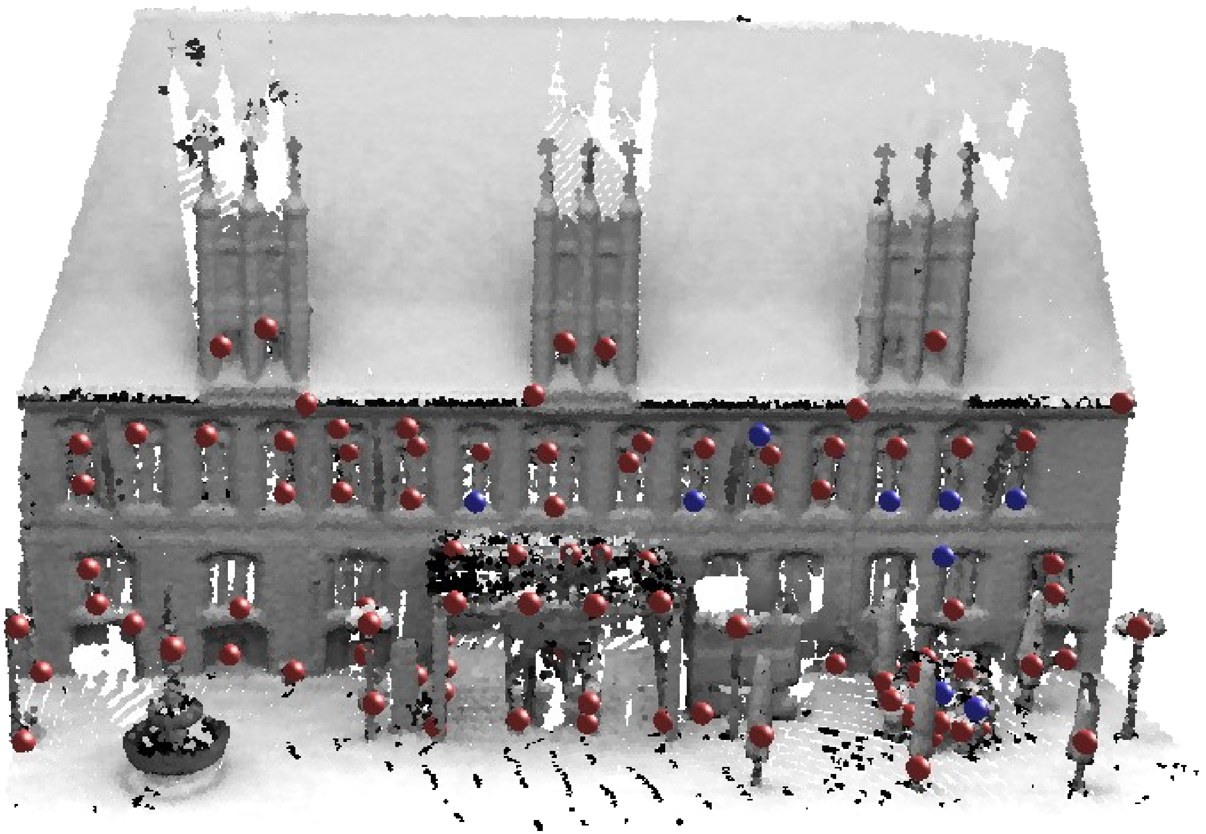
Extracting Point Features for Symmetry Detection

Bachelor thesis preview
Daniel Mewes



Overview

- Problem description
  - Symmetry detection
  - Feature extraction
- My approach
  - The framework
  - Scene structure analysis
- Preliminary results

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Symmetry Detection

- Given a 3D scene
- Detect repeating structures

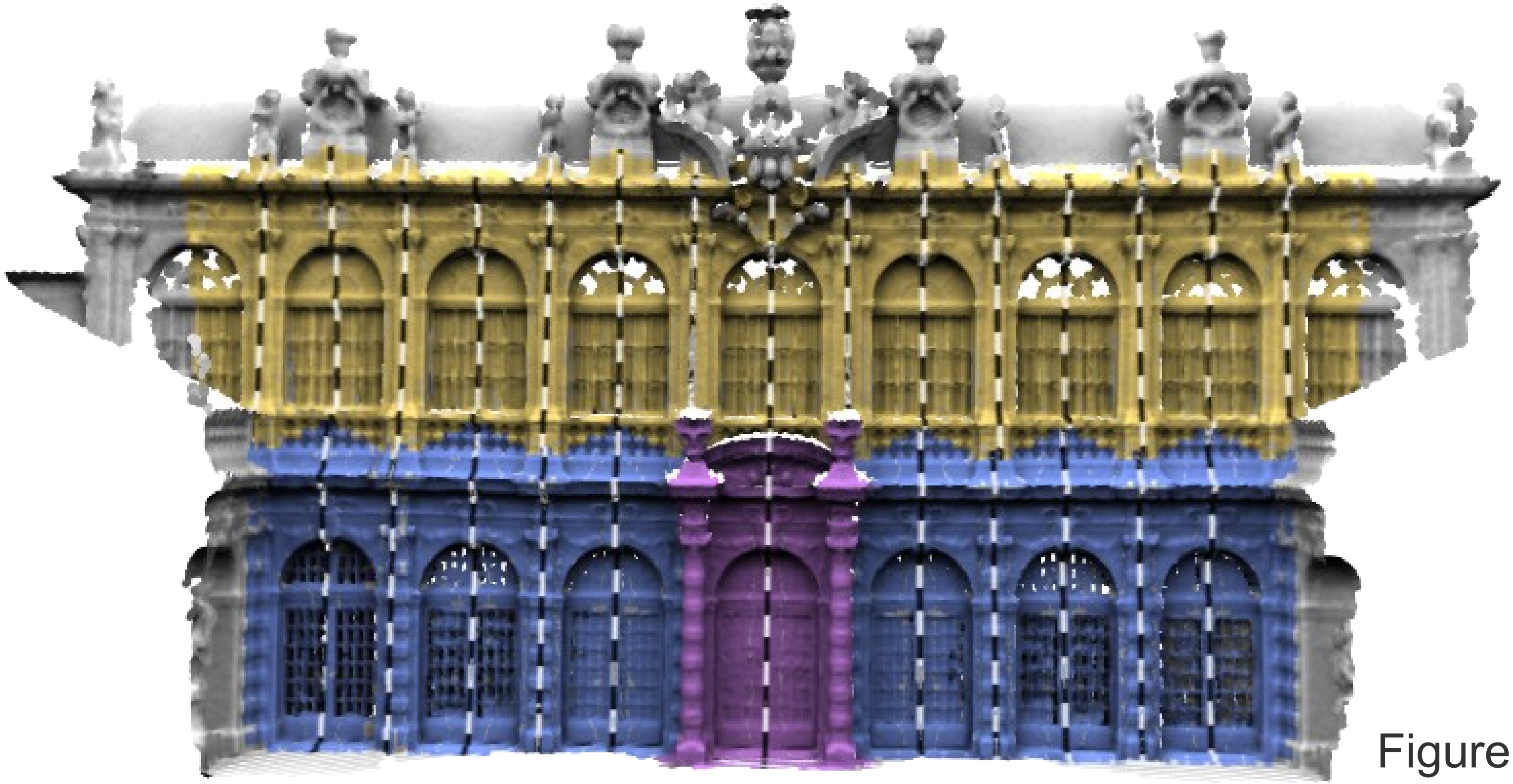
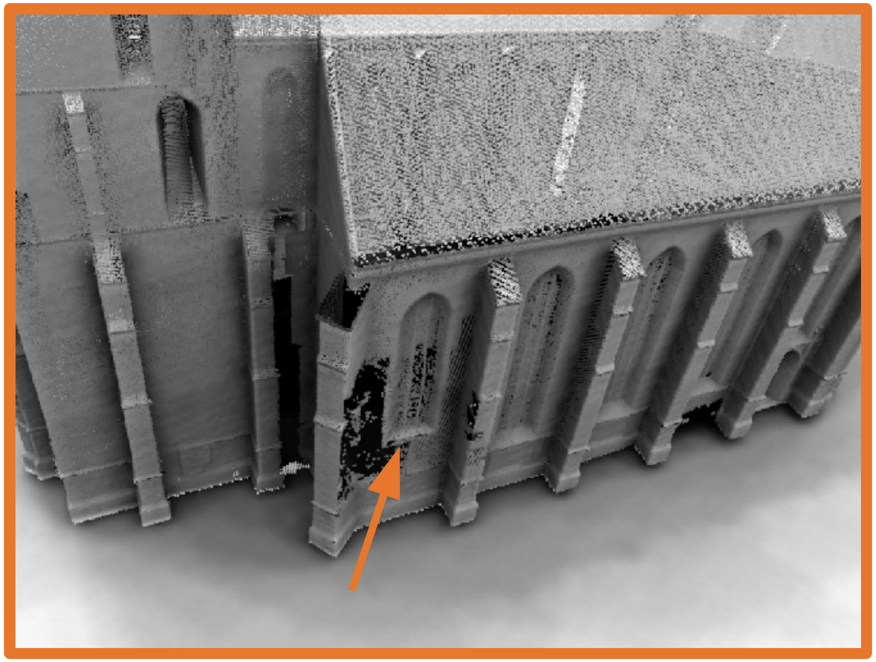


Figure from
Bokeloh et al. 2009

Symmetry Detection

- Many useful applications, e.g.
  - Simultaneous editing
  - Data compression
  - Data reconstruction and refinement



Symmetry Detection

- Input $\Omega \subset \mathbb{R}^3$
- Find subsets $S \subset \Omega$ with corresponding transformations $f_1, \ldots, f_n : S \to \Omega$
- Rigid case: $f_1, \ldots, f_n$ are rigid transformations

Features

- Symmetry Detection is computationally complex
- Techniques to reduce computational costs:
  - Downsampling
  - Randomized approaches (RANSAC)
  - Features
  - Combinations of these

Features

- Idea:
  - Preselect relevant subset of the data
  - Find symmetry candidates in the subset
  - Validate
- Simplest class: Point features

Feature Extraction

- Goal for feature extraction for symmetry detection
  - Problem:

One instance misses a feature → No symmetry candidate → Undetectable symmetry

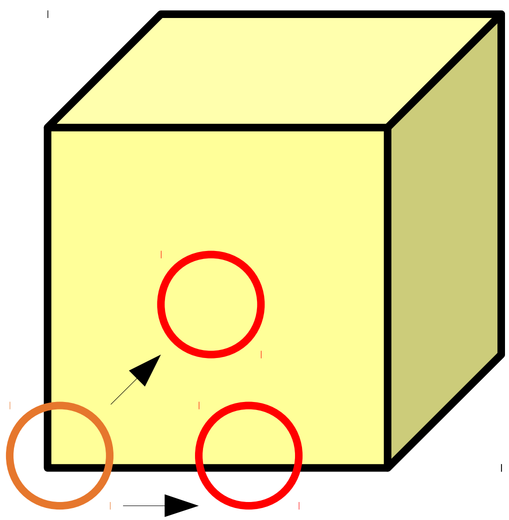
→ Consistent features across all instances

Feature Extraction

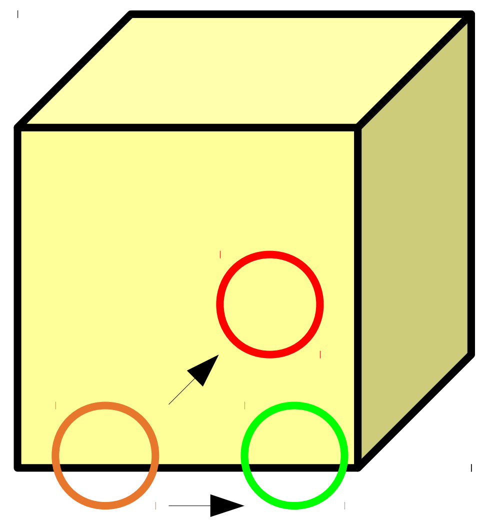
- How to extract point features?

Feature Extraction

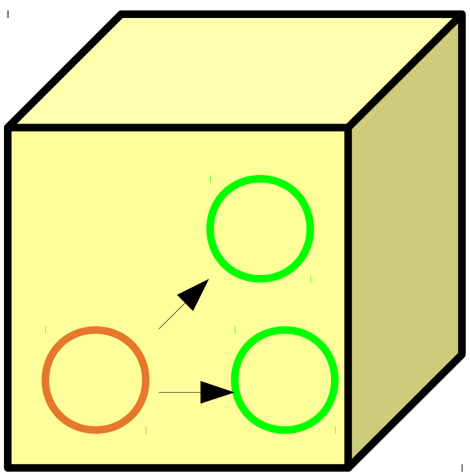
- Related work: Slippage features (Bokeloh et al. 2008, Gelfand et al. 2004)
  - Perform local slippage analysis
  - Select local maxima



No slippable translations



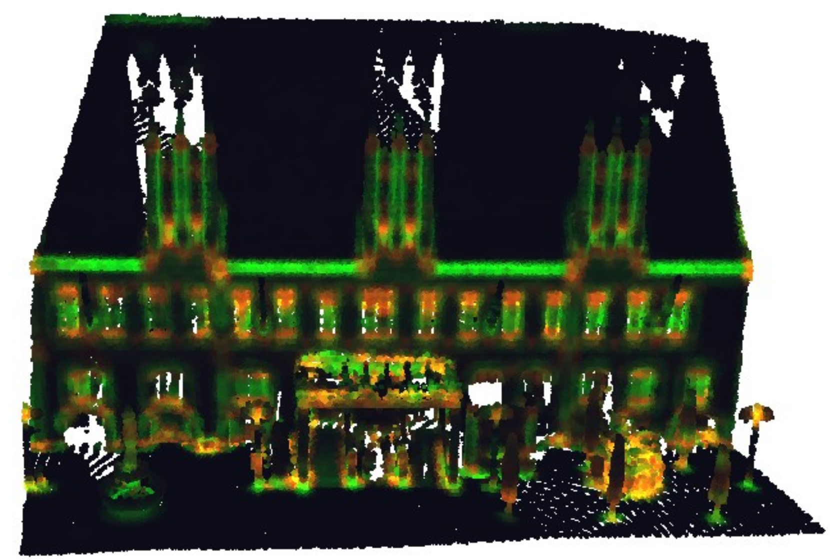
Slippable to the "right"



Slippable in two translational dimensions

Feature Extraction

- Example: Slippage features (Bokeloh et al. 2008, Gelfand et al. 2004)

