Passive dynamic system for energy returning on trans-tibial prosthesis

Ph.D Thesis Overview

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Introduction

Introduction

The purpose of this presentation is to let you know the general research question, the objectives, activities done to date and the tasks in this internship.

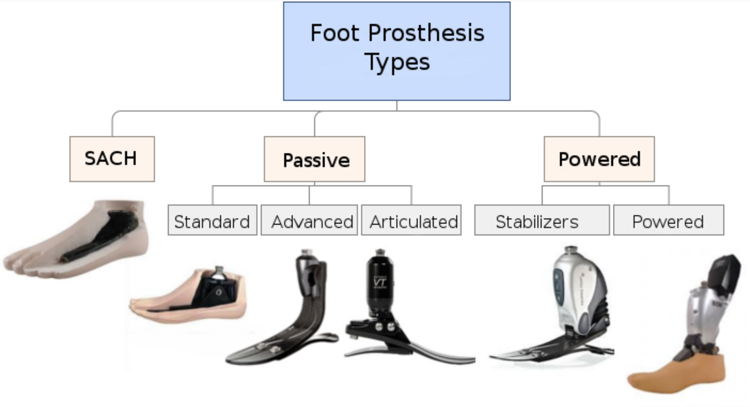


Figure 1: Generalized categorization of ankle-foot prosthesis according to Cherelle *et al.*[3] and Versluys *et al.* [15]. From left to right: SACH foot, sagital degree of freedom foot, OSSUR® flex foot, Echelon foot®, Proprio foot from OSSUR® and BiOM® from iWalk Inc.

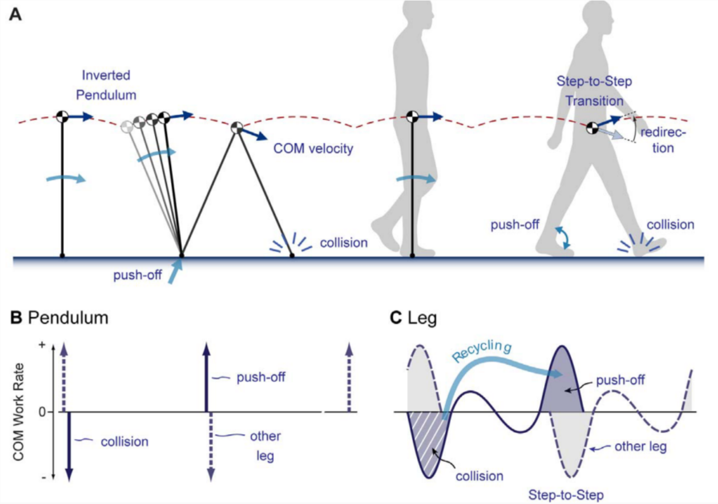


Figure 2: *(A) Synthesizing bipedal walking to an inverted pendulum to support the body COM. The COM velocity is redirected between steps when the other leg contacts the ground with a dissipative collision. (B) The rate of work performed on the COM by ideal pendulum-like legs vs. stride time. Work is theoretically minimized by pushing off impulsively (indicated by arrows) just before the opposite leg's collision"* Paragraph and figure taken from Collins and Kuo[4].

Dynamic Joint stiffness

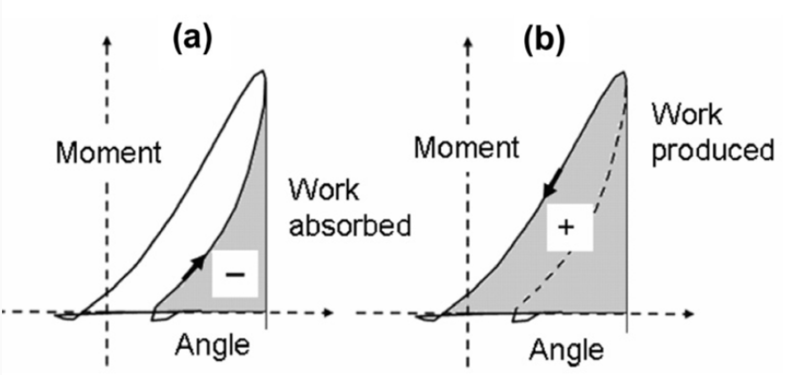


Figure 3: Representation of Work Produced, Net work and Work Absorbed Section with particular reference to the work absorbed (left panel) and work produced (right panel) in ankle DJS[5].

