

Dynamic Robot-Assisted Surgery with Hierarchical Class-Incremental Semantic Segmentation

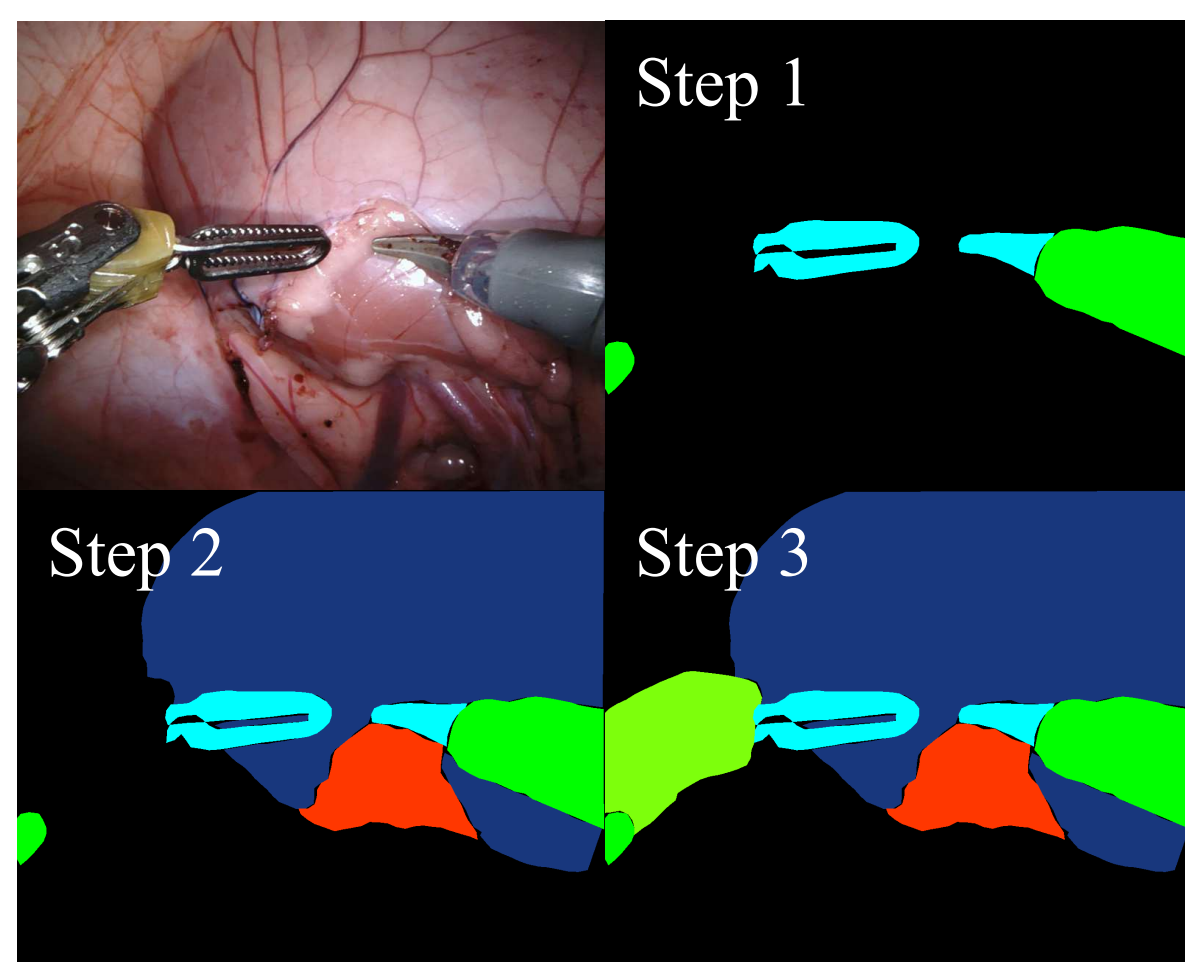
