Nowadays, mobile robots perform many tasks related to transportation, agriculture, search-and-rescue, inspection, and many more, which are laborious, repetitive, or dangerous. Most of these tasks are handled by wheeled/tracked robots or drones, which characterize the ease of moving from point A to point B. However, these types of robots have also their drawbacks: wheeled/tracked robots have problems with traversing over more considerable obstacles and gaps, and have issues with moving in unstructured and confined spaces, whereas drones are prone to weather conditions, have much more limited payload, and can not interact directly with the physical environment. These imperfections can be covered up with walking robots, as their characteristics are agility and adaptability of locomotion. The importance of legged systems as the emerging technology with a high potential of real-world deployments acknowledges the latest 20 mln CHF investment in ANYbotics spin-off of ETH Zurich developing ANYmal and the recent acquisition of Boston Dynamics by Hyundai for the sum of 1 bln USD.

Recently research in legged robots, particularly quadrupeds, focuses on equipping the walking machines with agility comparable to their animal counterparts, which resulted in the development of the platforms like MIT Cheetah, BostonDynamics SpotMini, IIT HyQ, or ETH ANYmal. However, there are still many interesting and challenging fundamental research questions and technological developments that need to be addressed to match the agility and adaptability of legged animals as we observe in nature. For instance, legged robots are still missing:

- physical intelligence understood as the ability to use and learn from physical interactions between their body and the environment,
- adaptability to the changing environmental conditions or hardware failures,
- coupling between robot perception and actions,

This project aims to address these gaps between human-made walking robots and their biological counterparts by developing a fundamental methodology to design highly autonomous legged platforms. The approach will benefit from innovations in the fundamentals of perception, control, and robot learning coupled together to build the robot's physical intelligence and ability to adapt and interact with the environment. All this will lead us to the robot's semi-autonomous agile and safe locomotion in unstructured, confined, and dynamic environments, as well as improvements of its performance over time.

We will develop the perception module to make robots perceive and physically act on the surrounding world to achieve this fundamental methodology. We will enable robots to sense the terrain parameters while walking using sensors mounted in the legs and the articulated spine. Moreover, we will distill the information essential for adapting the robot's gait and actions to the actual situation, similar to animals. Furthermore, we will couple the signals from vision and touch senses gained through interaction with the environment to transfer the knowledge between senses to build and update the world's internal models.

Next, we will focus on improving the locomotion skills of the robot. Using reinforcement learning and based on the perception system's contextual information, we will develop algorithms to adapt the robot to different and changing environmental conditions. Moreover, we will enable the robot to use contacts with the environment to improve its agility and ability to navigate in confined spaces. Because it is hard to manually define the reward function to drive the robot to desired behaviors, we will use inverse reinforcement learning and a set of demonstrations gathered from both robotic platforms and motion capture of animals' gaits to learn it. Furthermore, we will develop new reinforcement learning-based algorithms to control the robot with an articulated spine, which was never done before.

Finally, we will compose the perception and locomotion components into a hierarchical controller, which selects appropriate gait taking into account the information about terrain type and reactively corrects the foot placement while walking, based on the local irregularities properties of the terrain. Furthermore, most of the current robots are avoiding collisions of the robot body with the environment. However, humans and animals can exploit them, e.g., to keep balance. We will equip the legged robots with similar abilities by learning how to use contacts with the environment to move in the way currently unavailable to the legged robots.

An essential part of scientific development is testing and comparing proposed solutions on standardized testbeds with relevant criteria. Thus, we will evaluate the proposed algorithms in the task which requires agility and navigating through narrow passages - the robotic cave inspection. We will consider several performance measures such as speed for traversing a particular terrain, energy efficiency, peak interaction forces with the environment, etc.