

Dynamics-Aligned Latent Imagination in Contextual World Models for Zero-Shot Generalization



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tl;dr We show that dynamics-aligned representations improve zero-shot generalization for contextual world models.



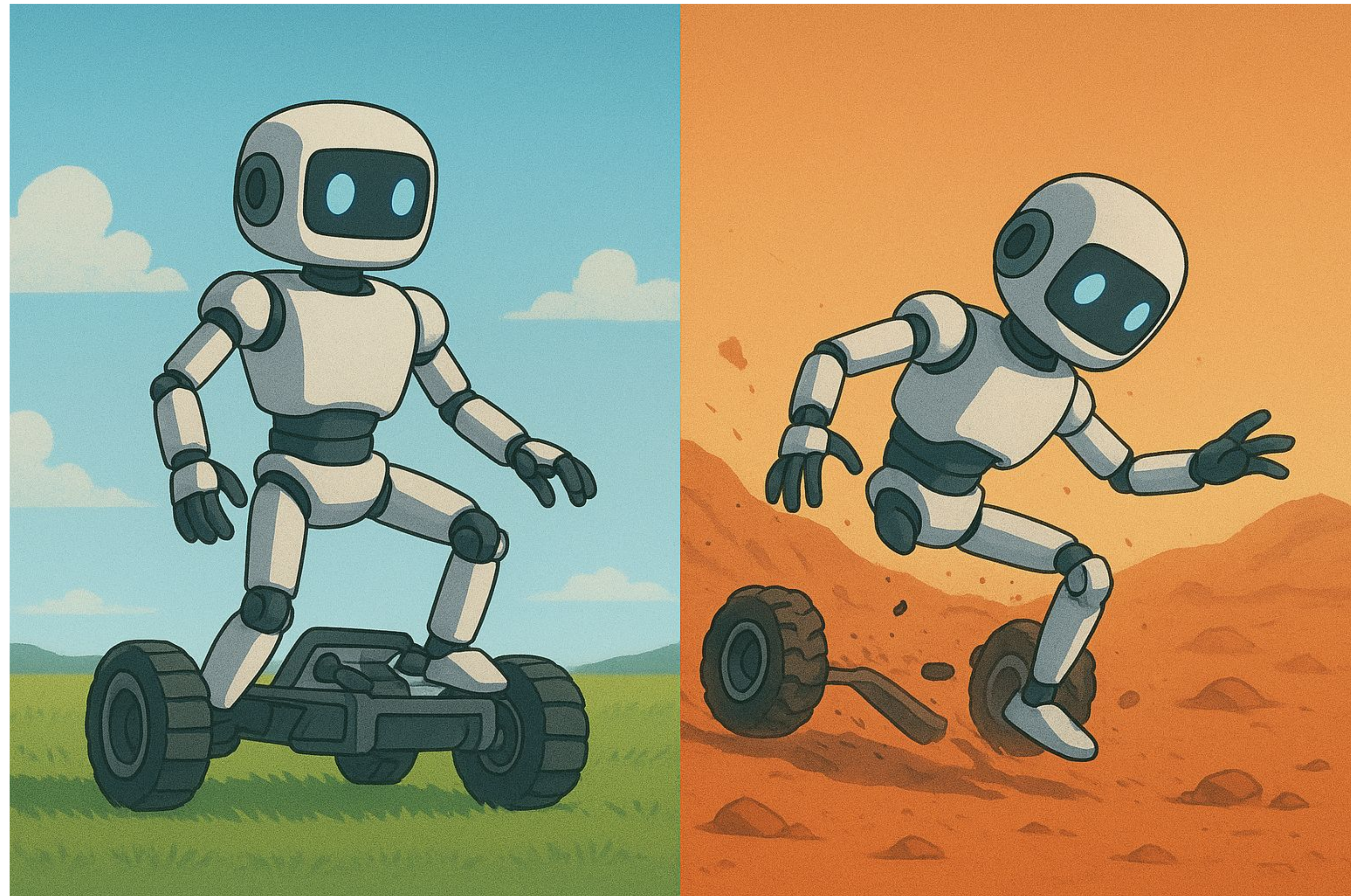
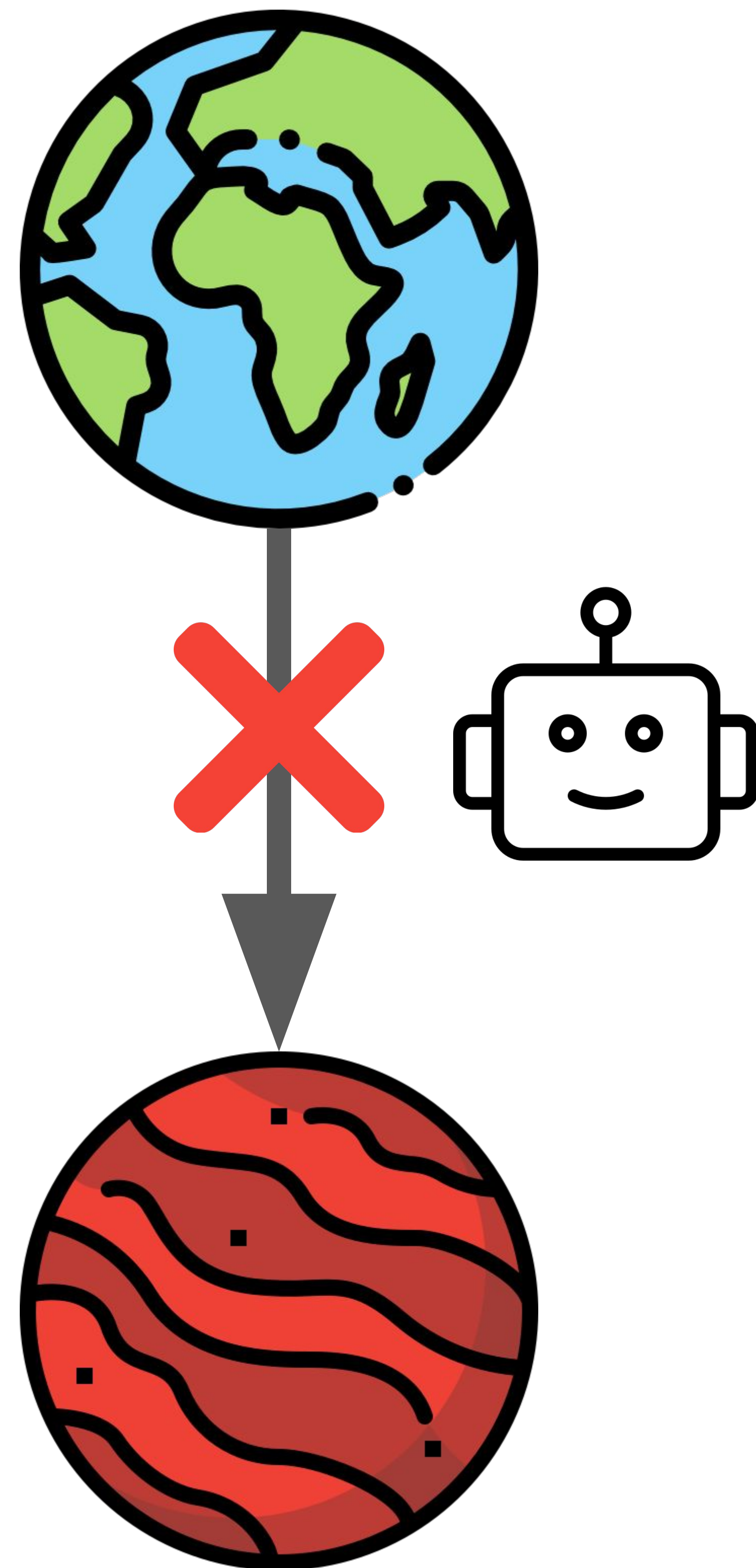
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Motivation

