**MFG 599: Seminars in Smart Manufacturing**

Winter 2018

**Course Information**

**Co-Instructors:**

Judy Jin (Professor, IOE) <jhjin@umich.edu)

Chinedum Okwudire (Associate Professor, ME) <okwudire@umich.edu>

**Lectures:** Every Friday: 11am~noon seminar talk, noon-~1pm faculty & students discussion

Attendance at lectures is required for all on-campus students. Online Distance students are not required to attend the live lectures but are need to watch the recorded video. All lectures will be posted for the next-day viewing on the course website.

**Grading:** 1.5 credit hours as a required course for DEng and MEng students before MFG503 for all new students starting from F18. Other students are highly encouraged to attend. 1.5 CH can be flexibly considered into any non-concentrated course area.

On-campus students

* Attendance (on campus students 50%)
* Seminar Discussion and Team Assignments (on campus students 50%)

Online students

* Watch recoded seminar video & assignments (100%)

**Course Description**

This seminar course brings together experts in various aspects of manufacturing-relevant technologies with experts (e.g., academic researchers, industry, and funding agency) involved in research and applications that require cutting edge technologies for smart manufacturing. Smart manufacturing is a broad category of manufacturing with the goal of optimizing concept generation, production, and product transaction. While manufacturing can be defined as the multi-phase process of creating a product out of raw materials, smart manufacturing is a subset that employs computer control and high levels of adaptability. Smart manufacturing aims to take advantage of advanced information and manufacturing technologies to enable flexibility in physical processes to address a dynamic and global market [Davis, et al, 2012]. The invited seminar speakers will discuss some of key building technologies for smart manufacturing, which may include but not limited to: advanced materials/structures and manufacturing processes; computer simulations and augmented reality for product/process design; sensors, automation and robots for automatic production monitoring and execution; data analytics and optimizations for production planning, quality control, and optimal equipment operation and maintenance; Industrial IoT, network security, cloud computing and optimal decision-making for robust supply chain management and enterprise operation.

This seminar course will be offered for both on-campus students and online distant learning students who will review recorded videos. A portion of each lecture will be devoted to student discussion and assignments.

[ref]: Davis, Jim; Edgar, Thomas; Porter, James; Bernaden, John; Sarli, Michael (2012-12-20). ["Smart manufacturing, manufacturing intelligence and demand-dynamic performance"](http://www.sciencedirect.com/science/article/pii/S0098135412002219). *Computers & Chemical Engineering*. FOCAPO 2012. **47**: 145–156. [doi](https://en.wikipedia.org/wiki/Digital_object_identifier):[10.1016/j.compchemeng.2012.06.037](https://doi.org/10.1016/j.compchemeng.2012.06.037)The

Tentative Seminar Agenda:

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| **Dates** | **Title** | **Speakers** | Abs&Bio |
| Jan. 5 | No talk |  |  |
| Jan. 12 | Micro and Nano Manufacturing for Smart Manufacturing | Liwei Lin  (U. C. Berkeley) | Attached |
| Jan. 19 | Seru Production System: An Organizational Extension of JIT | Kathryn Stecke  U. of Texas at Dallas | Attached  With Paper website |
| Jan. 26 | Smart manufacturing of Custom Assistive Devices | Albert Shih  (ME) | Attached |
| Feb. 2 | Manufacturing Execution Optimization | Leyuan Shi  U. of Wisconsin | Attached |
| Feb. 9 | Smart Production Systems: Theoretical Foundations, Computational Tools, and Practical Design | Semyon Meerkov  EECS | Attached |
| Feb.16 | Batch Mode Micromanufacturing Based on Micro Electro-Discharge Machining and Micro Ultrasonic Machining for Micro Electro Mechanical Systems (MEMS) | Tao Li & Yogesh Gianchandani  EECS | Attached |
| Feb. 23 | from NSF | Wait for confirmation |  |
| March 2 | Winter Break |  |  |
| Mar. 9 | from Rockwell | Wait for confirmation |  |
| Mar. 16 | New Materials & Process for New Energy Storage and Biomedical Tech | Jeff Sakamoto  (ME) |  |
| March 23 | Closing the Loop in IoT-enabled Manufacturing Systems: Challenges and Opportunities" | Kira Barton  (ME) |  |
| March 30 | TBD |  |  |
| April 6 | DoE Funding Opportunities in Smart Manufacturing (Tentative) | Sudarsan Rachuri, DOE Program Director |  |
| April 13 | MFG student team presentation |  |  |

