NSF I-UCRC on Intelligent Maintenance Systems;
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A SYSTEM-BASED APPROACH TO MONITORING OF HUMAN NEUROMUSCULOSKELETAL SYSTEMS

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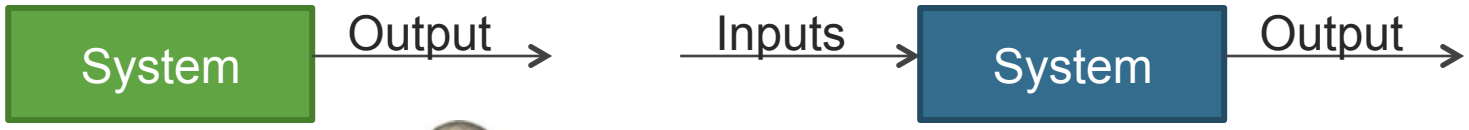
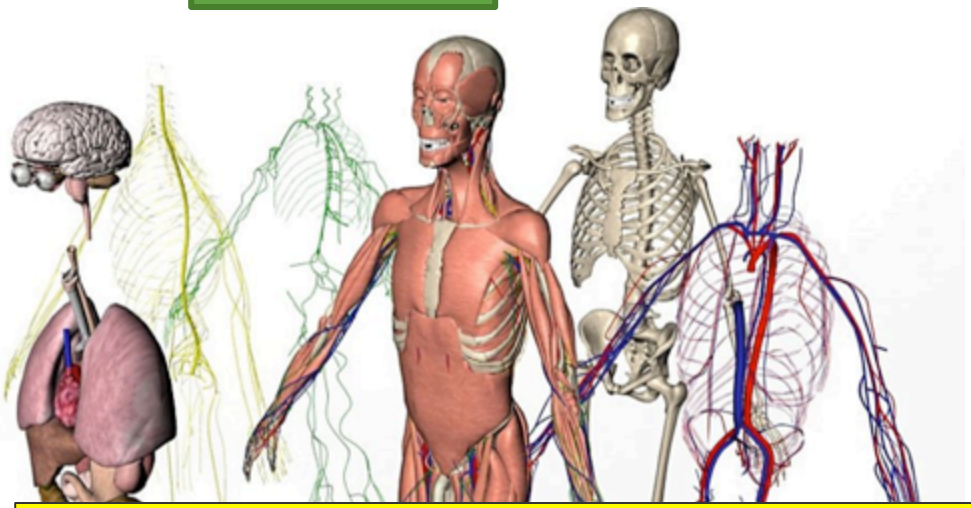
PRESENTATION OUTLINE

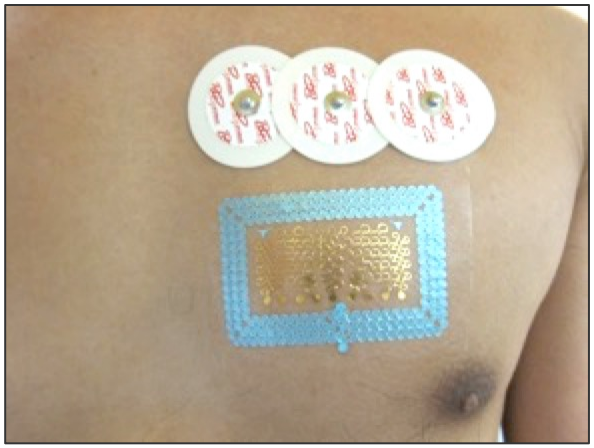
- Introduction
- Methods for System Based Monitoring of Performance of Human Neuromusculosceletal (NMS) Systems
- Results
- Conclusions and Future Work

CONDITION MONITORING PARADIGM FOR HUMAN BODY SYSTEMS

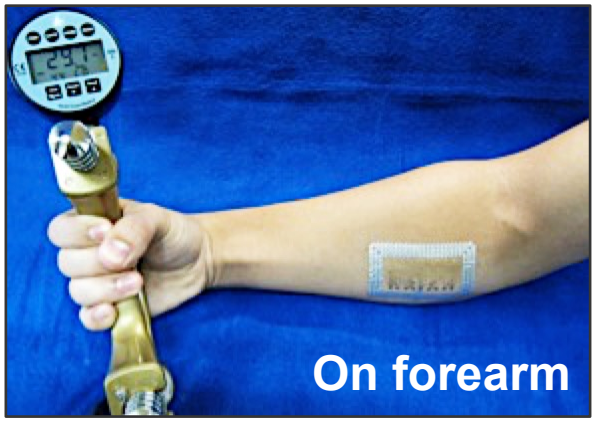
- Symptomatic versus system-based monitoring







Challenges:
- Incomplete system information
- Inaccessibility of input
- Indirect measure of output
- Nonlinear input-output relationship



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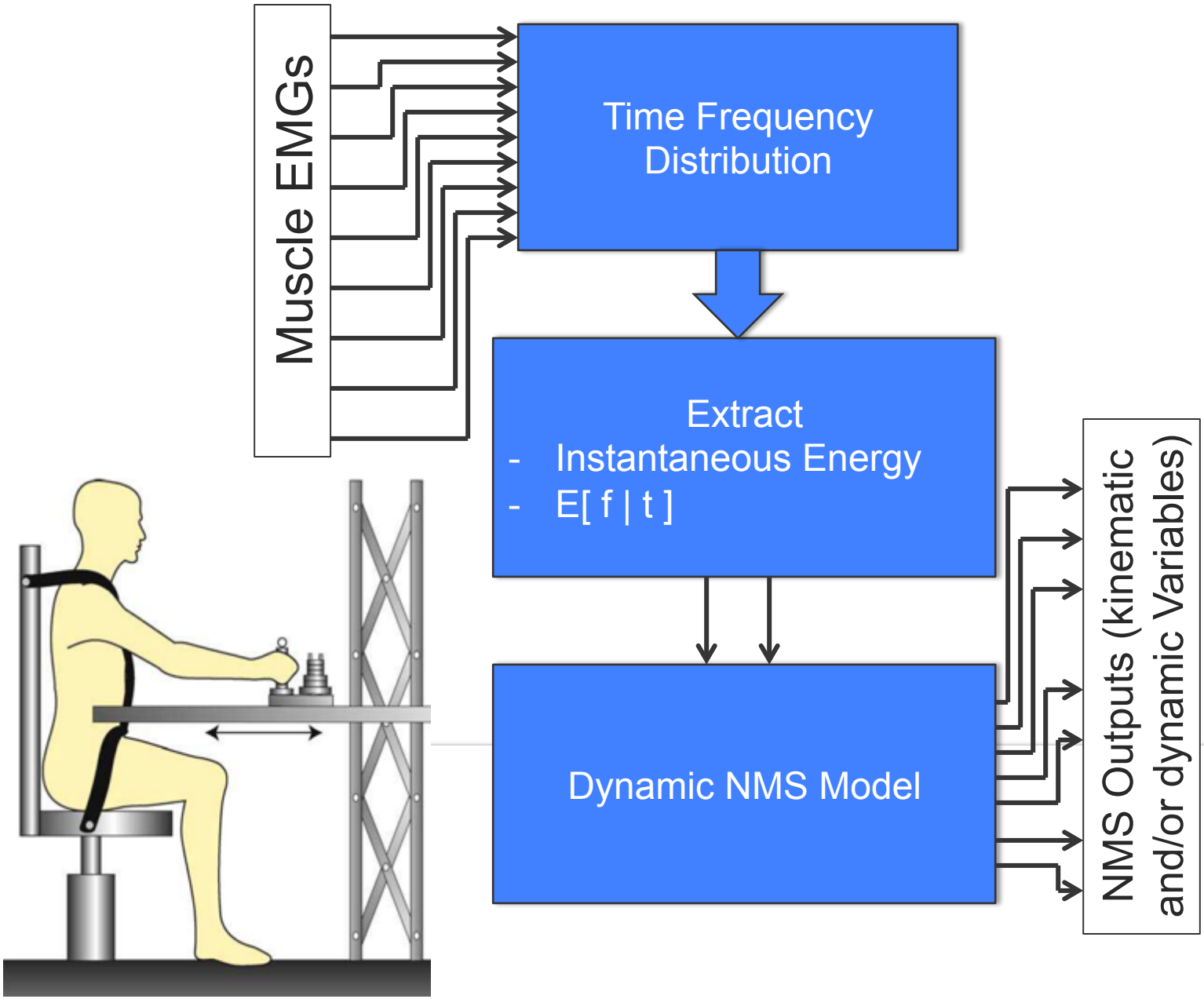
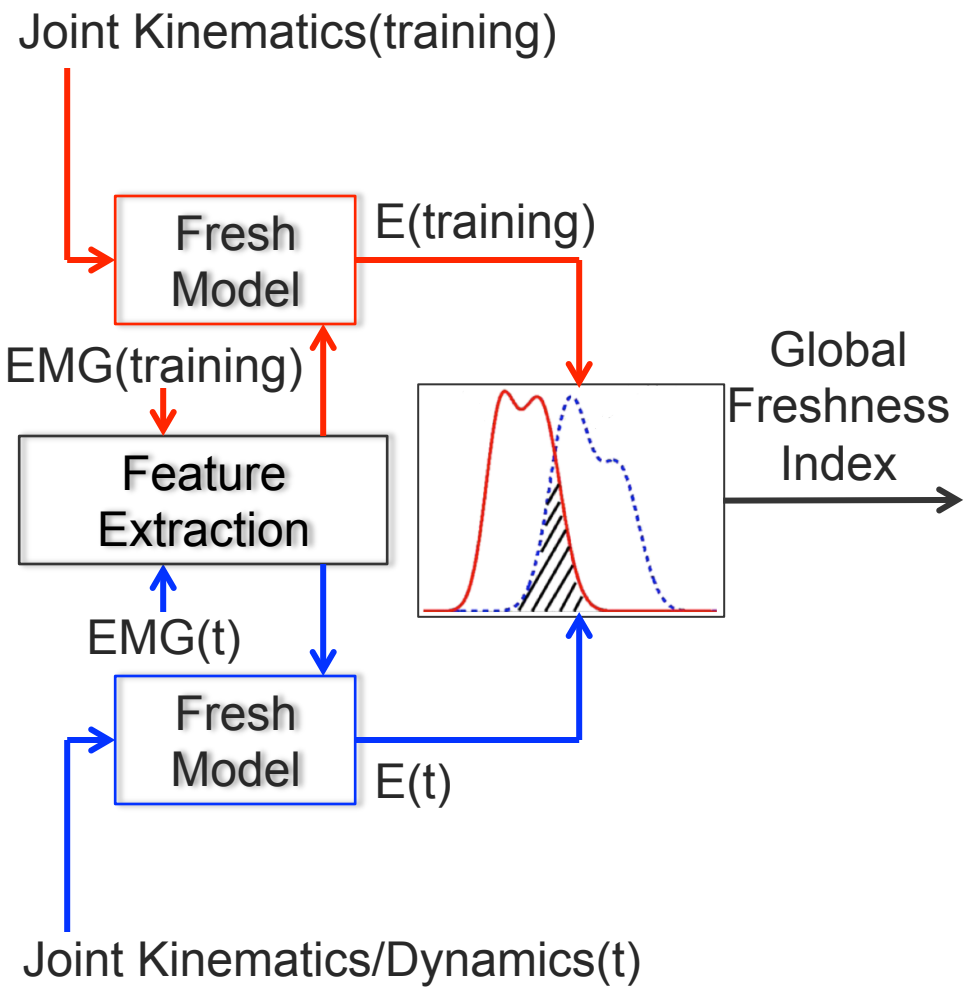
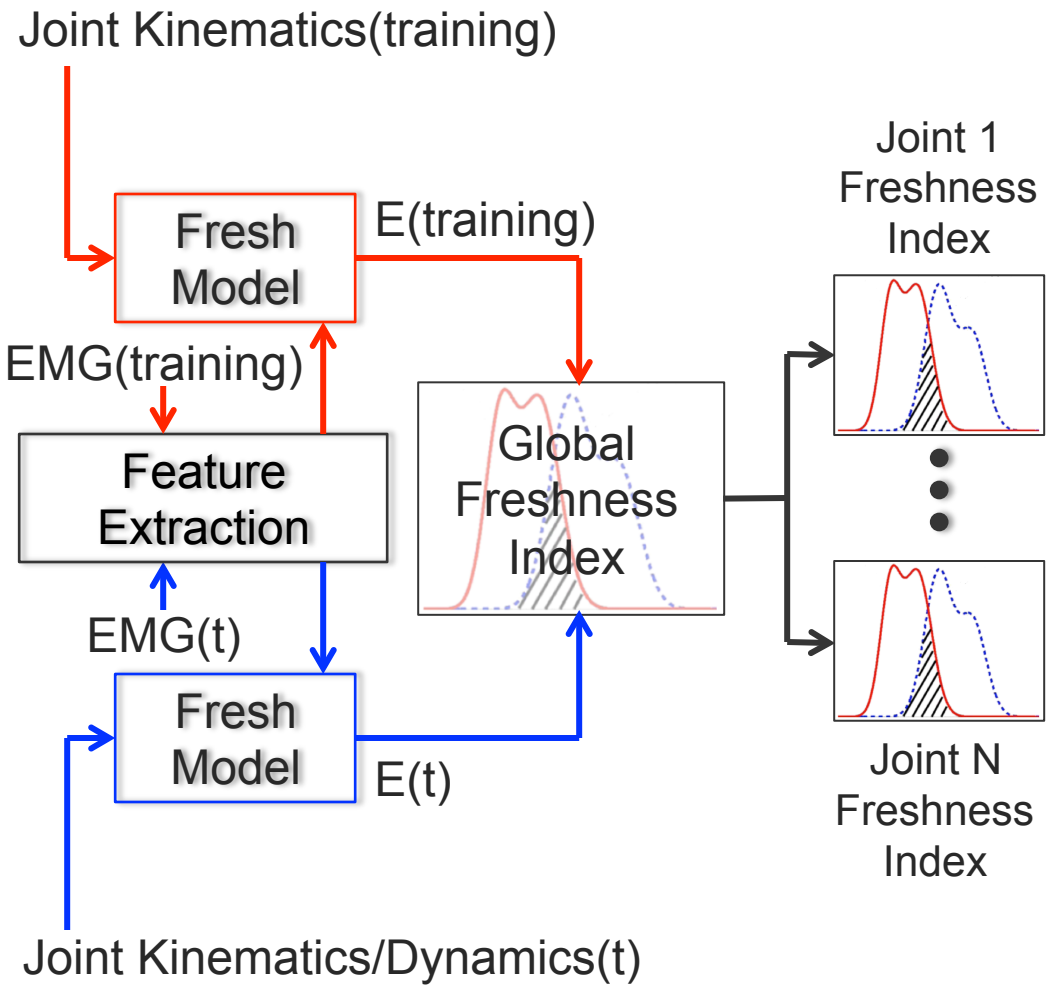
MODELING PARADIGM



