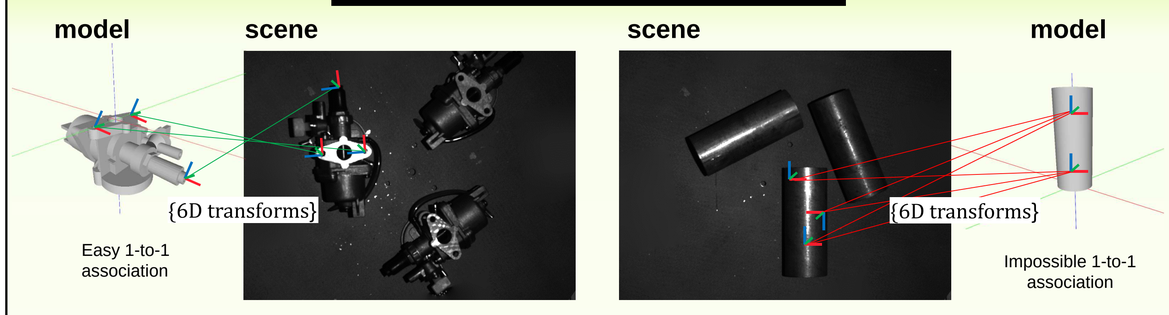
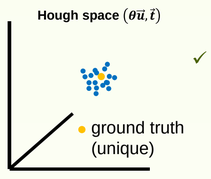
HSPA: HOUGH SPACE PATTERN ANALYSIS AS AN ANSWER TO LOCAL DESCRIPTION AMBIGUITIES FOR 3D POSE ESTIMATION

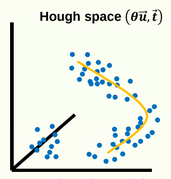
3D registration and ambiguity of description



- Local descriptor matches between model and scene generate correspondences, which generate 6D transformation hypotheses
- Transformations write $(\theta\vec{u}_{angle\ axis}, \vec{t})$ in Hough space



✓ Perfectly distinctive descriptors / unambiguous objects → one single point in Hough space (or a tiny cluster when considering sensor noise)



× Realistic descriptors (3-1000 dimensions) / ambiguous objects → ambiguous correspondences → distinct points and clusters in Hough space

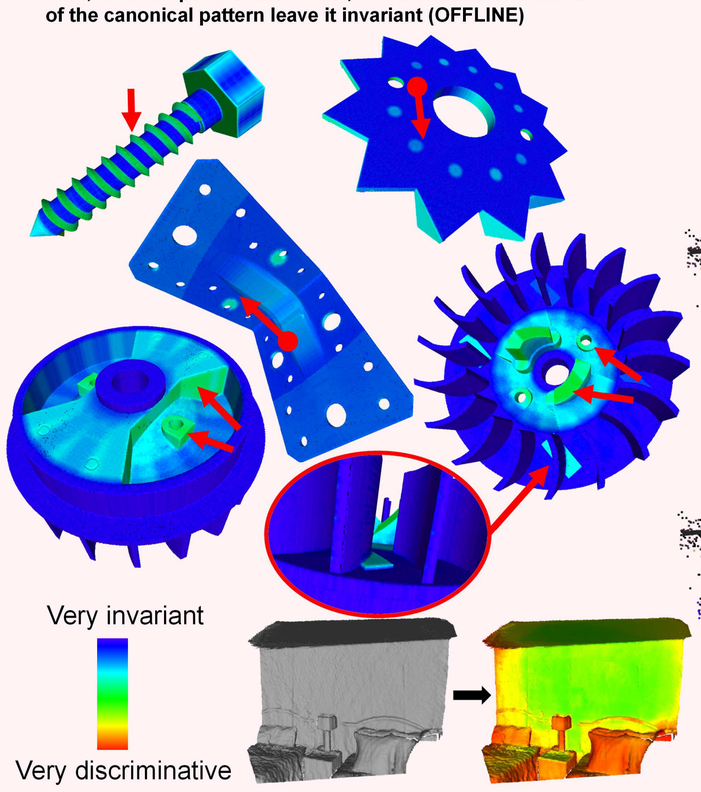
● « ground truth » with unconstrained DOF (multiple solutions)

