



Landmark-Guided Coarse-to-Fine Registration of Intraoral Scans and Cone-Beam CT



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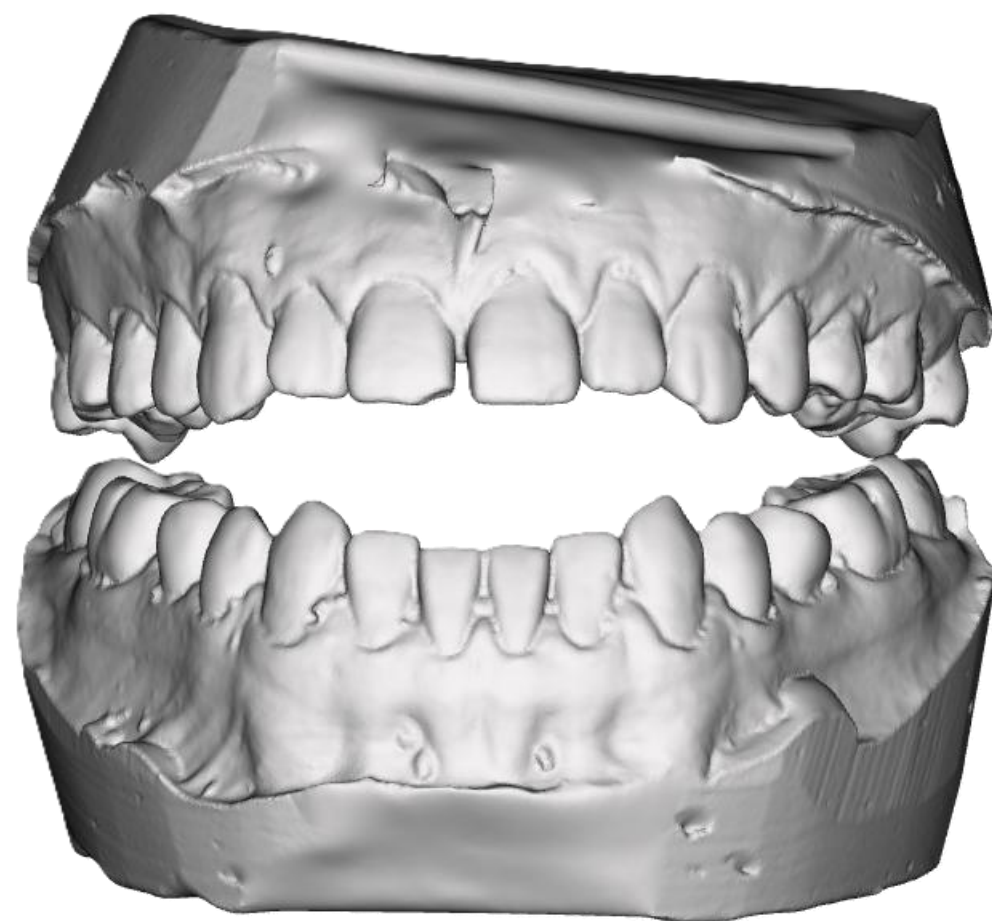