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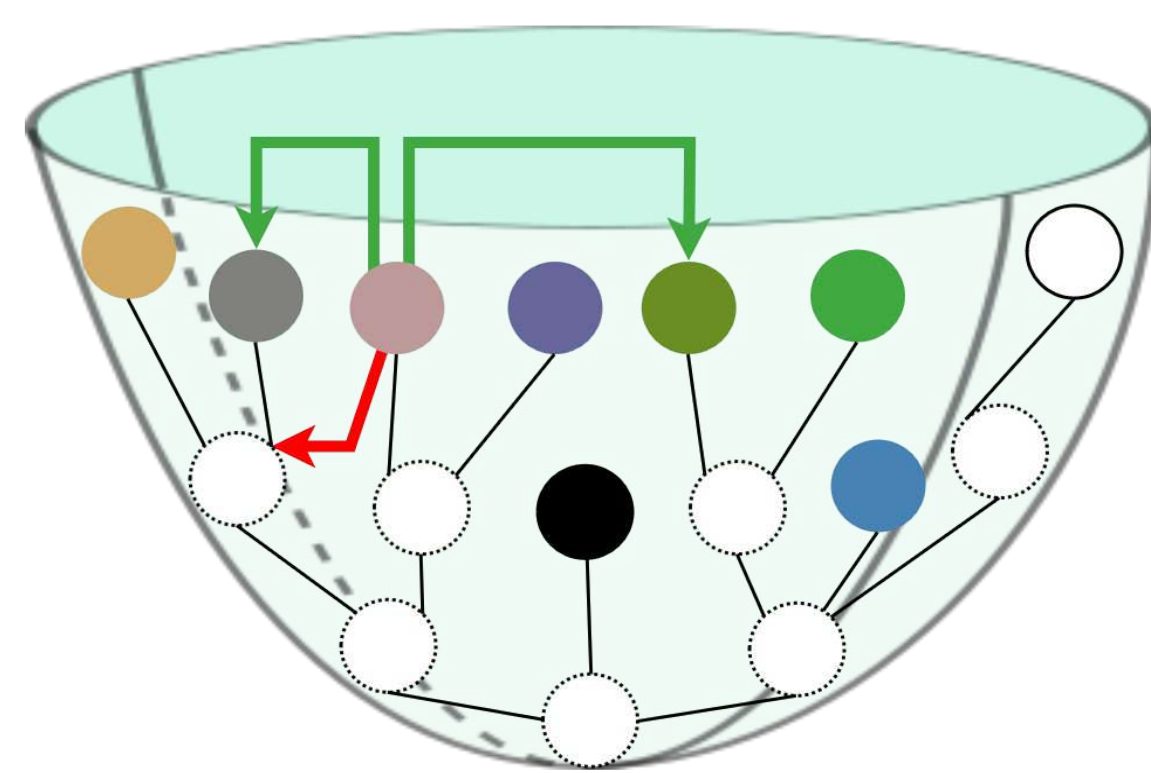
Motivation

