SALT: Parameter-Efficient Fine-Tuning via Singular Value Adaptation with Low-Rank Transformation

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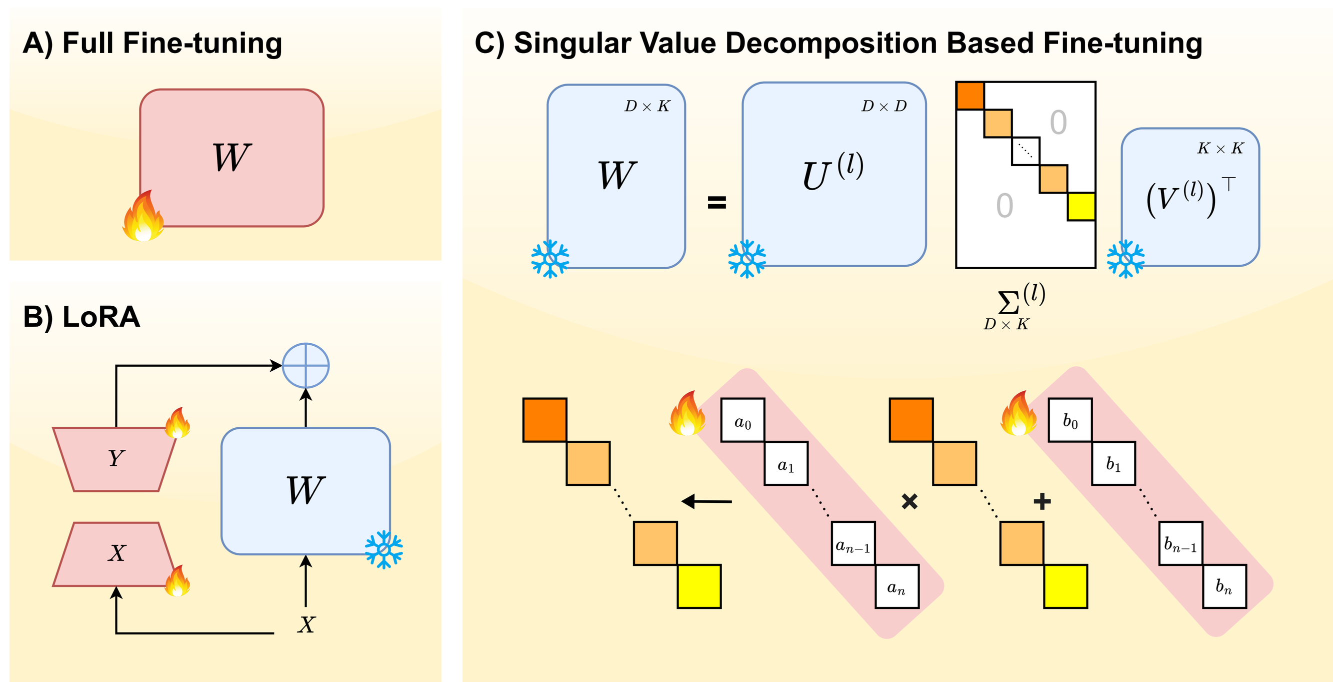
Paper