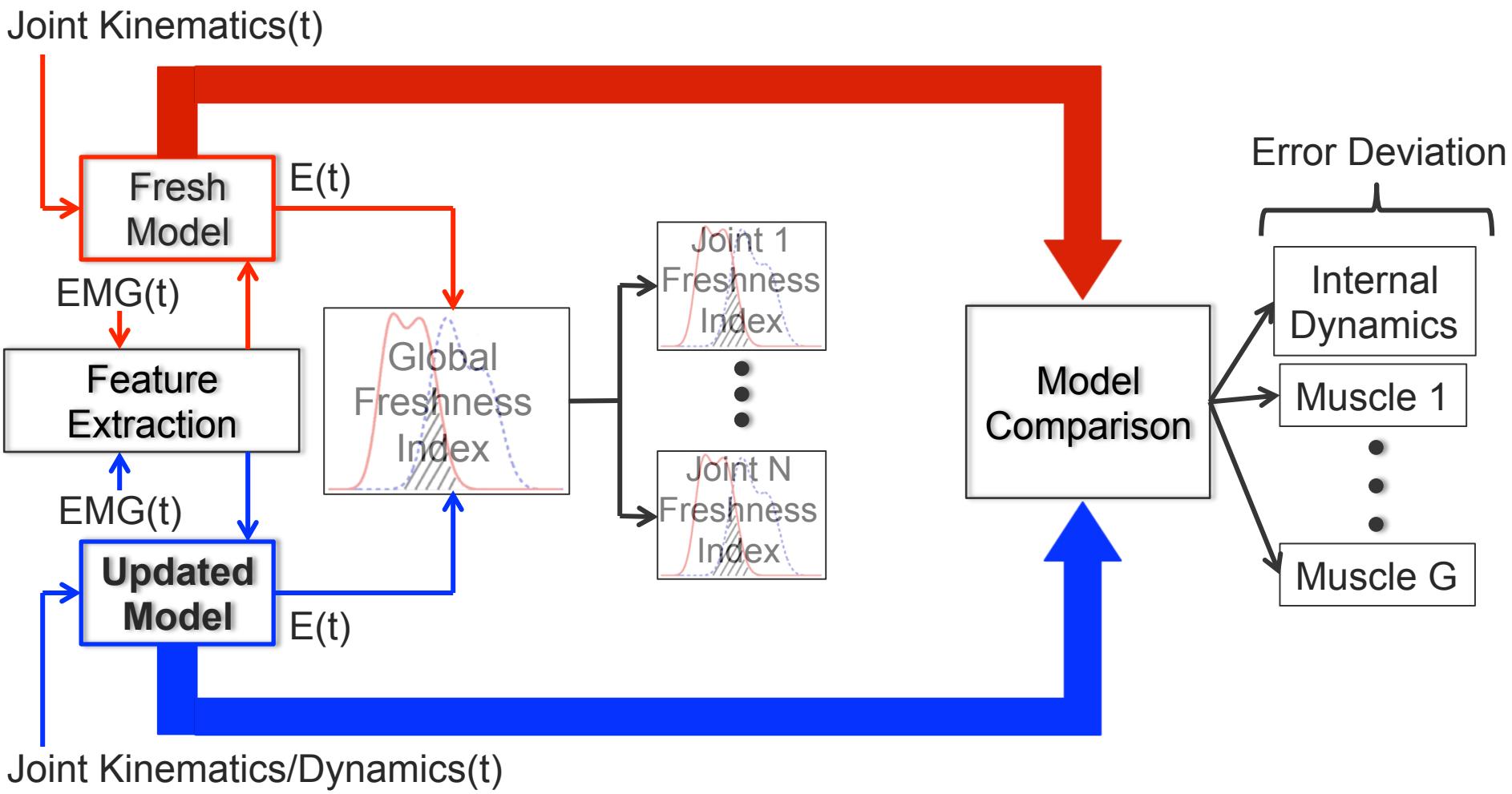
PERFORMANCE MONITORING (OVERALL MULTIPLE INPUT/MULTIPLE OUTPUT - MIMO SYSTEM)



PERFORMANCE MONITORING (JOINT LEVEL MULTIPLE INPUT/SINGLE OUTPUT - MISO SYSTEM)



PERFORMANCE MONITORING (MUSCLE/JOINT LEVEL SINGLE INPUT/SINGLE OUTPUT – SISO SYSTEM)



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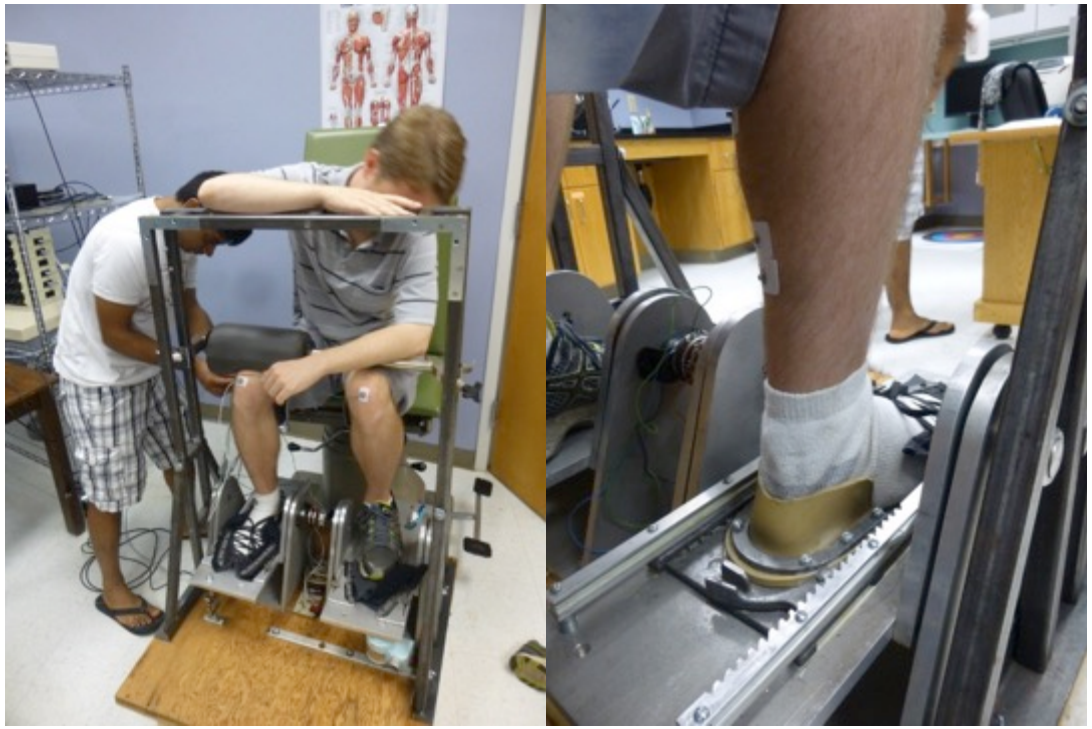
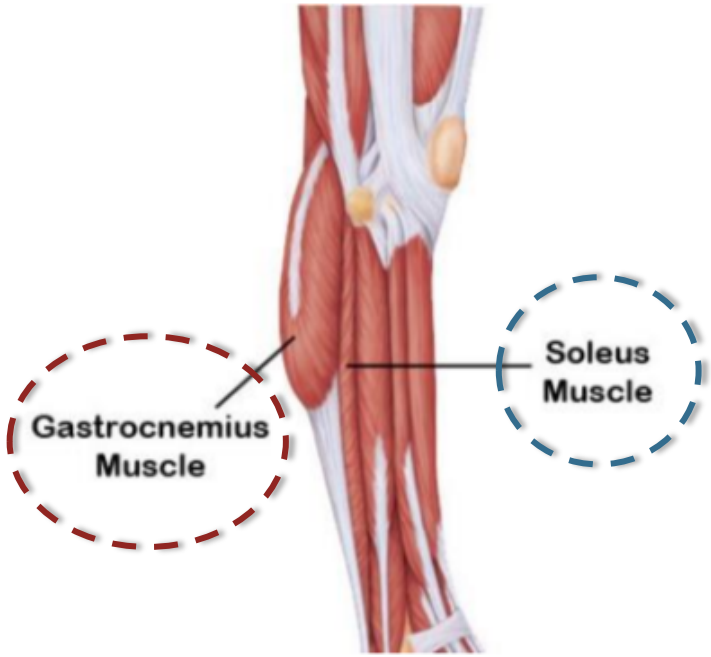
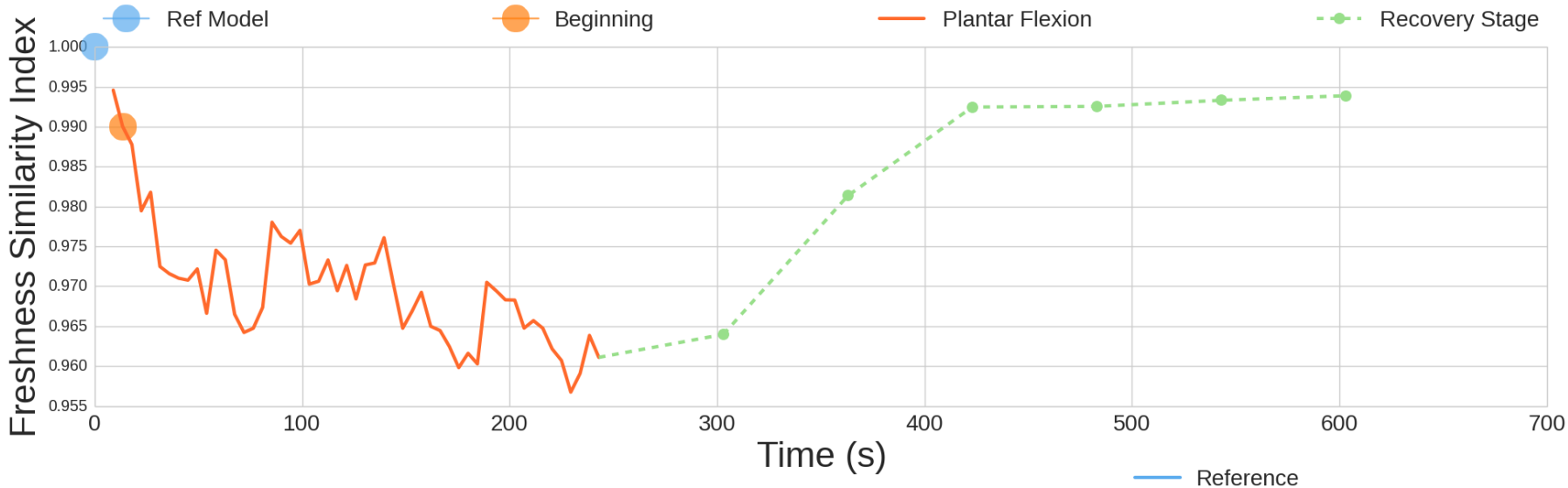


