Master Project

Online Impedance Parameter Adjustment for Active Knee Prosthesis Using Reinforcement Learning

Can Çetindağ, Signals & Systems, TU Delft
c.cetindag@student.tudelft.nl

Koty Robert McAllister, Delft Center for Systems and Control, TU Delft
R.D.McAllister@tudelft.nl

Peyman Mohajerin Esfahani, Delft Center for Systems and Control, TU Delft
P.MohajerinEsfahani@tudelft.nl

Context

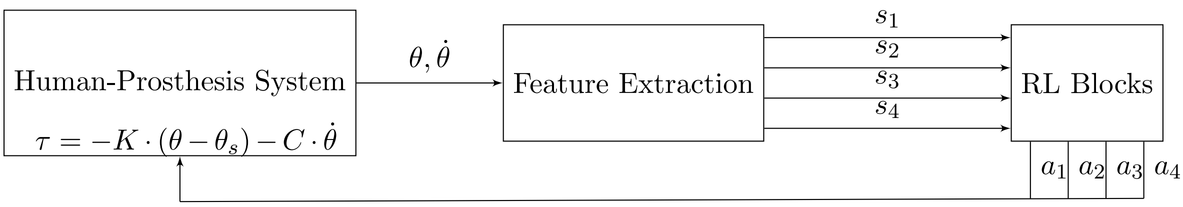
With the advancements in motorized wearable devices, the potential of the assistive and rehabilitative robotics increased remarkably. As one of the member of this family of devices, knee prostheses is not an exception. The active assistance provided by the device helps user to compensate the missing muscles and sustains low metabolic energy consumption as well as improving their gait symmetry. However, these devices suffer from the high number of parameters to fully benefit the advantages of the device. The adjustment process is usually held at the prosthetic workshop, where the prosthesis is fitted to the patient. As a result, the process is disturbed by the following situations,

1. The principle of the adjustment process is trial-and-error based on user feedback, thus, it is a tedious and long process.

2. As it is based on user feedback, it is suboptimal when the user doesn't know what to expect.

3. The prosthetist needs to be trained as they usually lack the technical knowledge and experience to comment on the parameters.

On top of the hardship of the manual parameter adjustment process, every individual has a unique way of walking. This variability is even higher within the amputee community. To capture these differences and reflect the necessary changes on the parameters, we propose the following basic reinforcement learning based system design.



The node depicted as *Human-Prosthesis System* is the custom MuJoCo (Multi-Joint dynamics with Contact) environment that will be designed as the first part of this thesis. This environment aims to simulate the interactions between human, prosthesis, and environment by applying the *Impedance Control Law* to each joint of the human model. Knee kinematics $(\theta, \dot{\theta})$ throughout the gait will be used to extract the states of the system through the node *Feature Extraction*. Each state $(s_1, s_2, ...)$ corresponds to a phase of the gait, which the final number will be determined during the design. *RL Blocks* are expected to learn the optimal policy to take an action (an upgrade on the impedance parameters $\Delta K, \Delta\theta_s, \Delta C$ of the knee) given the set of states. Desired outcome of the project is to personalize an active prosthetic knee in a reasonable amount of time and eliminate the mentioned problems of the trial-and-error based parameter adjusment process.

Project tasks

As a product of this thesis project, it is expected to achieve a reinforcement learning based walking parameter adjustment algorithm that will personalize the prosthetic leg to the user, in a reasonable amount of time and without any safety concerns. Requirements set on the algorithm are:

1. Personalize the walking parameters of the prosthetic leg such that the walking dynamics and symmetry of the user is improved.
2. Achieve convergence in a reasonable amount of time/steps.
3. Should be user-independent, convergence should occur regardless of the user's age, gender or body type.
4. Ensure the safety of the user during the personalization process.

This master thesis project is done in coorporation with Reboocon Bionics. The algorithm will be designed and validated through simulations, then will be implemented on real active knee prosthesis provided by Reboocon Bionics.