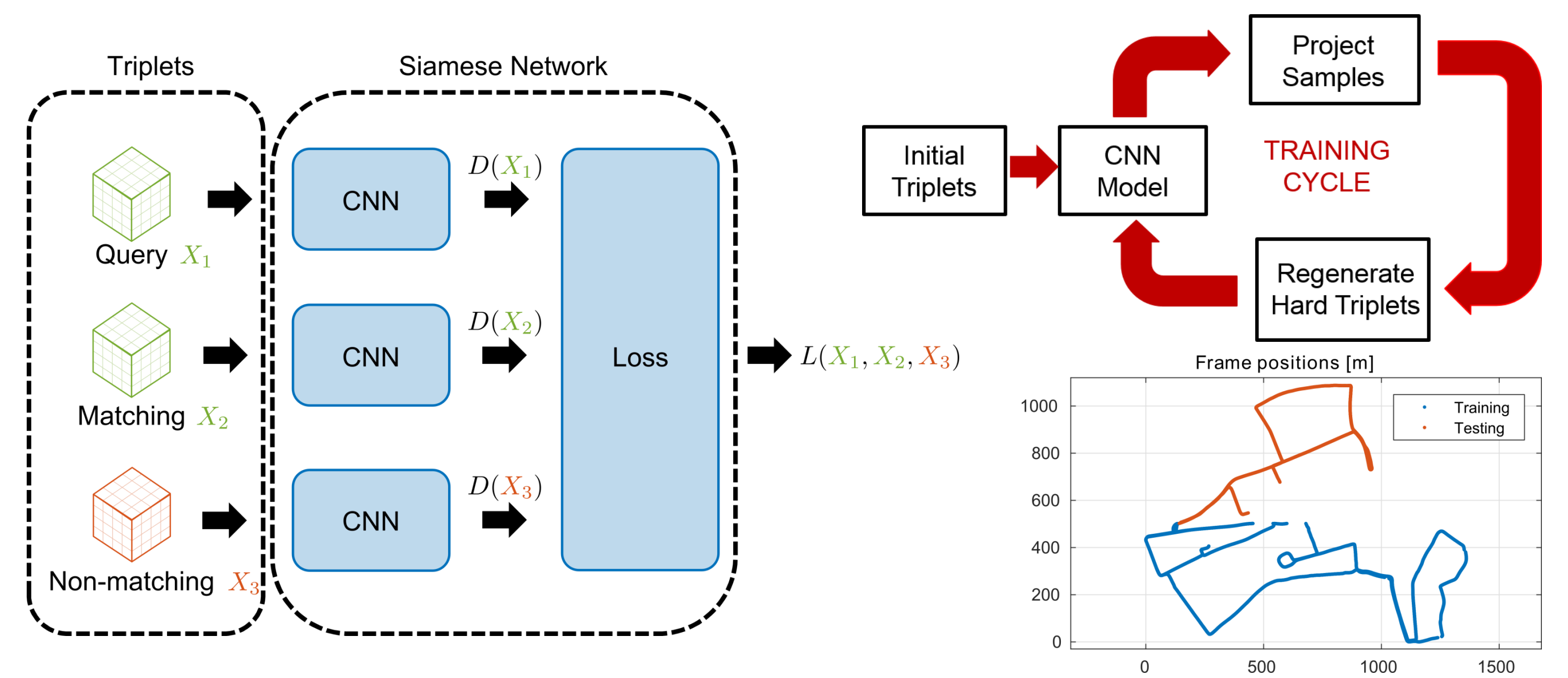- Components: Normalization, Bins, Binary comparisons

Learned Descriptors

ReLu

ReLu + L2 Pooling (2x2x2)