Federico Bolelli

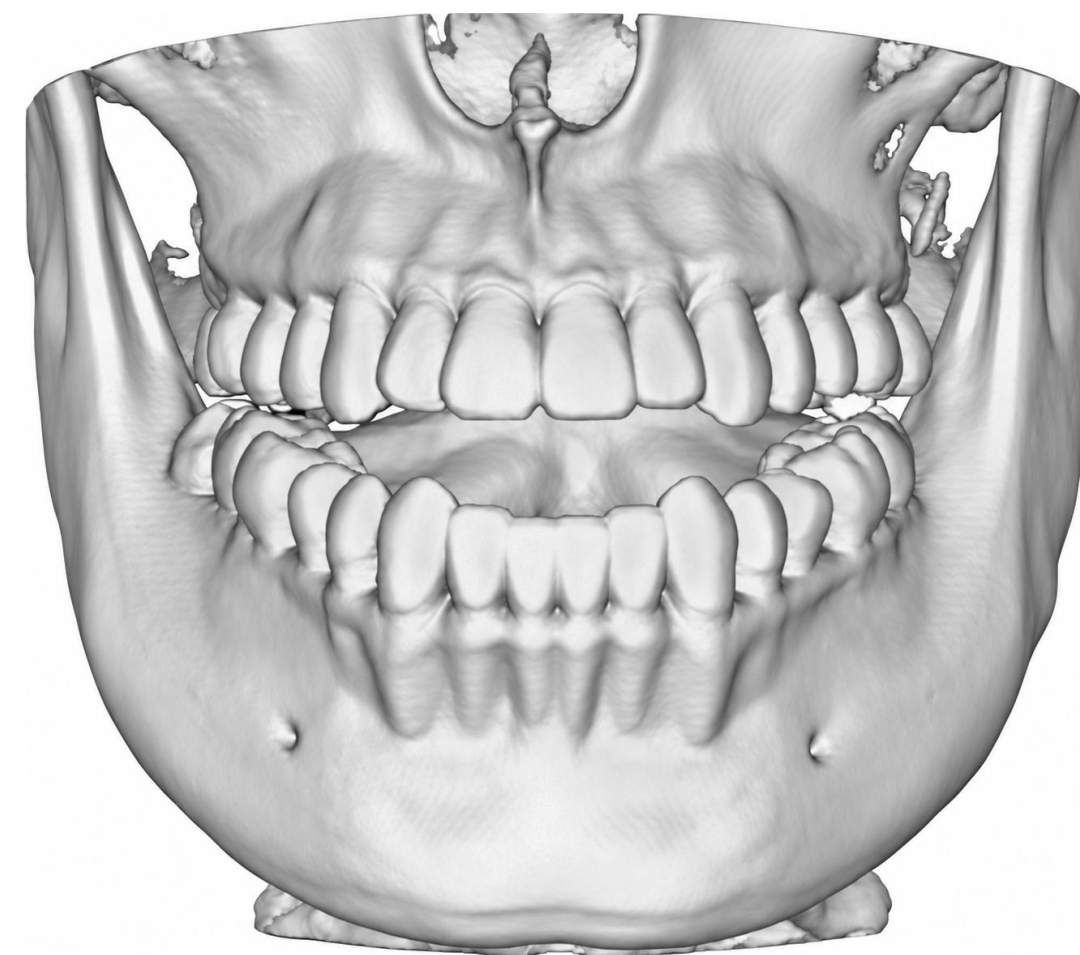
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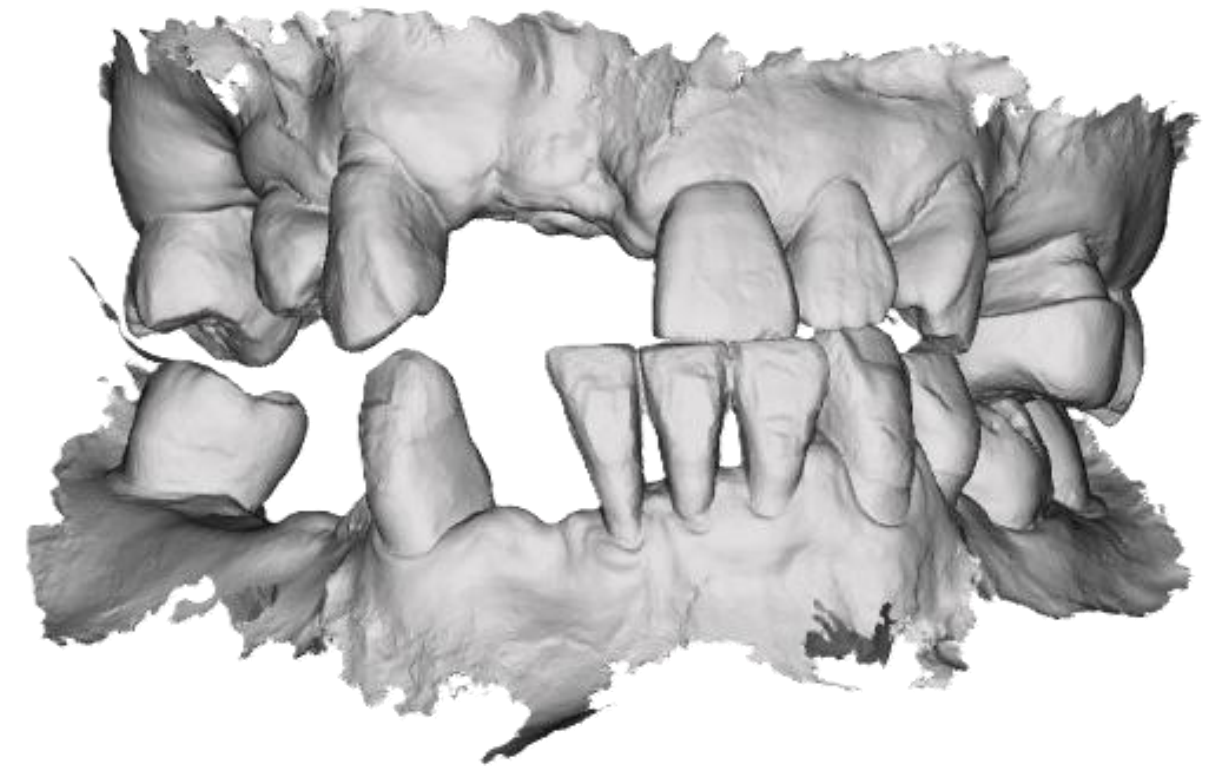
Intraoral Scan



