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An End-to-End UAV Obstacle Avoidance Approach Fusing Wavelet Convolution and KAN Networks

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Abstract

This work proposes an end-to-end UAV navigation framework based on deep reinforcement learning, which integrates Kolmogorov-Arnold Networks and wavelet convolution. The proposed method achieves efficient low-altitude obstacle avoidance and faster convergence than traditional CNN and ResNet18 baselines.

Methods

We propose an end-to-end UAV obstacle avoidance framework that integrates wavelet convolutional networks with Kolmogorov-Arnold Networks (KAN) within a Soft Actor-Critic (SAC) reinforcement learning architecture (Fig. 1). Our method formulates navigation as a Markov Decision Process (MDP), incorporating depth images and motion states. Specifically, it employs Haar wavelet transforms to extract multi-frequency features from noisy depth maps, and leverages KAN's function approximation for policy and Q-value estimation.

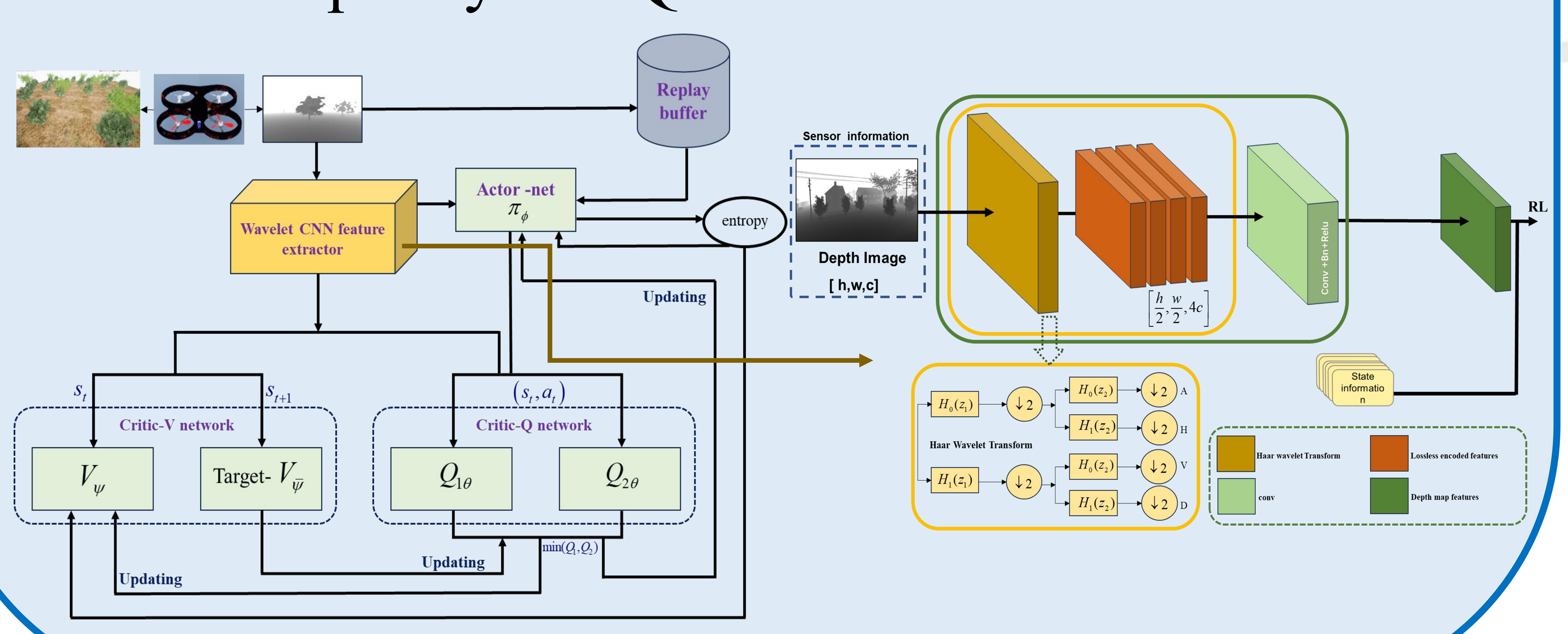

Fig.1. Algorithmic Infrastructure

Conclusion

Our proposed navigation solution achieves >95% success rates while maintaining computational efficiency, leveraging Haar wavelet's noise-resistant processing and KAN's high-efficiency high-dimensional approximation capability. Currently extending to sim2real deployment, with promising physical-world validation.

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Experimental Results

In the 3D forest environment simulated by AirSim (with hardware/software configurations detailed in Table 1), the proposed wavelet-KAN-SAC framework exhibits exceptional performance. As demonstrated in Figures 1–4, it achieves an obstacle avoidance success rate exceeding 95%, significantly surpassing traditional baseline models. The framework enhances training convergence speed by 50% while maintaining path planning duration at approximately 200 steps. Notably, as shown in Table 2, our approach requires a substantially smaller parameter scale compared to conventional networks.