- Scene understanding for robotic surgeries need to quickly adapt to new annotation protocols, equipment, and/or patient populations.
- Class-Incremental Semantic Segmentation (CISS)** aims to update the model with new classes at periodic timesteps.
- State-of-the-art methods highlight the suitability of modeling tree-like structures in hyperbolic space to mitigate forgetting.

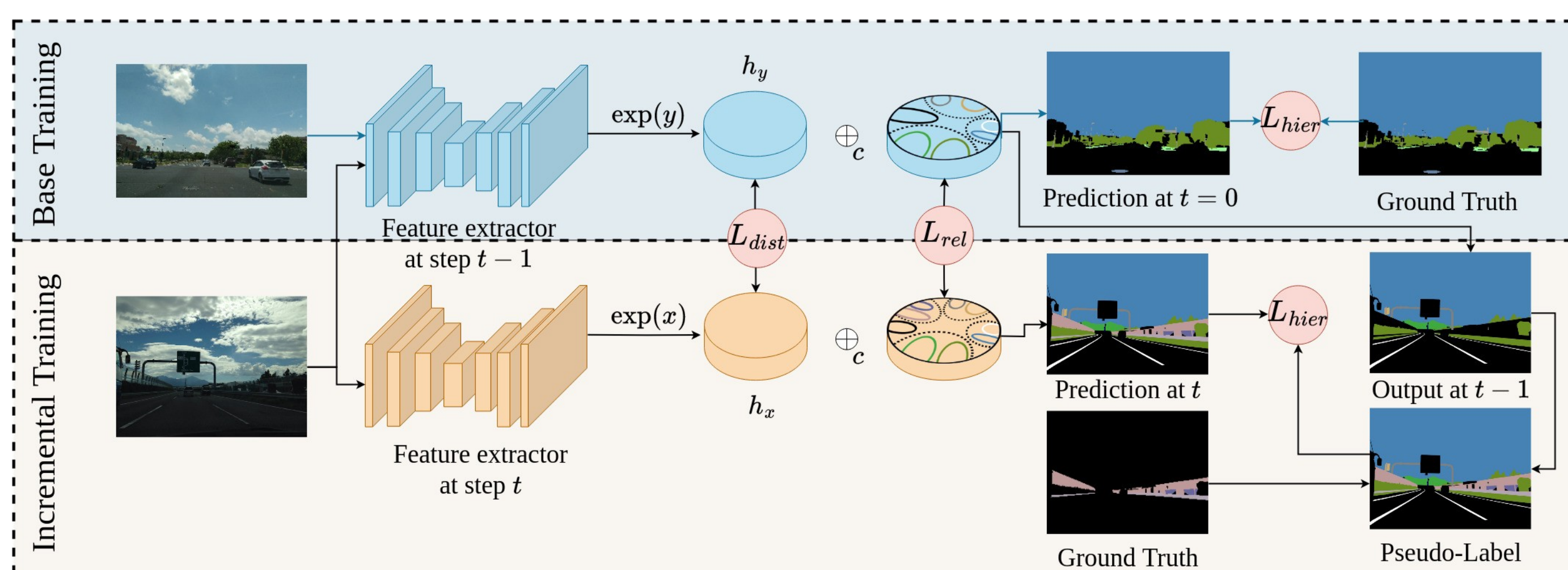
Class-Incremental Semantic Segmentation



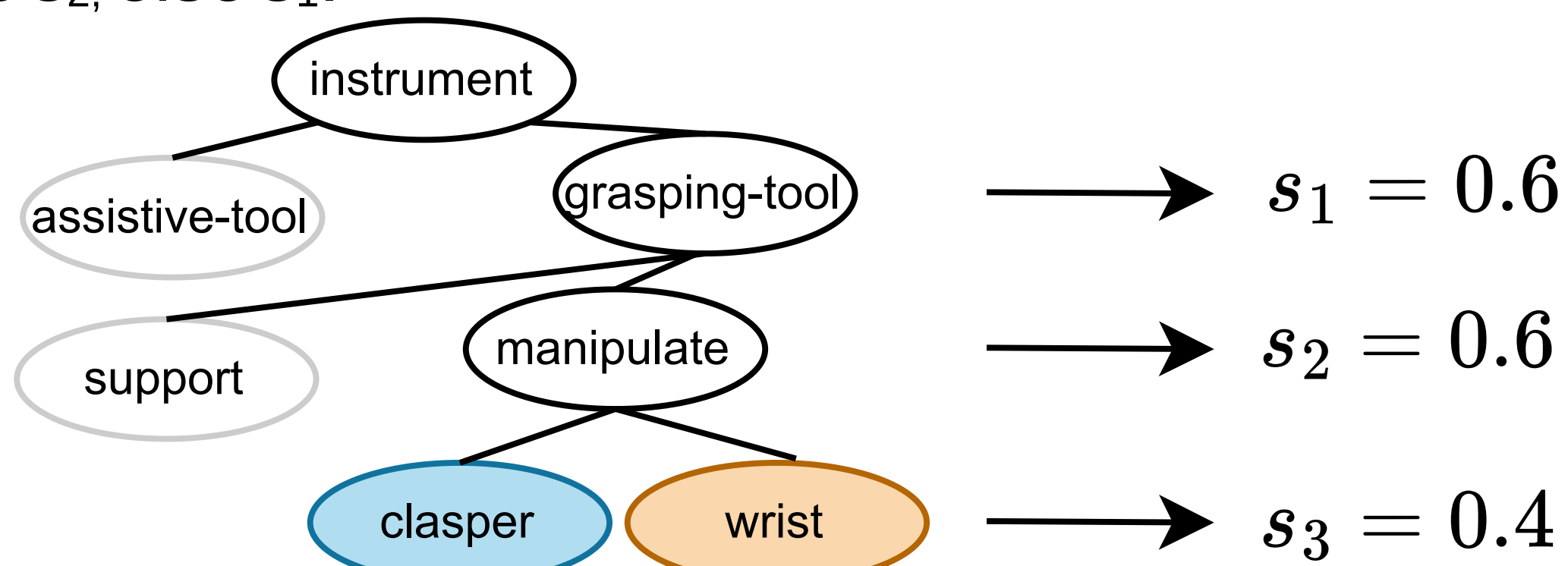
Taxonomy tree in hyperbolic space



Method

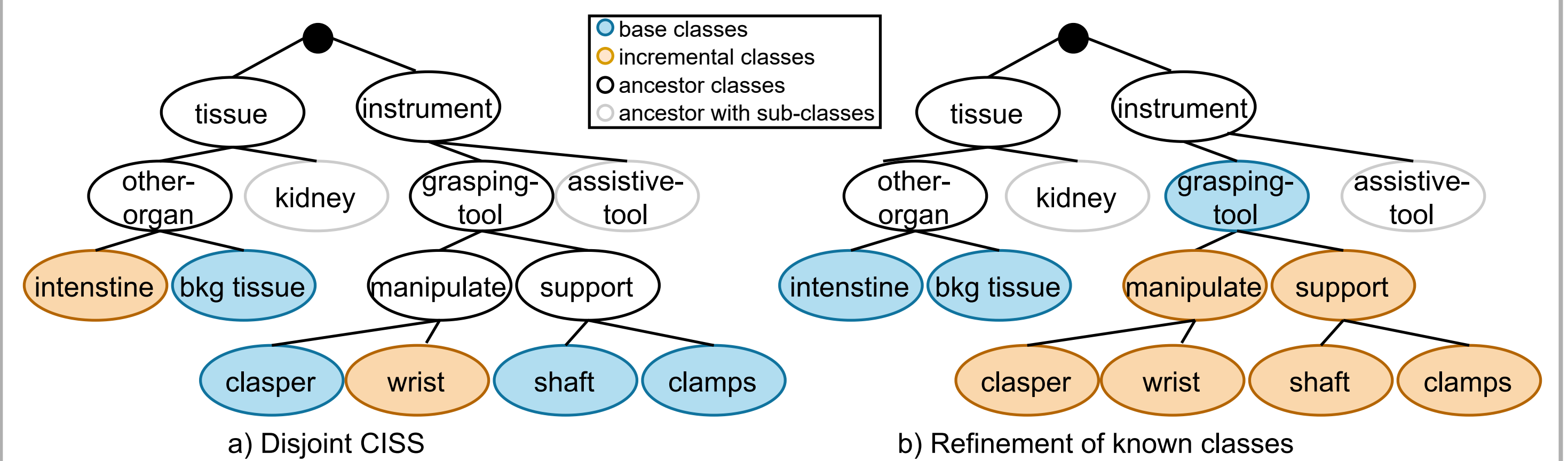


- We propose **TOPICS+** which extends TOPICS (*T*axonomy-*O*riented *P*oincaré-regularized *I*ncremental *C*lass *S*egmentation) by integrating the **Dice loss** into hierarchical training and introducing **hierarchical pseudo-labeling**.
- We first train the model on the **base dataset**. The class hierarchy is explicitly enforced (L_{hier}) in the final network layer which is mapped on the Poincaré ball. We integrate the Dice loss in L_{hier} .
- During the **incremental steps**, we leverage the old model's weights to create **hierarchical pseudo-labels** for the background by assigning the most specific class exceeding s_3 , else s_2 , else s_1 .