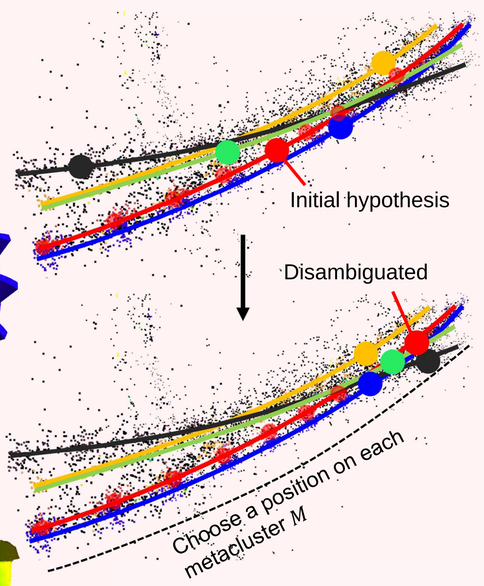
- **Ambiguous description is unavoidable** (finite dimension descriptors, occlusions and observation incompleteness, …)
- **Ambiguous matches form patterns in Hough space**, corresponding to transformations aligning part of the model to the scene
- **The Hough patterns can be viewed as a global description**.
  - It is dual to individual descriptors (better descriptors <–> simpler patterns in Hough space)

HSPA - disambiguation

Principle

- **Find, for each point of the model, whether transformations of the canonical pattern leave it invariant (OFFLINE)**
- **Use this information to navigate within the canonical pattern and disambiguate quasi-symmetries (ONLINE)**



