NSF I-UCRC on Intelligent Maintenance Systems;
University of Texas at Austin

SYSTEM BASED MODELING AND MONITORING OF HUMAN NEUROMUSCULOSKELETAL PERFORMANCE

PROF. DRAGAN DJURDJANOVIC
UNIVERSITY OF TEXAS AT AUSTIN
DEPT. OF MECHANICAL ENGINEERING

MOTIVATION FOR INTELLIGENT MAINTENANCE

Operational safety, maintenance cost effectiveness and asset availability have a direct impact on the competitiveness of organisations and nations. Today's complex and advanced machines demand highly sophisticated and costly maintenance strategies. Domestic plants in the United States spent more than $600 billion to maintain their critical plant systems in 1981 and this figure doubled within 20 years [1]. An even more alarming fact is that one-third to one-half of this expenditure is wasted through ineffective maintenance. The trend is similar in many other countries including Australia [2]. Therefore, there is a pressing need to continuously develop and improve current maintenance programs.

Heng, Zhang, Tan and Matthew, 2009, Rotating machinery prognostics: State of the art, challenges and opportunities, Mechanical Systems and Signal Processing, Vol. 23,pp 724-739

eIMS CENTER FOR INTELLIGENT MAINTENANCE SYSTEMS

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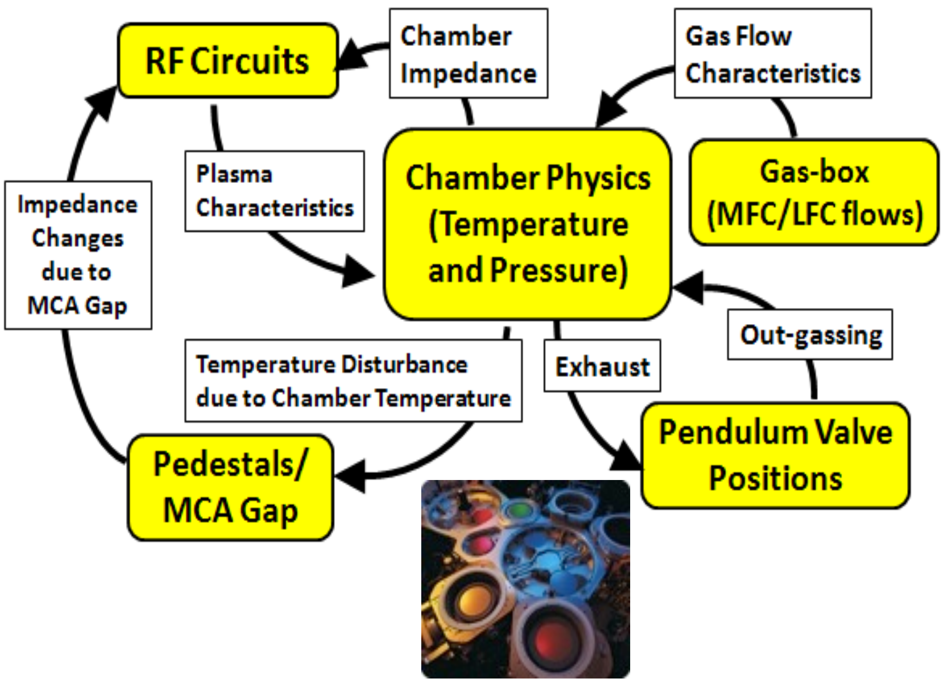


University of Texas Member Companies

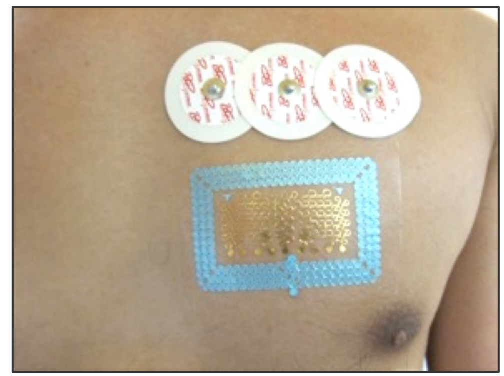
Samsung · GTI Spindle Technology (www.gtispindle.com) · MathWorks · Abbott Diagnostics · Lam Research · Intel

Performance Monitoring of Human Body Systems

- Symptomatic versus system-based monitoring

System → Output

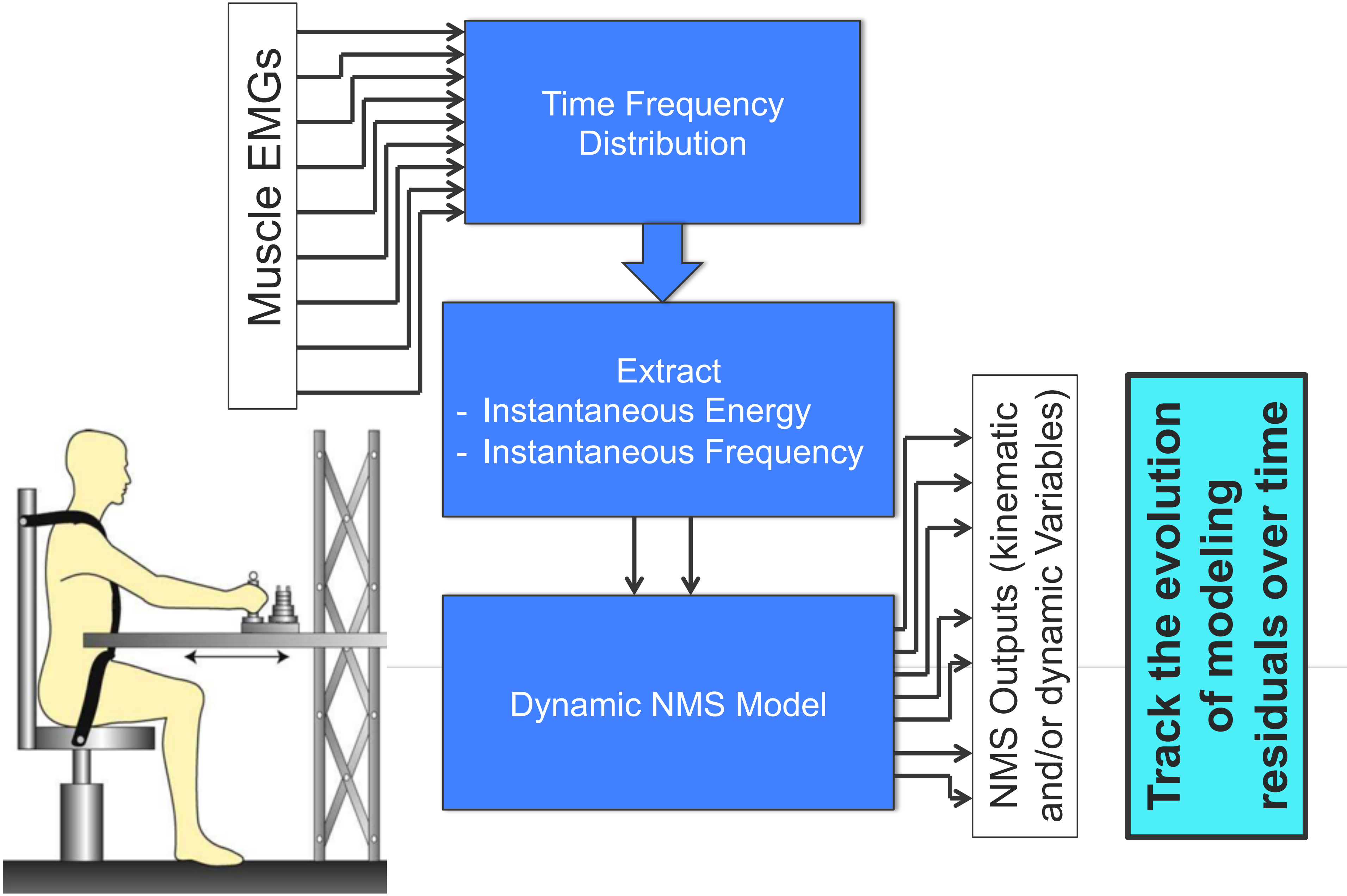
Inputs → System → Output



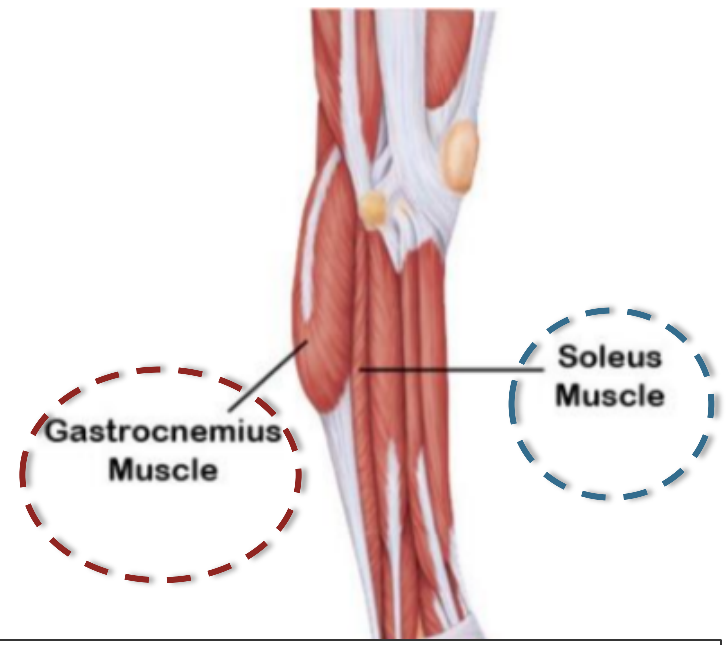
Challenges:
- Incomplete system information
- Inaccessibility of input
- Indirect measure of output
- Nonlinear input-output relationship