**Jan 12, Speaker 1**

**Micro and Nano Manufacturing for Smart Manufacturing**

Liwei Lin

James Marshall Wells Professor, Department of Mechanical Engineering

Co-Director, Berkeley Sensor and Actuator Center (BSAC)

Co-Deputy Director, Tsinghua Berkeley Shenzhen Institute (TBSI)  
University of California   
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Micro and nano manufacturing are advanced manufacturing processes attracting great interests in recent years. Fundamental investigations on the design, synthesis, assembly and integration of materials and nanostructures have led to potential applications in sensors, energy and other fields for potential applications including smart manufacturing. Leveraging from our core technologies in MEMS (Microelectromechanical Systems), we have been working on the micro and nano manufacturing for sensors and energy generation/storage applications toward possible applications such as smart manufacturing, including: (1) synthesis, assembly and integration of 1D and 2D nanostructures for pressure and gas sensing applications; (2) 1D piezoelectric nanofibers as nanogenerators; (3) self-aligned 1D nanostructures for energy storage applications; and (4) 3D-printed wireless sensor. I will also introduce some of our current works in the seminar.

**Biographical Sketch**

Professor Liwei Lin received PhD degree from the University of California, Berkeley, in 1993. He was an Associate Professor in the Institute of Applied Mechanics, National Taiwan University, Taiwan (1994~1996) and an Assistant Professor in Mechanical Engineering Department, University of Michigan (1996~1999). He joined the University of California at Berkeley in 1999 and is now James Marshall Wells Professor at the Mechanical Engineering Department and Co-Director at Berkeley Sensor and Actuator Center (BSAC), an NSF/Industry/University research cooperative center. His research interests are in design, modeling and fabrication of micro/nano structures, sensors and actuators as well as mechanical issues in micro/nano systems including heat transfer, solid/fluid mechanics and dynamics.  Dr. Lin is the recipient of the 1998 NSF CAREER Award for research in MEMS Packaging and the 1999 ASME Journal of Heat Transfer best paper award for his work on micro scale bubble formation. He led the effort to establish the MEMS division in ASME and served as the founding Chairman of the Executive Committee from 2004~2005. He is an ASME Fellow and has 20 issued US patents in the area of MEMS. He was the general co-chair of the 24th international conference on Micro Electro Mechanical Systems at Cancun, Mexico. Currently, he serves as a subject editor for the IEEE/ASME Journal of Microelectromechanical Systems and the North and South America Editor of Sensors and Actuators –A Physical.

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**Jan 19, Speaker 2**

***Seru* Production System: An Organizational Extension of JIT**

Professor Kathryn E. Stecke  
          Ashbel Smith Professor of Operations Management  
         University of Texas at Dallas  
          Naveen Jindal School of Management  
          P.O. Box 830688, SM 30  
          Richardson, Texas 75083-0688, Phone: (972) 883-4781

**Abstract:**  A *seru* system is a new type of production system, widely used in Japan but unknown outside of Asia.  Developed by Sony, it is used in all of Canon’s factories.  It is more flexible, efficient, and productive than conventional manufacturing systems, for the industries in which it is appropriate.  *Seru*’s history, development, and benefits will be described and discussed.

