

A Two-Stage Semi-Supervised nnU-Net Model for Automated Tooth Segmentation in Panoramic X-ray Images

MICCAI STS 2024 Challenge Task 1

Team: SJTU_EIEE_2-426Lab

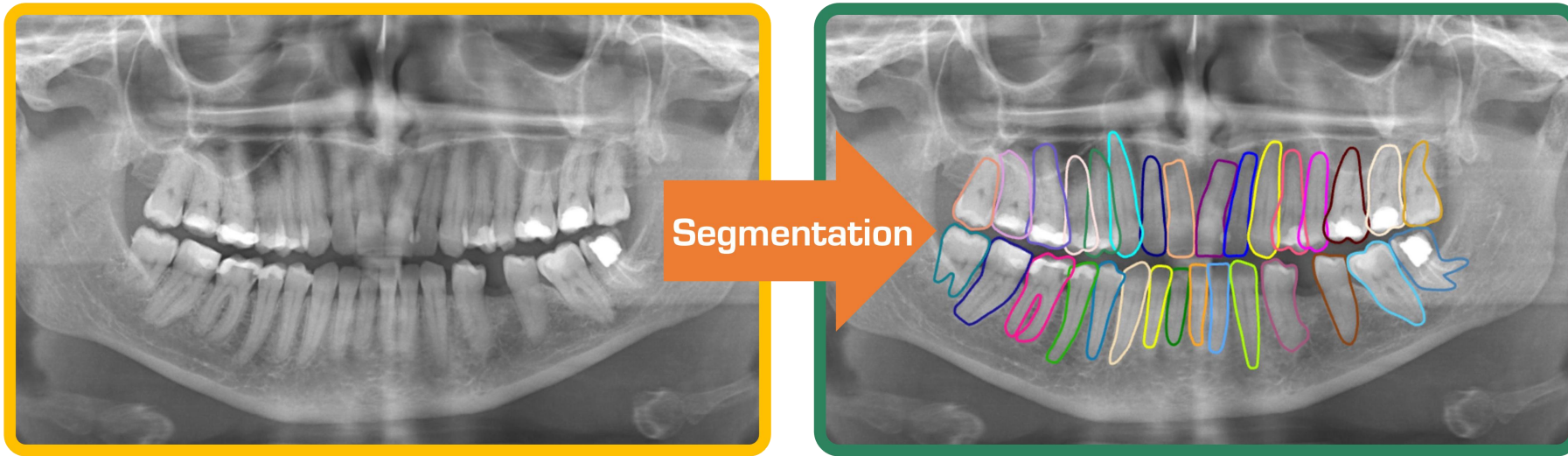
Presenter: Chuanyi Huang

covering joint work with:

Changkai Ji¹, Yusheng Liu¹, Lanshen He¹, Yuxian Jiang¹, Chuanyi Huang¹, and Lisheng Wang^{1*}

- Introduction
- Contributions
 1. We designed a self-training framework based on nnU-Net, enhancing model performance through **selective iterative training**.
 2. Our algorithm improves segmentation accuracy while **maintaining inference efficiency**, striving for an optimal balance between precision and performance.
 3. At the competition's test phase, our method secured **third place**, further demonstrating its efficacy in dental segmentation tasks.
- Results

- Panoramic X-rays are crucial in dental diagnosis, but manual segmentation is time-consuming and operator-dependent.
- Develop an automated tooth segmentation method to improve efficiency and consistency.
- Simultaneous segmentation of permanent and deciduous teeth, balancing accuracy and computational efficiency.