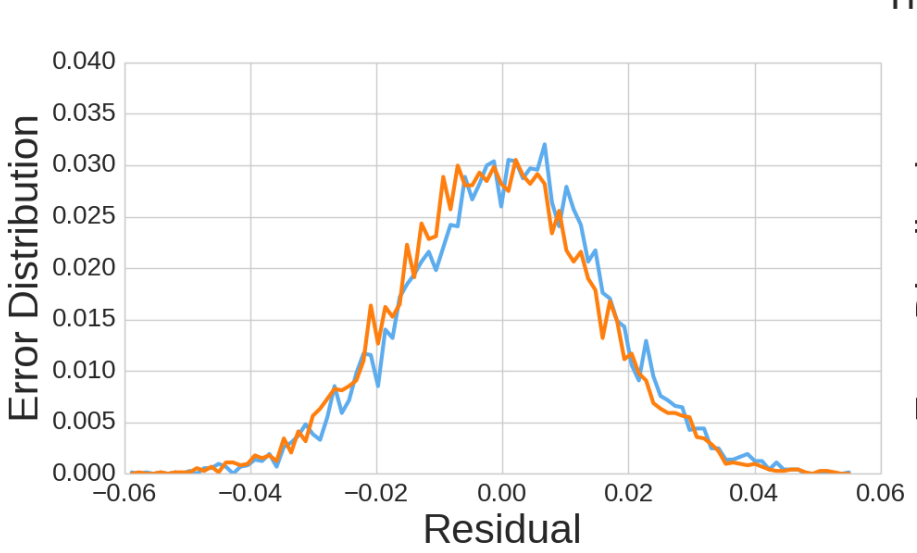


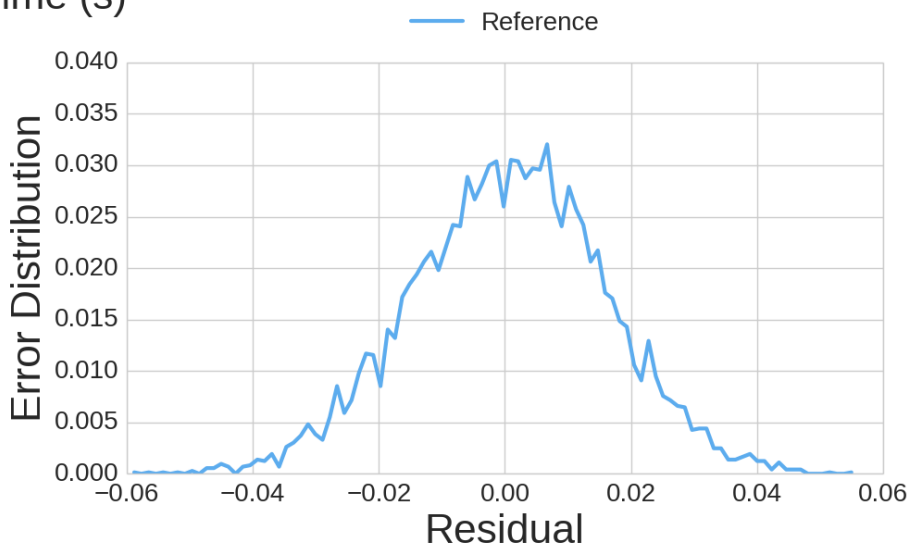
Sampling rate: 1212 Hz
Related muscles: Gastrocnemius and Soleus
Experiment Procedure:

- Hold 75% of maximum voluntary contraction (MVC) until it fails below 60% MVC
- After the 4 min constant contraction test, the subject conducts few recovery tests (attempting to maintain 75% MVC for a few seconds, followed by 1 minute rests)
- sEMG signals and output force are collected simultaneously

DATA SET 1: MONITORING RESULTS







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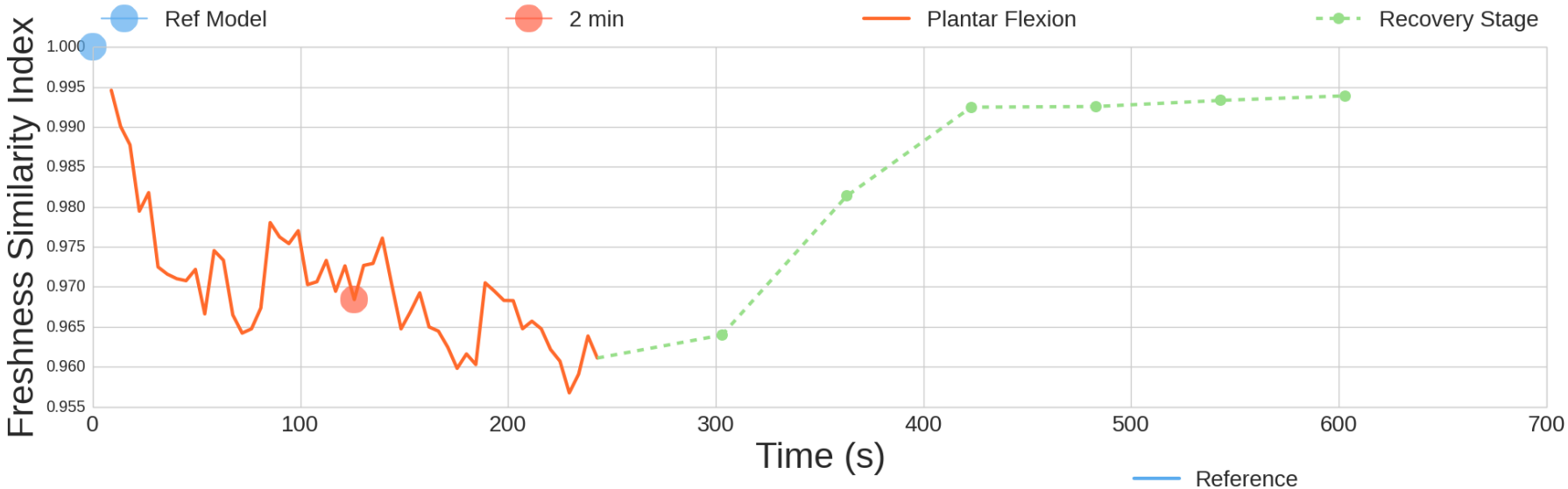

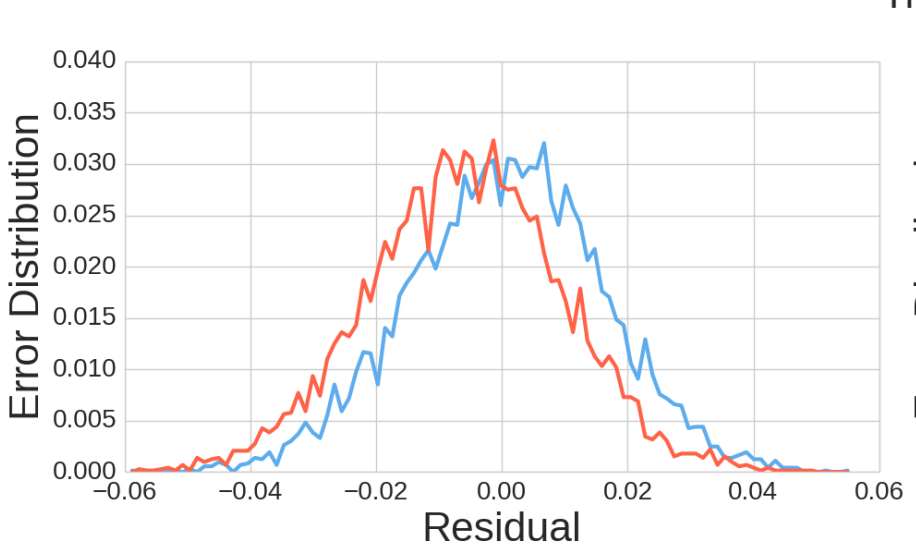

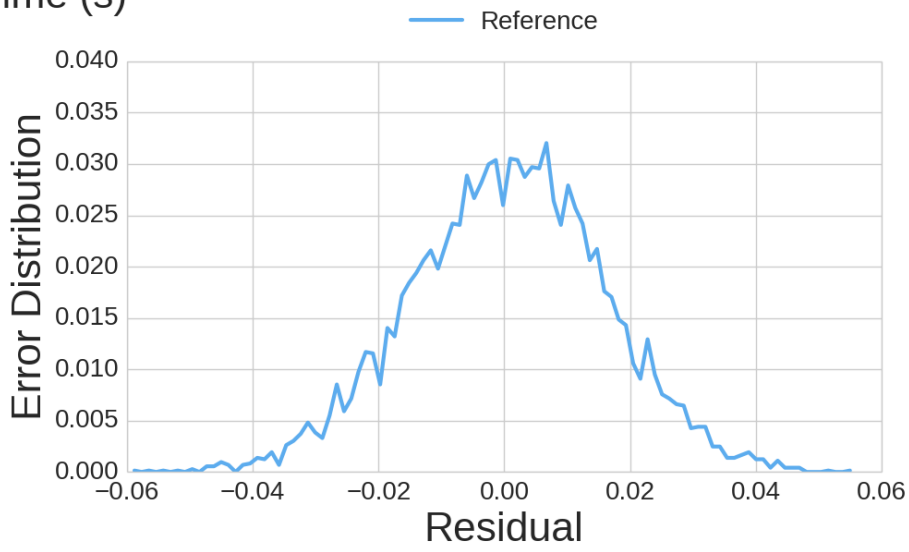

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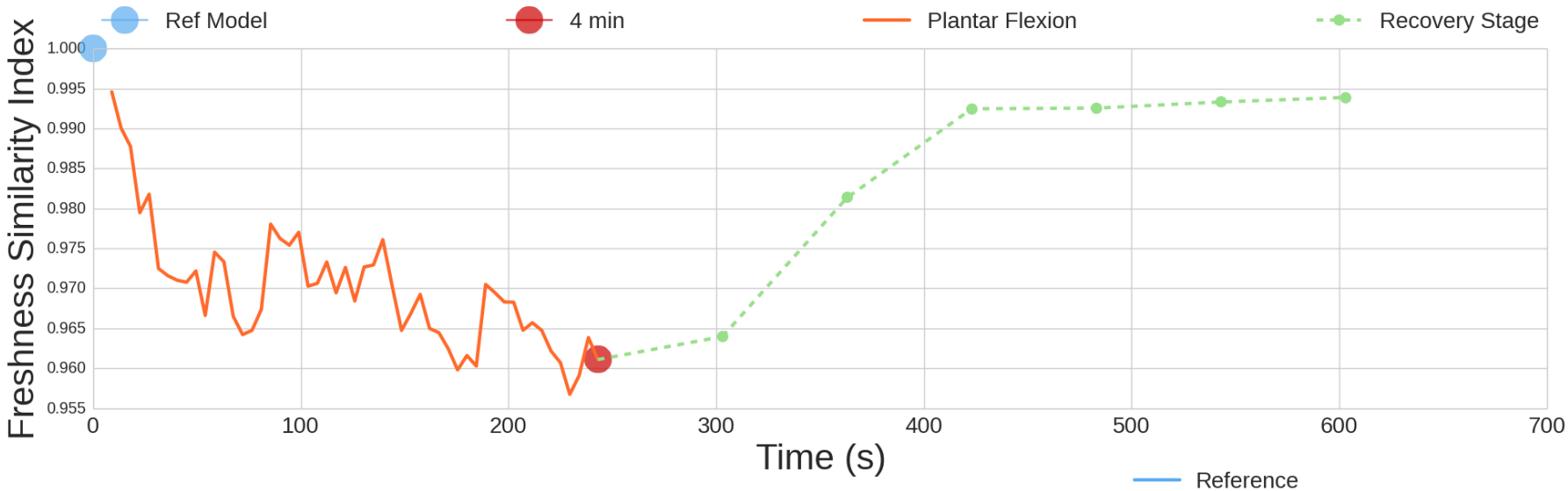