**References:**

Her talk is related to 3 following papers, which can be download from website below

1. “An Implementation Framework for *Seru* Production”, ChenGuang Liu, Kathryn E. Stecke, Jie Lian, and Yong Yin, *International Transactions in Operational Research*, Vol. 21, No. 1, pp. 1-19 (January 2014). <http://onlinelibrary.wiley.com/doi/10.1111/itor.12014/epdf>
2. “Lessons from *Seru* Production on Manufacturing Competitively in a High Cost Environment,” Yong Yin, Kathryn E. Stecke, Morgan Swink, and Ikou Kaku, *Journal of Operations Management*, Vols. 49-51, pp. 67-76 (March 2017). <http://www.sciencedirect.com/science/article/pii/S0272696317300116>
3. “The Evolution of Production Systems from Industry 2.0 through Industry 4.0”, Yong Yin, Kathryn E. Stecke, and Dongni Li, International Journal of Production Research, forthcoming, 2018. <http://www.tandfonline.com/eprint/MuwWQP4aXP7XgmnJQM5H/full>

**Jan 26 Speaker 3:**

**Smart manufacturing of Custom Assistive Devices**

Prof. Albert Shih

Mechanical Engineering Department

University of Michigan

This talk provides an overview of the cyber-based design and additive manufacturing (AM) for custom assistive devices at the University of Michigan Orthotics and Prosthetics Center (UMOPC). Assistive devices, such as orthoses and prostheses (O&P), and devices to help people regain their mobility, function, and independent living are critical for the quality of life.  Custom assistive devices have personalized fit, better comfort, and superior efficacy in treatment.  This talk outlines our on-going journey to develop a smart manufacturing system at UMOPC for a wide variety of custom assistive devices. The manufacturing system has the digital scanning, cyber-based software for design, and material extrusion (MEX) for AM that aim to improve patient care. Key elements of this manufacturing system presented in this talk include the: 1) 3D scanning to identify the geometry of the body shape, 2) computer aided design for clinicians to modify the shape, 3) cyber- and model-based design, 4) wavy structure tool path planning for O&P, 5) MEX for hard structure and soft silicone for wearable assistive devices, 6) quality control using the nano-CT technology, and 7) inertia measurement unit (IMU) for gait analysis, evaluation, and monitoring of users. An example of custom ankle-foot orthosis (AFO) with fabrication time that enables one-day visit for patient care is presented.

**Albert Shih** is Professor in the University of Michigan.  He was a manufacturing engineer at Cummins and a Professor in NC State University.  Dr. Shih’s research area is manufacturing. He is a pioneer in biomedical manufacturing, the application of manufacturing technologies to advance the safety, quality, efficiency and speed of healthcare service and biomedical science.  He has 10 US patents, a textbook in Machining and Machine Tools, and authored or co-authored over 190 archival journal papers.  Dr. Shih is the recipient of Fulbright Scholar, ASME Milton Shaw Manufacturing Research Medal and Blackall Machine Tool and Gage Award, Society of Automotive Engineers Ralph Teetor Educational Award, and Best Paper awards in ASME International Manufacturing Science and Engineering Conference (MSEC), North American Manufacturing Research Conference (NAMRC), International Conference on Frontiers of Design and Manufacturing (ICFDM).  Dr. Shih is Fellow of both ASME and SME and associate member of CIRP.

**February 2, speaker 4**

**Manufacturing Execution Optimization**

Prof. Leyuan Shi

Department of Industrial & Systems Engineering

University of Wisconsin-Madison

Many manufacturing firms use aggregated data to provide scheduling/decision solutions for handling their daily operations. Given the nature of shop floor operating in real-time, these average-based scheduling systems cannot be fully executed since unexpected events will almost always occur such as rush orders, design changes, machine breakdowns, defective parts, and delivery delays etc. Currently, shop-floor responds to unexpected events via manually scheduling or by Excel, which leads to poor predictability and visibility of performance, slow response to uncertainties and market changes, and low efficiency of their production and supply chain systems.

In this talk, Manufacturing Execution Optimization (MEO) technologies developed by Dr. Shi and her team will be presented. MEO aims to bridge the gap between the top-level management data typically from ERP systems and the shop-floor operations. By establishing top floor to shop floor communication, manufacturing firms will be able to significantly improve their production and supply chain efficiency while achieving a faster response to changes and disturbances in the most time-optimal manner. MEO is developed based on Nested Partitions (NP) optimization framework. The coordination nature of the NP framework provides an efficient and effective platform for information sharing and exchange in real time. In this talk, two new simulation optimization methods will also be discussed and a case study will be presented.