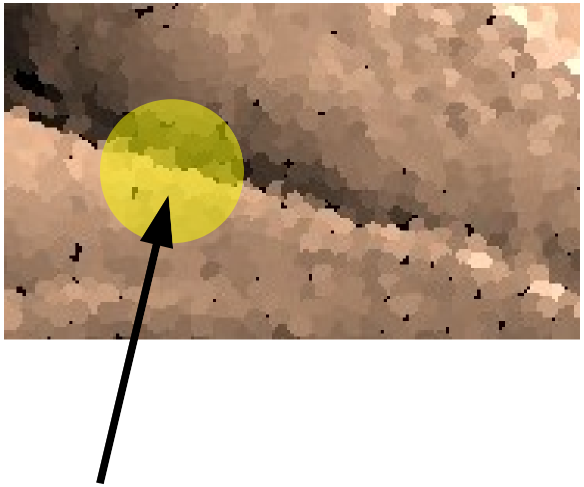


non-slippable

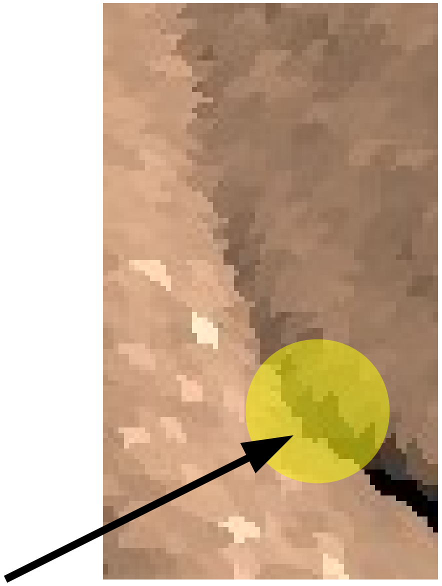
one slippable motion

Feature Extraction

- So far: Local criteria



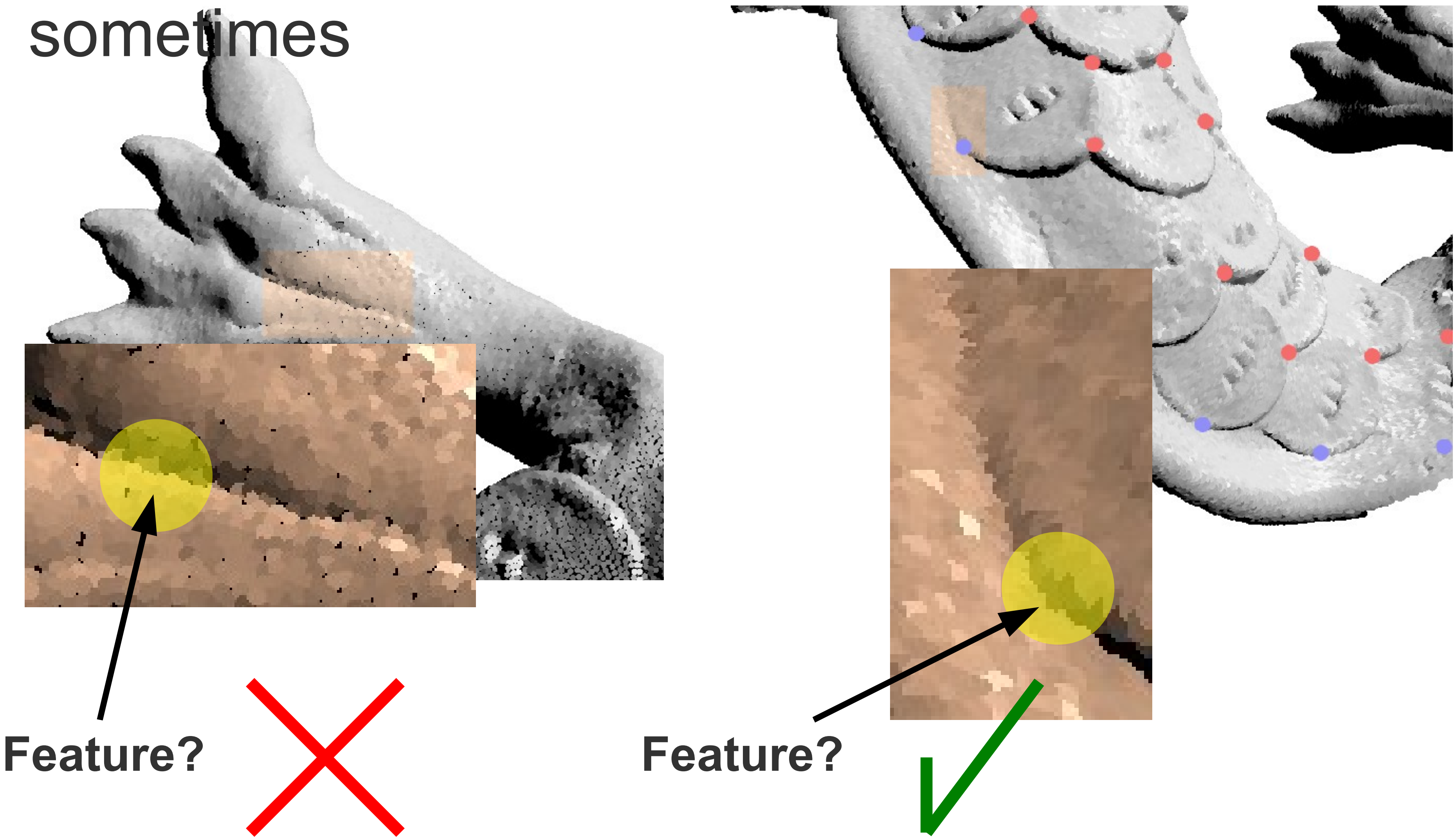
Feature?



Feature?

Feature Extraction

- Turns out local criteria are insufficient sometimes



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- **My approach**
  - **The framework**
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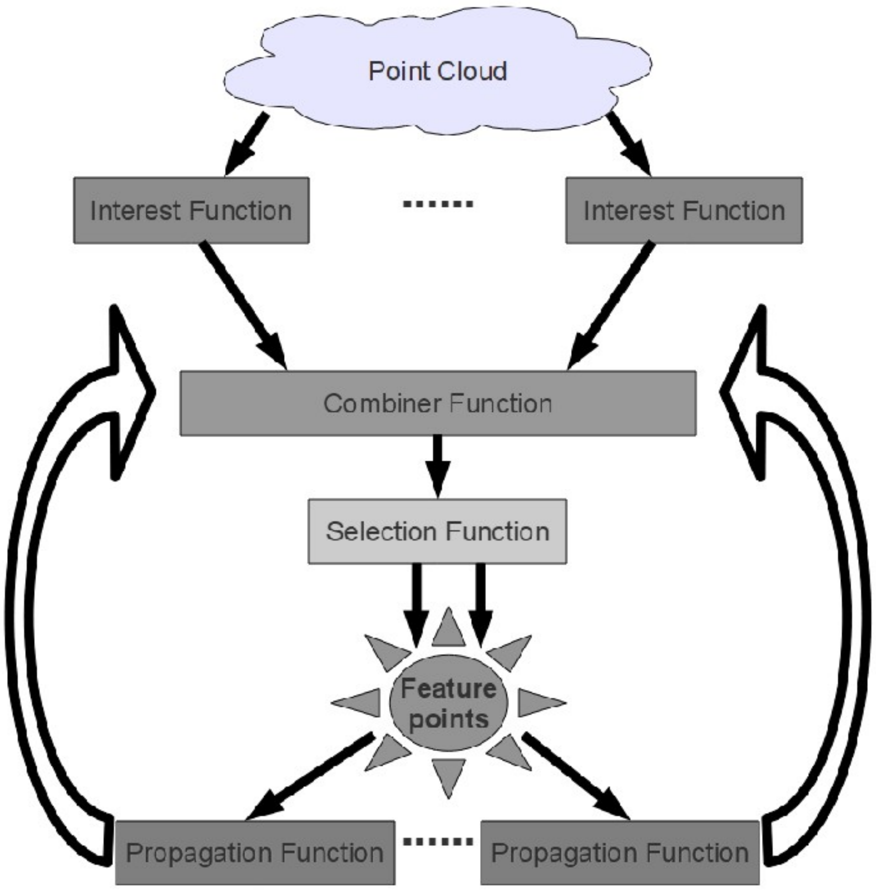
My Approach

- Interleave iteratively:
  - Feature extraction
  - Partial symmetry detection
- Missing features $\leftarrow$ reconstruct from other instances

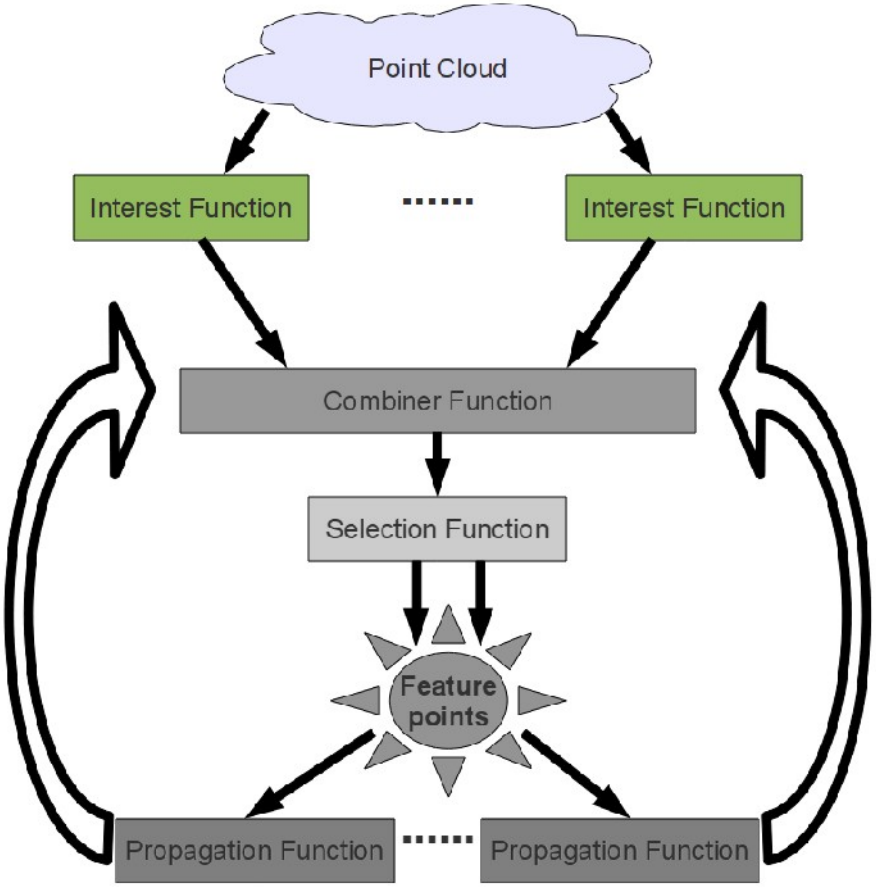
The Framework

- Input



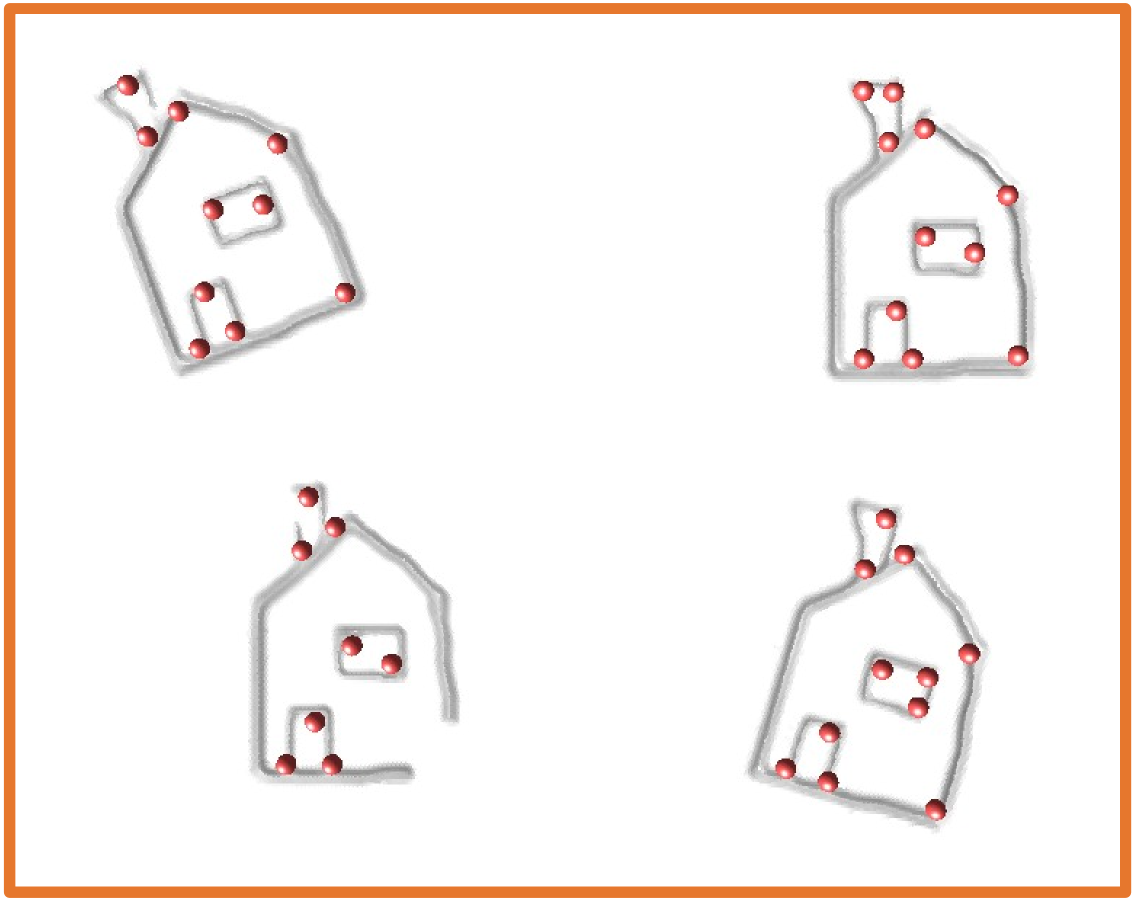
The Framework

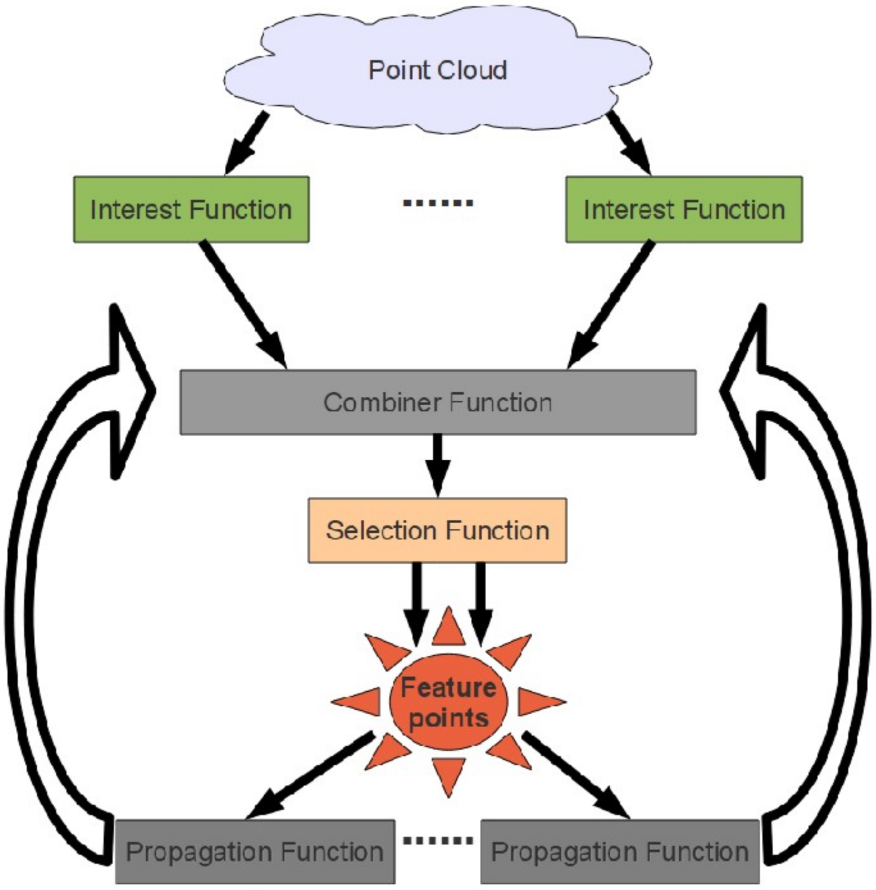
- Interest Function: Assigns local scores to points
- e.g. slippage analysis



