Industrial Master's Degree Topic Thesis Defense

Intra-Limb Adaptive Compliance-Based Locomotion Learning Control

Run Janna

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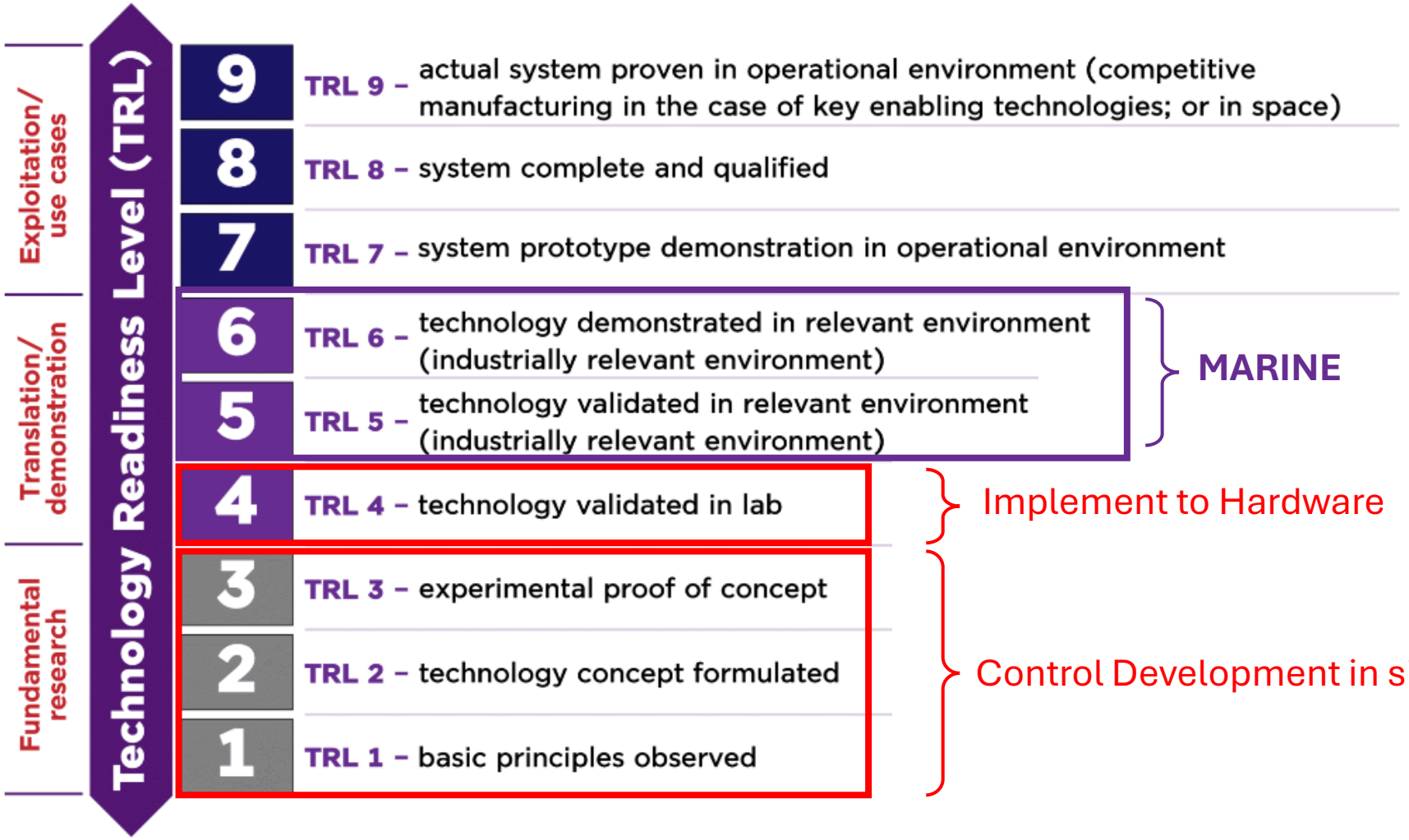
PTT Exploration and Production Public Company Limited

Technology Readiness Level (TRL)



Black Mirror

https://brain.vistec.ac.th/research/projects

MARINE

Inspection robot in Challenged Environment

Splash Zone Pole Inspection

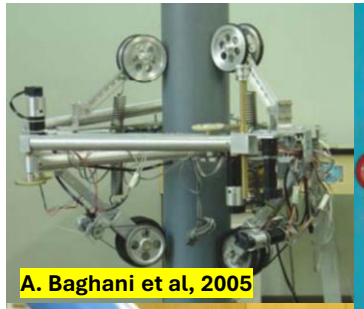
- Low magnetic Force
- Perturbation (e.g., wind, sea water wave)

Underwater & Seabed Inspection

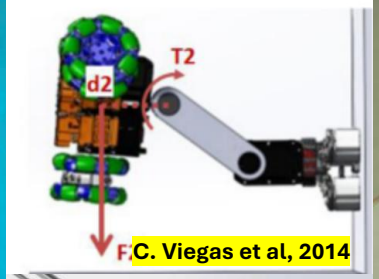
- Outer Pipe Obstacle (e.g., Valve, Frank Joint)
- Underwater wave
- Seabed walking