Challenge: Adapt to environmental changes



[Kirk et al. 2023]

DreamerV3

- SOTA model-based approach
- Struggles with context changes

RSSM

Bottleneck

Sequence model: $h_t = f_\theta(h_{t-1}, z_{t-1}, a_{t-1})$

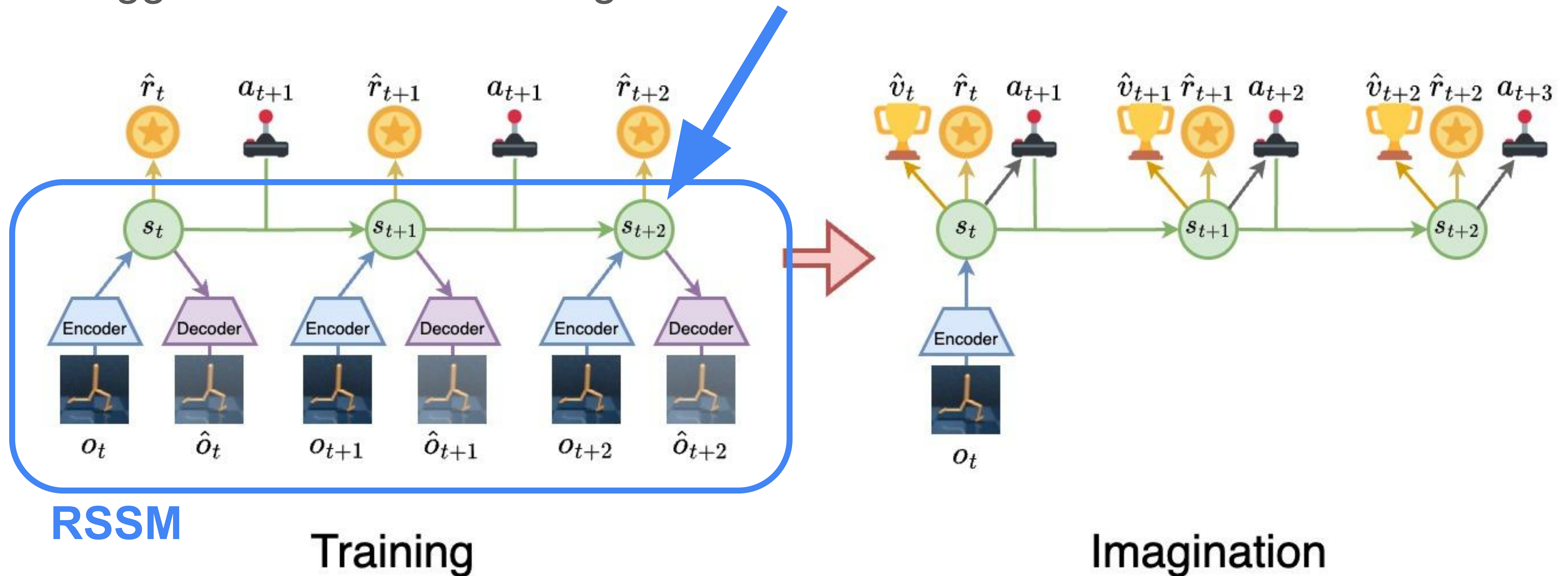
Encoder: $z_t \sim q_\theta(z_t | h_t, o_t)$