The Framework

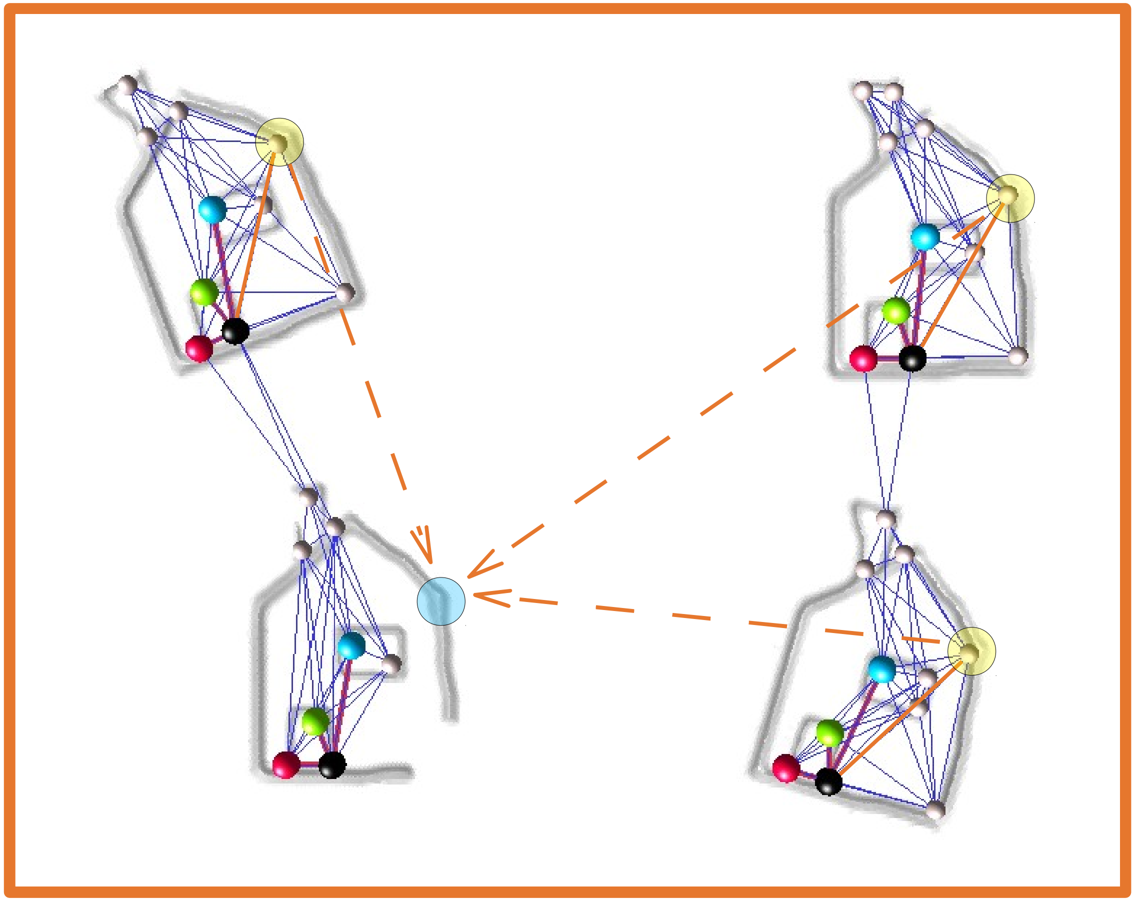
- Selection Function: Select feature points based on per-point scores

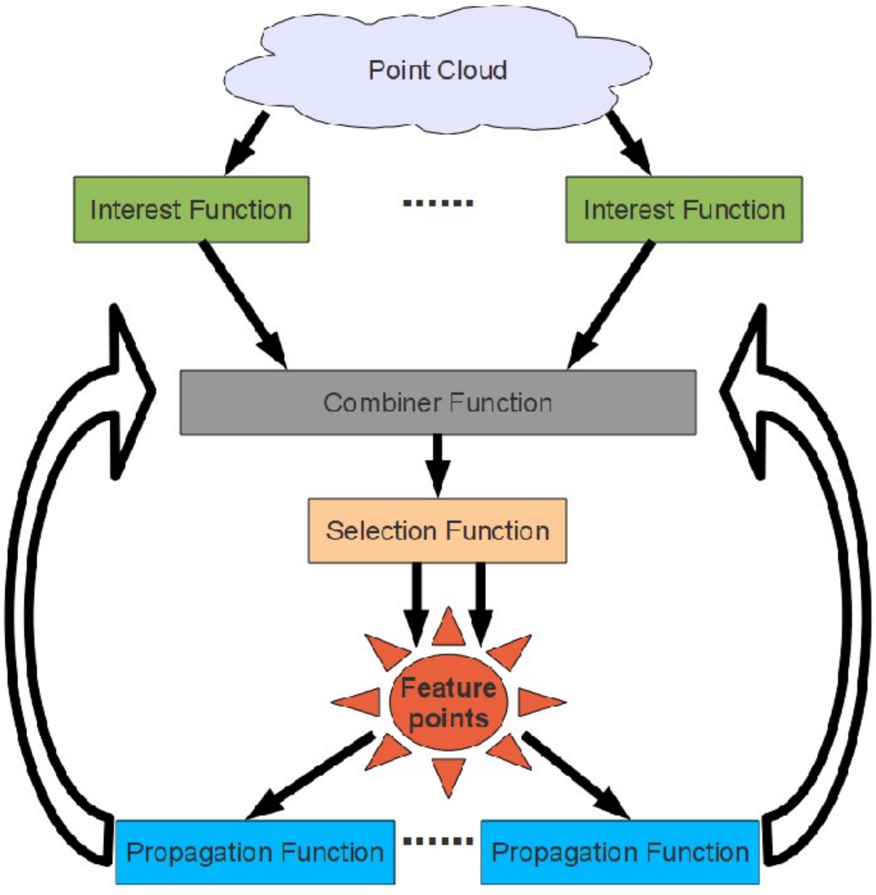




The Framework

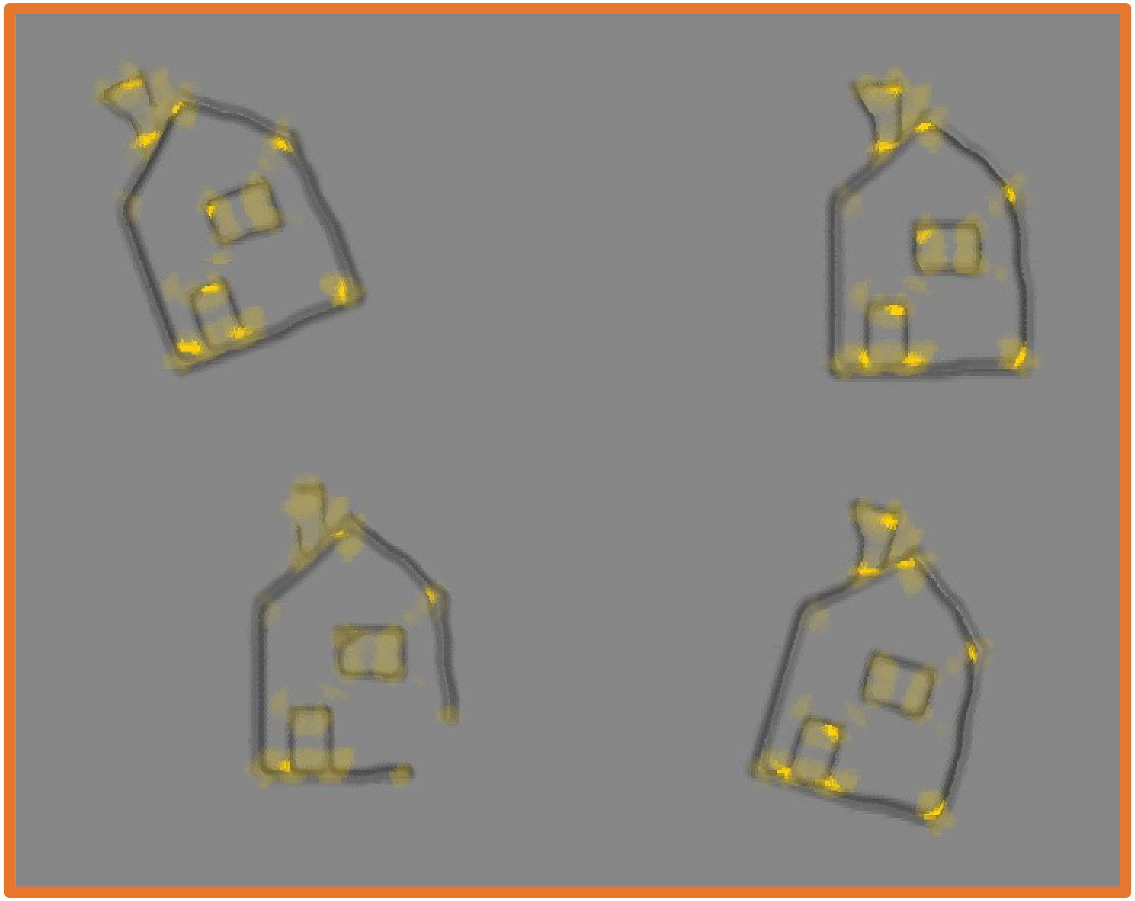
- Propagation Function: analyze structure, guess about additional features

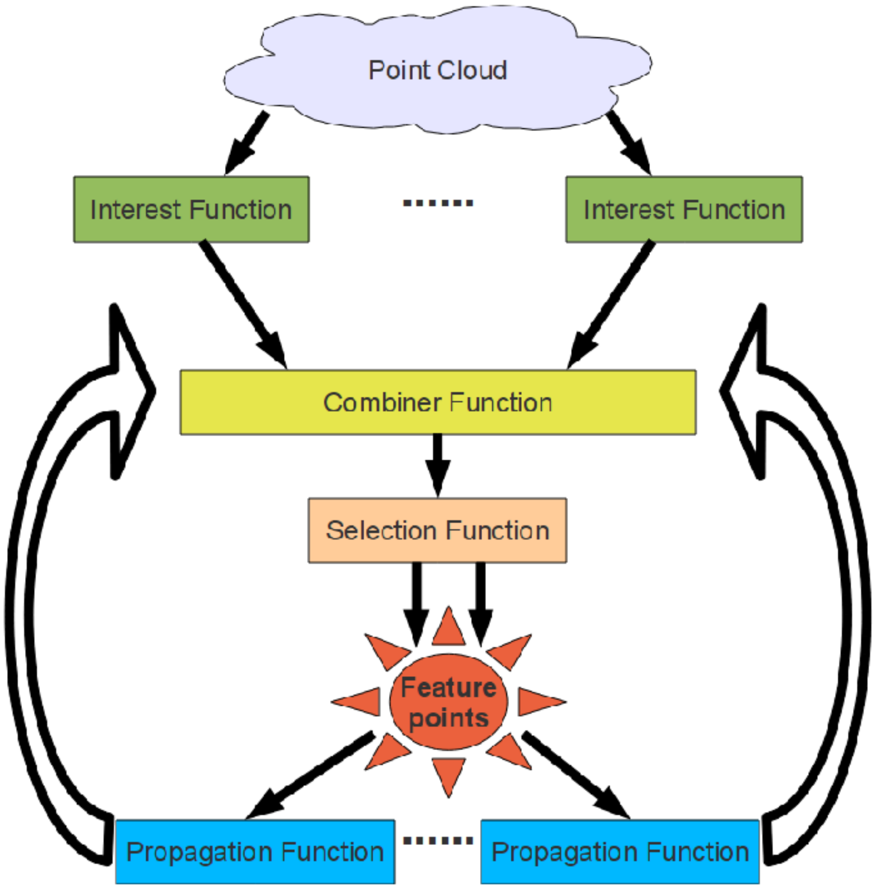




The Framework

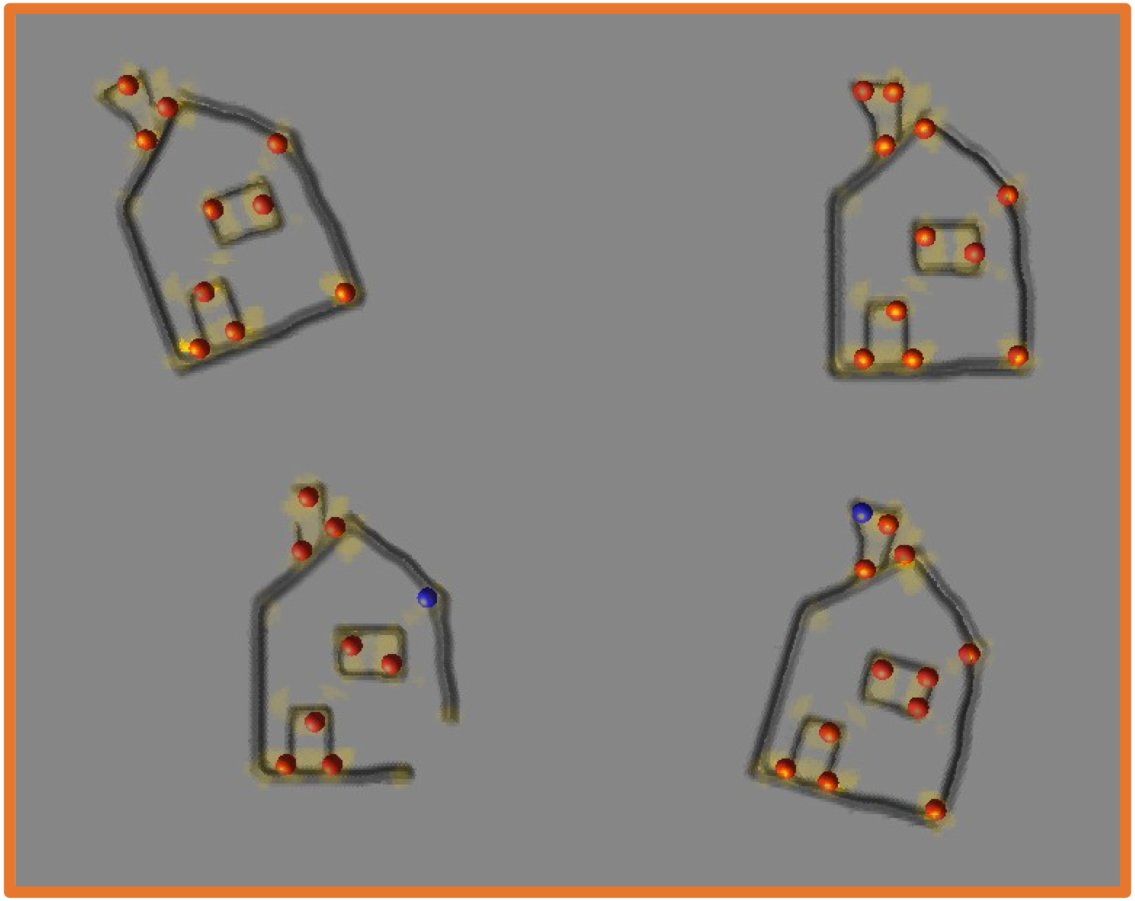
- Combiner Function: Incorporate guesses into per-point scores

