Mechanical Engineering in the A. James Clark School of Engineering
University of Maryland, College Park

Course Syllabus for ENME 737 – Fall 2019
Prognostics and Health Management

Instructor: Professor Michael Pecht (pecht@calce.umd.edu)
Class Time: 9:30 AM – 12:10 PM on Mondays (US Eastern)
Venue: J. M. Patterson Building (Bldg. 083), Room 2216
Credits: 3
Grade Method: REG/AUD

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 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

Office Hours: 9:15 AM – 11:00 AM on Fridays (US Eastern)

You are welcome to drop by course coordinator's office anytime. Emailing (mskang@calce.umd.edu) in advance is suggested. Questions raised due to skipping of the class should be avoided.

Office: Room 1100, Engineering Lab. Building (Bldg. 089)

Communication Style

Ask questions whenever they occur to you. Email communication through the class web page is also encouraged.

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.

Grading

All the on- and off-campus students are required to take 2 exams, do homework individually, and conduct a project. The breakup of the grades is:

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

- All the students who will take this PHM course are required to take the two exams: midterm exam (and final exam.
- 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.
- 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 set 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.
- Homework will be announced on the class web site. Frequent access to the class web site is required.
- Note that all the on- and off-campus students are required to conduct a project either individually or in a group. The course project will be a major part of the learning and it will also determine the grade.
- Projects may include development and demonstration of concepts, models, software programs, hardware prototypes (e.g., scaled models, bread-broad circuits) for implementing prognostics and health management of real life applications.

References

[Books]

- M. G. Pecht and M. Kang, *Prognostics and Health Management of Electronics: Fundamentals, Machine Learning, and the Internet of Things*, Wiley, New York, NY, August 2018
- 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