Robot Literature

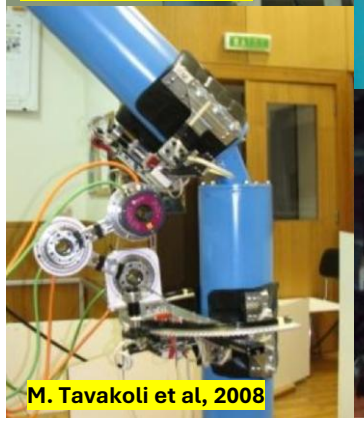
- Outer pipe inspection robot


A. Baghani et al, 2005

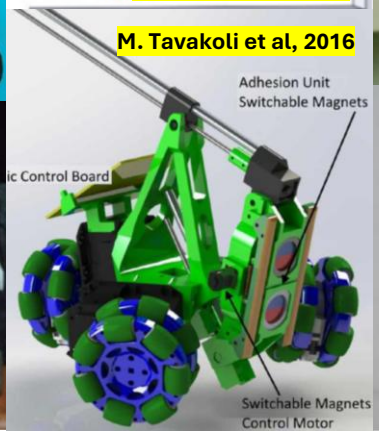
Y. Guan et al, 2011



C. Viegas et al, 2014


M. Tavakoli et al, 2008

Z. Bi et al, 2012



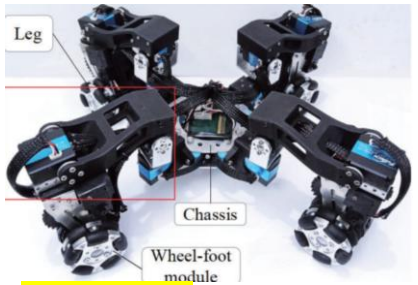
M. Tavakoli et al, 2016

J. Kim et al, 2018

D. Qiaoling et al, 2019

G. Chen et al, 2019

T. Chuthong et al, 2023



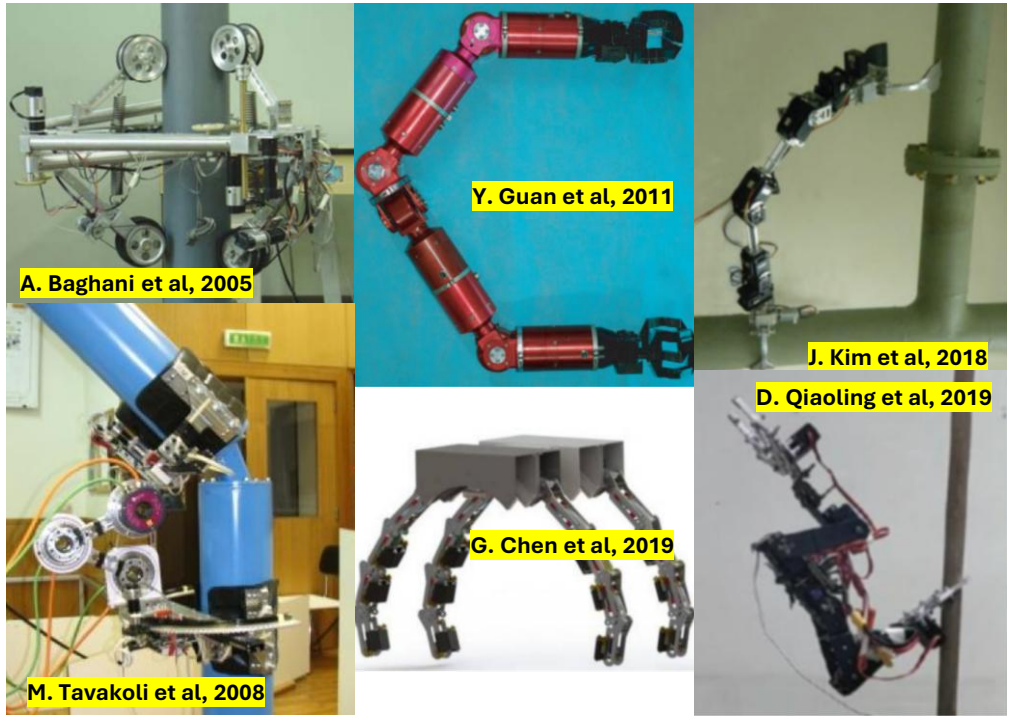
Y. Bu et al, 2022

M. KHAN et al, 2020

Outer Pipe Robot

Robot Literature

- Outer pipe inspection robot



Outer Pipe Robot
Low magnetic Force

Robot Literature

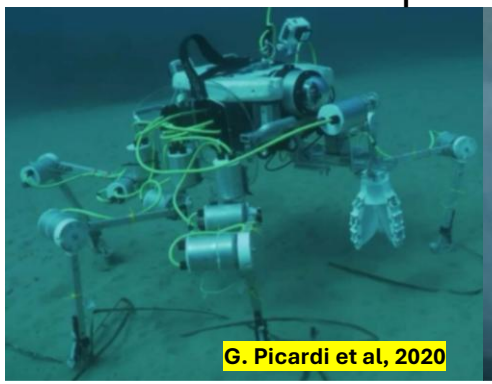
- Outer pipe inspection robot

~~**Outer Pipe Robot**~~

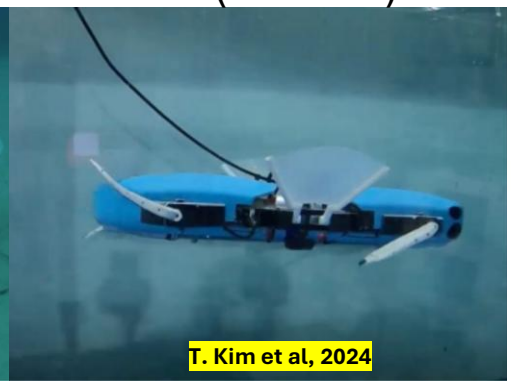
Low magnetic Force

Amphibian Environment

- Underwater inspection robot (Seabed)



