Adapting Stepping Regulation to Laterally Maneuver

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***Abstract*— Humans regulate both step width and mediolateral position during normal, steady state walking. Here, we determined if such a control template could capture human stepping dynamics during lateral maneuvers. We demonstrate that varying the stepping goals and modulating the control proportion dramatically extends the applicability of this template to many walking tasks.**

Keywords—Goal-Directedness, Regulation, Lateral Maneuvers

I. Introduction

Humans maintain balance and achieve other walking-specific goals by modulating foot placement from step-to-step [1]. We previously developed a computational framework for lateral stepping regulation in which goal functions are used to theoretically define a task and determine the set of all possible task solutions [2]. During straight-ahead steady-state walking, multi-objective regulation of step width and lateral position, [w, z_B], replicates human stepping dynamics [2].

However, humans readily perform many more adaptable locomotor behaviors than steady-state walking [3], including lateral maneuvers. It is not clear *a priori* that our previous framework, derived to replicate only straight-ahead steady-state walking, could capture complex locomotor tasks. Indeed, one might reasonably expect entirely new frameworks, involving very different stepping strategies and goal functions, be required to execute such highly non-steady-state lateral maneuvers.

II. Experiment

Twenty young, healthy adults (9M/11F; age 18-35) each performed 4 lateral maneuvers between 2 parallel paths, centered 0.6m apart, projected onto a treadmill in a virtual environment. Stepping time series (z_L, z_R, z_B, w) were extracted from each maneuver. From these, means and standard deviations were quantified at each step. Humans performed these lateral maneuvers quickly and easily in 2-3 steps (Fig. 1).

III. Simulations

Our original multi-objective model could not replicate human stepping during lateral maneuvers (Fig. 1; red). Here, we assessed whether modulating the parameters within this model would capture human stepping during lateral maneuvers.

We first derived the optimal two step strategy to change from any initial stepping goals, $[w^*, z_B^*]_i$, to any final stepping goals, $[w^*, z_B^*]_f$. We then allowed the model to systematically adapt its control proportion (e.g., the relative weighting between w and z_B control). When combining these two adaptions, the mean w and z_B predicted by the model fell within the experimental range at each step of the lateral maneuver (Fig. 1; blue).

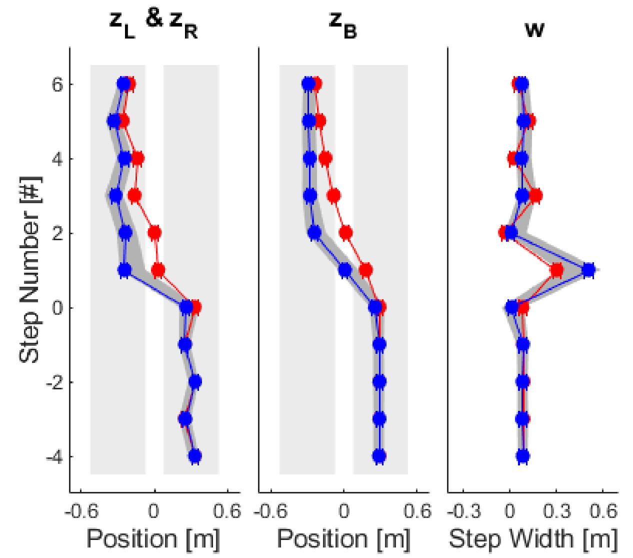

Fig. 1: Time series simulations from the original model (red) [2] and the novel adaptive model (blue) overlayed on top of the experimental ranges (dark grey) during the lateral maneuver.

IV. Discussion

Here, we show that, despite its simplicity, our multi-objective framework also captured human stepping during challenging lateral maneuvers. Our original model was developed for steady-state walking, assuming errors with respect to the goals and subsequent stepping corrections would be small. This assumption supported the use of a simple, linear, single-step controller to generate each step [2]. As the lateral maneuvers assessed here strongly violate this steady-state assumption, one cannot assume *a priori* that regulating these same task goals alone would be sufficient to even perform such a task, much less capture human stepping during this task.

The lateral maneuver assessed here was relatively abrupt and thus among the more challenging of those humans are likely to experience during real-world walking. Therefore, the success of our new adaptive step-to-step stepping regulators implies that our goal-directed multi-objective lateral stepping regulation template [2] extends to a wide range of many walking tasks well beyond just straight-ahead steady-state walking.

References

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