Identifying mechanisms underlying variable responses to interventions during walking

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***Abstract*— Effectively prescribing interventions to improve mobility is challenging. Methods that can identify underlying mechanisms that drive heterogeneous responses between individuals may improve outcomes. Simple gait measures, like center-of-mass motion, must be controlled during walking, regardless of physiology. If inter-individual differences in center-of-mass control influence responses to an intervention, like prescription of an ankle-foot orthosis, these outcomes may help differentiate between individuals and guide treatment. We used a template model-based approach combined with data-driven identification of hybrid reduced-order dynamics to estimate center-of-mass control policies.**

Keywords—data-driven modeling, hybrid dynamics, pathological gait

I. Introduction

Effectively prescribing surgical interventions or assistive devices for individuals with motor impairments is challenging and intervention responses are variable [1]. Identifying mechanisms driving individual responses may inform interventions. However, individual differences in motor control and physiology make identifying mechanisms difficult [2]. Better quantifying center-of-mass (COM) control, which is fundamental to walking regardless of pathology, provides an initial step toward testing potential mechanisms.

We propose a template model-based approach, combined with data-driven identification of hybrid nonlinear dynamics to approach this challenge [3, 4]. If two individuals exhibit different intervention responses, we expect that the structure or timing of the dynamics describing each individual's COM control will also differ. Such analyses can help us understand how individuals with motor impairments control locomotion and may also indicate the nature of mechanisms impacting intervention responses. We investigated template control policies of unimpaired and impaired walking.

II. Methods

We estimated COM walking dynamics using a modified spring-loaded inverted pendulum template [4]. We collected marker trajectories and ground reaction forces (GRFs) from seven unimpaired individuals and one stroke survivor with left-leg hemiparesis walking on a split-belt treadmill.

We identified reduced-order hybrid dynamics using sparse regression and used information criteria to select "plausible" model dynamics, which contain low-complexity and high predictive accuracy compared to other candidate dynamics [3]. This approach is analogous to rapidly testing and refuting hypotheses about COM control. We fit 3-D dynamics explaining GRFs during walking, selecting and comparing plausible dynamics across subjects [4].

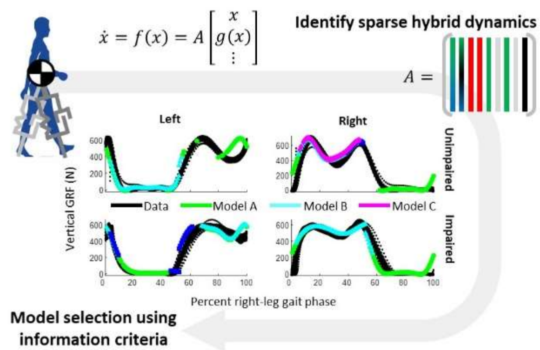

Fig. 1. An overview of the analysis pipeline. Different hybrid dynamics of vertical GRFs (center) are shown in different colors.

III. Results and Discussion

Plausible unimpaired dynamics of vertical GRFs typically consisted of four sets of dynamics consisting of three-to-six terms and reflecting single and double-limb support phases for each leg (Fig. 1). Limb stiffness was consistently included in the dynamics. Conversely, the stroke survivor's impaired-leg exhibited purely damped dynamics during left leg loading response, consistent with this individual's preference for right-leg propulsion. Extension to other individuals or impairments, or more physiologically-detailed models may help identify mechanisms driving intervention responses.

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