Adults

FDI two-digit tooth numbering system															
Teeth numbering chart for adult teeth															
upper right							upper left								
18	17	16	15	14	13	12	11	21	22	23	24	25	26	27	28
48 47 46 45 44 43 42 41							31 32 33 34 35 36 37 38								
molars			premolars		canines		incisors		canines		premolars		molars		
lower right							lower left								

Children

FDI two-digit tooth numbering system									
Teeth numbering chart for primary teeth									
upper right					upper left				
55	54	53	52	51	61	62	63	64	65
85 84 83 82 81					71 72 73 74 75				
lower right					lower left				

Covers various age groups and pathological effects

Training Set: 2,380 Panoramic X-ray Images (30 labeled; 2,350 unlabeled)

Validation Set: 20 Panoramic X-ray Images



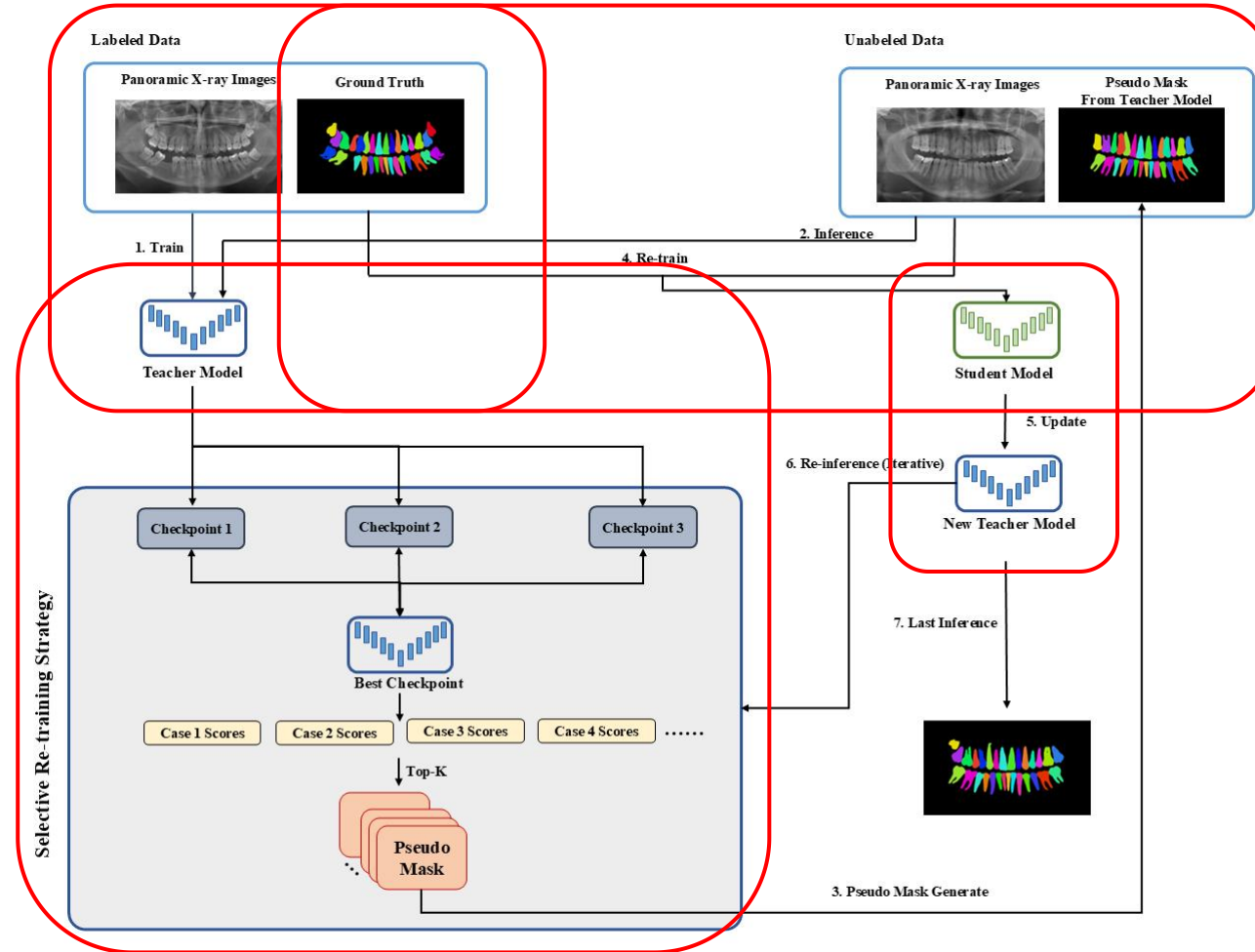
Permanent teeth

