# Virtual Constraint Control of a Powered Prosthetic Leg: Experiments with Transfemoral Amputees

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*Abstract*—**Powered prosthetic legs could significantly improve mobility for lower-limb amputees, but the performance and clinical viability of these devices are currently limited by complex control systems that independently control different joints and time periods of the gait cycle. Recent efforts have been made to address these challenges with a unifying control model used by recent bipedal robots, in which virtual constraints define joint patterns as functions of a monotonic variable that continuously represents the gait cycle phase. This talk reports initial results of virtual constraint control of a powered prosthetic leg with three transfemoral amputee subjects walking overground and at variable cadences on a treadmill.**

***Keywords: powered prosthetics; control; virtual constraints***

## I. Introduction

With the addition of sensors and motors, powered prosthetic legs must continuously make control decisions throughout the gait cycle [4], thus increasing the complexity of these devices. This complexity is currently handled by discretizing the gait cycle into multiple discrete "phases," each having its own separate control model—sometimes with more than a dozen control parameters per joint. Multiple tasks (e.g., walking, standing, and stair climbing) add up to hundreds of parameters for a multi-joint prosthetic leg, presenting a critical challenge to the clinical viability of these high-tech devices. In an initial effort to address these challenges, this talk presents recent experimental results with a novel nonlinear control method that continuously parameterizes the gait cycle with a mechanical phase variable, by which the prosthesis matches the human body's progression through the cycle [1, 2].

## II. Methods and Results

This autonomous control method was inspired by recent breakthroughs in walking robots, which can walk, run, and climb stairs by "virtually" enforcing kinematic constraints that define desired joint patterns as functions of a mechanical variable [5]. We modeled two virtual constraints using a popular concept in the prosthetics field known as *effective shape*—the trajectory of the center of pressure (COP) mapped into a leg-based reference frame [3]. These virtual constraints depend on the COP as a phase variable, which moves monotonically from heel to toe during steady gait. We designed and implemented a control system to enforce these virtual constraints on the powered above-knee Vanderbilt leg (designed in [4]).

Recent experiments with three above-knee amputee subjects at the Rehabilitation Institute of Chicago will be presented. All three subjects achieved stable walking overground (Fig. II) and on a treadmill at variable cadences, demonstrating the clinical viability of this novel control approach.

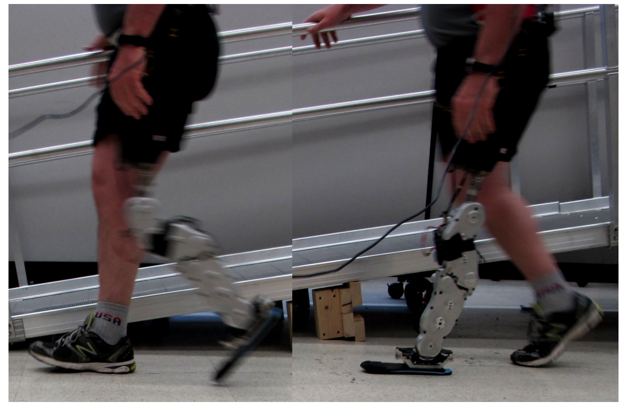

Fig. 1. Images of transfemoral amputee subject walking on the Vanderbilt prosthetic leg (designed in [4]) using virtual constraints.

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