Dynamics predictor: $\hat{z}_t \sim p_\theta(\hat{z}_t | h_t)$

Reward predictor: $\hat{r}_t \sim p_\theta(\hat{r}_t | h_t, z_t)$

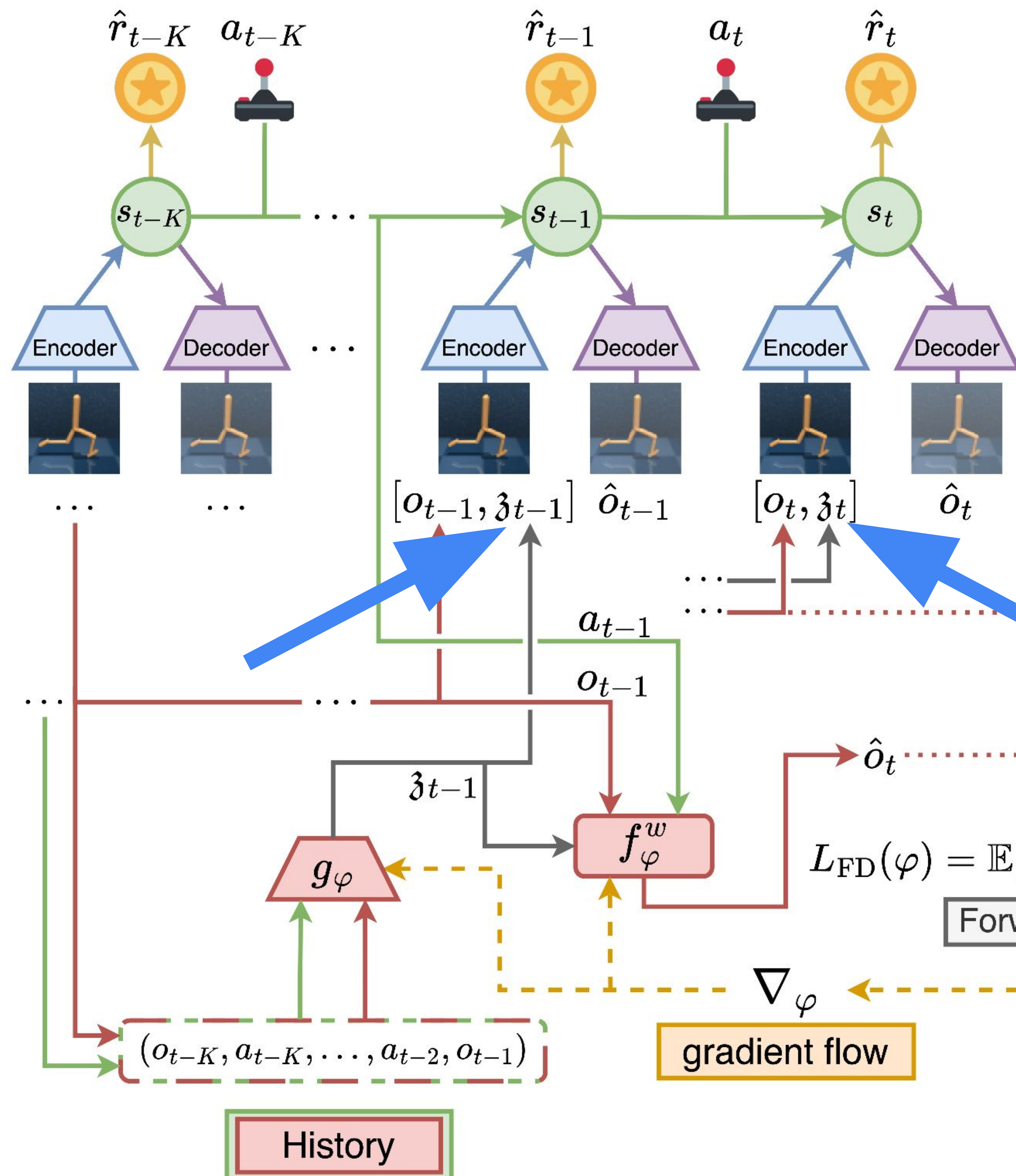
Continue predictor: $\hat{n}_t \sim p_\theta(\hat{n}_t | h_t, z_t)$

Decoder: $\hat{o}_t \sim p_\theta(\hat{o}_t | h_t, z_t)$.



[Hafner et al. 2019, 2020, 2021, 2025]

DALI - Dynamics-Aligned Latent Imagination



Context encoder: $\mathfrak{z}_t = g_\varphi(o_{t-K:t}, a_{t-K:t-1})$.

Sequence model: $h_t = f_\theta(h_{t-1}, z_{t-1}, a_{t-1})$,

Encoder: $z_t \sim q_\theta(z_t | h_t, o_t, \mathfrak{z}_t)$,

Dynamics predictor: $\hat{z}_t \sim p_\theta(\hat{z}_t | h_t)$,

Reward predictor: $\hat{r}_t \sim p_\theta(\hat{r}_t | h_t, z_t)$,

Continue predictor: $\hat{n}_t \sim p_\theta(\hat{n}_t | h_t, z_t)$,

Decoder: $\hat{o}_t \sim p_\theta(\hat{o}_t | h_t, z_t)$.

$$L_{FD}(\varphi) = \mathbb{E} \|f_\varphi^w(o_{t-1}, a_{t-1}, \mathfrak{z}_{t-1}) - o_t\|_2^2$$

