Analytical decomposition of gait kinematics reveals spatial and temporal sources of step length asymmetry post-stroke

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1 Motivation

Post-stroke survivors often adopt an asymmetric walking pattern that impairs their mobility. Notably, taking asymmetric steps leads to poorer transfer of energy during step-to-step transition[1], likely affecting these patients walking speed [2]. Consequently, a primary effort in gait rehabilitation of people after stroke is to correct their step length asymmetry.

2 State-of-the Art

While step length asymmetry is often considered to be directly dependent on the poor control of limb position (i.e., spatial limb control), our previous work suggests that it is also affected by the control of step timing (i.e., temporal limb control)[3], and that these two domains can be controlled independently[4]. Consequently, multiple combinations of spatial and temporal control deficits can cause the same degree of step asymmetry post-stroke. Therefore, to effectively correct patients' step length asymmetry, it is necessary to identify the patient-specific contributions of spatial and temporal factors underlying their individual asymmetry.

3 Own Approach

The goal of this study is to characterize the relative contributions of spatial and temporal aspects of gait to step length asymmetry. To this end, we developed an analytical model that parses asymmetry into independent spatial and temporal contributions.

We verified our model by using it to reproduce the wide range of asymmetry values that 25 healthy subjects adopted when walking on a split-belt treadmill, which has two belts that move at different speeds. Split-belt treadmill walking causes a significant increase in step length asymmetry in healthy subjects and this asymmetry is gradually reduced over the course of adaptation as subjects counteract the predictable and sustained split-belt perturbation.

Finally, we applied the model to dissociate the spatial and temporal contributions to asymmetry in 4 hemiparetic individuals.

4 Current Results

We found that our analytical model could describe asymmetry values accurately. We could account on average for 99% of the variability in asymmetry values in two groups of healthy subjects experiencing different magnitudes of split-belt perturbations (2:1 and 3:1 speed-belt ratio).

As expected, we found that deficits in both foot placement (spatial control) and timing (temporal control) can make significant contributions to asymmetry post-stroke (Figure 1)

Interestingly, we observed instances when temporal and spatial deficits opposed one another in their contributions to asymmetry, resulting in patients with seemingly symmetric walking patterns (i.e., patient S1).

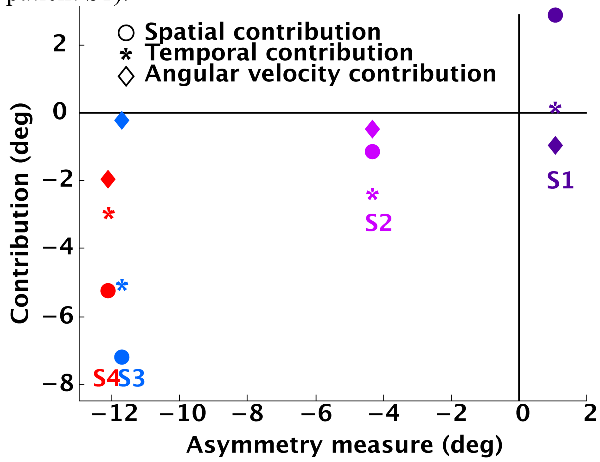

Figure 1. Examples of the spatial and temporal contributions to asymmetry in 4 stroke survivors. The contributions of spatial, temporal and speed dependent deficits to each patient's asymmetry (value in x-axis) are represented by a different color.

5 Best Possible Outcome

Promising studies have shown that step asymmetries post-stroke can be corrected after walking on a split-belt treadmill (e.g.[5]. While promising, split-belt training does not have similar effects across all patients[5], likely because of patient-specific gait impairments. Therefore, our analysis holds the promise of being able to reveal patient-specific deficiencies that can be used to tailor the parameters of split-belt training to patient-specific impairments.

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