Cone-Beam CT

Complementary information

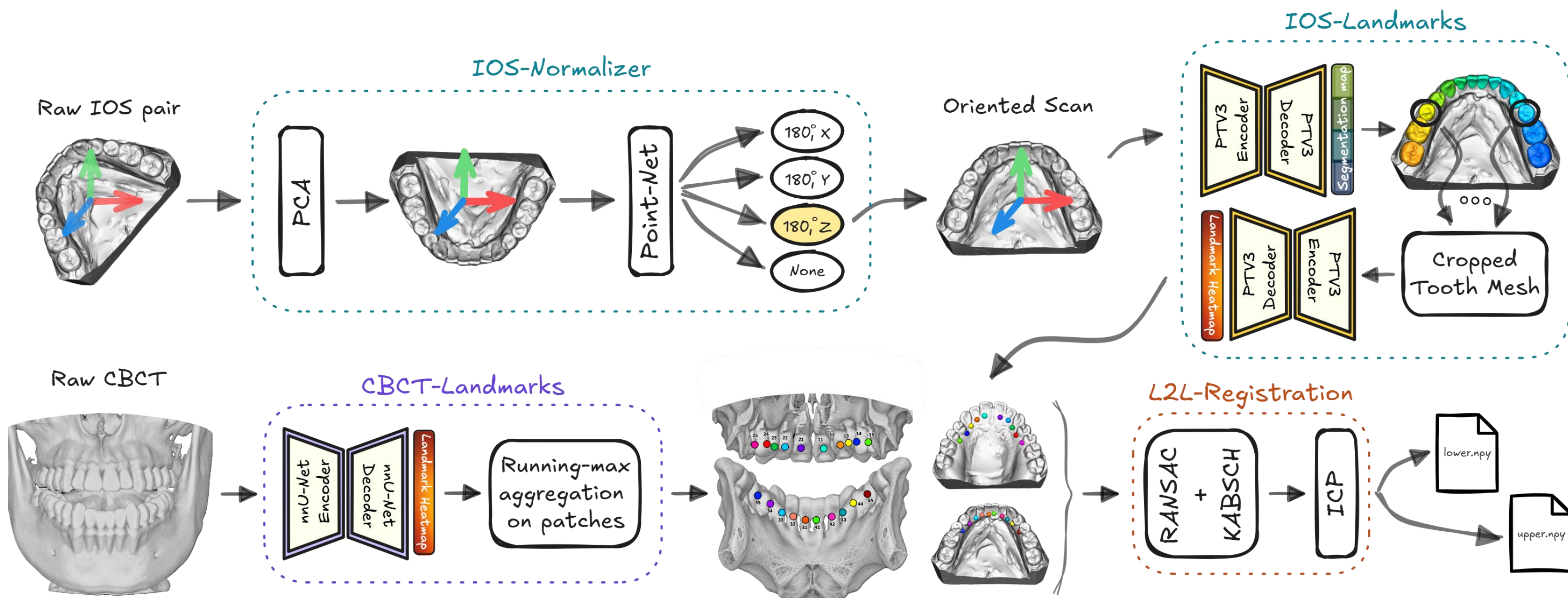
- Multimodal data;
- Limited shared anatomical region;
- Orthodontics appliances;
- Missing teeth;
- Imaging artifacts.



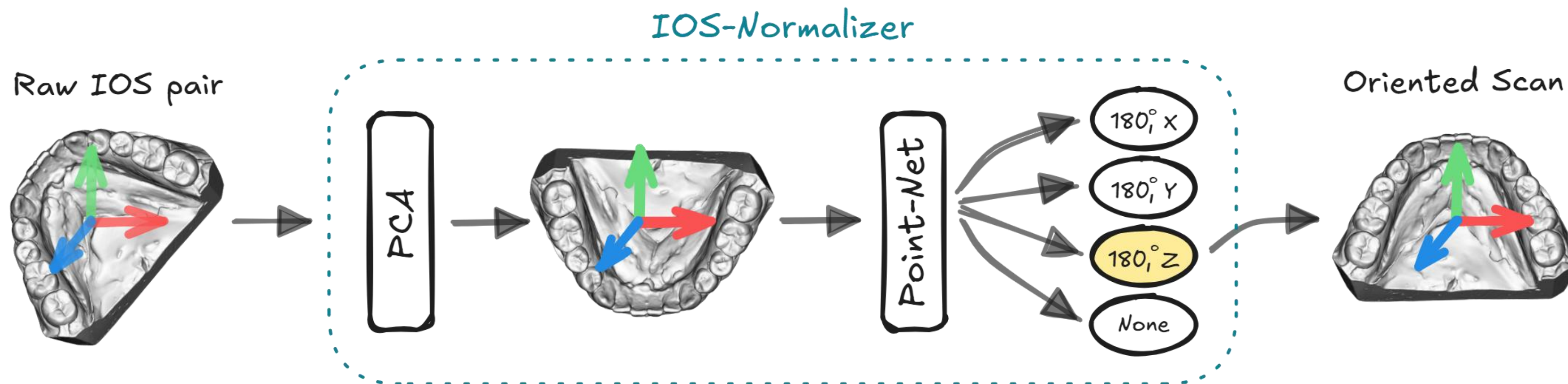
Set	Cases	Labels	Training	Evaluation
Train Labeled	30	✓	✗	✓
Train Unlabeled	300 201	✗*	✓	✗
Validation	50	✗	✗	✓