http://www.geocaching.com/seek/cache_details.aspx?wp=GC39084

MODELING AND MONITORING PARADIGM



DATA SET 1: CONSTANT LEG CONTRACTION

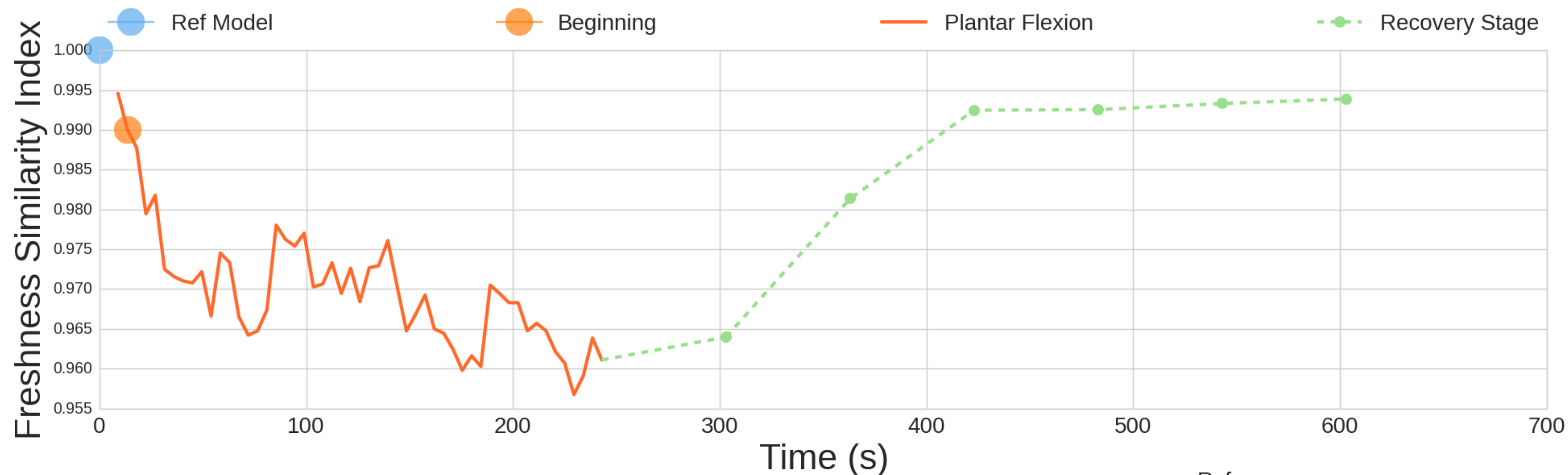


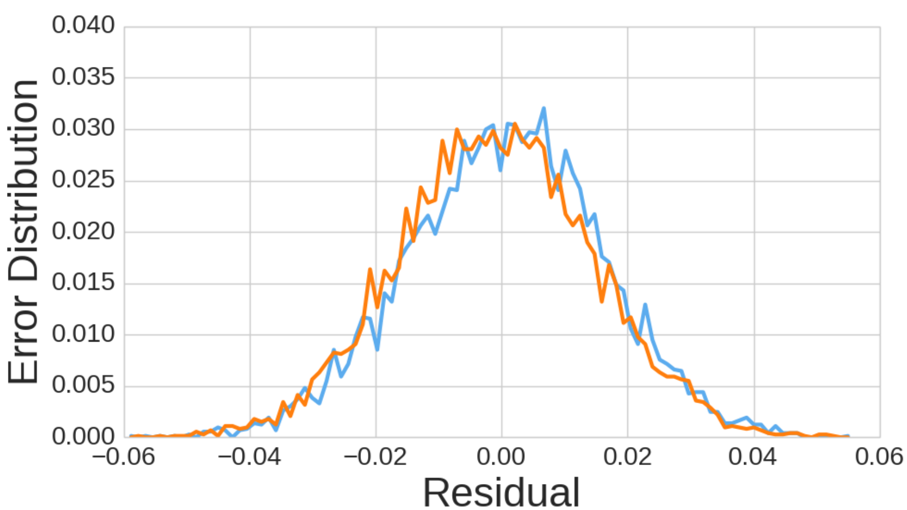
Yu Yang Xie, "*A Model Based Approach for Evaluating Human Neuromusculoskeletal System Performance,*" MS Thesis, University of Texas at Austin, 2016

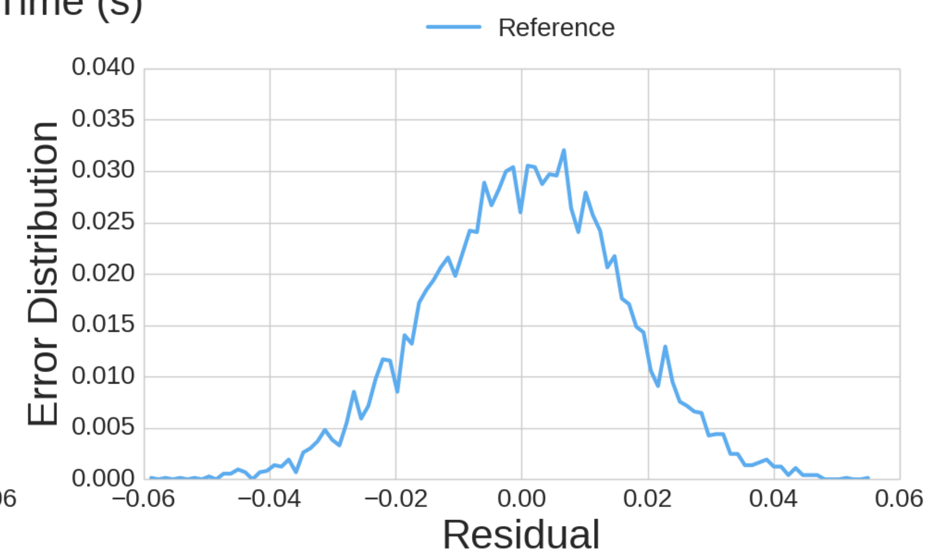
Sampling rate: 1212 Hz
Related muscles: Gastrocnemius and Soleus
Experiment Procedure:

- 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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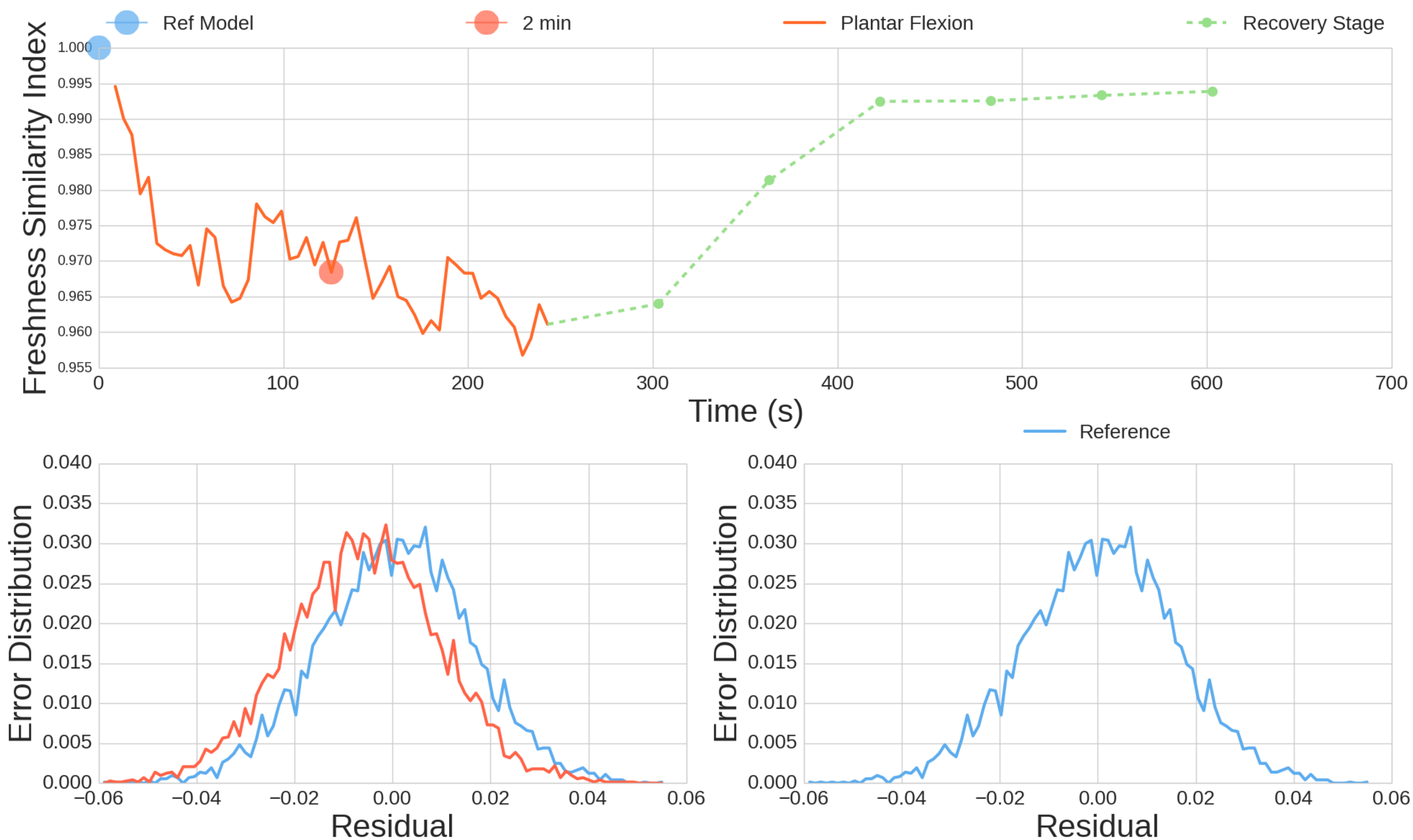

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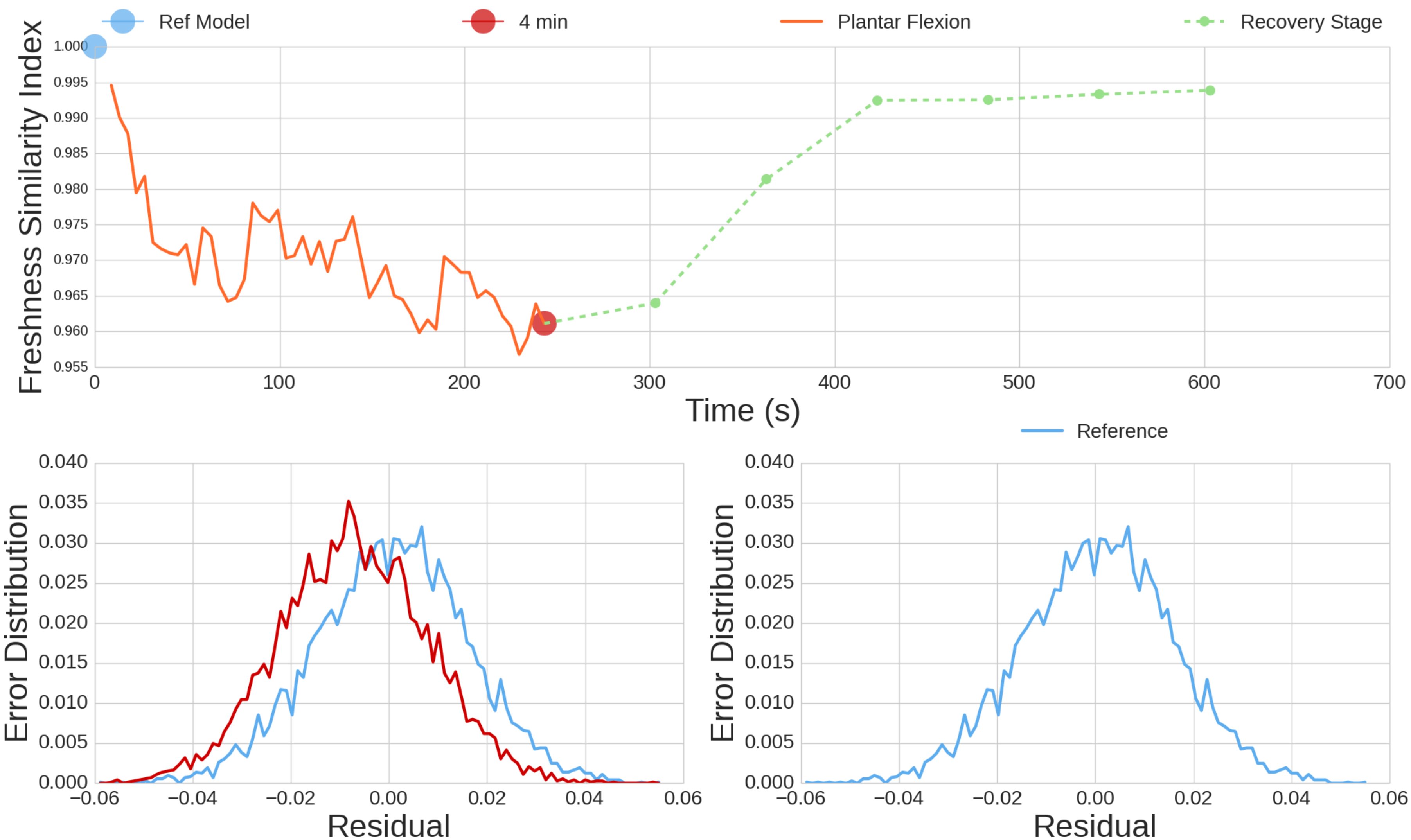

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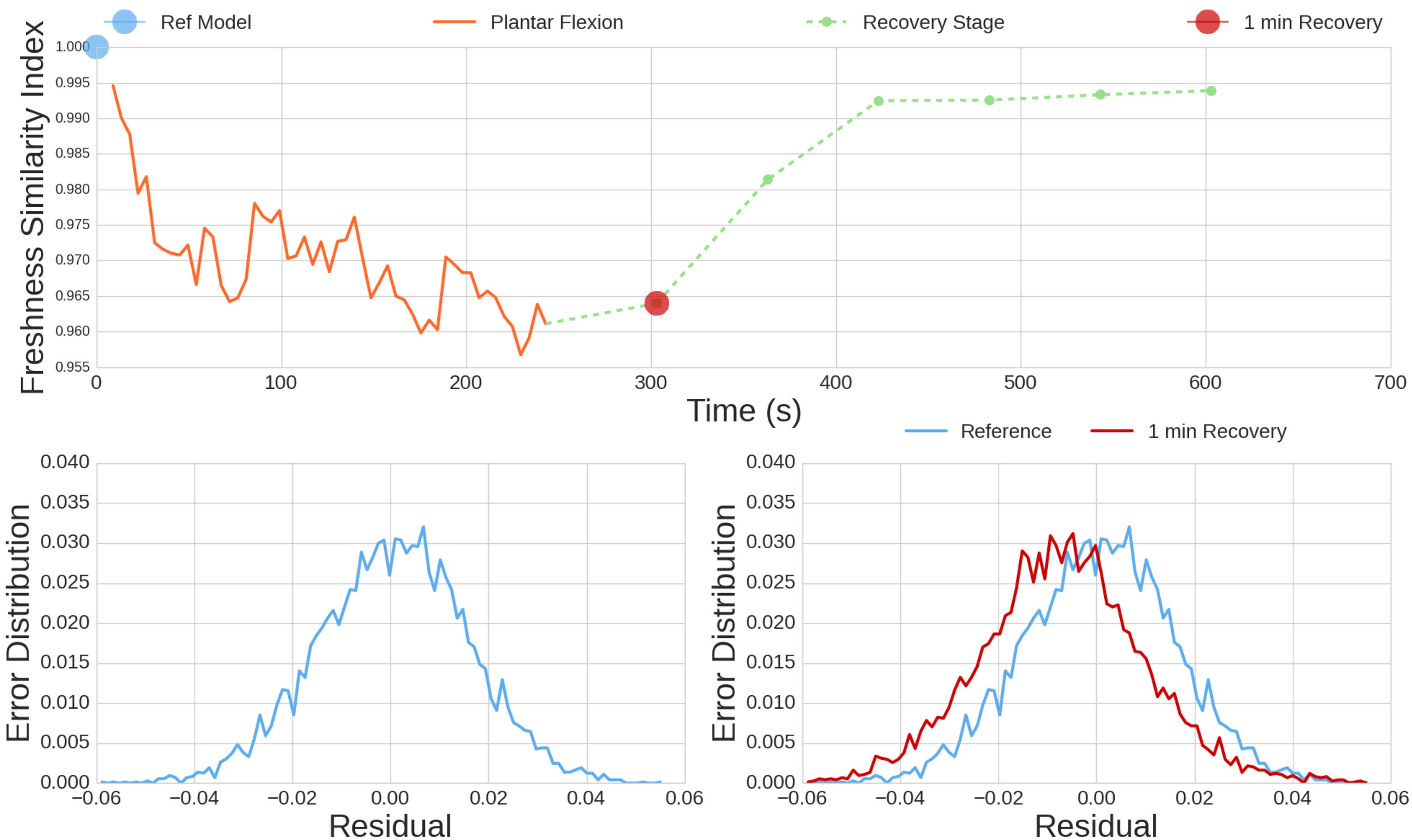

