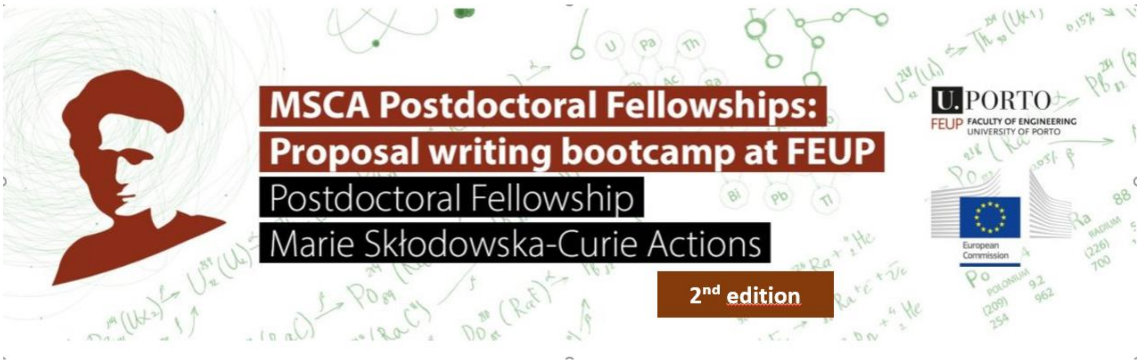


SUPERVISOR INFORMATION	
First and Last name	António Ramos Silva
URL of supervisor webpage	https://sigarra.up.pt/feup/pt/func_geral.formview?p_codigo=524991
Department	Mechanical Engineering
Field(s) of research	Automatic Control, Reinforcement Learning, evolutionary computation
PROJECT PROPOSAL	
Title (optional)	Overcoming Catastrophic Forgetting: Structuring walking movement with the MHC
Brief project description	

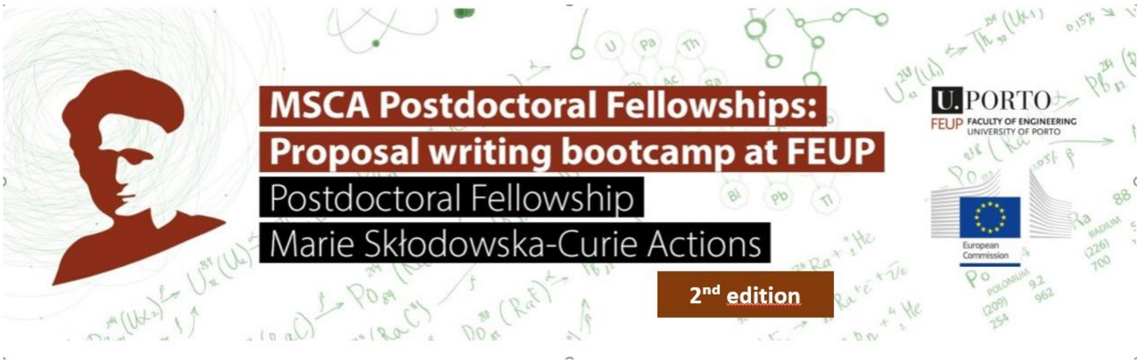
The phenomenon of catastrophic forgetting presents a significant barrier to developing Artificial Neural Networks (ANN) that aim to learn continuously. This project seeks to overcome this limitation by leveraging the Modular Hierarchical Controller (MHC) to structure and control walking and running movements. The MHC, inspired by biological systems, provides a modular and hierarchical approach to motor control, offering a framework to tackle the challenges of lifelong learning in dynamic environments.