* Pseudo-labels by a private model used to transfer IOS Landmarks to CBCT Landmarks

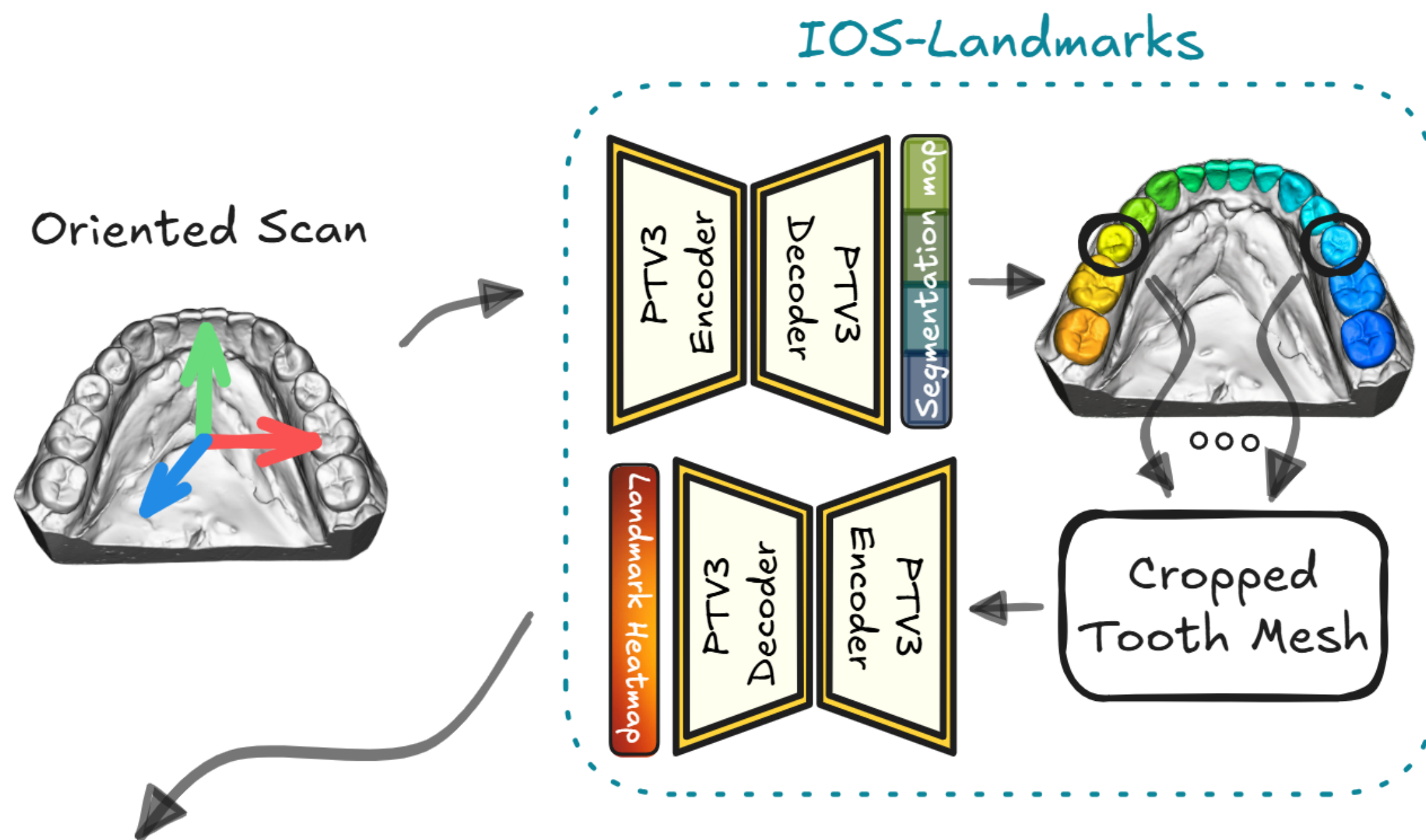
Landmark-Guided Coarse-to-Fine Framework