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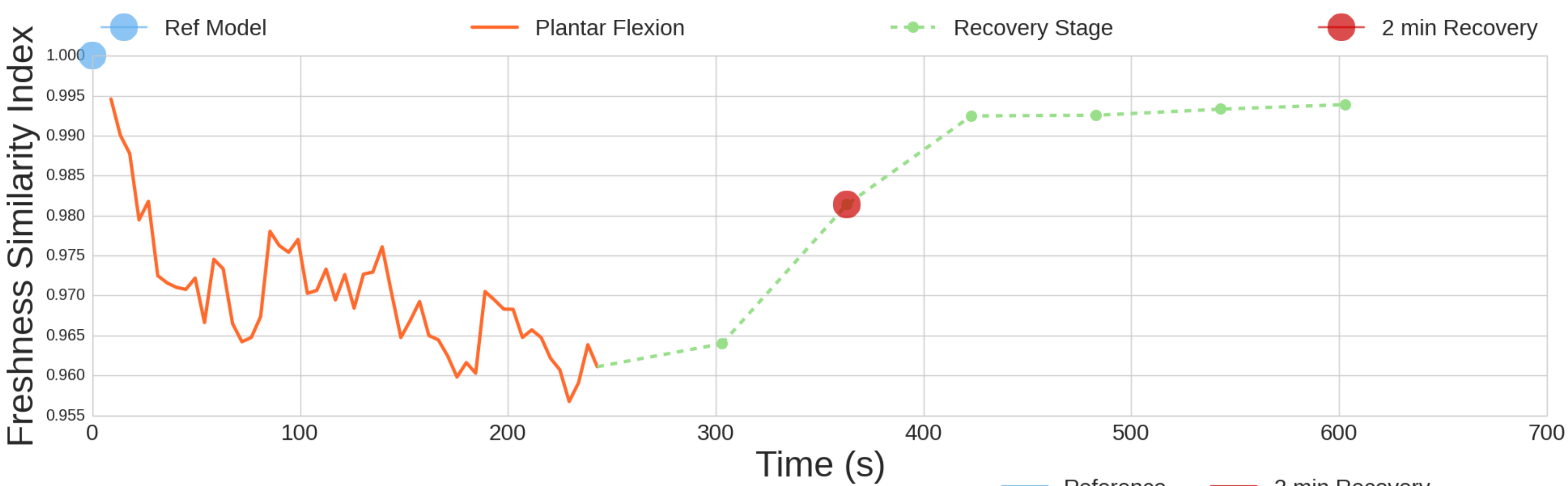

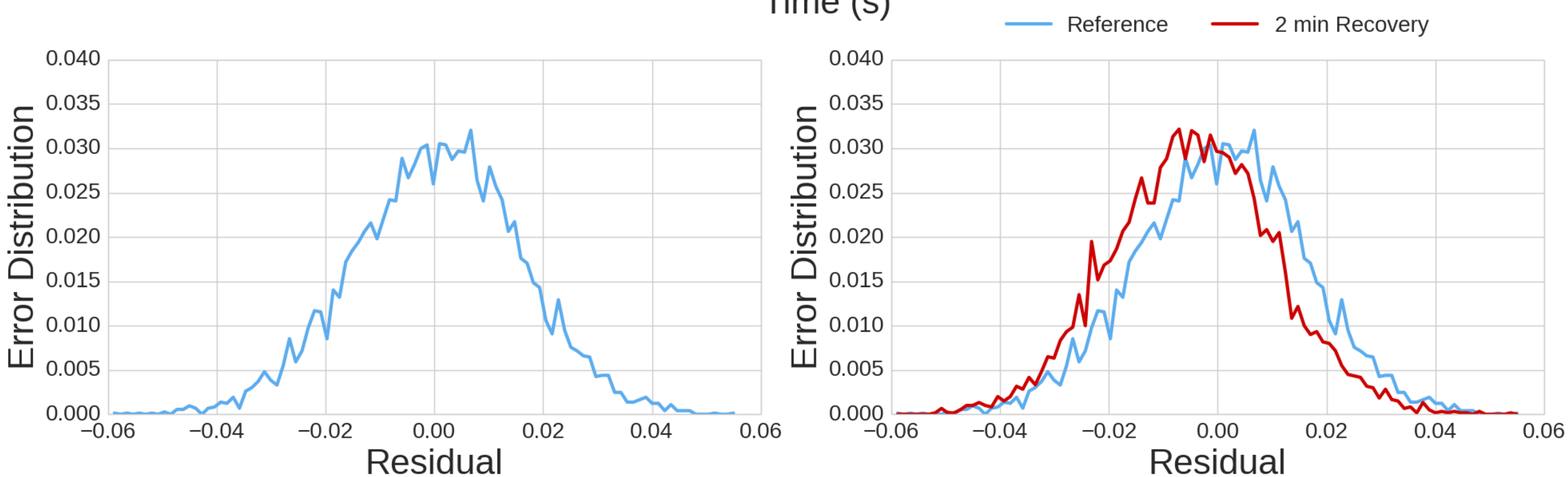

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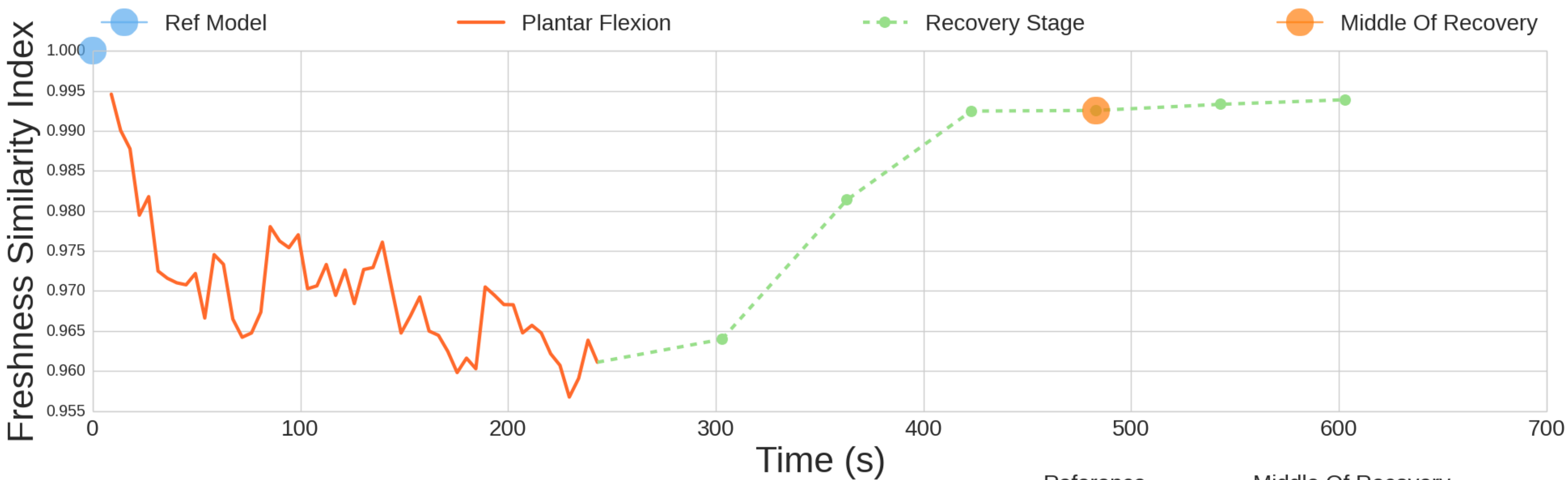