Forward Dynamics Loss

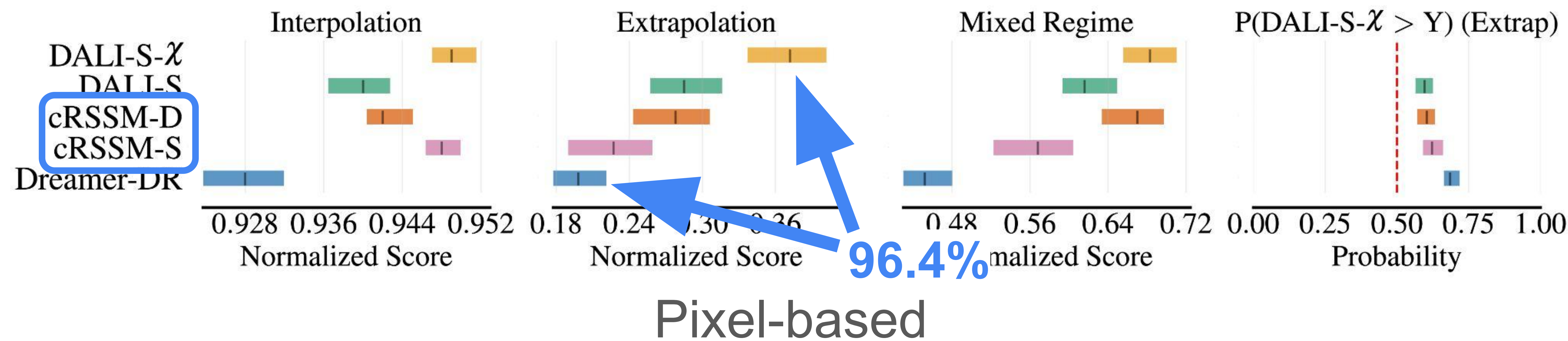
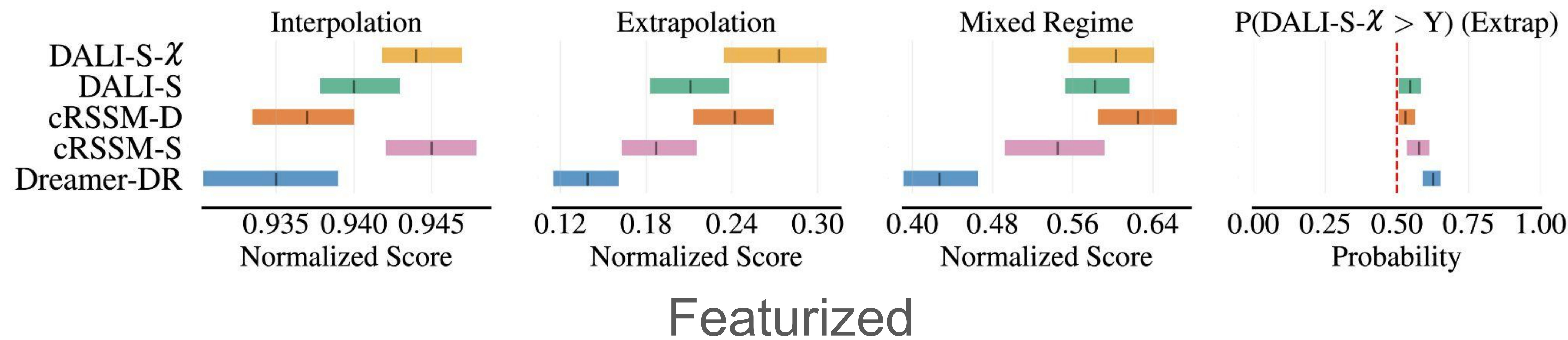
∇_φ