Dynamic Joint stiffness

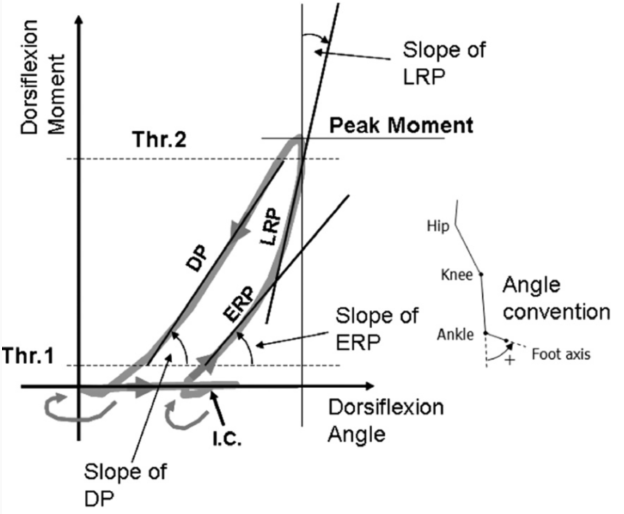


Figure 4: Descriptive parameters of the moment–angle loop. Taken from Crenna and Frigo[5]

Specific Objectives

Problem Statement

The recent passive prosthesis for transtibial amputees produce disorders in the dynamic parameters of the gait, owing to the absence of positive work of the limb loss.

General Objective

To suggest an ankle-foot prosthesis being able to generate — through a passive dynamic system — the positive work needed for push-off after dual-flexion phase, taking advantage of the energy lost at initial contact of the gait.

Specific Objectives and Deliverables

Objective No 1

Option A

Through the extraction of experimental data, we will identify the biomechanical parameters and the work-loop slope in ESR prosthesis users and able-bodied people in order to obtain the ankle quasi-stiffness in both cases and establish different dynamic patterns in both.

Deliverables

An article relating the pathological Dynamic Joint Stiffness of the ankle-joint — and other joints if it is possible — compared with able-bodied subjects.

Real experiments

No.	Amputation condition	No. of subjects.	No. of trials per patient	Total.	General Observations
1	Bilateral	2	3	6	
2	Trans-tibial	3 left, 3 right	5	30	
3	Trans-Femoral	7 left, 3 right	5	50	Different speeds and sockets

Table 1: Experimental gait analysis in Colombian amputees

Data Available in Literature

No.	Title	Authors	No. of subjects
1	A multiple-task gait analysis approach: Kinematic, kinetic and EMG reference data for healthy young and adult subjects	Bovi et al. [2]	40
2	An elaborate data set on human gait and the effect of mechanical perturbations.	Moore et al. [12]	15
3	Regression analysis of gait parameters with speed in normal children walking at self-selected speeds.	Stansfield et al. [14]	16
4	Benchmark Datasets for Bilateral Lower-Limb Neuromechanical Signals from Wearable Sensors during Unassisted Locomotion in Able-Bodied Individuals	Hu et al. [7]	10

Table 2: Selected Studies to be analyzed

Data Available in Clinical Databases

ID	Name	No. of studies	Requirement						samples accepted
			—1	2	3	4	5	6	
1	Physiobank databases [6]	<100	—X	-	-	O	O	O	0
2	Clinical Gait analysis [10]	13	—O	X	O	O	O	O	1
3	Koroibot [11]	544	—O	O	-	O	O	O	10
4	Motion Capture HDM05 [13]	< 50	—O	O	X	O	O	O	0
5	CMU Graphics Lab Motion Capture [1]	< 50	—O	-	X	O	O	-	0
6	MAREA Dataset [9]	2	—O	O	X	-	O	O	1
7	ENABL3S [7]	1	—O	O	X	O	O	O	1

Table 3: Clinical Databases found in the web.

Example of analyzed data

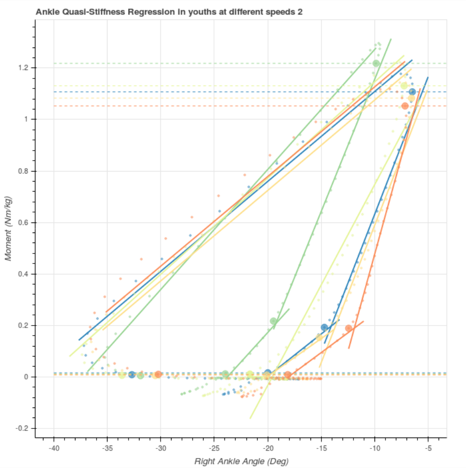


Figure 5: Dynamic Joint Stiffness of the ankle, being linearized according to each sub-phase of the gait

Objective No. 2

Design Optimization

Through the analysis of pure data found in the literature, we will attempt to give insights about the dynamic behaviour of the ankle could describe unseen aspects of different types of gait and also to identify non-linear approximations of the quasi-stiffness.