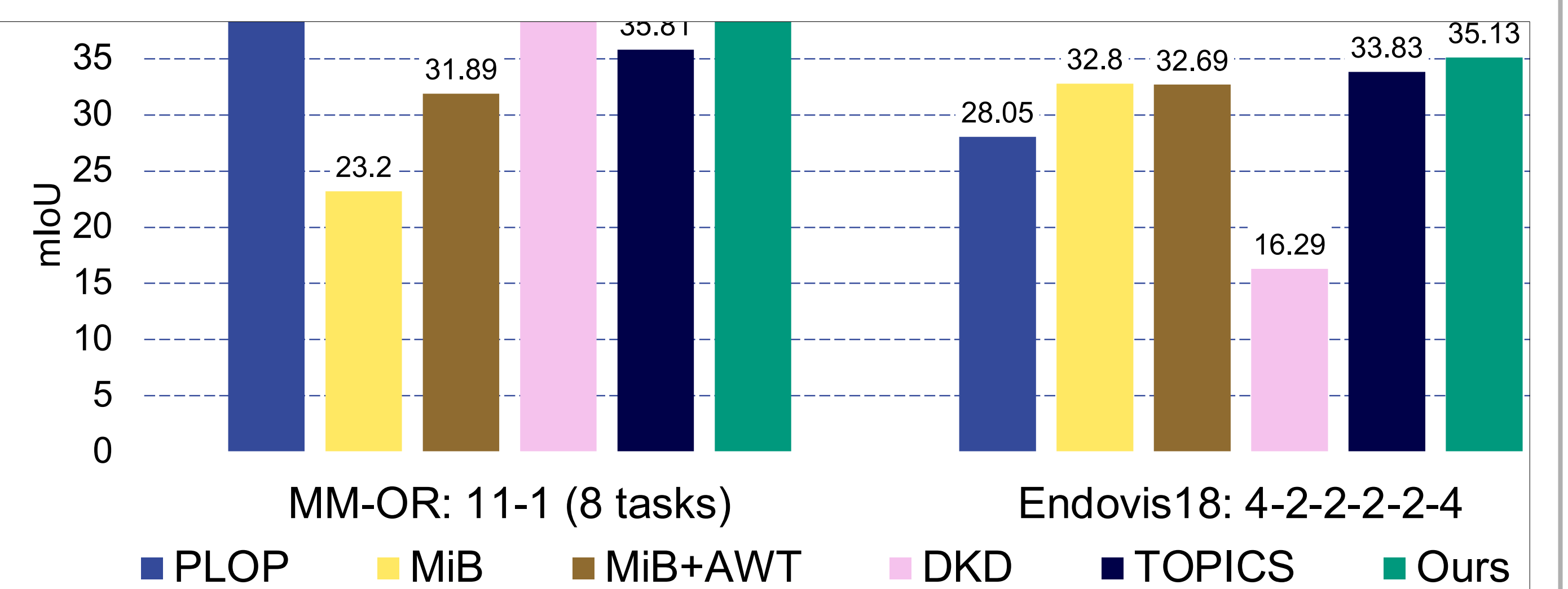


- We employ **scarcity and relation regularization** losses as employed in TOPICS to maintain classes in a similar constellation in the updated model (L_{rel}) and enforce features of the new and old model to be equidistant from the center of the Poincaré ball (L_{dist}).