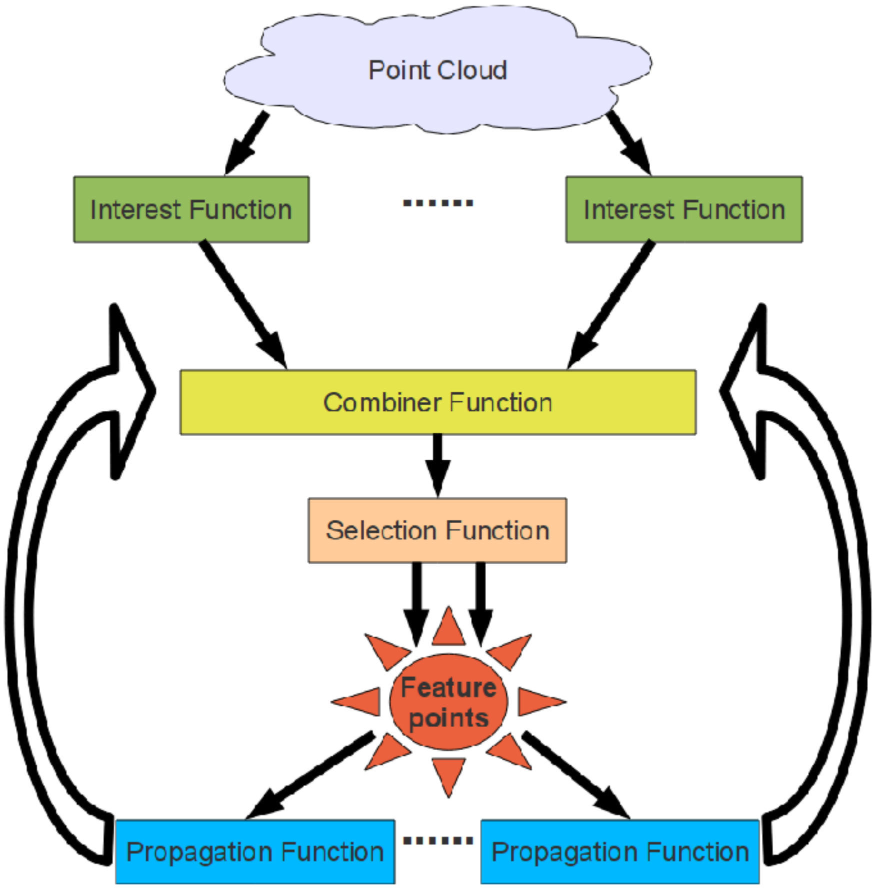




The Framework

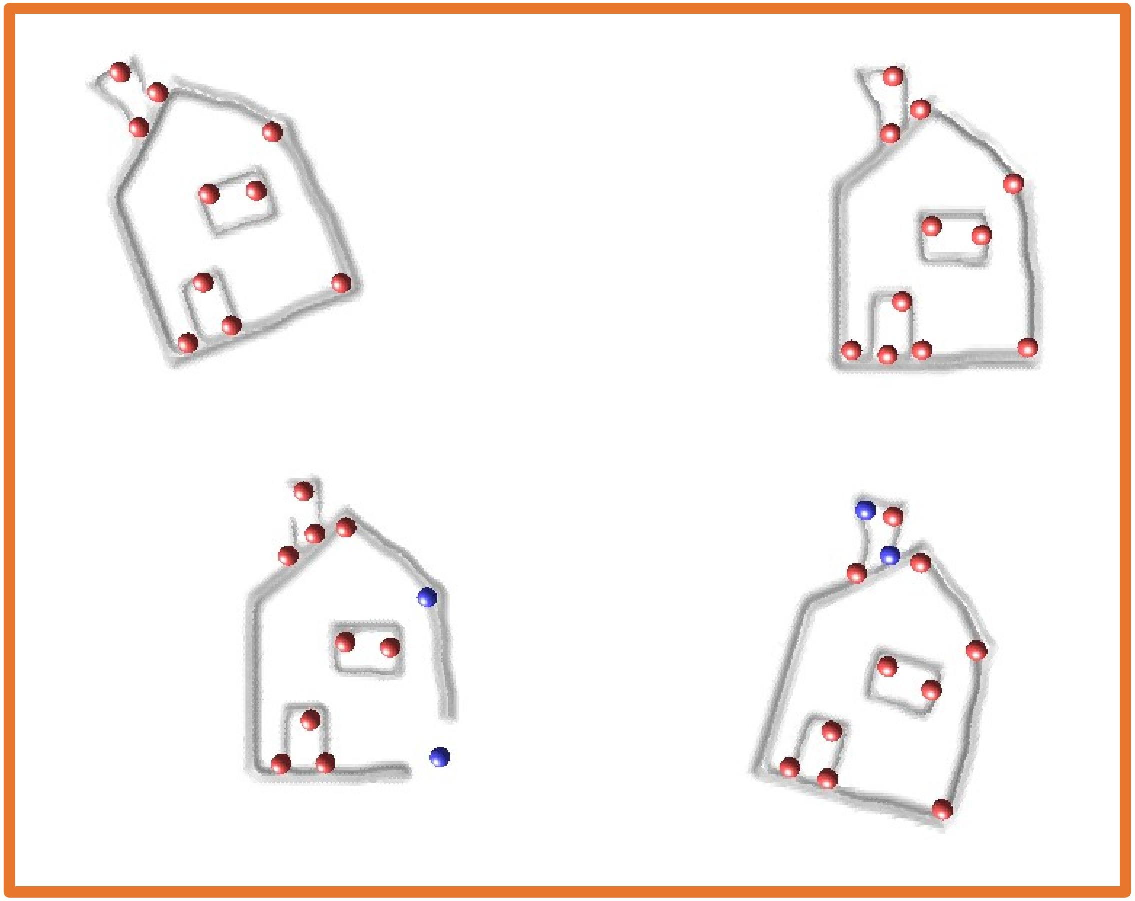
- Select new set of feature points based on the combined scores

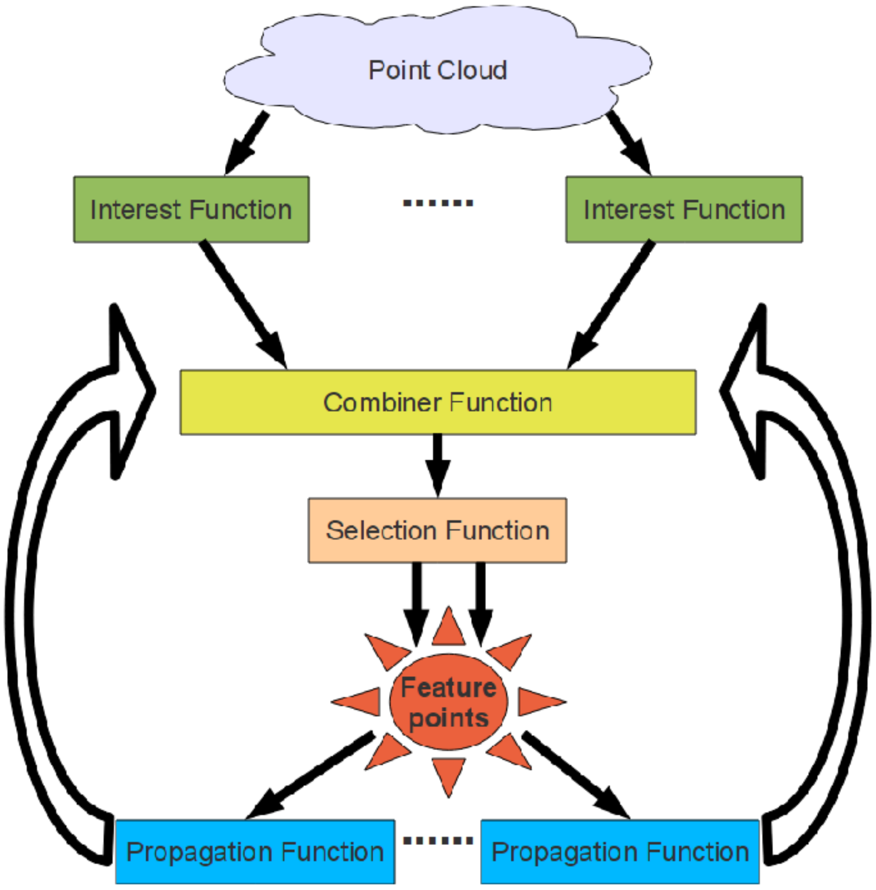




The Framework

- Iterate: repeat propagation, combination and selection with new feature points...





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Scene Structure Analysis

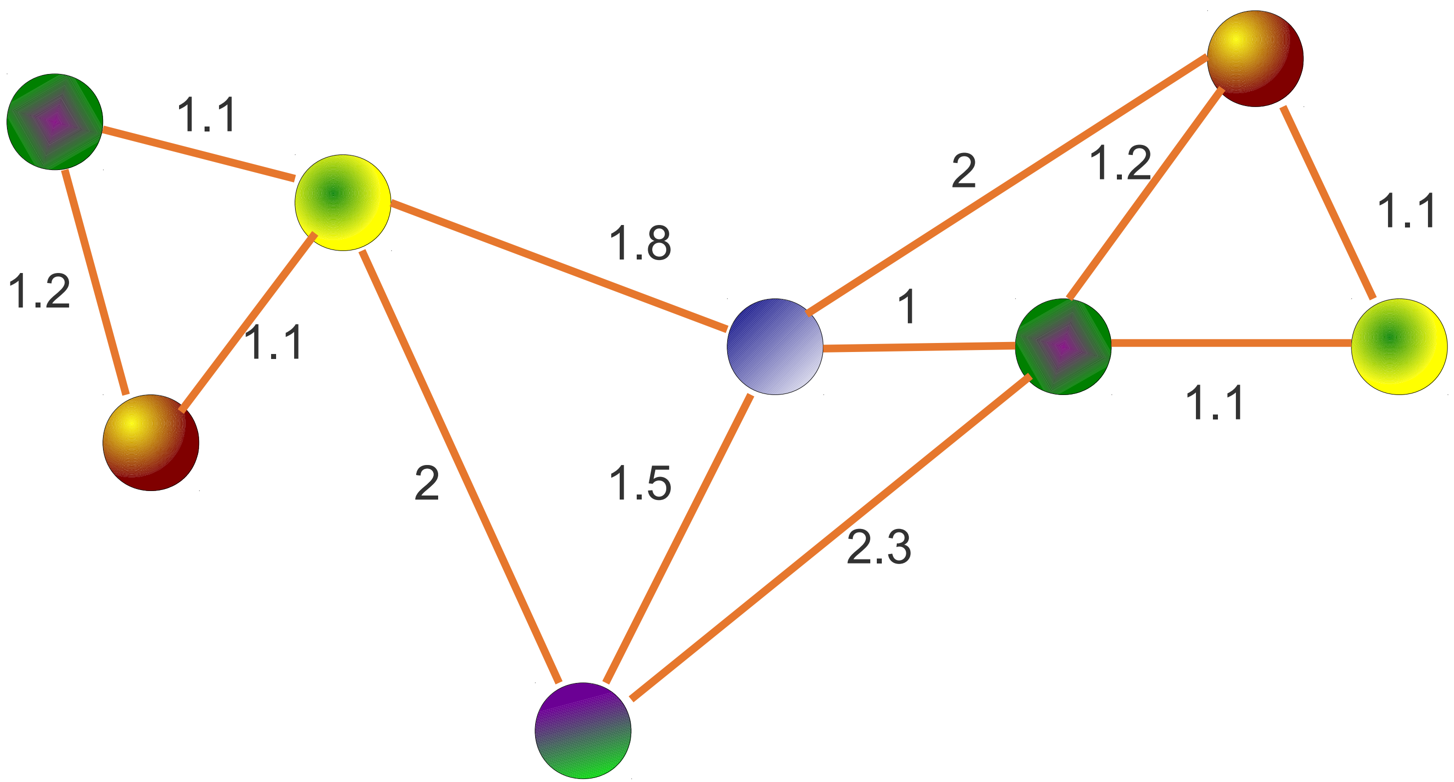
- How to analyze the scene's structure?

Scene Structure Analysis

- Related work: Graph-based symmetry detection (Berner et al. 2008)
  - Extract slippage features
  - Build neighborhood graph
  - Annotate:
    - Edges with their lengths
    - Features with curvature descriptor
  - Find isometric subgraphs

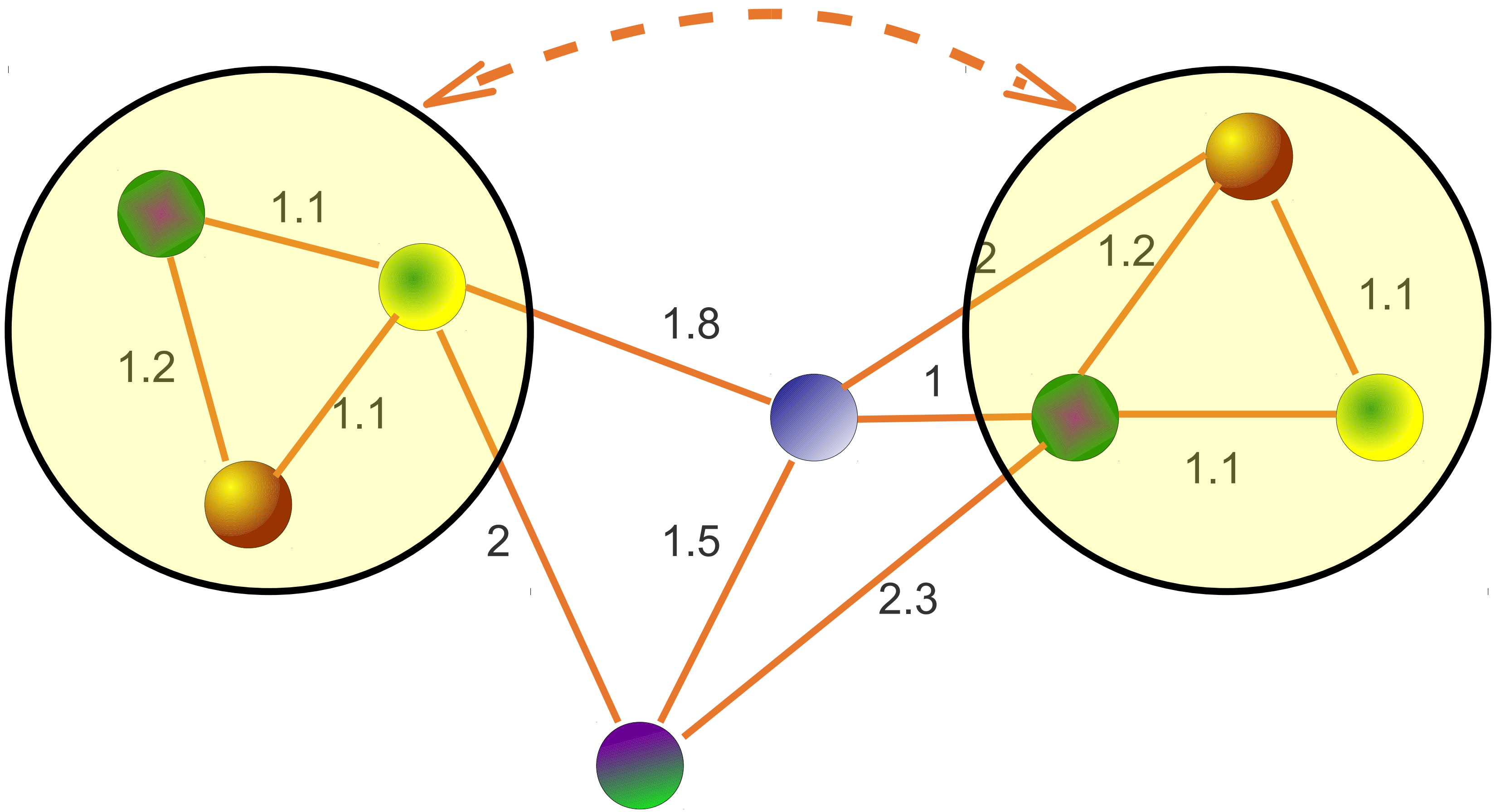
Scene Structure Analysis

- Related work: Graph-based symmetry detection (Berner et al. 2008)