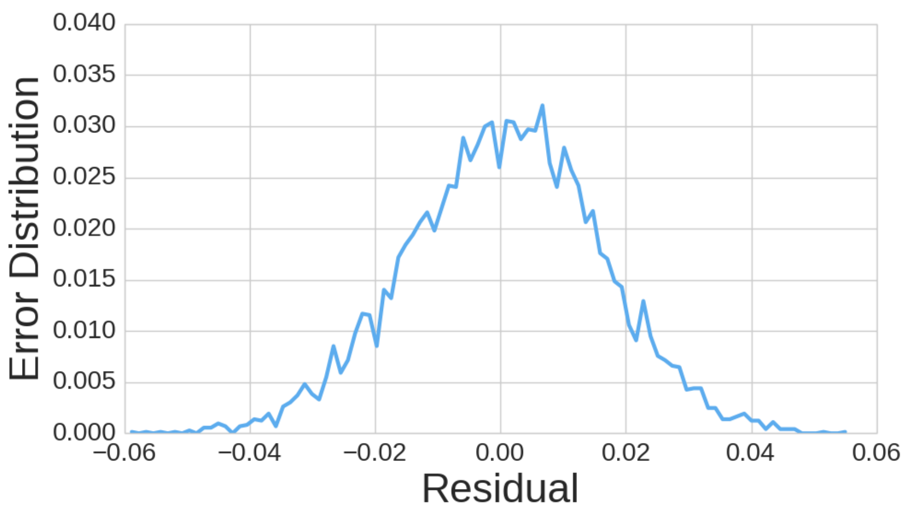

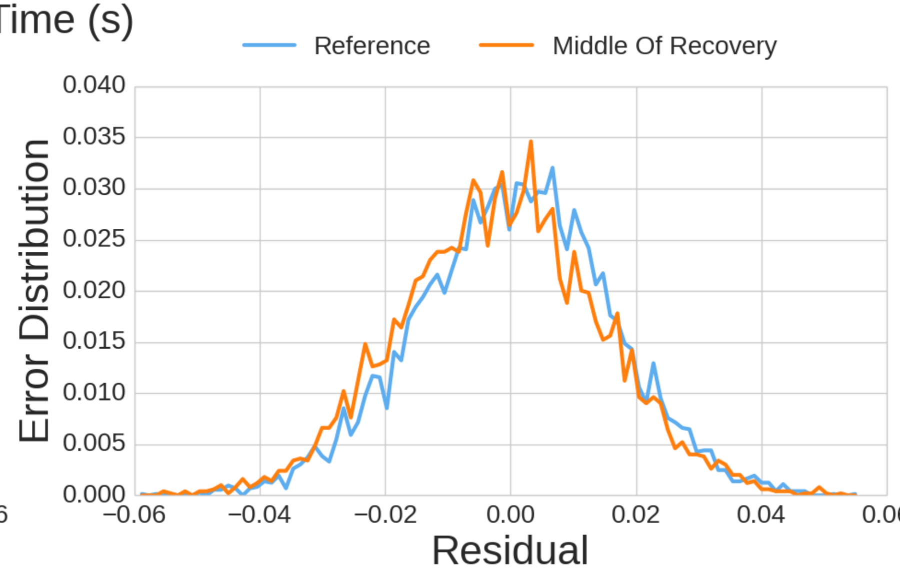

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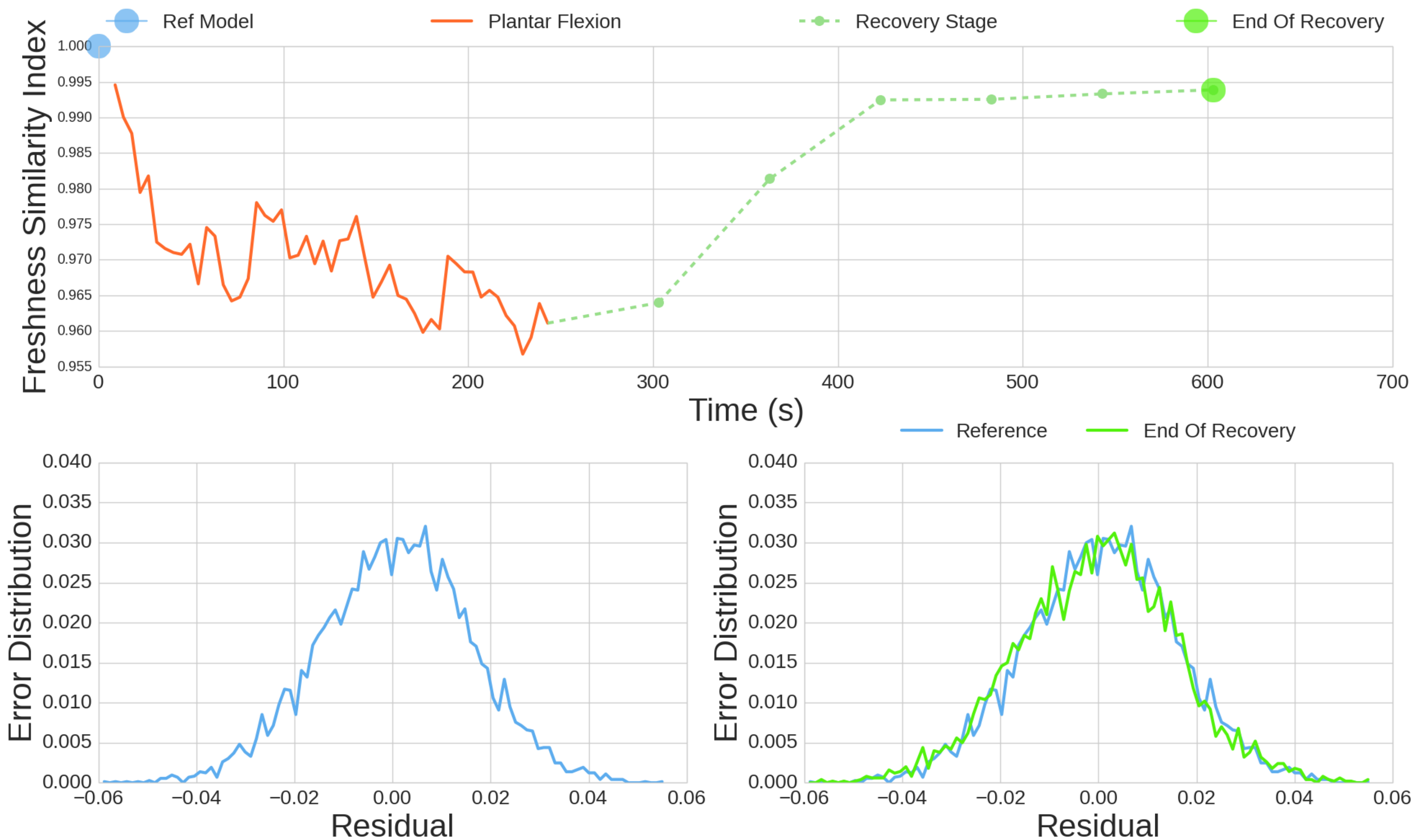
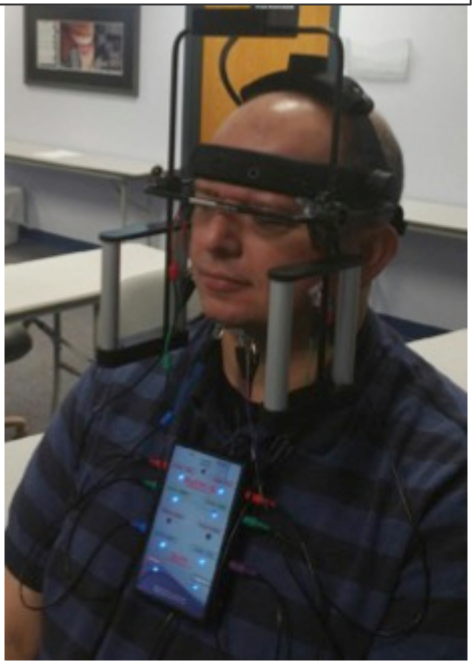
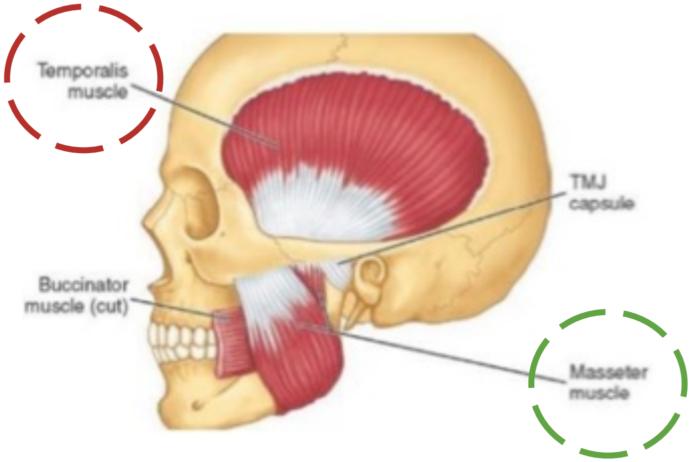