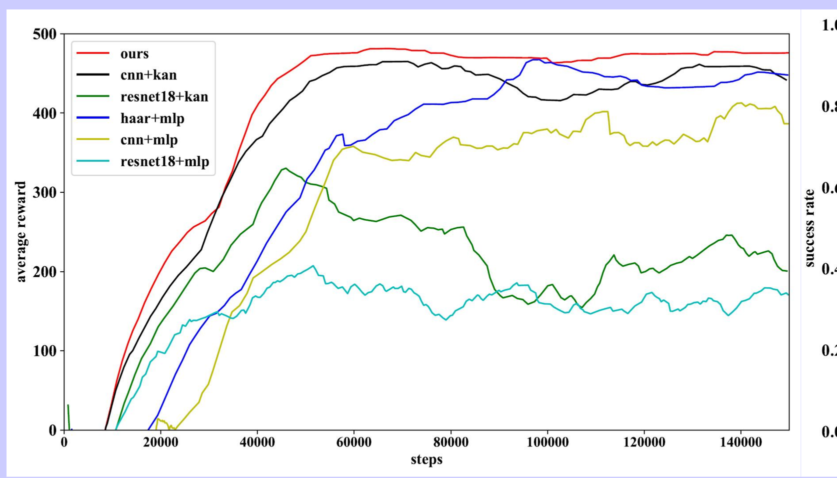

Fig.1.Average rewards vs. training steps for different algorithms.

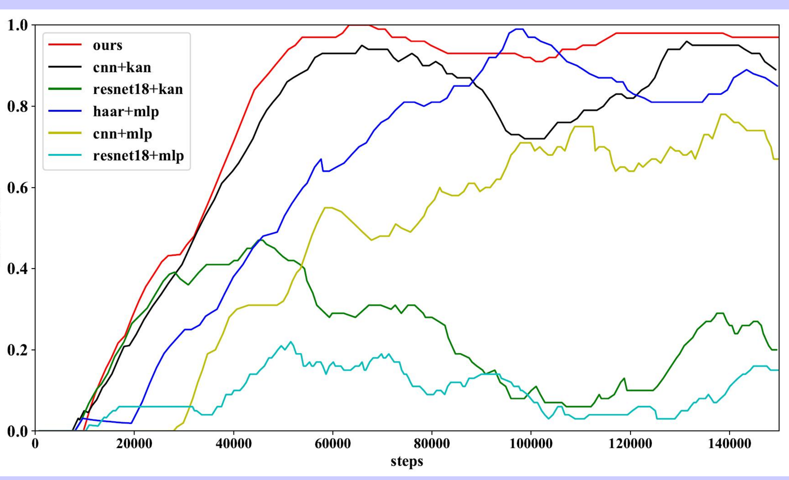

Fig.2. Task success rates vs. training steps.

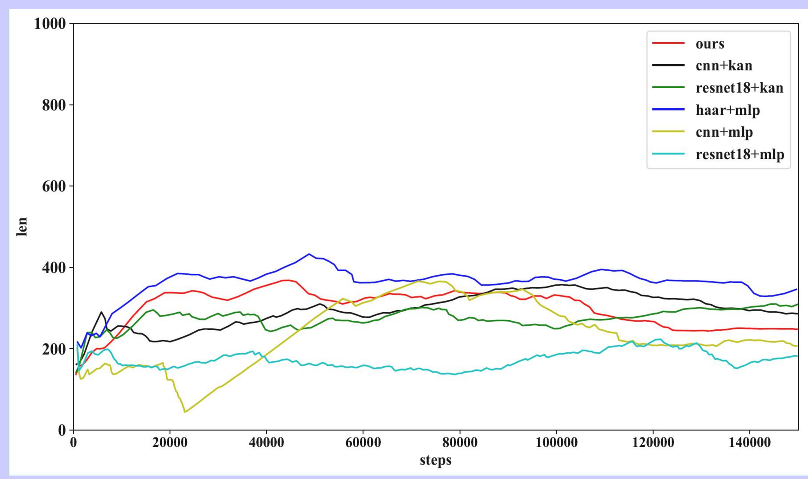

Fig.3. The loss value of the online critic-Q network vs. training steps for different algorithms.

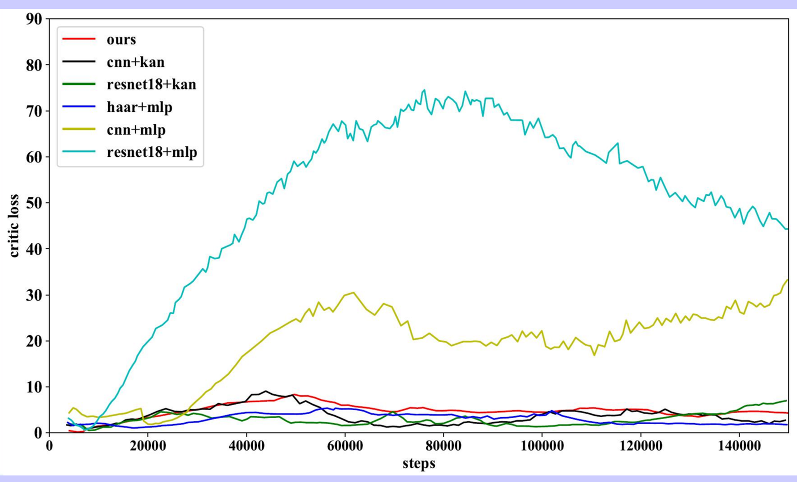

Fig.4.The average path length of different algorithms.

Table 1 Hyperparameter settings for algorithm training.

Hyperparameters	Value
Layer number of CNN	3
Layer parameters of KAN	[32 (in), 17, 16 (out)]
Batch size	1280
Replay buffer size	50000
Learning rate	1e-3
Random exploration steps	3000
Training frequency	500
Mean of action noise	0.1

Table 2 Model component scales

Model Component	Parameter Size (K)
CNN	5.88
Haar-CNN	8.55
ResNet18	11721.54
KAN	2.25
MLP	4.72