G. Picardi et al, 2020



T. Kim et al, 2024

T. Kim et al, 2024

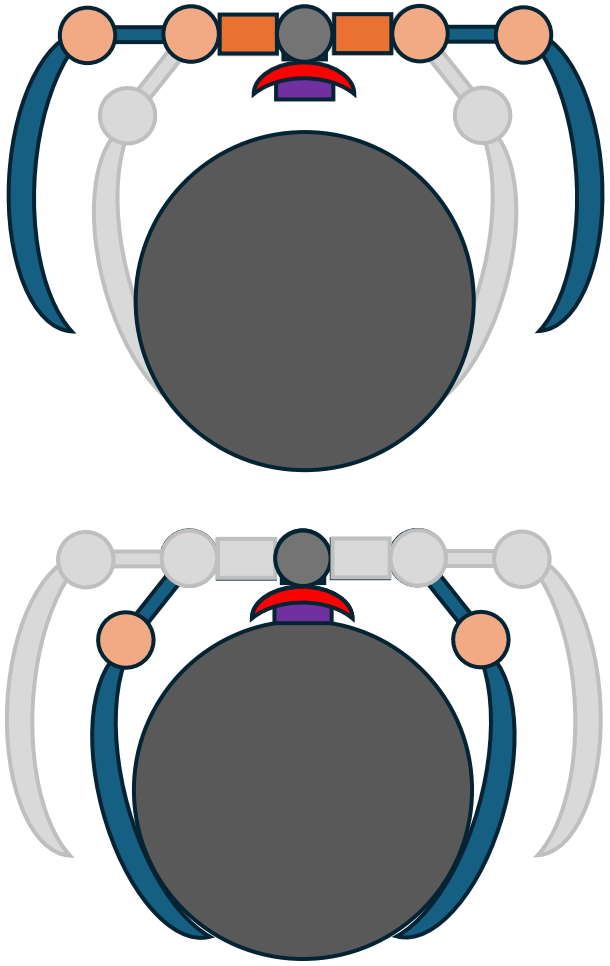
Conceptual Robot Design

Outer Pipe Robot

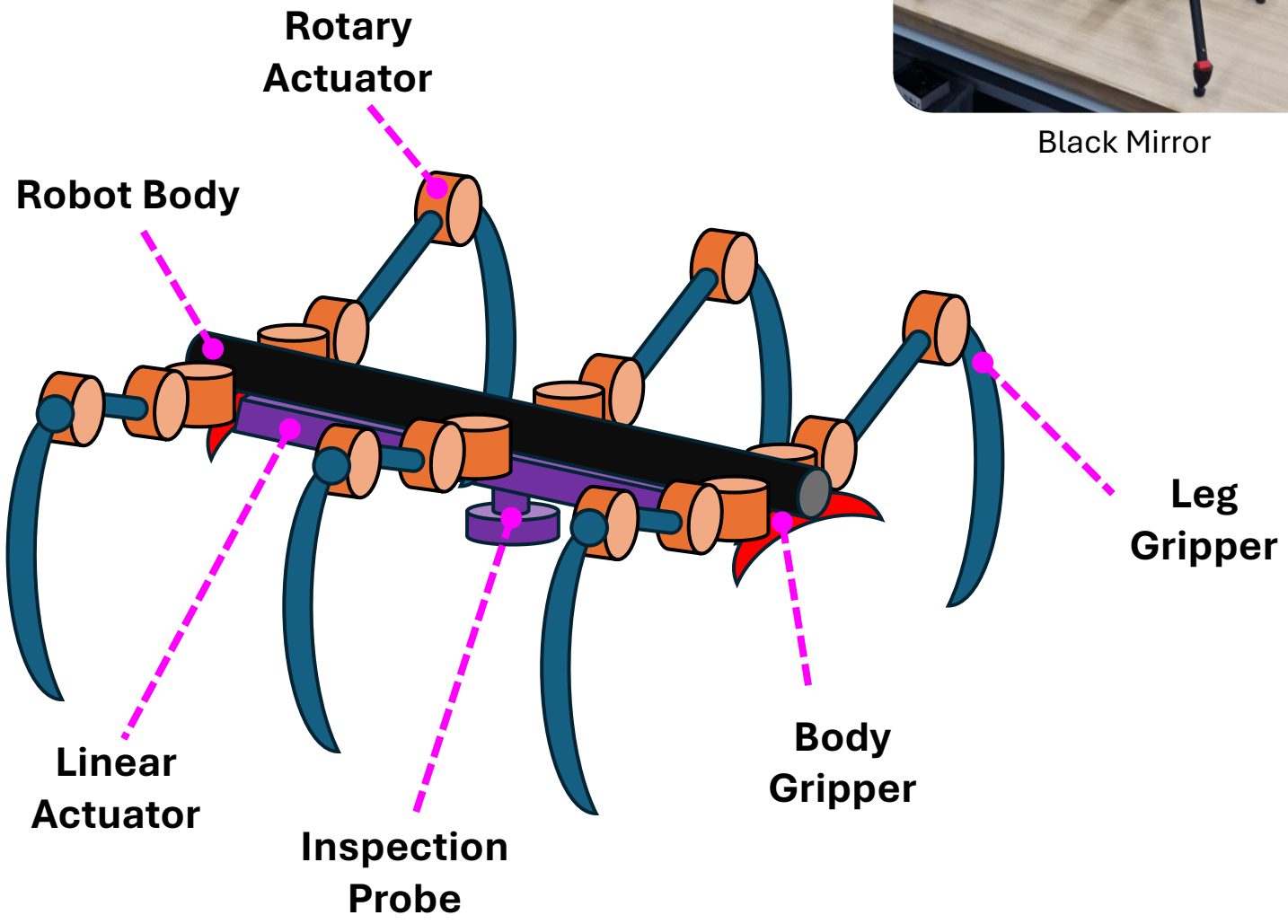
Low magnetic Force

Amphibian Environment

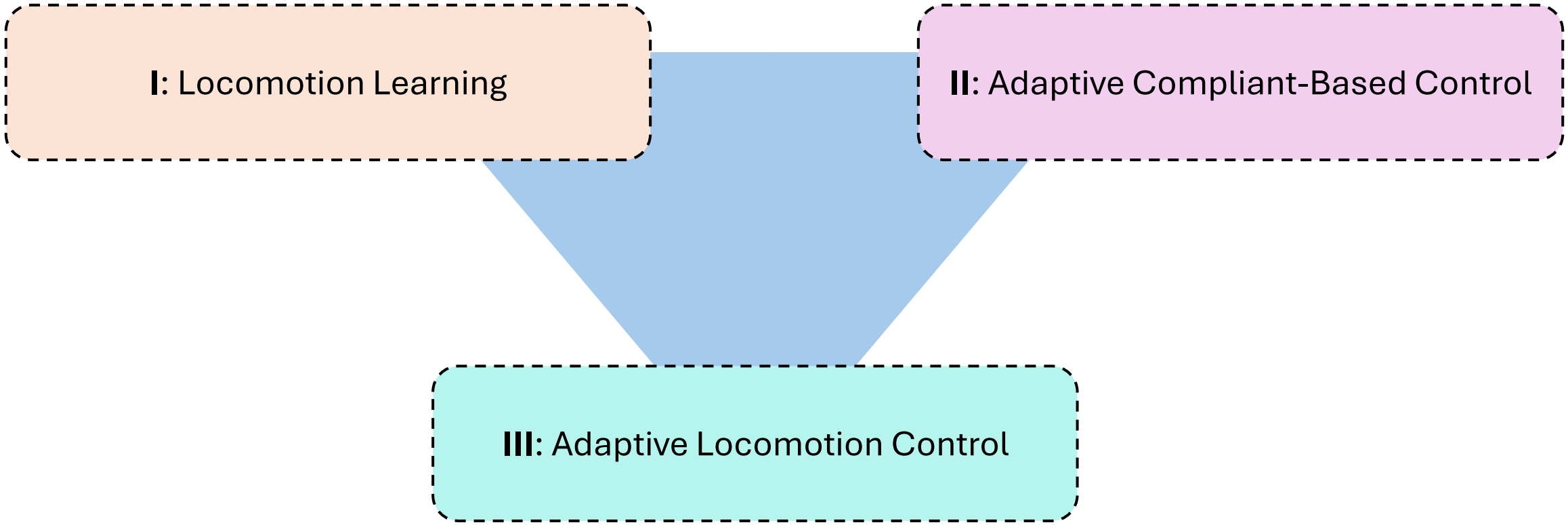
Black Mirror



Front View



Intra-Limb Adaptive Compliance-Based Control and Locomotion Learning



I. Locomotion Learning:

II. Central Pattern Generator-Radial Basis Function network (CPG-RBF)

Demonstration

Youtube: KennethKramm

Youtube: Deep Blue Discovery

Youtube: Ali Yahya

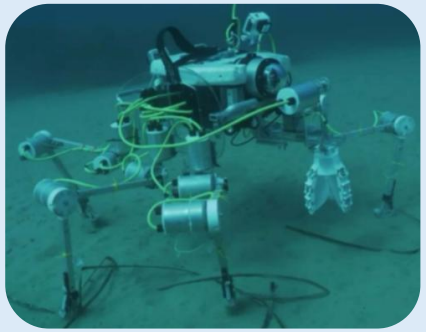
Record/ *Encode*

Locomotion Learning

CPG-RBF

Play/ *Decode*

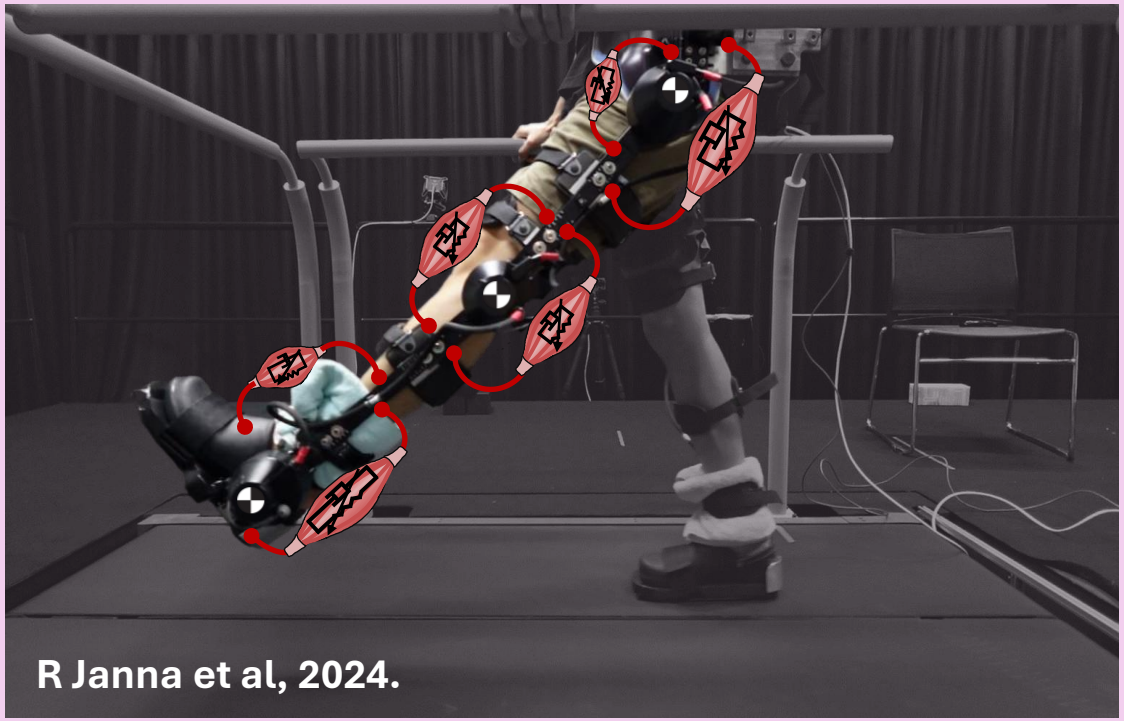
Robot Locomotion



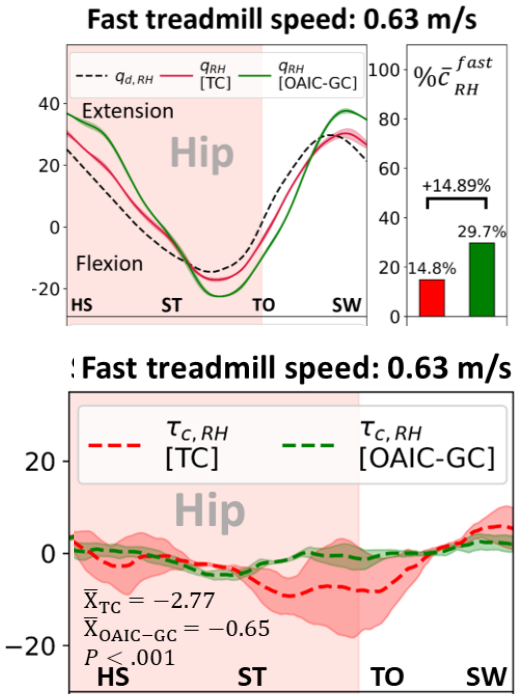
II. Adaptive Compliance-Based Control:

Online Adaptive Impedance Control (OAIC)