Results

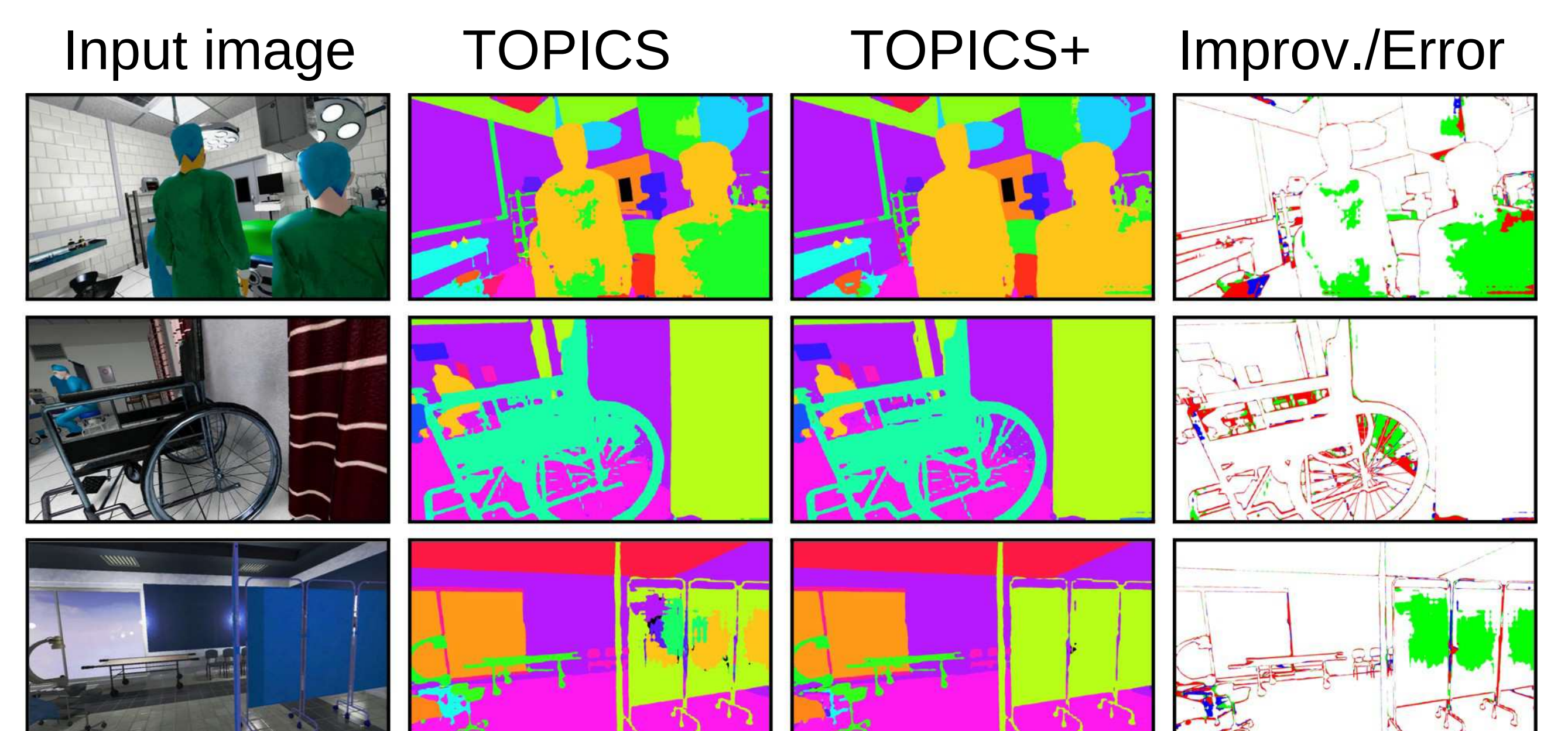


- We evaluate TOPICS+ on the **Endovis18**, **MM-OR** and **Syn-Mediverse** datasets.



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- TOPICS+ outperforms all baselines on all datasets.
- Qualitative results show that our method remembers old classes, such as person and medical curtain, and continuously predict them after having learned new classes.



- Further, we release the extended Syn-mediverse benchmark with 144 refined classes.

Conclusion

- In this work, we proposed TOPICS+, a replay-free CISS approach for continual robot-assisted surgical scene segmentation.
- We incorporate the dice loss for hierarchical hyperbolic segmentation with class imbalances.
- We introduce hierarchical pseudo-labeling to improve accuracy across diverse backgrounds.
- We emphasize the benefit of hierarchical modeling in hyperbolic space and motivate future work to explore its potential for various open-world challenges.