Scene Structure Analysis

- Related work: Graph-based symmetry detection (Berner et al. 2008)



Scene Structure Analysis

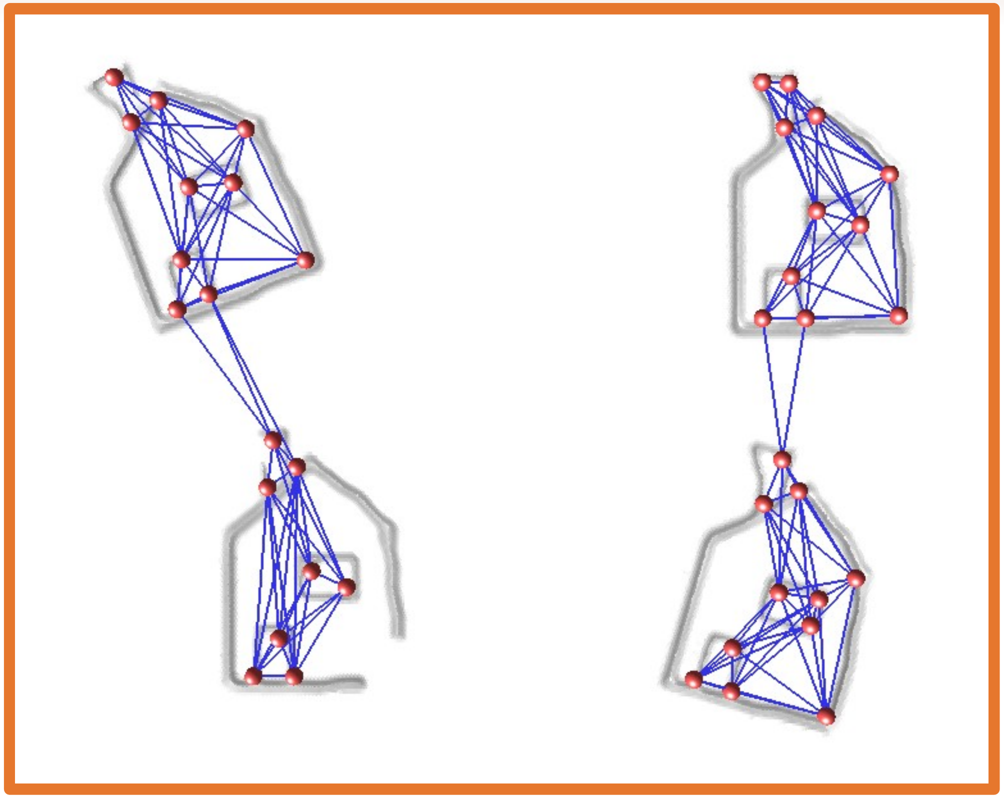
- More approaches:
  - Mitra et al. 2006, transformation voting
  - Pauly et al. 2008, detect grid structures
  - ...and lots more

Sub-Symmetry Detection

- My approach: use metric relation of feature points to each other
- Loosely inspired by Berner et al. 2008
- Aimed at detecting small sub-symmetries

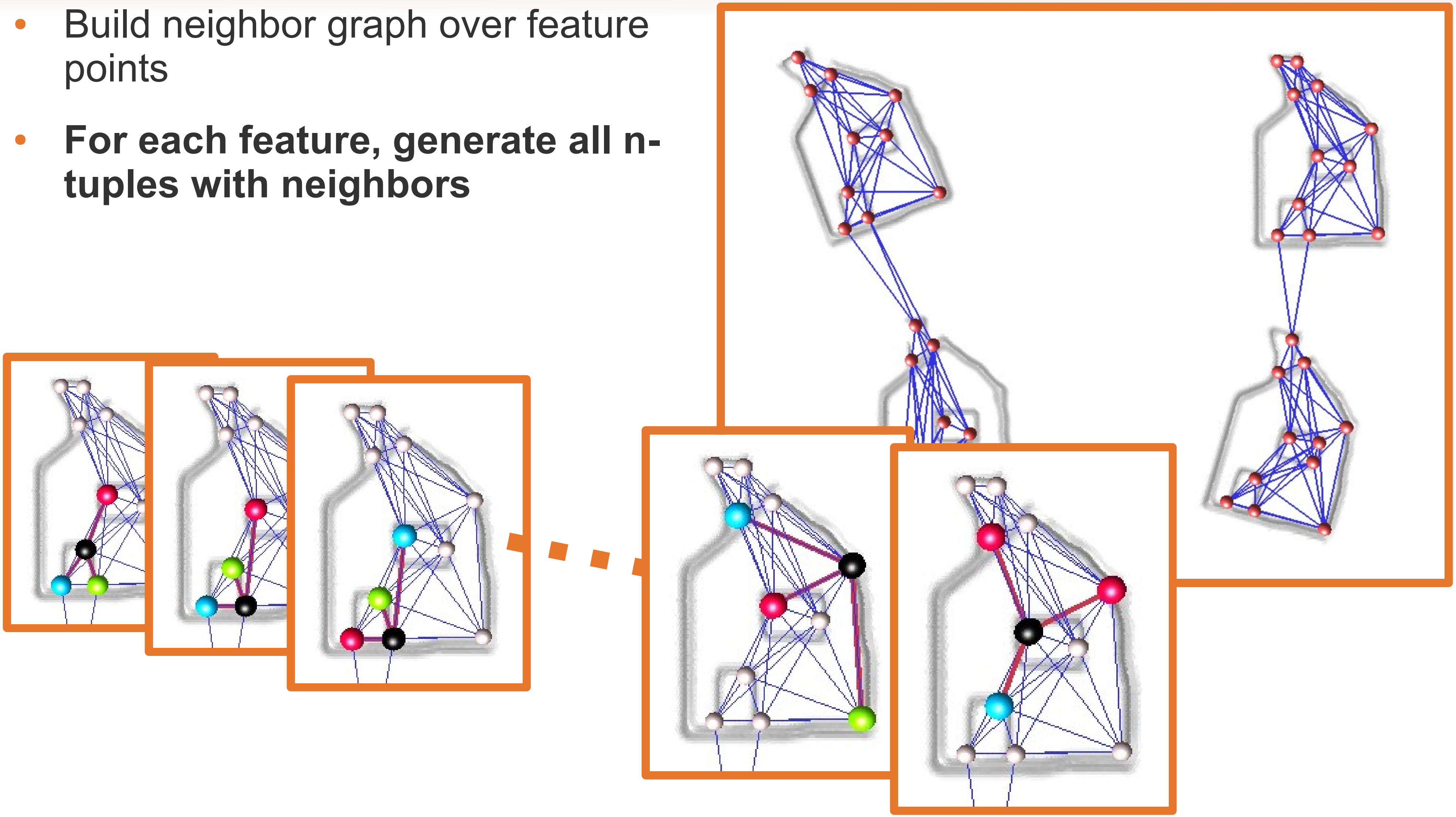
Sub-Symmetry Detection

- **Build neighbor graph over feature points**



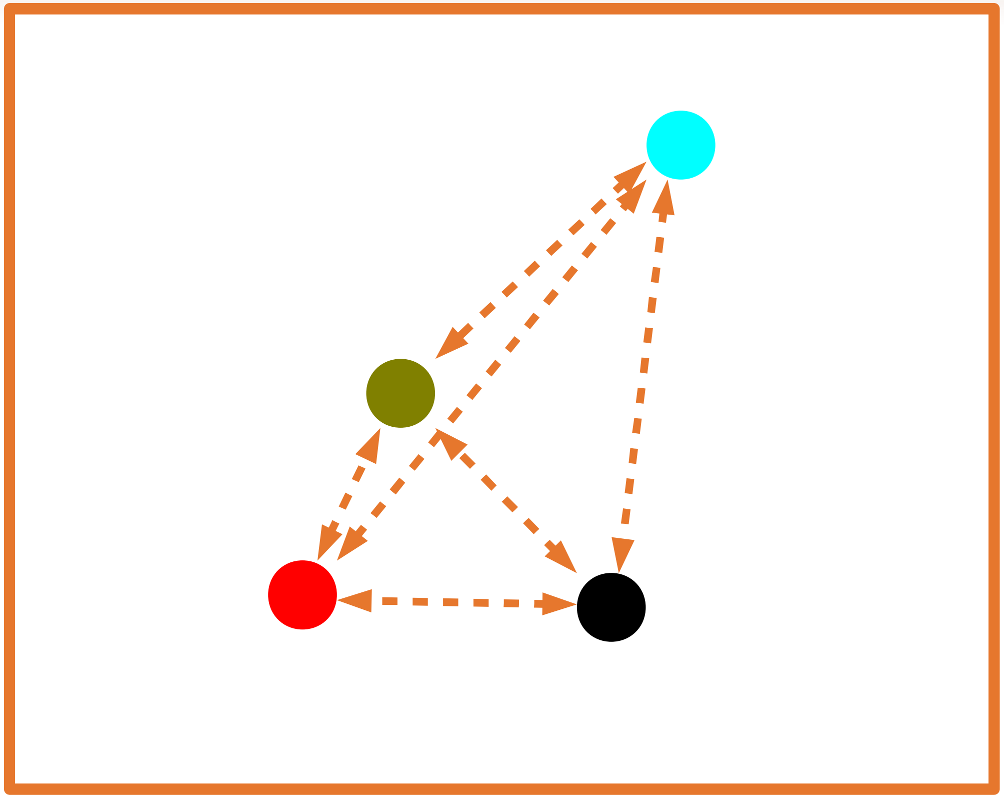
Sub-Symmetry Detection

- Build neighbor graph over feature points
- **For each feature, generate all n-tuples with neighbors**



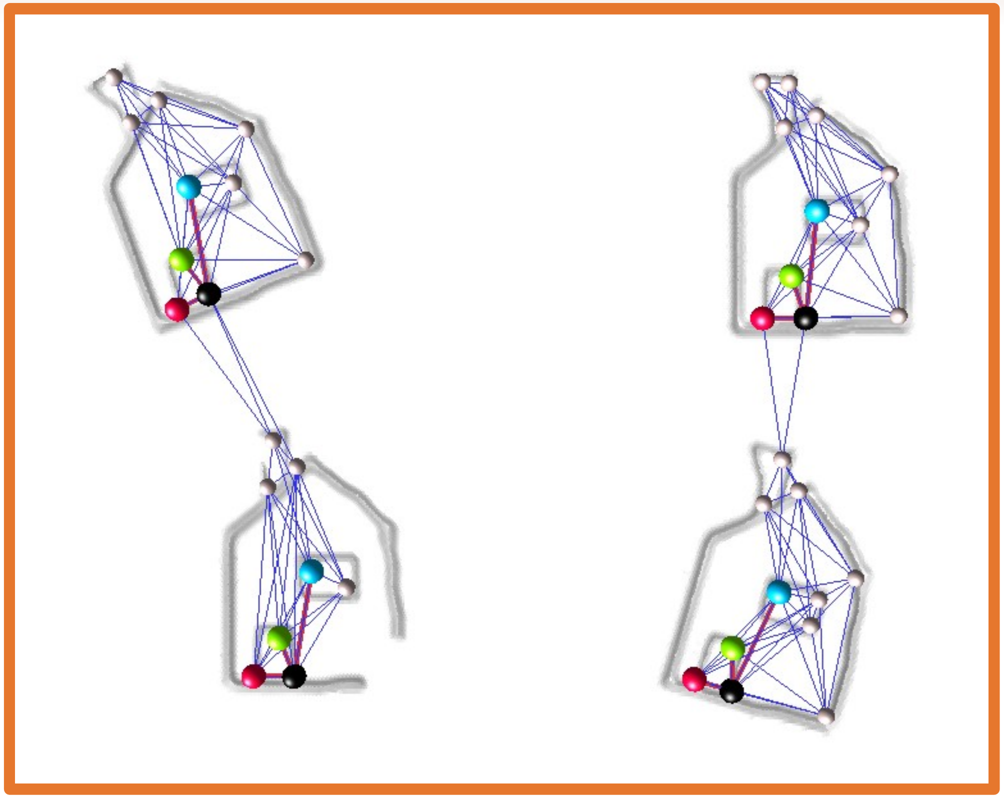
Sub-Symmetry Detection

- Build neighbor graph over feature points
- For each feature, generate all n-tuples with neighbors
- **Characterize tuples by a vector of pairwise distances**



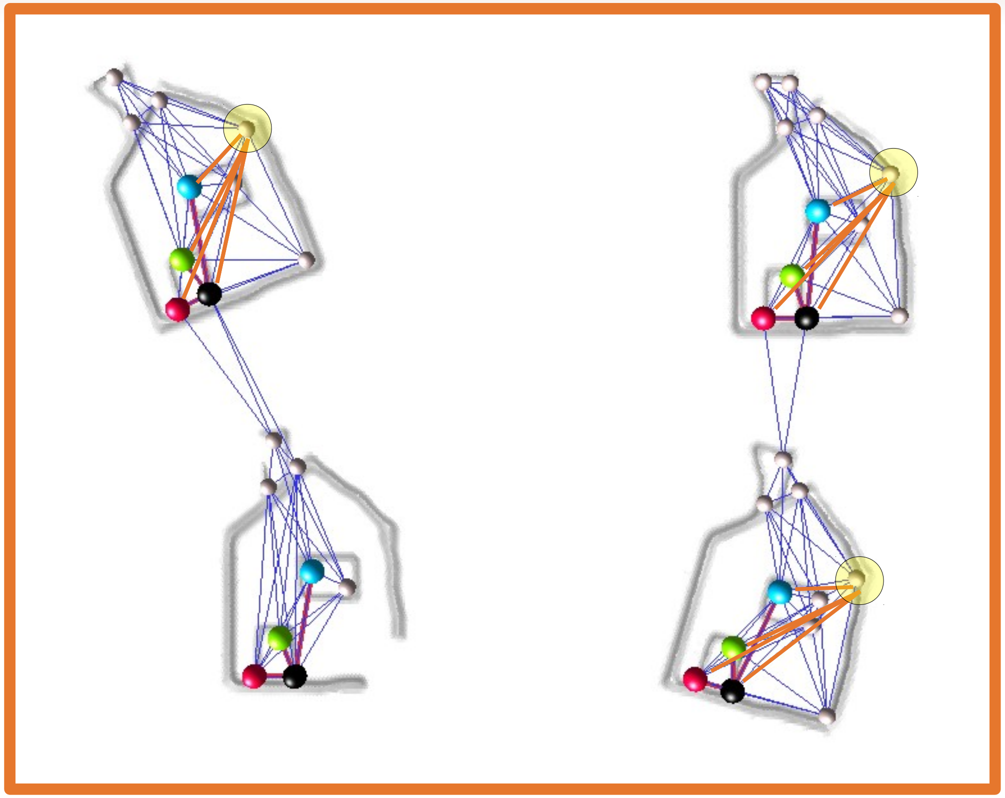
Sub-Symmetry Detection

- Build neighbor graph over feature points
- For each feature, generate all n-tuples with neighbors
- Characterize tuples by a vector of pairwise distances
- **Establish correspondence between similar ones**