gradient flow

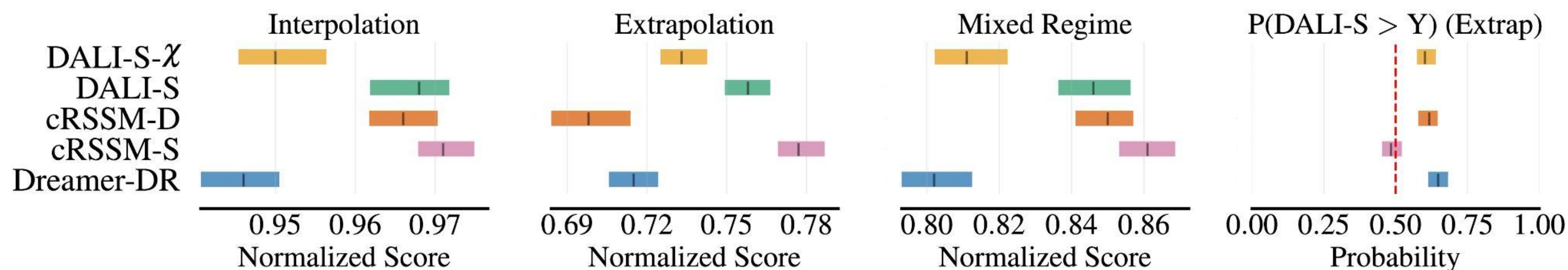
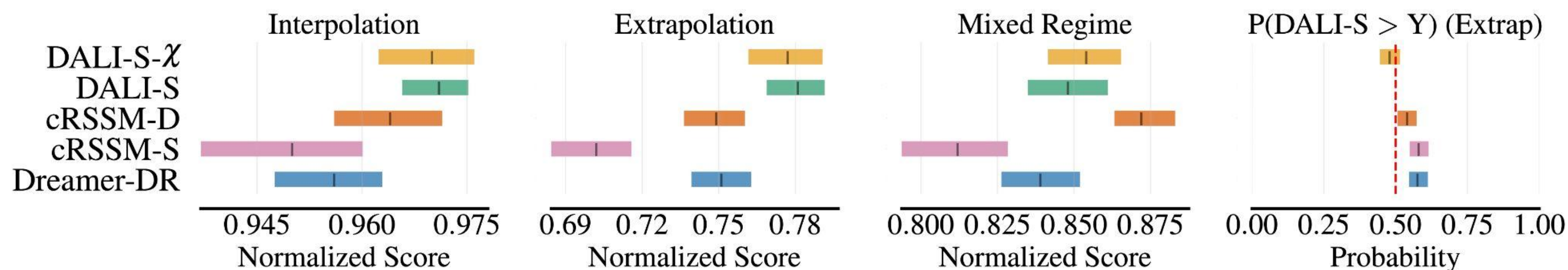
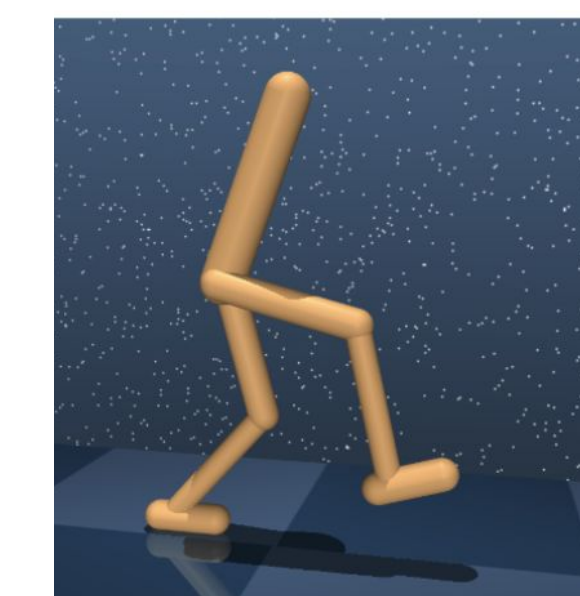
- Transformer-based
- +4% #parameters