ReLu

FC

FC

32x32x32

Filter size: 5x5x5

(14x14x14)x32

Filter size: 3x3x3

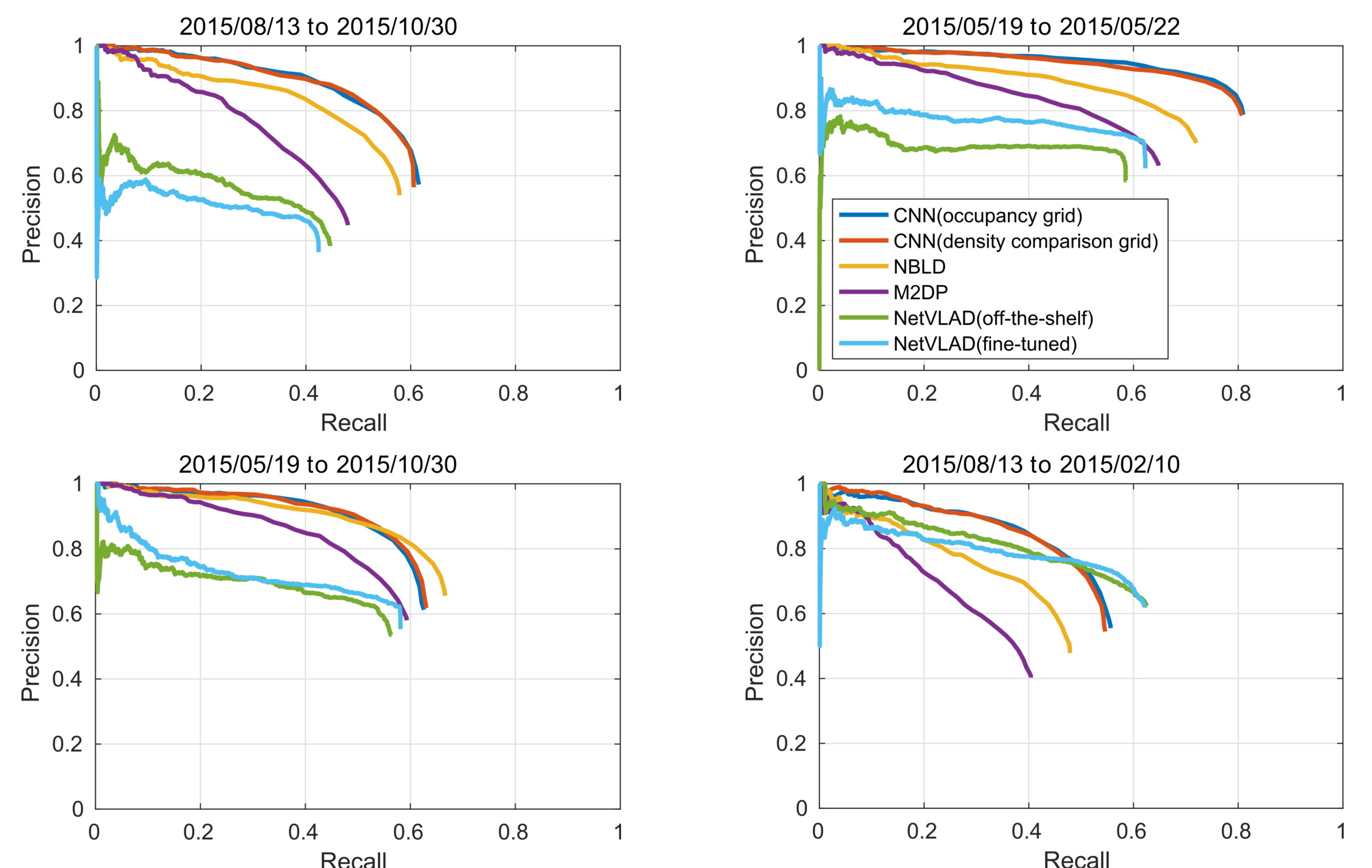(6x6x6)x32

1024x1x1

512x1x1

- Input layer: Occupancy grid / binary density comparison grid
- Two **3D conv.** layers + ReLU, two FC layers

Training Learned Descriptors

Triplets

Siamese Network

Query X_1 → CNN → $D(X_1)$

Matching X_2 → CNN → $D(X_2)$ → Loss → $L(X_1, X_2, X_3)$

Non-matching X_3 → CNN → $D(X_3)$

Initial Triplets → CNN Model → Project Samples / Regenerate Hard Triplets — TRAINING CYCLE

Frame positions [m]
— Training
— Testing

- **Triplet loss**: If two patches match, their descriptors should be closer than if they do not
- A training cycle that focuses on **"hard"** batches
- **Geographical** split of training and testing data

Results

2015/08/13 to 2015/10/30

2015/05/19 to 2015/05/22
- CNN(occupancy grid)
- CNN(density comparison grid)
- NBLD
- M2DP
- NetVLAD(off-the-shelf)
- NetVLAD(fine-tuned)

2015/05/19 to 2015/10/30

2015/08/13 to 2015/02/10

- Evaluated on the **Oxford Robotcar Dataset**
- Also compared to photometric descriptor **NetVLAD**
- Varying results, depending on the pairs of seasons
- Mostly, **geometric > photometric** and **learned > hand-crafted**