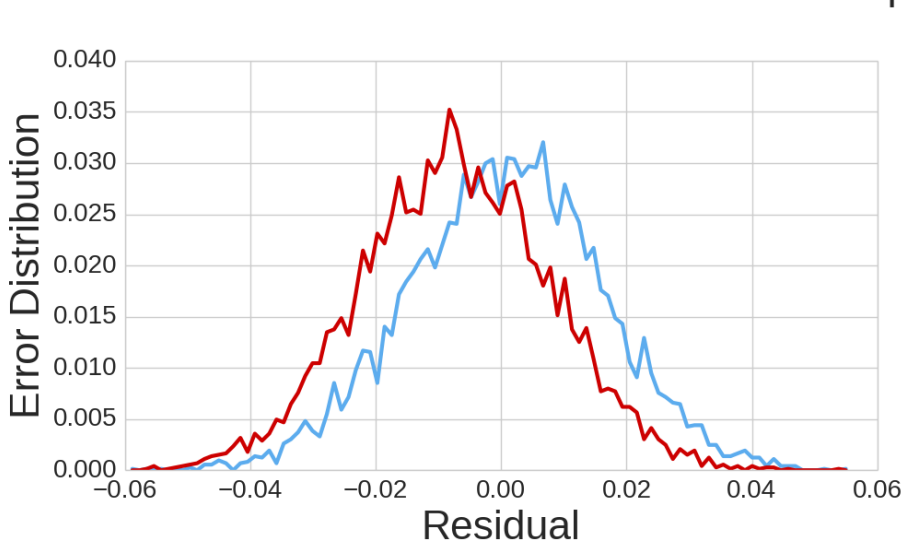

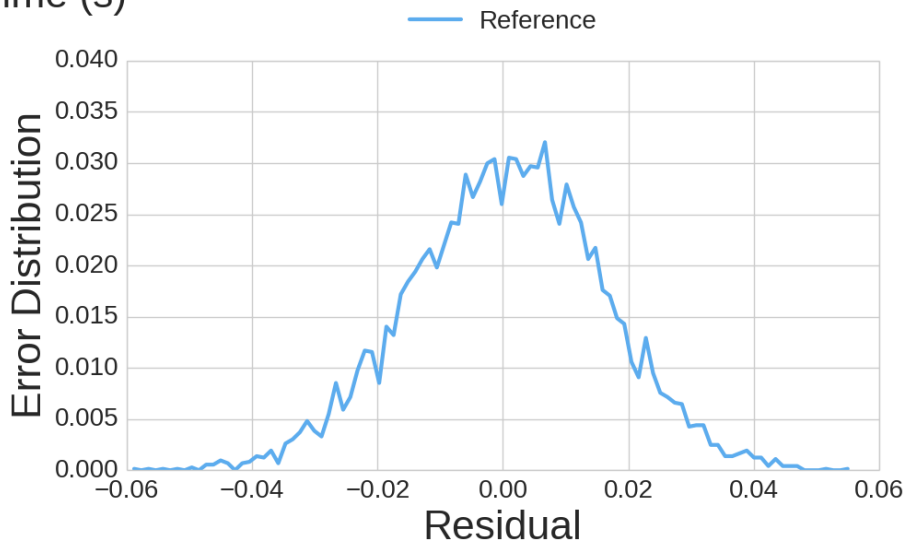

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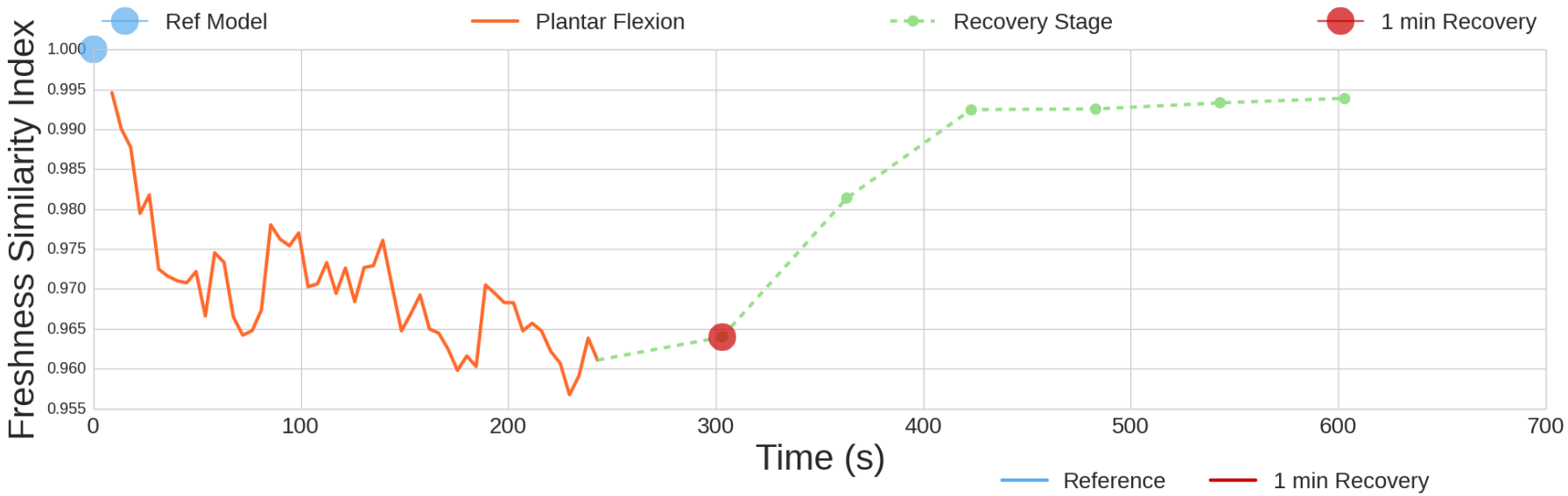

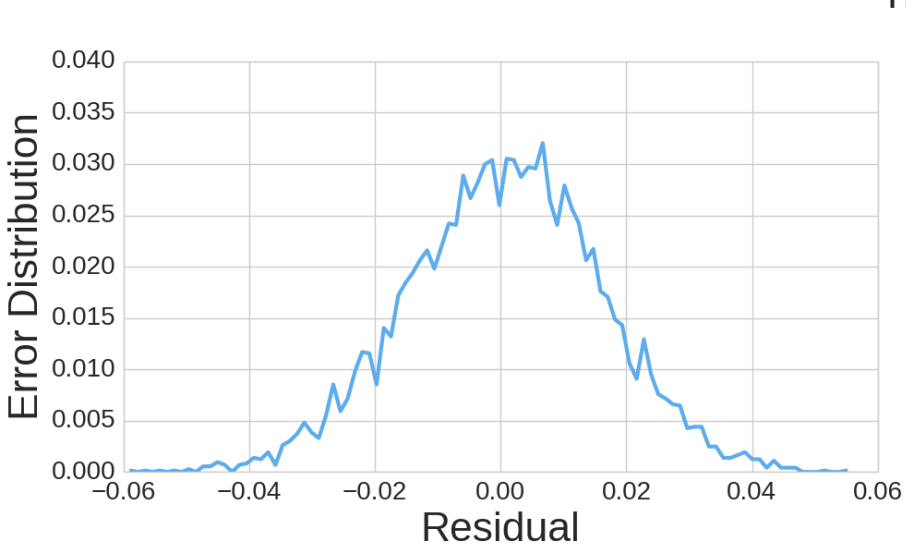

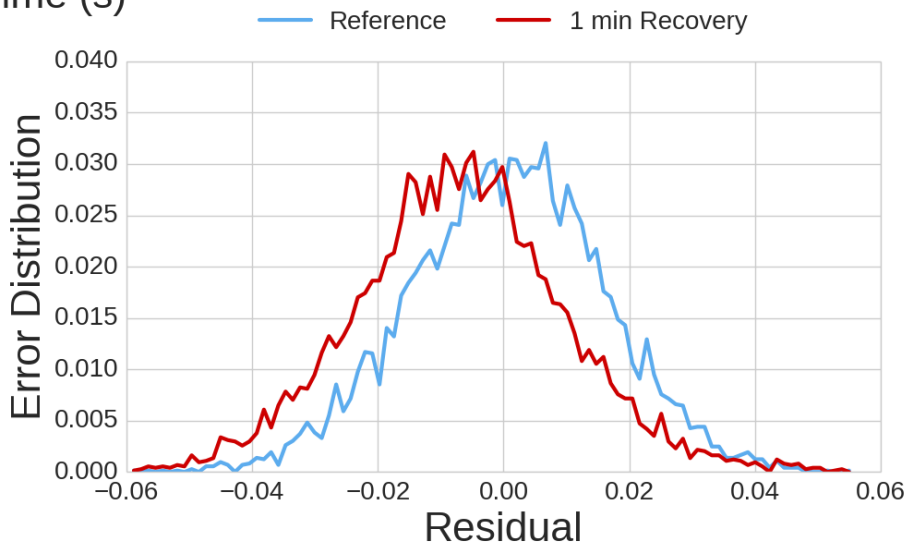

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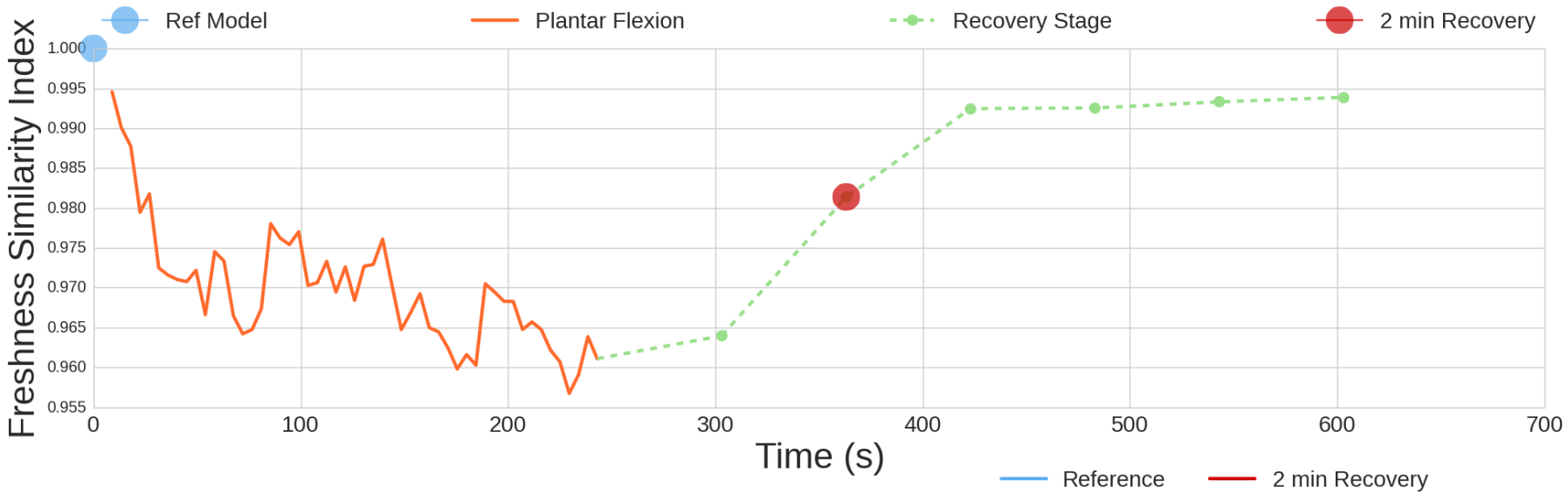

