Ranking on Cross-Domain Manifold for Sketch-based 3D model Retrieval

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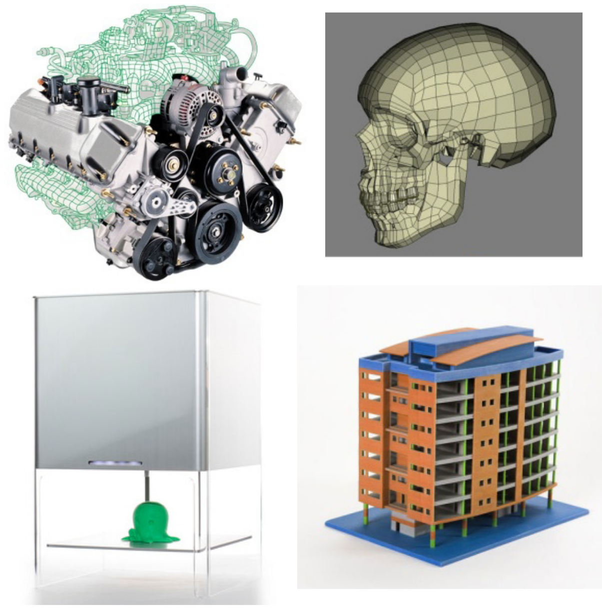
Introduction

- 3D models are widely used.
  - Mechanical CAD, Games,…
  - 3D range scanners, 3D printers,…
  - User generated.
    - Trimble 3D warehouse, ...



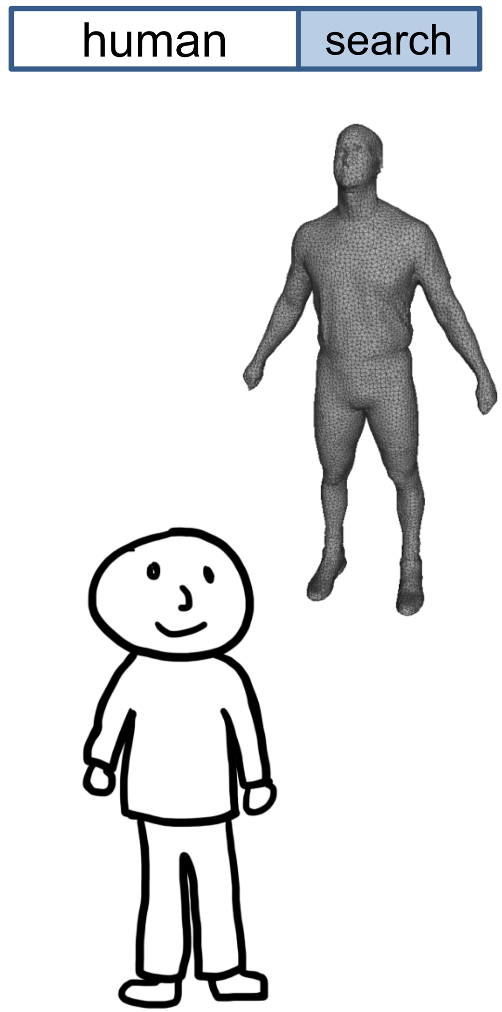
- 3D model retrieval is essential.
  - High retrieval accuracy.
  - Efficiency.
  - Ease of use.

Focuses of this research

accurate
and
easy to use

Why sketch-based ?

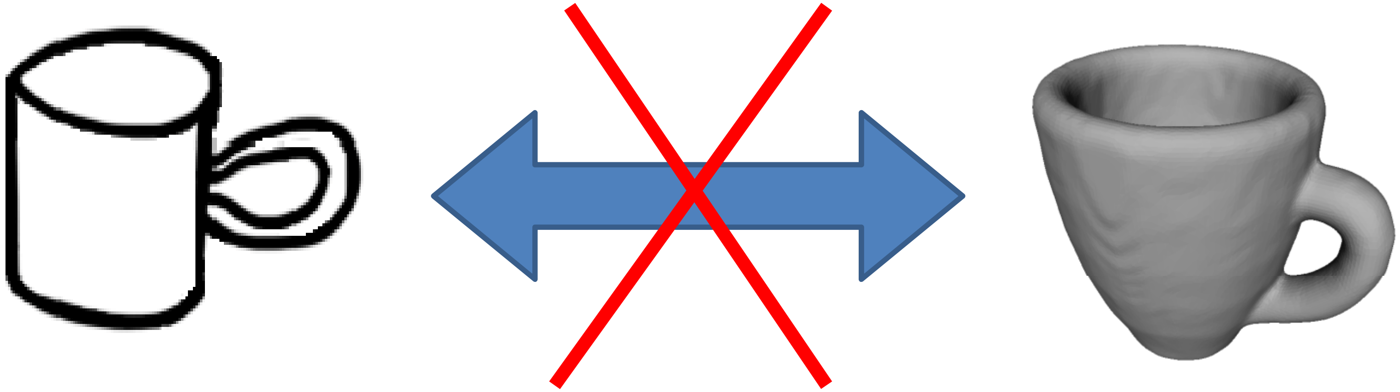
- Keywords
  - ✓ Accessible for most people.
  - × 3D models lack textual tags.
- 3D model
  - ✓ Sufficiently accurate for certain applications.
  - × 3D models often unavailable.
- 2D hand-drawn sketch
  - ✓ Accessible for most people.
  - ✓ Intuitively specify 2D shape.
  - × Inaccurate.
    - Even the best method yields MAP = 11% using SHREC 2013 benchmark.



Cross-domain matching problem

- How do we compare a 2D sketch and a 3D model?

Can't be compared directly.



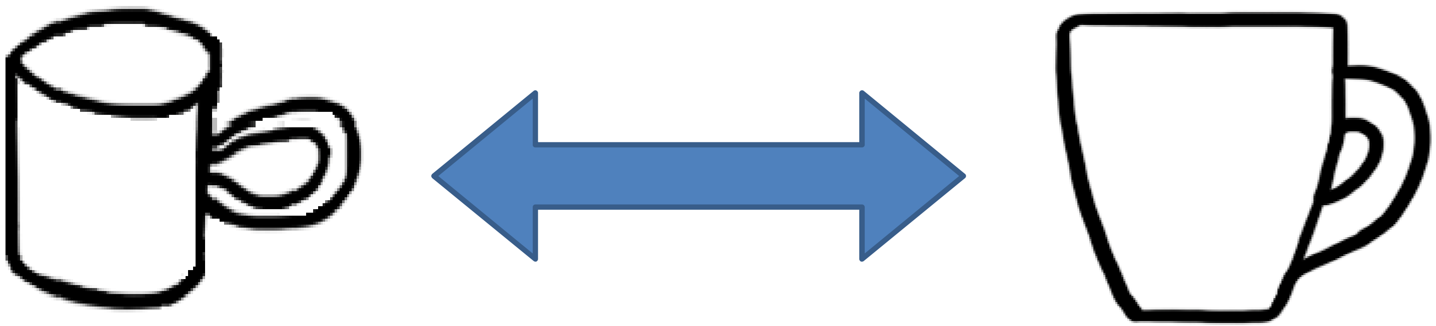
2D sketch

3D model

Cross-domain matching problem

- Approach 1 : Image feature-based comparison.
  - Renders 3D models into lines.
    - e.g., Suggestive contour [DeCarlo03], …
  - Adopted by most.

Can be compared.

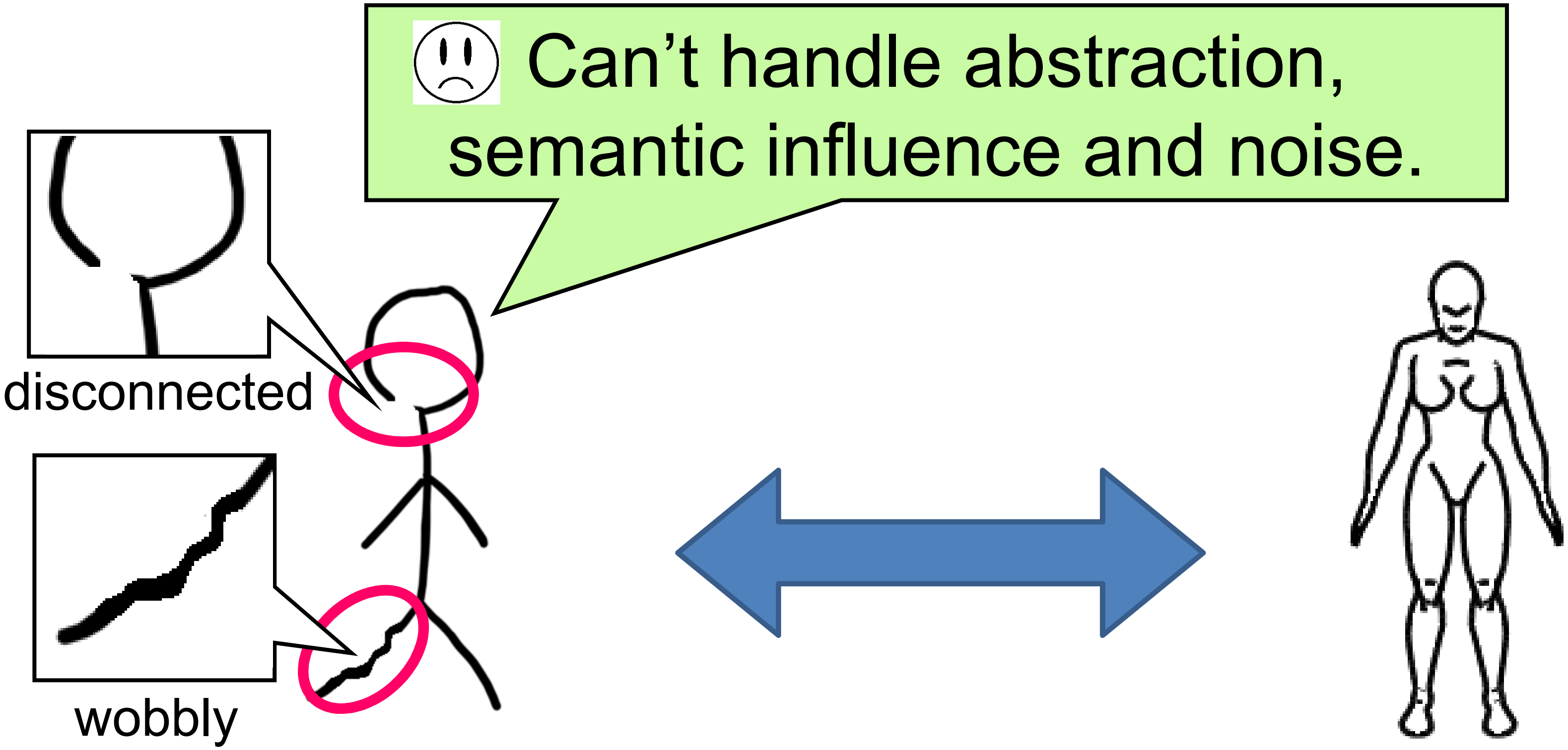


2D sketch

2D sketch-like image

Cross-domain matching problem

- Approach 1 : Image feature-based comparison.

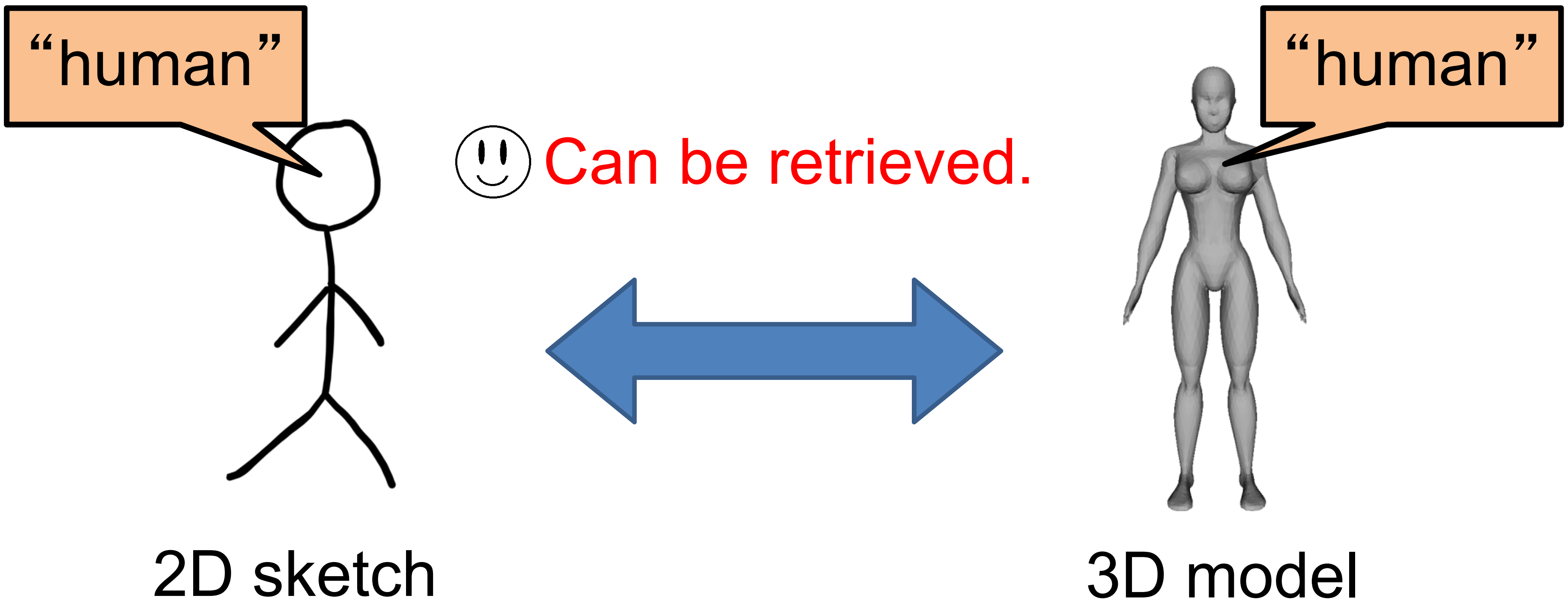


2D sketch

2D sketch-like image

Cross-domain matching problem

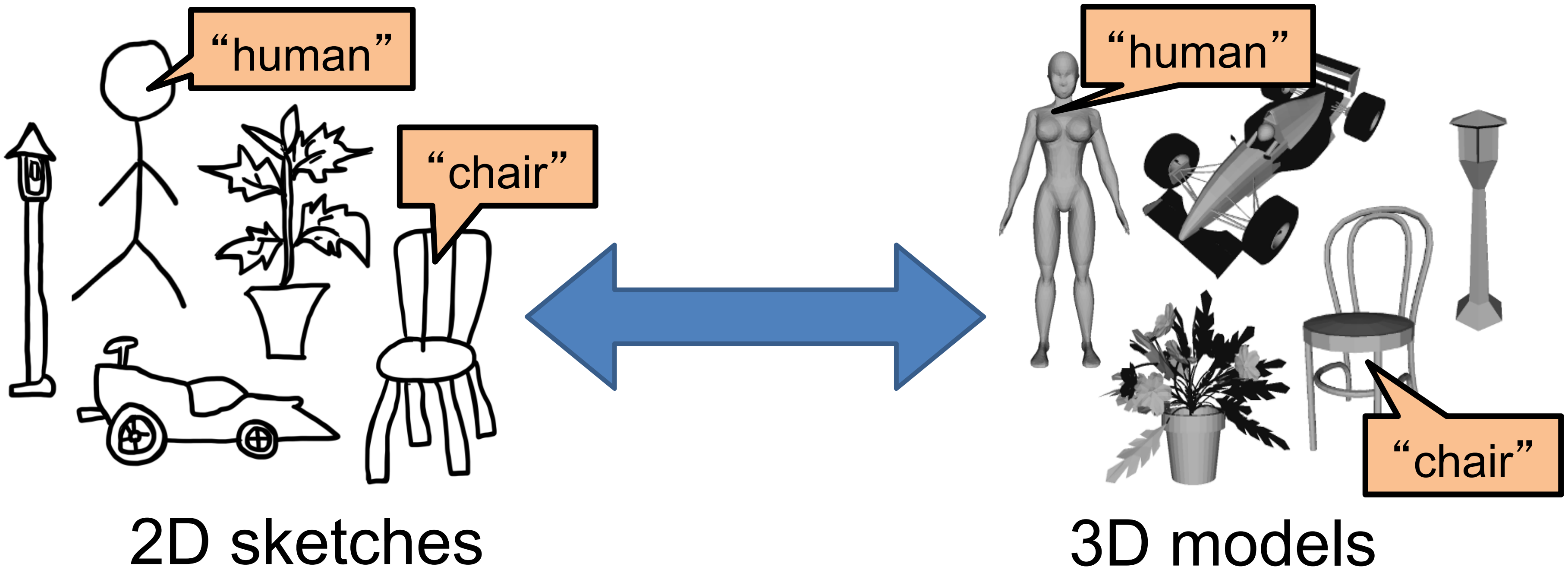
- Approach 2 : Semantic label-based comparison.



Cross-domain matching problem

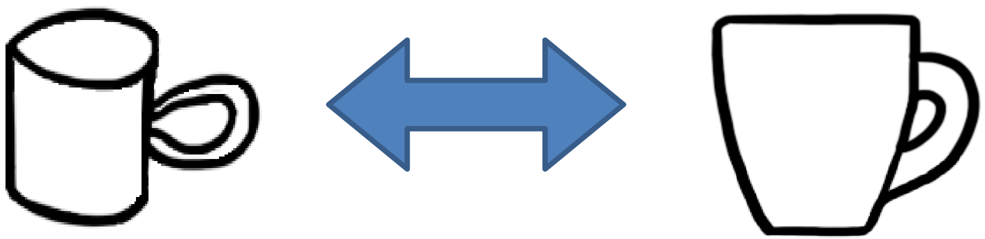
- Approach 2 : Semantic label-based comparison.

☹ Learning sparse labels is difficult.

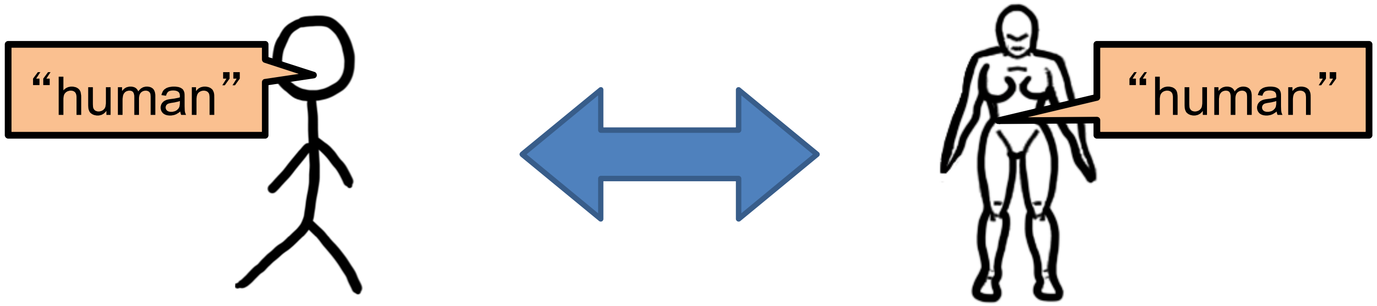


Our approach

- Combination of features and labels.
  - ✓ Matching by image features.



