From Tabula Rasa to Emergent Abilities:
Discovering Robot Skills via Real-World Unsupervised Quality-Diversity

Adaptive & Intelligent Robotics Lab

IMPERIAL

CORL

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We introduce Unsupervised Reset-free Skill Acquisition (**URSA**), a Quality-Diversity framework that discovers a **diverse repertoire** covering the **reachable skill space** in real-world environments, **without any simulation**.

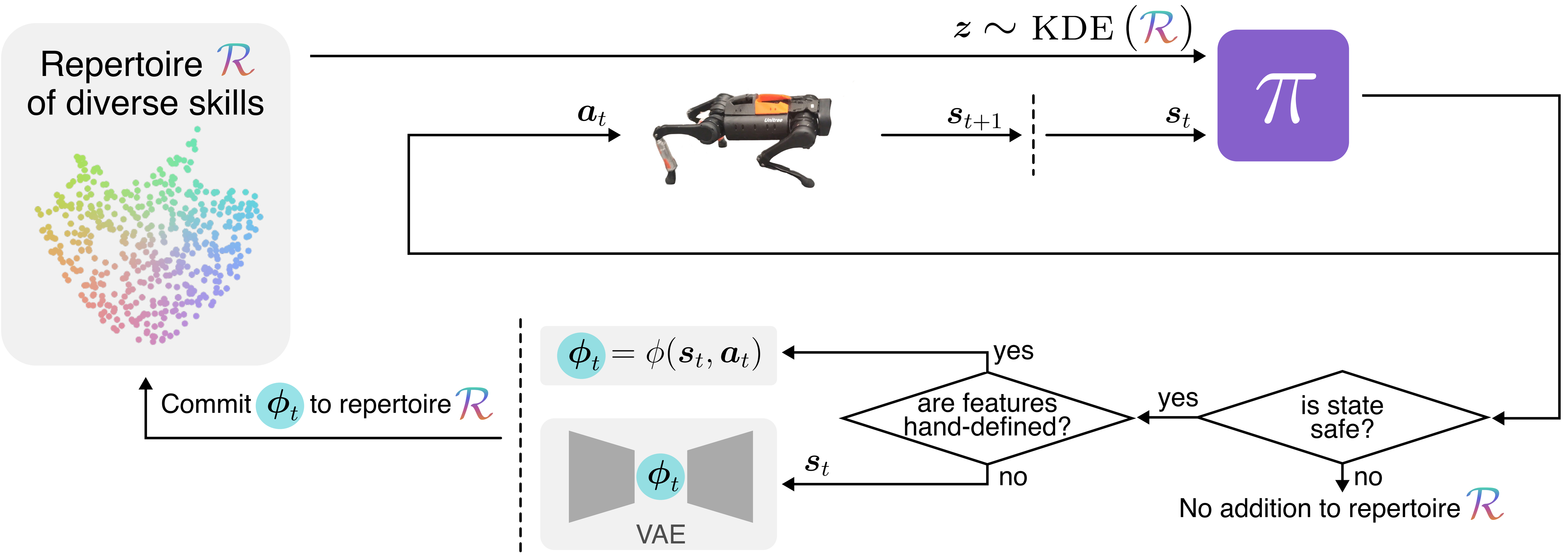
maximize $V(\boldsymbol{s}, \boldsymbol{z})$ — *Performance*

subject to $\|(1-\gamma)\boldsymbol{\psi}(\boldsymbol{s}, \boldsymbol{z}) - \boldsymbol{z}\|_2 \leq \delta$ — *Skill reachability*

