Agent with Warm Start and Active Termination for Plane Localization in 3D Ultrasound

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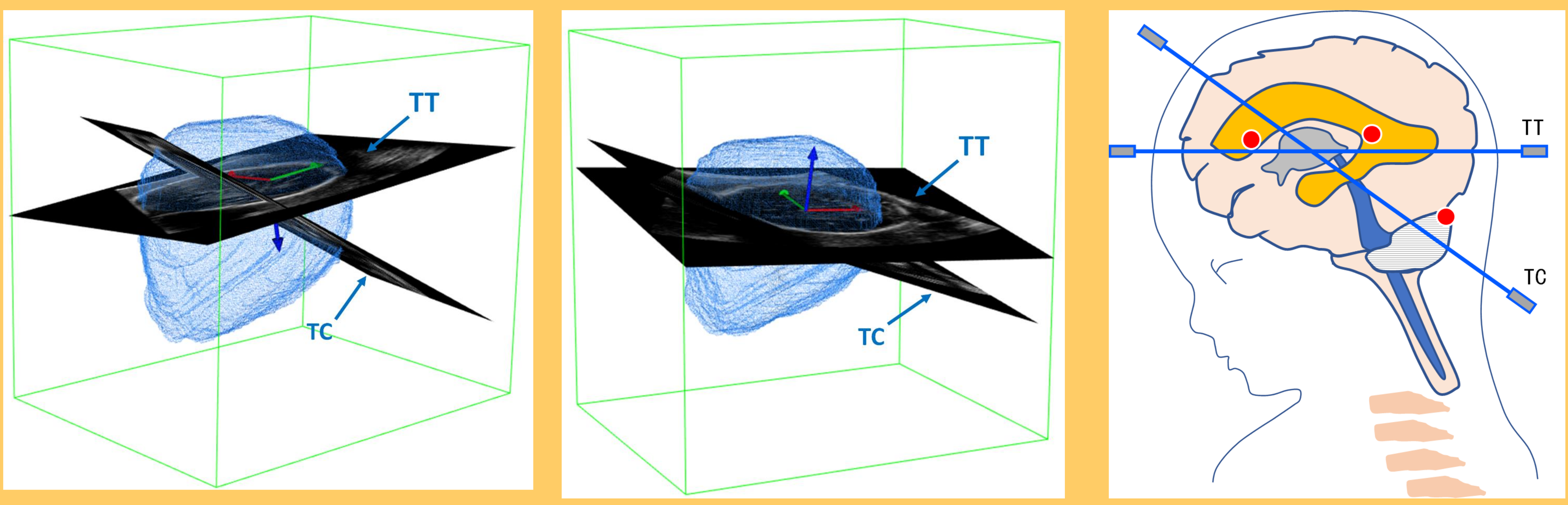
Introduction

Objective:

To develop a deep reinforcement learning based system for automatic localize fetal brain standard planes in 3D Ultrasound

Challenge:

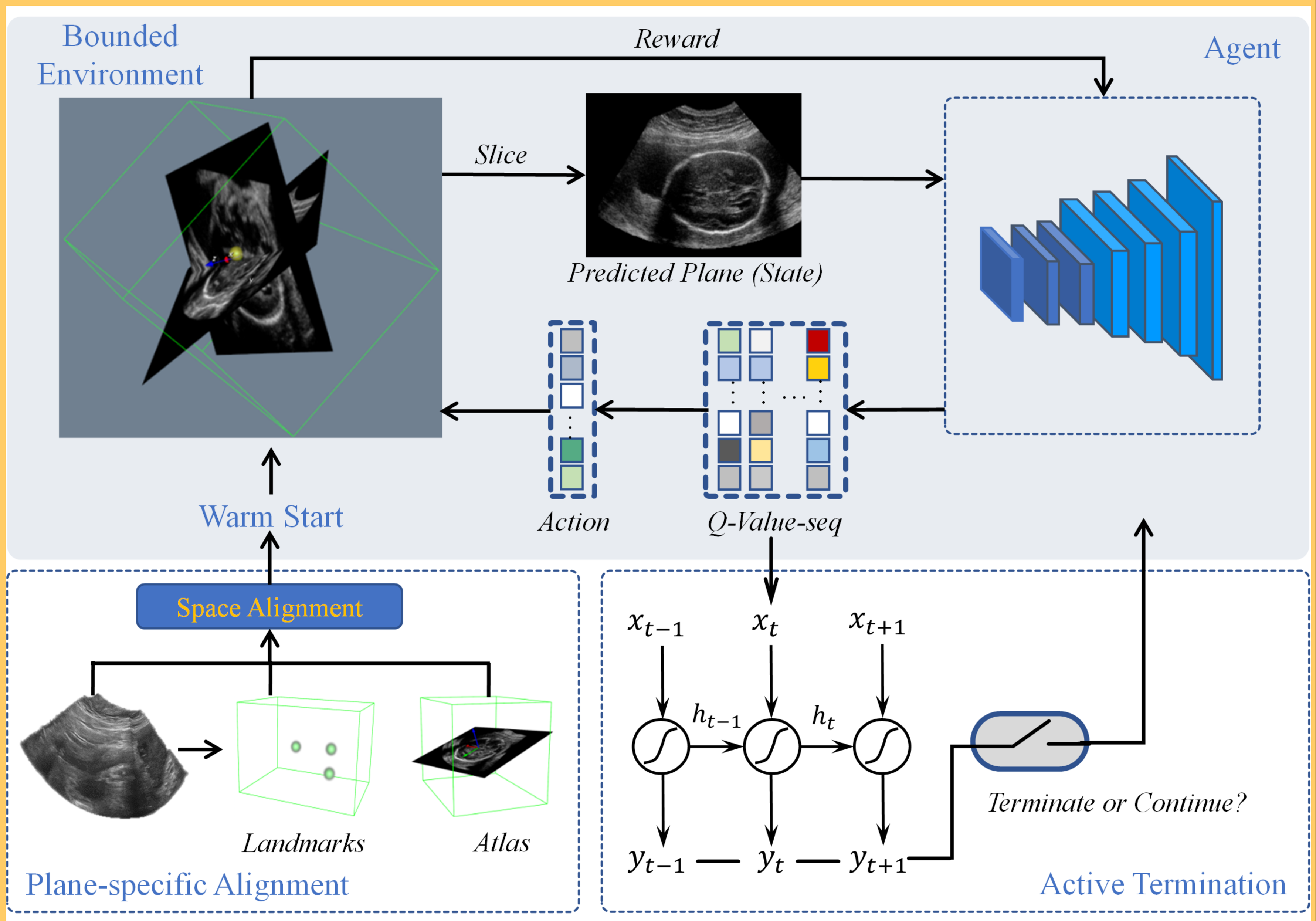
- Huge search space
- Large fetal posture variability
- Low image quality



Contribution:

- we equip the RL framework with a landmark-aware alignment module for warm start to ensure its effectiveness.
- we propose a recurrent neural network based strategy for active termination of the agent's interaction procedure.

Methodology

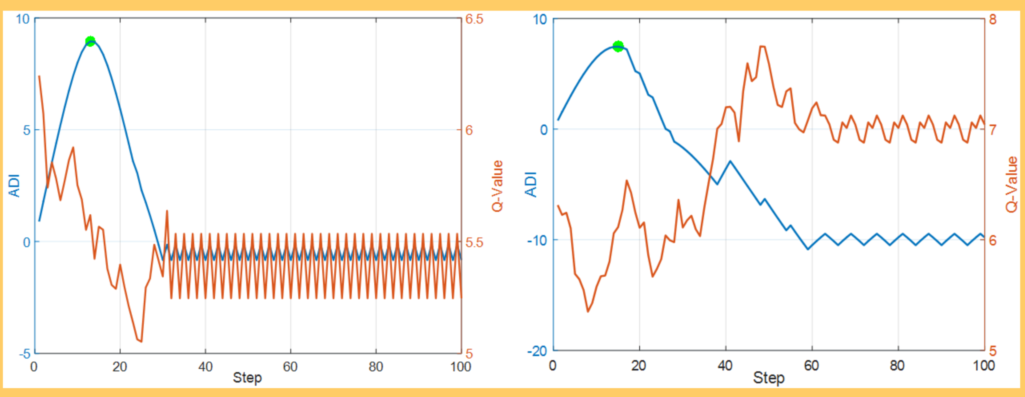


Landmark-aware Plane Alignment for Warm Start:

1. Detecting three landmarks of fetal brain with UNet.
2. Landmarks are used to align the testing volume with the atlas, which contains both the reference landmarks and standard plane parameters.
3. Standard planes of atlas are mapped to testing volumes and serve as a warm start for our agent

Recurrent Neural Network based Active Termination:

A RNN-based active termination (AT) module is proposed to tell the agent when to stop.



