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**DOCTOR OF ENGINEERING SCIENCES**

of **Vu Thi Thu Huong**

The public defense will take place on **Friday 15th September 2023 at 1:00pm** in room **D.2.01** (Building D, VUB Main Campus)

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**GAIT DETECTION ALGORITHM APPLYING FOR TRANSTIBIAL PROSTHESIS**

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Abstract of the PhD research

New generations of powered transtibial prostheses have been developed throughout the past decade. Significant advancements in the prosthetic design aimed to restore both walking functionalities and amputation appearance. Nonetheless, there are still technological limitations. Amputees wearing prostheses consistently walk at slower speeds and with higher metabolic expenditure than those with biological limbs. While mechanical design efforts have primarily been focused, gait phase detection and locomotion mode detection algorithm are constrained.

Gait phases refer to the different periods within a walking step, dividing into specific phases such as stance phase, swing phase, initial contact, foot flat, heel off, toe off, etc. An accurate gait phase detection algorithm is essential for effective control of active prosthesis devices, which is designed to work based on the principle of energy cutting/injection to the motor to enhance user support and energy efficiency. Consequently, active prostheses require a more detailed gait phase than the passive ones in order to provide better mimic the natural movements of a biological limb to the control algorithm.

To tackle this challenge, this thesis aims to embed the gait phase prediction into the prosthetic control strategy to improve the prosthesis's precision and stability, thereby increasing the user's safety. Therefore, this thesis proposed a novel gait phase prediction algorithm called Exponentially Delayed Fully Connected Neural Network (EDFNN) that could predict a full gait cycle discretized within one percent. Besides, with a gait phase prediction, the prosthesis still struggles to emulate human walking because it is difficult to adjust the movements to respond to the transitions to different environments that they encounter during daily activities such as going up and down stairs, slopes, stopping waking, and flat walking.

Though existing studies have employed several classical machine learning methods for locomotion mode recognition, these approaches prove less effective for data with complex decision boundaries, leading to misclassifications. Accordingly, This thesis introduces several deep learning models - Recurrent Neural Network (RNN), Long Short-Term Memory (LSTM) neural network, and Convolutional Neural Network (CNN) for locomotion mode recognition, including level ground walking (LW), standing (ST), and stair ascent/stair descent (SA/SD) and evaluates their performance of them. The results show that CNN and LSTM models outperform other models and these models are promising for applying locomotion mode recognition in real-time for robotic prostheses.

The proposed gait phase detection method was applied for the AMP-foot, which is an active prosthesis in the Robotics & Multibody Mechanics research group. In order to collect the necessary data for training the deep learning neural network models, the thesis proposes an electronic measurement unit, which mainly consists of a microcontroller board, one IMU sensor attached to the lower shank, and two force sensors mounted beneath the foot. This unit records the acceleration and velocity of the subjects during various walking scenarios. Although the experiments are conducted offline, the detectable capabilities of the deep learning approaches provide an opportunity to reduce detection delays for real-time applications and the capability to reproduce the dynamic functions of the limbs of amputees.