  - ✓ Matching by semantic labels.

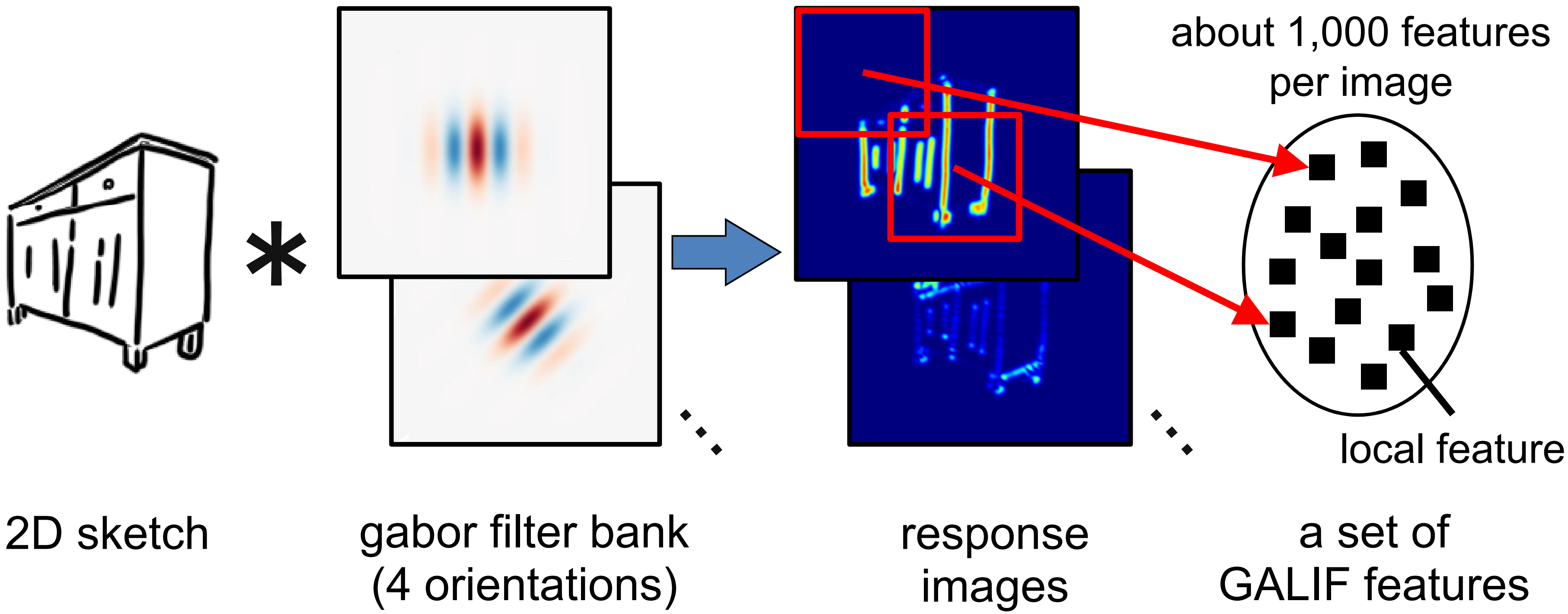


Outline

- Related work
  - BF-GALIF [Eitz12]
    - Algorithm for sketch-based 3D model retrieval
  - Manifold Ranking [Zhou03]
    - Algorithm for distance metric learning
- Proposed method
- Experiments and results
- Conclusion and future work

BF-GALIF [Eitz12]

- Efficiently compares sets of local features.
  1. Densely extracts Gabor filter-based local features.
  2. Integrates local features into a vector by Bag-of-Features.



Related work : Sketch-to-3D model matching algorithm
BF-GALIF [Eitz12]

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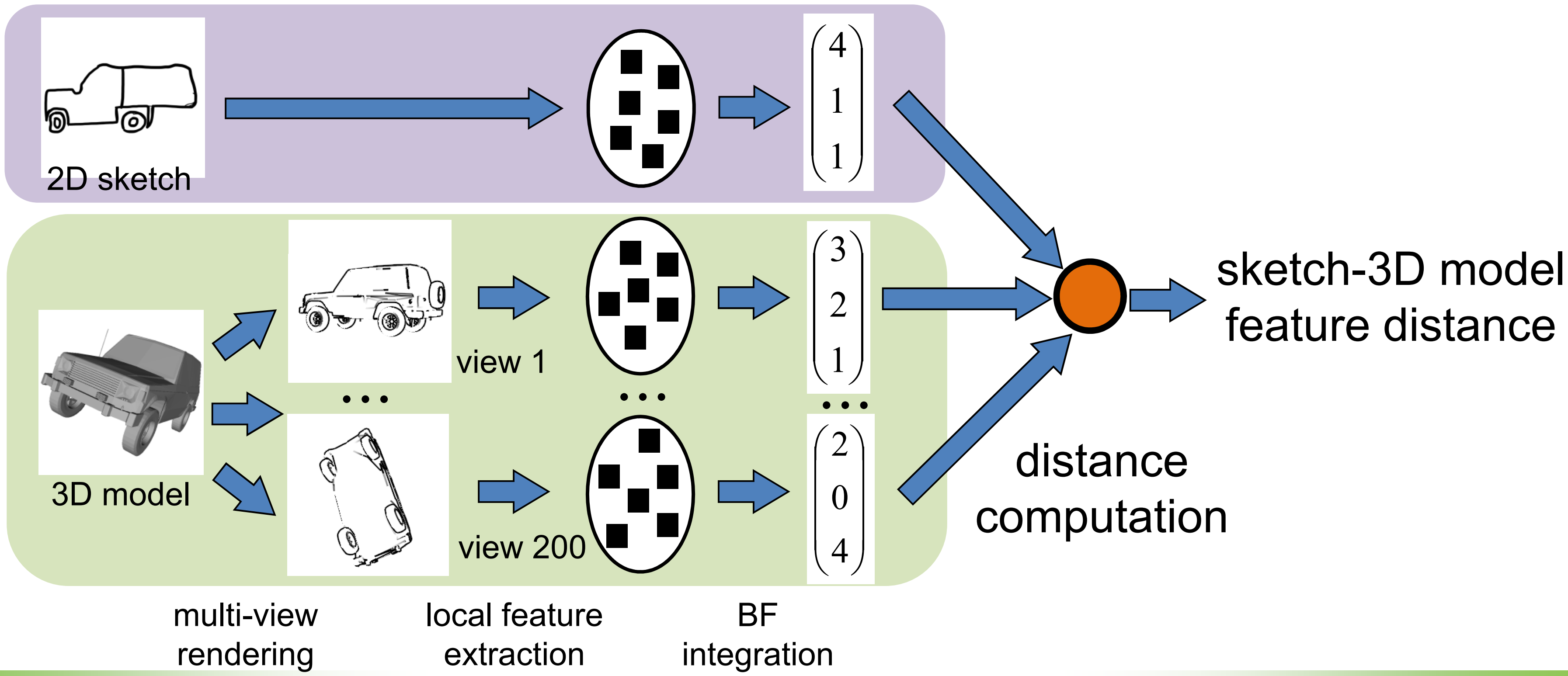


Related work : Sketch-to-3D model matching algorithm
BF-GALIF [Eitz12]

- Efficiently compares sets of local features.

☺ Robust against articulation of 2D shape.

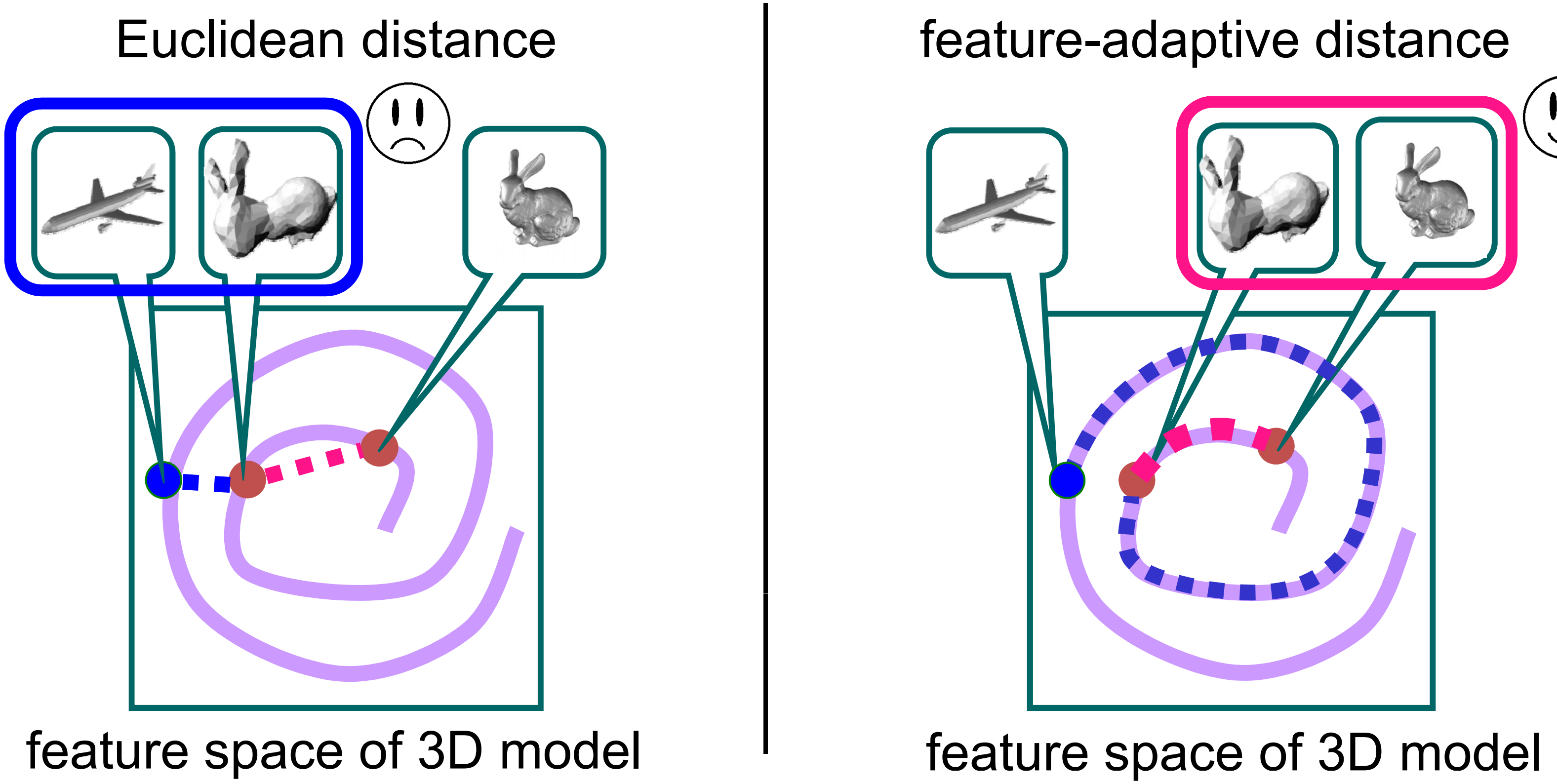
☺ Among the most accurate methods.

☹ Yet, insufficient …

Our approach
・better feature comparison.
・semantic labels.

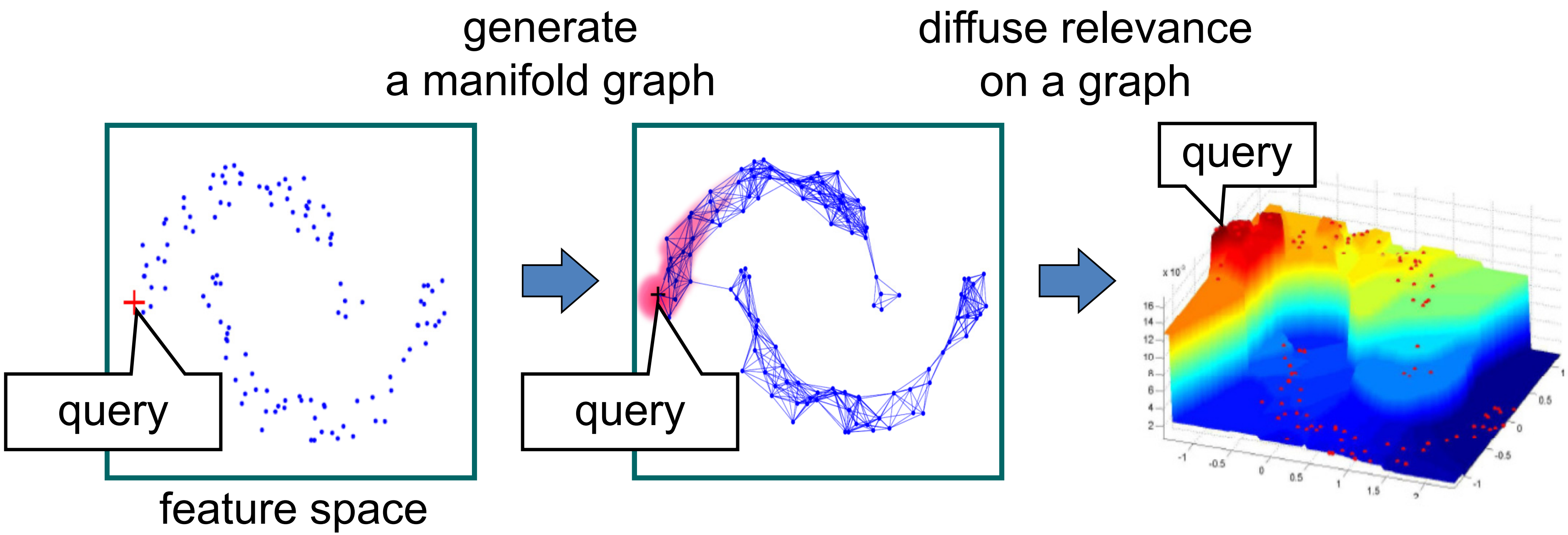
Improving single-domain feature comparison

- Learns feature-adaptive distance metric on manifold.



Related work : Distance metric learning
Manifold Ranking [Zhou03]

- Diffusion distance on a feature manifold graph.

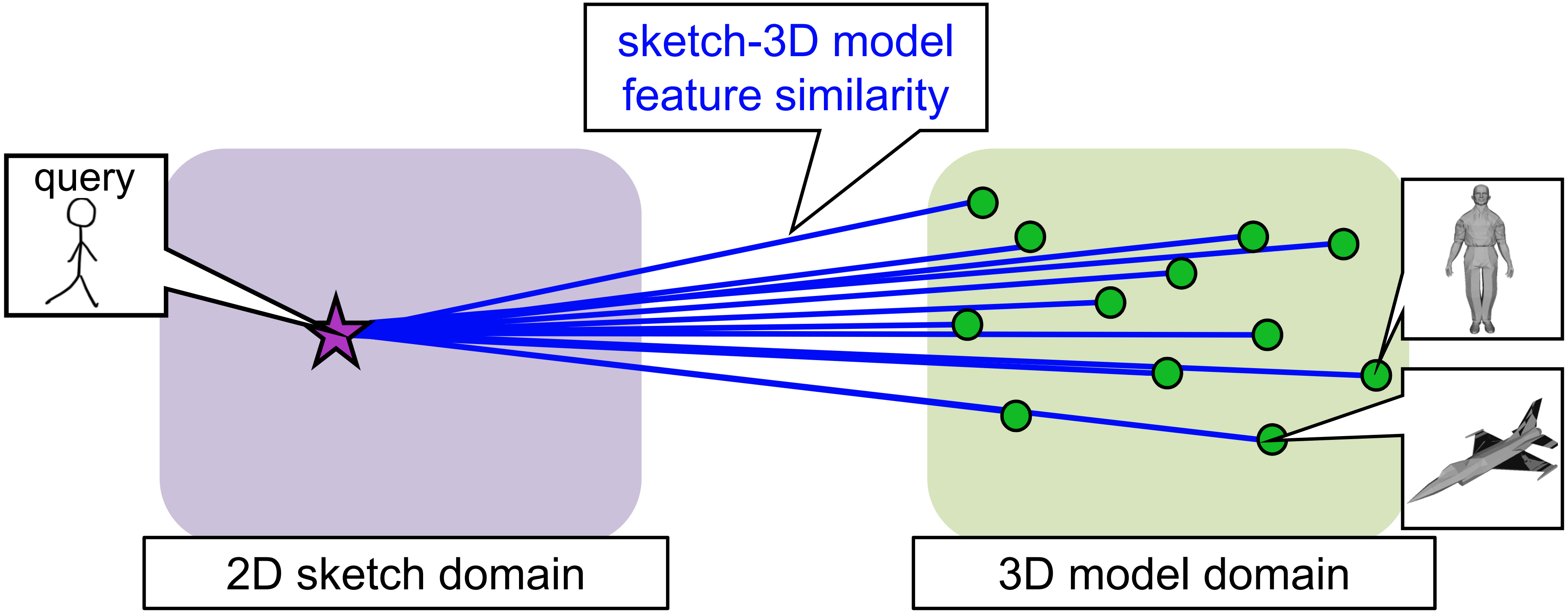


Our approach

・ extends Manifold Ranking to cross-domain.

Improving cross-domain feature comparison

- BF-GALIF [Eitz12]
  - ☹ Structure of feature manifold is ignored.