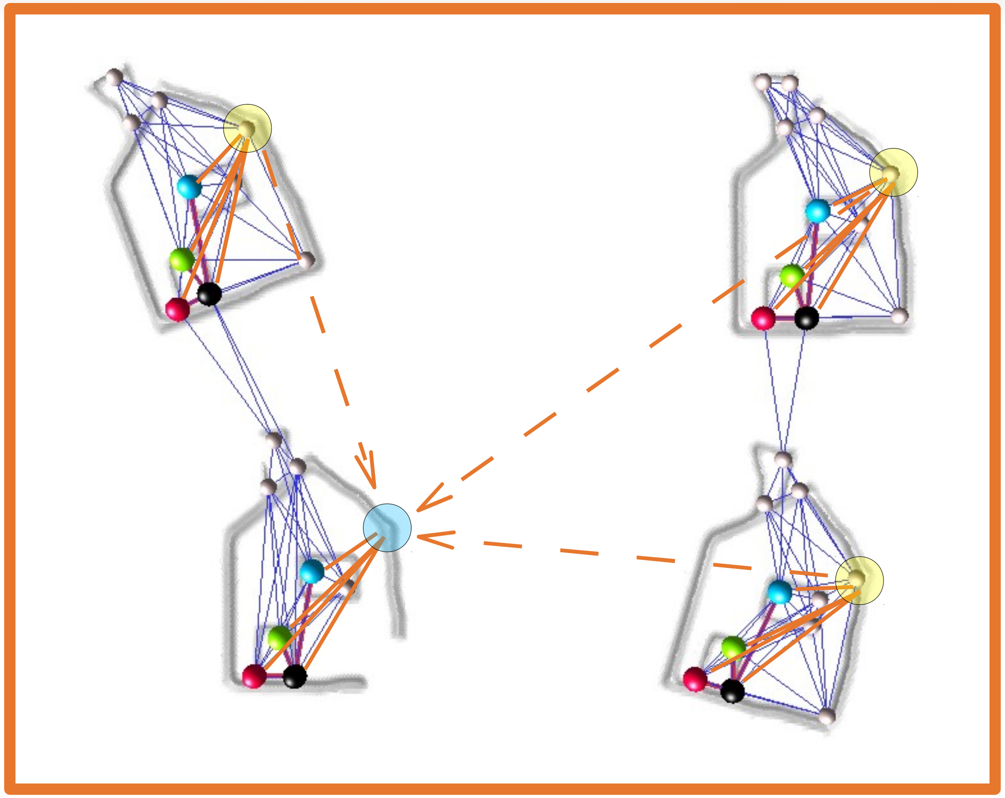
Sub-Symmetry Detection

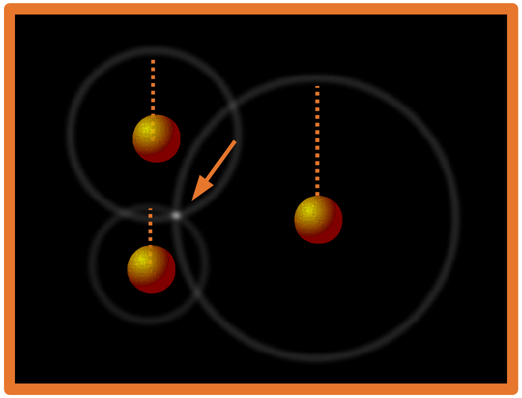
- Build neighbor graph over feature points
- For each feature, generate all n-tuples with neighbors
- Characterize tuples by a vector of pairwise distances
- Establish correspondence between similar ones
- **"Triangulate" nearby features using tuple features as reference points**
- **Establish correspondence between similar ones**



Sub-Symmetry Detection

- Build neighbor graph over feature points
- For each feature, generate all n-tuples with neighbors
- Characterize tuples by a vector of pairwise distances
- Establish correspondence between similar ones
- "Triangulate" nearby features using tuple features as reference points
- Establish correspondence between similar ones
- **Use tuple-relative coordinates to propagate features**





2D triangulation

Handling Feature Guesses

- Result: Large set of feature guesses
- Some guesses are wrong
- Some are badly constrained
- How to handle that robustly?

?

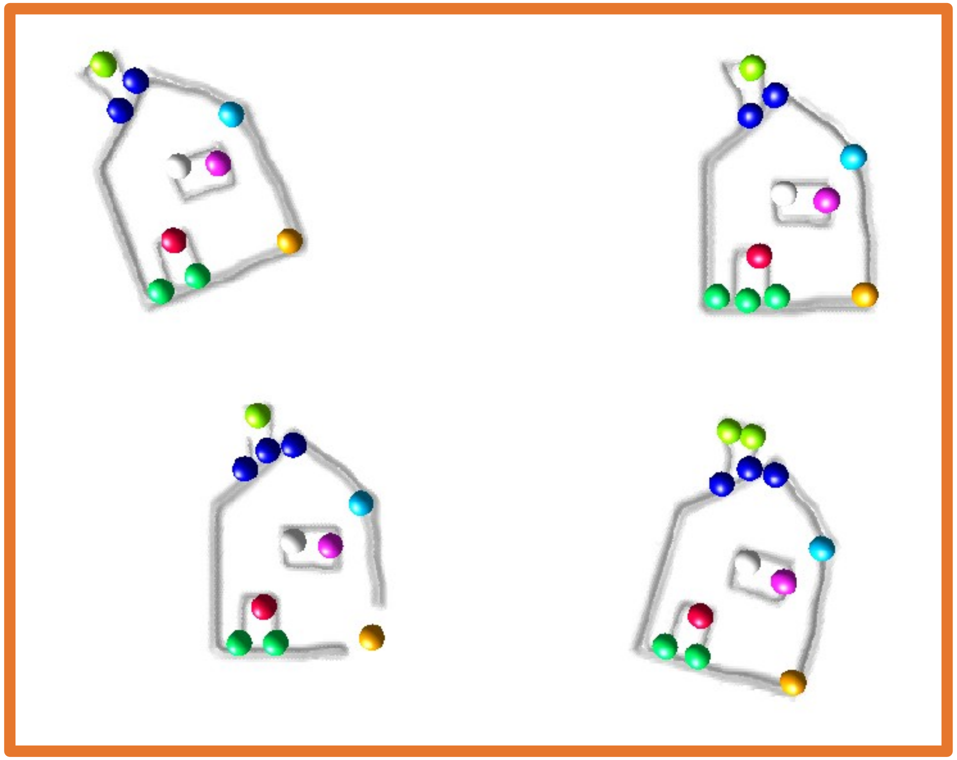
Handling Feature Guesses

- Assign a certainty to each guess
- Merge spatially related guesses
- Boost certainty if many guesses predict the same feature
- Others can be neglected

%

Handling Feature Guesses

- Bonus: Extract feature-to-feature correspondences
- Remember: Guesses were derived from partial symmetries



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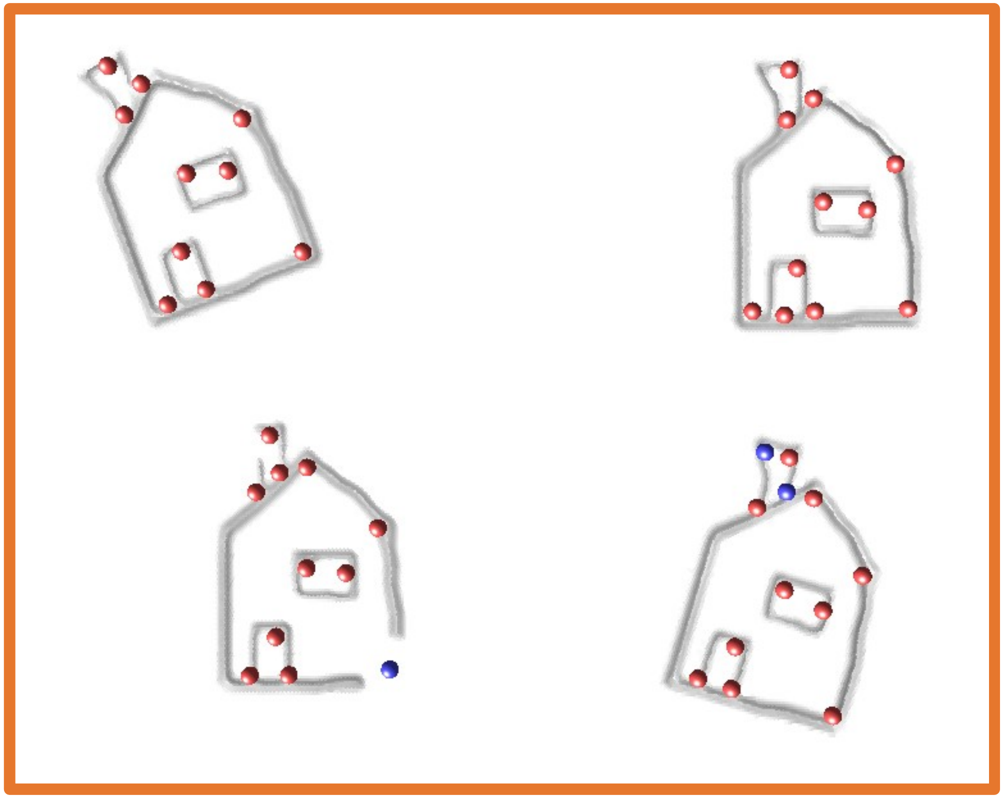
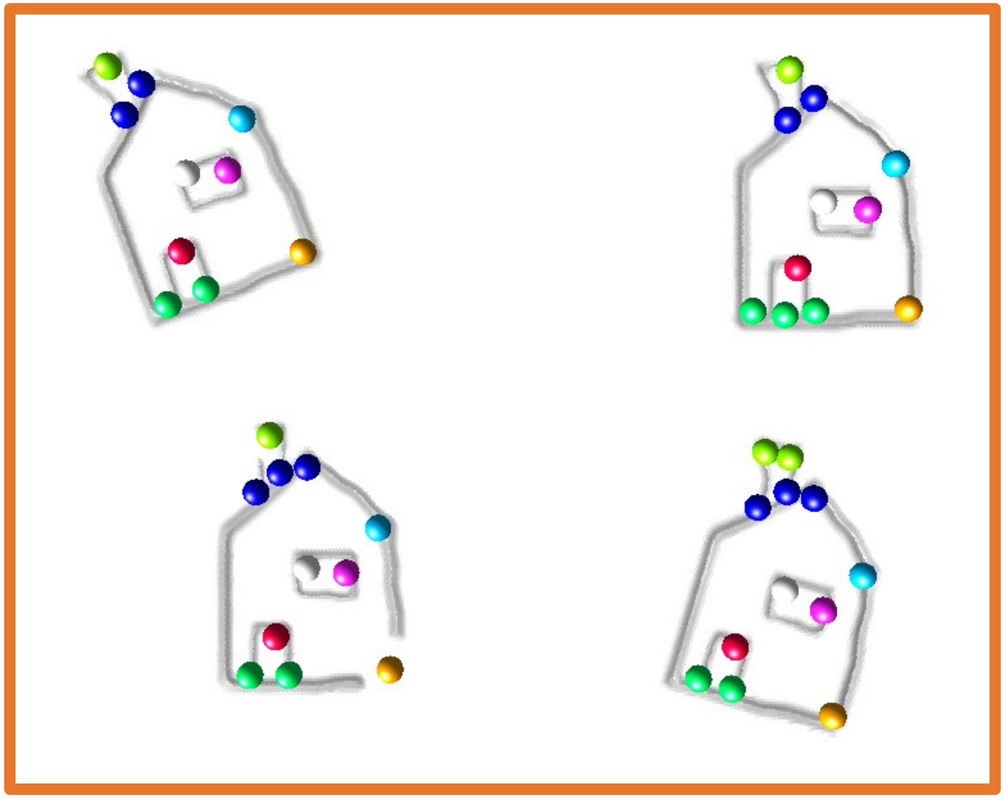
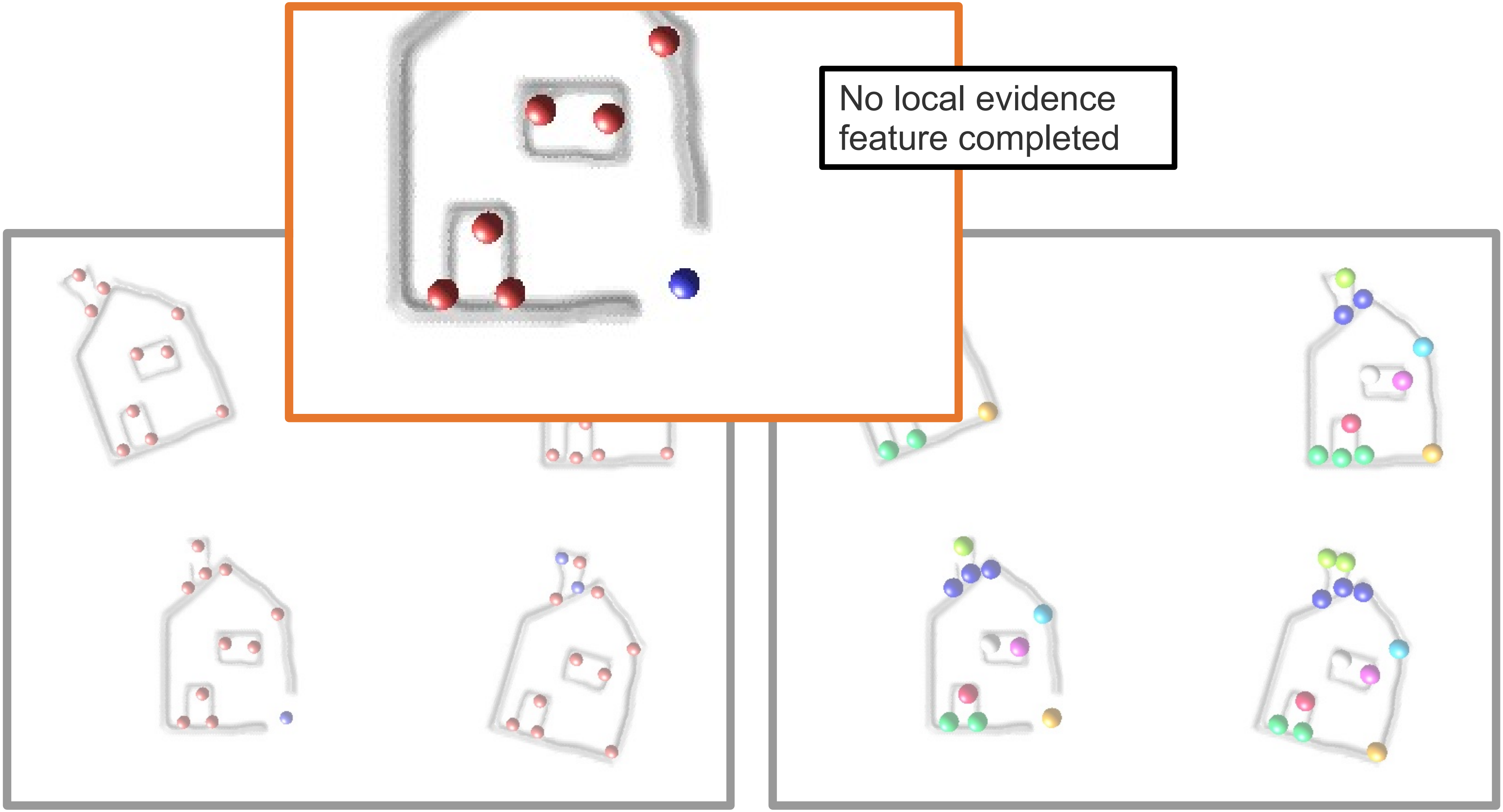
Preliminary Results

