Peng Wang, Ph.D.

Assistant Professor

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EDUCATION

Ph.D., August 2017:	**Mechanical & Aerospace Engineering**, Case Western Reserve University, Cleveland, OH GPA: 4.0/4.0 **Advisor:** Prof. Robert X. Gao
Research Assistant, 2013-2015	**Mechanical Engineering**, University of Connecticut, CT GPA: 3.86/4.0
M.S., December 2012:	**Computer Science**, College of Information Science and Technology, Beijing University of Chemical Technology, China GPA: 3.48/4.0; Class rank: top 5%
B.E., July 2010:	**Communication Engineering**, College of Information Science and Technology, Beijing University of Chemical Technology, China GPA: 3.84/4.0; Class rank: top 1%

RESEARCH INTERESTS

- Stochastic modeling-based predictive science for dynamical system condition monitoring, fault diagnosis, and remaining service life prognosis, with applications to manufacturing machines and equipment, aircraft engines, building HVAC systems, etc.
- Deep Learning for modeling and analysis in complex manufacturing system modeling; explainable Deep Learning structure
- Multi-mode data fusion and sensing orthogonal analysis for in-process quality inference

PROFESSIONAL EXPERIENCE

August 2019 - Present

Assistant Professor, University of Kentucky

- **Stochastic Modeling for Performance Degradation Prediction**
  - ✓ Investigate the Lévy process in conjunction with distributed particle filter to relax the requirements on physical models while improving model accuracy and computational efficiency
  - ✓ Propose a fractional Lévy model to describe non-homogeneity due to transients in the degradation process
  - ✓ Develop a distributed PF by partitioning the posterior distribution from high-dimensional space to lower subspaces, with the partitioned estimation executed in parallel
- **Data Fusion for Product Quality Assessment**
  - ✓ Develop an orthogonal analysis to investigate what sensing modality contributes the most to describing the variation in quality when apply multivariate data fusion for process monitoring
  - ✓ Integrate data-driven analysis into process-related physical models, to leverage insight obtained from data analytics to enhance understanding of the mechanisms underlying manufacturing processes
- **Explainable Deep Learning for Process Modeling**

- ✓ Investigate layer-wise relevance propagation (LRP) that redistributes network outputs backwards to generate relevance scores for relating the contributions of inputs and hidden neurons to the outputs, to improve transparency in Deep Learning-based decision-making
- ✓ Quantify dependencies of e.g., material or energy efficiency on process parameters, which is of significance to manufacturing process optimization towards improved manufacturing, energy, and material efficiency

November 2017 – July 2019

Postdoctoral Research Associate, Case Western Reserve University

- **Deep Learning-based Human Motion Prediction for Context-Aware Human-Robot Collaboration** (funded by NSF)
  - ✓ Investigated Deep Learning as an advanced machine learning technique for continuous human motion analysis. Specifically, a transfer learning-enabled deep convolutional neural network is developed for context-aware human motion recognition
  - ✓ Proposed a variable-order Markov model to accurately parse human actions and environmental contexts for discovering and learning human behavior patterns, with human heterogeneity in performing the same manufacturing tasks fully considered through capturing the high and low order Markov dependencies between human actions
- **Industrial Artificial Intelligence for Advanced Manufacturing**
  - ✓ Investigated Lévy process for stochastic description of the machine/system dynamics, and formulated machine/system performance degradation in general as accumulations of successive and jump increments, with modelling uncertainty evaluated through Bayesian inference-based data calibration
  - ✓ Proposed a streamlined hierarchical structure to simulate a production line by first partitioning it into individual process and then integrate at system level through a Markov chain. At individual process level, causal effects of process variables on energy and manufacturing efficiency will be modeled and quantified through explainable deep learning structures

February 2015 – August 2017

Graduate Research Assistant, Case Western Reserve University

- **Stochastic Modeling for Improved Spare Parts Inventory Management in Aircraft Engines** (funded by NSF)
  - ✓ Developed a virtual sensing model based on Bayesian inference for performance degradation prognosis of aircraft engines at the module level
  - ✓ Developed an enhanced particle filtering (PF) method by improving the resampling strategy and leveraging the interacting filtering architecture, to improve prognosis accuracy and confidence level, as well as the reliability of the established prognostic models
  - ✓ Incorporated various sensing techniques into gas path analysis, for engine performance estimation and prognosis at the component level
- **Fault Detection, Diagnosis, and Prognosis for HVAC Systems** (funded by NSF)
  - ✓ Proposed a set of physical indicators of system performance based on thermal and fluid dynamics principles, for system characterization, fault detection, diagnosis, and prognosis
  - ✓ Investigated deep learning methods (e.g., deep belief network and deep convolutional neural network) to improve fault detection and diagnosis accuracy, in particular at fault incipient stage
  - ✓ Developed a filtering method by integrating particle filtering and total variation filtering, for improved robustness in tracking performance degradations with time-varying deterioration modes and rates, and abrupt fault occurrences