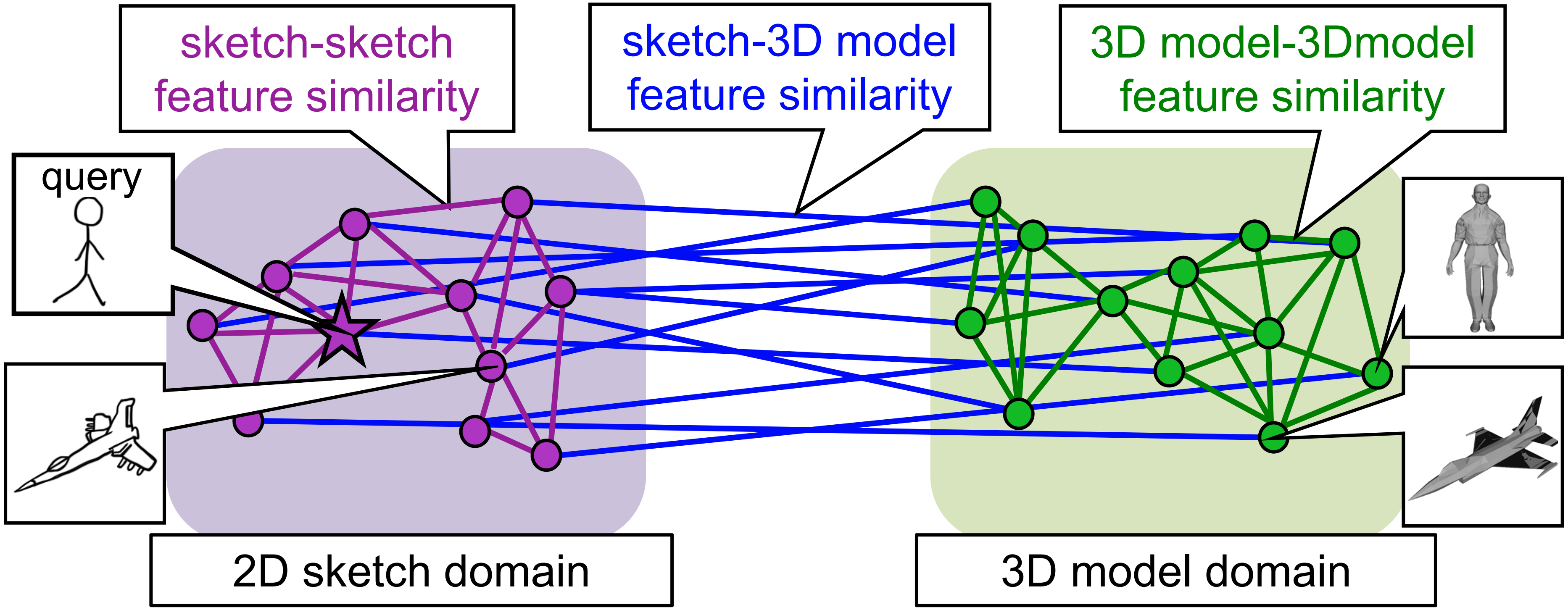


Outline

- Related work
- Proposed method
  - Cross-Domain Manifold Ranking (CDMR) algorithm
- Experiments and results
- Conclusion and future work

Improving cross-domain feature comparison

- Ranking by diffusion distance on a Cross-Domain Manifold (CDM).
  - ☺ Structure of each feature manifold is kept.



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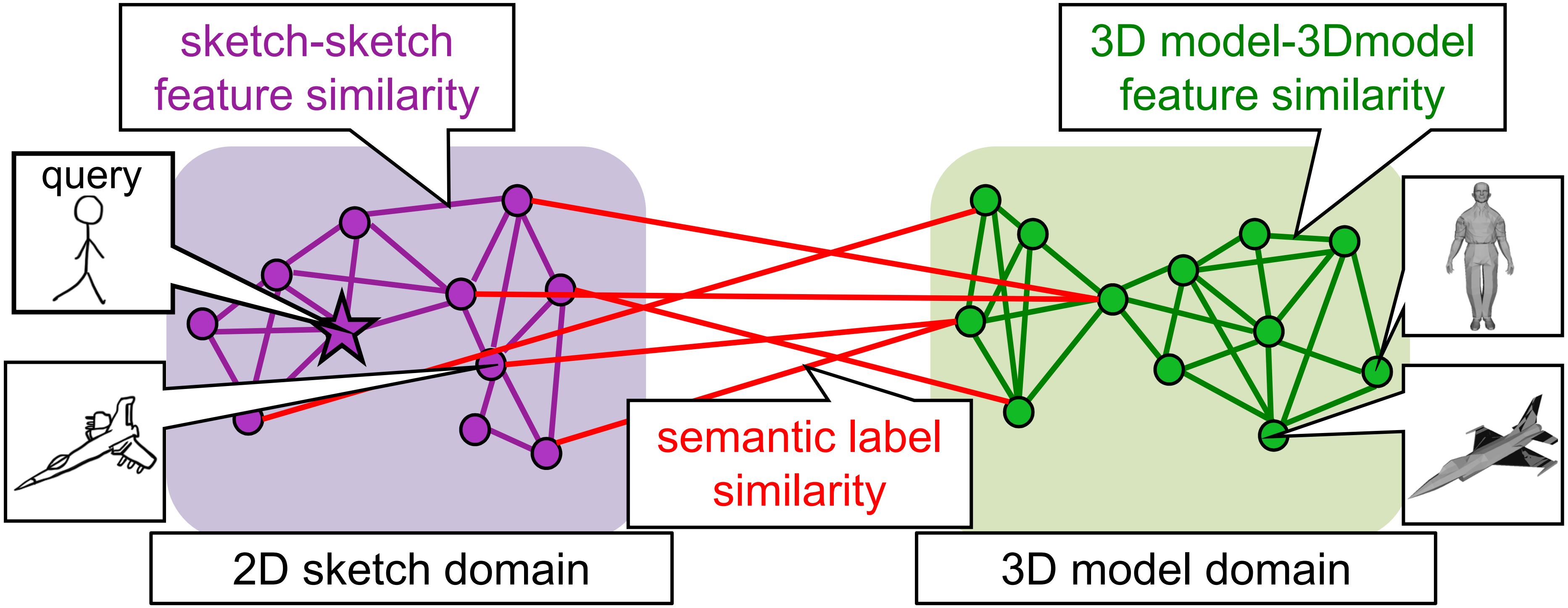

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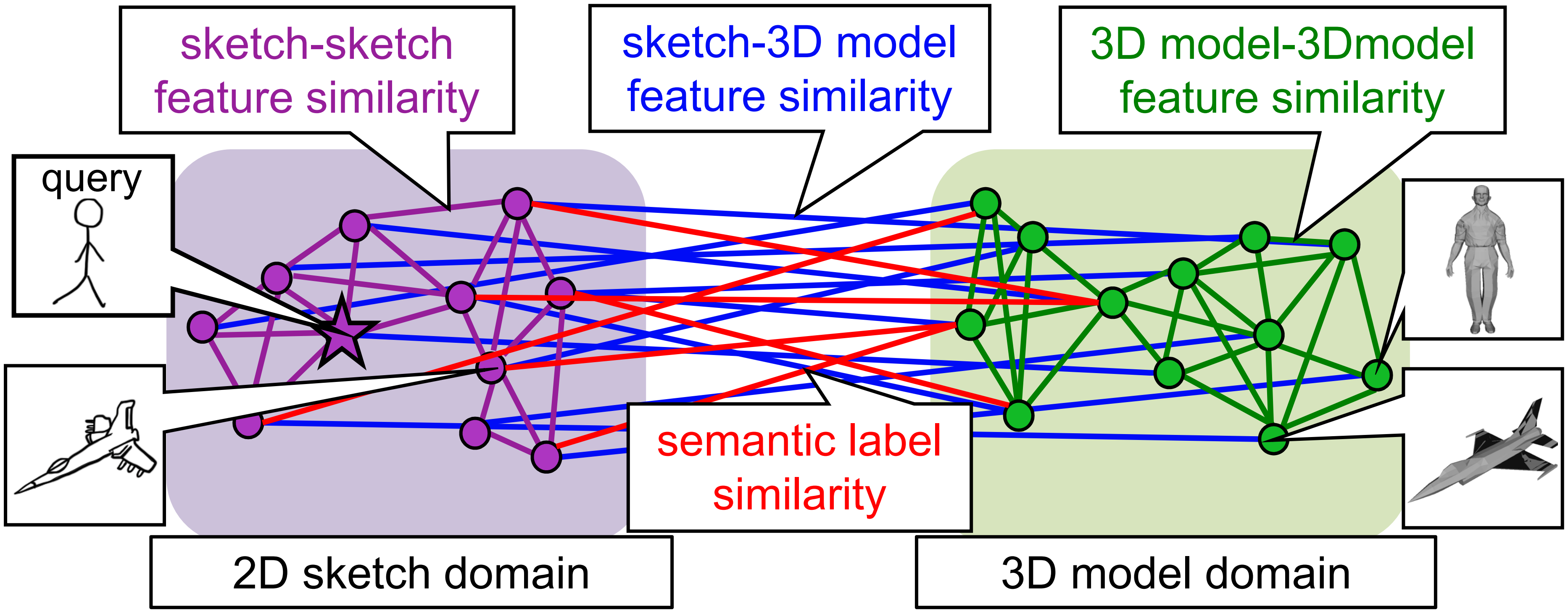
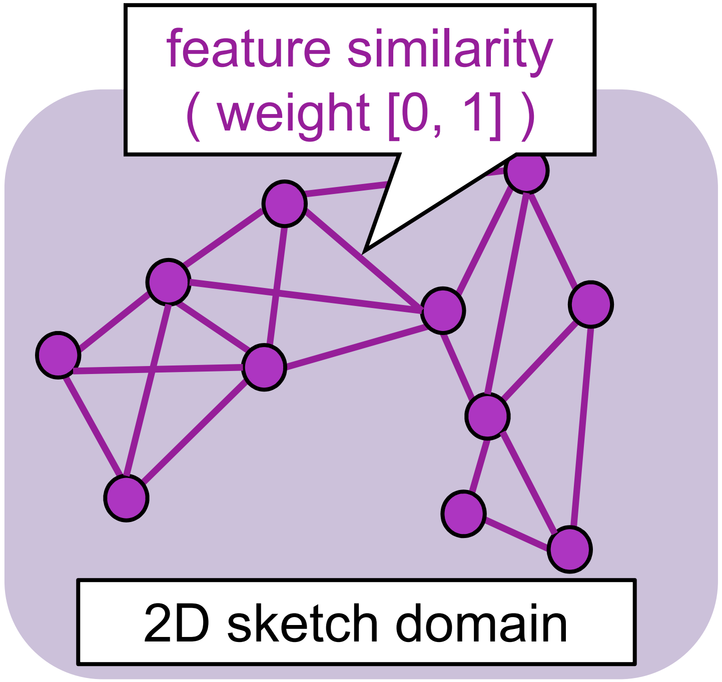
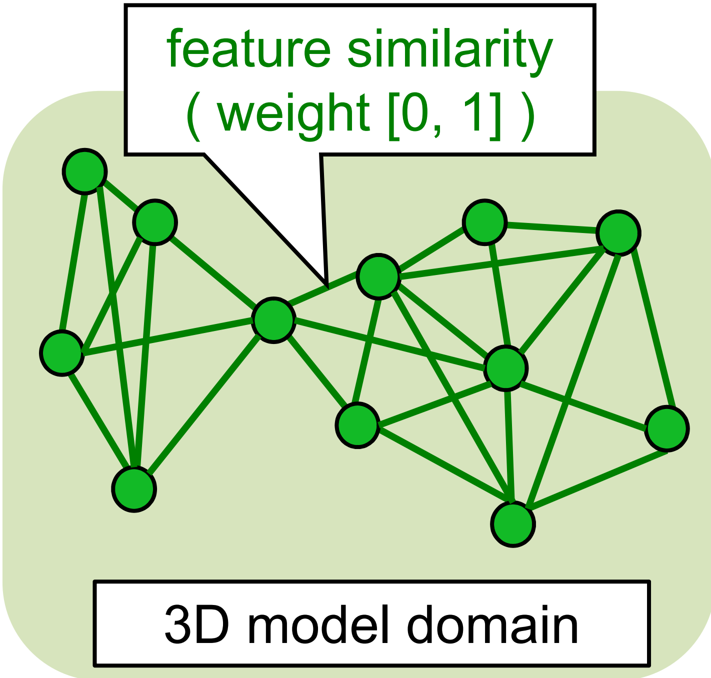


Proposed method
Cross-Domain Manifold Ranking (CDMR)

- Ranking by diffusion distance on the CDM.
  1. Generates a feature manifold on each domain.
  2. Links the two manifolds by feature and label similarity.
  3. Diffuses relevance from the query.





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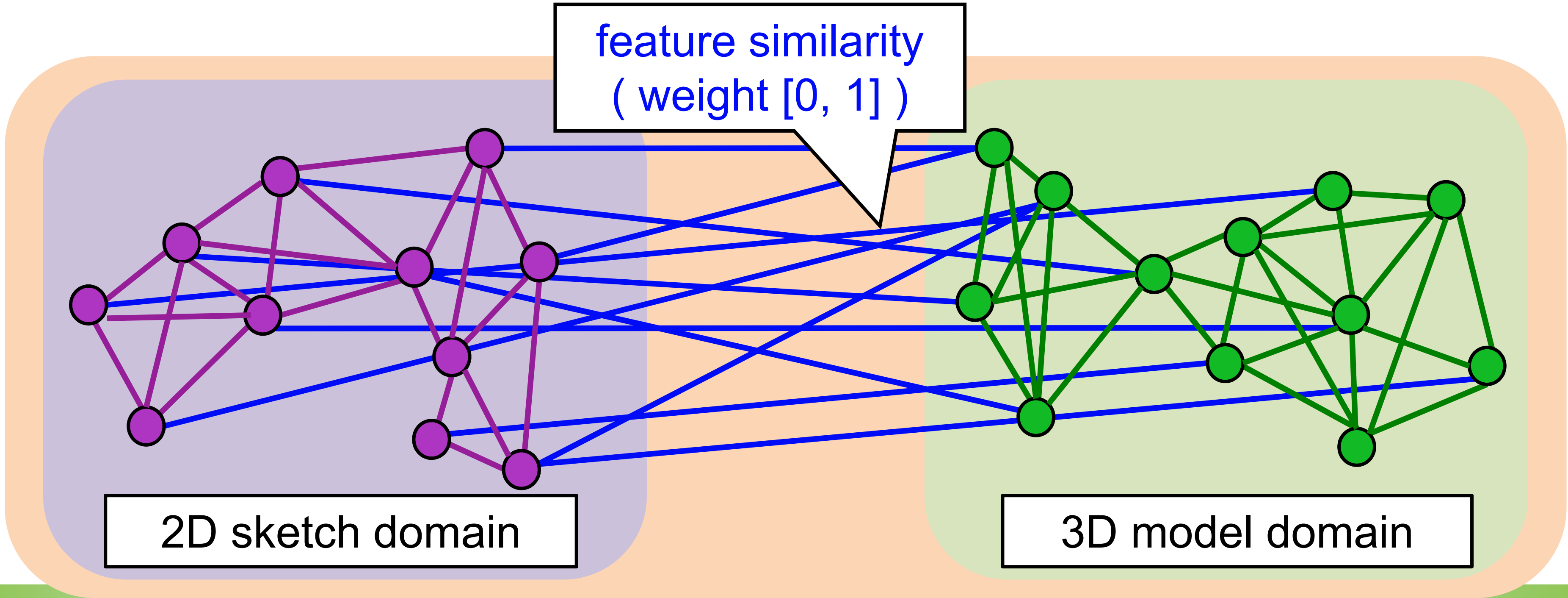

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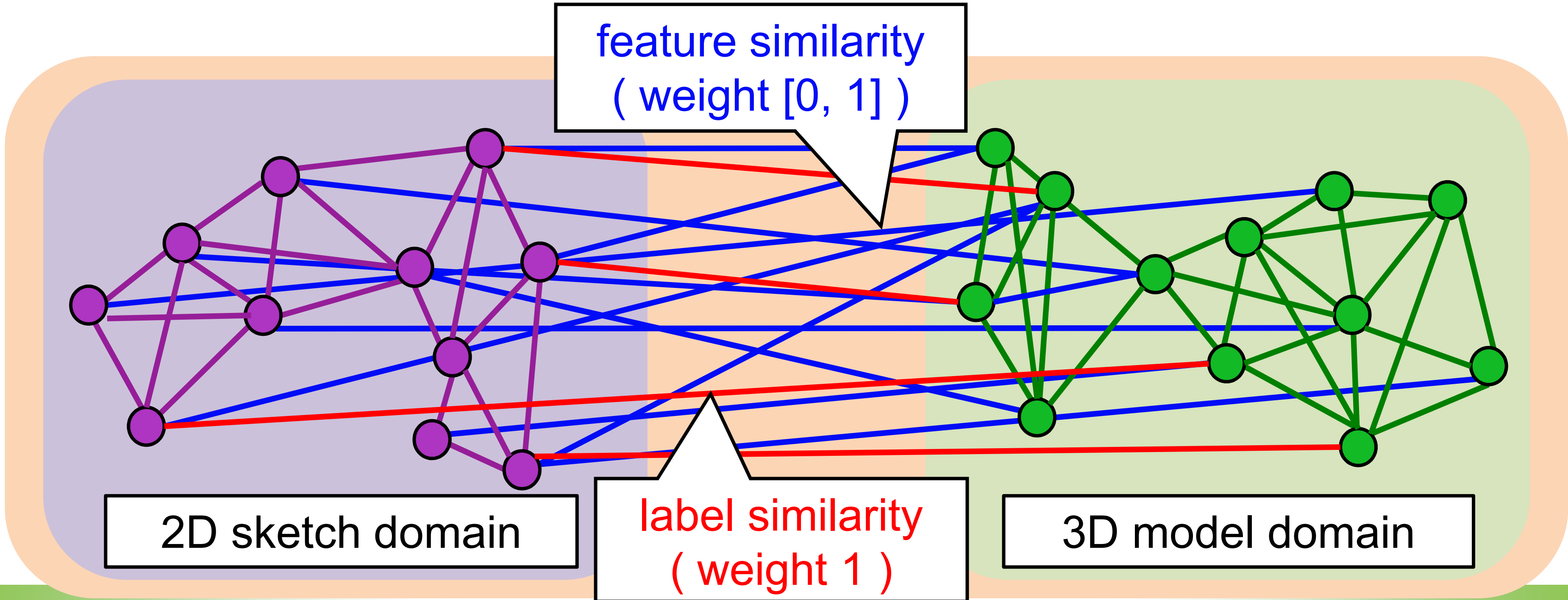