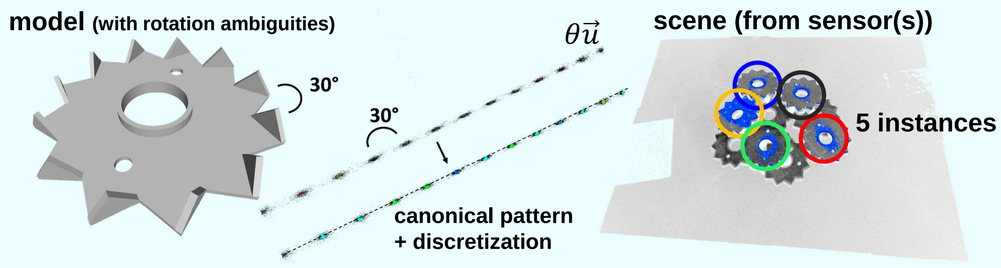


Hough Space Pattern Analysis (HSPA) - identification

Principle

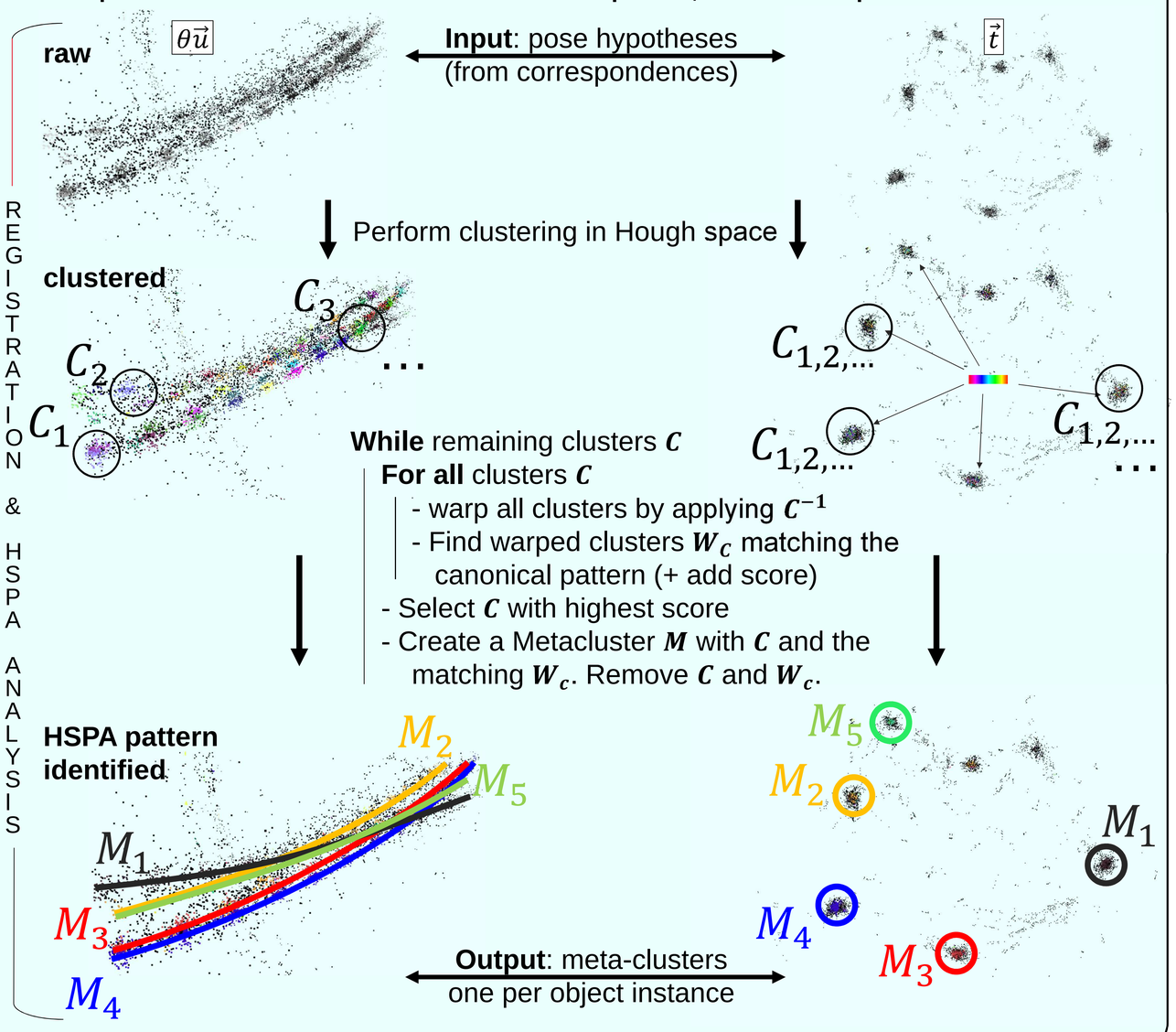
- **Match the model to a noisified version of itself**. This produces a **canonical Hough-space invariance pattern**. This pattern is formed of transformations which leave (part of) the model invariant and is stored as a global model descriptor.
- **Match the model and scene, producing another Hough invariance pattern**
- Find (one of) **the transformation(s) that best aligns the invariance pattern to the canonical invariance pattern**
  - This new formulation generalizes well to problems with more than one solution (ex. : finding cylinders)
- **Aggregate points in the invariance pattern** that match the canonical pattern (→ one cluster per model instance in Hough space)