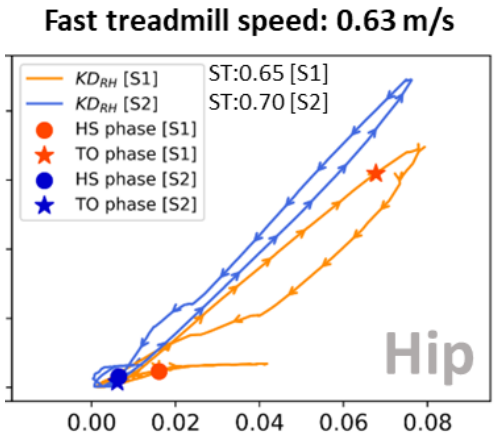
Adaptive Compliance-Based Control



Joint Compliance Mechanism

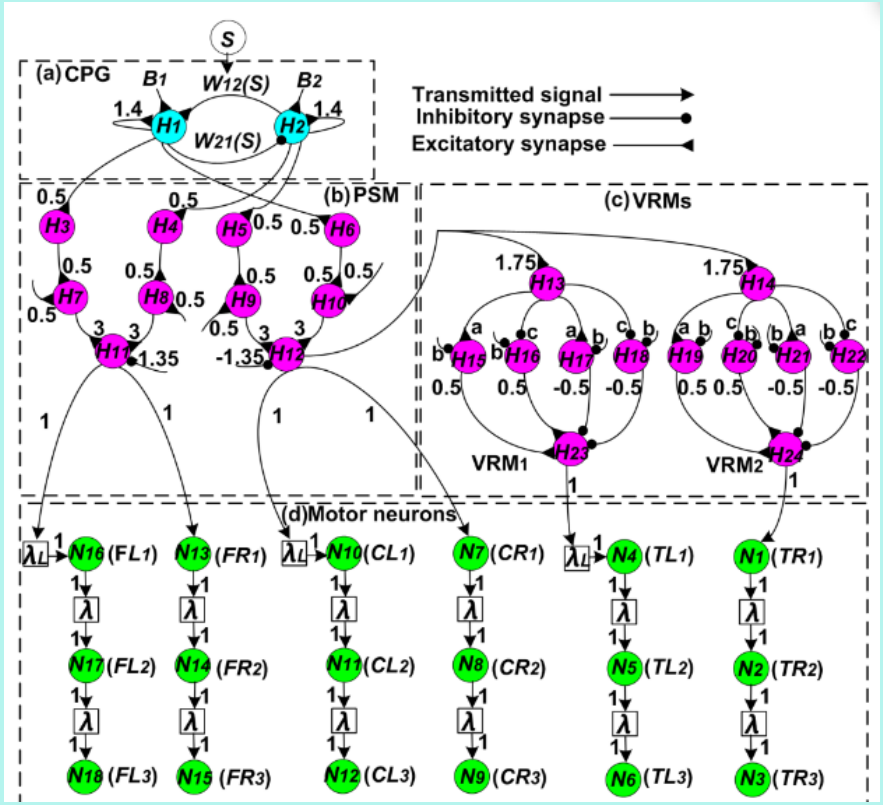


Impedance Observer



III. Adaptive Locomotion Control: Novel method

Adaptive
Locomotion Learning

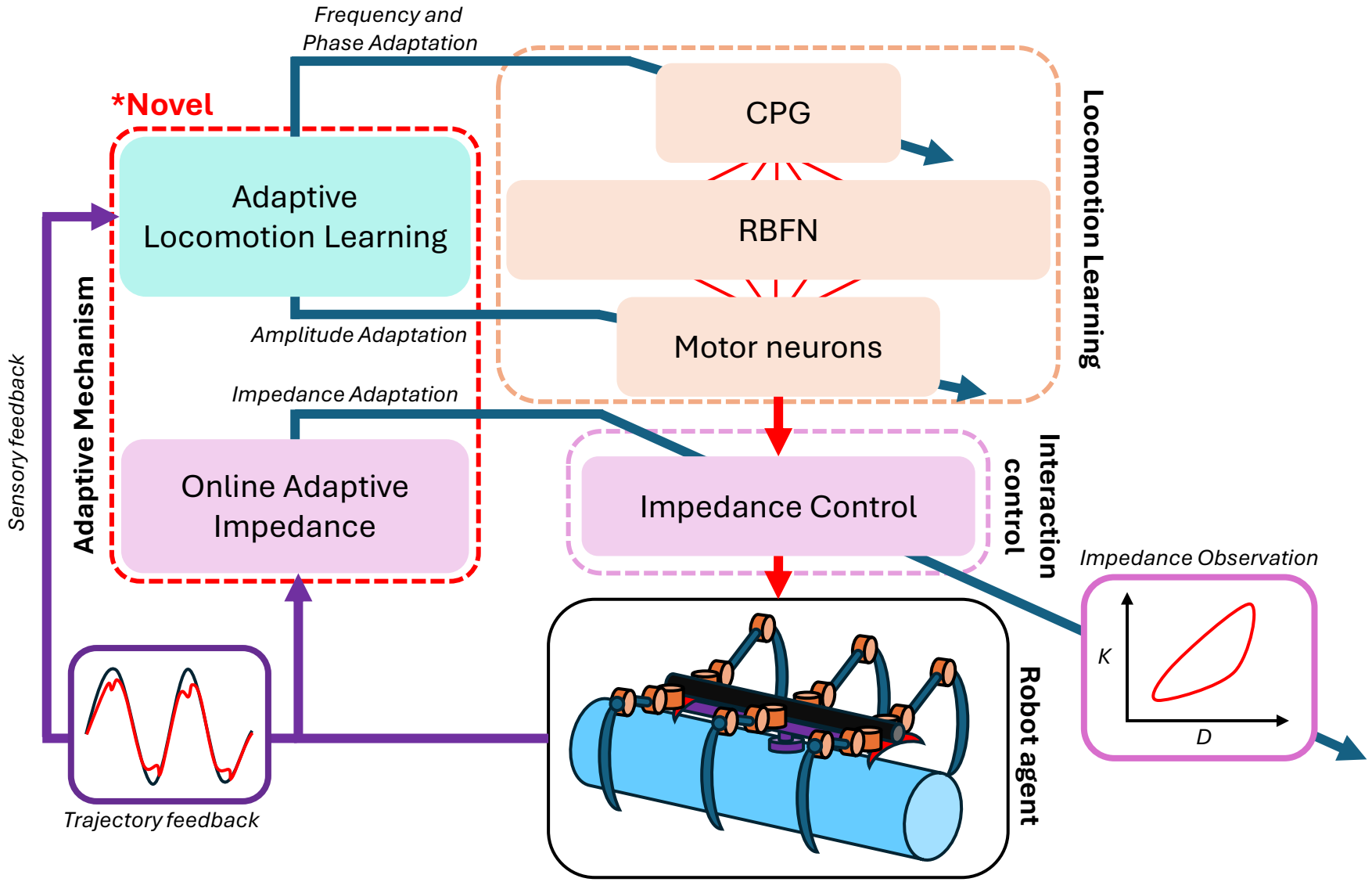


X Xiong, P Manoonpong , et al., 2014

Modular Neural Network

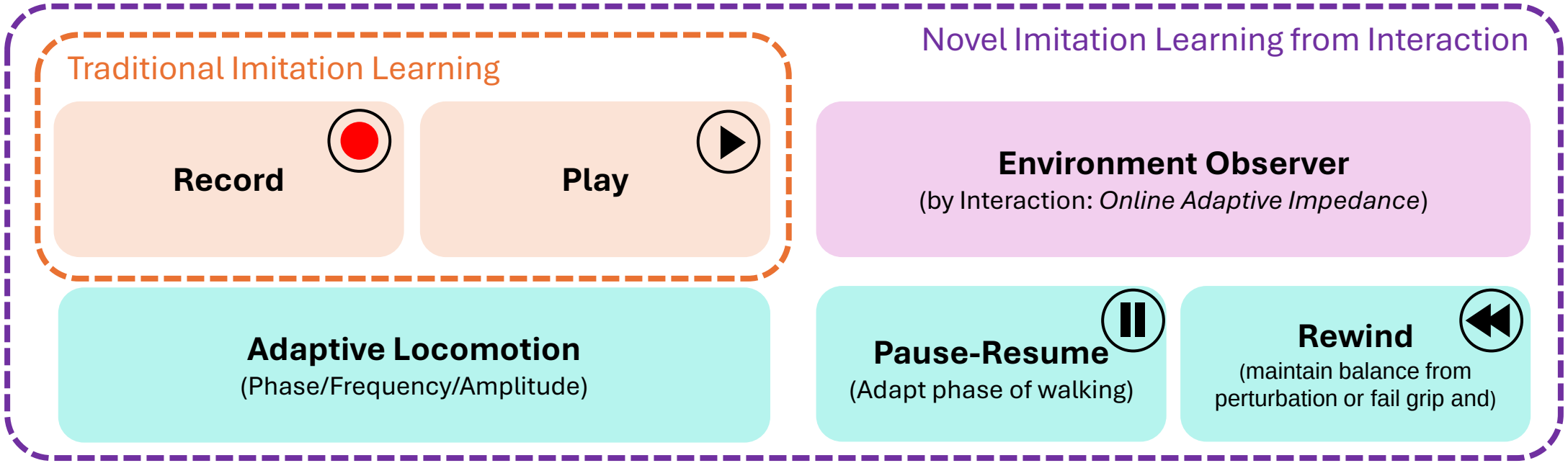
Conceptual Control

Intra-Limb Adaptive Compliance-Based Control and Locomotion Learning



Conceptual Control

Intra-Limb Adaptive Compliance-Based Control and Locomotion Learning