**Leyuan Shi:** Professor in the Department of Industrial and Systems Engineering at University of Wisconsin-Madison and also the founding chair of the Department of Industrial Engineering and Management at Peking University of China. She received her Ph.D. in Applied Mathematics from Harvard University in 1992. Her research interests include simulation modeling and large-scale optimization with applications to operational planning and scheduling and digital supply chain management. She has developed a novel optimization framework, the Nested Partitions Method that has been applied to many large-scale and complex systems optimization problems. Her research work has been funded by NSF, NSFC, NIH, AFSOR, ONR, MOST of China, State of Wisconsin, and many private industrial companies with a total funding of more than 15 million dollars. Shi has published 3 books and more than 130 papers. She is currently serving as Editor for *IEEE Trans on Automation Science and Engineering* and had served on the editorial board for *Manufacturing & Service Operations Management* and *INFORMS Journal on Computing.* She was General Chair, co-Chair, and program committee for many national and international conferences. She is also one of the inventors for a set of digital tools including Manufacturing Execution Optimization (MEO), Maintenance Repair & Overhaul Optimization (MRO2), and Dynamic Manufacturing Critical-Path Time (DMCT). She is an IEEE Fellow.

**Feb 9th Speaker 5**

**Smart Production Systems:**

**Theoretical Foundations, Computational Tools, and Practical Design**

Semyon M. Meerkov

Department of Electrical Engineering and Computer Science

University of Michigan

Ann Arbor, MI, USA

Abstract

Smart Production Systems (SPS) are manufacturing systems capable of self-diagnosing and providing operation managers with an advice concerning optimal continuous improvement projects, with analytically predicted results. In SPS, both manufacturing equipment and decision-making processes are automated. As such, SPS can be viewed as a part of the Industry 4.0 movement.

To be “smart”, a production system must be equipped with an Advising Tool (AT) intended to calculate the optimal decision for productivity improvement. The AT developed in this work consists of three units: Information Unit (IU), Analytics Unit (AU), and Optimization Unit (OU). The IU is intended to utilize sensing, computing, and communication devices (e.g., Industry 4.0 technology), in order to monitor system’s performance metrics (i.e., throughput, WIP, blockages, starvations, etc.) and machine parameters (i.e., cycle time, MTBF, MTTR, etc.), and communicate this information to AU and OU. Based on this information and the theory of Production Systems Engineering (see our textbook under the same title, Springer 2009), the AU is intended to quantitatively evaluate the “health” of the production system, investigate various “what if” scenarios for potential improvement, and autonomously design a continuous improvement project, along its analytically predicted results. Finally, the OU is intended to develop an optimal way for implementing the above continuous improvement project, using the methods of Artificial Intelligence. The outputs of AU and OU form the advice to the operations manager. In this talk, the theoretical foundations of all three units of AT will be discussed, and an SPS development for an automotive underbody assembly system will be described.

Bio

Semyon M. Meerkov received his MSEE degree from the Polytechnic of Kharkov, Ukraine, in 1962 and Ph.D. in Systems Science from the Institute of Control Sciences, Moscow, Russia, in 1966. He was with the Institute of Control Sciences until 1977. From 1979 to 1984 he was with the Department of Electrical and Computer Engineering, Illinois Institute of Technology, Chicago, IL. Since 1984 he has been a Professor at the Department of Electrical Engineering and Computer Science of the University of Michigan, Ann Arbor, MI. He held visiting positions at UCLA (1978-1979), Stanford (1991), Technion, Israel (1997-1998, 2008, and 2017), Tsinghua, China (2008), and Ben-Gurion University, Israel (2011). He was the Editor-in-Chief of *Mathematical Problems in Engineering*, Department Editor for Manufacturing Systems of *IIE Transactions* and Associate Editor of several other journals. Presently, he is on the Editorial Board of the *International Journal of Production Research* and Associate Editor of *Automation and Remote Control*. He is Foreign Member of the Russian Academy of Sciences and Life Fellow of IEEE. His current research is in Systems and Control (with applications to production systems) and in Mathematical Theory of Rational Behavior (with applications to resilient monitoring and control).