January 2013 – January 2015

Graduate Research Assistant, University of Connecticut

- **Non-Interference Stress Measurement through Subspace Estimation Technique** (funded by Pratt & Whitney)

- ✓ Developed and evaluated an Enhanced ESPRIT (E^2SPRIT) algorithm to process blade tip time-of-arrival data in the presence of high-order vibration modes and low signal-to-noise ratio
- ✓ Designed a blade tip timing signal simulator for both synchronous and asynchronous vibrations

CONTRIBUTION TO WINNING PROPOSALS

- "Cloud-Enabled Machines with Data Driven Intelligence", Digital Manufacturing and Design Innovation Institute (DMDII), DMDII-15-14-01, 2/2017-9/2018, Funded.
- "Manufacturing USA: NRI: INT: COLLAB: Intelligent Human Robot Collaboration for Smart Factory", National Science Foundation, CMMI-1830295, 9/2018-9/2022, Funded.

HONORS AND AWARDS

- **Outstanding Reviewer Award**, North American Manufacturing Research Conference (NAMRC), June, 2019.
- **Outstanding Reviewer Award**, North American Manufacturing Research Conference (NAMRC), June, 2018.
- **Outstanding Graduate Research Award**, Department of Mechanical and Aerospace Engineering, Case Western Reserve University, May, 2018.
- **Outstanding Paper Award**, 2017 North American Manufacturing Research Conference, University of California, Los Angeles, June, 2017.
- **First Prize,** DMDII DMC Hackathon, Chicago, IL, July, 2016.
- **Best Student Paper Award,** IEEE International Conference on Automation Science and Engineering (CASE), Gothenburg, Sweden, August, 2015.
- **Outstanding Presentation Award**, International Conference on Motion and Vibration, Sapporo, Japan, August, 2014.

BOOK CHAPTER

B1. R.X. Gao and P. Wang, "Sensors to Control Processing and Improve Lifetime and Performance for Sustainable Manufacturing", in *Encyclopedia of Sustainable Technologies* (ed. Martin Abraham), Elsevier, 2016.

B2. R. Gao, P. Wang, and R. Yan, "Machine Tool Prognosis for Precision Manufacturing", in *Precision Manufacturing: Metrology* (ed. Wei Gao), ch. 8, Springer Nature, 2019.

B3. R. Gao, R. Yan, and P. Wang, "Advanced Data Analytics for Health Monitoring and Prognostics in Manufacturing", in *Smart Manufacturing*, World Scientific, under review.

JOURNAL ARTICLES

J1. S. Shao, R. Yan, Y. Lu, P. Wang, and R. Gao, "DCNN-based Multi-signal Induction Motor Fault Diagnosis", IEEE Transactions on Instrument and Measurement, 2019. in press.

J2. P. Wang, Z. Liu, R. Gao, and Y. Guo, "Heterogeneous Data-Driven Hybrid Machine Learning for Tool Condition Monitoring", *CIRP Annals-Manufacturing Technology,* Vol. 68, No. 1, pp. 455-458, 2019.

J3. D. Zhao, W. Cheng, R. Gao, R. Yan, and P. Wang, "Generalized Vold-Kalman Filtering for Compound Faults Detection of Bearing and Gearbox Under Nonstationary Condition", *IEEE Transactions on Instrument and Measurement*, Vol. 26, pp. 1213-1220, 2019.

J4. J. Zhang, P. Wang, and R. Gao, "Deep Learning-Based Tensile Strength Prediction in Fused Deposition Modeling", *Computers in Industry*, Vol. 107, pp. 11-21, 2019.

J5. R. Zhao, R. Yan, Z. Chen, K. Mao, P. Wang, and R. Gao, "Deep Learning and Its Applications to Machine Health Monitoring", *Mechanical Systems and Signal Processing*, Vol. 115, pp.213-237, January, 2019.

J6. C. Sun, P. Wang, R. Yan, R. Gao, and X. Chen, "Machine Health Monitoring based on Locally Linear Embedding with Sparse Representation for Neighborhood Optimization", *Mechanical Systems and Signal Processing*, Vol. 114, pp. 25-34, 2019.