Landmark-Guided Coarse-to-Fine Framework

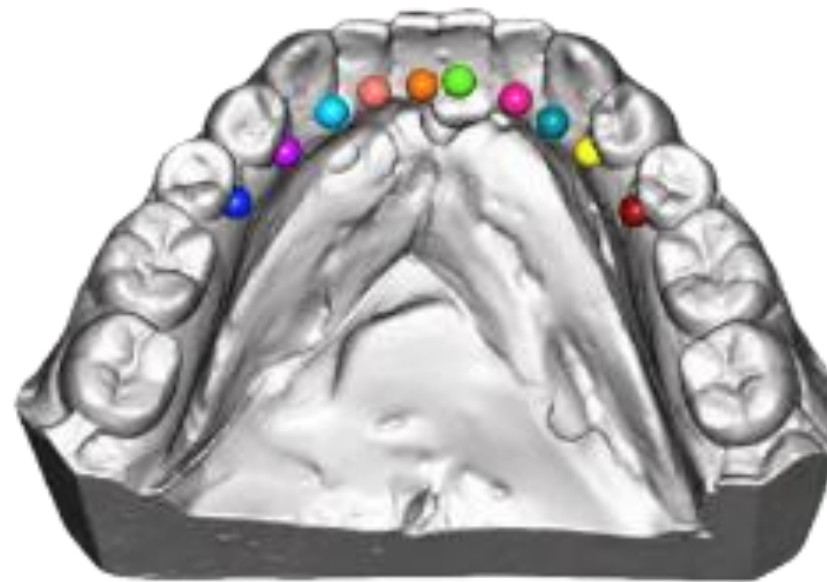


Landmark-Guided Coarse-to-Fine Framework



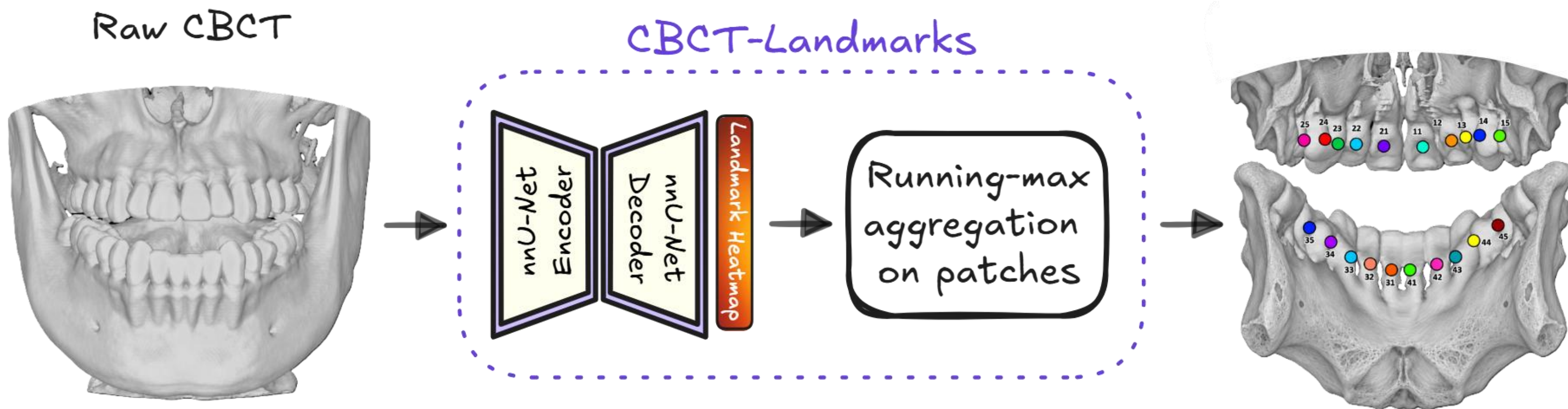
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Palatal

