Prognostics and Health Management

ENME 808A – Fall 2009
Thursdays 2:00 PM – 4:30 PM (EGR 1102)
Instructor: Professor Michael G. Pecht

Prognostics is the process of predicting the future reliability of a product by assessing the extent of deviation or degradation of a product from its expected normal operating conditions. Prognostics and health management (PHM) is a method that permits the reliability of a system to be evaluated (health) and predicted (prognostics) in its actual application conditions. Based on PHM, engineering solutions can be developed to mitigate, manage risks and maintain the product. In recent years, prognostics and health management (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. For example, today your car can have integrated sensors, on-board algorithms, telemetry systems, and a global positioning system. The vehicles can be tracked using the unique vehicle identification number and interrogated from a remote location to acquire sensor data and assess its on-going health and suggest time and extent for next maintenance. 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 structures, machine-tools, aircrafts, electronics, computers, and even human health. Topics covered include methods for in-situ monitoring, approaches for resource efficient data collection, algorithms for data reduction and parameter extraction, software for damage assessment, methods for identifying and analyzing precursors based on failure mechanisms, and techniques for predictions that can be used for assisting maintenance and logistics decisions. This is an interdisciplinary course and students in many areas including mechanical, electrical, civil, and aerospace engineering, public policy, and engineering management are welcome. Students will get the opportunity to learn the basic scientific foundations that enable prognostics and health management 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. Some lectures will be made by academic researchers

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 in develop and implement PHM concepts for electrical, mechanical, electro-mechanical, civil, aerospace, and electronic systems. Specifically you will have the knowledge needed to:

- Develop novel methods for in-situ monitoring of products and systems in actual life-cycle conditions
- Plan and implement telemetry and data processing concepts
- Develop algorithms and models for data reduction and parameter extraction
- Assess methods for damage estimation of components and systems due to field loading conditions
- Identify and analyze failure precursors based on failure mechanisms
- Understand statistical techniques used techniques for making predictions
- Understand the logistics and supply-chain challenges in PHM implementation
- Assess the cost and benefits of prognostic implementations

Office Hours of Instructor: Monday and Friday 2:00 – 3:00 PM. You are welcome to drop by my office anytime. Calling or emailing in advance is suggested. Questions raised due to skipping of class should be avoided.

Web site: https://bb.eng.umd.edu/

All registered students will be given access to the course web site. Visit the site for instructions on instructions on how to obtain login/password.

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

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

UMD Lecturers:

Professor Michael Pecht Room 1103 EGL Tel: (301) 405-5323 pecht@calce.umd.edu	**Professor Peter Sandborn** Room 3127 EGR Tel: (301) 405-3167 sandborn@calce.umd.edu	**Professor Abhijit Dasgupta** Room 2110C EGR Tel: (301) 405-5251 dasgupta@calce.umd.edu
Dr. Michael Azarian Room 3131 EGR Tel: (301) 405-7555 mazarian@calce.umd.edu	**Dr. Diganta Das** Room 1100 EGL Tel: (301) 405-7770 digudas@calce.umd.edu	**Dr. Ravi Doraiswami** Room 0122EGR Tel (301) 405-7334 ravidsw@umd.edu
Prof. Benjamin Kedem 4411 Mathematics Building Tel:(301) 405-5112 Email: bnk@umd.edu	**Prof. Radu Balan** 2308 Mathematics Building Tel (301) 405-5492 Email: rvbalan@umd.edu	**Prof. Bilal Ayub** 0305 Martin Hall Tel: (301) 405-1956 Email: ba@umd.edu

Project:

The course project (in teams) will be the major part of the learning and it will also determine the grade. Each team (2 persons) will come up with a detailed project description based on the suggested topics provided in the class web site. Projects may include development and demonstration of concepts, models, software programs, hardware prototypes (e.g., scaled models, bread-board circuits) for implementing prognostics and health management of real life applications. You will be graded on your contribution to the state-of-the-art as shown in your written report, classroom presentations, and demonstrations of software or sensor-system prototypes.

