Course Syllabus

Prognostics and Health Management

Using AI to Ensure Reliable and Safe Products

ENME 737
Fall 2021

Course Description

Prognostics and health management (PHM) is an enabling discipline consisting of technologies and methods to assess the reliability and safety of a product in its actual life cycle conditions and determine the advent of failure and mitigate system risks. In recent years, PHM has been used to: provide an early warning of failure, forecast maintenance as needed; reduce maintenance cycles; assess the potential for life extensions, and improve future designs and qualification methods.

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

- 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
- Cost of PHM implementation and return on investment
- Valuation and optimization of PHM-enabled maintenance decisions
- Software tools for PHM
- Predictive maintenance
- PHM applications cases

This interdisciplinary course is suitable for students in mechanical, electrical, civil, and aerospace engineering, applied mathematics, and business. Guest lectures by experts from industry, government, and academia will be offered to highlight the interdisciplinary nature of PHM.

Upon completing this course, students will have the fundamental knowledge and skills to develop and implement PHM concepts. 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 prognostics 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

Co-listed as:
ENRE648J: Special Problems in Reliability Engineering

Professor Michael Pecht
pecht@umd.edu

Discussion Session
Monday
09:30am – 10:30pm
J.M. Patterson Building
BLD #083, Room 2216

Teaching Assistants
Zhou He
zhe12@umd.edu

Namkyoung Lee
nklee@umd.edu

Varun Khemani
vkheman@umd.edu

Prerequisites
Undergraduate degree in engineering, science, or mathematics

Course Communication

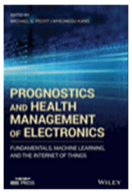
Ask questions whenever they occur to you.

Use communication tools on the class web page.

- Increase system availability through an extension of maintenance cycles and/or timely repair actions
- Reduce the occurrence of no fault found (NFF) conditions
- Reduce 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

(If you cannot download the full text, please log in with your UMD account through VPN and refresh the page. The VPN download page can be found in "Network" at https://terpware.umd.edu/)

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

- Homework will be assigned on the course ELMS page every class day. Except in an emergency, late assignments will not be accepted for credit.
- On-campus students are required to take exams in class.

Papers and Research Documents

Various reading materials will be assigned as required reading. 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. You need 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 https://academiccatalog.umd.edu/undergraduate/registration-academic-requirements-regulations/academic-integrity-student-conduct-codes/.

Grades

All the on- and off-campus students are required to take 2 exams and do homework individually. The breakdown of the grades is:

- Homework: 20 % of the total grade
- Mid-term exam: 30 % of the total grade
- Final exam: 50 % of the total grade

All the on-campus students will take the mid-term exam from 9:30 AM to 11:00 AM during in-class meets on a Monday (same room as the class sessions).

All the off-campus students (i.e., remote students) will have 48 hours (9 PM on Sunday through 9 PM on Tuesday) to complete the mid-term exam. The test will be sent to pre-approved proctors through a secure site or by email for administering the examination. The process for taking the final exam will be the same as the mid-term exam.

More Details about Exams/Homework

- All the students who will take this PHM course must take the two exams: midterm exam and final exam.
    - Each student can bring **1 sheet** of letter-sized paper with notes on both sides for the midterm exam and **2 sheets** of letter-sized paper with notes on both sides in the final exam.
    - Notes can be handwritten or printed.
- Off-campus students will need to take the tests as proctored exams. More details about proctoring can be found at https://mage.umd.edu/proctoring.

- Homework will be announced on the class website each week. Frequent access to the class website is required.

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

Late work will not be accepted for course credit, so please plan to submit it 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 Online Course Schedule

Week	Date	Lecture Topics	Reading Materials
Introduction			
1	Aug. 30	• Introduction to Systems Health Management (Prof. Pecht)	Chapter 1
2	Sep. 06	• **No In-person session** (Labor Day) • Sensor Systems for PHM (Dr. Azarian)	Chapter 2
3	Sep. 13	• 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. 20	• Fundamentals of Machine Learning (Dr. Azarian)	Chapter 4
5	Sep. 27	• Data Pre-Processing (Dr. Azarian) • Feature Discovery (Dr. Azarian)	Chapter 5
6	Oct. 04	• Approaches to Anomaly Detection for PHM (Dr. Azarian)	Chapter 6
7	Oct. 11	• Machine Learning for Diagnostics (Dr. Kang) • Machine Learning for Prognostics (Dr. Kang)	Chapter 7
8	Oct. 18	• Bayesian Method for Prognostics (Dr. Matei, PARC) • Prognostics Metrics, Uncertainty Management in Prognostics (Dr. Saha, PARC)	Chapter 8
Applications of PHM			
9	Oct. 25	• **Midterm Exam** • Predictive Maintenance in IoT Era (Ms. Rashmi Shetty – SAP) • Measurement Science Roadmap for PHM for Smart Manufacturing S ystems (Dr. Brian Weiss, NIST)	Chapter 21 Chapter 23
9	Oct. 27	• 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
10	Nov. 01	• PHM of Client Computer Systems (Dr. Nikhil Vichare, Dell Inc.)	Chapter 12
11	Nov. 08	• PHM of Batteries (Dr. Laura Xing)	Chapter 13
12	Nov. 15	• Use of PHM in an Implanted Medical Device (Mary Capelli-Schellpfeffer, MD, MPA)	Chapter 15

Week	Date	Lecture Topics	Reading Materials
13	Nov. 22	• PHM of Connected Vehicles (Dr. Yilu Zhang, GM Global R&D)	Chapter 17
14	Nov. 29	• The Role of PHM at Commercial Airlines (Ms. Rhonda Walthall, UTC Aerospace Systems)	Chapter 18
15	Dec. 06	• Prognostics of Data Storage Devices (Dr. Jay Sarkar, HGST, UT Austin)	Chapter 19
16	Dec. 13	• **Last Day of Classes** • A Hands-On Practice of Big Data Analytics in PHM (Dr. John Patanian, GE Power & Water) • Structural Health Monitoring (Dr. Clifford J. Lissenden, Penn State University)	Chapter 20
	TBD	• **Final exam** – date TBD in between December 15 and 21	

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.

Additional 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

Related 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

Related 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