Course Syllabus

Prognostics and Health Management

ENME 737
Fall 2020

Course Description

Prognostics and health management (PHM) is an enabling discipline consisting of technologies and methods to assess the reliability of a product in its actual life cycle conditions to determine the advent of failure and mitigate system risk. PHM permits the reliability of a system to be evaluated and predicted in its actual application conditions. In recent years, PHM has emerged as a key enabling technology to provide an early warning of failure; to forecast maintenance as needed; to reduce maintenance cycles; to assess the potential for life extensions, and to improve future designs and qualification methods. In the future, PHM will enable systems to assess their own real-time performance (self-cognizant health management and diagnostics) under actual usage conditions and adaptively enhance life cycle sustainment with risk-mitigation actions that will virtually eliminate unplanned failures.

The application areas of PHM include aerospace structures and avionics, automobiles, civil structures, consumer and industrial electronics, defense infrastructure and medical equipment, and machine tools. Some of the topics covered in this course include:

- Fundamentals of PHM
- Data Pre-processing (Data Cleansing, Feature Extraction, Feature Selection, Feature Learning)
- Internet of Things, Big Data, and Sensors for PHM
- Physics-of-Failure Approach to Prognostics
- Machine Learning and Artificial Intelligence for Anomaly Detection, Diagnostics, and Prognostics
- Bayesian Statistics, Uncertainty Interpretation, Quantification, and Management in Prognostics
- PHM Cost and Return on Investment
- Valuation and Optimization of PHM-enabled Maintenance Decisions
- Software Tools for PHM
- Predictive Maintenance
- PHM Applications in Industry
- Challenges and Opportunities in PHM

This is an interdisciplinary course and students in many areas including aerospace, civil, electrical, and mechanical engineering, and engineering management are welcome. Students will get the opportunity to learn the basic scientific foundations that enable PHM and work on its implementation for real-life applications through projects. Guest lectures in this course will be taught by experts from industry, government, and academia.

The knowledge of PHM methodologies and technologies will prepare students to develop and implement PHM to provide an early warning of failure; to forecast maintenance as needed to avoid scheduled maintenance and extend maintenance cycles; to assess the potential for life extensions; to reduce the amount of redundancy, and to improve future designs and

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Class Meets for On-line Discussions
Monday
09:30am – 10:30am

Teaching Assistants
Namkyoung Lee
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Prerequisites
Undergraduate degree in engineering, science or mathematics

Course Communication

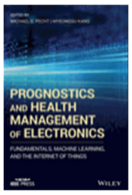
Ask questions whenever they occur to you. Use communication tools on the class web page.

qualification methods. On completion of this course, you will have the fundamental knowledge and skills to develop and implement PHM concepts for aerospace, civil, electrical, electro-mechanical, electronic, and mechanical systems. Specifically, you will have the knowledge needed to:

- Assess methods for damage estimation of components and systems due to field loading conditions
- Assess the cost and benefits of prognostic implementations
- Develop algorithms and models for data processing and feature engineering
- Develop novel methods for in-situ monitoring of products and systems in actual life-cycle conditions
- Enable condition-based (predictive) maintenance
- Identify and analyze failure precursors based on failure mechanisms
- Increase system availability through an extension of maintenance cycles and/or timely repair actions
- Reduce the occurrence of no fault found (NFF)
- Subtract life-cycle costs of equipment from the reduction in inspection costs, downtime, and inventory
- Understand data analytics (machine learning) methods used for anomaly detection, diagnostics, and prognostics
- Understand the logistics and supply-chain challenges in PHM implementation

Required Resources

Course website: **elms.umd.edu**



Prognostics and Health Management of Electronics:
Fundamentals, Machine Learning, and the Internet of Things
Michael G. Pecht, Myeongsu Kang
First edition (2018).
ISBN #9781119515326
The book is available for FREE download at:
https://onlinelibrary.wiley.com/doi/book/10.1002/9781119515326

CAMPUS Policies

It is our shared responsibility to know and abide by the University of Maryland's policies that relate to all courses, which include topics like:

- Academic integrity
- Student and instructor conduct
- Accessibility and accommodations
- Attendance and excused absences
- Grades and appeals
- Copyright and intellectual property

Attendance (on-line classes and discussion sessions)

This class will be conducted on-line. Each week lectures will be posted. Students can watch the lectures as many times as they wish. There will be extra hour for discussions on Monday's from 9:30 – 10:30am for any students that have questions about the course videos and reading materials. Zoom will be used for these sessions. Homework will be assigned on the course ELMS page.

Papers and Research Documents

Various articles will be assigned as required reading every week. The contents of these articles are part of course coverage.

Academic Integrity

The University of Maryland, College Park has a nationally recognized Code of Academic Integrity, administered by the Student Honor Council. This Code sets standards for academic integrity at Maryland for all undergraduate and graduate students. As a student, you are responsible for upholding these standards for this course. It is very important for you to be aware of the consequences of cheating, fabrication, facilitation, and plagiarism. For more information on the Code of Academic Integrity or the Student Honor Council, please visit http://www.shc.umd.edu.