DATA SET 2: TMJ MUSCLE CYCLIC MOTION

Yu Yang Xie, "*A Model Based Approach for Evaluating Human Neuromusculoskeletal System Performance,*" MS Thesis, University of Texas at Austin, 2016





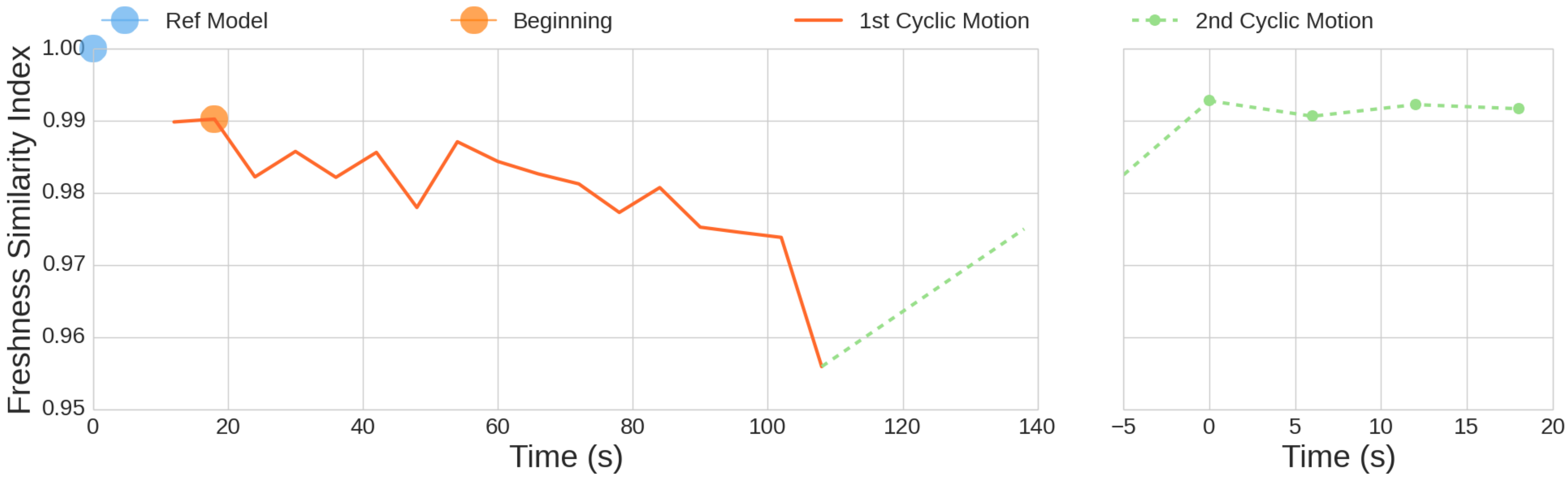
Sampling rate: 2000 Hz

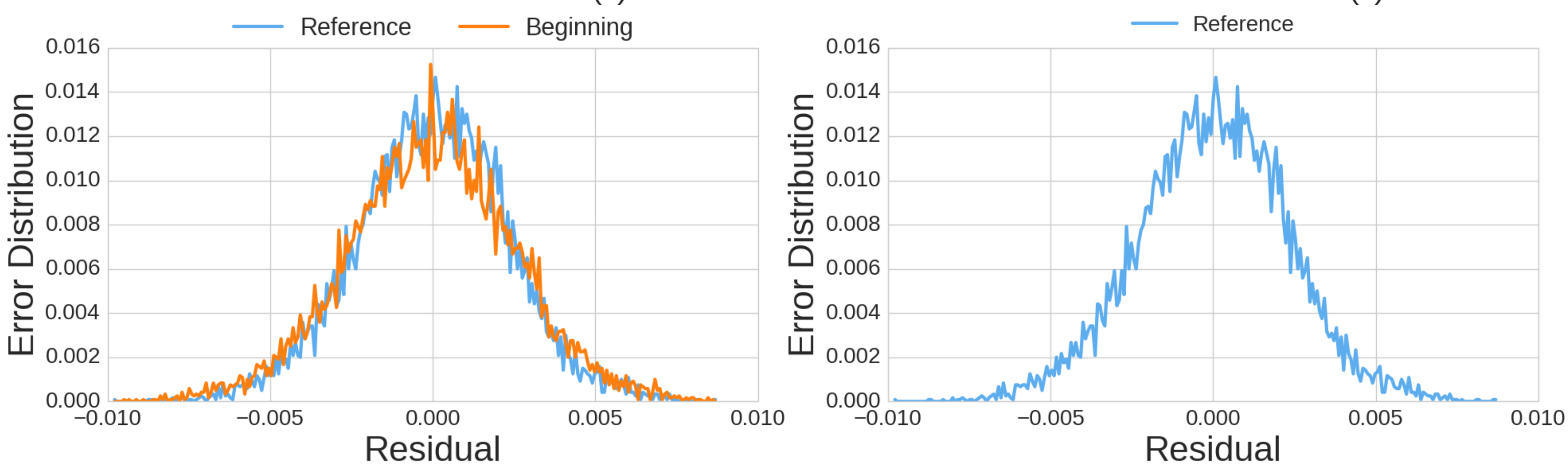
Related muscles: Temporalis, Masseter and Depressor

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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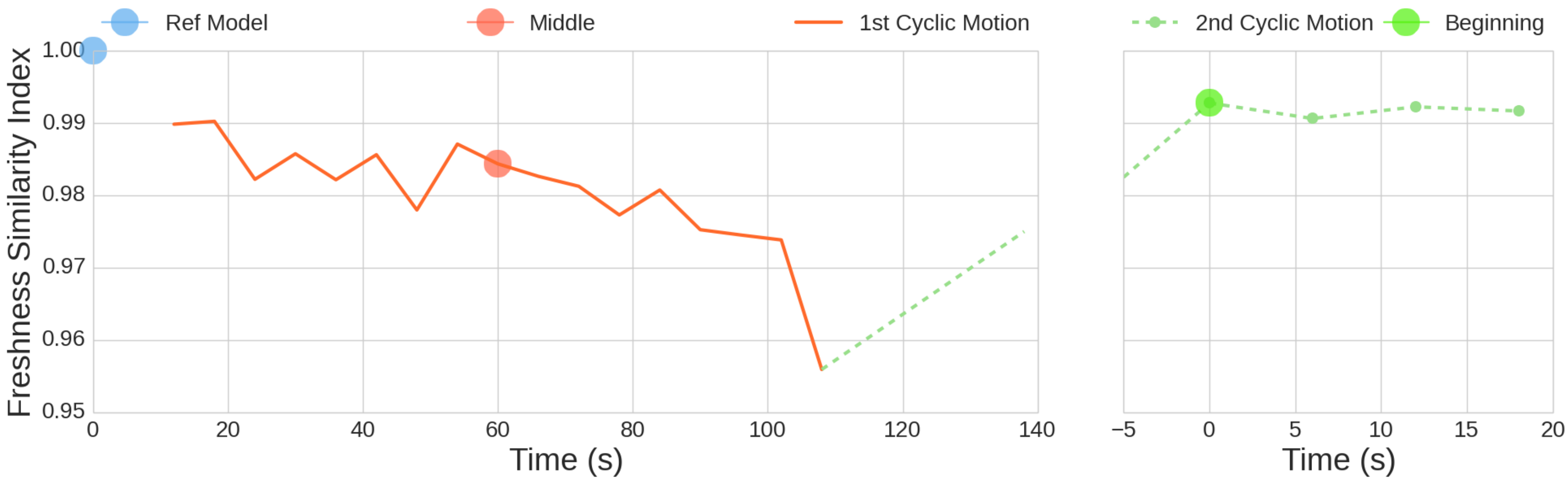

