SDU Robotics

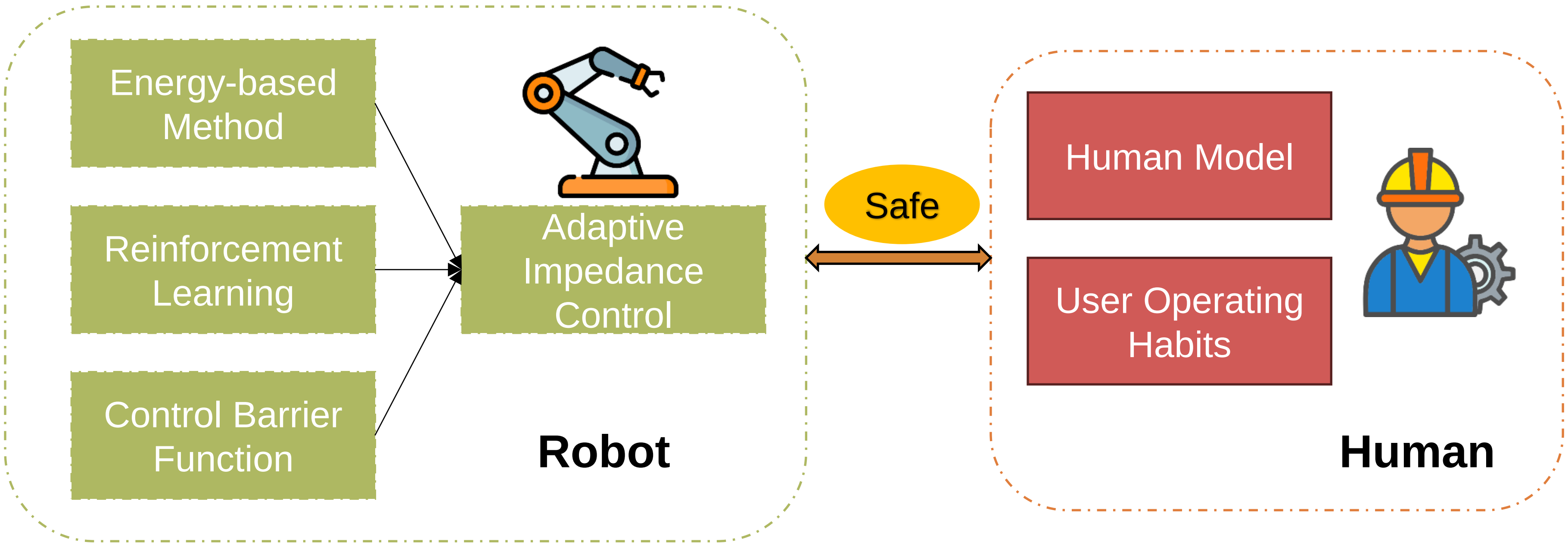
Safe Energy-aware Robotic Teleoperation

Rui Luo
Principal supervisor: Cheng Fang
Co-supervisor: Henrik Gordon Petersen and Wesley Roozing

sdu.dk

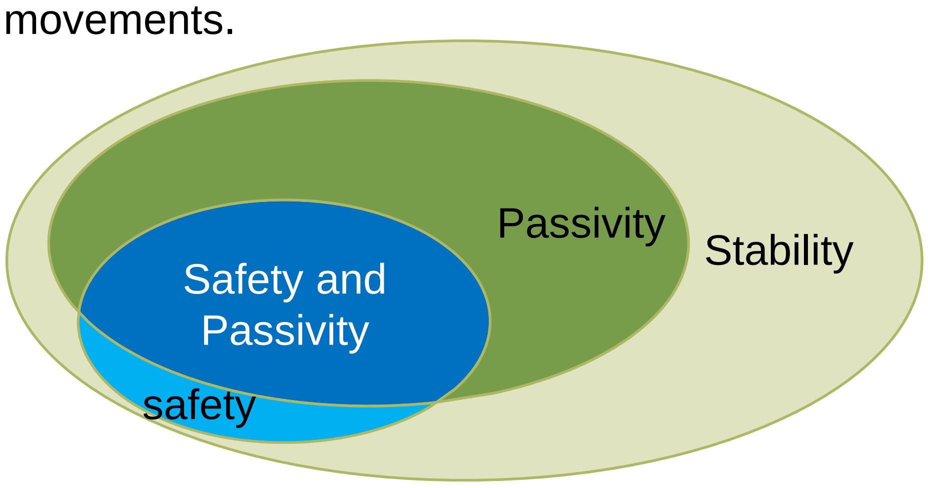
#sdudk

Background: The SENSIBLE Project (Symbiotic teleoperation for Safe and cost-efficient wind turbine blade maintenance) is a Danish research initiative enhancing wind turbine maintenance via teleoperation. It aims to enable human operators to remotely control robots for complex tasks like leading-edge repairs. The associated PhD research focuses on developing a stable, safe and reliable teleoperation system using energy-tank approaches, Reinforcement Learning (RL), and Control Barrier Functions (CBF) to handle the effects of dynamic human and environmental factors and large time delays on the stability and safety.



Objective: Stability is the most fundamental requirement for robot control. However, in teleoperation control, external energy interactions can affect stability. Therefore, to ensure the overall human-robot system remains stable, we utilize the port-Hamiltonian theory to guarantee system passivity, ensuring stability under all circumstances.

To enhance the adaptability of control parameters across various scenarios, reinforcement learning is employed to optimize parameter selection. Furthermore, a passive system alone cannot guarantee safe human-robot interaction. Sudden force or kinetic energy inputs may cause harm to the operator. Therefore, a Control Barrier Function (CBF) is incorporated to restrict overly aggressive robotic movements.



Requirements Definition for Robot Control

Main Tasks:

- Develop a control energy-based framework that ensures passivity and energy consistency in robot teleoperation while maintaining adaptability to dynamic environments.
- Incorporate CBF to enforce real-time safety constraints, ensuring that robot interactions adhere to predefined safety specifications (with or without human arm dynamics model).
- Utilize RL to enable adaptive variant impedance control, allowing the system to learn optimal control strategies from interactions and improve performance in uncertain teleoperation scenarios.

SDU