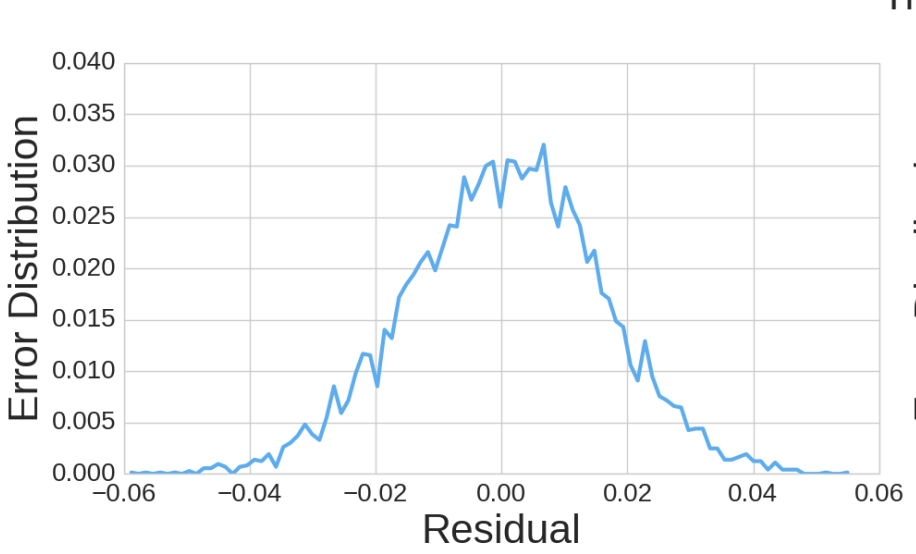

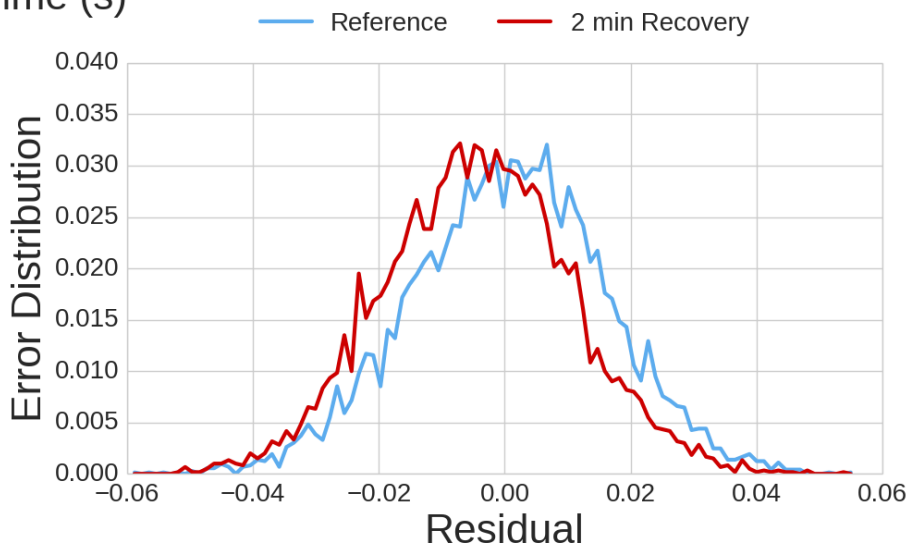

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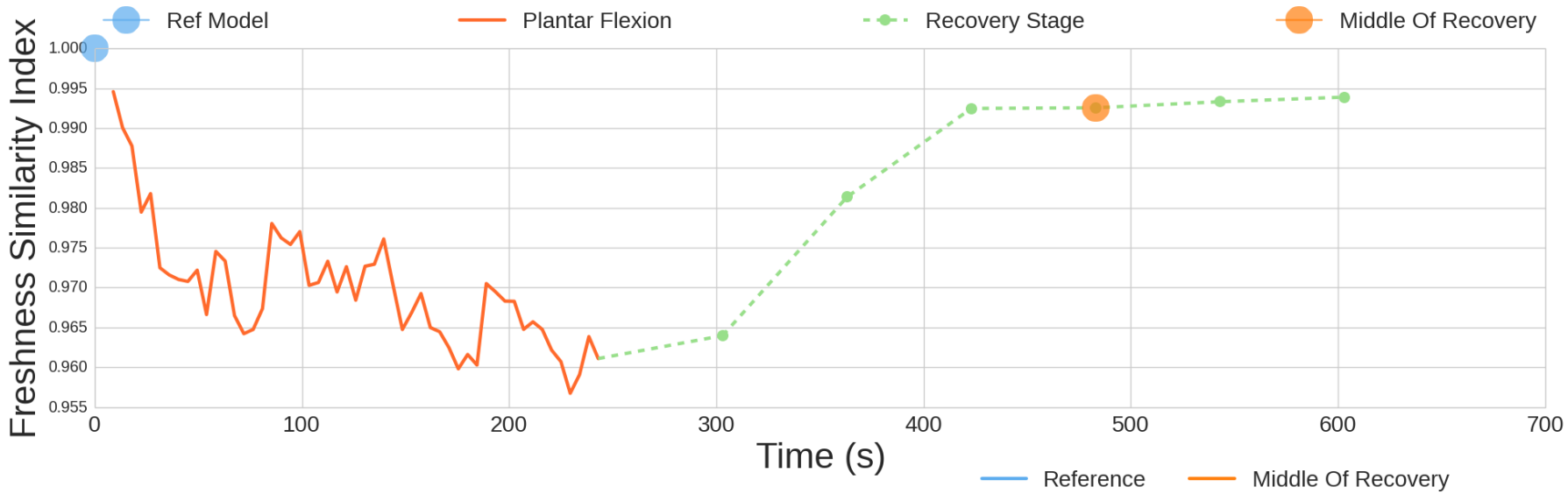

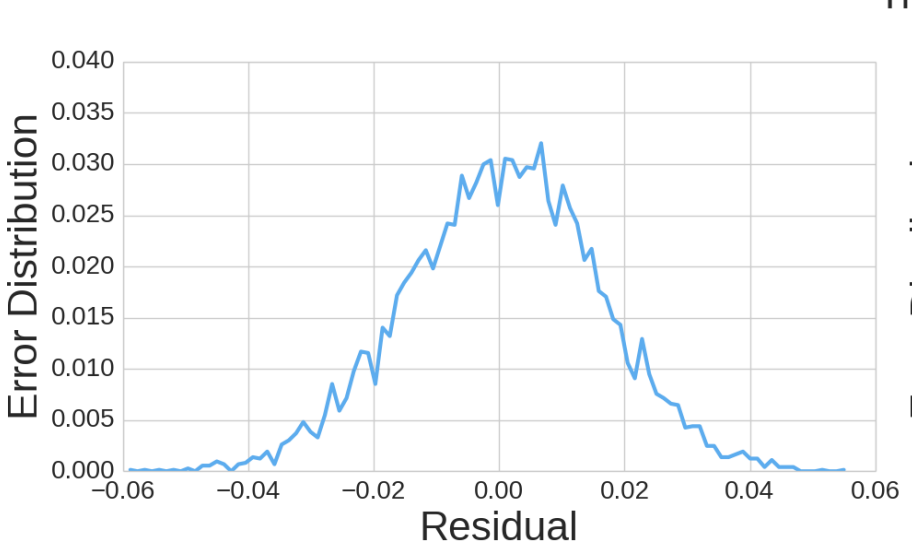

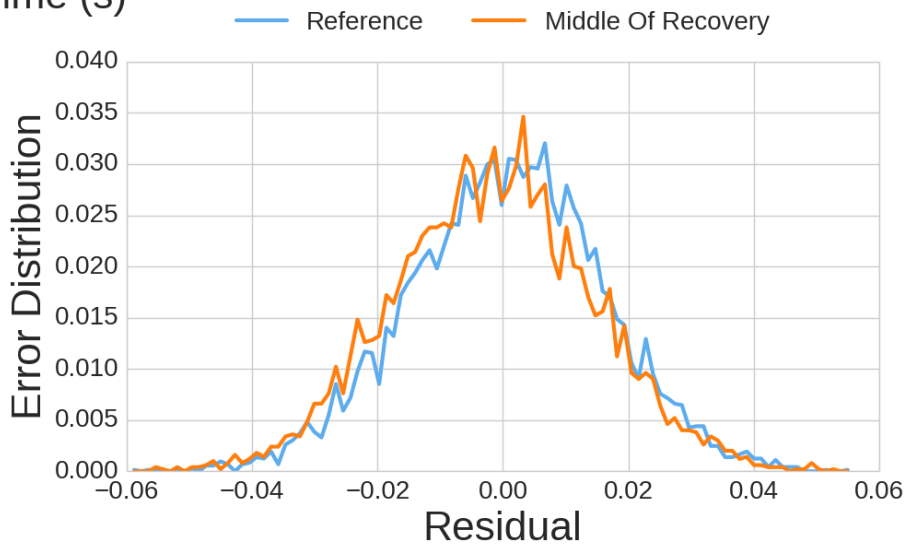

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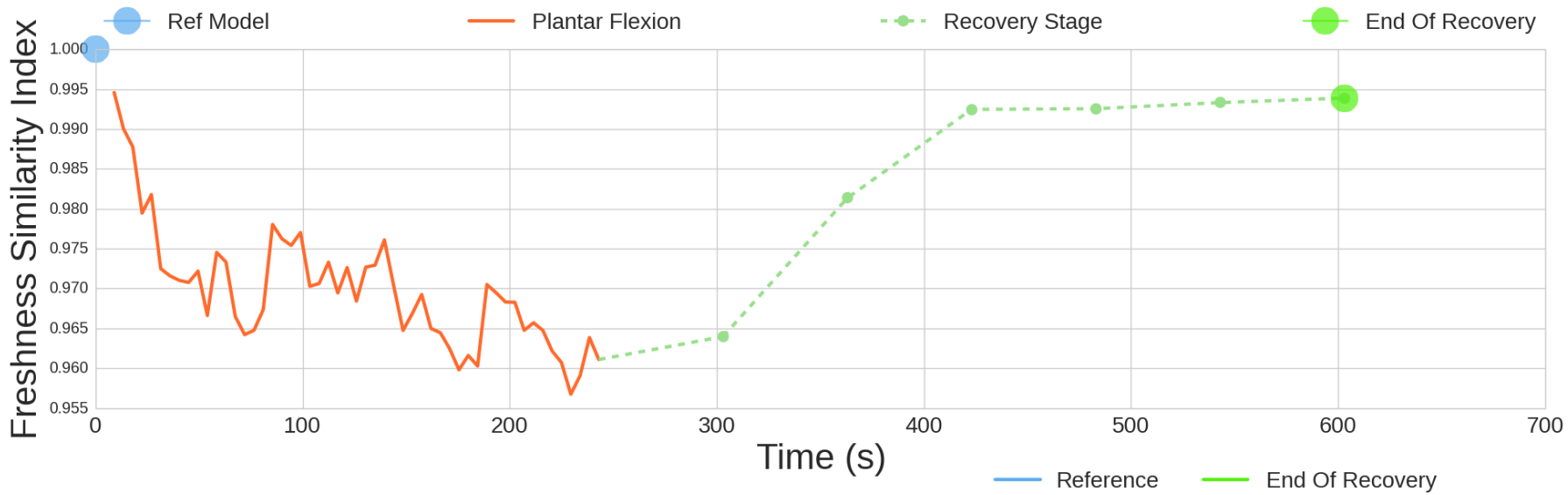
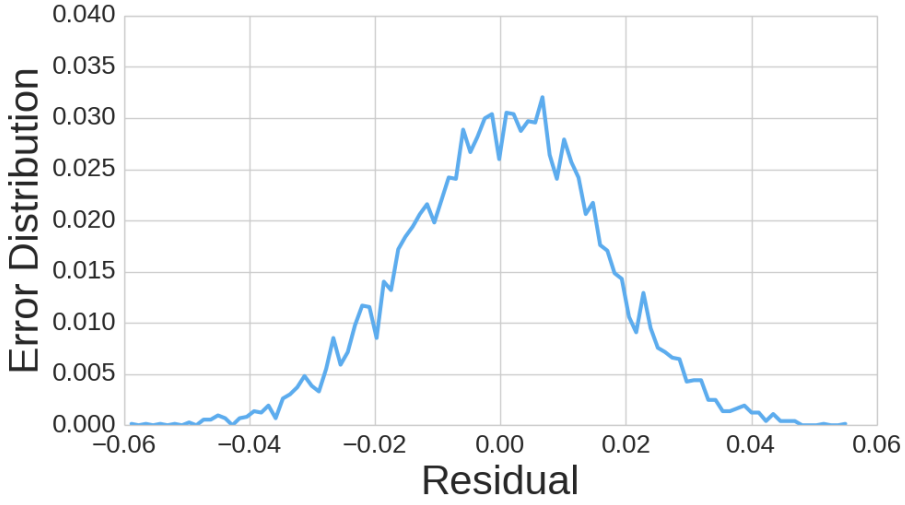
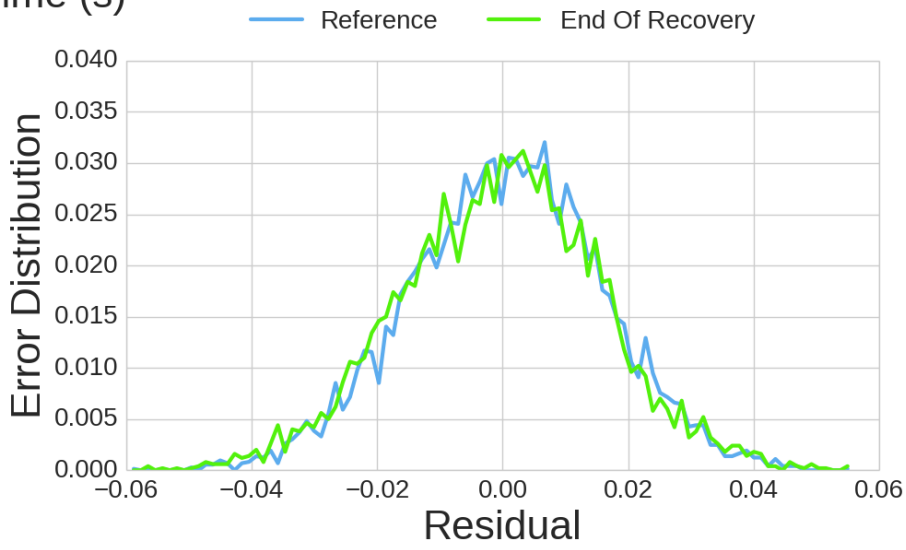
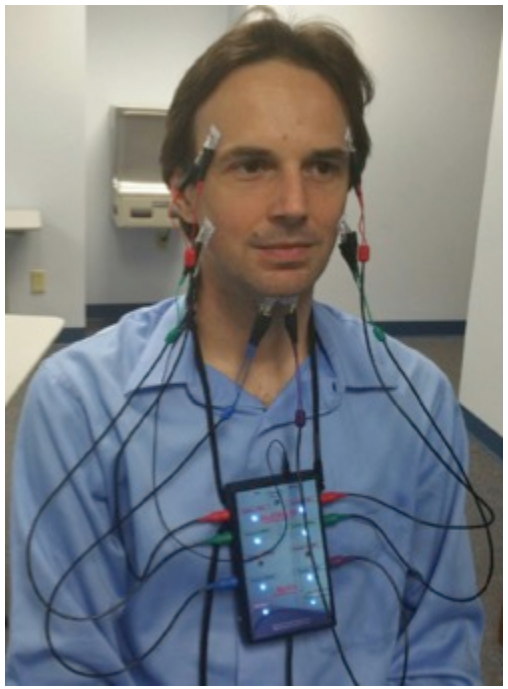
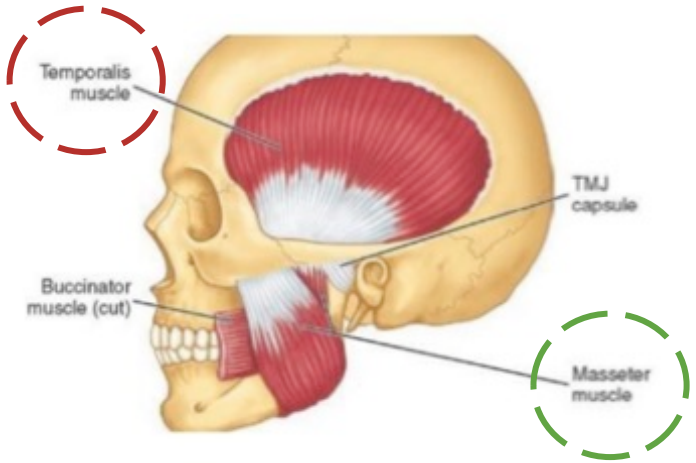