Contribution of **MARINE**

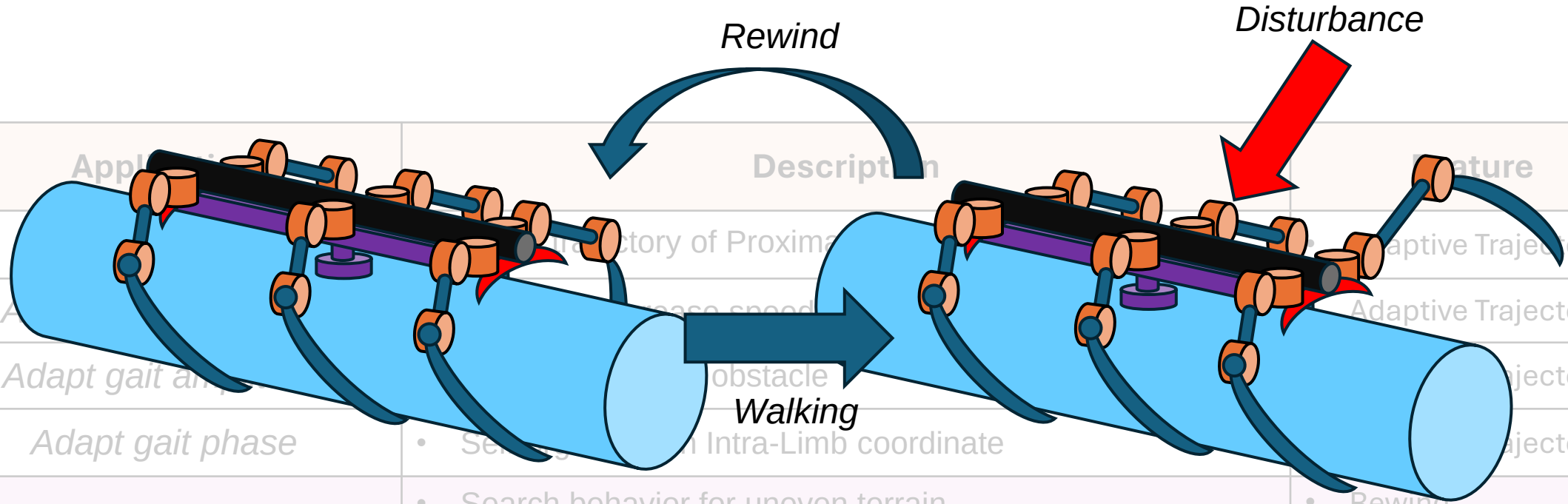
Application	Description	Feature
Recovery walking	• Adapt trajectory of Proximal leg to recover broken leg	• Adaptive Trajectory
Adapt gait frequency	• Increase/decrease speed of walking	• Adaptive Trajectory
Adapt gait amplitude	• Across and avoid obstacle	• Adaptive Trajectory
Adapt gait phase	• Self-organization Intra-Limb coordinate	• Adaptive Trajectory
Exploration Locomotion	• Search behavior for uneven terrain • Interactive Obstacle Avoidance	• Rewind • Pause-Resume
Self-Stabilization	• Redistribute gait trajectory to keep robot stable from disturbance and balance body on Constrain environment	• Rewind
Environment Observer	• Observe stiffness/damping of environment	• Online Adaptive Impedance

Contribution of **MARINE**

Bio-inspired

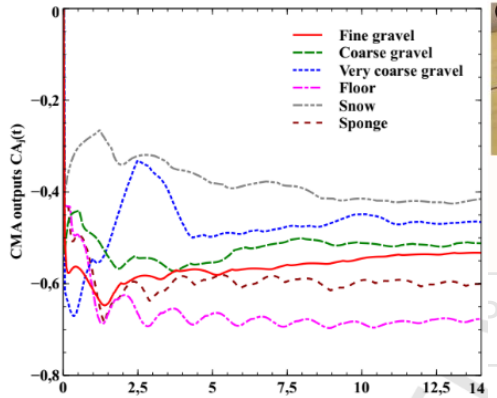
Adapt gait phase	• Self-organization Intra-Limb coordinate	• Adaptive Trajectory
Exploration Locomotion	• Search behavior for uneven terrain • Interactive Obstacle Avoidance	• Rewind • Pause-Resume

