Artificial Intelligence for the codesign of new dynamic legged robots : a multidisciplinary and generic design approach

Context and objectives

Legged walking robots have made important and visible progress these past years. Simple but effective quadruped designs [Fank18, Katz19, Grim20], controlled through AI-based methods [Mast20], have gained robust mobility skills such as walking, running, or jumping. However, the gap remains large before moving forward with accessible and reliable bipeds. Most of the current biped designs suffer from mechatronic weakness or unfortunate technical choices that no controller can solve afterwards. The success of advanced American bipeds (Atlas [Nels19] or Digit [Hurst19]) can be partly explained by the iterative codesign approach the manufacturers take, where a transverse team simultaneously develops the mechatronic design and the control of the robot.

If a common consensus has been reached within the robotics community on the importance of mechatronic design approaches, the scope of such approaches is often limited to hardware (mechanical structure, actuation, sensors) design, modeling, dimensioning and optimization. Optimal robots could only be developed by additionally considering task-oriented specifications and by integrating the control strategy and requirements at the first steps of the design process. Therefore, the project aims at **developing a multidisciplinary and generic design approach** which will cover the variety and complexity of a collaborative-design brief. We propose to **leverage mastered AI-based methods** (simulation, planning, optimization) to guide the mechatronic design cycles and to provide tools to assist designers. The transversal approach will be applied to the **codesign of a new dynamic legged robot**, the right balance between versatile but heavy robots (Atlas, Talos [Stas17]) and light robots limited to walking (Digit). Ultimately, a prototype of the biped should be built and experimentally validated.

Methodology and research axes

The PhD Thesis is part of a collaboration between the *Gepetto* team (Mouvement des systèmes anthropomorphes) at LAAS (CNRS) and the *RoBioSS team* (Robotique, Biomécanique, Sport et Santé) at Pprime institute (University of Poitiers, CNRS). This multidisciplinary collaboration will bring the complementary expertise in mechatronic design and AI, essential to meet the project objectives.

During the thesis works, a comprehensive mechatronic codesign strategy will be proposed, as depicted in the Figure below. It will guide the design of a robotic system from scratch, by iteratively modeling and optimizing both the mechanical structure and the actuation, planning critical end-use tasks, and simulating the control outputs and the robot behavior. **We aim at developing a generic mechatronic methodology, suitable for the design of different robots**, and based on common and open IA tools.

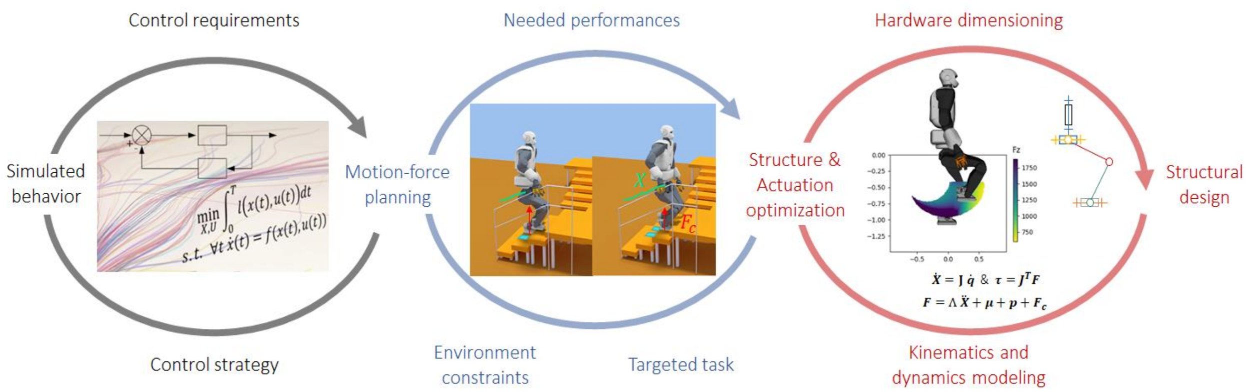

Figure 1. Framework of a mechatronic codesign approach

At each stage of the project, the mechatronic-design methodology and related AI tools will be used to develop a novel high-dynamics biped robot. Several leg kinematic architectures, transmission and actuation systems will be suggested, modeled and optimized, through the iterative design process. These technical alternatives must meet the specifications of locomotion tasks, extracted from trajectory optimization [Mast20]. The leg behavior along its workspace will be determined by dynamically modeling [Carp19] the architecture. Significant structural and actuation parameters will be identified and optimized [Vull18, Chad20, Fadi21, Sema21] with respect to dynamic criteria, such as minimizing the effective inertia at the foot or maximizing the force capability to perform a given trajectory or targeted task. Back and forth between simulations and experimental evaluations of instrumented prototypes will assess the performances of different solutions and validate the design strategy at once. The ultimate design could be an initial reference for the new humanoid experimental platform RENOIR (EQUIPEX TIRREX) of the French robotics community.

References

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Project team

The PhD candidate will be closely working with researchers of the *Gepetto* and *RoBioSS* teams. The *Gepetto* team is interested in motion analysis, trajectory generation, and control for anthropomorphic robotic systems. Its expertise covers dynamics modeling and simulation, force-motion planning and optimal control of robots; human motion analysis ; and novel robot actuation systems. Research works at the *RoBioSS* team include design, modeling, and control of novel mechatronic systems (haptic devices, robot arms, dexterous grippers…) for collaborative robotics. The team is also interested in biomechanics and human motion analysis in work, sport, or health contexts.

The recruited PhD student will be mainly working at the *Gepetto* team facilities :

Equipe Gepetto, LAAS, CNRS
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31400 TOULOUSE

Skills

Technical skills in Mechanical Design, and Programming (C++, Python) are required. Experiences in Mechanism Optimization, Mechatronics, Experimental Robotics, or Robotic Modeling and Control would be appreciated. Makers are very welcome to apply!

Contact and application

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You can submit your application by email.

The application must include a resume, a cover letter, and Master's grades.