Gait Event Detection Using an LSTM Network

10-701 Project Presentation

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Introduction

- Goal: accurately detect gait events (heel strike, toe off) in video-based motion capture data of human walking gait
- Necessary to analysis of changes in gait that arise from training, disease, aging, etc.

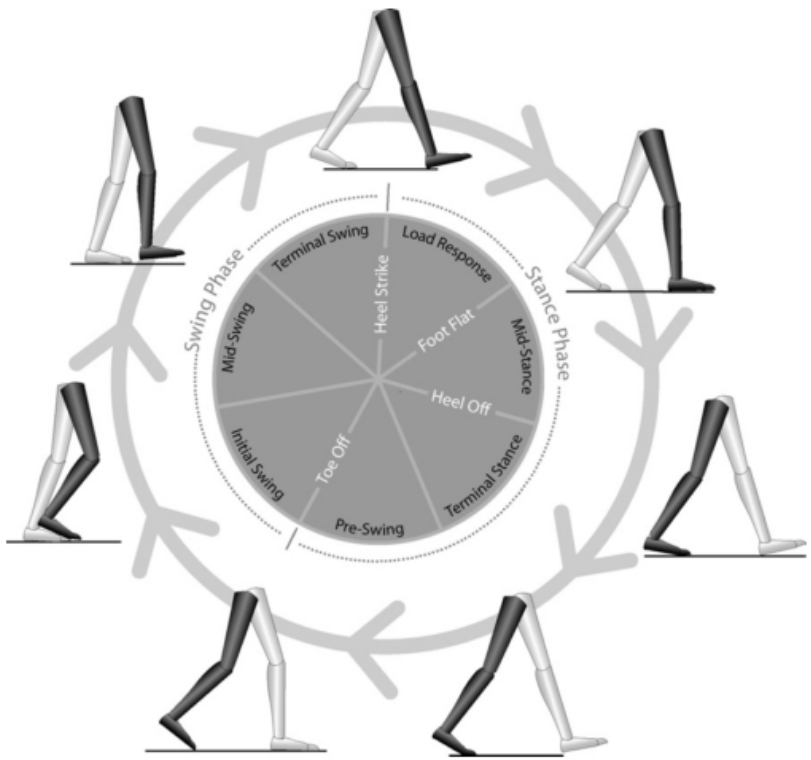


Figure 1: Gait events [Rueterbories et al., 2010]

Data

- All data are time series
- **Input:** 3D locus of 18 motion capture markers (54*N reals)
- **Output:**
  - Raw: Event takes place $\Rightarrow$ 1; else $\Rightarrow$ 0 (4*N bools)
  - Equivalent: Leg in stance phase $\Rightarrow$ 1; else $\Rightarrow$ 0 (2*N bools)
- Training dataset:
  - Sample rate: 100 Hz
  - 240 000 samples (8 subjects $\times$ 3 trials $\times$ 10 000 samples)
  - Ground truth from force plates on treadmills (very accurate)

Baseline Methods

- Signal processing approach [O'Connor et al., 2007]
  - Heuristic based on position and speed of heel and toe markers
  - **Pros:**
    - No training is needed
    - Good accuracy when input data is clean
  - **Cons:**
    - Sensitive to noise in input; resulting in gross mis-predictions
    - Need to manually specify sensitive thresholds
    - Heavy pre-filtering helps reduce noise but reduces accuracy
- Feed-forward Neural Network [Miller, 2009]
  - Sliding window centered around the desired marker
  - **Pros:**
    - TODO
  - **Cons:**
    - Heavy preprocessing (dimensionality reduction, windowing, etc.); requires manual picking of parameters
    - TODO

Our Approach: LSTM

- Motivation:
  - Avoid manual picking of sensitive parameters (window size, threshold, filter cutoff, etc.)
  - Human walking can be modeled as a dynamic system; RNN (Recurrent Neural Network) learns dynamic systems
  - Any gait cycle may depend on ones preceding it
- LSTM cell: RNN building block for variable time-dependence
- Network architecture:
  - Inputs (54 reals)
  - n LSTM cells (n reals in $[-1, +1]$)
  - Output layer (softmax/sigmoid)
  - Outputs (2 reals in $[0, 1]$)
- Implementation:
  - Torch/Lua
  - LSTM cell by de Freitas (Oxford University, Google Deepmind)
  - AWS EC2 GPU instance (g2.2xlarge)