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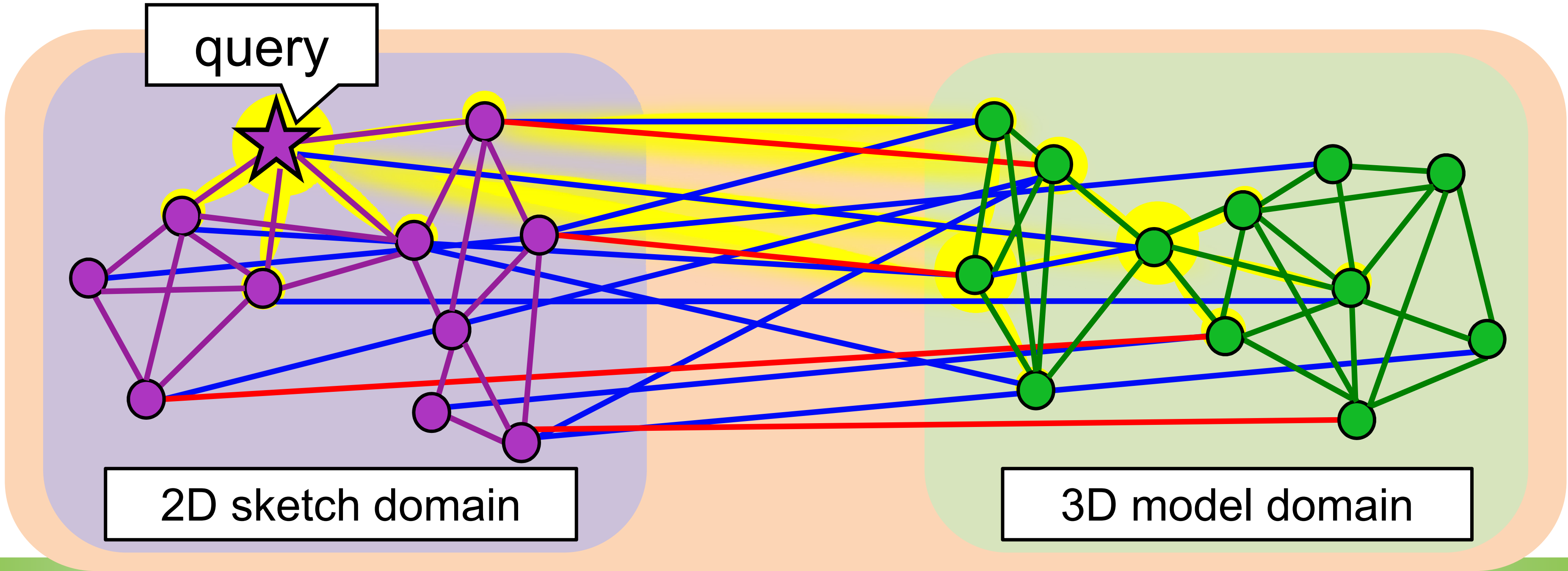
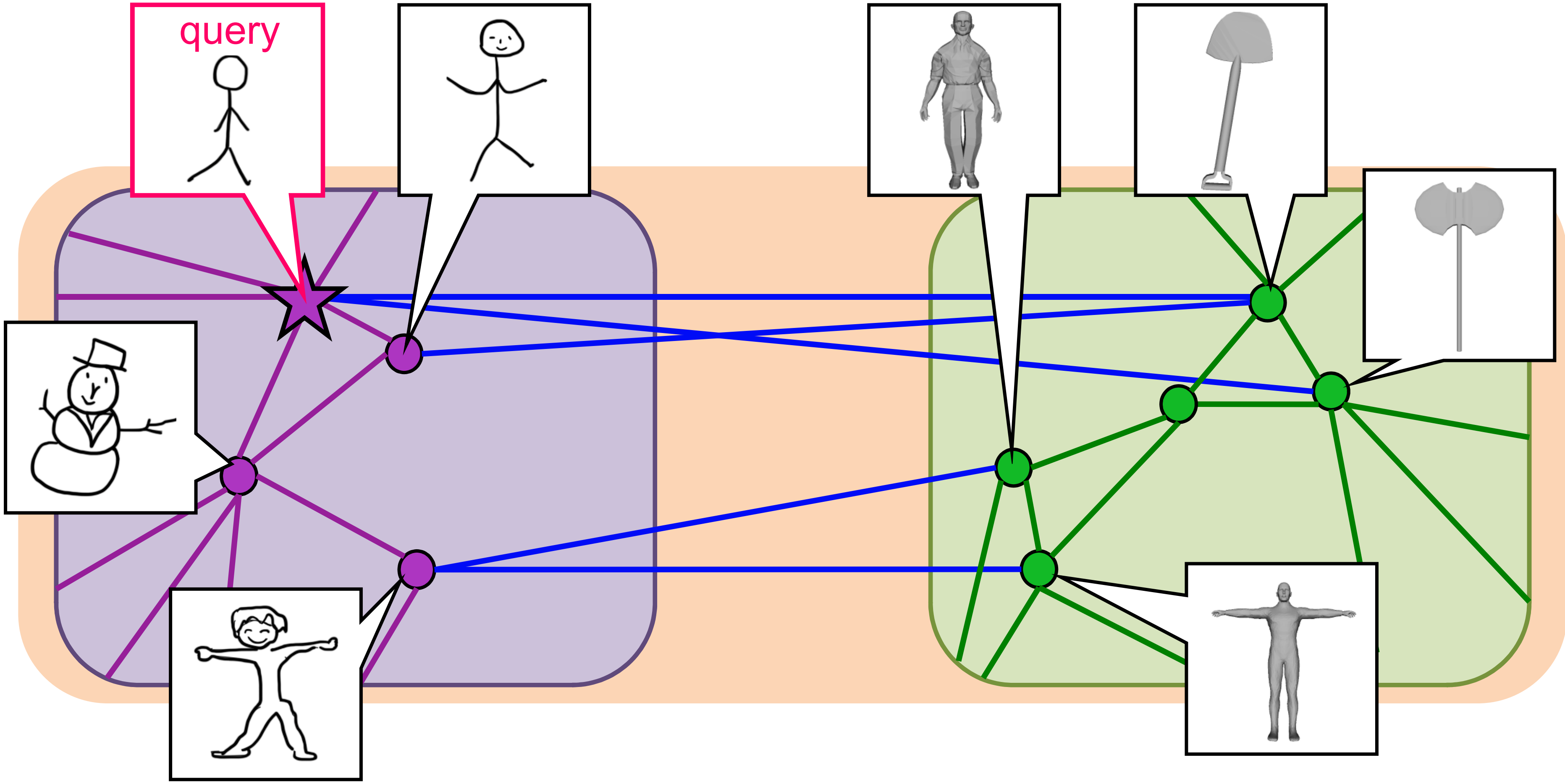


Cross-Domain Manifold Ranking (CDMR)

- Example 1 : Ranking by label similarity.



Proposed method
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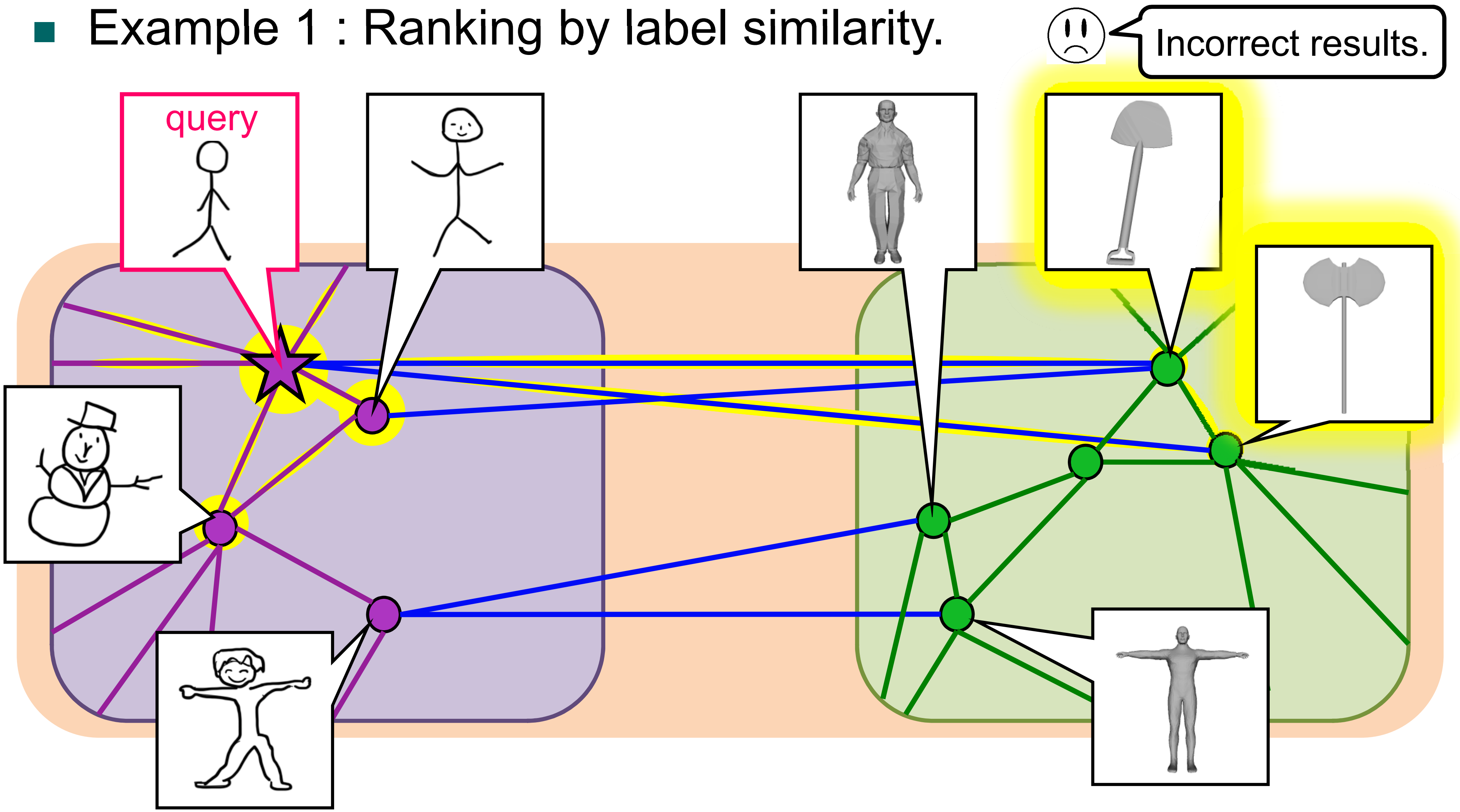

Proposed method

Cross-Domain Manifold Ranking (CDMR)

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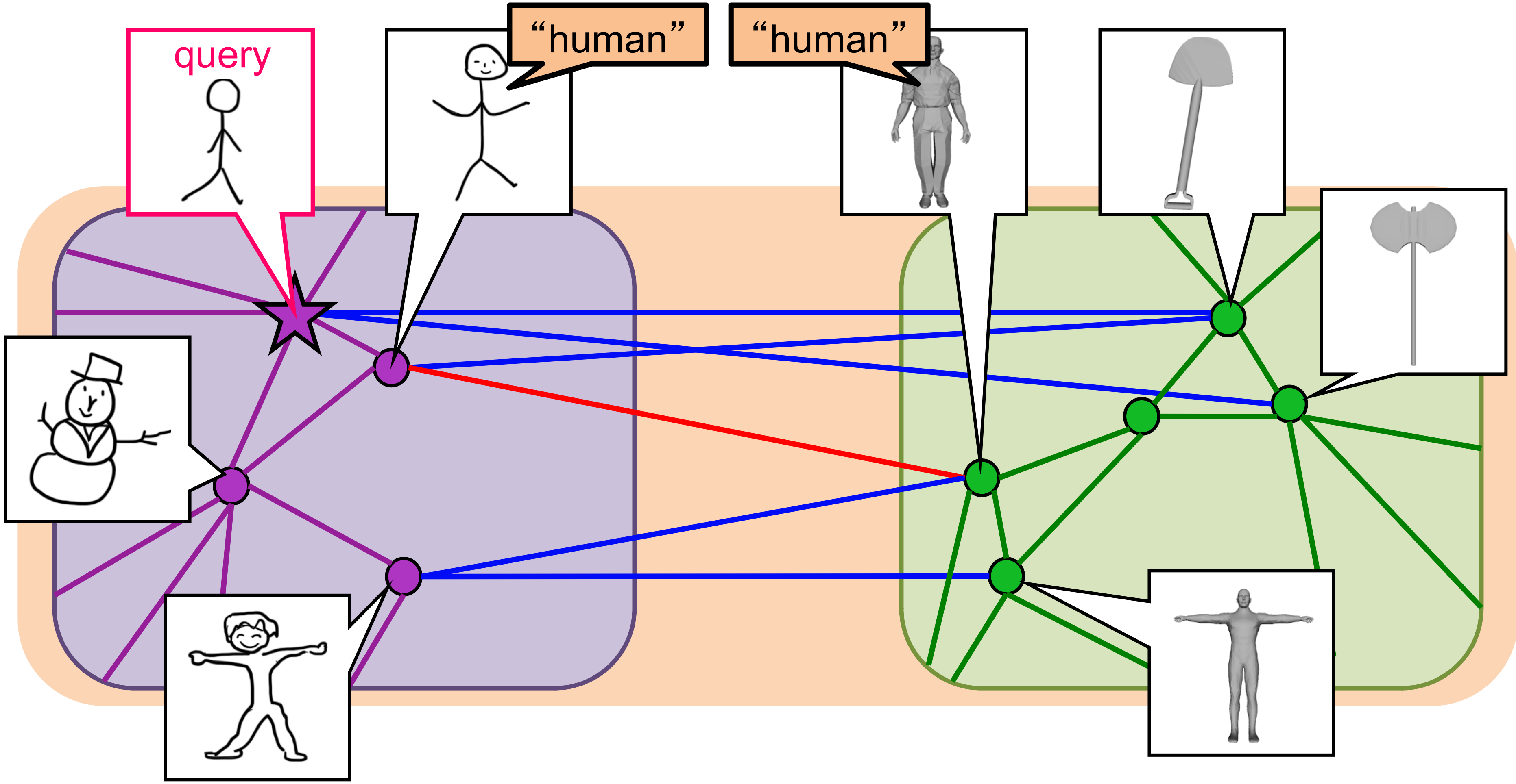

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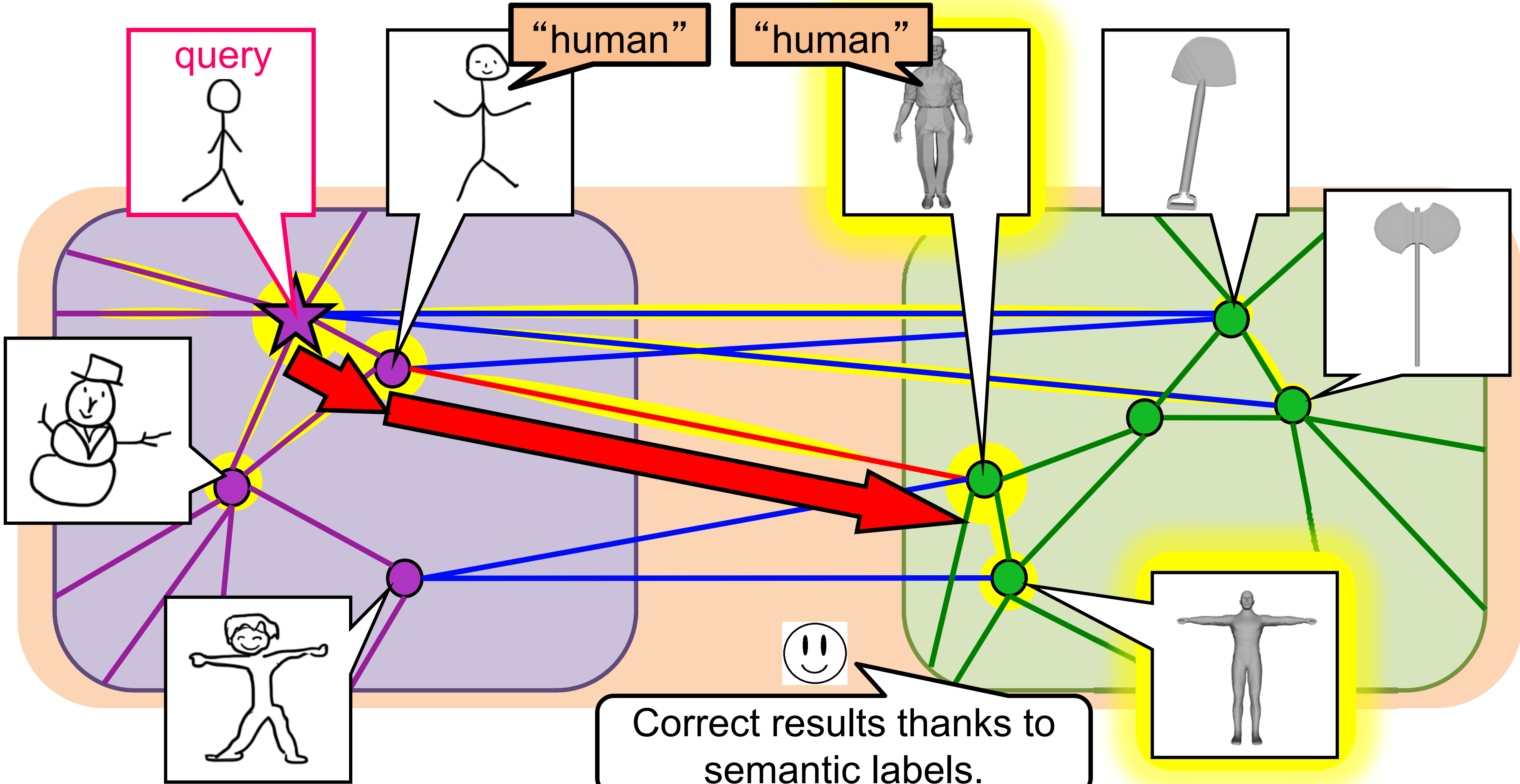
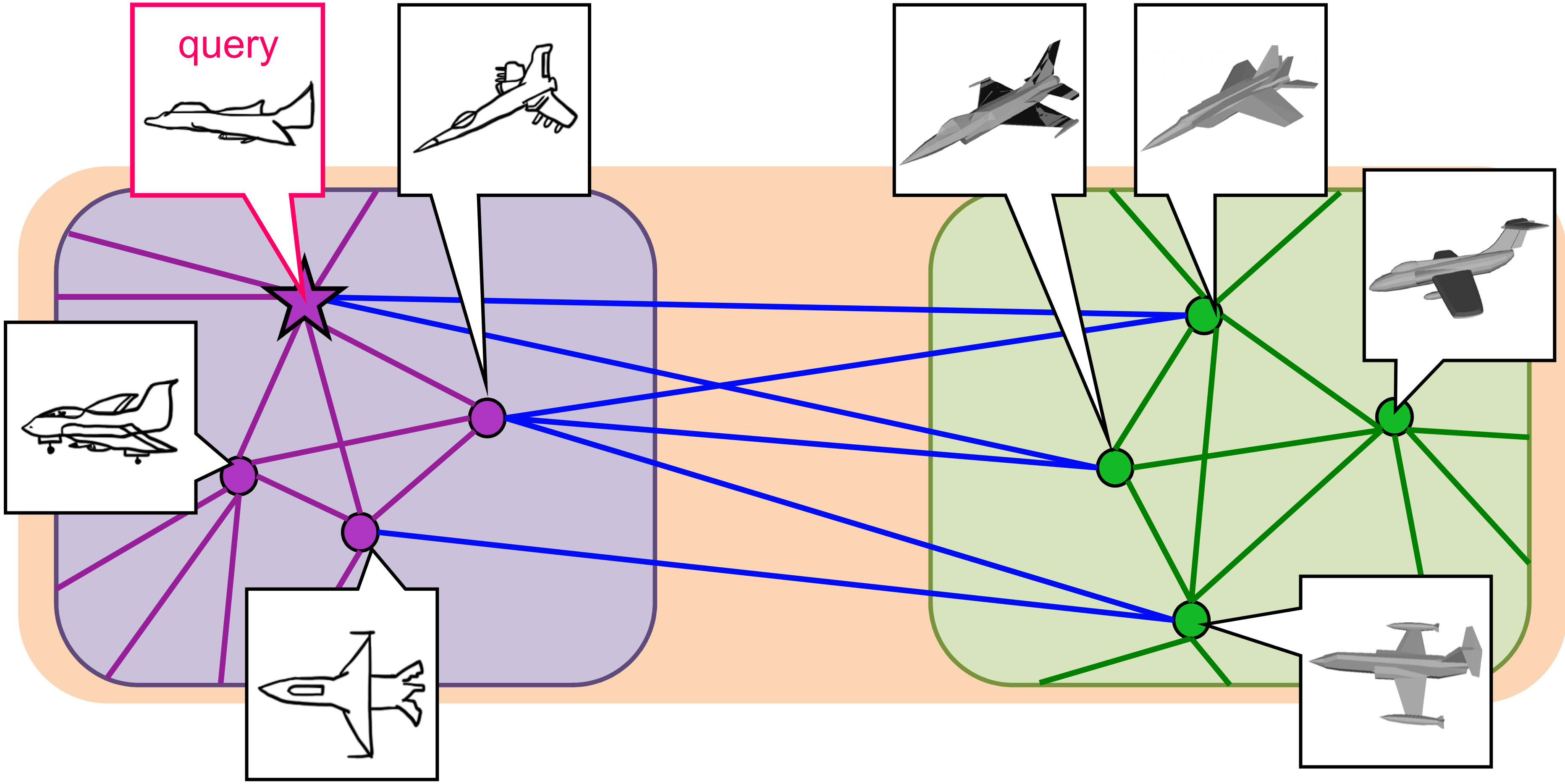