Code

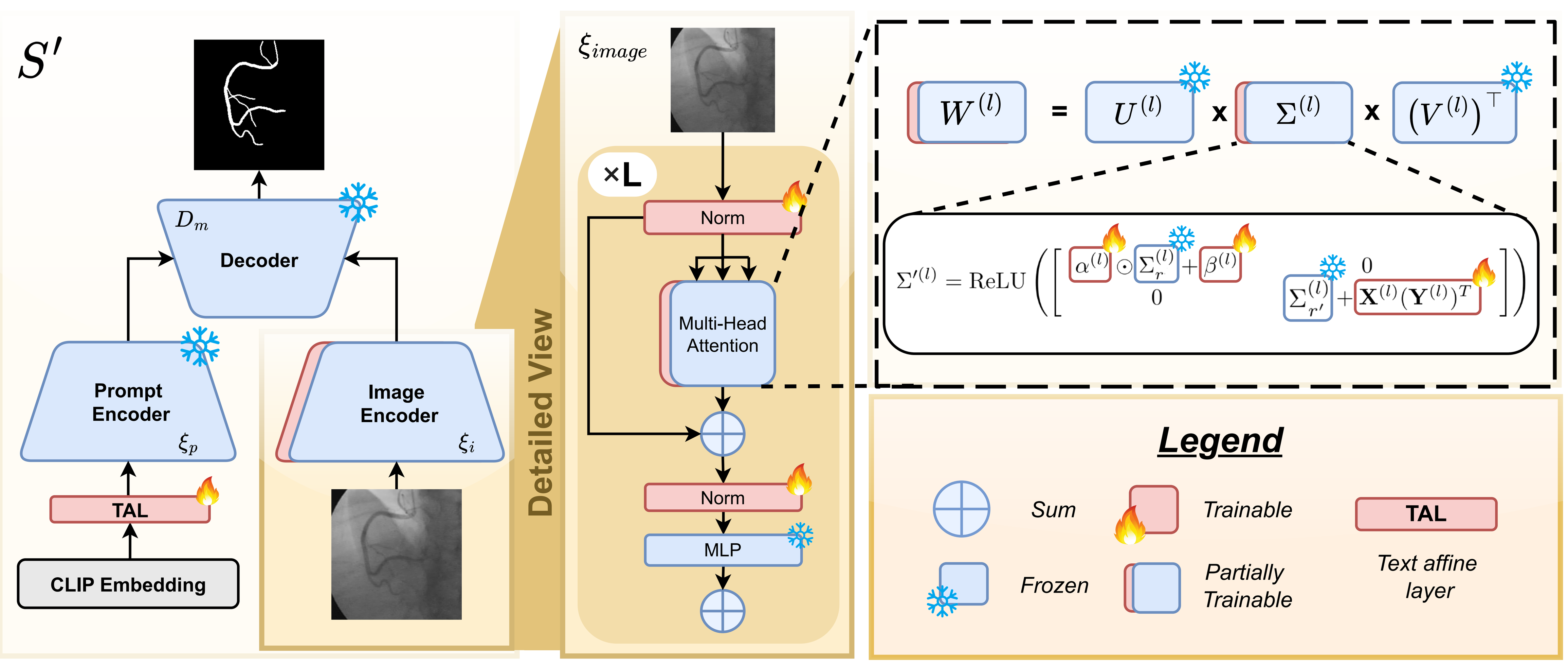
I. Introduction & Motivation

- ***Challenge:*** Fine-tuning large foundation models like SAM for medical segmentation is computationally expensive.
- ***Limitation***: LoRA underfits with low ranks; SVD-based methods lack flexibility for domain-specific adaptation.
- ***Impact:*** SALT combines both approaches, adapting top singular values with scale/shift while applying low-rank updates to remaining components. Achieves 2-5% Dice improvement over SOTA PEFT with only 3.9% trainable parameters.

