Generalizable Category-Level Topological Structure Learning for Clothing Recognition in Robotic Grasping

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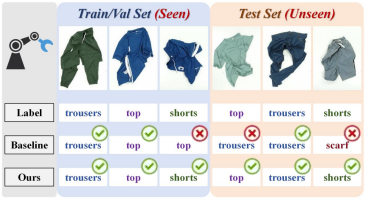
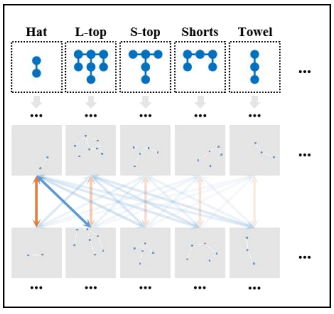
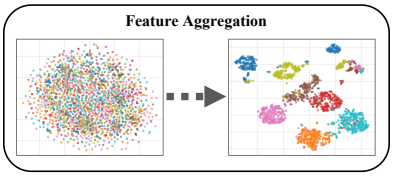
Motivation



- Clothing **deformation features** are highly coupled and rely on **color and texture**.
- Lack of **clothing category-level structural feature learning** process, **low model generalization**.

Topological Structure Representation and Optimization

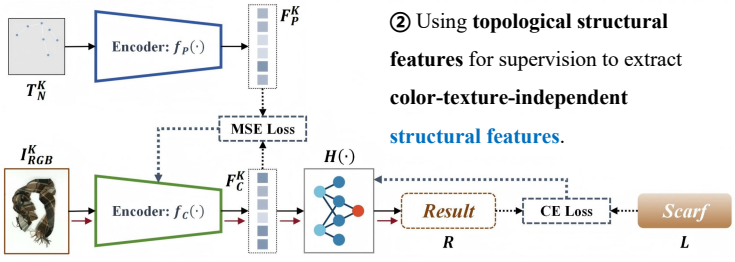




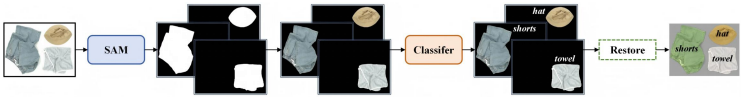
Training Process:

① Extract the **topological structure features** of clothing based on **contrastive learning**;

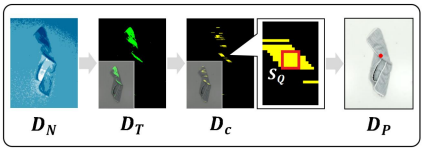
② Using **topological structural features** for supervision to extract **color-texture-independent structural features**.



Multi-clothing Classification Framework



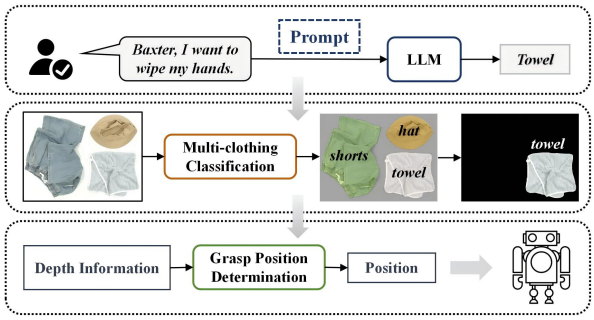
Grasping Position Estimation



- **Depth-Image Protrusion Filtering**
- **Max-Square Grasp Point Lock-on**

Humans are accustomed to looking for **raised wrinkles** on the clothing surface to achieve suitable grasping. The core of our method is to search for **suitable wrinkles** on the clothing surface.

Robotic Clothing Grasping System



- **System Inputs:** **Text data** entered by the user; **RGB images** for multi-clothing classification; **depth information** for grasp position estimation.
- **LLM** is used to analyze user instructions; **regional category information** is output based on a **Multi-Clothing Classification Framework**; and based on the proposed **Grasping Position Estimation Method**, **grasping position information** is output and sent to the robot to complete the user-specified clothing grasping task.

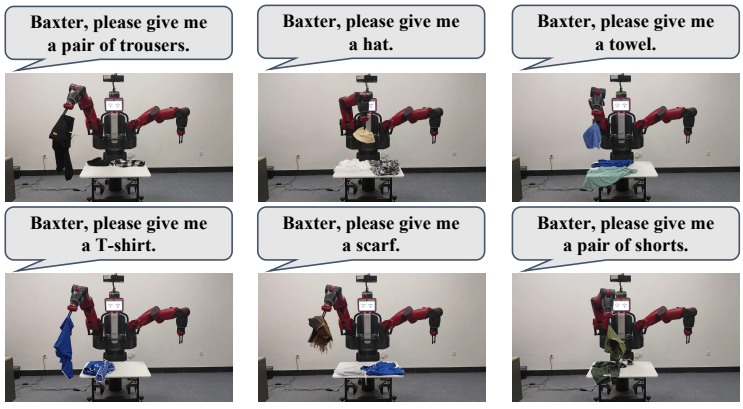
Comparative Analysis

Methods	Seen ↑	Unseen ↑
Shehawy et al.[3]	76.67%	74.52%
Chen et al.[4]	53.81%	52.86%
Ours	**89.29%**	**79.29%**

Methods	Seen ↑	Unseen ↑
GarFusion [2]	76.67%	65.00%
Ours	**89.29%**	**79.29%**

Methods	Classification		Grasping	
	Seen ↑	Unseen ↑	Seen ↑	Unseen ↑
MobileNetV2 [1]	97.11%	53.48%	90.72%	53.57%
Ours	**94.84%**	**84.01%**	**89.29%**	**79.29%**

Real-World Robotic Grasping



- ✓ Our dataset includes **7 categories** and **38 different clothing items**.
- ✓ This **system** enables the **Baxter** to grasp any clothing item based on **user instructions** while demonstrating **strong generalization to unseen targets**.

[1] M. Sandler, A. Howard, M. Zhu, A. Zhmoginov, and L.-C. Chen, "Mobilenetv2: Inverted residuals and linear bottlenecks," in IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR), pp. 4510–4520, 2018.
[2] L. Huang, T. Yang, R. Jiang, X. Tian, F. Zhou, and Y. Chen, "Deforming garment classification with shallow temporal extraction and tree-based fusion," IEEE Robotics and Automation Letters, pp. 1114–1121, 2023.
[3] H. Shehawy, P. Rocco, and A. M. Zanchettin, "Estimating a garment grasping point for robot," in IEEE International Conference on Advanced Robotics (ICAR), pp. 707–714, 2021.
[4] W. Chen, D. Lee, D. Chappell, and N. Rojas, "Learning to grasp clothing structural regions for garment manipulation tasks," in IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), pp. 4889–4895, 2023.

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