PREPARATION

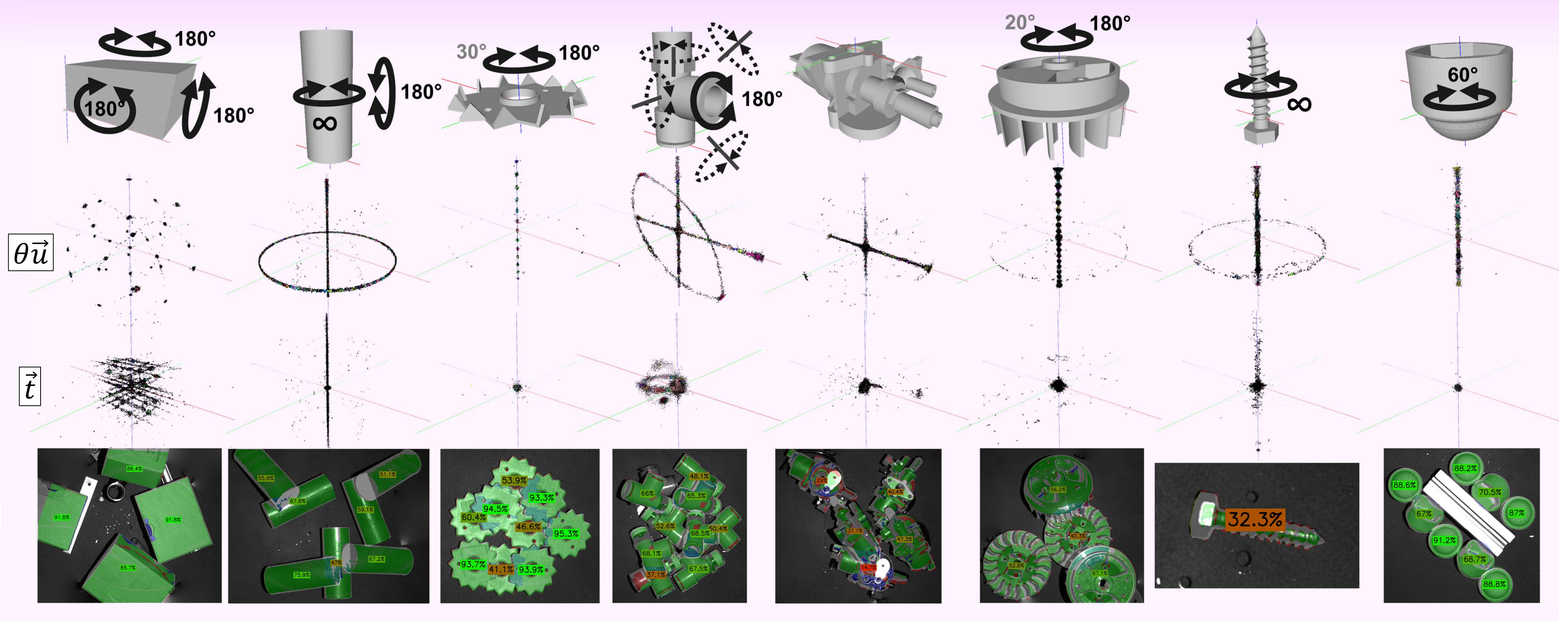


scene pattern: deformed instances of the canonical pattern, one instance per model in the scene

REGISTRATION & HSPA ANALYSIS



Example Hough patterns and results



BOP/ ITODD	Method name	recall	Time (s)
	Drost-Edges-Halcon19	<u>0.462</u>	5.838
	Vidal-Sensors 2018	0.435	3.419
	Drost-Halcon19	0.316	2.0
	Baseline (local descriptor matches)	0.412	0.535
	HSPA (inv. analysis no disambiguation)	0.458	**0.471**
	HSPA (full)	**0.511**	<u>0.567</u>

Main takeaways

- **The missing information due to description ambiguities can be found in Hough space**
- **Canonical Hough patterns can be precomputed by comparing an object to itself (with added noise)**
- **The object localisation problem then turns into a pattern correlation problem in Hough space**
- **It is possible to detect parts that break symmetries (foolproofing marks for instance) to refine localisation**
- **Our work describes a pipeline to perform this task. This pipeline is very flexible and notably accomodates deep-learning based description and pose hypothesis generation**
- **We are expecting further applications of Hough space pattern processing for other parametric problems**

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