Proposed method
Cross-Domain Manifold Ranking (CDMR)

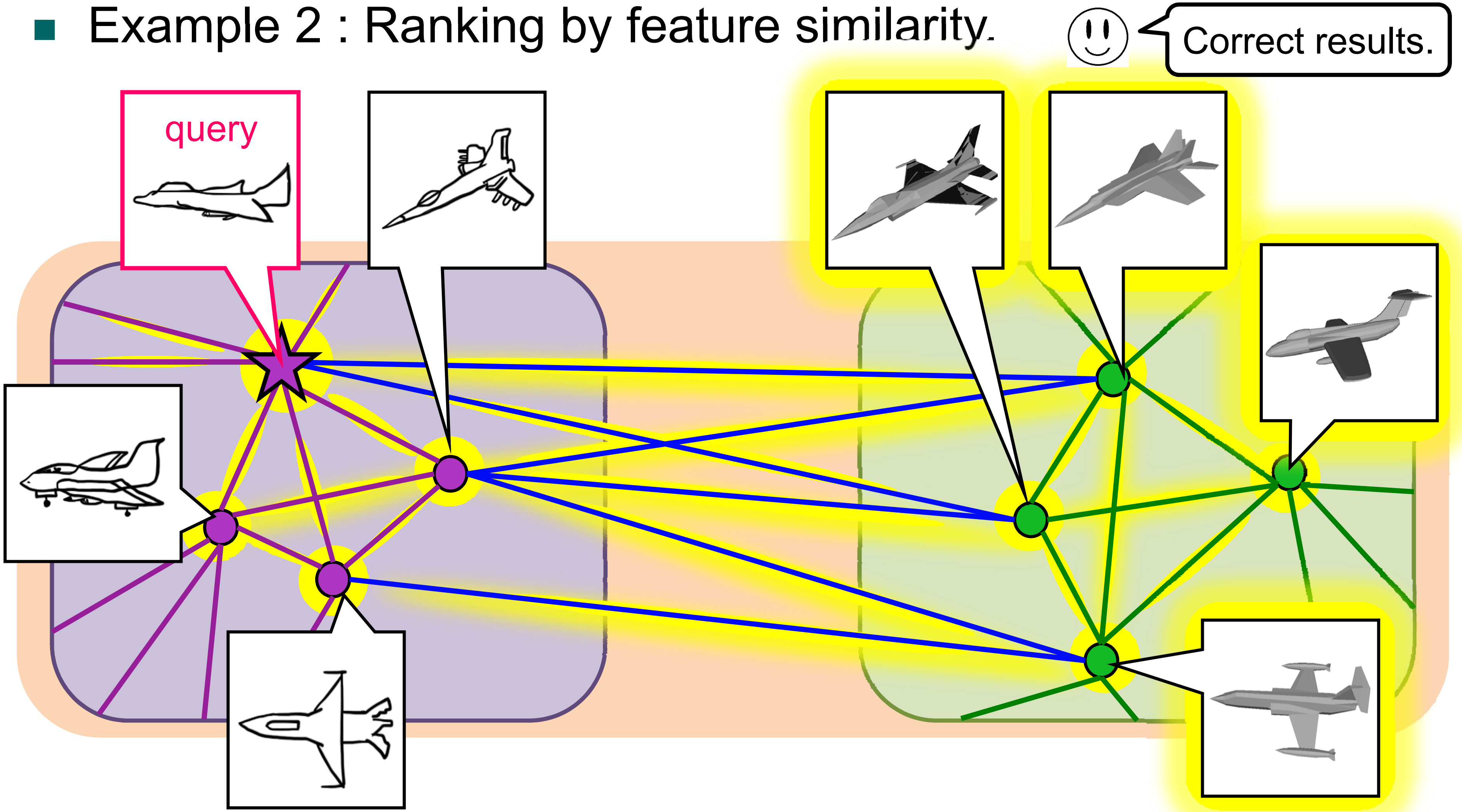
- Example 2 : Ranking by feature similarity.



Proposed method

Cross-Domain Manifold Ranking (CDMR)

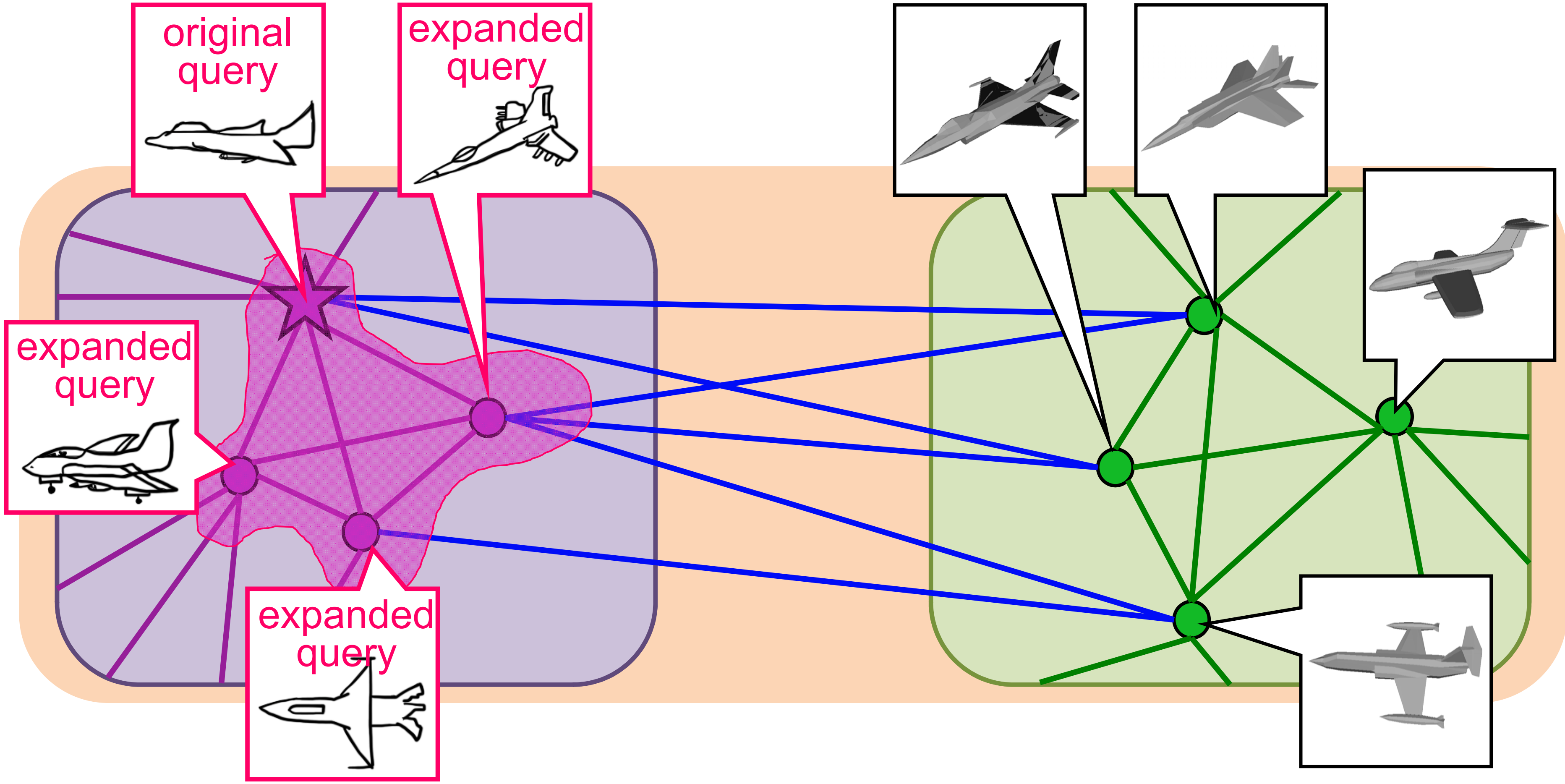
- Example 2 : Ranking by feature similarity.



Proposed method

Cross-Domain Manifold Ranking (CDMR)

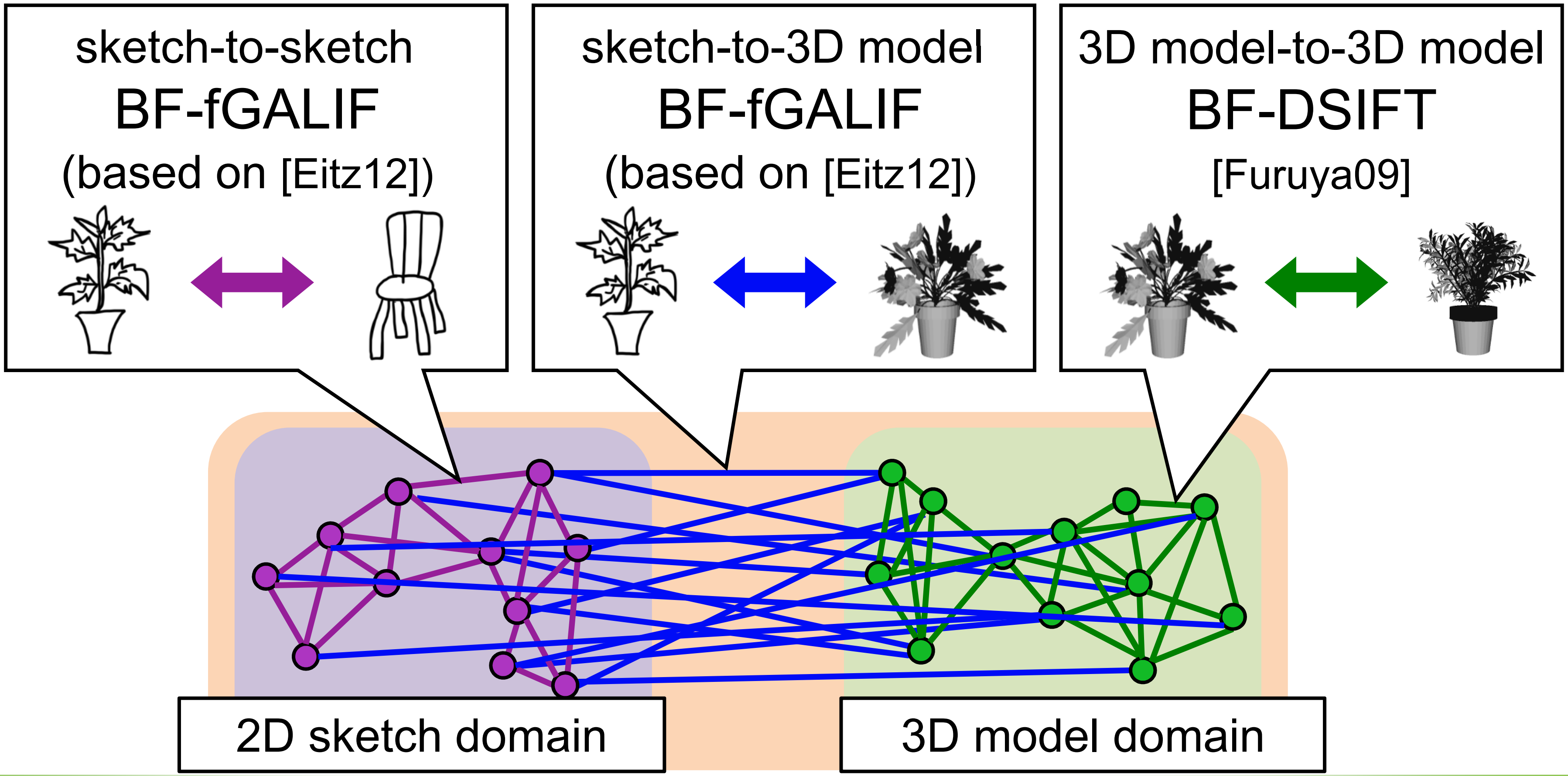
- CDMR embodies an automatic query expansion.



Proposed method

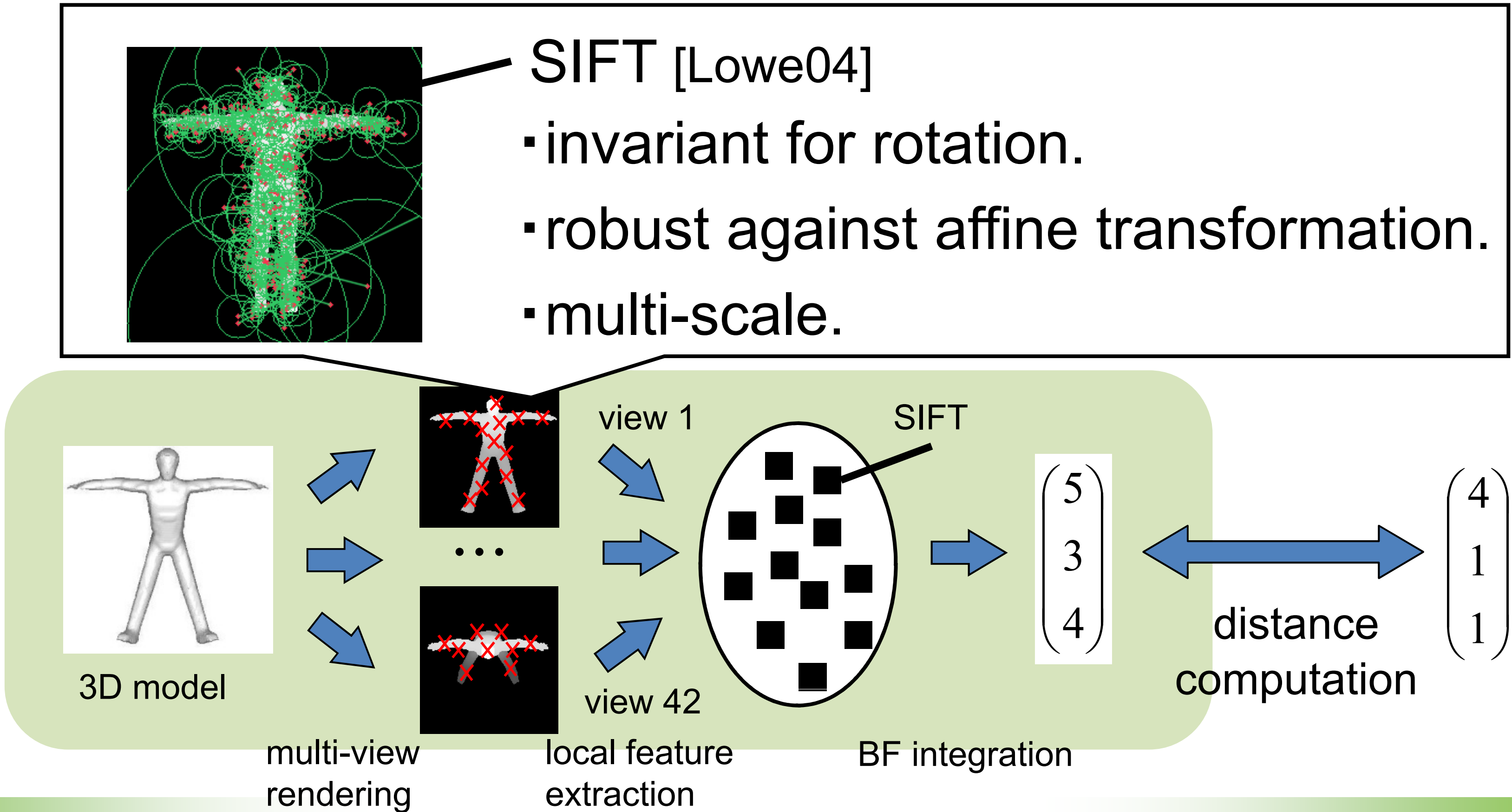
Cross-Domain Manifold Ranking (CDMR)

- Feature comparison methods.



3D model-to-3D model comparison
BF-DSIFT [Furuya09]

- Dense and random extraction of local visual features.
- Per-model BF integration.



