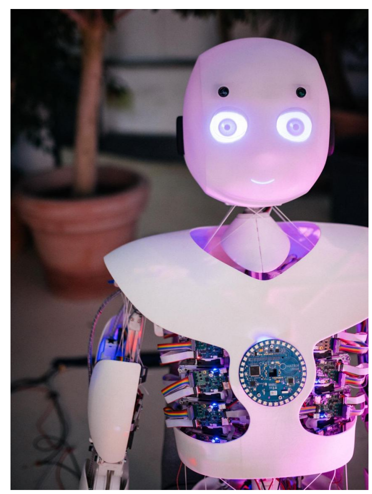
Model-free few-shot autonomous learning for a tendon-driven humanoid Roboy 3.0

Goal

Over the course of this project, prospective students will implement the state-of-the-art algorithms developed by the Brain-Body Dynamics Lab at the UCS and deploy them on the hardware of the musculo-skeletal robot developed by Devanthro - the Roboy Company. This project is aimed for students to get hands-on experience with hardware and software stack of the tendon-driven humanoid robot Roboy 3.0, control theory algorithms and machine learning approaches in robotics.

Description



In this project, we are going to enable design-agnostic autonomous learning - a biologically plausible G2P (general to particular) algorithm[1,2] - in a tendon-driven robotic system - a ball-and-socket 3 DoF shoulder joint of Roboy 3.0. To do so, we first need to randomly activate actuators and collect the resulting kinematics (motor babbling). Next, we will train an Artificial Neural Network (ANN) using these actuations and collected kinematics so that the ANN can predict needed activations for any given desired kinematics. Lastly, we will have the robotic system follow the desired trajectories by first, predicting needed activations by the ANN (trajectory kinematics in, predicted activations out) and then, feeding these predicted activations to its motors.

Breakdown of the steps will be as follows:

- Familiarizing with the general topics in the robotic control and the specific hardware/software used in this project
  - Reviewing the literature on controls in robotics
  - Reviewing the literature tendon-robotic control
  - Getting comfortable with the hardware in use
  - Getting comfortable with the G2P algorithm

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[1] Marjaninejad A, Tan J, Valero-Cuevas FJ Autonomous Control of a Tendon-driven Robotic Limb with Elastic Elements Reveals that Added Elasticity can Enhance Learning *42th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, 2020

[2] Marjaninejad A, Urbina-Meléndez D, Cohn BA, and Valero-Cuevas FJ Autonomous functional movements in a tendon-driven limb via limited experience *Nature Machine Intelligence*, 2019

- Getting comfortable with the robotic control interface, data acquisition, and control
  - Getting comfortable with the Roboy UI (ROS-based)
  - Being able to read and plot the sensory information
  - Being able to run some basic actuation signals (e.g. circular patterns) to the system and record the resulting kinematics
  - Being able to run some basic closed-loop controls on the system (PI controller)
- Implementing the G2P algorithm on the hardware
  - Creating the motor babbling functions
  - Creating the ML pipeline
    - Building the model in tensorflow
    - Setting up the hyperparameters in tensorflow
    - Setting up the data preprocessing pipeline in tensorflow
  - Running the motor babbling on the hardware
    - Adjusting amplitudes based on the physical observations
    - Storing the actuation values and the resulted kinematics
  - Training the ANN using the ML pipeline and the collected data
  - Controlling the robotic hardware for the desired trajectories using the G2P algorithm

Prerequisites

- Python
- ROS
- Tensorflow
- Fundamentals of robotics & control

Character

Guided Research | Bachelor thesis

Remarks

This project is a part of a long-term collaboration between the Valero Lab and Roboy. Successful students might be invited to continue their research as a Master Thesis or internship at USC or Roboy.