Test-Time Motion Steering for Perceptive Humanoid Fall Recovery

RISE · *Perceptive Recovery via Intent Steering*

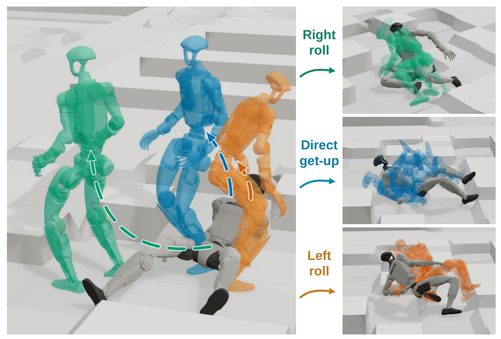
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Project page

Motivation

The same fallen pose admits ***different ways to stand.***



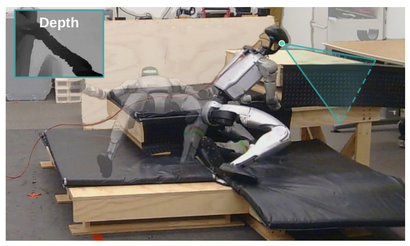
The scene and task should guide the recovery.

Highlights

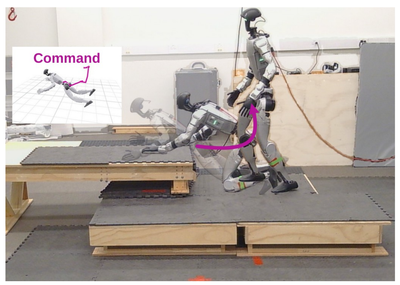
Multimodal recovery repertoire



Perception and state-first planning



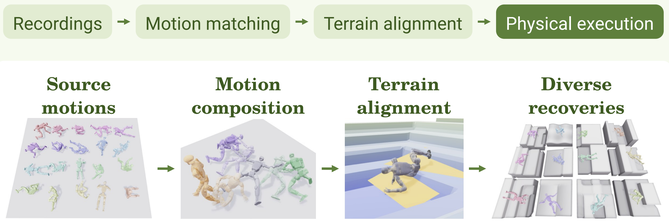
Steer recovery without retraining

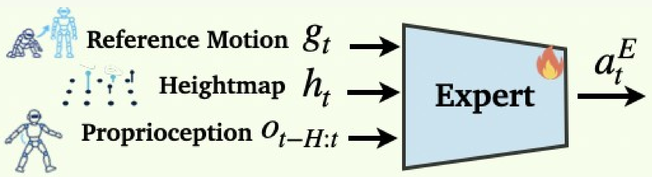


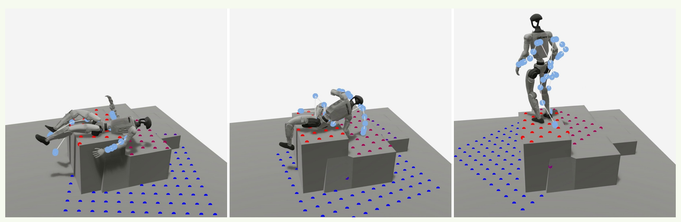
Method

1. Recovery repertoire

Recordings → Motion matching → Terrain alignment → Physical execution

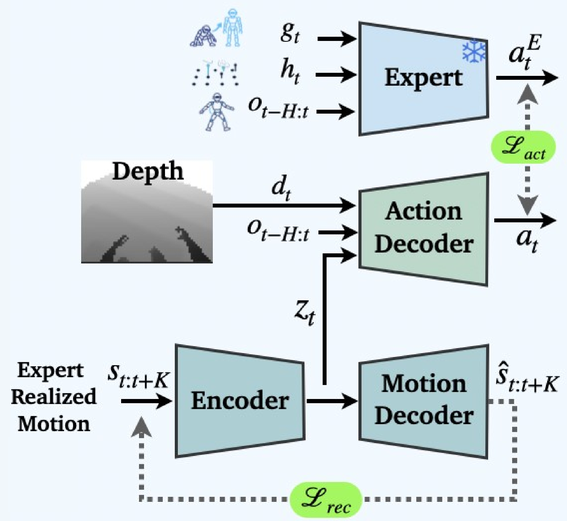






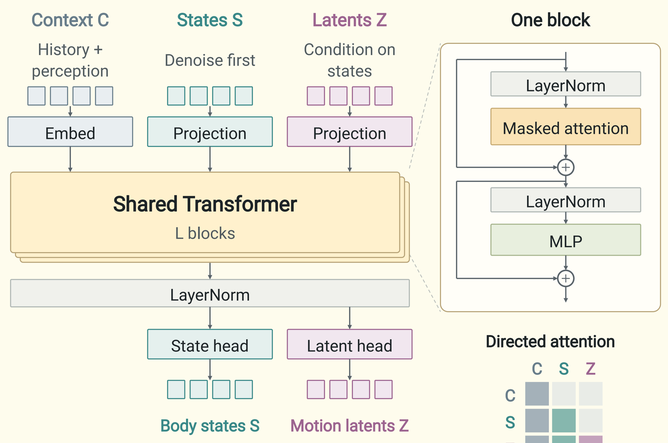
2. Recovery vocabulary

Motion → Latent → Feedback decoder → Motor actions



3. Visual state-first diffusion

Realized states + latents → Predict states → Generate latents



Shared weights for both steps

$$p(\mathbf{S}, \mathbf{Z} \mid c) = \underbrace{p(\mathbf{S} \mid c)}_{\text{predict states}} \underbrace{p(\mathbf{Z} \mid \mathbf{S}, c)}_{\text{generate latents}}$$