Grades

This course will not have any exams. Instead there will be a lot of homework and a project.

- Homework: 70% of total grade
- Project: 30% of the total grade

All assessment scores will be posted on the course ELMS page. If you would like to review any of your grades or have questions about how something was scored, please email me to schedule a time for us to meet in my office.

Late work will not be accepted for course credit so please plan to have it submitted well before the scheduled deadline. I am happy to discuss any of your grades with you, and if I have made a mistake, I will immediately correct it. Any formal grade disputes must be submitted in writing and within one week of receiving the grade.

Tentative On-Line Course Schedule

Week	Date	Lecture Topics	Reading Materials
Introduction			
1	Aug. 31	• Introduction to Systems Health Management (Prof. Pecht)	Chapter 1
2	Sep. 07	• Sensor Systems for PHM (Dr. Azarian)	Chapter 2
3	Sep. 14	• Physics of Failure: Fundamentals for PHM (Prof. Dasgupta) • Physics of Failure Approach to PHM (Dr. Chetan S. Kulkarni – NASA Ames)	Chapter 3
Machine Learning Based PHM			
4	Sep. 21	• Fundamentals of Machine Learning (Dr. Azarian)	Chapter 4
5	Sep. 28	• Data Pre-Processing (Dr. Azarian) • Feature Discovery (Dr. Azarian)	Chapter 5
6	Oct. 05	• Approaches to Anomaly Detection for PHM (Dr. Azarian)	Chapter 6
7	Oct. 12	• Machine Learning for Diagnostics (Dr. Kang) • Machine Learning for Prognostics (Dr. Kang)	Chapter 7
8	Oct. 19	• Bayesian Method for Prognostics (Dr. Matei, PARC) • Prognostics Metrics, Uncertainty Management in Prognostics (Dr. Saha, PARC)	Chapter 8
Applications of PHM			
9	Oct. 26	• Predictive Maintenance in IoT Era (Ms. Rashmi Shetty – SAP) • Measurement Science Roadmap for PHM for Smart Manufacturing Systems (Dr. Brian Weiss, NIST)	Chapter 21 Chapter 23
10	Oct. 28	• Cost and Return on Investment (ROI) Analysis for PHM (Prof. Peter Sandborn) • Availability Contracting and Design for Availability (Prof. Peter Sandborn)	Chapter 9 Chapter 10
11	Nov. 02	• PHM of Client Computer Systems (Dr. Nikhil Vichare, Dell Inc.)	Chapter 12
12	Nov. 09	• PHM of Batteries (Dr. Laura Xing)	Chapter 13
13	Nov. 16	• Use of PHM in an Implanted Medical Device (Mary Capelli-Schellpfeffer, MD, MPA)	Chapter 15
14	Nov. 23	• PHM of Connected Vehicles (Dr. Yilu Zhang, GM Global R&D)	Chapter 17
15	Nov. 30	• The Role of PHM at Commercial Airlines (Ms. Rhonda Walthall, UTC Aerospace Systems)	Chapter 18
16	Dec. 07	• Prognostics of Data Storage Devices (Dr. Jay Sarkar, HGST, UT Austin)	Chapter 19

Week	Date	Lecture Topics	Reading Materials
17	Dec. 14	• A Hands-On Practice of Big Data Analytics in PHM (Dr. John Patanian, GE Power & Water)	Chapter 20
18	Dec. 21	• Structural Health Monitoring (Dr. Clifford J. Lissenden)	

Note: This is a tentative schedule, and subject to change as necessary – monitor the course ELMS page for current deadlines. In the unlikely event of any problems, adjustments to the course schedule, deadlines, and assignments may be made.

References

Books

- G. Vachtsevanos, F. L. Lewis, M. Roemer, A. Hess, and B. Wu, *Intelligent Fault Diagnosis and Prognosis for Engineering Systems*, Wiley, New York, NY, September 2006
- D. J. Inman, C. R. Farrar, V. L. Junior, and V. S. Junior, *Damage Prognosis: For Aerospace, Civil and Mechanical Systems*, Wiley, New York, NY, April 2005
- W. J. Staszewski, C. Boller, and G. R. Tomlinson, *Health Monitoring of Aerospace Structures: Smart Sensor Techniques and Signal Processing*, Wiley, New York, NY, February 2004

Key Journals

- IEEE Transactions on Industrial Electronics
- IEEE Transactions on Reliability
- International Journal of Prognostics and Health Management
- Mechanical Systems and Signal Processing
- Applied Energy
- Sensors
- International Journal of Structural Health Monitoring
- Journal of Power Sources
- Expert Systems with Applications
- Reliability Engineering & System Safety
- IEEE Access

Conference Proceedings

- Annual Conference of the Prognostics and Health Management Society
- IEEE International Conference on Prognostics and Health Management
- ACM SIGKDD Workshop on Machine Learning for Prognostics and Health Management