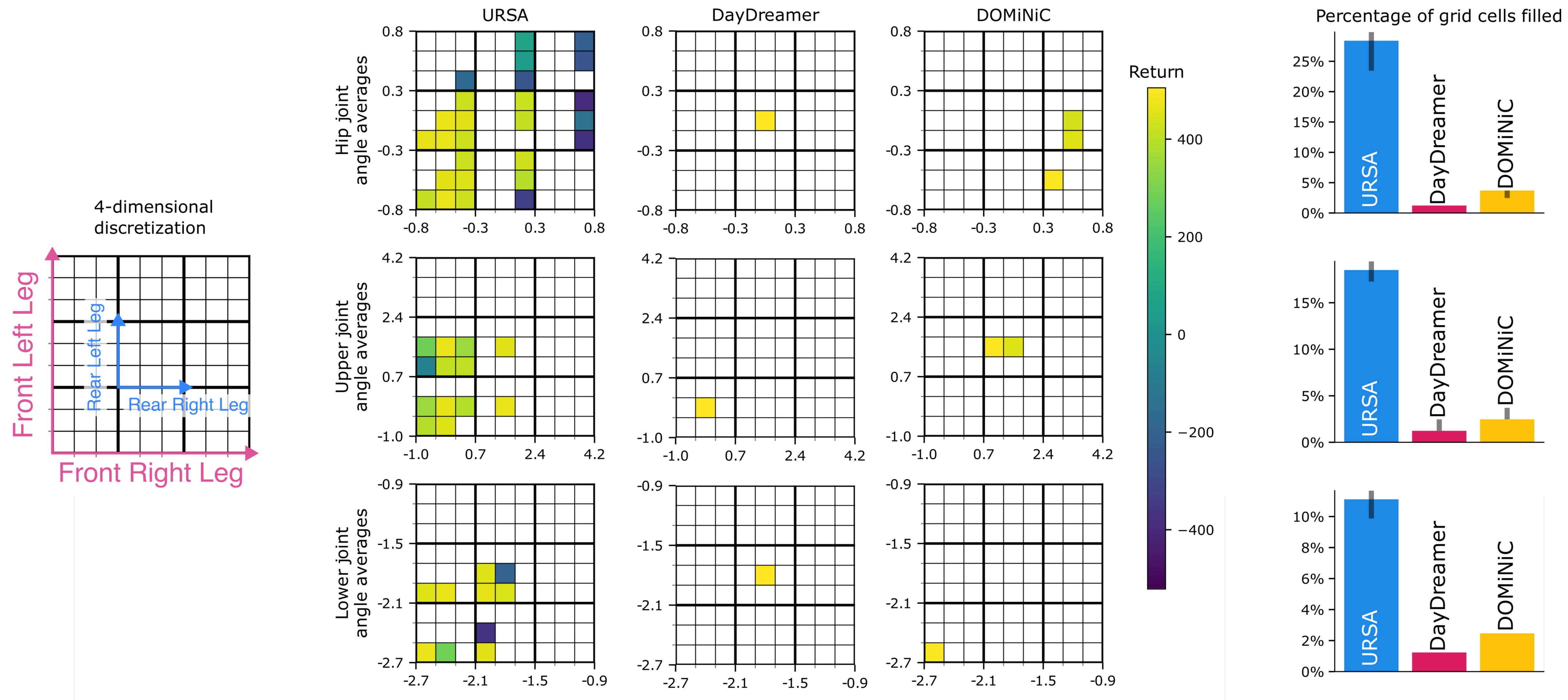
and $C(\boldsymbol{s}, \boldsymbol{z}) \leq 0$ — *Safety constraints*

$$V(s, \mathbf{z}) = \mathbb{E}_{\pi(\cdot|\mathbf{z})}\left[\sum_{i=0}^{\infty} \gamma^i r_{t+i} \middle| s_t = s\right]$$

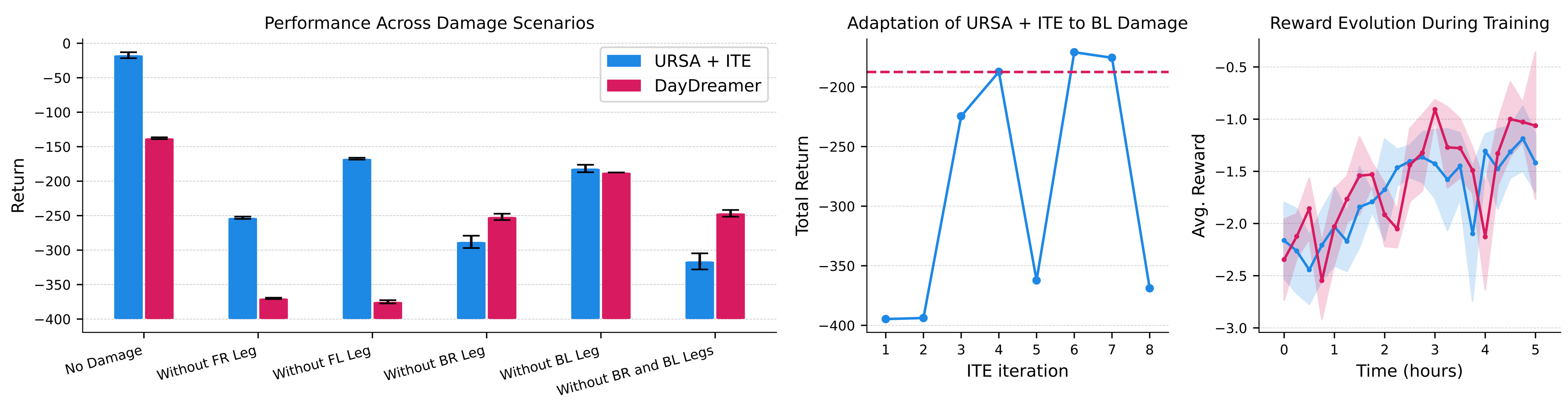
$$\boldsymbol{\psi}(s, \mathbf{z}) = \mathbb{E}_{\pi(\cdot|\mathbf{z})}\left[\sum_{i=0}^{\infty} \gamma^i \boldsymbol{\phi}_{t+i} \middle| s_t = s\right]$$



