I. BACKGROUND

The gait cycle is typically viewed as a periodic sequence of discrete events, starting with heel contact during initial stance and ending with knee extension during late swing. This convention has informed the design of control strategies for powered prostheses and orthoses, which almost universally utilize the concept of a finite state machine (FSM), e.g., the five states in Fig. 1. Each state (or phase) of the FSM has a separate control model that usually enforces joint impedances \(^1\) or tracks patterns of joint angles, velocities, or torques. These prosthetic legs switch between control models based on switching rules or estimates of gait cycle phase that rely on multiple sources of sensory feedback. The higher-level state machines required for multiple ambulation modes (e.g., level ground, ramps, and stairs) can involve hundreds of control and switching parameters, presenting a critical challenge to the clinical viability of powered prostheses and orthoses \(^2\).

II. PROPOSED APPROACH

This talk will pose the question as to whether the field should pursue alternative approaches to the FSM. Instead of discretely representing the phases of gait, a continuous representation of phase could parameterize a nonlinear control model for larger portions of the gait cycle, such as the stance period, swing period, or possibly even the entire gait cycle (Fig. 1). One continuous representation of phase could be a mechanical variable that is measured by a prosthesis to match the body’s progression through the cycle \(^3\). This autonomous control method is 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 phase variable \(^4\).

Recent experiments tested a unified stance controller with three above-knee amputee subjects walking overground and on a treadmill at variable cadences \(^3\). A unified swing controller was then proposed in \(^3\). This talk will show preliminary results on unifying the entire gait cycle using virtual constraints. These new controllers will soon be tested on the UTD leg in Fig. 2. Although FSMs may remain necessary for switching between ambulation modes, the proposed methods promise to minimize or eliminate switching within each gait cycle.

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REFERENCES