4. Test-time steering

Predicted motion → Task cost → Guided diffusion → Requested recovery

Heading

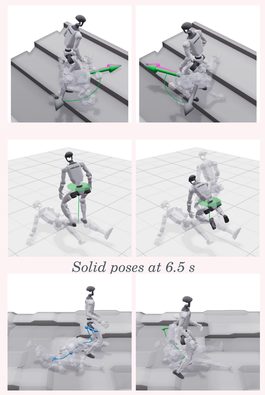
$$J_{\text{heading}} = \text{wrap}(\alpha_F - \alpha^\star)^2$$

Rise speed

$$J_{\text{speed}} = \frac{1}{F}\sum_{j=1}^{F}(h_j - h_j^\star)^2$$

Path + posture

$$J_{\text{path}} = \frac{1}{F}\sum_{j=1}^{F}\left[\|\mathbf{p}_j - \mathbf{p}_j^\star\|_2^2 + \lambda_R\|\mathbf{R}_j - \mathbf{R}_j^\star\|_F^2\right]$$



Solid poses at 6.5 s

Guidance during state diffusion

$$\mathbf{x}_{k-1} = \underbrace{\text{DDIM}_k(\mathbf{x}_k, \mathbf{S}(\mathbf{x}_k))}_{\text{recovery prior}} - \underbrace{\eta_k \nabla_{\mathbf{x}_k} J(\mathbf{S}(\mathbf{x}_k))}_{\text{task guidance}}$$

Cost on denoised states → gradient through the denoiser → steer noisy states

Results

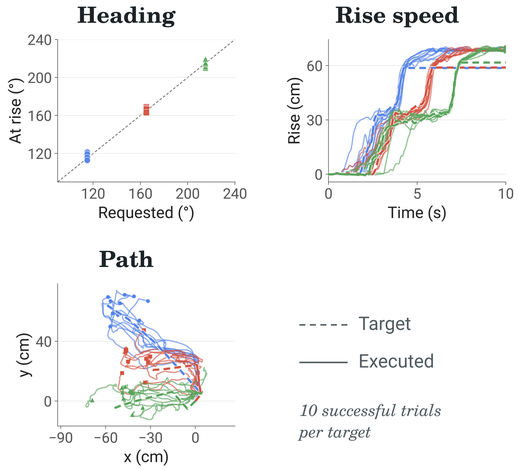
Reliable unguided recovery

920 trials per method · simulation

Method	Success ↑ (%)	Force ↓ (kN)
FIRM	8.2	6.5
VIGOR	80.8	2.5
RISE (ours)	93.0	1.4

Force: mean peak contact force

Steering without retraining



Real-world recovery across scenes