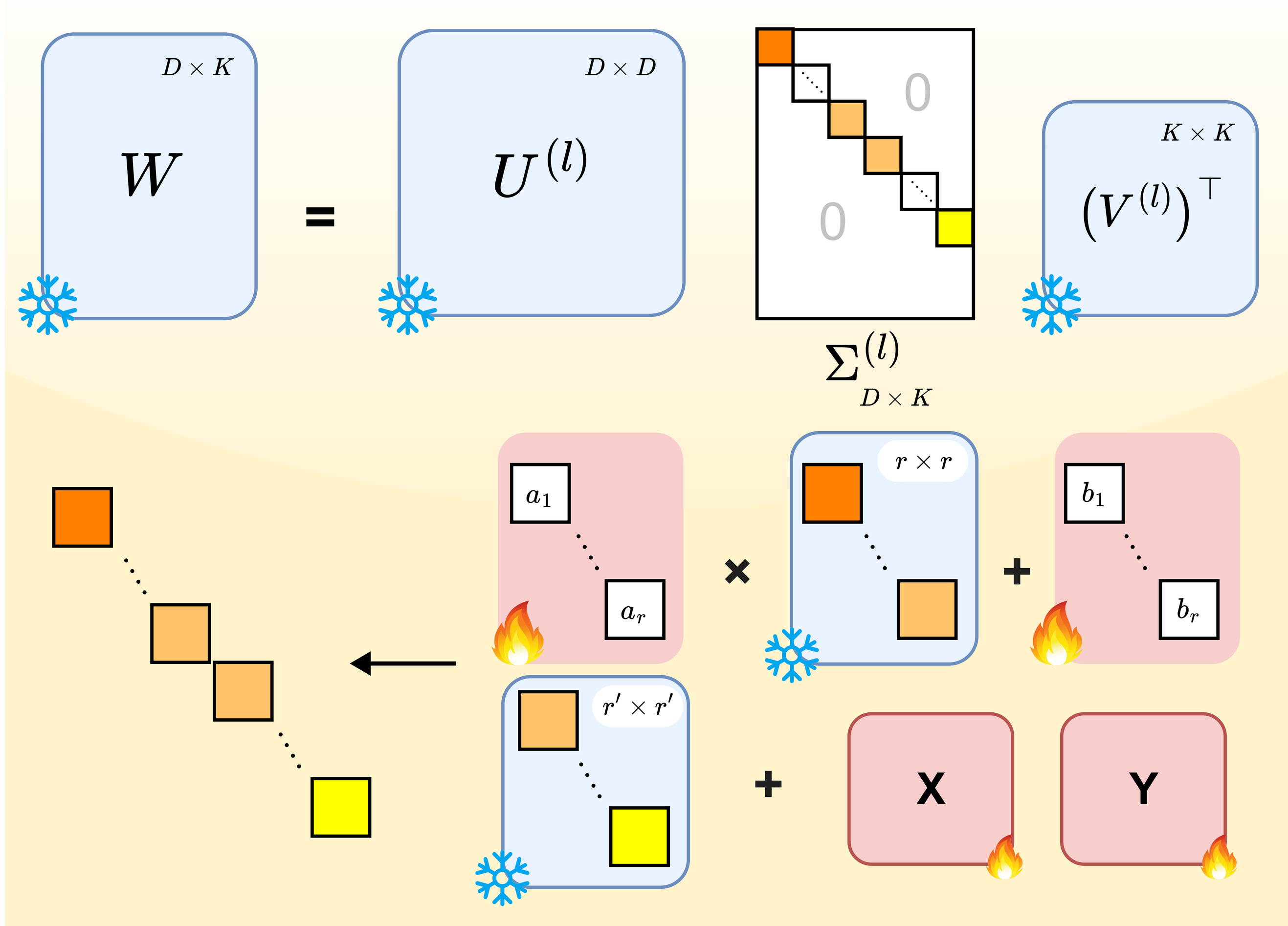


II. Singular Value Adaptation With Low Rank Transformation (SALT)

A. Main Architecture

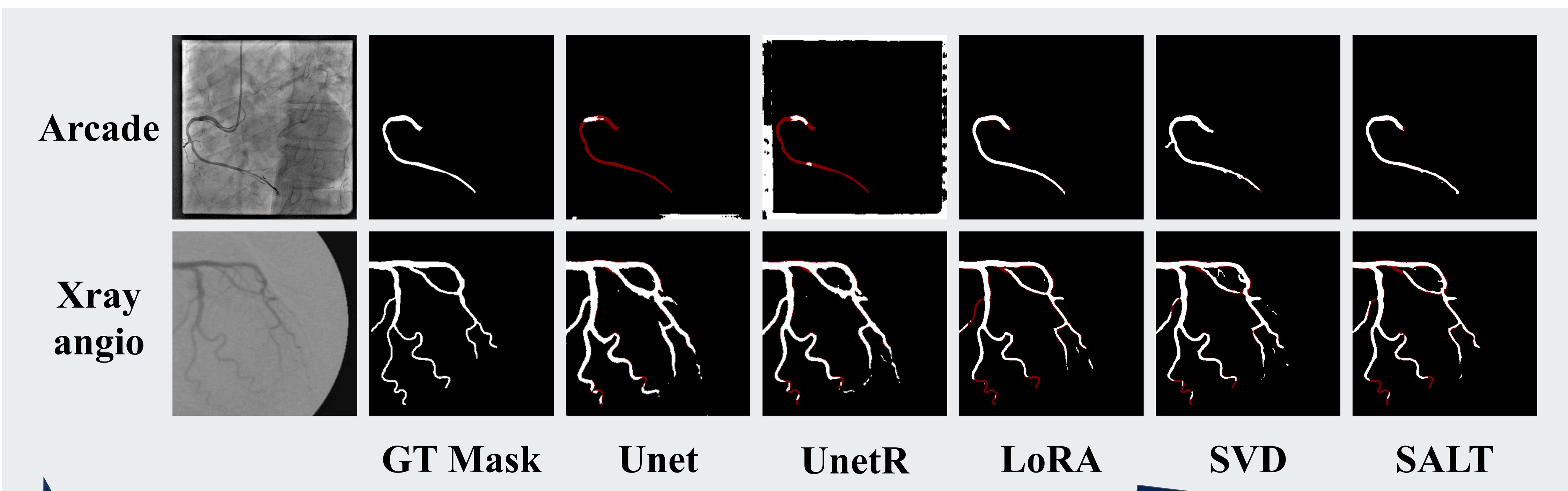


B. Tuning weights of SAM Image Encoder



III. Experiments & Results

Model	Rank	%Trainable	ARCADE Dice ↑	ARCADE HD95 ↓	...	ROSE Dice ↑	ROSE HD95 ↓	Avg. Dice ↑	Avg. HD95 ↓
Traditional DL Methods									
UNETR	–	100%	0.48	162.44	...	0.63	8.96	0.52	81.91
RegUNet	–	100%	0.11	247.79	...	0.22	58.08	0.31	126.08
SegNet	–	100%	0.14	231.11	...	0.38	9.09	0.18	145.05
DeepLabV3+	–	100%	0.55	103.22	...	0.52	12.90	0.56	47.12
Segformer	–	100%	0.53	113.98	...	0.56	11.21	0.58	50.47
SAM-Based PEFT Methods (241M)									
SAM w/ prompts	–	–	0.00	–	...	0.00	–	0.01	–
MedSAM	–	–	0.18	115.18	...	0.32	131.89	0.23	129.83
S-SAM	–	0.40%	0.76	52.44	...	0.65	12.41	0.71	30.12
LoRA	4	0.64%	0.78	39.58	...	0.59	16.26	0.66	26.29
LoRA	256	14.08%	**0.81**	**36.89**	...	0.62	14.62	0.70	25.94
SALT (ours)	4	0.46%	0.78	51.74	...	0.66	12.19	0.72	29.82