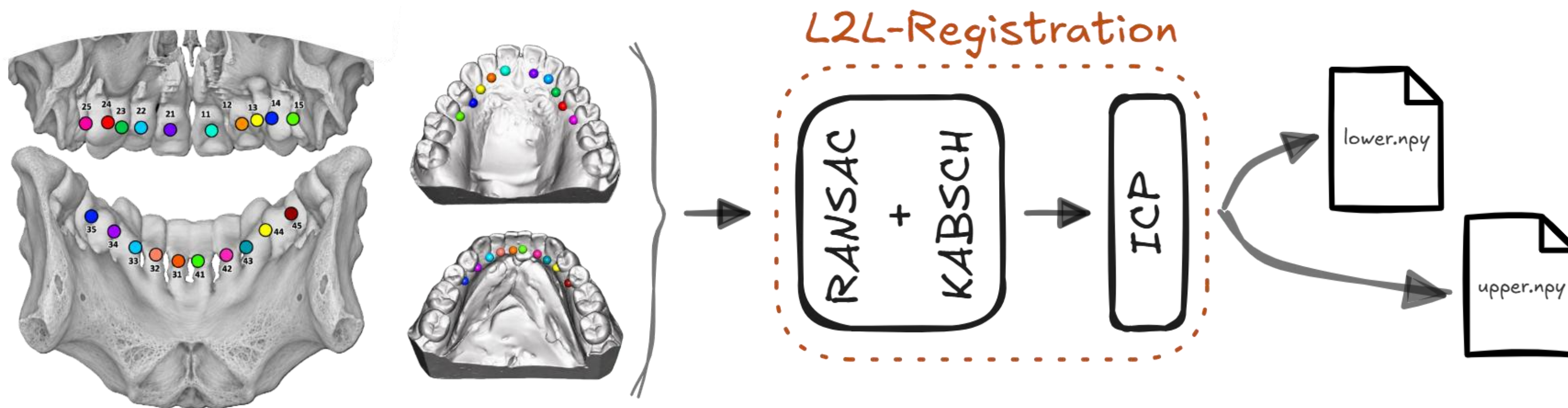


Lingual

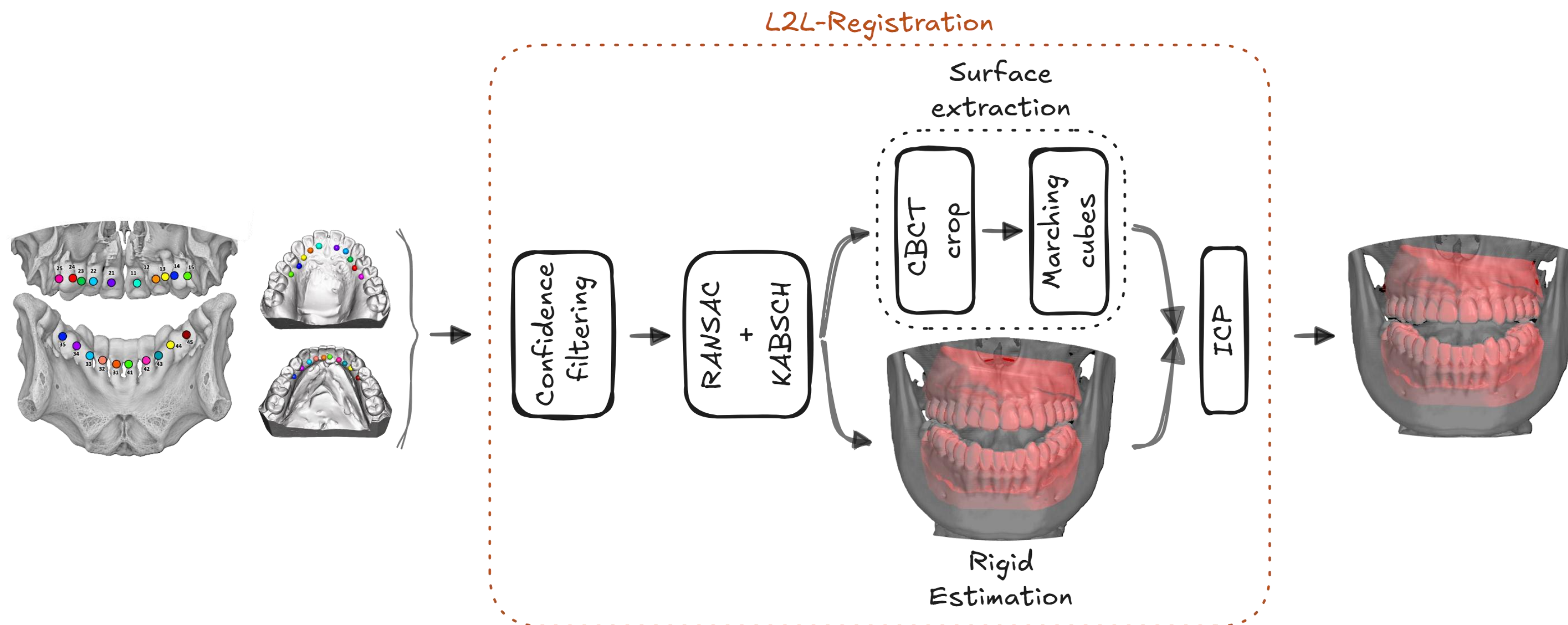
Landmark-Guided Coarse-to-Fine Framework