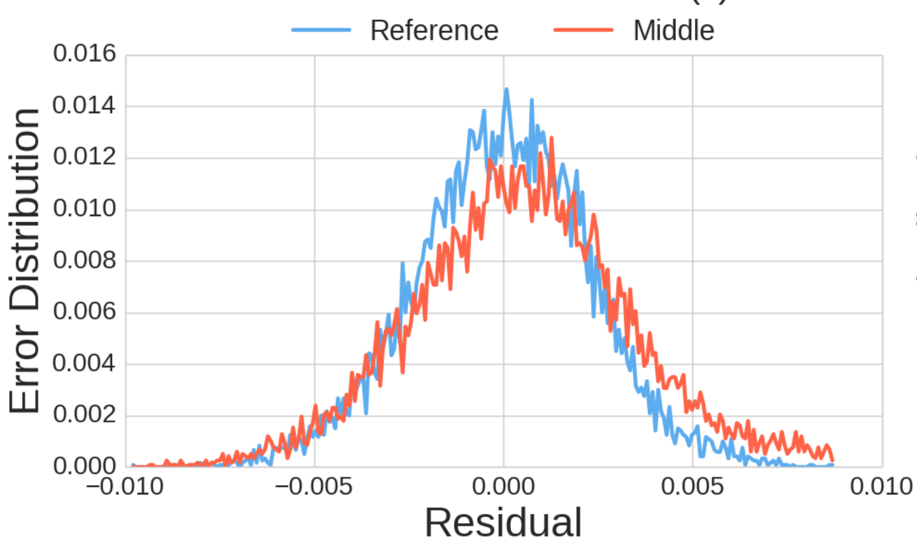

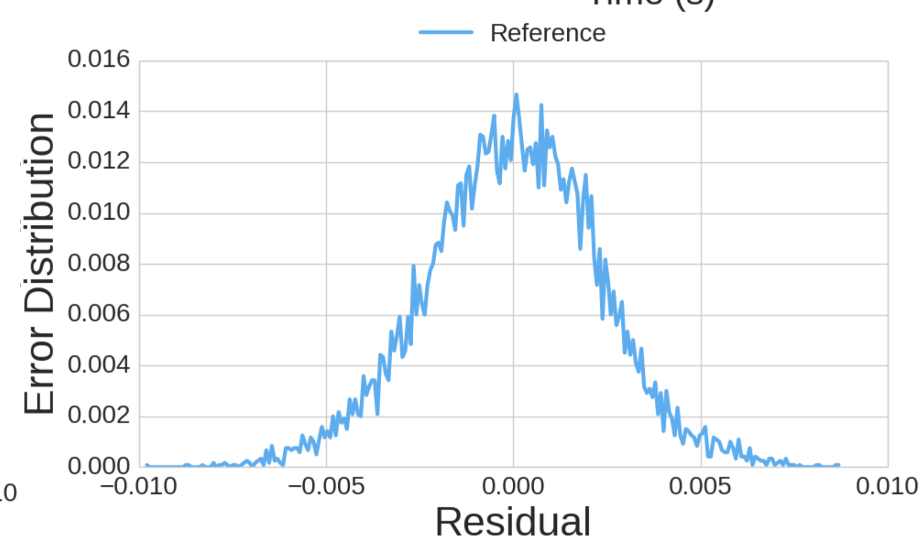

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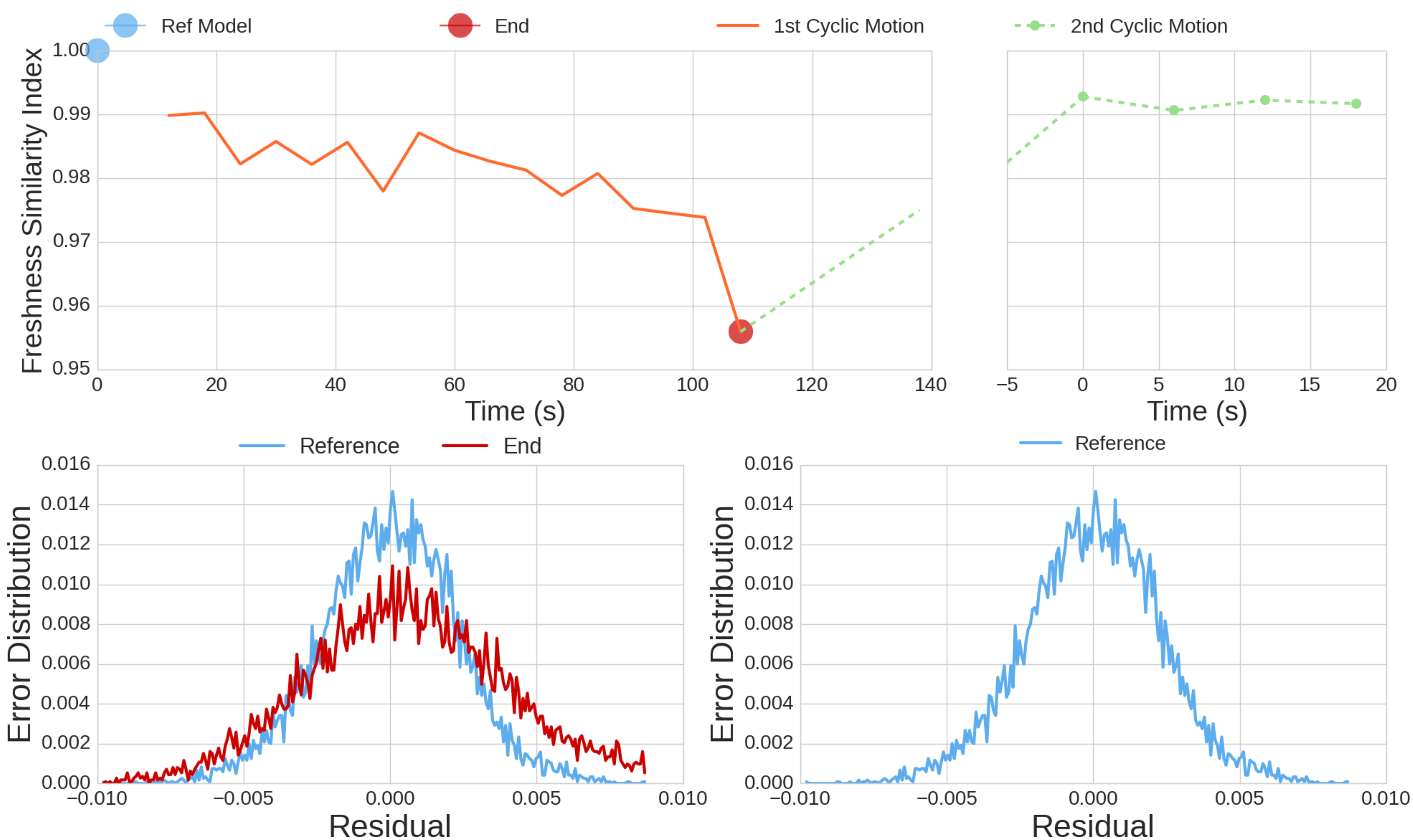