- Synthetic example: “IPSFX houses”
- 3 iterations



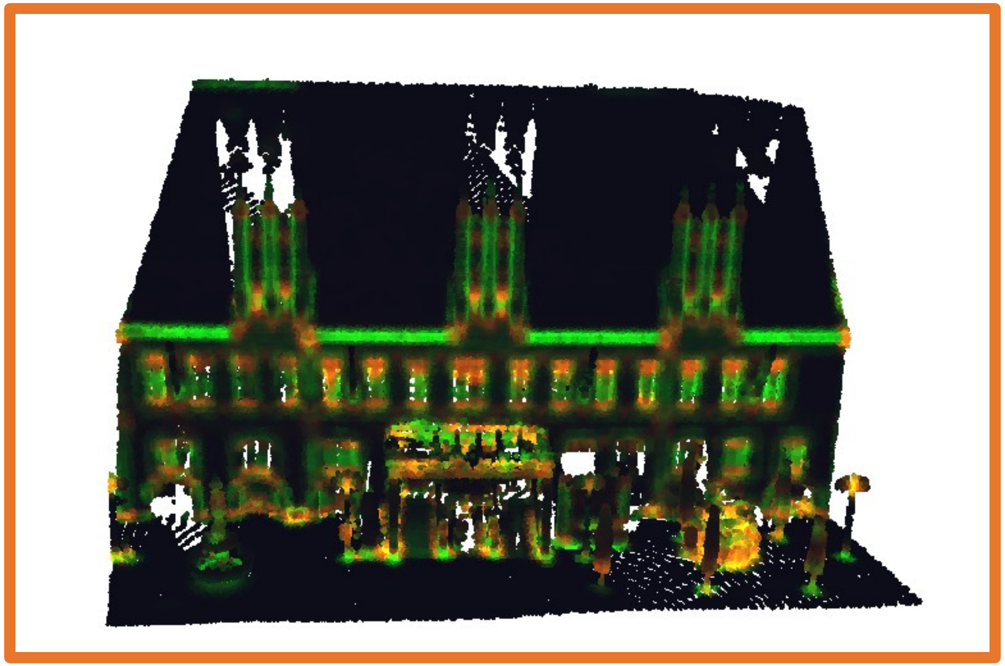


Preliminary Results



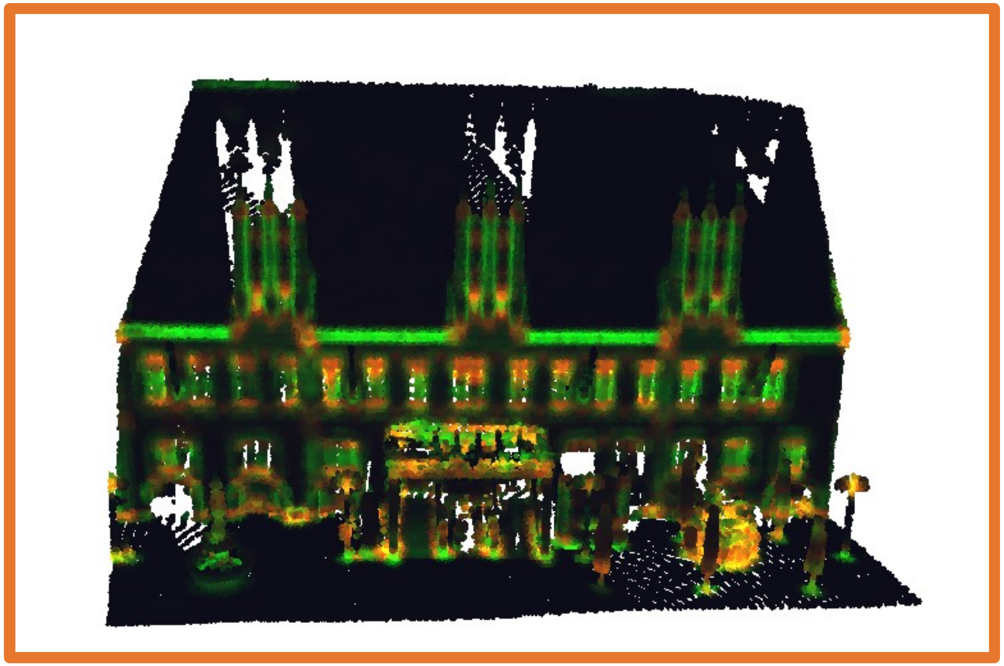
Preliminary Results

- Scanned example: Hannover town hall
- Input data and slippage:



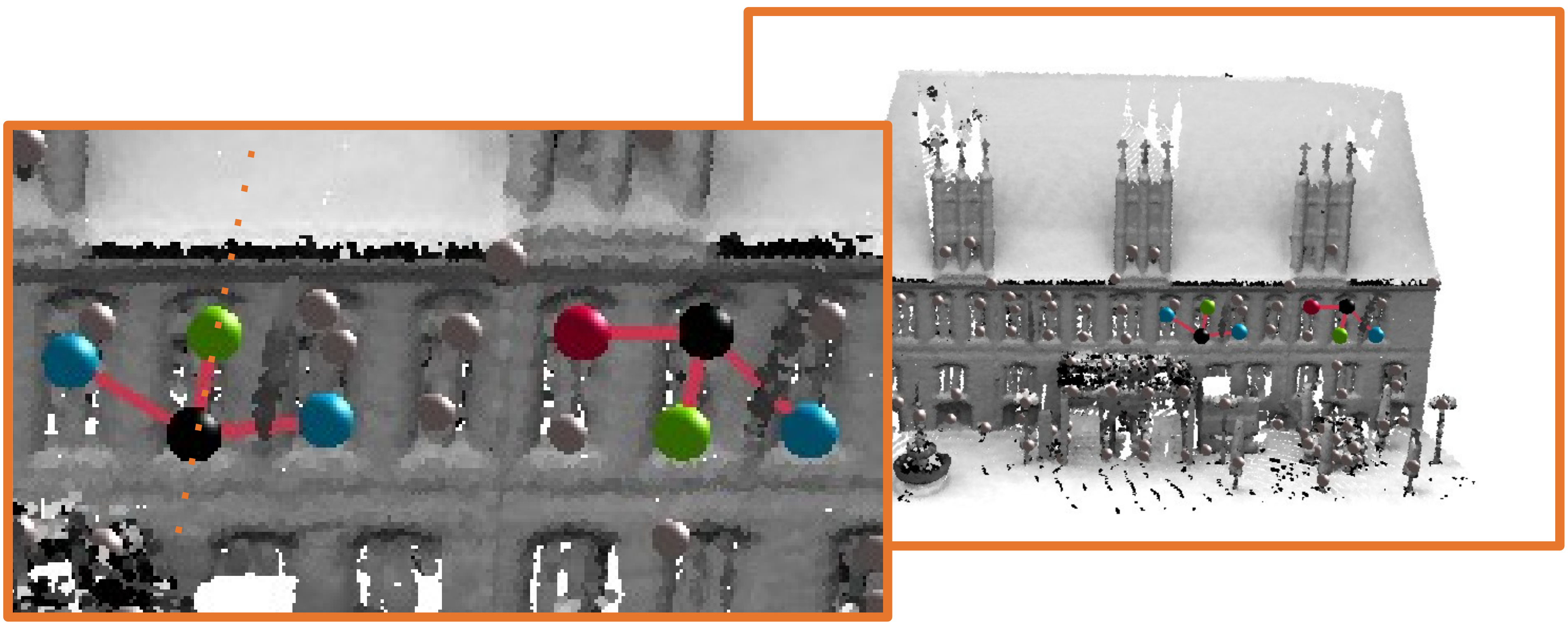
Preliminary Results

- Scanned example: Hannover town hall
- 1st iteration (interest based features):



Preliminary Results

- Scanned example: Hannover town hall
- Propagation quadlets (example):



Preliminary Results

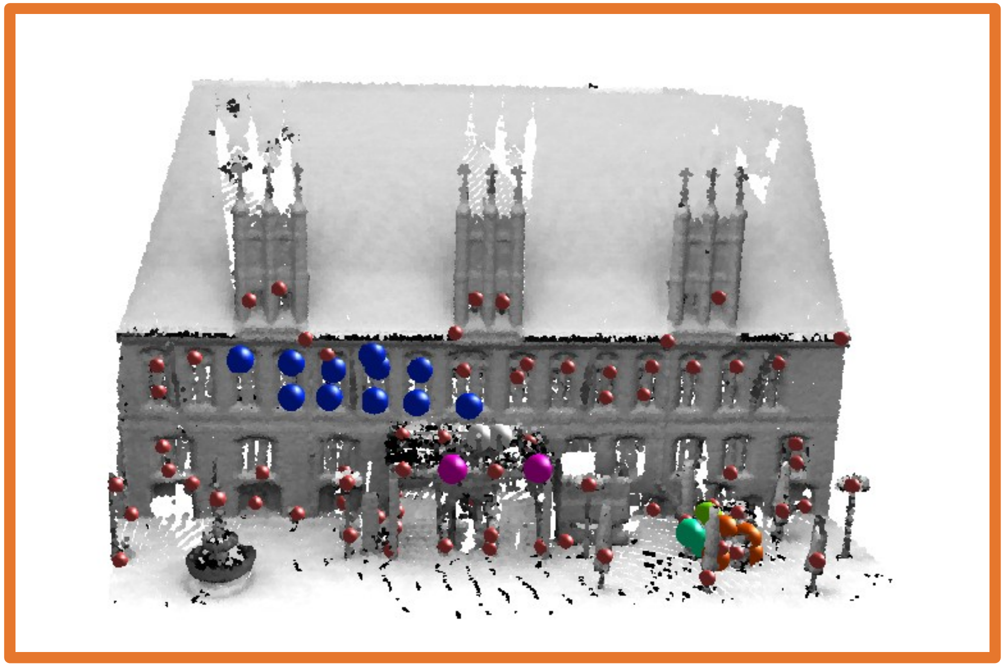
- Scanned example: Hannover town hall
- 2nd iteration, features and correspondences:

Preliminary Results

- Scanned example: Hannover town hall
- 3rd iteration, features and correspondences:

Preliminary Results

- Scanned example: Hannover town hall
- 4^{th} iteration, features and correspondences:

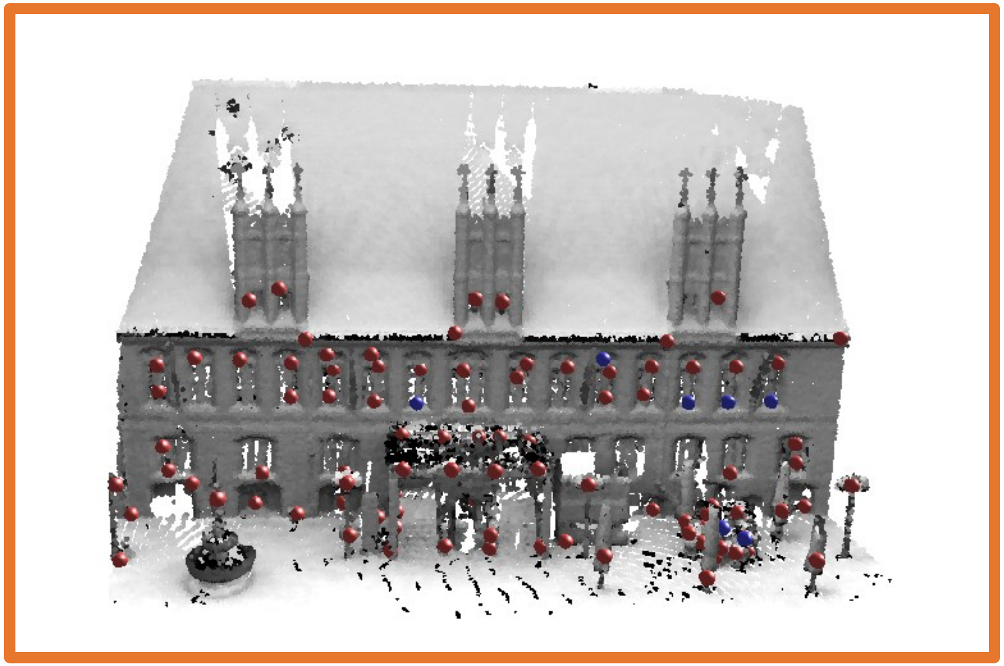


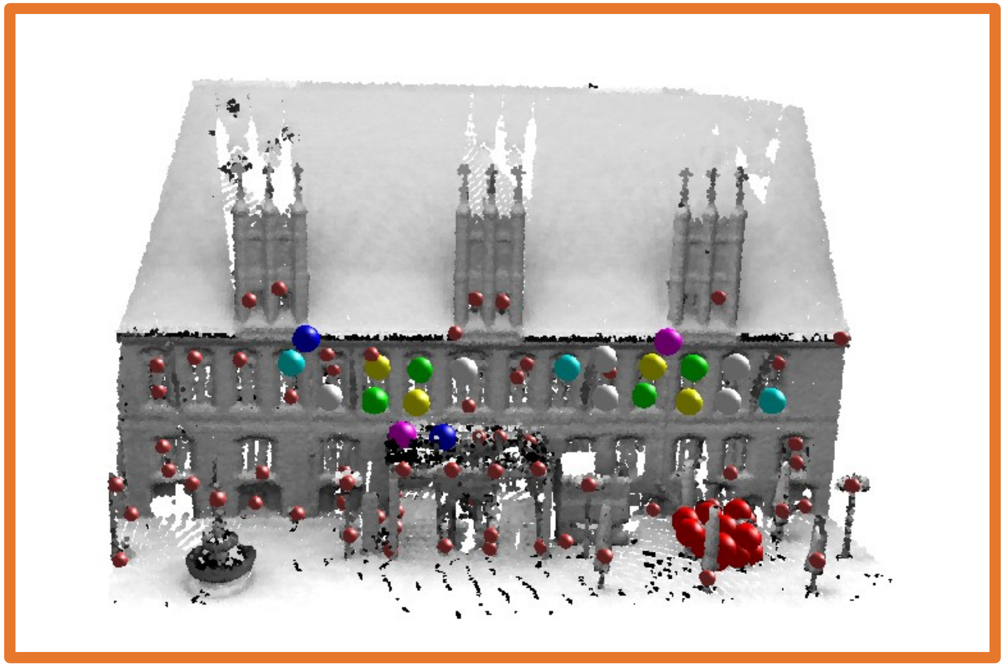
Preliminary Results

- Scanned example: Hannover town hall
- 5th iteration, features and correspondences:

Preliminary Results

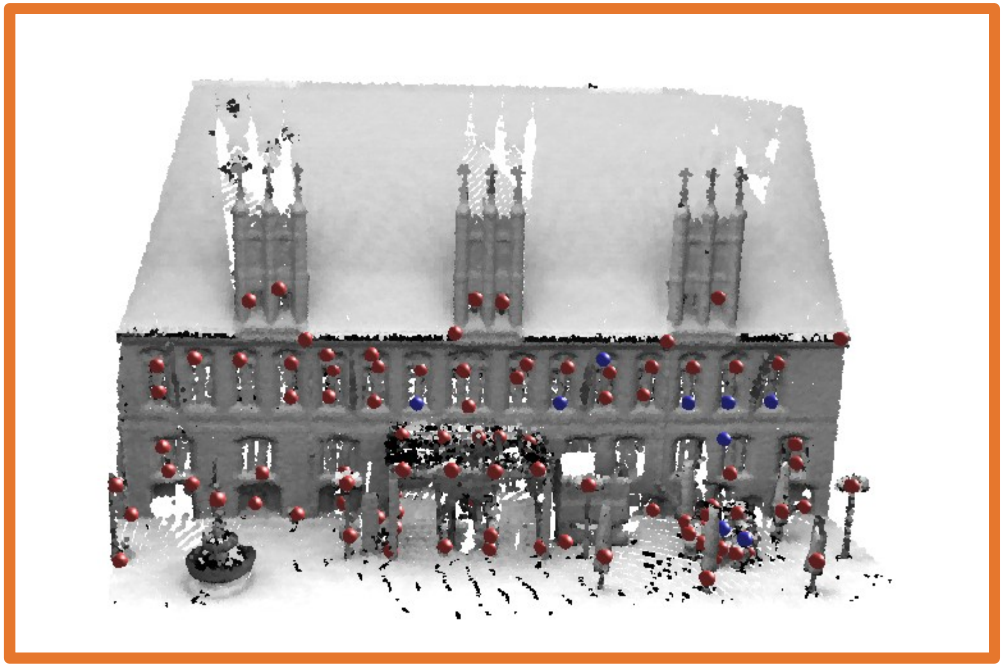
- Scanned example: Hannover town hall
- 6th iteration, features and correspondences:



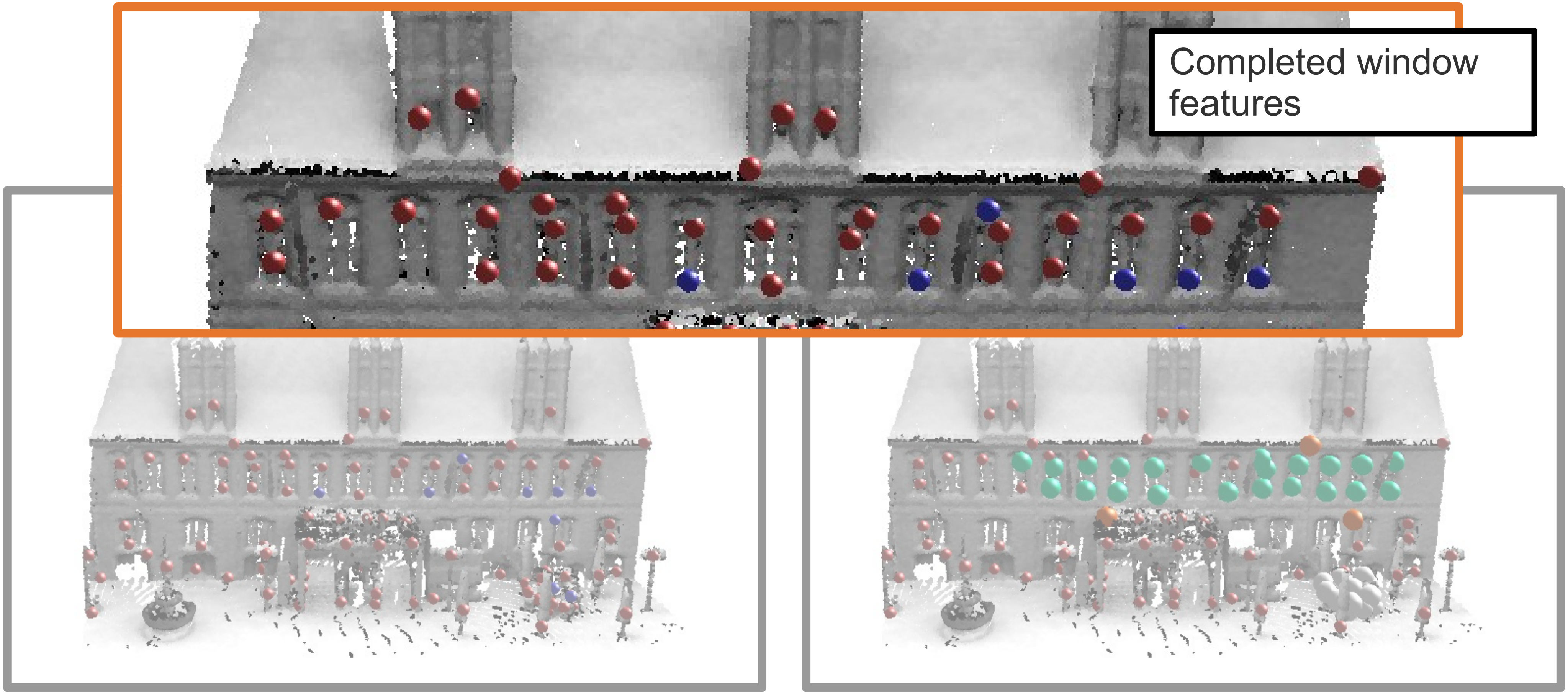


Preliminary Results

- Scanned example: Hannover town hall
- 7th iteration, features and correspondences:



Preliminary Results

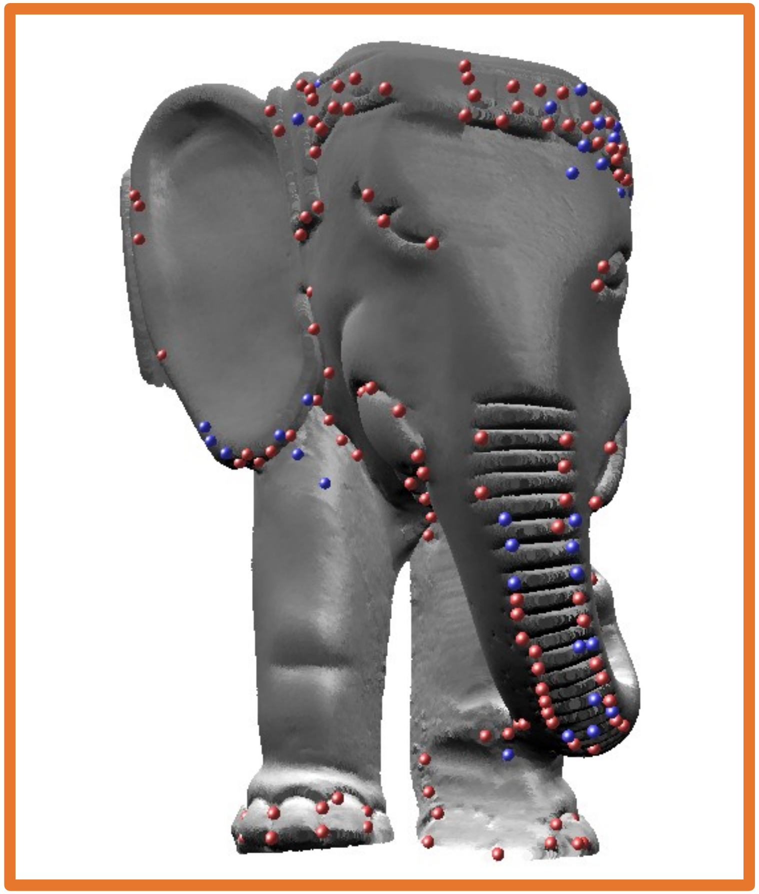


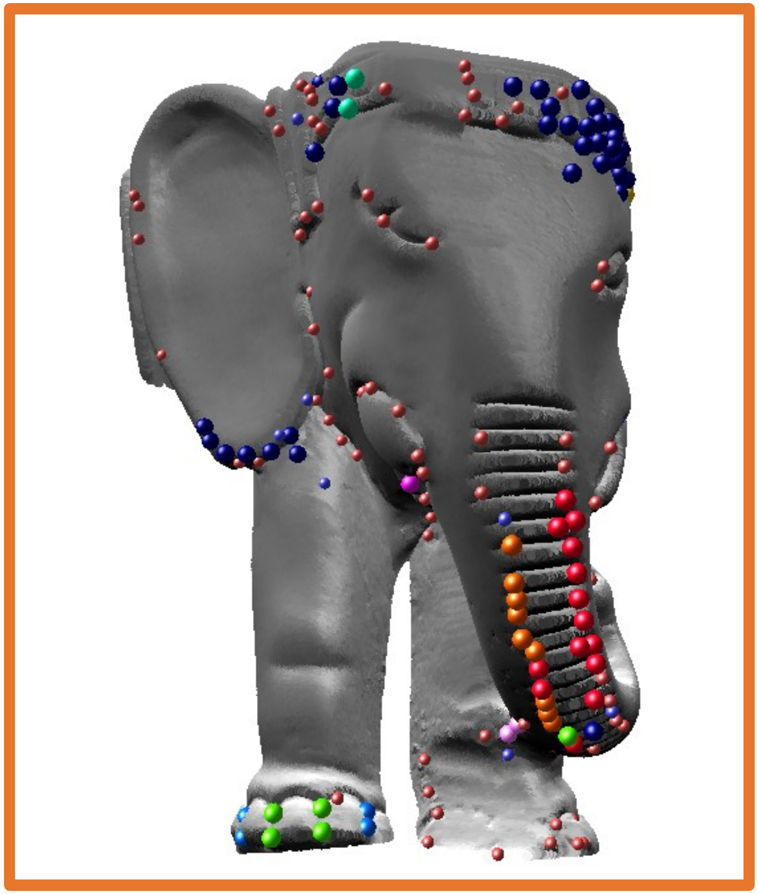
Preliminary Results

- Scanned example: Thai elephant statue
- Input data and slippage:

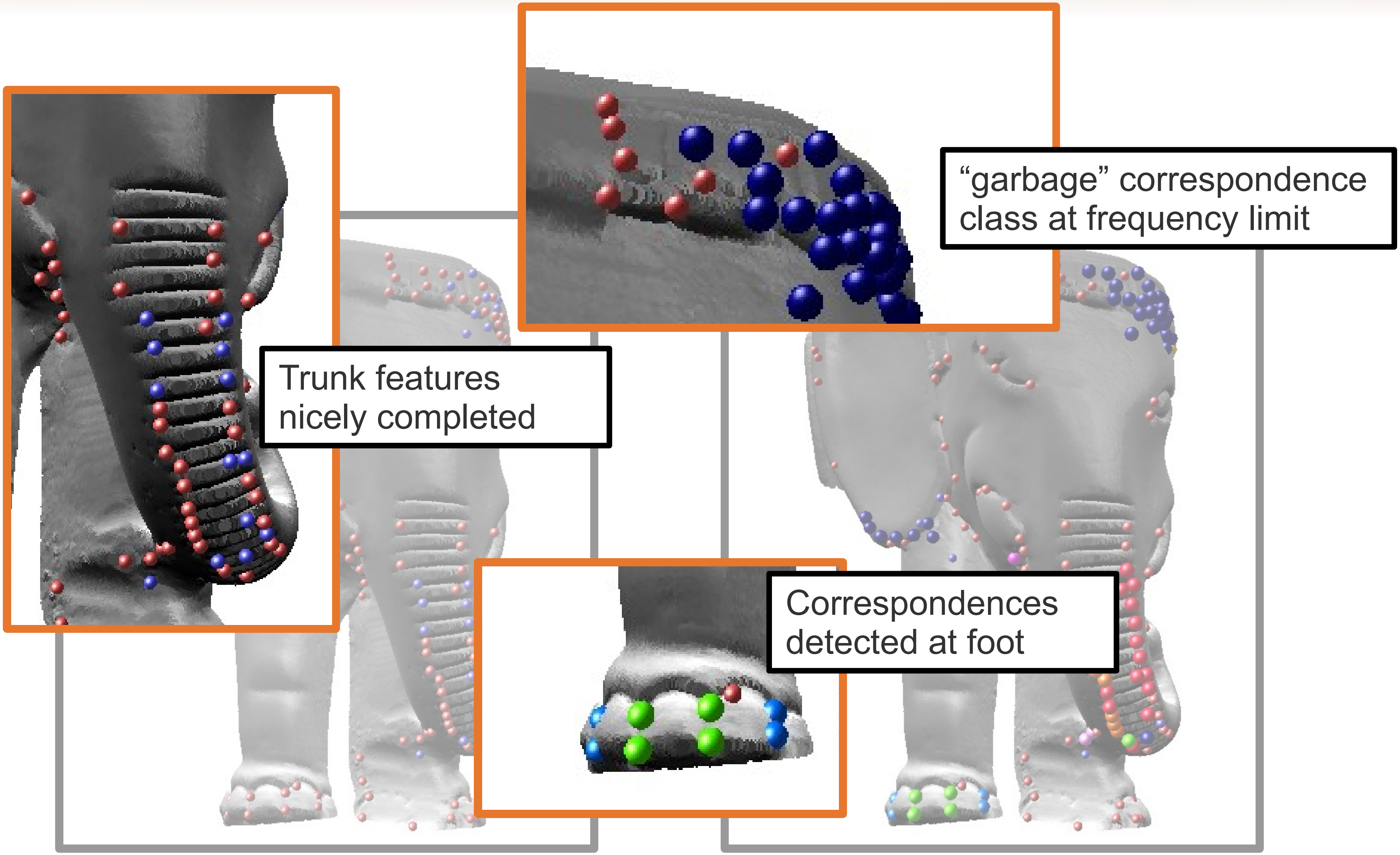
Preliminary Results

- Scanned example: Thai elephant statue
- 5 iterations





Preliminary Results



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Conclusion

- Good feature extraction requires global understanding of the scene's structure
- I propose:
  - A framework for interleaved feature selection and partial symmetry detection
  - A robust approach to sub-symmetry detection

References

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