DATA SET 2: TMJ MUSCLE CYCLIC MOTION

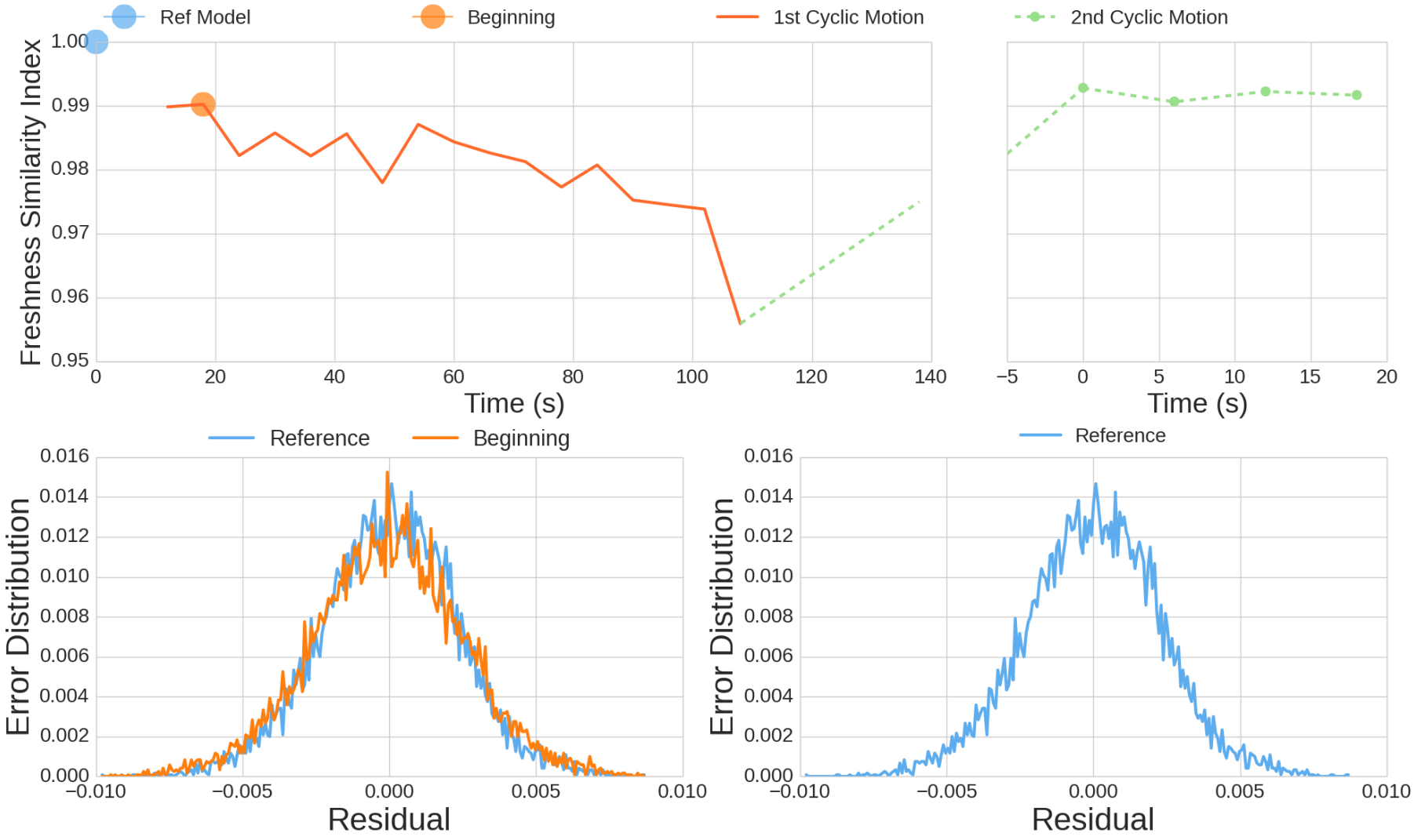




Sampling rate: 2000 Hz
Related muscles: Temporalis, Masseter and Depressor
Experiment Procedure:

- Perform mouth open-and-close motion repeatedly for 2 minutes
- After sufficient rest, another cyclic motion is performed for around 30 seconds
- Both sEMG signal and mandible velocity are collected at the same time

DATA SET 2: MONITORING RESULTS



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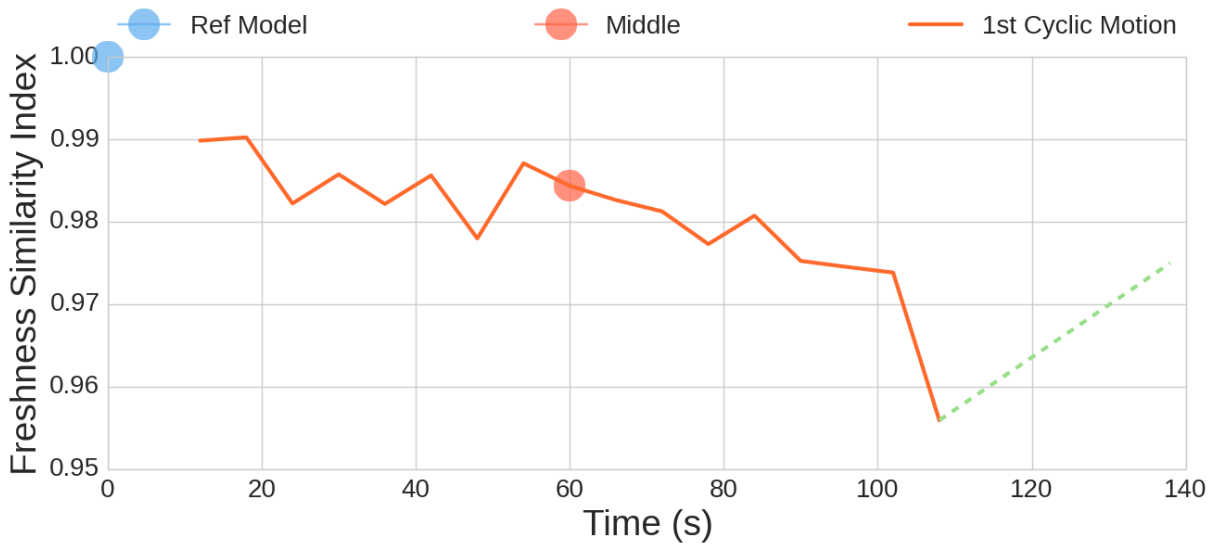