Result

Table I. Quantitative evaluation of our proposed framework

Method	Transcerebellar (TC)			Transthalamic (TT)		
	Ang(°) ↓	Dis(mm)↓	SSIM↑	Ang(°) ↓	Dis(mm)↓	SSIM↑
Regress	27.04±8.40	4.10±3.81	0.672±0.087	24.27±17.05	7.62±6.00	0.507±0.100
AtlasRegist	14.14±7.54	3.40±2.28	0.681±0.148	13.43±4.63	2.62±1.54	0.682±0.138
RegistRegress	12.44±7.78	2.18±2.12	0.684±0.157	13.87±11.77	2.80±2.16	0.660±0.141
DDQN-nA	31.54±24.24	5.12±3.67	0.685±0.131	30.44±24.43	5.03±3.82	0.615±0.132
DDQN-maxS	11.71±14.32	3.53±2.55	0.684±0.165	12.36±8.53	2.95±2.94	0.694±0.154
DDQN-minQ	10.68±9.76	3.40±2.27	0.688±0.165	10.78±7.62	2.62±1.54	0.705±0.163
DDQN-AT(FC)	10.36±9.60	3.40±2.28	0.689±0.165	9.61±5.79	2.66±1.55	0.707±0.161
DDQN-AT(RNN)	9.96±10.19	3.41±2.27	0.691±0.167	9.53±5.74	2.64±1.62	0.709±0.164
DDQN-AT(LSTM)	9.61±8.97	3.40±2.77	0.693±0.168	9.11±5.56	2.66±2.06	0.709±0.163