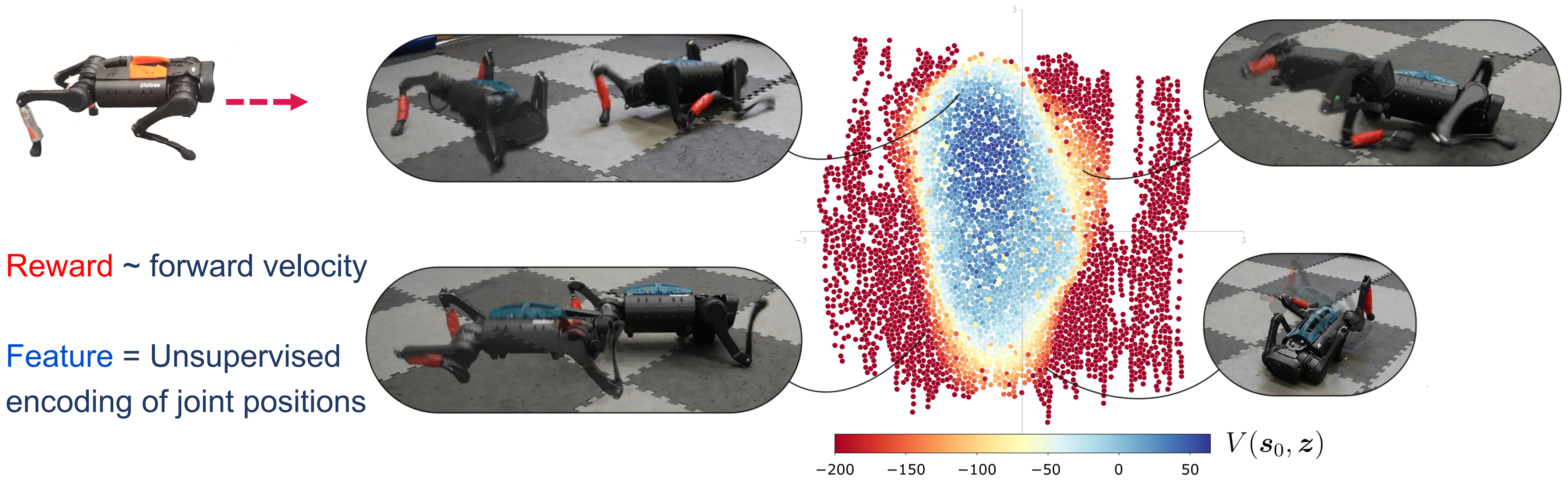
In simulation, URSA discovers **significantly more diverse locomotion patterns** than baselines, achieving greater average joint angle coverage.



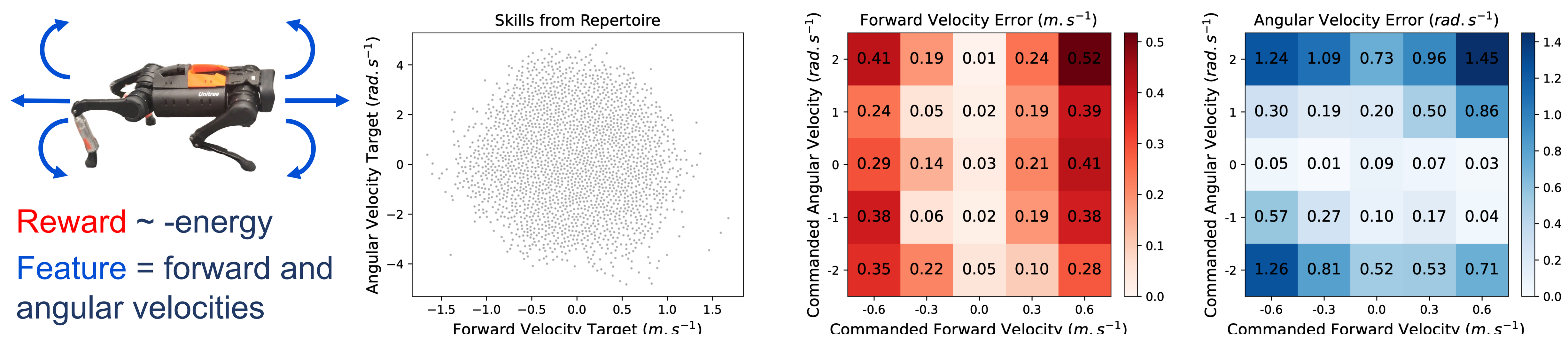
This diversity of skills enables **greater adaptation** under joint failures.



URSA discovers a **wide range of forward motions**, covering diverse average joint angles across all legs.



URSA can also learn to control the robot across a **broad range of target forward and angular velocities**.



References:

- **DayDreamer**: Wu, Philipp, et al. "Daydreamer: World models for physical robot learning."
- **DOMiNiC**: Cheng, Jin, et al. "Learning diverse skills for local navigation under multi-constraint optimality."
- **ITE**: Cully, Antoine, et al. "Robots that can adapt like animals."