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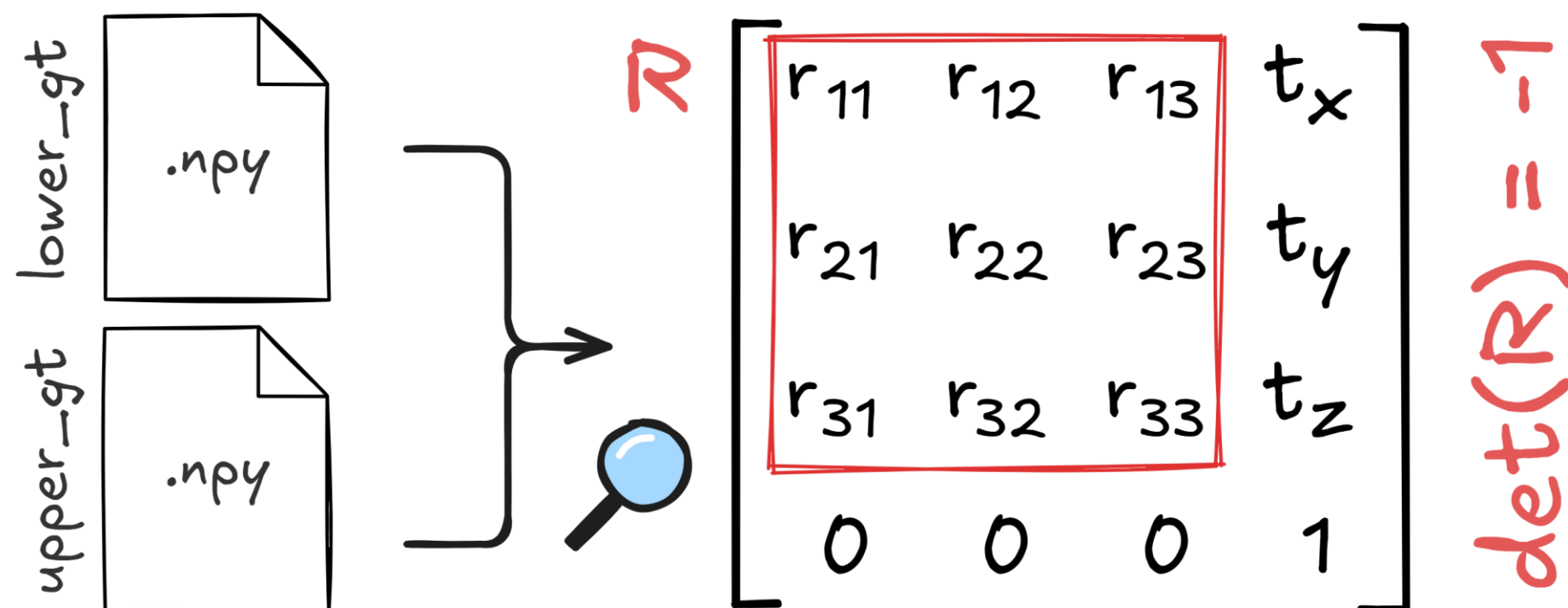
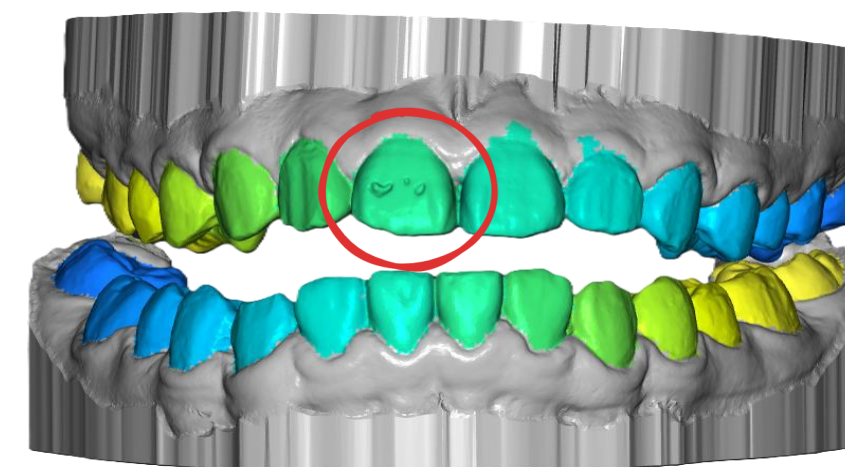