Deliverables

An article relating with a methodology to give an accurately prediction detecting the instances in gait or predicting relationships between different parameters of the gait (i.e. Velocity, Body length, Body mass).

Framework of the Biomechanical process

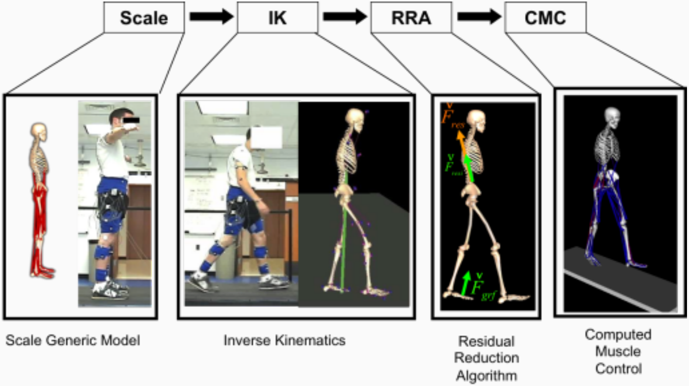


Figure 6: Typical work-flow for generating a muscle-driven simulation after importing experimental data.

Objective No. 3

Option B

To get an optimal design of an ankle-foot prosthesis made mainly by composites so that the resulting macro-structure has the maximum energy returning capacity.

Deliverables

An article related with the framework of the design process to obtain the prosthesis and a patent probably.

Example of the optimization activity

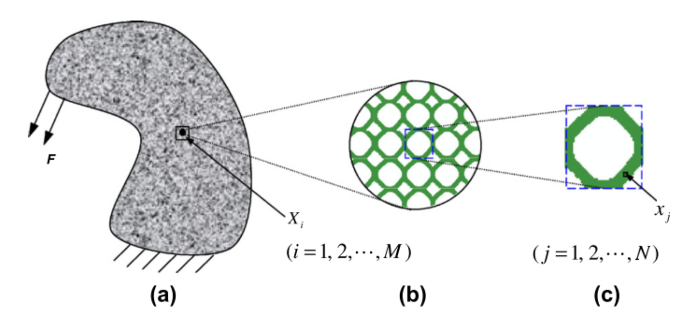
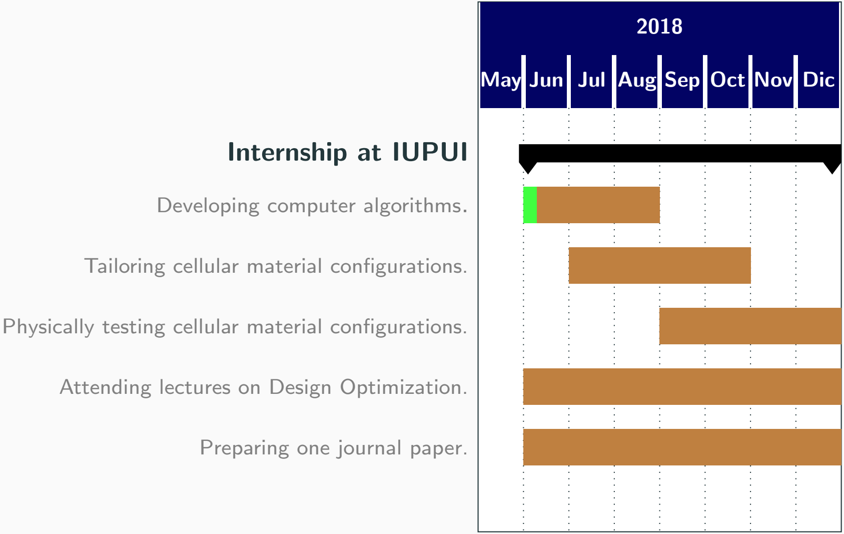


Figure 7: A structure composed of cellular materials or composites (a) macro-structure; (b) micro-structure; (c) a unit cell. Taken from [8]

Internship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Internship at IUPUI
Developing computer algorithms.
Tailoring cellular material configurations.
Physically testing cellular material configurations.
Attending lectures on Design Optimization.
Preparing one journal paper.

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Questions

Thank you!