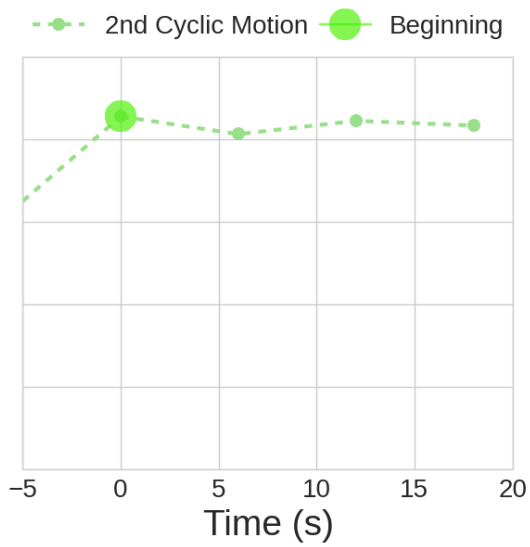

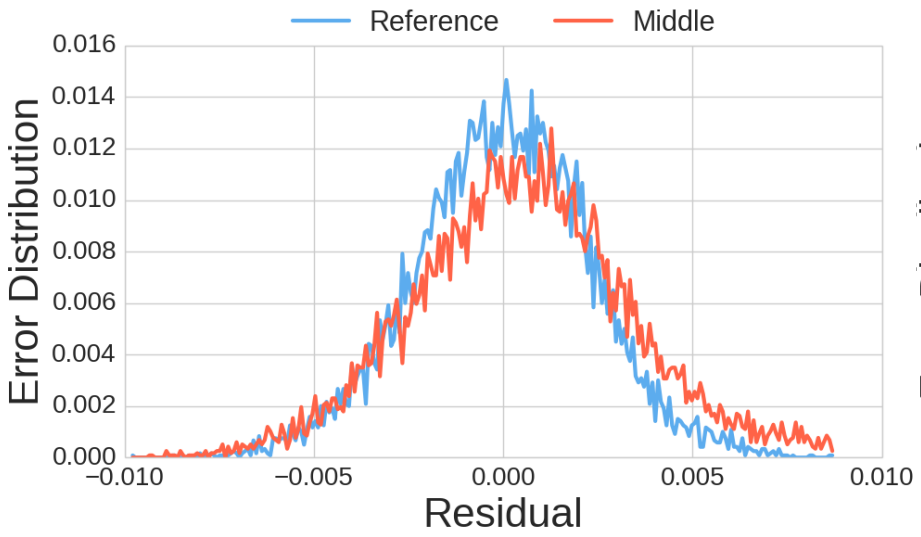

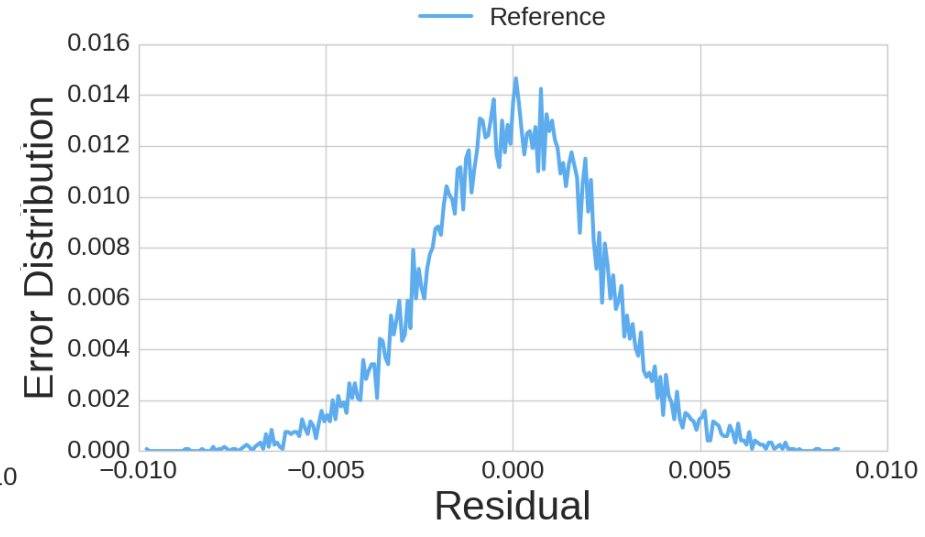

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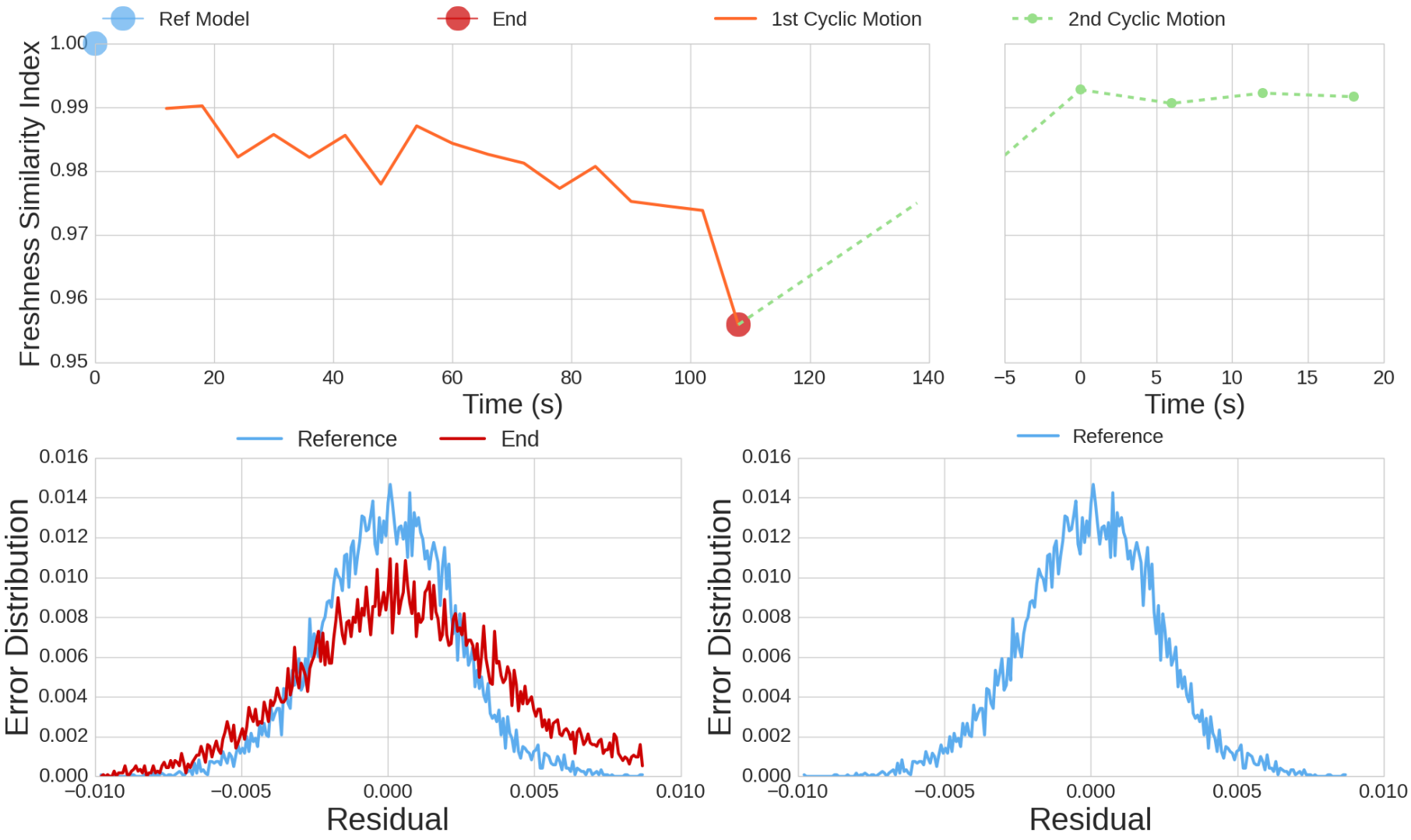

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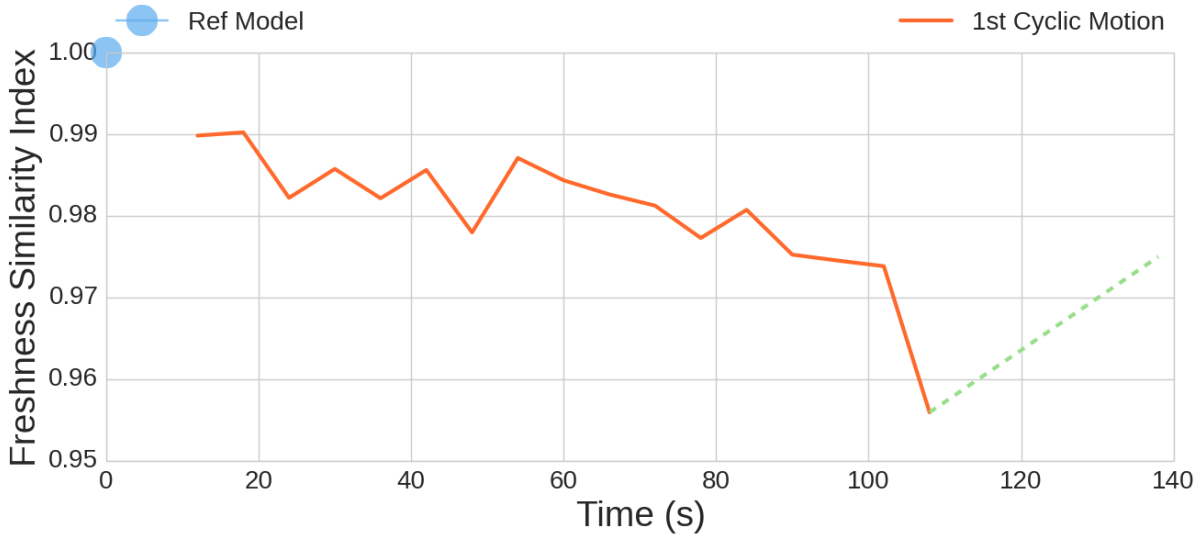
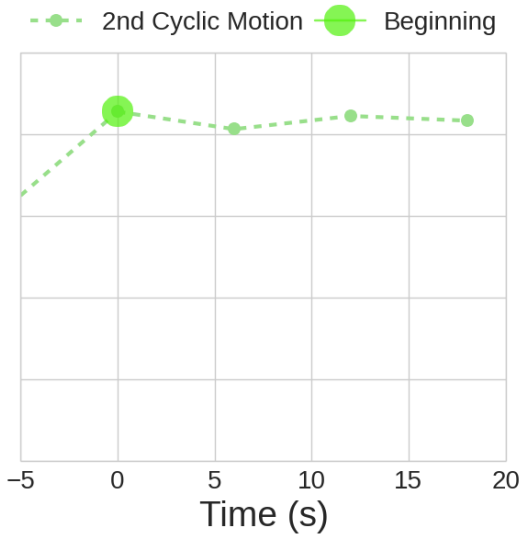
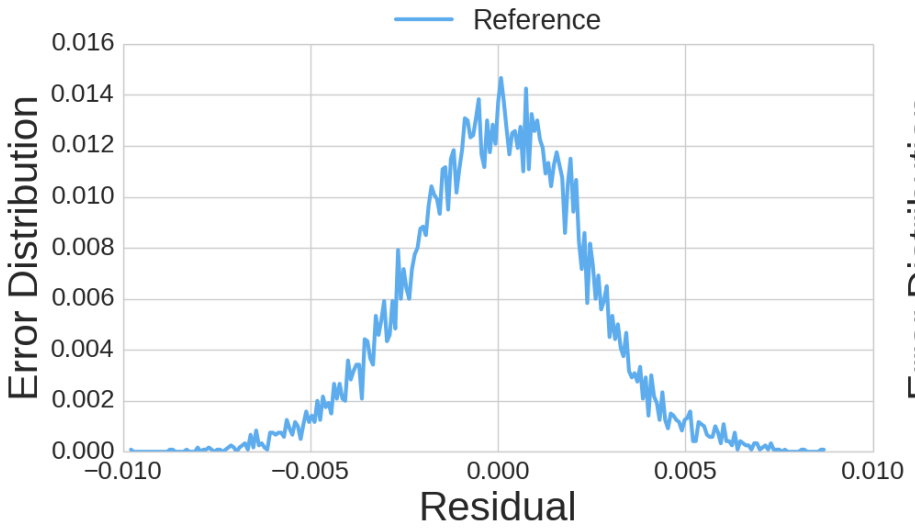
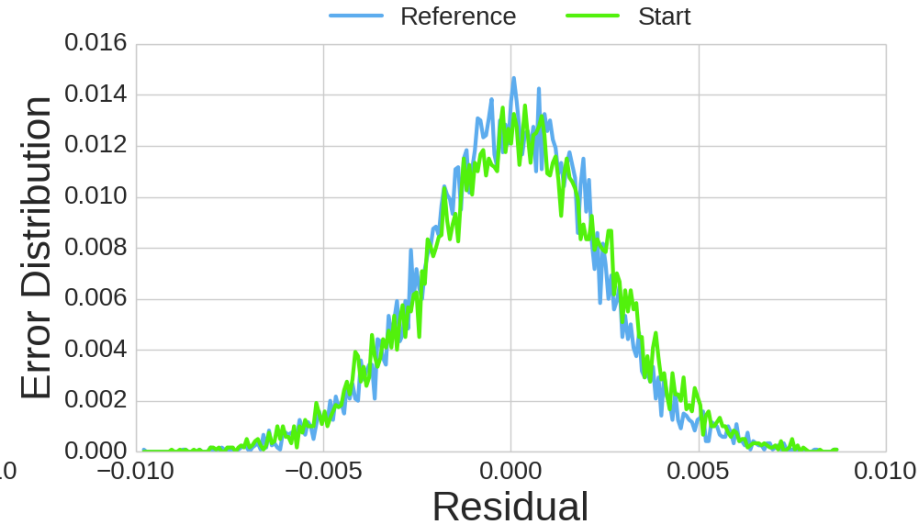