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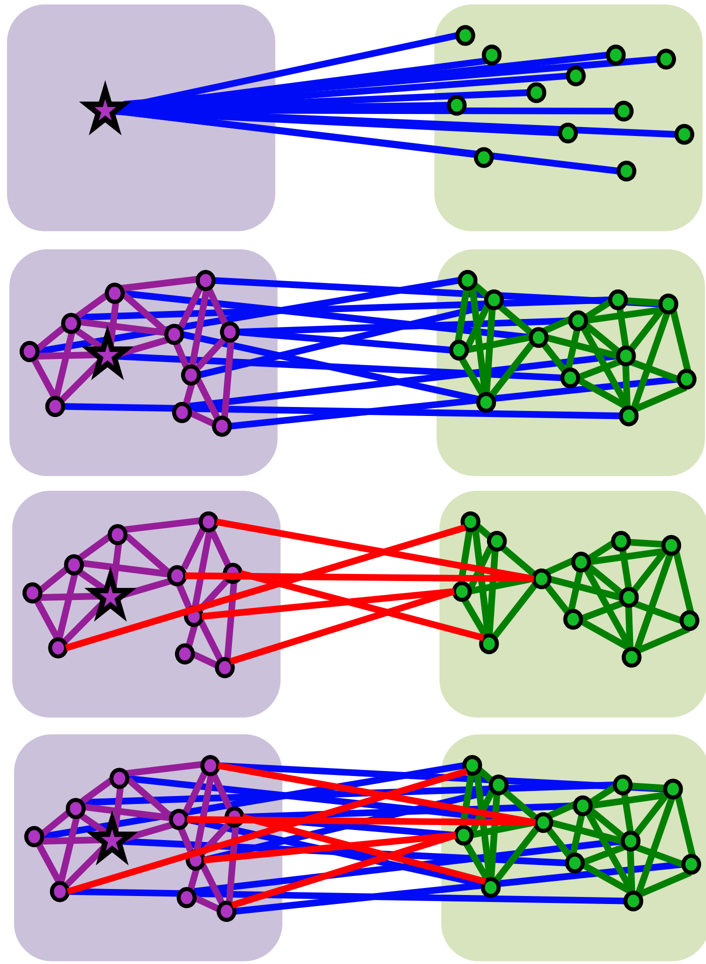
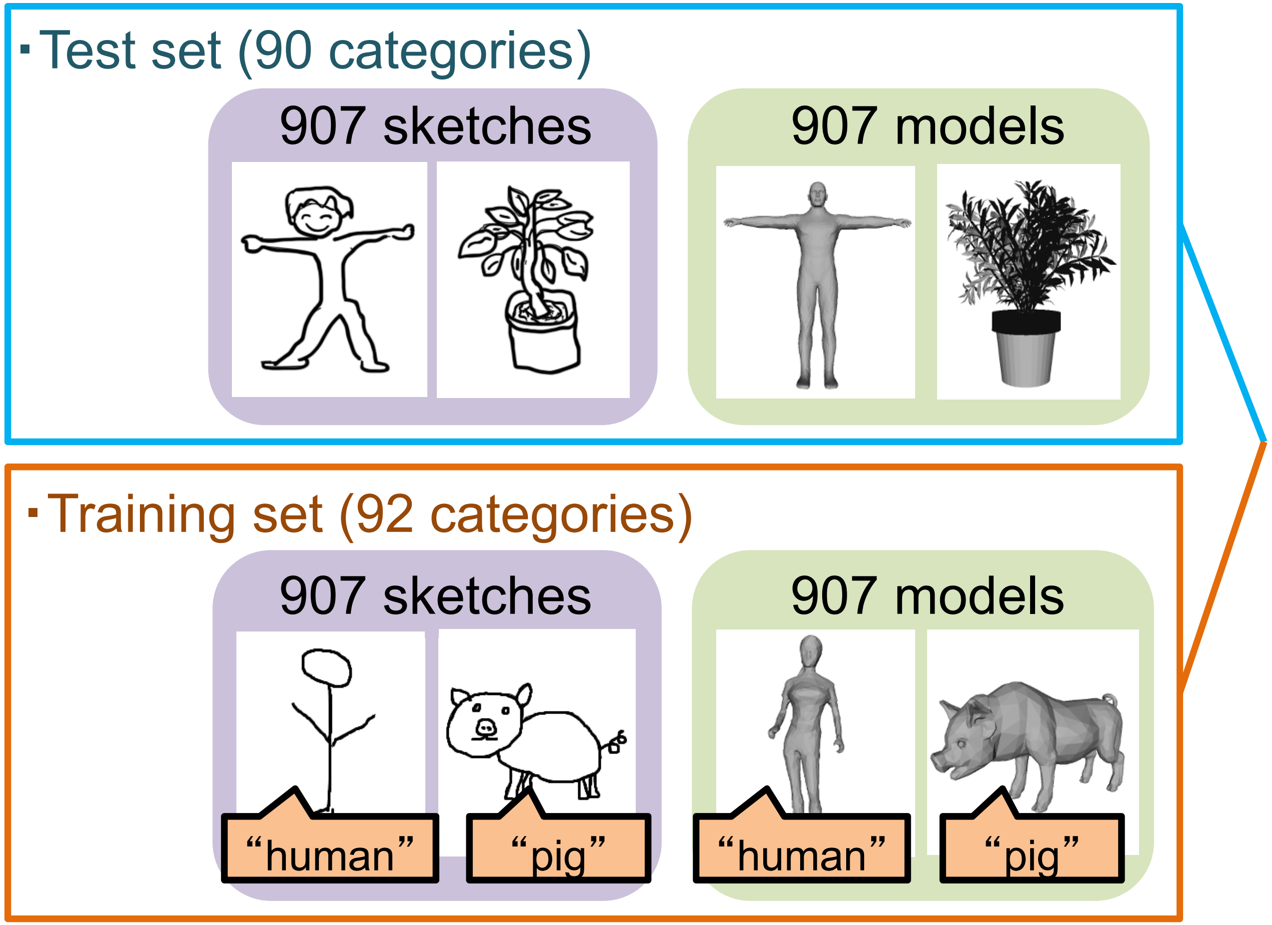
Experiments

- Evaluate retrieval accuracy.
  - BF-fGALIF (≒[Eitz12])
    - No distance metric learning.
    - Baseline
  - CDMR-BF-fGALIF (F)
    - Unsupervised learning.
  - CDMR-BF-fGALIF (L)
    - Supervised learning.
  - CDMR-BF-fGALIF (F+L)
    - Semi-supervised learning.



Experiments
Benchmark databases

- S-PSB [Eitz12]



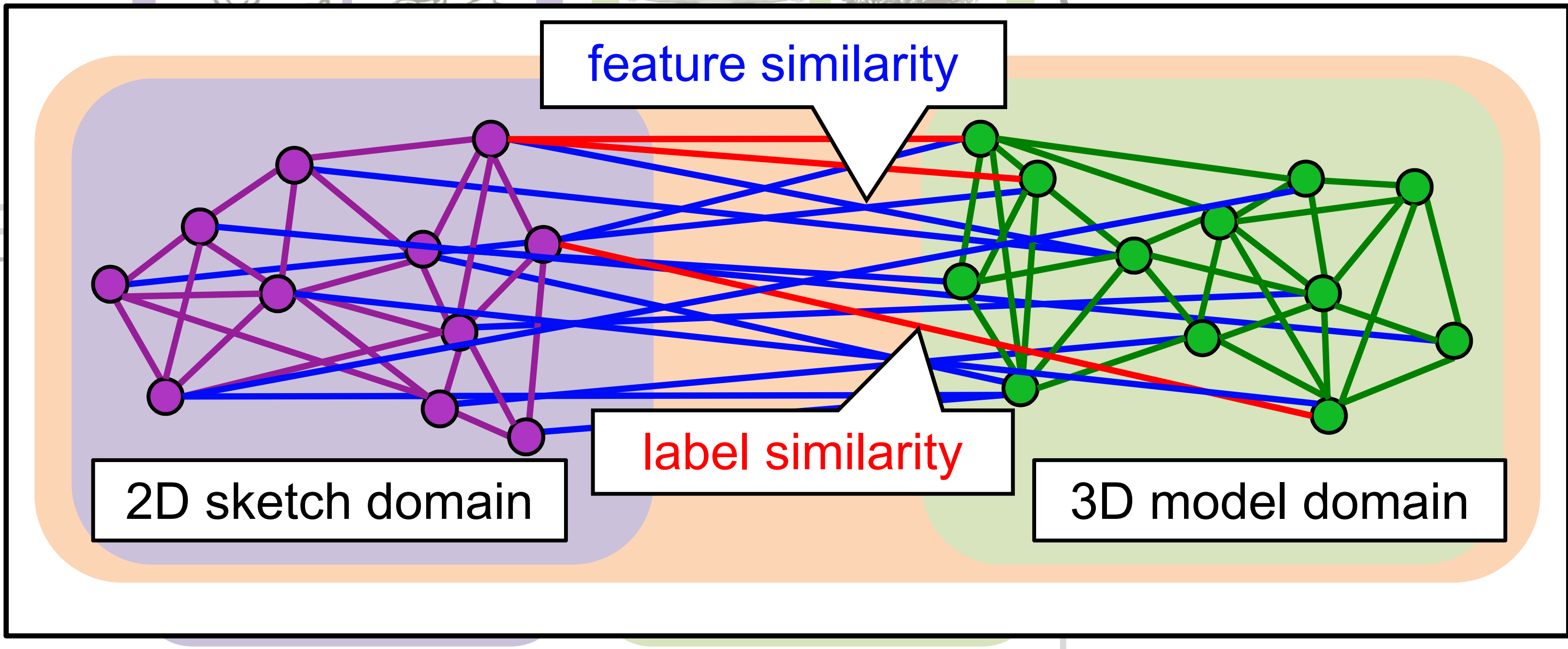
Difficult to learn labels.

- 21 shared categories.
- As few as 4 labels per category.

Experiments
Benchmark databases

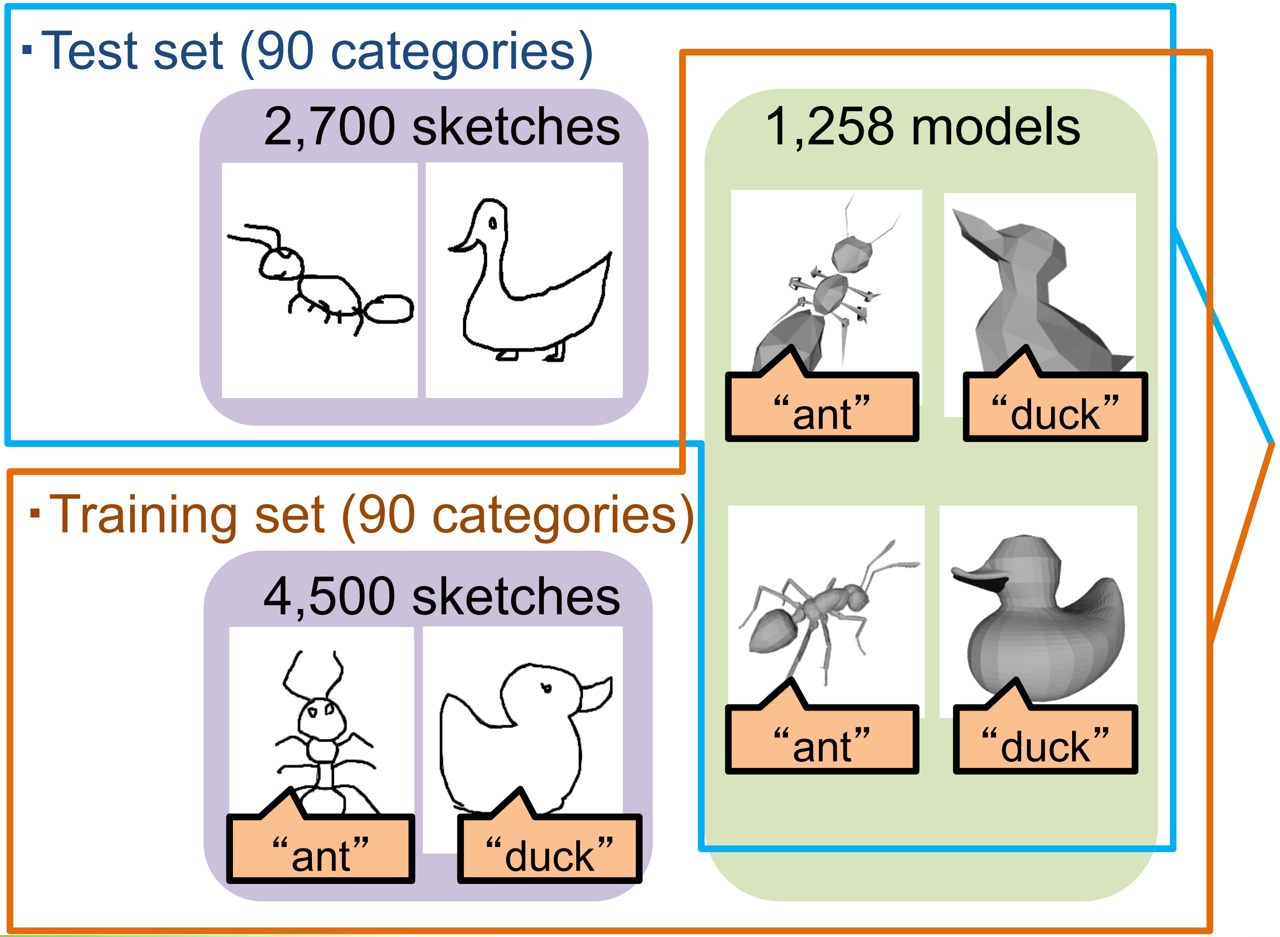
- S-PSB [Eitz12]

Difficult to learn labels.



Experiments
Benchmark databases

- SHREC2013 sketch-based 3D shape retrieval (SH13) [Li13]



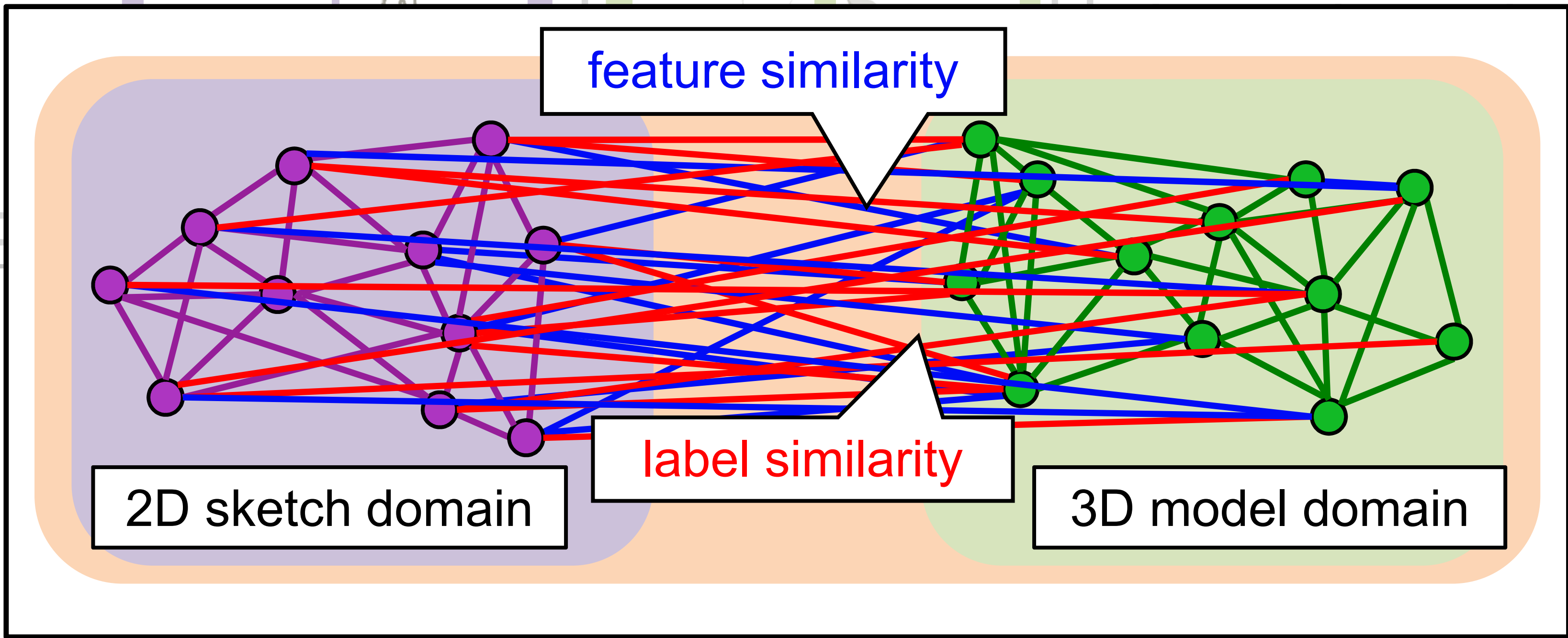
Easy to learn labels.

- share all categories.
- 50 labels per category.

Experiments
Benchmark databases

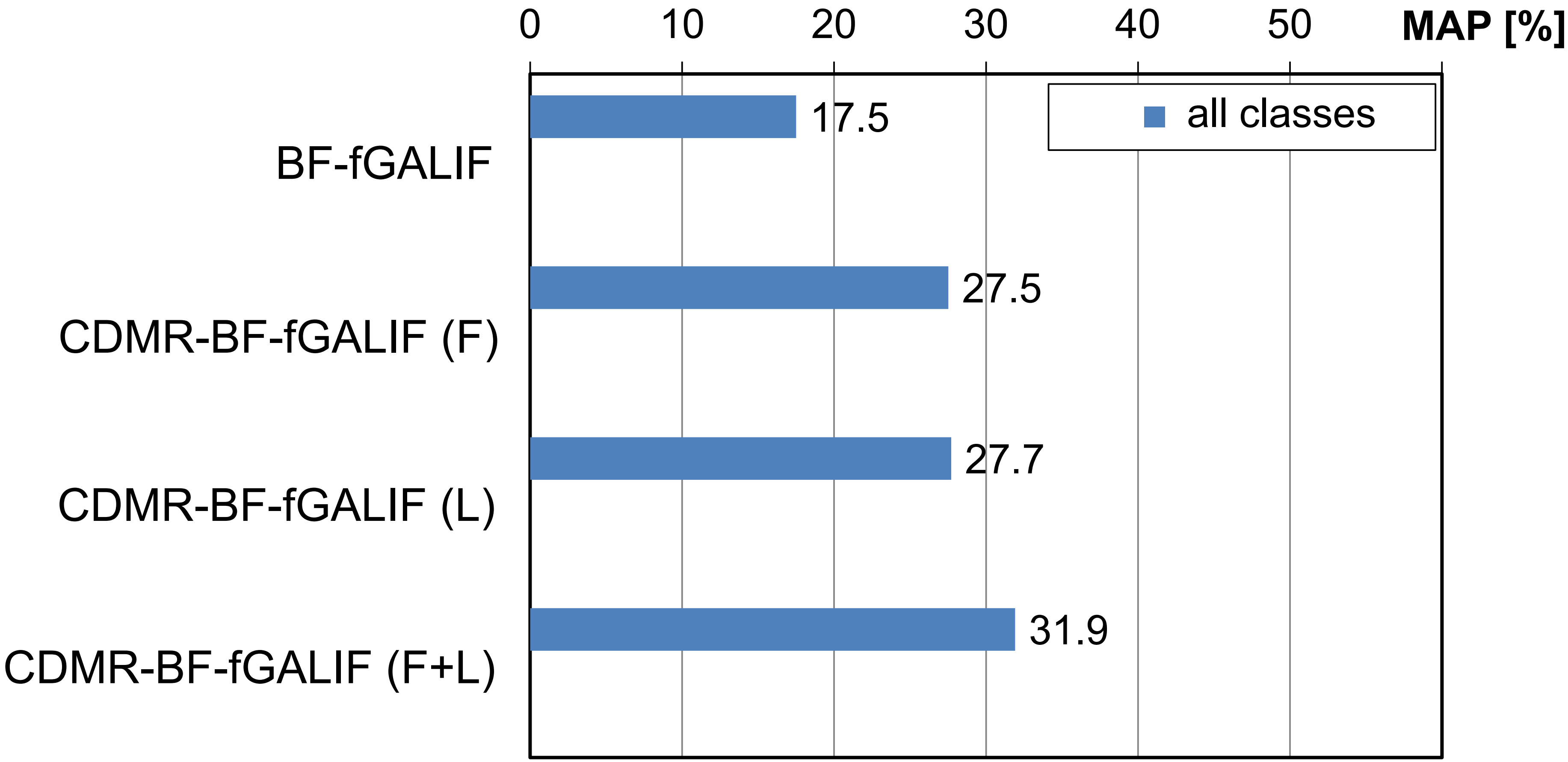
- SHREC2013 sketch-based 3D shape retrieval (SH13) [Li13]

Easy to learn labels.