Dynamics Alignment

IQM Performance - DMC Ball-in-Cup



IQM Performance - DMC Walker Walk



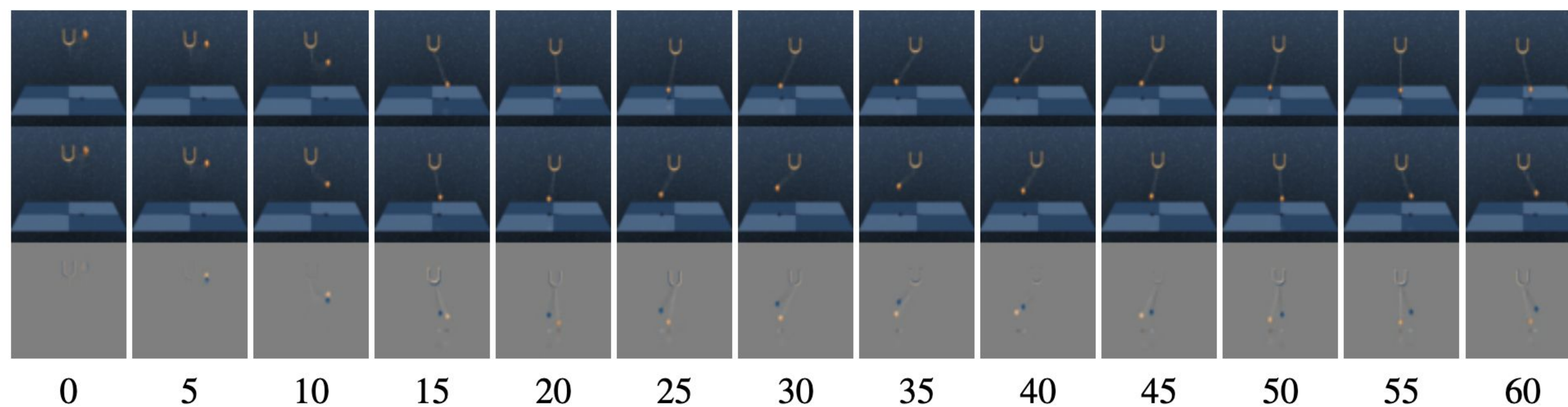
[Tassa et al. 2020, Agarwal et al., 2021, Prasanna et al. 2024]