**Feb 16 Speaker 6**

**Batch Mode Micromanufacturing Based on Micro Electro-Discharge Machining and Micro Ultrasonic Machining for Micro Electro Mechanical Systems (MEMS)**

Tao Li and Yogesh Gianchandani

Center for Wireless Integrated MicroSensing and Systems (WIMS2)

University of Michigan, Ann Arbor

**Abstract:** Micro electro-discharge machining (µEDM) is a manufacturing method that is very attractive for parts made from alloyed metals. Although metal alloys have material properties that are very appealing for MEMS, µEDM is not perceived to be compatible with the lithographic manufacturing methods that are used in the semiconductor industry. Batch-mode µEDM uses lithographically-fabricated electrode arrays with high density and high uniformity to achieve high-throughput and high-precision micromachining. To date, reported applications include gears, smart stents with embedded sensors, etc., and will be reviewed in the presentation. Similarly, batch-mode micro ultrasonic machining (µUSM) provides lithographic compatibility to the micromachining of hard ceramics, glasses and other dielectric materials such as glass-mica ceramic, lead zirconate titanate (PZT), single crystal quartz, ruby and glasses. Such dielectric materials cannot be directly machined by µEDM. However, batch µEDM can be used to define cutting tools for the µUSM process, typically in stainless steel. This two-step process has been applied to the batch fabrication of piezoelectric microsensors for tissue contrast detection and piezoelectric microheaters for tissue cauterization during the medical procedures of needle biopsy. Resonators in planar and 3D geometries made from high-Q materials such as quartz, ZerodurTM, fused silica, and other glasses will also be discussed.

**Bios:**

Tao Li is an Associate Research Scientist in the Department of Electrical Engineering and Computer Science at the University of Michigan, Ann Arbor, and a research faculty member in the Center for Wireless Integrated MicroSensing and Systems (WIMS2). He received the B.S. and M.S. degrees in engineering from Tsinghua University, Beijing, China, and Ph.D. in Electrical Engineering from the University of Michigan, Ann Arbor. His research interests include microsystem packaging, nontraditional microfabrication technologies, micromachined sensors and actuators, and sensor interface and embedded systems. He has a broad, interdisciplinary background among the areas of electrical, biomedical and mechanical engineering, with over 14 years of in-depth experience working on a number of micromachined transducers and microsystems and their packaging and integration, particularly for biomedical and environmental monitoring applications. He has over 33 peer-reviewed journal and conference publications and 4 patents issued or pending.

Yogesh B. Gianchandani is a Professor at the University of Michigan, Ann Arbor, with a primary appointment in the Electrical Engineering and Computer Science Department and a courtesy appointment in the Mechanical Engineering Department. Dr. Gianchandani also serves as the Director for the Center for Wireless Integrated MicroSensing and Systems (wims2.org). Created in 2000 with support from the National Science Foundation, the Center brings together research in core technologies to facilitate microsystems for healthcare, environmental monitoring, and infrastructure monitoring. Dr. Gianchandani’s research interests include all aspects of design, fabrication, and packaging of microfabricated sensors and actuators ([web.eecs.umich.edu/~yogesh/](http://eecs.umich.edu/~yogesh/)). He has graduated about 35 Ph.D. students, and contributed to about 45 issued or pending US patents, and published about 330 papers in journals and conferences. He was a Chief Co-Editor of *Comprehensive Microsystems: Fundamentals, Technology, and Applications*, published in 2008, and he serves on the editorial boards and program committees of a number of journals and conferences. From 2007 to 2009 he also served at the National Science Foundation, as the program director for Micro and Nano Systems within the Electrical, Communication, and Cyber Systems Division (ECCS). Dr. Gianchandani is a Fellow of IEEE.