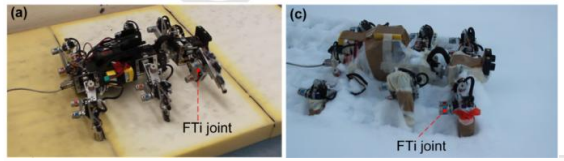
Contribution of **MARINE**



Application	Description	Feature
	ctory of Proxima	aptive Trajectory
	ease speed	Adaptive Trajectory
Adapt gait amp	obstacle	jectory
Adapt gait phase	• Se n Intra-Limb coordinate	jectory
Exploration Locomotion	• Search behavior for uneven terrain • Interactive Obstacle Avoidance	• Rewind • Pause-Resume
Self-Stabilization	• Redistribute gait trajectory to keep robot stable from disturbance and balance body on Constrain environment	• Rewind
Environment Observer	• Observe stiffness/damping of environment	• Online Adaptive Impedance

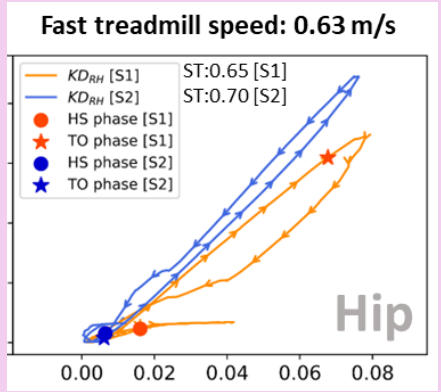
Contribution of **MARINE**



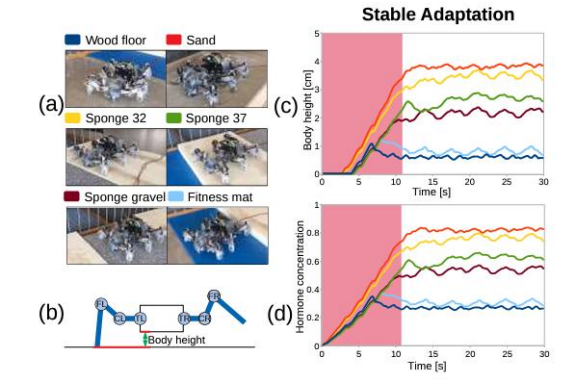


X Xiong, P Manoonpong , et al., 2014

Impedance Observer



R Janna et al, 2024.



J. Homchanthanakul, P Manoonpong , et al., 2019

Environment Observer	• Observe stiffness/damping of environment	• Online Adaptive Impedance

Literature State-of-the-art Controls

	Publish Year	Author(s)	Control Feature(s)	Robot Type	Control Space	Additional Observer	Control-Based
Imitation Learning	2009	Andrej Gams	Record-Play, Adapt, Obstacle Avoidance, Pause-Resume	Robot Arm (Stationary)	Cartesian Space, Joint Space	None	DMP
	2010	Andrej Gams	Record-Play, Adapt, Pause-Resume	Robot Arm (Stationary)	Cartesian Space, Orientation Space	Vision, Interaction Force	DMP
	2023	Francesco Iori	Record-Play, Adapt	Robot Arm (Stationary)	Cartesian Space	Vision, Interaction Force	DMP
	2021*	Tao Sun	Pause-Resume, Adapt	Legged Robot (Mobile)	Joint Space	Interaction Force	CPG-RBF
	2023	Chaicharn Akkawutvanich	Record-Play, Adapt	Lower Limb Exoskeleton	Joint Space	None	CPG-RBF
	2023	Arthicha Srisuchinnawong	Record-Play, Adapt	Lower Limb Exoskeleton	Joint Space	None	CPG-RBF
	2019	Matheshwaran Pitchai	Record-Play, Adapt	Legged Robot (Mobile)	Joint Space	None	CPG-RBF and RL
	2021	MathiasThor	Record-Play, Adapt	Legged Robot (Mobile)	Joint Space	None	CPG-RBF and RL
	2021	MathiasThor	Record-Play, Adapt	Legged Robot (Mobile)	Joint Space	Interaction Force	CPG-RBF and RL
	2023	Alexander Dupond Larsen	Record-Play, Adapt	Legged Robot (Mobile)	Joint Space	Interaction Force	CPG-RBF
Adaptive Interaction	2010	Etienne Burdet	Adapt	Robot Arm (Stationary)	Joint Space	Interaction Force, Impedance	Impedance/Force Control
	2010*	Gowrishankar Ganesh	Adapt	Robot Arm (Stationary)	Joint Space	Interaction Force, Impedance	Impedance/Force Control
	2018*	Yanan Li	Adapt	Robot Arm (Stationary)	Cartesian Space	Interaction Force, Impedance	Impedance/Force Control
	2018	Xiaofeng Xiong	Adapt	Robot Arm (Stationary)	Joint Space	Impedance	Impedance/Force Control
Learning from Interaction	2017	Andrea Bajcsy	Record-Play, Adapt, Obstacle Avoidance	Robot Arm (Stationary)	Cartesian Space	Interaction Force	RL
	2021*	Dylan P. Losey	Record-Play, Adapt, Obstacle Avoidance	Robot Arm (Stationary)	Cartesian Space	Interaction Force	RL
	2025	**Run Janna**	**Record-Play, Pause-Resume, Rewind/Reverse, Adapt, Interactive Obstacle Avoidance, Environment Observer, Self-Stabilization, Exploration Locomotion**	**Legged Robot (Mobile)**	**Joint Space**	**Interaction Force, Impedance**	**CPG-RBF and Impedance/Force Control**

Thank you for your attention

Presenter

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