Results

	mean	std	mistake
O'Connor	XXXXXXX	XXXXXXX	XXXXXXX
Miller	XXXXXXX	XXXXXXX	XXXXXXX
LSTM	XXXXXXX	XXXXXXX	XXXXXXX

Results

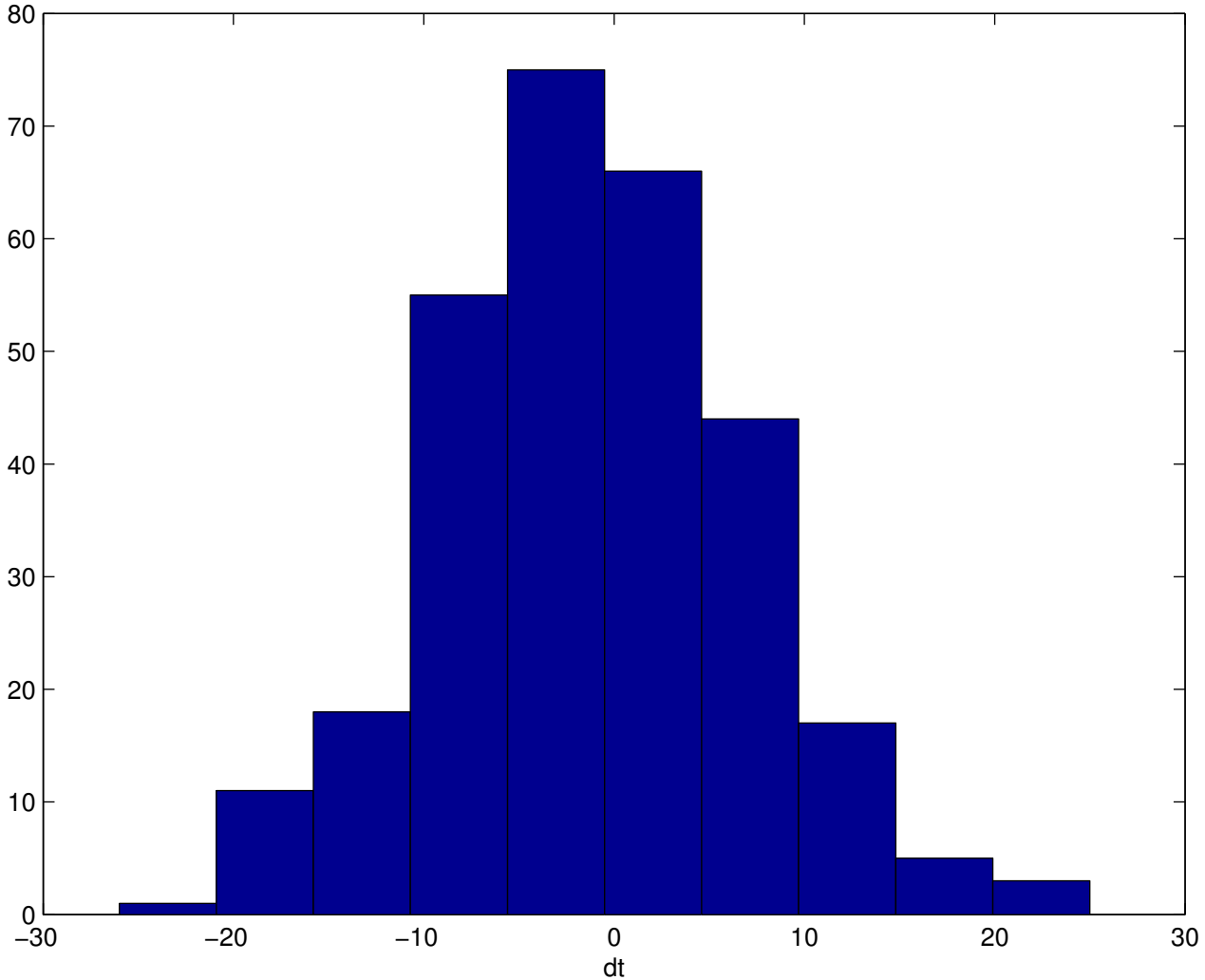
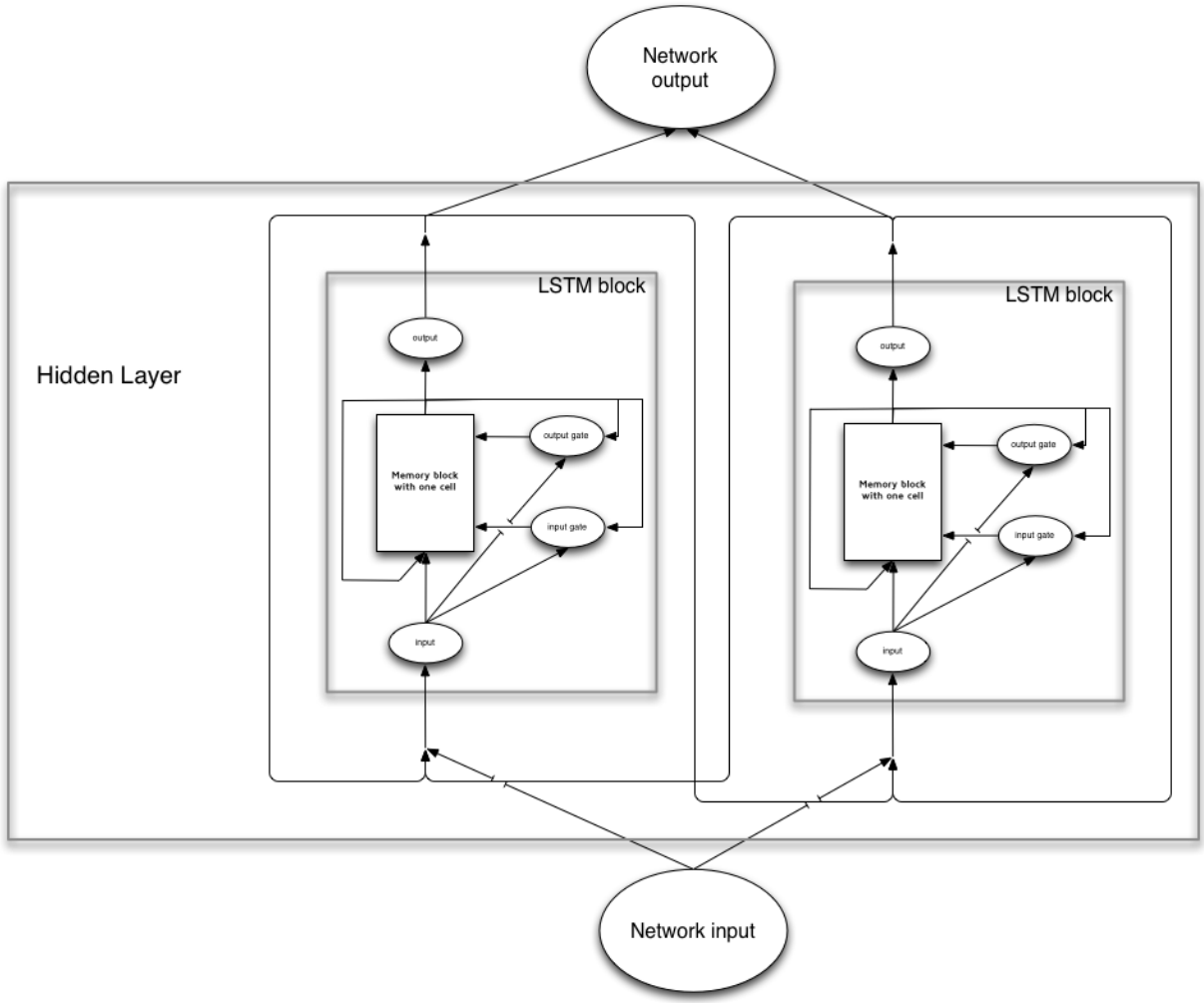