J7. J. Zhang, P. Wang, R. Yan, and R. Gao, "Long Short Time Memory for Machine Remaining Life Prediction", *SME Journal of Manufacturing Systems*, Vol. 48, pp. 78-86, 2018.

J8. J. Zhang, P. Wang, R. Gao, C. Sun, and R. Yan, "Induction Motor Condition Monitoring for Sustainable Manufacturing", *Procedia Manufacturing*, Vol. 33, pp. 802-809, 2018.

J9. D. Zhao, J. Li, W. Cheng, P. Wang, R. Gao and R. Yan, "Vold-Kalman generalized demodulation for multi-fault detection of gear and bearing under variable speed", Vol. 26, pp. 1213-1220, 2018.

J10. J. Zhang, P. Wang, and R. Gao, "Modeling of Layer-Wise Additive Manufacturing for Part Quality Prediction", *Procedia Manufacturing*, Vol. 16, pp. 155-162, 2018.

J11. P. Wang, H. Liu, L. Wang, and R. Gao, "Deep Learning-based Human Motion Recognition for Context-Aware Human Robot Collaboration", *CIRP Annals-Manufacturing Technology*, Vol. 67, No. 1, pp. 17-20, July, 2018.

J12. J. Zhang, P. Wang, R. Gao, and R. Yan, "An Image Processing Approach to Machine Fault Diagnosis Based on Visual Words Representation", *Procedia Manufacturing*, Vol. 19, pp. 42-49, 2018.

J13. S. Shao, W. Sun, R. Yan, P. Wang, and R. Gao, "A Deep Learning Approach for Fault Diagnosis of Induction Motors in Manufacturing", *Chinese Journal of Mechanical Engineering*, Vol. 30, No. 6, pp. 1347-1356, November, 2017.

J14. P. Wang, Z. Fan, D. Kazmer, and R. Gao, "Orthogonal Analysis of Multi-Sensor Data Fusion for Improved Quality Control", *ASME Journal of Manufacturing Science and Engineering*, Vol. 139, No. 10, pp. 101008, August, 2017.

J15. P. Wang, R. Gao, and R. Yan, "A Deep Learning-Based Approach to Material Removal Rate Prediction in Polishing", *CIRP Annals-Manufacturing Technology*, Vol. 66, No. 1, pp. 429-432, April, 2017.

J16. J. Wang, Y. Zheng, P. Wang, and R. Gao, "A Virtual Sensing based Augmented Particle Filtering for Tool Condition Prognosis", *SME Journal of Manufacturing Processes*, Vol. 28, No. 3, pp. 472-478, April, 2017.

J17. P. Wang, Ananya, R. Yan, and R. Gao, "Virtualization and Deep Recognition for System Fault Classification", *SME Journal of Manufacturing Systems*, Vol. 44, No. 2, pp. 310-316, April, 2017.

J18. P. Wang and R. Gao, "Automated Performance Tracking for Heat Exchangers in HVAC", *IEEE Transactions on Automation Science and Engineering*, Vol. 14, No. 2, pp. 634-645, March, 2017.

J19. P. Wang and R. Gao, "Markov Nonlinear System Estimation for Engine Performance Tracking", *ASME Journal Engineering for Gas Turbine and Power*, Vol. 138, No. 9, pp. 091201, March, 2016.

J20. P. Wang, R. Gao, and Z. Fan, "Cloud Computing for Manufacturing: Benefits and Limitations", *ASME Journal of Manufacturing Science and Engineering*, Vol. 137, No. 4, pp. 040901, July, 2015.

J21. P. Wang and R. Gao, "Adaptive Resampling-Based Particle Filtering For Tool Life Prediction", *SME Journal of Manufacturing Systems*, Vol. 37, No. 2, pp. 528-534, April, 2015.

J22. J. Wang, P. Wang, and R. Gao, "Enhanced Particle Filter for Tool Wear Prediction", *SME Journal of Manufacturing Systems*, Vol. 36, pp. 35-45, April, 2015.

J23. P. Wang, D. Karg, R. Gao, Z. Fan, K. Kwolek, and A. Consiglio, "Non-Contact Identification of Rotating Blade Vibration", *Mechanical Engineering Journal*, *Japan Society of Mechanical Engineering,* Vol. 2, No. 3, pp. 1-12, March, 2015.