SALT (ours)	256	3.9%	**0.81**	42.50	...	**0.67**	12.64	**0.74**	**23.87**



Main Result

Parameter Efficient (3.9%) + Better DSC Score

IV. Ablation Studies

A. SAM2 Results

SAM2-Based Methods (125M)

Model	Rank	Trainable Params	ARCADE Dice	ARCADE HD95	ROSE Dice	ROSE HD95
SVD	–	0.2M	0.784	57.13	0.663	13.54
LoRA	4	0.9M	0.815	49.38	0.676	11.73
LoRA	256	44.6M	**0.824**	**46.08**	**0.679**	12.32
SALT (ours)	4	0.5M	0.804	53.54	0.672	12.43
SALT (ours)	256	19.7M	0.822	47.66	0.677	**11.63**

B. SALT Configurations

- ***LoRA Rank***: Higher ranks (4→256) boost Dice (0.72→0.76) with <6% parameters.
- ***SALT Rank***: Lower component ranks (700→200) improve adaptation via enhanced LoRA updates.
- ***Optimal Config***: Rank 256/200 achieves 0.76 Dice with 5.84% trainable parameters.

V. Conclusion

- ***SALT:*** *Hybrid PEFT combining SVD scaling/shifting with LoRA updates for efficient SAM adaptation to medical imaging.*
- ***Future Work****: Extend to other vision architectures, automate rank selection, and add boundary-aware training for improved edge precision.*