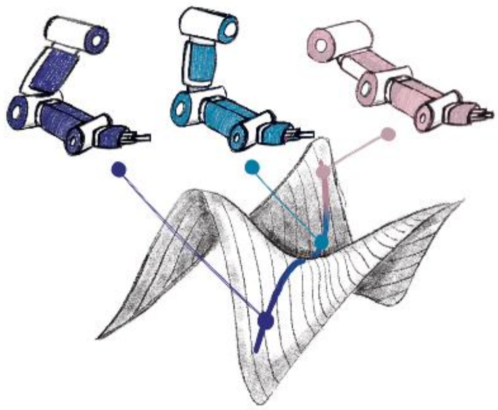
Inferring geodesic synergies for robot motion generation

Due to the high redundancy of the human muscular system, muscles are activated in a coordinated manner in order to achieve harmonic motions. To do so, the notion of muscle or motor synergies - coherent co-activation of motor signals - has been proposed and widely studied in the literature. In robotics, synergies are also viewed as a solution to efficiently learn and control motions of highly-redundant systems, such as humanoids or robotic hands.

In this project, we propose to infer synergies from a geometric perspective. To do so, we consider the space of whole-body postures as curved mathematical space, called a Riemannian manifold, whose curvature is related to the mass-inertia matrix of the body. Therefore, sequences of whole-body postures are equivalent to trajectories in this manifold. Moreover, it has been shown that generating minimum-energy and synergic motions correspond to following geodesic trajectories – the equivalent of shortest paths – on the manifold.



This leads to several challenges that we will tackle in this project. One of the main challenges concerns the selection of synergies to achieve a given robot motion. In order to complete a given task, the appropriate geodesic synergies have to be determined and executed simultaneously. To do so, we will aim at understanding how motion synergies can be identified based on observed human actions, and we will investigate how they can subsequently be transferred to a humanoid robot by using, e.g., imitation learning approaches. Another important challenge comes from the fact that the intrinsic Riemannian geometry of the whole-body postures has to be considered for learning and transferring the geodesic synergies. Therefore, we will investigate the use of Riemannian geometry in the learning algorithms to the transfer trajectories from the Riemannian manifold of human postures to the manifold of robot postures.

In this project, you will work with the humanoid robot ARMAR-6 both in simulation and in real-world scenarios, as well as several robotics and machine learning tools:

- ArmarX (C++, Python): armarx.humanoids.kit.edu
- Pytorch (Python): https://pytorch.org/

Contact: Noémie Jaquier (noemie.jaquier@kit.edu)