JOURNAL ARTICLES UNDER REVIEW

J24. B. Hou, R. Yan, P. Wang, and R. Gao, "Bearing Fault Diagnosis Based on MED-NSP and Teager-Kaiser Energy Operator", under review.

J25. P. Wang, R. Gao, and W. Woyczynski, "Lévy Process-Based Stochastic Modeling for Machine Performance Degradation Prognosis", under review.

J26. P. Wang, R. Yan, and R. Gao, "Multi-Mode Particle Filtering for Rolling Bearing Remaining Life Prediction", under review.

CONFERENCE PUBLICATIONS

C1. P. Wang and R. Gao, "Prognostic Modeling of Performance Degradation and Capacity Regeneration Phenomena in Lithium-ion Battery", *Proc. 2019 North American Manufacturing Research Conference*, Eire, PA, USA, June, 2019

C2. J. Grezmak, P. Wang, and R. Gao, "Explainable Deep Convolutional Neural Network for Rotary Machine Fault Diagnosis in Sustainable Manufacturing", *Proc. 26th CIRP Life Cycle Engineering (LCE) Conference*, West Lafayette, IN, USA, May, 2019.

C3. P. Wang, and R. Gao, "Lévy Process-Based Stochastic Modeling for Machine Performance Degradation Prognosis", *Proc. 44th Annual Conference of the IEEE Industrial Electronics Society*, Washington DC, USA, October, 2018.

C4. P. Wang, R. Yan, and R. Gao, "Multi-Mode Particle Filtering for Rolling Bearing Remaining Life Prediction", *Proc. 2018 ASME Manufacturing Science and Engineering Conference*, paper #: MSEC 2018-6638, College Station, TX, USA, June, 2018.

C5. J. Zhang, P. Wang, Y. Yan, and R. Gao, "Deep Learning for Improved System Remaining Life Prediction", Procedia CIRP (*Proc. CIRP Conference on Manufacturing Systems*), Vol. 72, pp. 1033-1038, 2018.

C6. J. Zhang, P. Wang, Y. Yan, and R. Gao, "Induction Motor Fault Diagnosis and Classification Through Sparse Representation", *Proc. 2017 ASME Dynamic Systems and Control Conference*, DSCC2017-5259, Tysons, Virginia, USA, October, 2017.

C7. P. Wang and R. Gao, "Through Life Analysis for Machine Tools: from Design to Remanufacture", *Procedia CIRP* (*Proc. CIRP Conference on Through-Life Engineering Services*), Vol. 59, pp. 2-7, 2017.

C8. S. Shao, W. Sun, P. Wang, R. Gao, and R. Yan, "Learning Features from Vibration Signals for Induction Motor Fault Diagnosis", *Proc. 2016 International Symposium on Flexible Automation*, Cleveland, OH, USA, August, 2016.

C9. C. Sun, P. Wang, R. Yan, and R. Gao, "A Sparse Approach to Fault Severity Classification for Gearbox Monitoring", *Proc. 19th IEEE International Conference on Information Fusion*, Heidelberg, Germany, July, 2016.

C10. P. Wang and R. Gao, "Online Fault Detection and Diagnosis for Chiller System", *Proc. 12th IEEE International Conference on Automation Science and Engineering*, Fort Worth, Texas, USA, August, 2016.

C11. Z. Fan, R. Gao, P. Wang, and D. Kazmer, "Multi-sensor Data Fusion for Improved Measurement Accuracy in Injection Molding", *Proc. 2016 IEEE International Instrumentation and Measurement Technology Conference*, Taipei, Taiwan, May, 2016.

C12. D. Wu, P. Wang, R. Yan, and R. Gao, "A Correlation-based Approach to Trustworthy Sensing for Cyber-Physical Systems", *Proc. 2016 IEEE International Instrumentation and Measurement Technology Conference*, Taipei, Taiwan, May, 2016.

C13. P. Wang and R. Gao, "Stochastic Tool Wear Prediction for Sustainable Manufacturing", *Procedia CIRP* (*Proc. CIRP Conference on Life Cycle Engineering*), Vol. 48, pp. 236-241, 2016.

C14. P. Wang, R. Gao, D. Wu, and J. Terpenny, "A Computational Framework for Cloud-Based Prognosis", *Procedia CIRP* (*Proc. CIRP Conference on Manufacturing Systems*), Vol. 57, pp. 309-314, 2016.

C15. P. Wang, R. Gao, Z. Fan, and X. Tang, "Trustworthy Sensing for Product Quality", *Proc.48th CIRP Conference on Manufacturing Systems*, paper #: PROCIR-D-15-00232, Naples, Italy, June, 2015.