Set	RANSAC	ICP	Flip ID > 269	MTE (mm) ↓	MRE (°) ↓
Train Labeled	✗	✗	✓	13.759	3.993
	✓	✗	✓	8.708	2.619
	✗	✓	✓	7.959	1.997
	✓	✓	✓	1.813	0.891
Validation	✓	✓	✗	10.037	22.809
	✓	✓	✓	4.988	1.421
Test corrected	✓	✓	✗	6.752	1.976

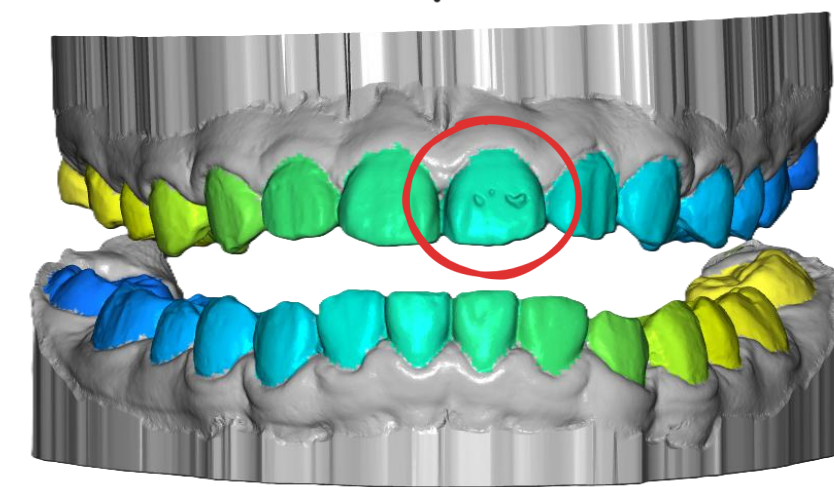
Set	RANSAC	ICP	Flip ID > 269	MTE (mm) ↓	MRE (°) ↓
Train Labeled	✗	✗	✓	13.759	3.993
	✓	✗	✓	8.708	2.619
	✗	✓	✓	7.959	1.997
	✓	✓	✓	1.813	0.891
Validation	✓	✓	✗	10.037	22.809
	✓	✓	✓	4.988	1.421
Test corrected	✓	✓	✗	6.752	1.976

Set	RANSAC	ICP	Flip ID > 269	MTE (mm) ↓	MRE (°) ↓
Train Labeled	$\times$	$\times$	$\checkmark$	13.759	3.993
	$\checkmark$	$\times$	$\checkmark$	8.708	2.619
	$\times$	$\checkmark$	$\checkmark$	7.959	1.997
	$\checkmark$	$\checkmark$	$\checkmark$	1.813	0.891

Train Labeled set Patient **IDs > 269** contain an **additional reflection** on the YZ plane.



GT
 4×4



Patient ID 274

Set	RANSAC	ICP	Flip ID > 269	MTE (mm) ↓	MRE (°) ↓
Train Labeled	<i>X</i>	<i>X</i>	✓	13.759	3.993
	✓	<i>X</i>	✓	8.708	2.619
	<i>X</i>	✓	✓	7.959	1.997
	✓	✓	✓	1.813	0.891
Validation	✓	✓	<i>X</i>	10.037	22.809
	✓	✓	✓	4.988	1.421

The **hidden Validation** set Ground Truth also has reflections for IDs > 269.

Set	RANSAC	ICP	Flip ID > 269	MTE (mm) ↓	MRE (°) ↓
Train Labeled	✗	✗	✓	13.759	3.993
	✓	✗	✓	8.708	2.619
	✗	✓	✓	7.959	1.997
	✓	✓	✓	1.813	0.891
Validation	✓	✓	✗	10.037	22.809
	✓	✓	✓	4.988	1.421

- ✓ Anatomical landmarks provide a reliable global initialization;
- ✓ Confidence-weighted RANSAC–Kabsch handles inconsistent correspondences;
- ✓ Point-to-plane ICP refines the alignment using local surface geometry;
- ✗ Requires at least 3 geometrically consistent landmark correspondences;
- ✗ Nearly collinear landmarks can lead to unstable registration;
- ✗ Large landmark errors may prevent ICP convergence.

Future work:

Increase the number and spatial coverage of cross-modal landmarks to improve robustness to missing teeth, incomplete scans, artifacts, and inaccurate predictions

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Thank you!



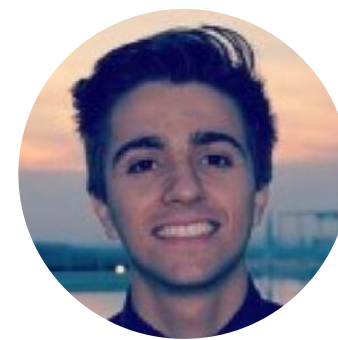
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