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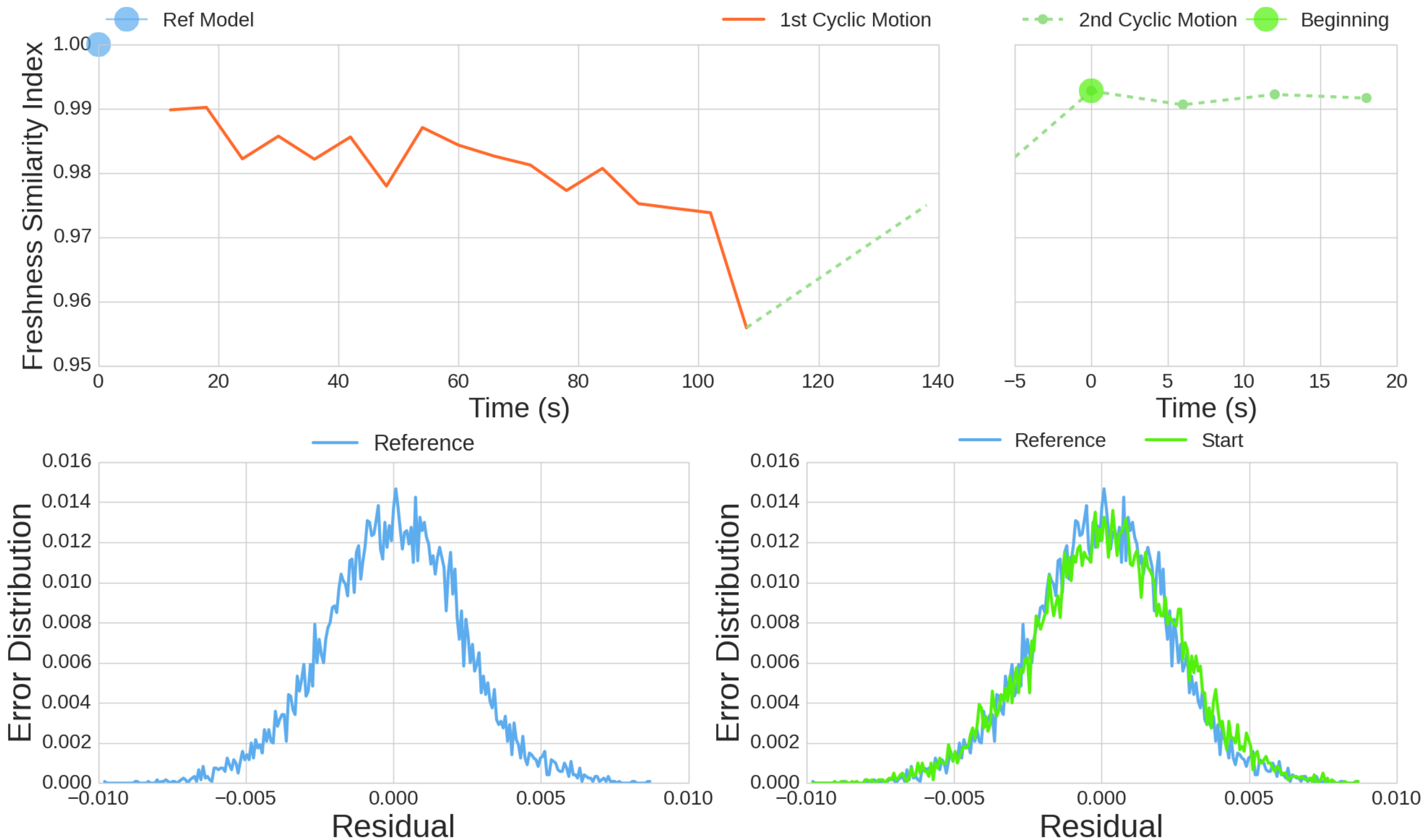
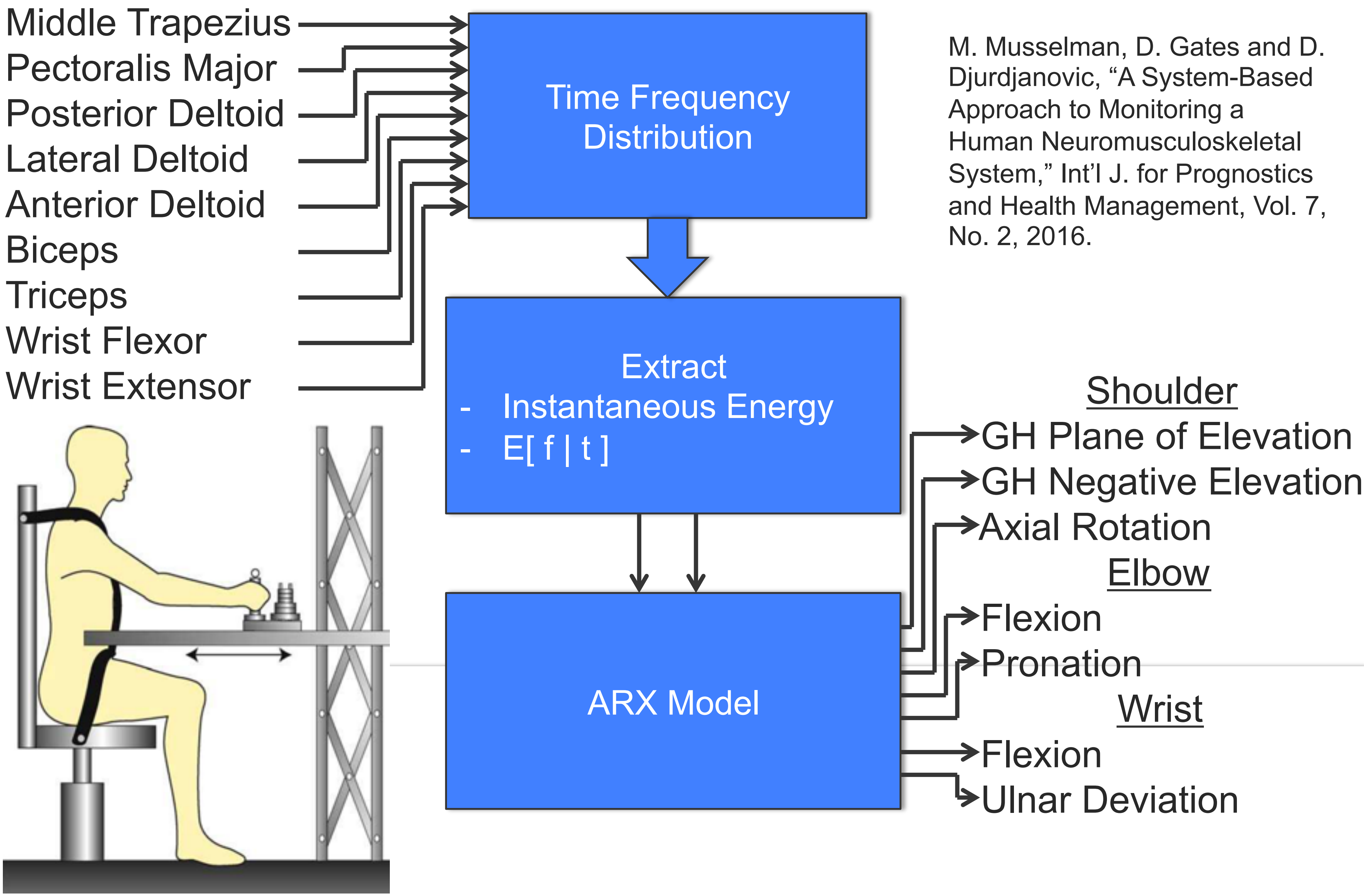


DATASET 3: ARM AND SHOULDER SYSTEM



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.

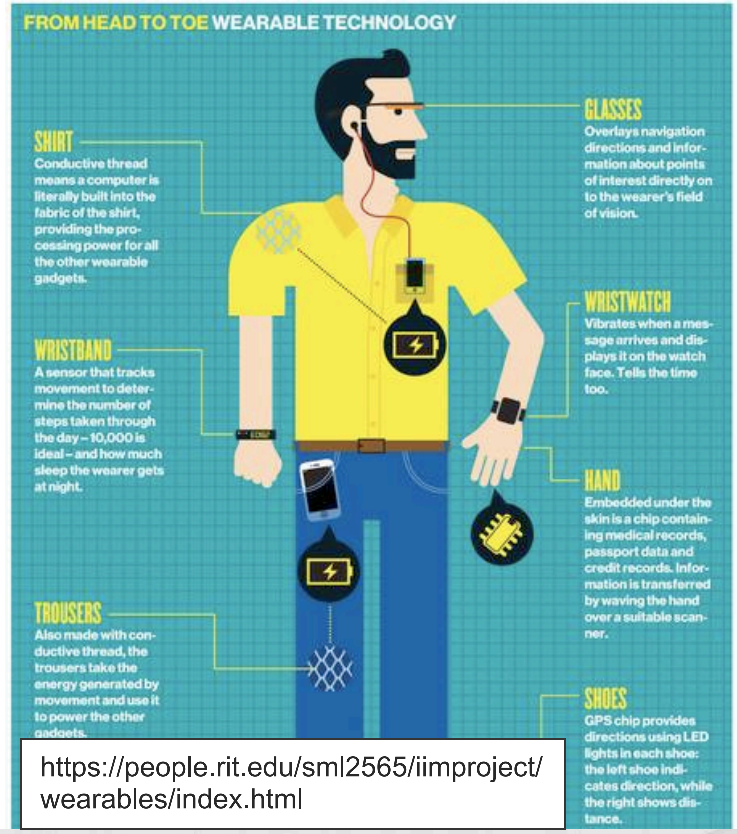
CONTRIBUTIONS AND FINDINGS

- **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