C16. P. Wang, X. Tang, and R. Gao, "Automated Performance Tracking for Heat Exchanger in HVAC", *Proc. 11th IEEE International Conference on Automation Science and Engineering*, pp. 949-954, Gothenburg, Sweden, August, 2015.

C17. P. Wang, R. Gao, and Z. Fan, "Switching Local Search Particle Filter for Heat Exchanger Degradation Prognosis", *Proc. 2015 IEEE International Instrumentation and Measurement Technology Conference*, pp. 539-544, Pisa, Italy, May, 2015.

C18. P. Wang and R. Gao, "Particle Filtering-Based System Degradation Prediction Applied to Jet Engines", *Proc. 2014 Annual Conference of the Prognosis and Health Management Society*, paper #067, Fort Worth, TX, USA, September, 2014.

C19. P. Wang, R. Gao, Z. Fan, D. Karg, K. Kwolek, and A. Consiglio, "Noninterference identification of rotating blade vibration", *Proc. 12th International Conference on Motion and Vibration*, paper #10205, Sapporo, Japan, August, 2014.

C20. J. Wang, P. Wang, and R. Gao, "Tool Life Prediction for Sustainable Manufacturing", *Proc. 11th Global Conference on Sustainable Manufacturing*, pp. 230-234, Berlin, Germany, September, 2013.

C21. P. Wang, R. Gao, H. Wang, and H. Yuan, "Defect Growth Prediction in Rolling Bearing based on Approximate Entropy", *Proc. 2013 ASME Dynamic Systems and Control Conference*, paper # V002T24A004, Stanford University, CA, USA, October, 2013.

INVITED TALKS

T1. Prognostic Modeling for System Remaining Life Prediction, Southeast University, Nanjing, China, October, 2017.

T2. Stochastic Modeling for Engine Remaining Life Prediction, Beijing University of Chemical Technology, Beijing, China, June, 2017.

T3. Robust Remaining Life Prediction of Aircraft Engine based on Hybrid Sensing, Annual Conference of the Production and Operation Management Society, Orlando, FL, May, 2016.

T4. Generalized and Robust Prognostics, Annual Conference of the Prognostics and Health Management Society, Coronado, CA, October, 2015.

TEACHING EXPERIENCE (AS TEACHING ASSISTANT OR PROJECT ADVISOR)

- CWRU/EMAE 181, Dynamics (Sophomore)
- CWRU/EMAE 350, Mechanical Engineering Analysis (Junior)
- CWRU/EMAE 370 Mechanical Component Design (Junior)
- CWRU/EMAE 398, Senior Project (as a project advisor for 3 Senior students to build a real-time process monitoring system for additive manufacturing and characterizing the correlation between process parameters and final part quality)
- UConn/ME 5160, Advanced Control (Graduate)

EDUCATIONAL SERVICES (AS CO-ADVISOR)

- CWRU graduate students: John Grezmak, Jianjing Zhang, Qianqian Xiong, Mingchen Cao, Fangfei Ju, Dezun Zhao,
- CWRU undergraduate students: Joe Pickard, Michael Hampton, Ishaan Rao, Lovish Mehndiratta, Carlos Lizarraga
- UConn undergraduate students: Donald Karg, Rosse Gates

PROFESSIONAL SERVICES

- Guest Editor, Special Issue on "Smart Sensing and Artificial Intelligence-Enabled Data Analytics for Health Monitoring of Engineering Systems", *IEEE Sensor Journal*, 2019.
- Member, North American Manufacturing Research Institution of SME (NAMRI/SME) Scientific Committee, 2018-2020.
- Guest Editor, Special Issue on "Deep Learning for Diagnosis and Prognosis in Manufacturing", *Computers in Industry*, 2018.

- Session Chair, Annual Conference of the Prognostics and Health Management Society, Coronado, CA, October, 2015.

REVIEWER FOR JOURNAL AND CONFERENCE PAPERS

- ASME Journal of Manufacturing Science and Engineering
- IEEE Transactions on Instrument and Measurement
- IEEE Transactions on Industrial Electronics
- IEEE Transactions on Industrial Informatics
- IEEE Transactions on Automation Science and Engineering
- SME Journal of Manufacturing Systems
- Mechanical Systems and Signal Processing
- Computers in Industry
- Measurement
- Annual Conference of Prognosis and Health Management Society
- IEEE International Instrumentation and Measurement Technology Conference
- Manufacturing Science and Engineering Conference