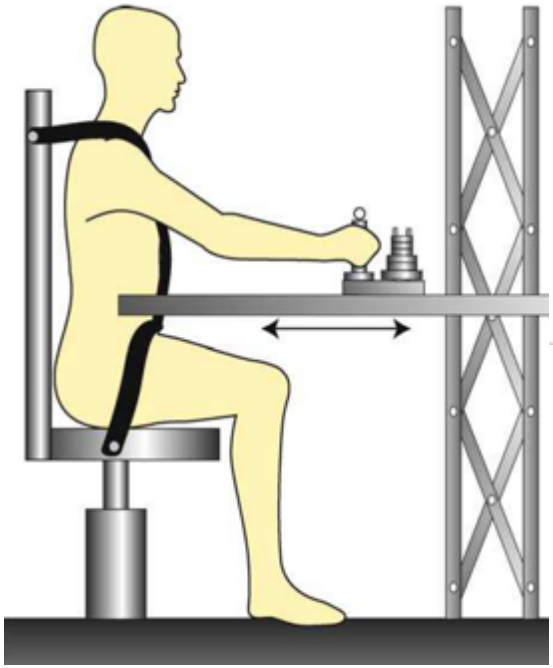






DATASET 3: ARM AND SHOULDER SYSTEM

Middle Trapezius
Pectoralis Major
Posterior Deltoid
Lateral Deltoid
Anterior Deltoid
Biceps
Triceps
Wrist Flexor
Wrist Extensor



Time Frequency Distribution

Extract
- Instantaneous Energy
- E[f | t]

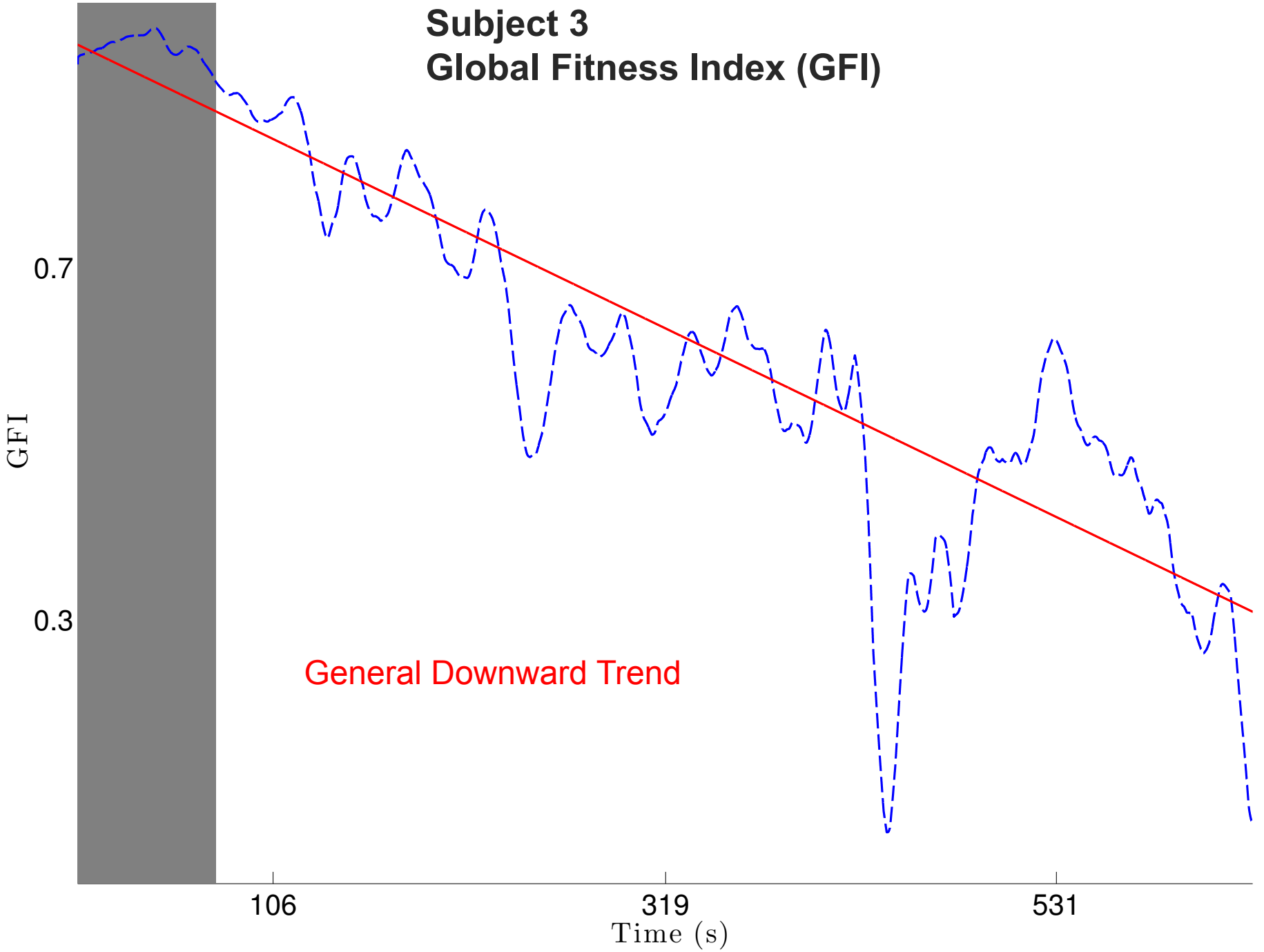
ARX Model

<u>Shoulder</u>
GH Plane of Elevation
GH Negative Elevation
Axial Rotation

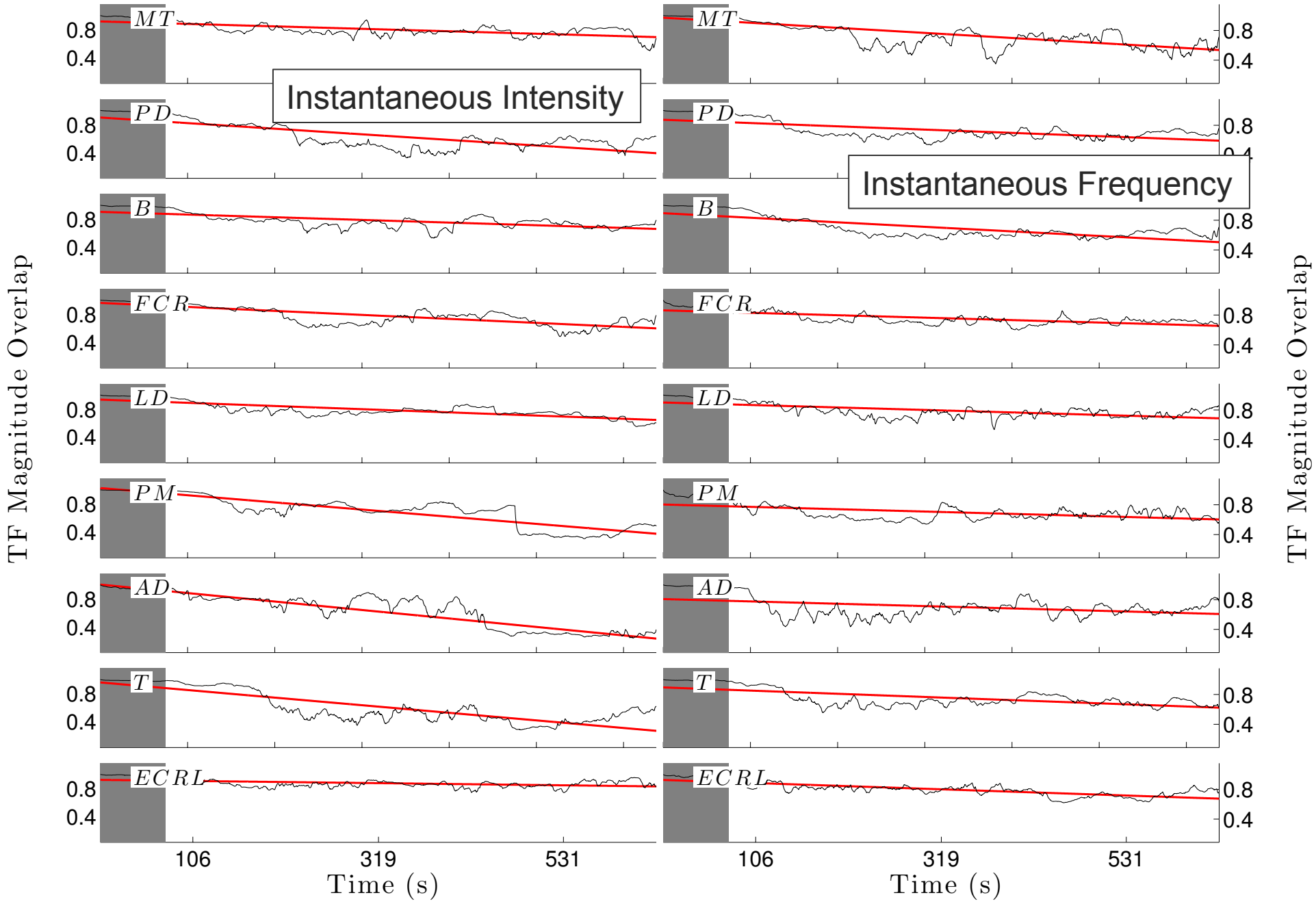
<u>Elbow</u>
Flexion
Pronation

<u>Wrist</u>
Flexion
Ulnar Deviation

M. Musselman, D. Gates and D. Djurdjanovic, “A System-Based Approach to Monitoring a Human Neuromusculoskeletal System,” Int’l J. for Prognostics and Health Management, Vol. 7, No. 2, 2016.


Subject 3
Global Fitness Index (GFI)
0.7
0.3
GFI
General Downward Trend
106
319
531
Time (s)

Transfer Functions to Shoulder Elevation (Subject 3)



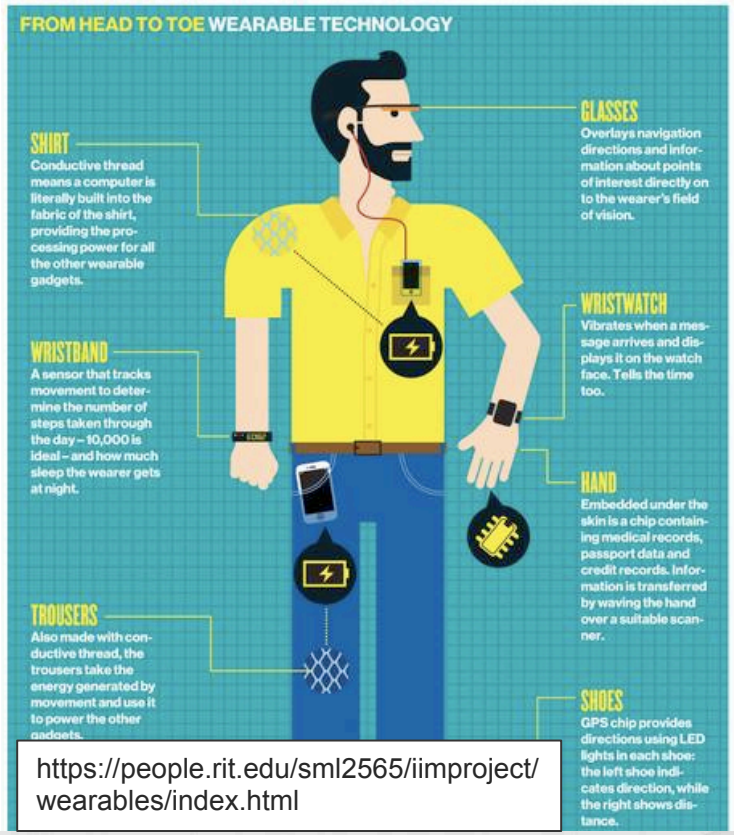
CONTRIBUTIONS AND FINDINGS

- **GFI with statistically significant decreasing trends for 100% subjects**
- **JFI with statistically significant decreasing trends for:**
  - - GHPE, GHAR, EP, WUD: 100% subject
  - - GHNE and WF: 92% subject
  - - EF: 75% subject
- Transfer function overlaps with statistical significant decreasing trends in 96% subject – muscle – input feature combinations

» - **7 subjects who exercised the shortest had all muscle joint**
» **combinations with significant linear decreasing trends**
» - **Two subjects** who performed the exercise the longest,
» **performed it twice as long as the next nearest subject** (1 was a
» triathlete) **accounted for 82% of the muscle/joint pairs that did**
» **not show degradation**

CONCLUDING REMARKS

- **Model based monitoring holds tremendous promise for NMS system monitoring**
  - Athletics
  - Rehabilitation
  - Military
  - Workplace safety
- Wearable electronics and pervasive computing are bringing us closer to the vision of performance oriented rather than pathology oriented monitoring.
- **Predictive and preventive maintenance of humans** should be one of the ultimate visions and goals of the PHM community!



https://people.rit.edu/sml2565/iimproject/wearables/index.html

http://www.businessinsider.com/wearable-technology-market-2013-5

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THANK YOU