Counterfactual Imagination - Ball in Cup

$\hat{O}_t$

$\odot$

Δ

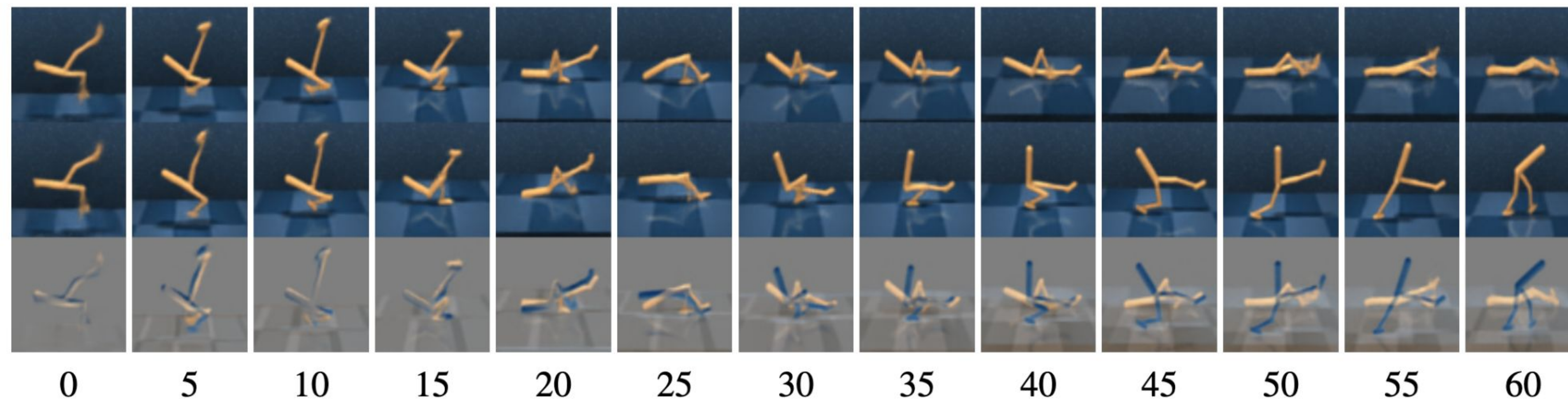


Counterfactual Imagination - Walker Walk

$\hat{O}_t$

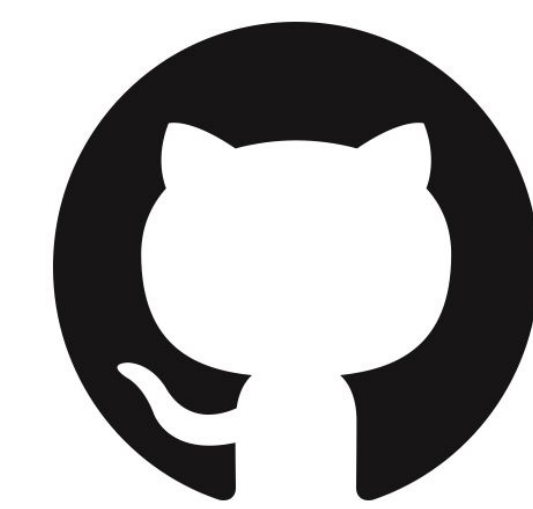
$\odot$

Δ

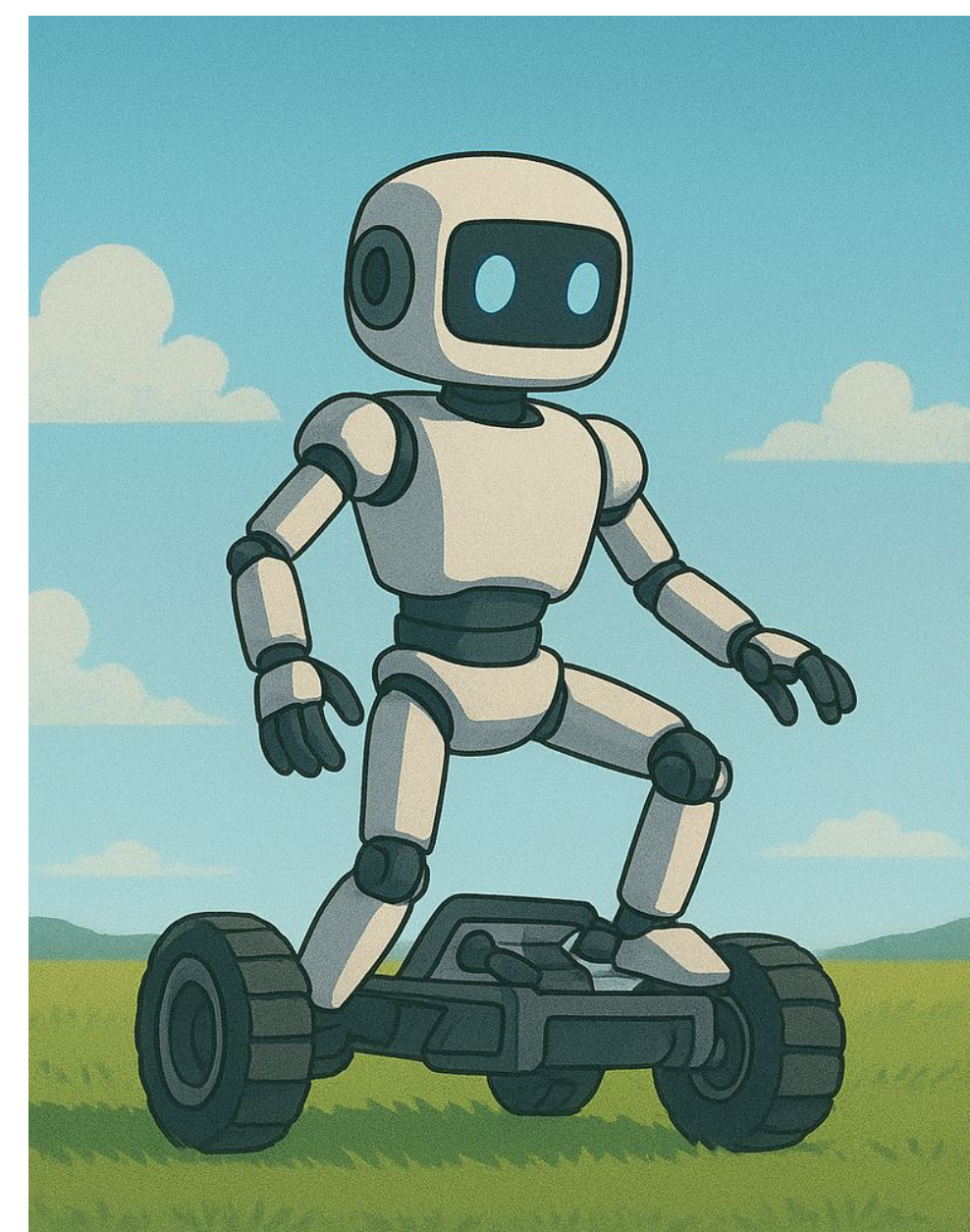


Summary

**Dynamics-Aligned
Latent Imagination aids
Zero-Shot
Generalization!**



Code



DALI