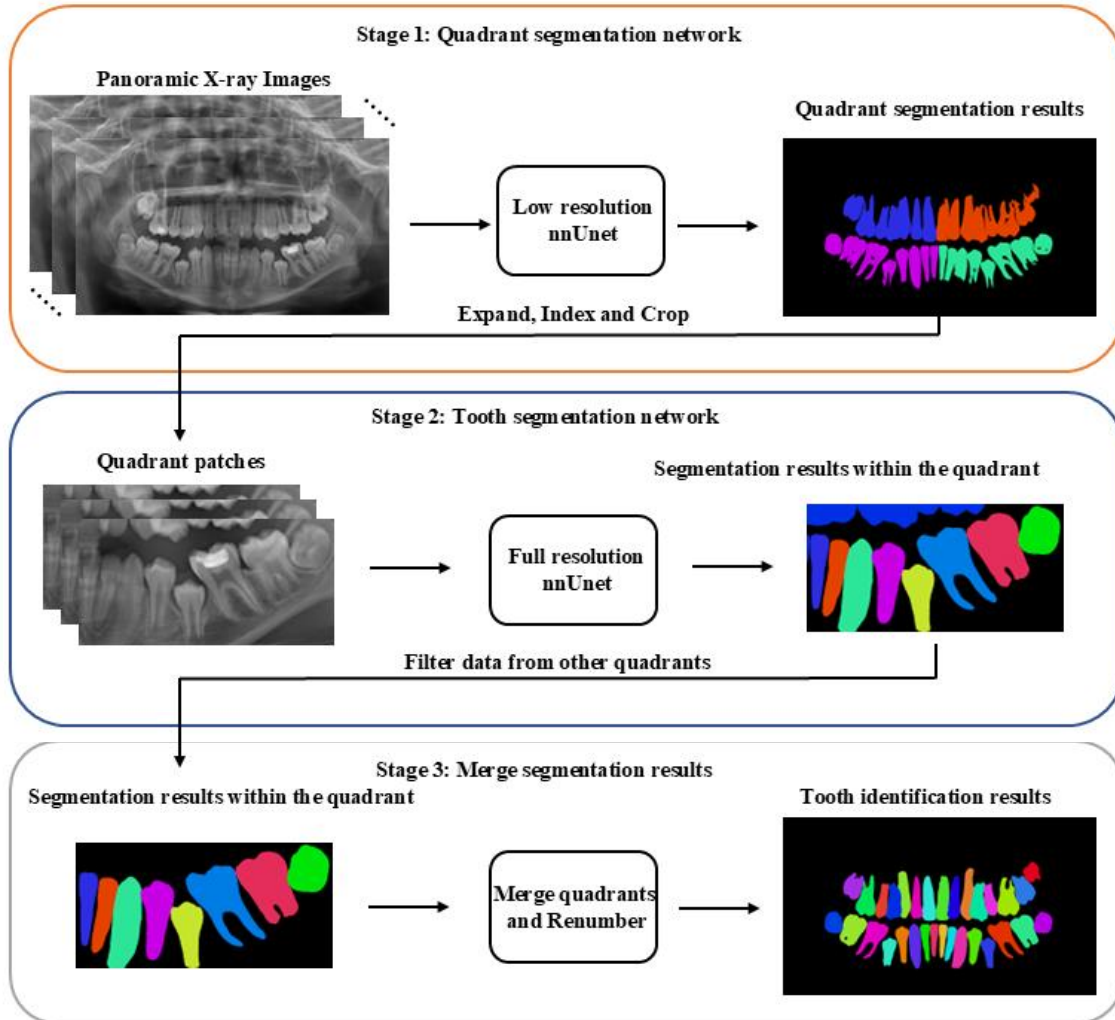


Deciduous teeth

Methods

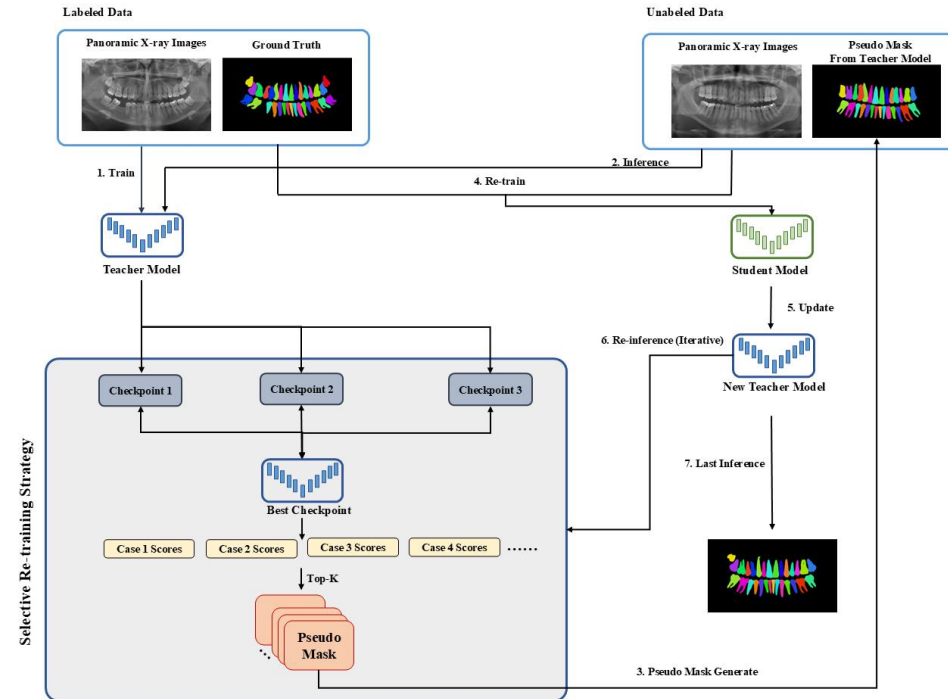
We transform the challenging task into a **semi-supervised** task. In each iteration, the student model is promoted to become the new teacher model.





- Stage 1: nnU-Net segments the input dental panoramic image into four categories, identifying the four dental quadrants.
- Stage 2: Based on the first stage results, teeth in each quadrant undergo fine segmentation. A 14-class nnU-Net segmentation model is applied, including eight classes of permanent teeth, five classes of deciduous teeth, and one class for teeth in other quadrants.
- Stage 3: Segmentation results from all four quadrants are combined to produce a comprehensive teeth segmentation map.
- Post-posing: Following each segmentation stage, we employ a post-processing step to eliminate or merge small connected components with adjacent larger regions.

Selective re-training strategy



- Three checkpoints are saved uniformly over 1/3, 2/3, 3/3 total iterations during training.
- To ensure a balance between the permanent and deciduous tooth data, we regard the 101 permanent tooth images and 101 deciduous tooth images with mean Dice scores greater than 0.9 as reliable images, and the rest as unreliable images.

Evaluation: segmentation accuracy and segmentation efficiency.

- 1) Segmentation accuracy: Dice similarity coefficient (DSC), normalized surface distance (NSD), mean Intersection-over-Union (mIoU), Identification Accuracy (IA).
- 2) Segmentation efficiency: GPU memory consumption (area under the GPU memory-time curve), running time (tolerance 45 seconds, single case maximum 60 seconds).

