Prosthetic Control by Learning: A Multi-Agent Cooperative Game Framework

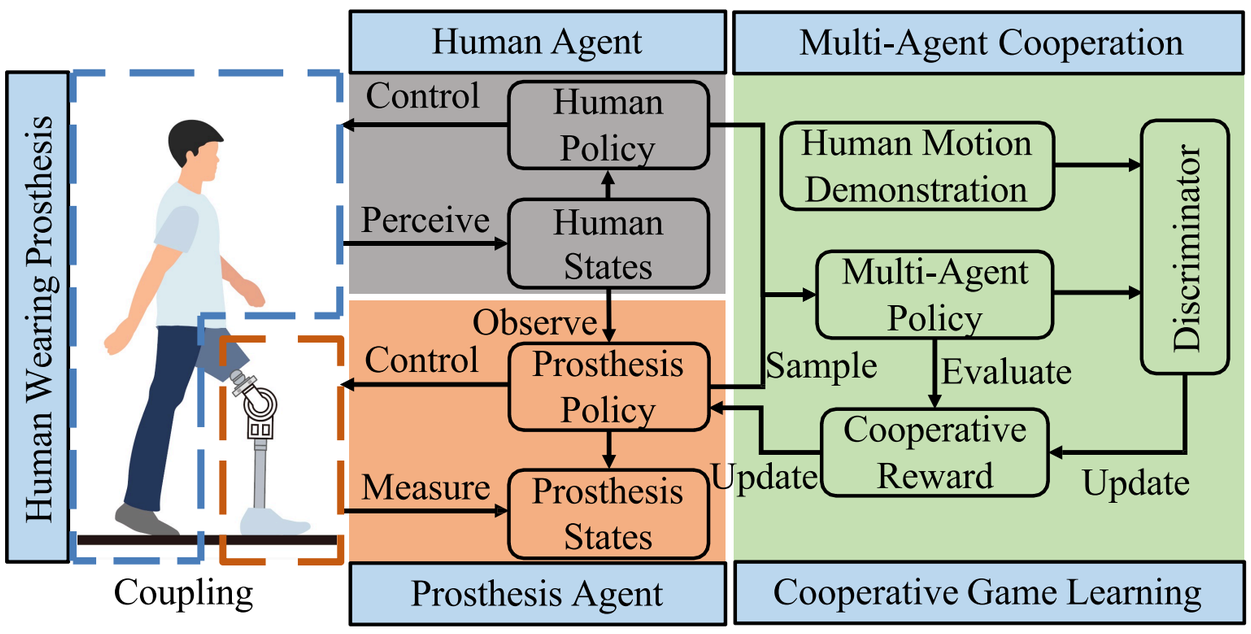
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Takeaways

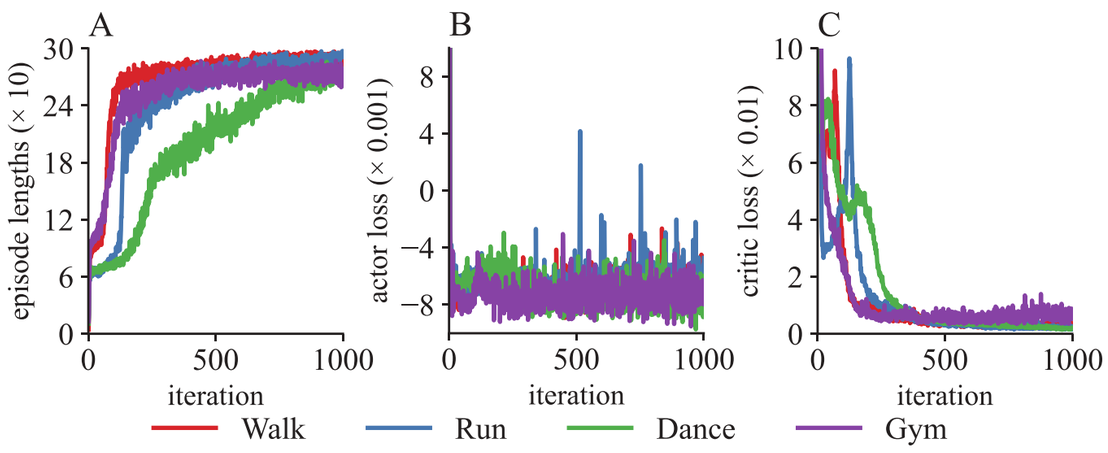
Problem: Lower-limb powered prostheses rely on structured, phase-based controllers designed for specific movement patterns, limiting their adaptability to diverse human motions.
Insight: Prosthetic control must accommodate the dynamic human-prosthesis interaction.
Method: We present a novel model-free reinforcement learning (RL) framework that explicitly models the human-prosthesis relationship as a cooperative multi-agent game.
Result: Our approach demonstrates that the framework can generate human-like motion across walking and complex tasks, establishing the effectiveness of the multi-agent cooperation perspective.
Significance: This framework offers a promising direction for developing more intuitive and versatile prosthetic systems that can adapt to diverse movement patterns.

Method

- We present a novel framework that explicitly models the human-prosthesis relationship as a cooperative multi-agent game by Markov Decision Process.
- The human-prosthesis cooperation is enhanced by a joint reward function.
- The human agent has its own closed-loop controls, which is only observed.
- The prosthesis's policy is updated using the Proximal Policy Optimization method.
- We use Human Motion Prior to update rewards to achieve natural and human-like movements.