Project Schedule and Grading:

Week of	**Deliverable**	**Percentage of grade**
Sep 17, 2009	Consultation with instructor and project mentor. Formation of project groups.	NA
Oct 1, 2009	Project proposal. Provide a two page document on concept, approach, and work plan (1-2 pages with initial references)	5
Oct 8, 2009	Commented proposal returned	N/A
Oct 22, 2009	Project status report #1: Achievement of a minimum of 30 % of project goals is expected.	10
Oct 29, 2009	Commented status reports returned	N/A
Nov 19, 2009	Project status report #2. Achievement of a minimum of 75% % of project goals is expected.	10
Nov 30, 2009	Commented status report returned	N/A
Scheduled day of final exam	Project presentation	30
Dec 17, 2009	Final report	45

- Project reports need to be written in MS Word. A template will be provided for format consistency.
- All work needs to be referenced in a formal manner.
- All reports need to be submitted in both hardcopy and in searchable and editable electronic format.

Expectations of Students:

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

Papers and research documents: Will be handed out in class and will be considered required reading.

References:

Books:

1. Prognostics and Health Management of Electronics, M. G. Pecht, Wiley-Interscience, New York, NY, August 2008
2. Health Monitoring of Aerospace Structures: Smart Sensor Technologies and Signal Processing / edited by W.J. Staszewski, C. Boller and G.R. Tomlinson, 2004.
3. Intelligent Fault Diagnosis and Prognosis for Engineering Systems / by G. Vachtsevanos, F. L. Lewis, M. Roemer, A. Hess, and B. Wu, 2006.
4. Damage Prognosis: For Aerospace, Civil and Mechanical Systems / edited by D. J. Inman, C. R. Farrar, V. L. Junior, and V. S. Junior, 2005.

Key Journals:

1. Aerospace Science and Technology
2. International Journal of Prognostics and Health Management
3. International Journal of Structural Health Monitoring
4. Journal of Artificial Intelligence Research (JAIR)
5. Journal of Intelligent Material Systems and Structures
6. Journal of Structural Control and Health Monitoring
7. Mechanical Systems and Signal Processing
8. Microelectronics Reliability
9. Reliability Engineering & System Safety
10. Sensors and actuators

Conference Proceedings:

1. AAAI Conference on Artificial Intelligence
2. Aircraft Airborne Condition Monitoring Conference
3. American Society of Civil Engineers—Structural Health Monitoring Division
4. Annual Conference of PHM Society
5. Annual Reliability & Maintainability Symposium (RAMS)
6. Proceedings of IEEE PHM conference
7. Proceedings of SPIE's Smart Structures and Materials / NDE for Health Monitoring and Diagnostics
8. Proceedings of IEEE Aerospace Conference
9. International Conference on Machine Learning and Cybernetics

Class Schedule

Lecture	Date	Topic
1	**9/3**	Introduction and overview of approaches to prognostics/ Anomaly detection techniques/ PHM metrics.
2	**9/10**	Life Cycle Cost and Return on Investment for PHM
3	**9/17**	Physics of Failure based Prognostics using fuses and canaries
4	**9/24**	Sensors for Prognostics
5	**10/01**	MEMS applications for PHM
6	**10/08**	Machine learning and Intelligent Systems
7	**10/15**	Industrial Application for PHM
8	**10/22**	Risk and Uncertainty Analysis
9	**10/29**	Empirical Methods for Process and Equipment Prognostics
10	**11/05**	Self Cognitive Capability for Anomaly Detection, Fault Analysis and Prognosis
11	**11/12**	Time Series Analysis
12	**11/19**	Prognostics Integrated Logistics
13	**11/26**	Thanksgiving Holiday
14	**12/3**	Structural Health Monitoring
15	**12/10**	Roadmap for PHM for Electronics
16	**Scheduled date for Final Exam**	Student Project Presentations