The primary goal is to develop/improve a learning system that can adapt to new motor tasks without compromising previously acquired skills. This is achieved through a two-pronged strategy:

1. Memory Consolidation Techniques

The first approach draws heavily from principles observed in biological memory processes, such as synaptic consolidation and replay. The system will implement methods to stabilize neural connections associated with previously learned movement patterns. Such as:

- **Elastic Weight Consolidation (EWC)**: By assigning greater importance to critical parameters in the learned model, the system ensures that changes to these parameters are minimized when learning new tasks.
- **Replay and Simulation**: Similar to how the brain replays past experiences during sleep, the system periodically revisits and reinforces earlier motor patterns. This ensures that older walking behaviors remain intact even as new skills are learned.
- **Module-Specific Isolation**: MHC's modularity enables the isolation of specific tasks (e.g., balance, limb coordination), reducing the risk of interference during memory updates



(learning). Each module retains its learned knowledge independently while coordinating with the overall system.

This consolidation mechanism ensures stability and minimizes performance degradation, paving the way for robust lifelong learning in motor control.

2. Reinforcement Learning for Localized Adaptation

The second approach focuses on utilizing reinforcement learning (RL) to enhance the adaptability of the MHC in dynamic and unpredictable environments. With an MHC's modular structure, RL will train individual modules for specific sub-tasks (torso, leg, arm movement control and others) while minimizing cross-module interference. Key aspects include:

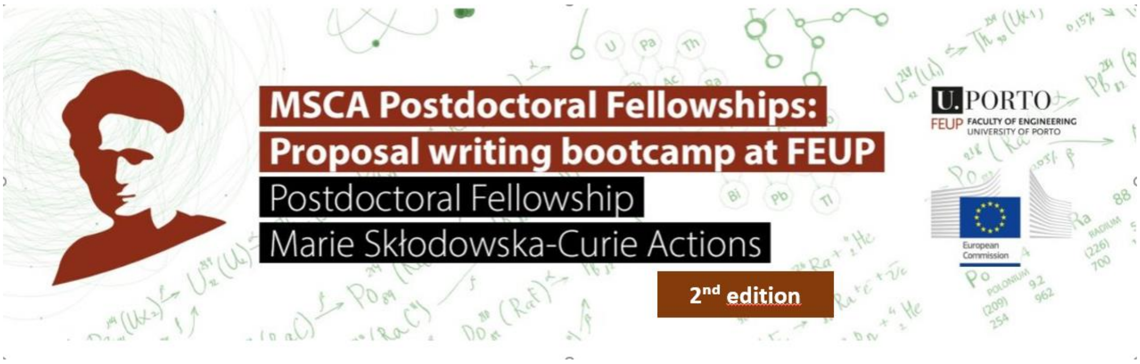
- **Terrain Adaptation**: Modules responsible for limb movement and balance will learn optimal behaviors for different terrains (e.g., slopes, uneven surfaces) through trial-and-error interactions, guided by reward mechanisms.
- **Incremental Skill Addition**: New walking skills, such as obstacle avoidance or dynamic gait adjustments, will be introduced incrementally, allowing the system to learn these without affecting core walking abilities.
- **Hierarchical Coordination**: The higher levels of the MHC will oversee task prioritization and sub-module integration, ensuring smooth transitions between different walking patterns (e.g., switching from normal walking to stair climbing).
- **Efficiency and Robustness**: RL within the MHC ensures that individual modules can specialize while maintaining overall system efficiency and robustness, essential for real-time applications.

Impact and Applications

This project addresses fundamental challenges in Machine Learning and robotics, where the ability to learn continuously and adapt dynamically is paramount. Memory consolidation techniques and RL within the modular framework of the MHC, the system promises to deliver:

- Lifelong adaptability in robotic systems for diverse and dynamic environments.
- Enhanced stability and flexibility in prosthetic and exoskeleton devices, improving the quality of life for users.
- A scalable framework for motor control machines, applicable to various autonomous systems.

By bridging biological insights and machine learning innovations, this project sets the stage for groundbreaking advancements in robotics, Machine Learning, and adaptable control systems. This



project will be inserted within a research group with the world's leading experts in the MHC, including its author, Professor Michael Commons from Harvard University