Prognostics and Health Management

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 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:

- Internet of Things, Big Data, and Sensors for PHM
- Fundamentals of PHM
- Physics-of-Failure Approach to Prognostics
- Data Pre-processing (Data Cleansing, Feature Extraction, Feature Selection, Feature Learning)
- 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

Professor Michael Pecht
pecht@calce.umd.edu

Class Meets
Monday
09:30am – 12:10pm
J.M. Patterson Building
BLD #083, Room 2216

Office Hours
Tuesday
9:30am – 11:30am
Engineering Lab Building
BLD #089 , Room 1103

Teaching Assistants
Weiping Diao
wdio@terpmail.umd.edu

Prerequisites
N/A
Graduate standing expected

Course Communication

Ask questions whenever they occur to you.

Email communication through the class web page is also encouraged.

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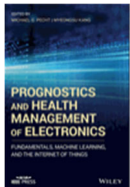
Prognostics and Health Management of Electronics: Fundamentals, Machine Learning, and the Internet of Things
Michael G. Pecht, Myeongsu Kang
First edition (2018).
ISBN #9781119515326
The book is available for download at:
https://onlinelibrary.wiley.com/doi/book/10.1002/9781119515326

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

Attending all classes generally leads to good grades. Except in an emergency, late assignments will not be accepted for credit.

Papers and Research Documents

At least one article will be assigned as required reading every week. The contents of these articles are part of examination 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

All the on- and off-campus students are required to take 2 exams, do homework individually, and conduct a project. The breakdown of the grades is:
- Mid-term exam[1]: 30 % of the total grade
- Homework and mini-project: 30% of total grade
- Final exam: 40% of the total grade

[1] All the on-campus students will take the mid-term exam from 9:30 AM to 10:45 AM on a day set before the beginning of the semester, whereas 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/Project
- All the students who will take this PHM course are required to take the two exams: midterm exam and final exam.
- Off-campus students will need to take the tests as proctored exams. A proctored exam is administered by an individual who supervised the student while he/she is taking the exam. More details about proctoring can be found at http://advancedengineering.umd.edu/frequently-asked- questions-proctoring.
- Homework will be announced on the class web site. Frequent access to the class web site is required.
- All the on- and off-campus students are required to conduct a project, likely in a group. The course project will be a major part of the learning and will also determine the grade.
- Projects may include development and demonstration of concepts, models, software programs, hardware prototypes (e.g., scaled models, breadboard circuits) for implementing prognostics and health management of real life applications.

Grades are not given, but earned. Your grade is determined by your performance on the learning assessments in the course and is assigned individually (not curved). If earning a particular grade is important to you, please

speak with me at the beginning of the semester so that I can offer some helpful suggestions for achieving your goal.

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 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.

Course Schedule

CLASS DATES		LECTURE TOPICS	READING MATERIALS (TEXTBOOK CHAPTERS)
Mon	8/26	Introduction to Systems Health Management, Anomaly Detection and Prognostics (Prof. Pecht)	Chapter 1
Mon	9/2	No class (Labor Day)	
Mon	9/9	Physics of Failure Approach to PHM (Dr. Chetan S. Kulkarni – NASA Ames)	Chapter 3
Mon	9/16	Sensor Systems for PHM (Dr. Azarian)	Chapter 2
Mon	9/23	Bayesian Methods for Reliability Prediction (Dr. Yan Liu – Medtronic)	To be posted in class web site
Mon	9/30	Stochastic Modeling for PHM: Filtering Techniques and Prediction Methods (Dr. Shankar Sankararaman -NASA Ames)	Chapters 7 and 8
Mon	10/07	Fundamentals of Machine Learning (Dr. Azarian) Data Pre-Processing (Dr. Azarian)	Chapters 4 and 5
Mon	10/14	Machine Learning: Feature Discovery (Dr. Azarian) Approaches to Anomaly Detection for PHM (Dr. Azarian)	Chapter 5
Mon	10/21	Midterm Exam Machine Learning for Diagnostics (Varun Khemani)	Chapter 6
Mon	10/28	Machine Learning for Prognostics	Chapter 7
Mon	11/04	Deep Learning for Prognostics and Health Management (Prof. Pecht)	Chapter 7
Mon	11/11	Particle Filter for Performance Prediction of Aircraft Engines, Machine Tools, and HVAC Systems (Prof. Robert X. Gao – Case Western Reserve University, Ohio)	To be posted in class web site
Mon	11/18	Prognostics of Data Storage Devices (Dr. Jay Sarkar – HGST, UT Austin)	To be posted in class web site

CLASS DATES		LECTURE TOPICS	READING MATERIALS (TEXTBOOK CHAPTERS)
Mon	11/25	Cost and Return on Investment (ROI) Analysis for PHM (Prof. Peter Sandborn) Availability Contracting and Design for Availability (Prof. Peter Sandborn)	Chapter 9 and 10
Mon	12/02	Predictive Maintenance in IoT Era (Ms. Rashmi Shetty – SAP)	Chapter 21
Mon	12/09	PHM of Client Computer Systems (Dr. Nikhil Vichare – Dell Inc.)	Chapter 12
	12/11-17	Final Exam – date TBD in the period of Dec. 11-17	

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 a prolonged university closing, or an extended absence from the university, adjustments to the course schedule, deadlines, and assignments will be made based on the duration of the closing and the specific dates missed.

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
- Applied Energy (for Battery Remaining Useful Life Estimation)
- IEEE Access
- IEEE Transactions on Reliability
- International Journal of Structural Health Monitoring
- Expert Systems with Applications
- IEEE Transactions on Industrial Electronics
- International Journal of Prognostics and Health Management
- Journal of Power Sources (for Battery Remaining Useful Life Estimation)
- Mechanical Systems and Signal Processing
- Reliability Engineering & System Safety

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