Experimental results
Effectiveness of CDMR for S-PSB

- CDMR is effective.



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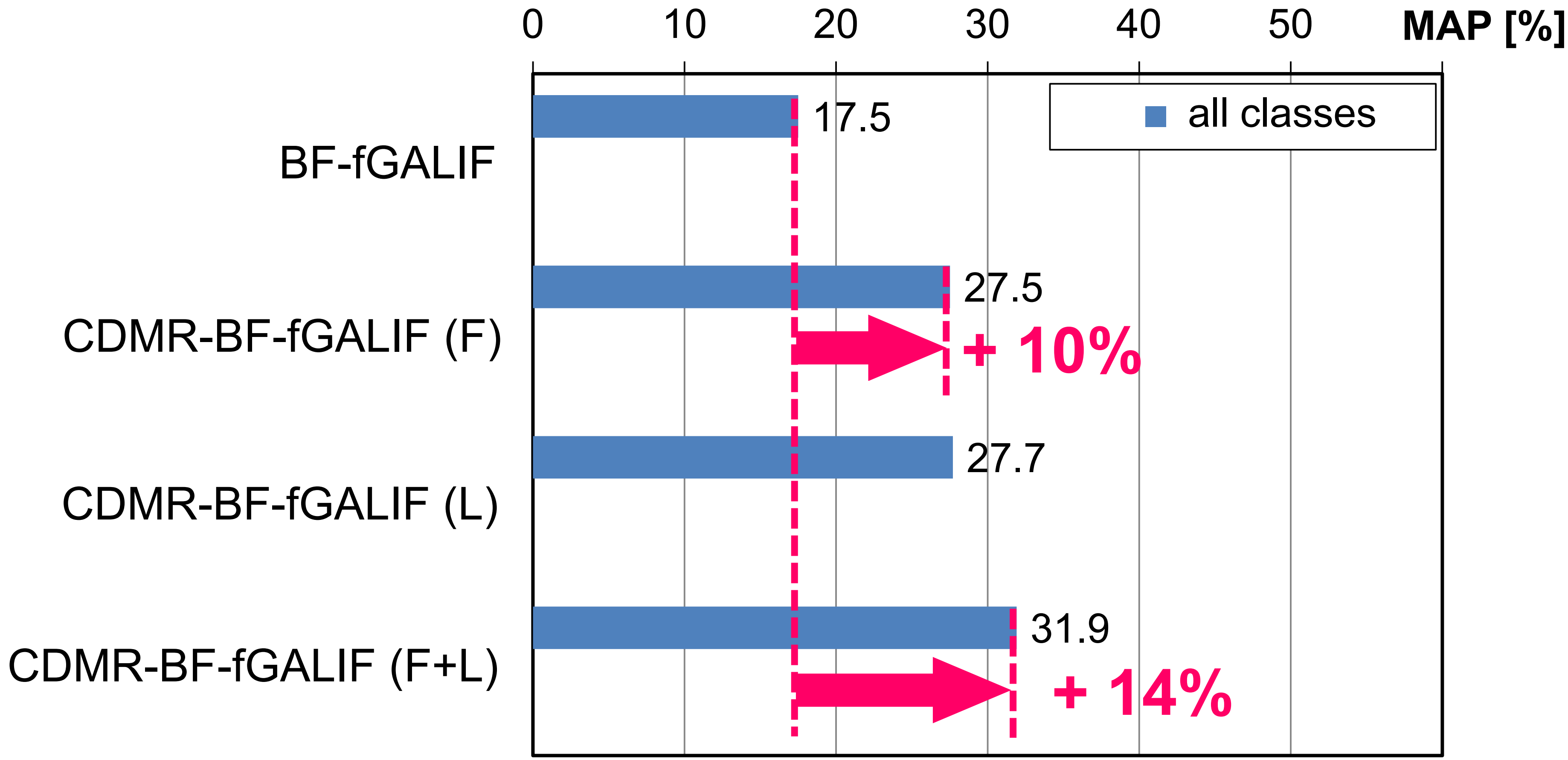
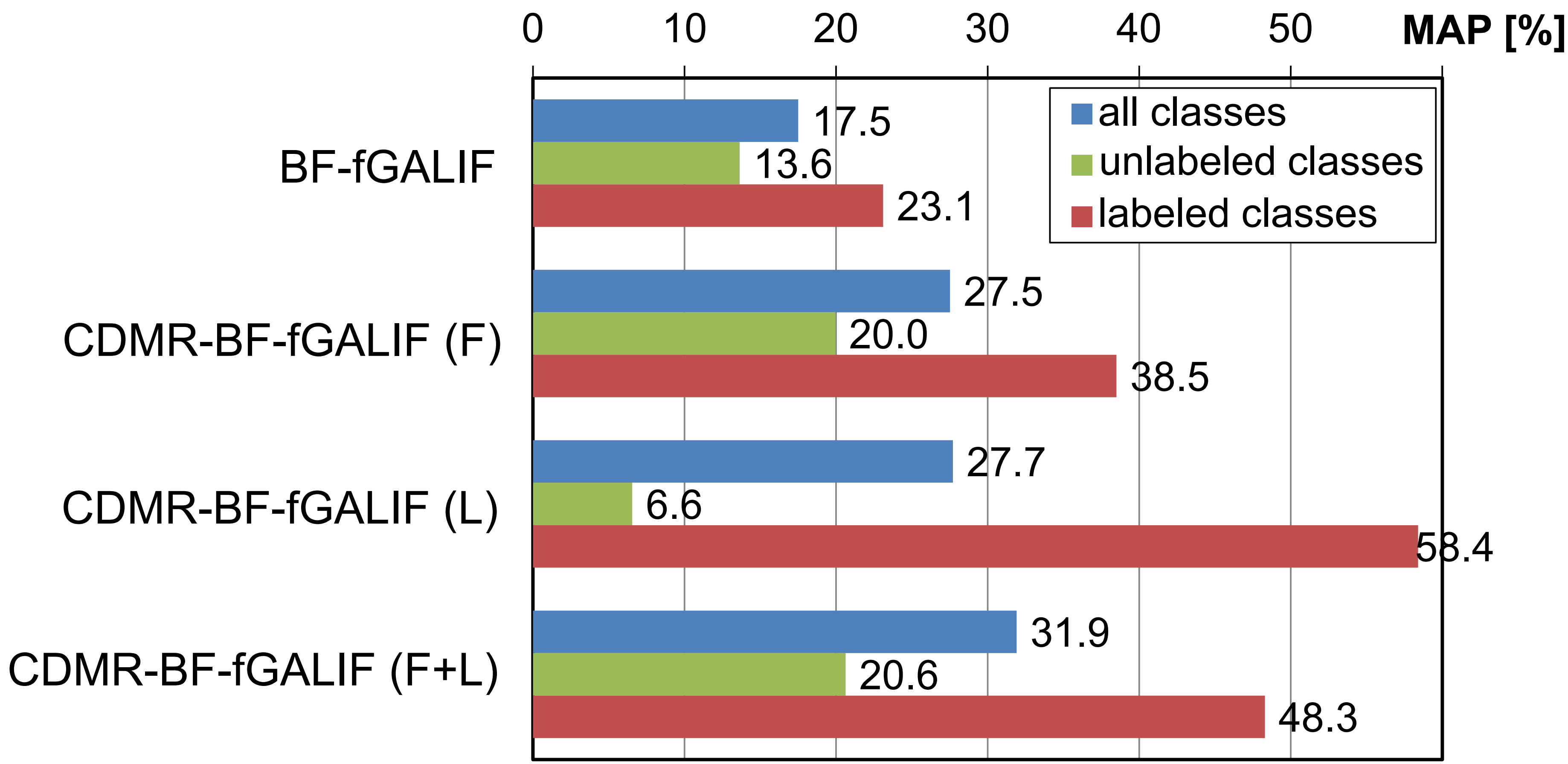


Experimental results
Effectiveness of CDMR for S-PSB

- CDMR (F+L) effectively learns sparse labeling.



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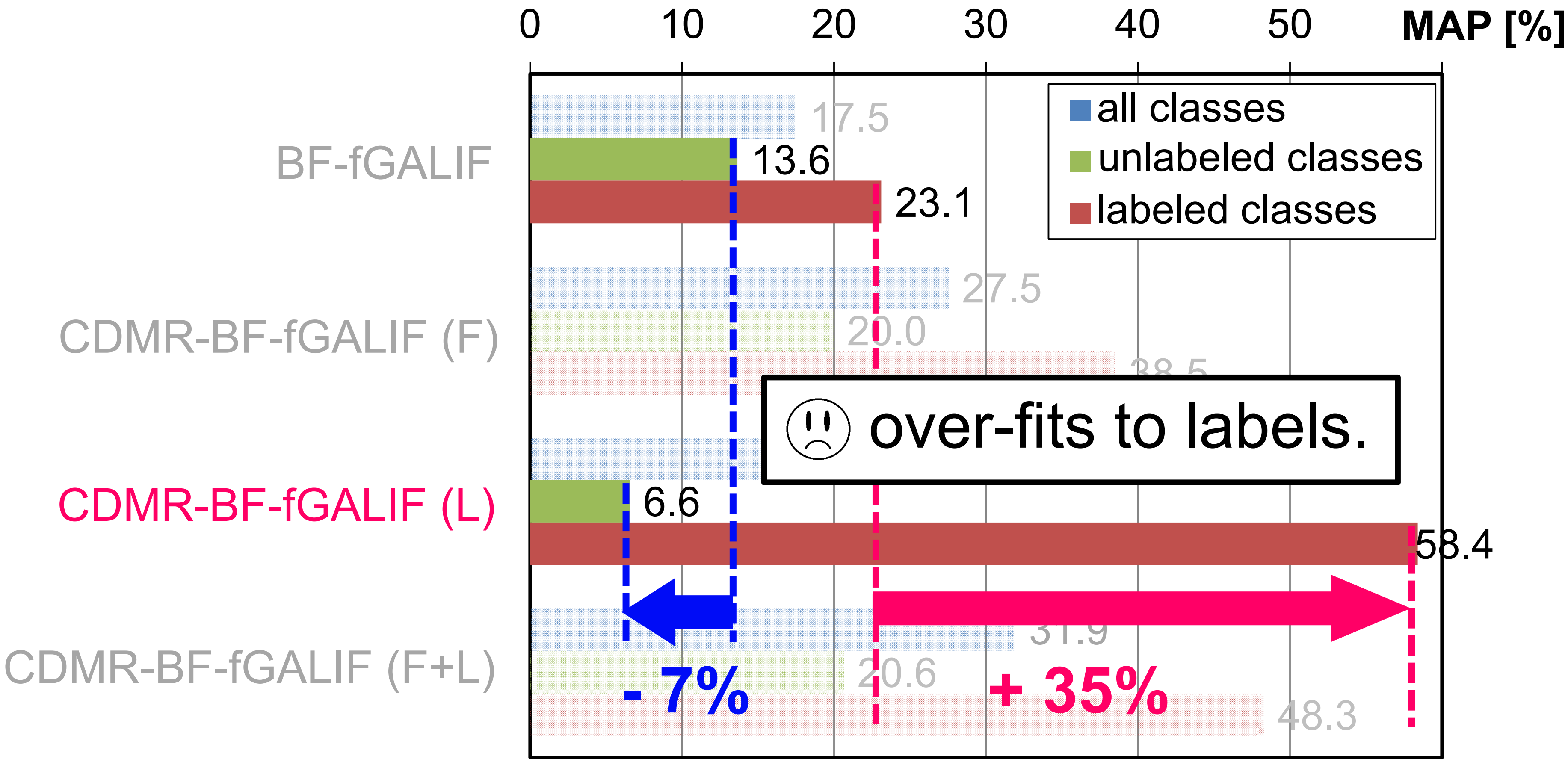

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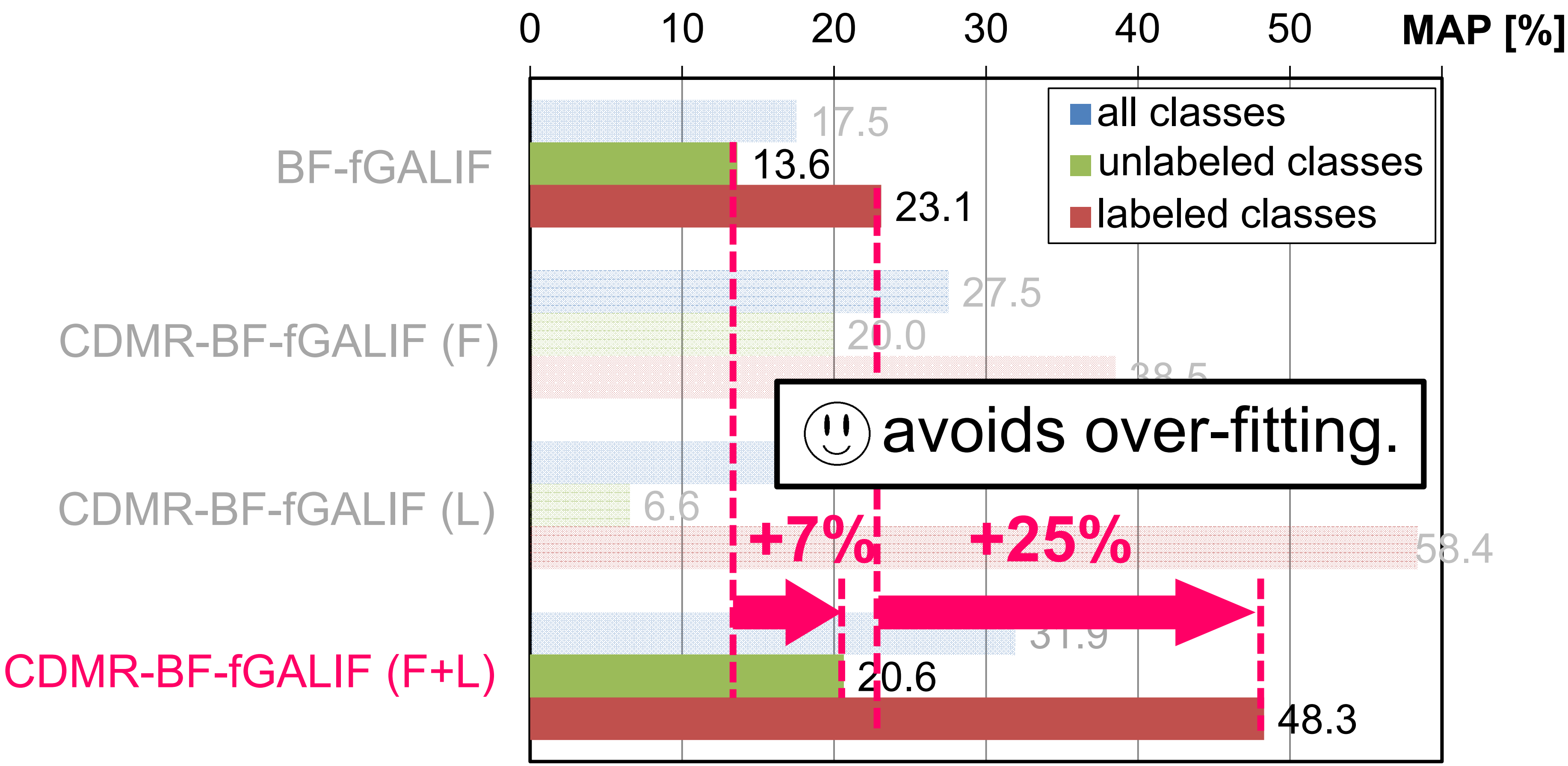
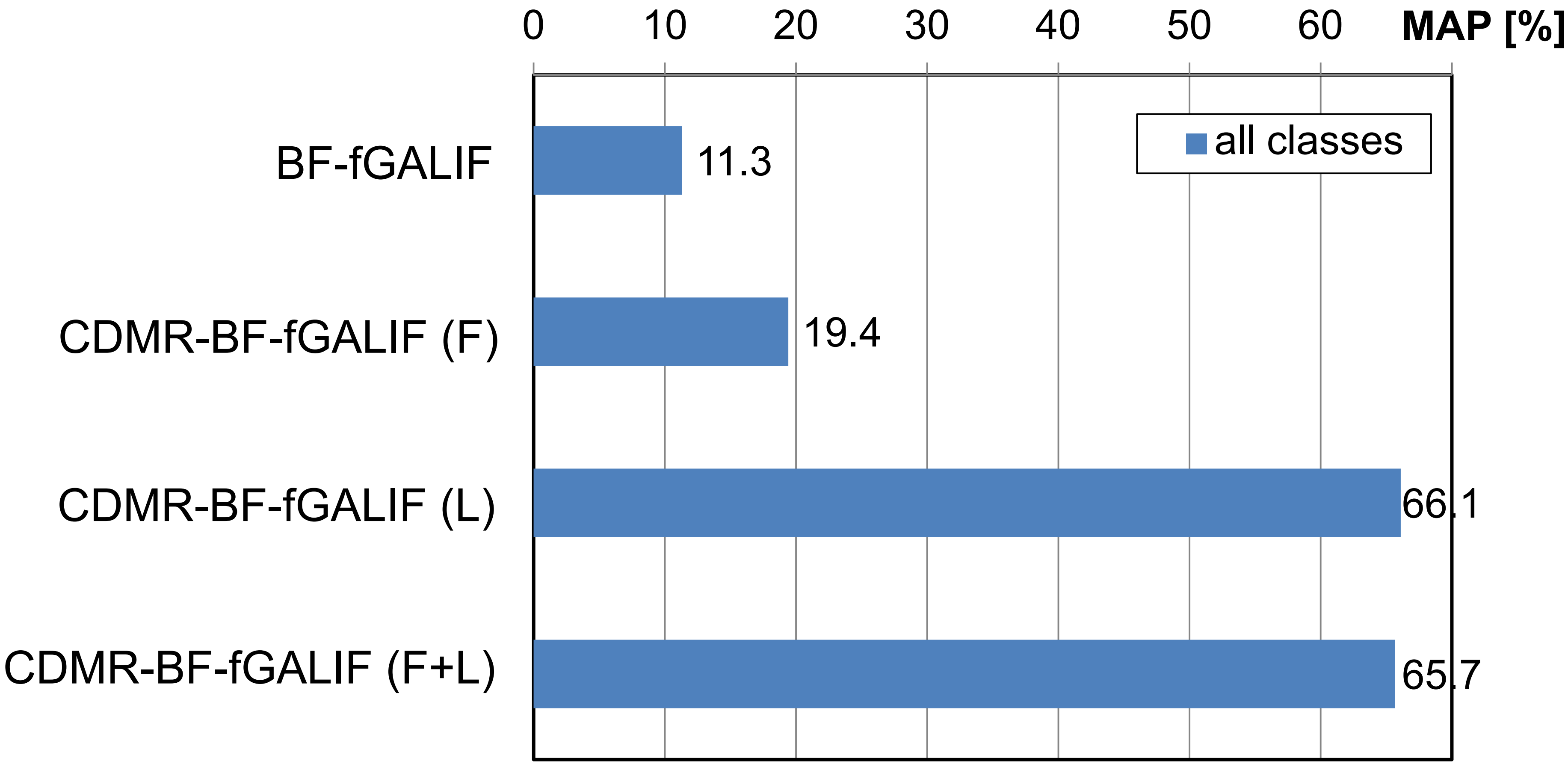


Experimental results
Effectiveness of CDMR for SH13

- Large improvement of MAP due to dense labeling.