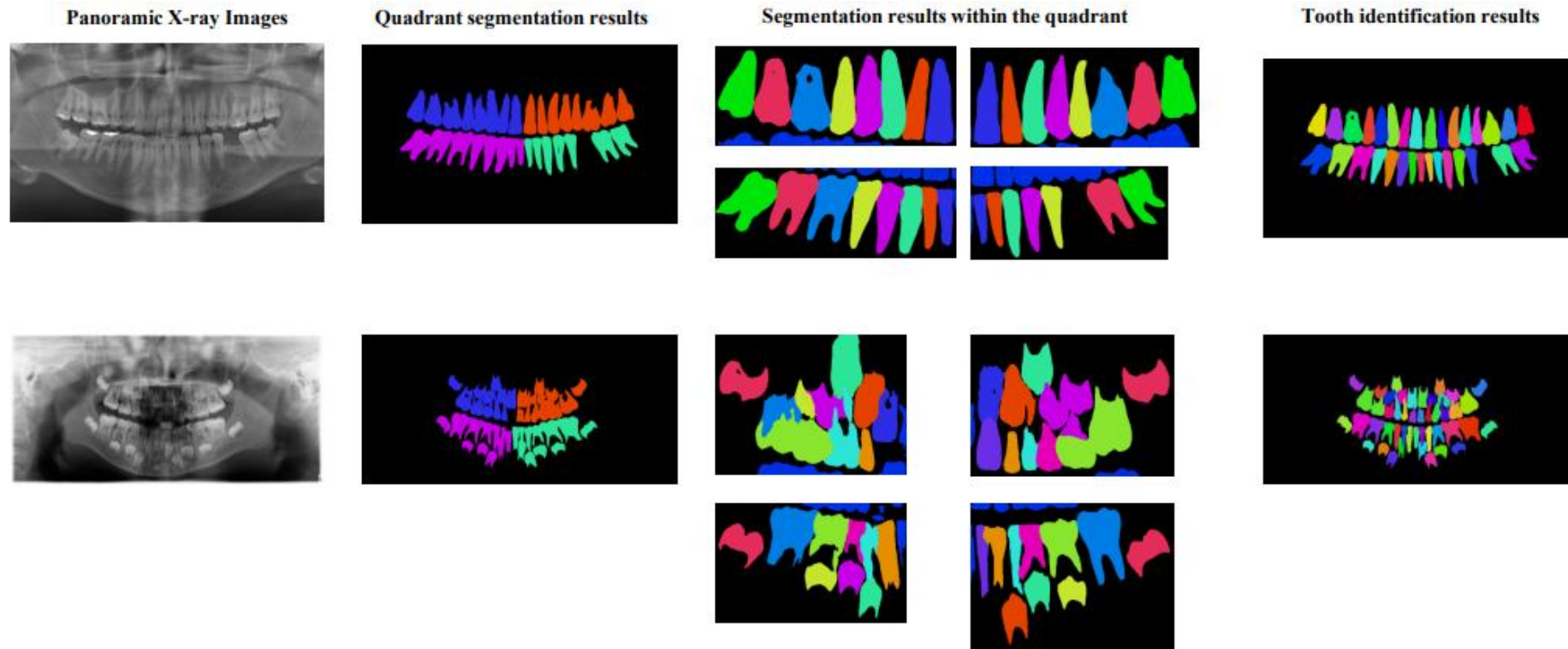
The ranking schema involves the following steps:

- 1) Compute two metrics, Dice and NSD, on a per-image basis to derive the algorithm's Dice (image_Dice) and NSD (image_NSD) scores at image-level.
- 2) Match the corresponding prediction results with the ground truth, allowing for the calculation of Dice (instance_Dice), NSD (instance_NSD), and IA (instance_IA) scores at the instance level.
- 3) Then, the evaluation will include measurements of running time and GPU consumption for each algorithm.
- 4) Take the mean of the eight metrics over the test cases, and rank separately among the teams.
- 5) A final overall rank is given by taking the average of the four ranks.

Results

- The qualitative and quantitative results are shown as below.

Dice (instance)	Dice (image)	NSD (instance)	NSD (image)	mIoU (instance)	mIoU (image)	IA
79.82%	94.02%	84.14%	96.74%	75.66%	88.77%	81.99%





Thank you for your attention!

changkaiji@sjtu.edu.cn