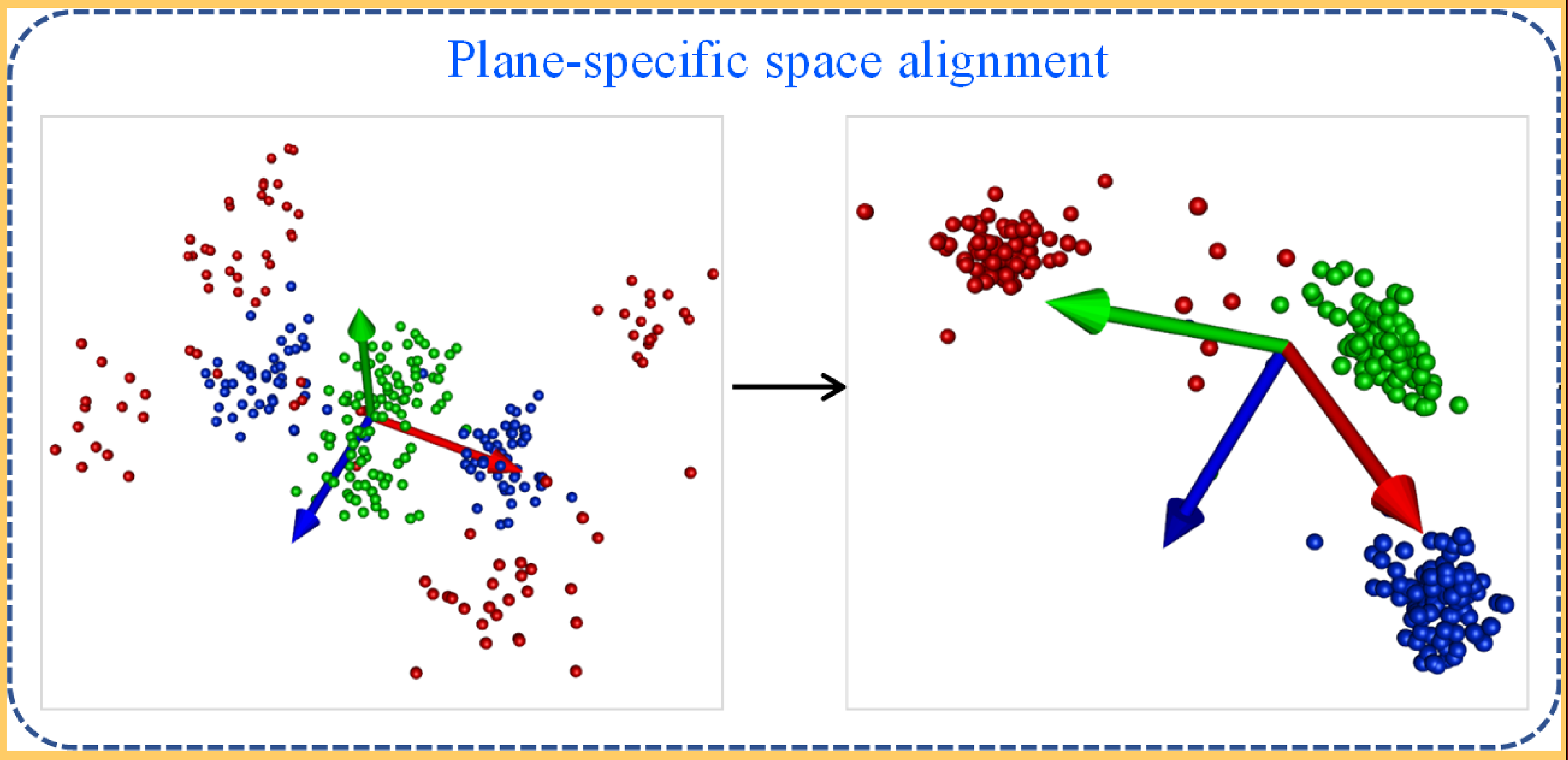


Fig. 1 Comparison of landmark location between Pre- and Post Alignment

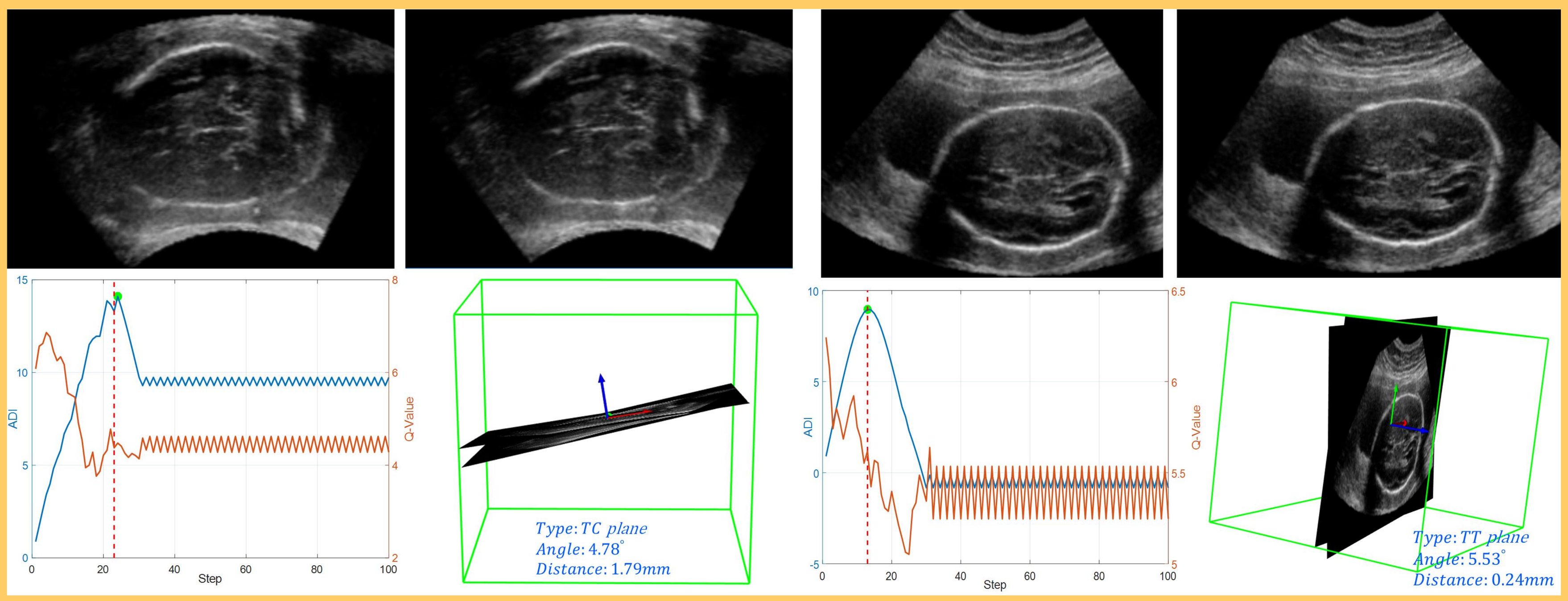


Fig. 2 TC (left) and TT (right) results. *Top row:* ground truth (left) and predicted (right) plane. *Bottom row:* left, active termination step (dotted red line) compared to optimal step in green dot, 3D visualization of ground truth and predicted plane (right).

Conclusion

We proposed a general framework for standard plane localization in 3D US with a RL agent. We use a landmark aware alignment model to exploit prior information about the standard planes from the atlas and provide the agent with an effective warm starting point. In addition, we devise a RNN-based active termination strategy to indicate the agent to stop once the optimal plane is localized, therefore improving its accuracy and efficiency. Experiments on our in-house large dataset validate the efficacy of our method and reveal its great potential for future practical applications.

Haoran Dou and XinYang contribute equally.