Estimating Muscle Excitations Using a Reduced sEMG Array Across a Range of Walking Speeds

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I. INTRODUCTION

- **Remote gait analysis** enables optimal patient evaluation and provides a means for personalizing rehabilitation.
- Innovations needed in remote gait analysis:
  1. Estimate clinically relevant biomechanics (e.g. muscle force)
  2. Practically deployable sensor systems (fewer sensors)
- Physics-based solutions are generally applicable but require many sensors
- Regression techniques are less general but can be trained to use inputs from fewer sensors

II. POTENTIAL HYBRID SOLUTION

- Figure 1 summarizes some (not all, very oversimplified) of the dynamics that must be learned by a regression-based solution.
- A **potential hybrid solution** may be to approximate the dynamics of the first (purple) box in Figure 1 and inform the other dynamics using physics-based techniques. This reduces to the problem of estimating unmeasured muscle excitations from a subset of measured excitations (from a few sEMG sensors).
- It has been suggested that this mapping may exist, and we recently proposed a Gaussian process regression-based solution.

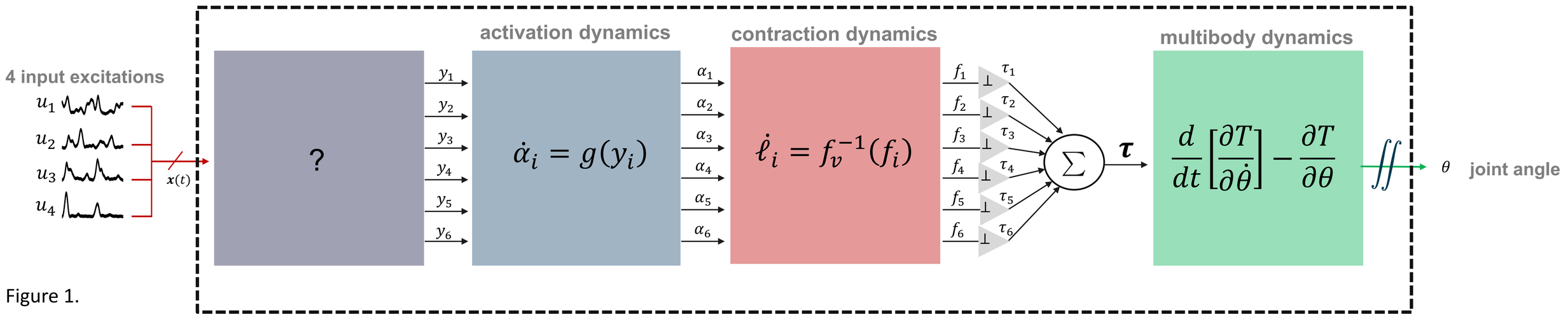

Figure 1.

III. APPROXIMATING SYNERGY FUNCTIONS

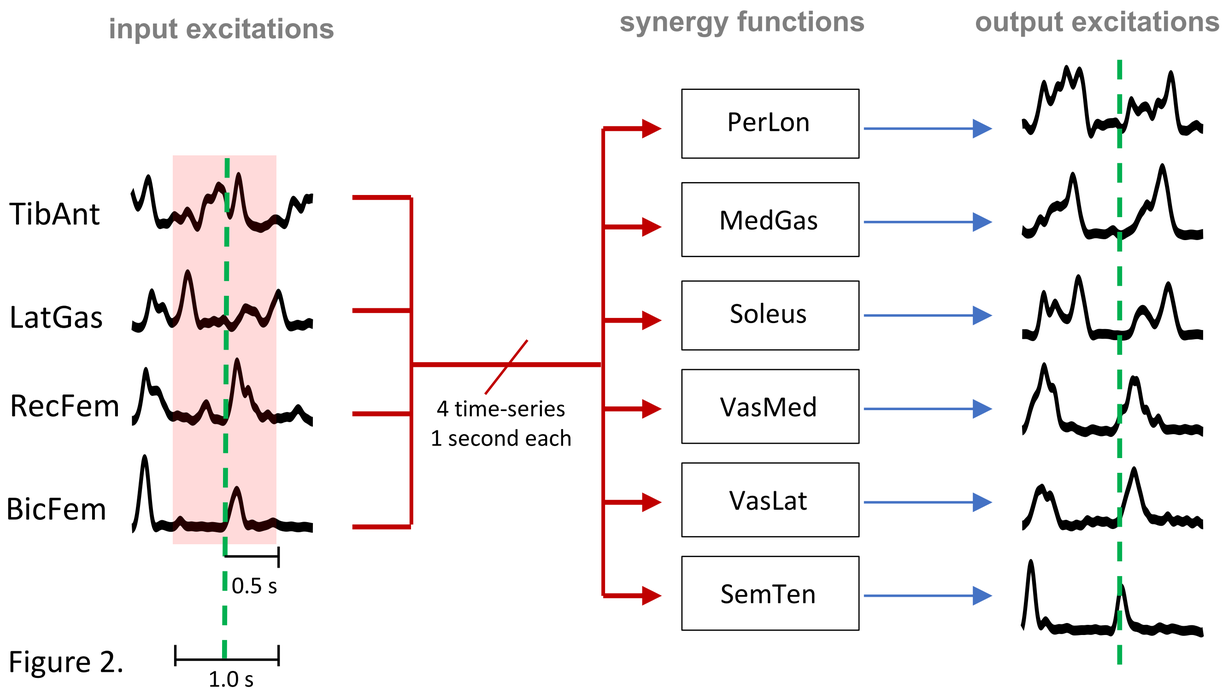

Figure 2.

- Synergy functions describe the mapping from a window (red shaded area) of input muscle excitations to the excitation of an output muscle at the output time (green dashed line).
- We recently proposed a Gaussian process regression-based technique for approximating these synergy functions
- The effect of training/testing using different walking speeds on estimation performance is unknown

IV. INVESTIGATING EFFECT OF SPEED

- One female walked for one minute at three self-selected speeds: slow (S, 0.4 m/s), normal (N, 0.8 m/s), and fast (F, 1.2 m/s)
- 10 sEMG sensors (1000 Hz) used to measure four input muscle excitations and six output muscle excitations (Figure 2).

Experiment 1 (interpolation)
Train: slow, fast
Test*: slow, normal, fast

	S	N	F
r	0.61	0.75	0.91
VAF	76%	82%	92%
MAE	3.4%	3.2%	2.1%

Experiment 2 (extrapolation)
Train: slow, normal
Test*: slow, normal, fast

	S	N	F
r	0.59	0.79	0.71
VAF	79%	85%	71%
MAE	3.2%	2.6%	4.7%

**All test set data were not included in the training set*

- Preliminary results suggest the proposed technique may allow estimation of muscle excitations for unseen walking speeds with superior performance for the interpolation case. The extrapolation results were similar to the estimation for slow walking speeds which were represented in the training set. We expect input window size plays a significant role in interpreting these results and will be investigated in future research with more subjects.