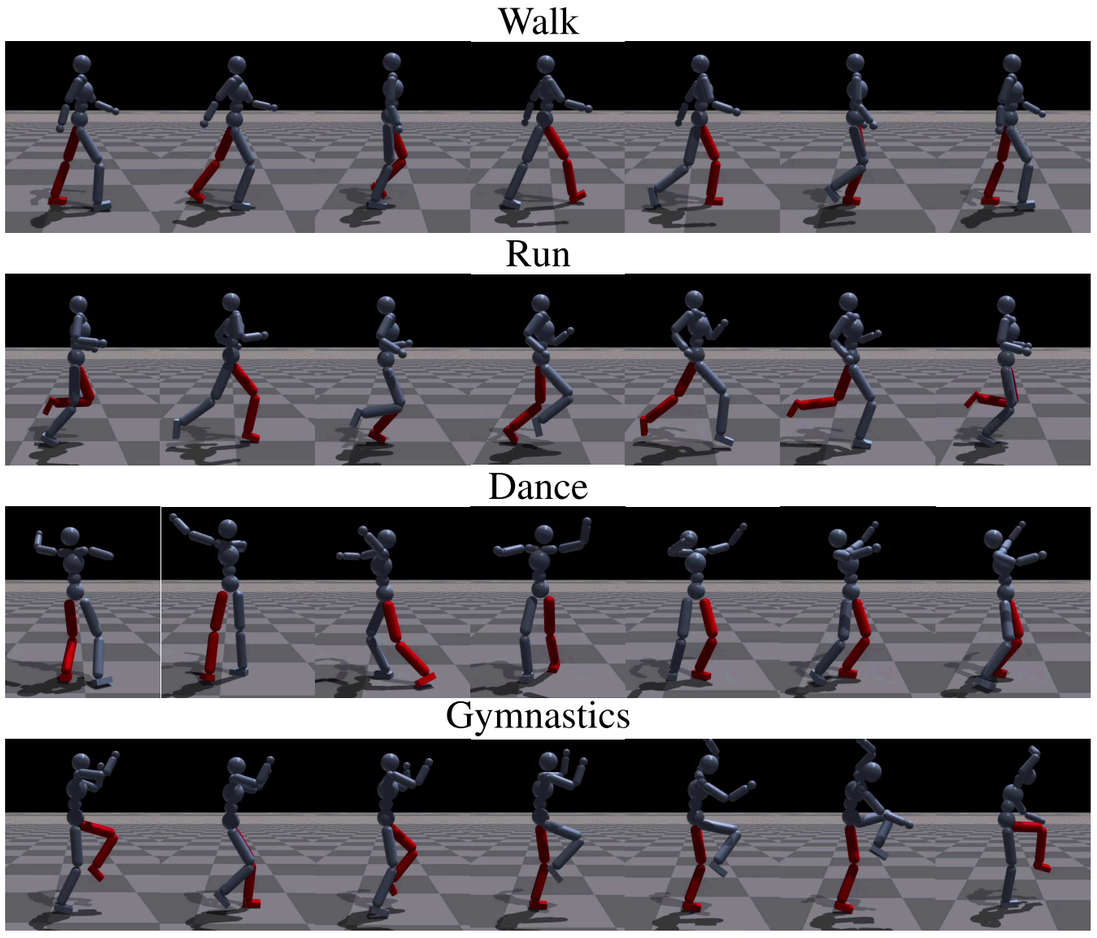


Convergence

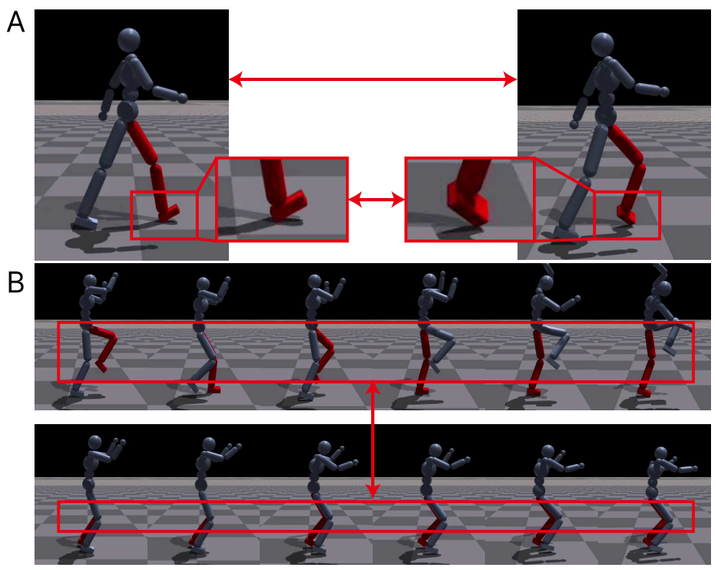


The training can converge within 1,000 epochs (approximately 3 hours).

Generalization to Various Motion Tasks



Similarity to Human Motions



EFFECTS OF REWARD UPDATES (RU) ON SIMILARITY TO REAL HUMAN MOTION

	w/ RU	w/o RU
walk	20.5	16.1
run	15.2	11.2
dance	35.7	31.4
gymnastics	38.7	35.1

The proposed method have better similarity to normal human walking than the policy without reward updates qualitatively and quantitatively.

EFFECTIVENESS TO PERFORM VARIOUS MOTION TASKS

	HC	*Ours*
walk	99.2	96.7
run	98.8	98.4
dance	95.5	91.8
gymnastics	92.0	94.9

Our prosthetic control policy (*Ours*) shows generalization across diverse motions and comparable success rate on various motion tasks with mimic human controllers (*HC*).