Figure 2: Histogram Miller

Q&A

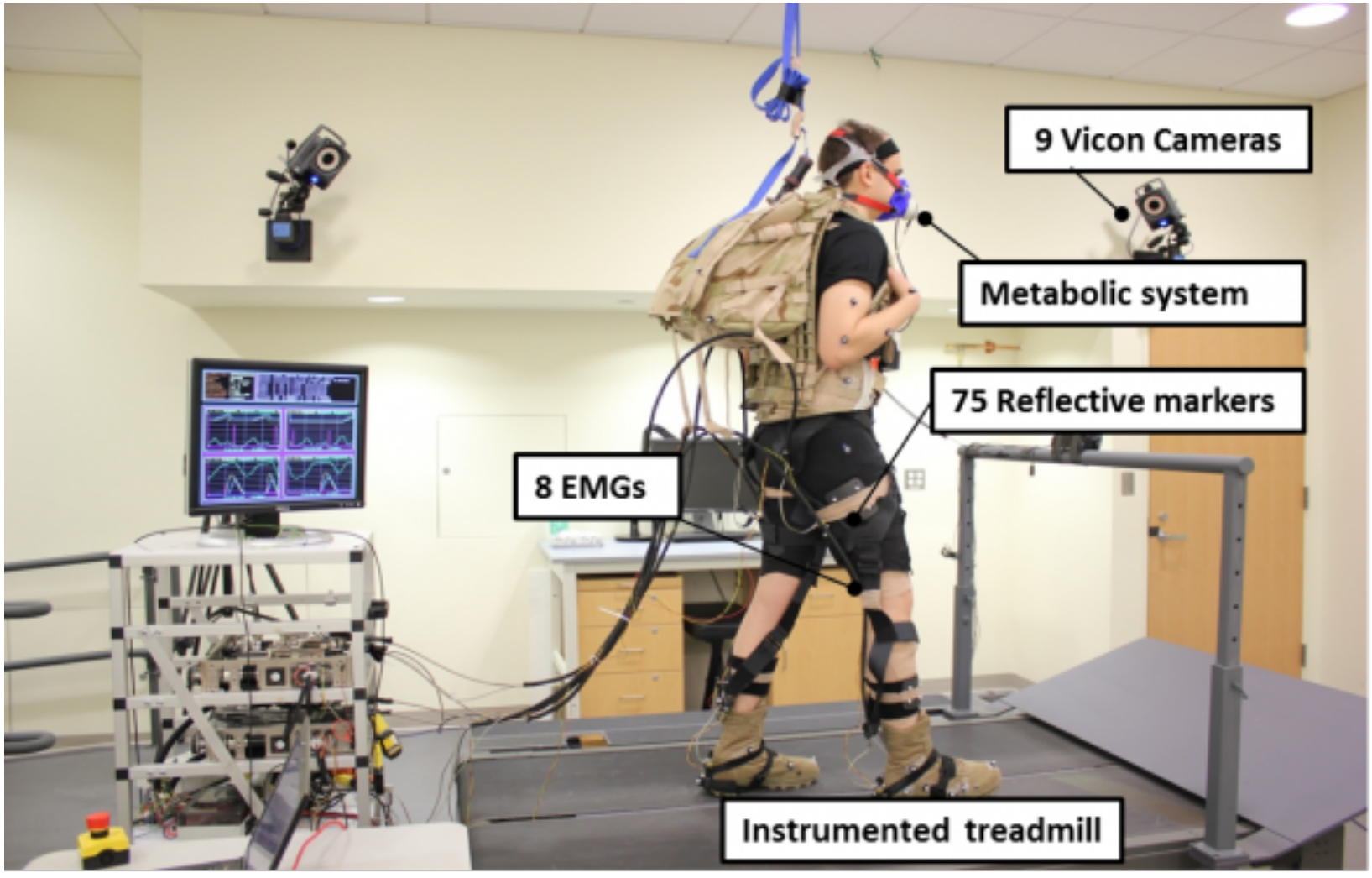
Thank you for your attention!

Network architecture



from `http://stackoverflow.com/q/17454402/1163213`

Lab setup (not our lab but similar)



from http://biodesign.seas.harvard.edu/soft-exosuits