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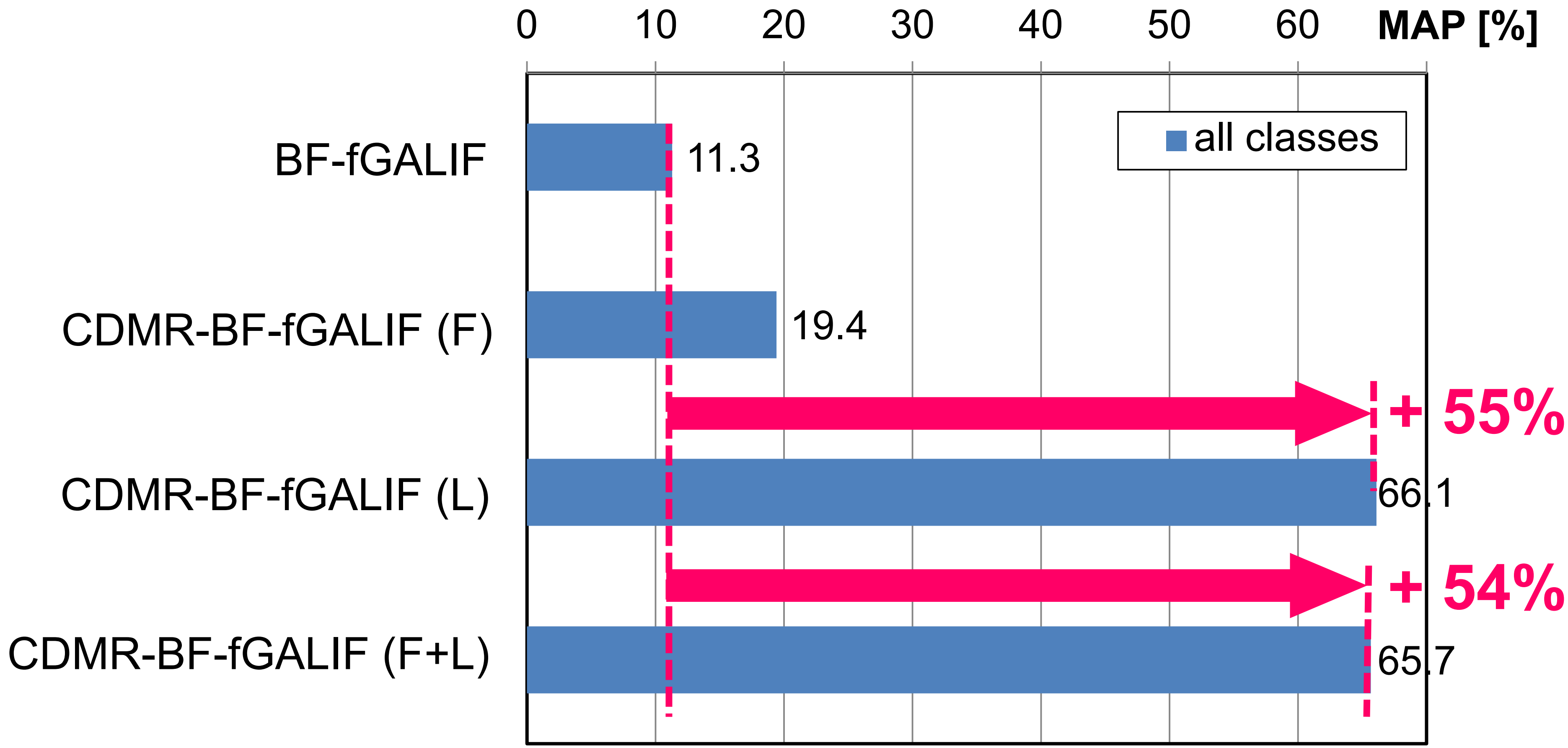
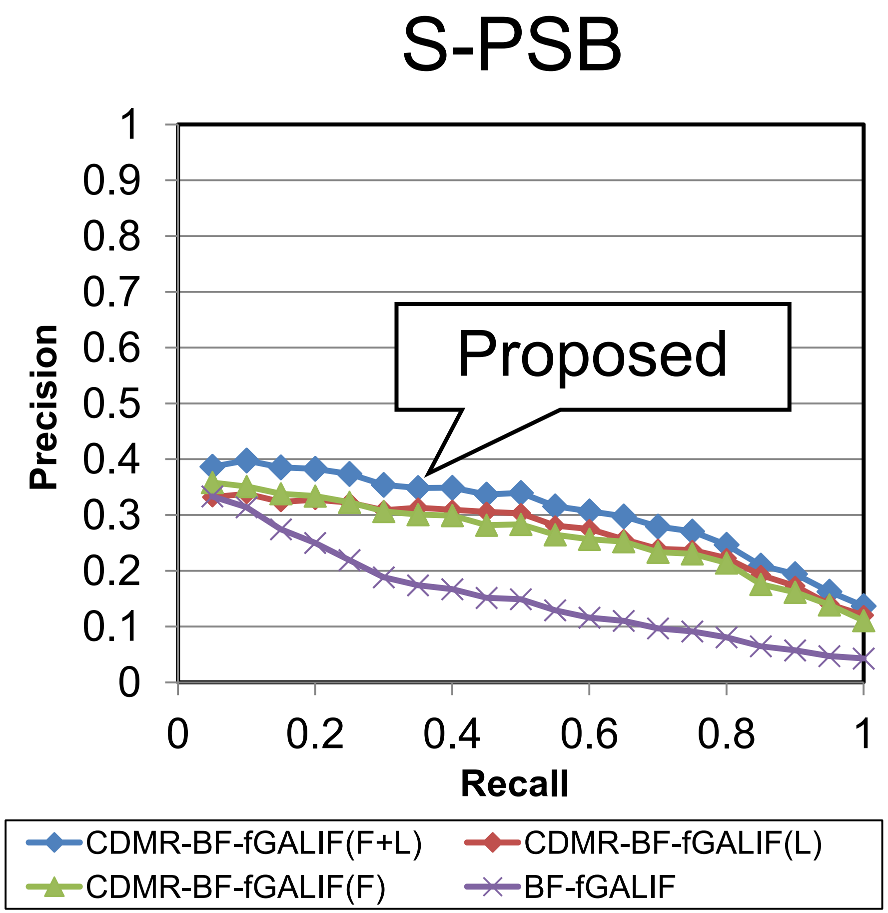
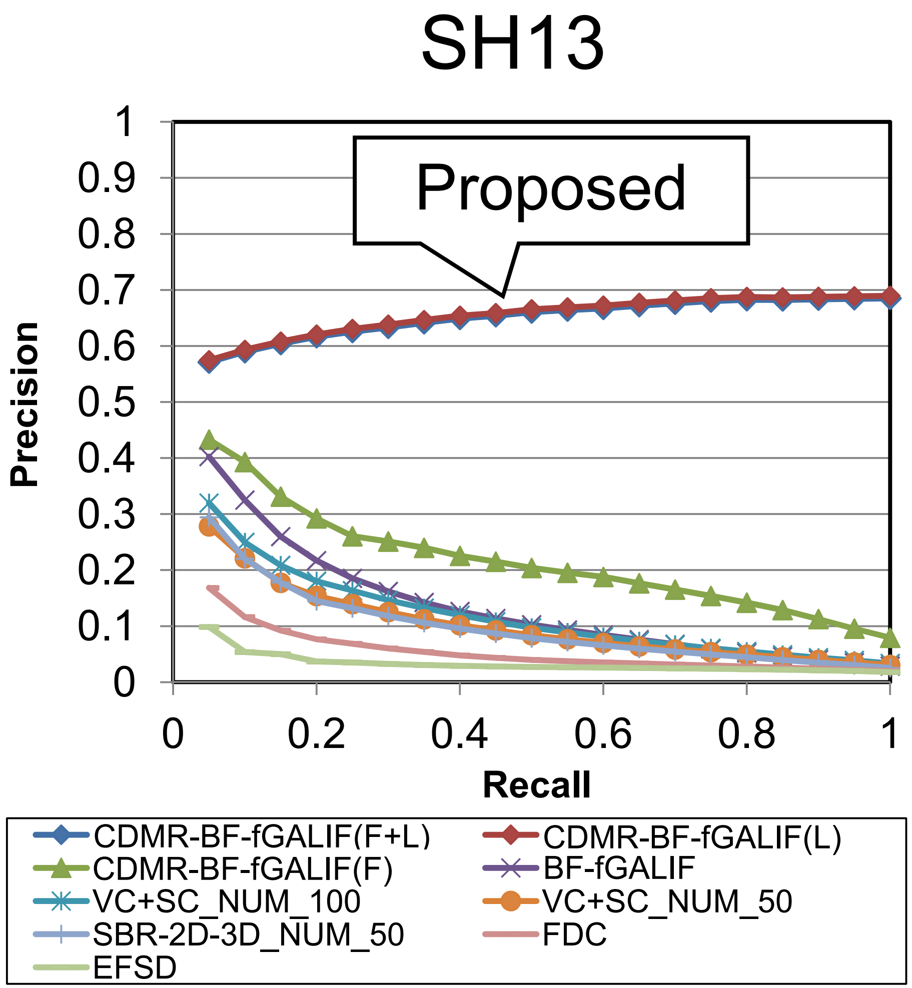


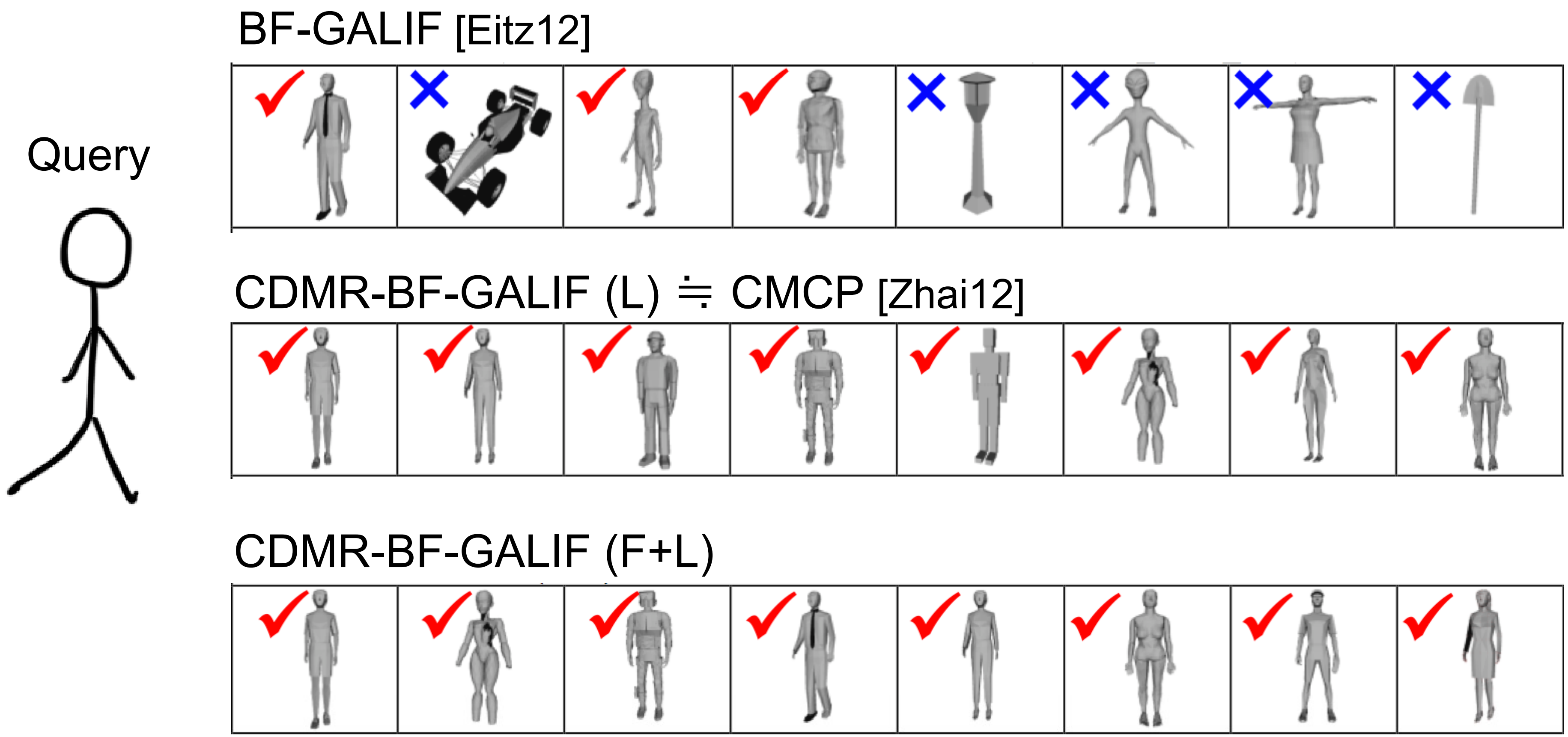
Experimental results
Comparison with other algorithms





Experimental results
Retrieval results (S-PSB)

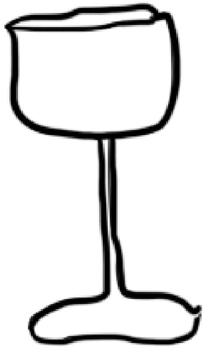
- “human” (labeled category)



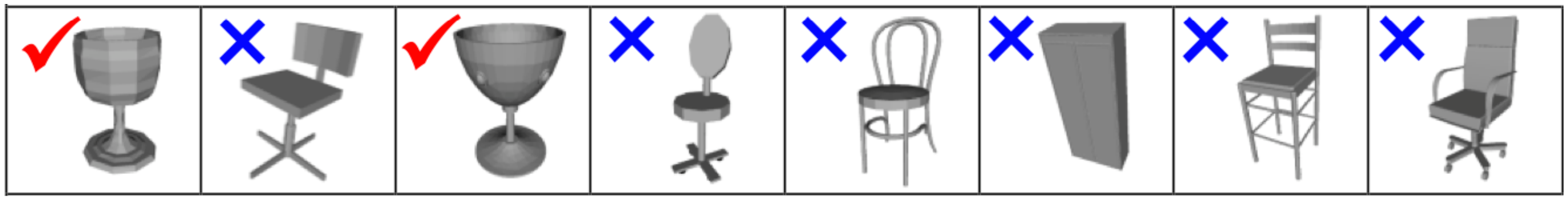
Experimental results
Retrieval results (S-PSB)

- "glass_with_stem" (unlabeled category)

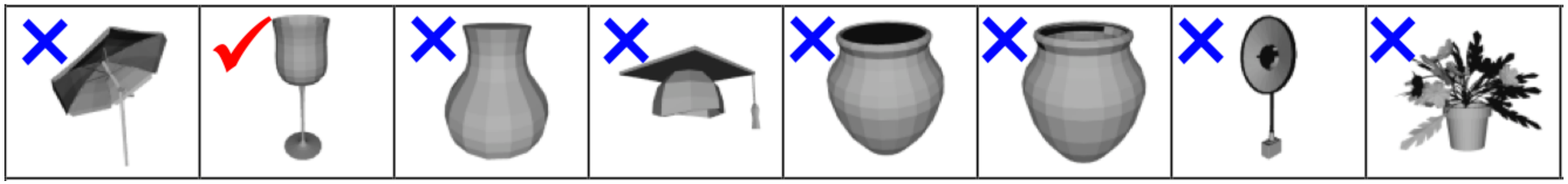
Query



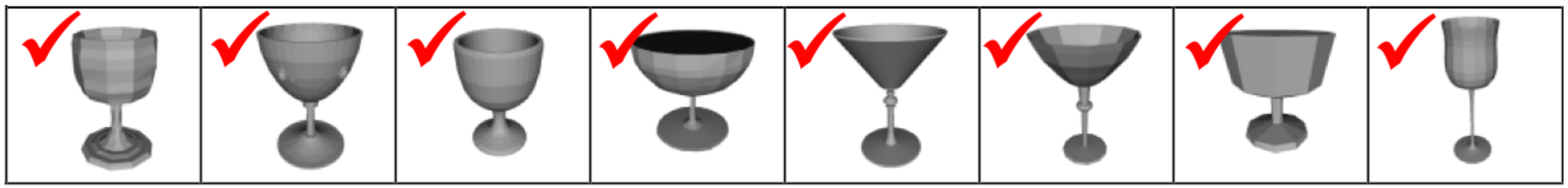
BF-GALIF [Eitz12]



CDMR-BF-GALIF (L) ≒ CMCP [Zhai12]



CDMR-BF-GALIF (F+L)



Experimental results
Computation time per query

Computation time per query for S-PSB [s]

methods	extract BF-GALIF	compute distance	CDMR (matrix size : 3,628 x 3,628)	total
BF-GALIF	0.11	1.59		1.70
CDMR-BF-GALIF	0.11	1.59	36.86	38.56

Computation time per query for SH13 [s]

methods	extract BF-GALIF	compute Distance	CDMR (matrix size : 8,458 x 8,458)	total
BF-GALIF	0.11	1.13		1.24
CDMR-BF-GALIF	0.11	1.17	659.93	661.21

measured by using: Intel Xeon E3-1245 @ 3.30 GHz, 32 GB of memory

Conclusion and Future work

- Conclusion
  - More accurate sketch-based 3D model retrieval.
    - Cross-Domain Manifold Ranking (CDMR)
      - Combines feature similarity and semantic similarity.
      - Outperforms previous methods.

- Future work
  - Faster computation (e.g., approximation of diffusion).
  - More accurate feature comparison.