
SIE 496/596

Smart Manufacturing Systems

Schedule: Mon. & Wed.
1:30 – 2:45 PM

Location: ENGR 301

Course Website: [SIE 496/596 FA26](#)

INSTRUCTOR

Name: Dr. Mohammed Shafae; Associate Professor, Department of Systems and Industrial Engineering

Email: shafae1@arizona.edu

Office: ENGR 317

Office Hours: By appointment only. Please send an email to schedule a meeting.

COURSE DESCRIPTION

Industry 4.0 is transforming manufacturing and other industrial domains including energy, healthcare, water, aerospace, and transportation through digitally integrated Smart Industrial Systems. These systems connect physical assets with digital intelligence via the digital thread, advanced analytics, machine learning, automation, and cybersecurity. The course provides both conceptual foundations and hands-on skills for understanding, evaluating, and applying smart manufacturing technologies. Students will study the building blocks of smart systems, explore digital product and process realization, and practice implementing the industrial machine learning pipeline on real-world datasets. The course also addresses cyber-physical systems cybersecurity challenges and defense strategies to highlight both opportunities and risks. By the end of the course, students will be able to assess smart manufacturing practices, design and analyze digital products and processes, and apply data-driven methods to industrial problem.

Prerequisite(S):

Advanced standing is required before taking this course. For Advanced Standing of undergraduate students, please visit the webpage for detail information to obtain the advanced standing: <http://sie.engr.arizona.edu/advanced-standing>.

COURSE OBJECTIVES

1. Introduce students to the **principles and building blocks of Smart Manufacturing Systems**, situating them in the context of Industry 4.0.
2. Develop understanding of the **digital thread and digital transformation strategies**, including their role in enabling enterprise-wide connectivity and innovation.
3. Provide exposure to **digital product ideation, design, and realization**, including simulation-driven design, Multiphysics analysis, industrial control, and automation.
4. Train students in the **end-to-end industrial machine learning pipeline**, from problem definition to deployment, with applications in manufacturing and supply chain contexts.
5. Engage students in **hands-on workshops using real industrial datasets** (e.g., water treatment monitoring, additive manufacturing process monitoring) to reinforce applied learning.
6. Raise awareness of **cybersecurity challenges in manufacturing CPS** and introduce defense-in-depth approaches for building resilient systems.
7. Equip students with the ability to **critically reflect on workforce, organizational, and societal implications** of smart manufacturing adoption.

8. **Encourage reflection on cross-sector adoption of smart systems**, comparing how concepts such as the digital thread, analytics, and machine learning apply in other industrial domains (e.g., energy, water, healthcare, aerospace).

EXPECTED LEARNING OUTCOMES

By successfully completing this course, all students in this course should be able to:

1. Explain the foundations of Industry 4.0 and Smart Manufacturing Systems, including the digital thread, advanced analytics, intelligent processes, and cybersecurity.
2. Analyze and compare digital transformation strategies.
3. Apply design thinking, QFD, simulation-driven design, and Multiphysics tools to translate user needs into requirements, generate alternatives, and justify design choices.
4. Describe industrial control systems and automation hierarchies and apply concepts to design simple control strategies and anomaly-recovery approaches.
5. Implement the machine learning pipeline in industrial contexts, including data collection (MTConnect, OPC UA, MQTT), feature engineering (statistical and spectral methods), model training, evaluation, and tuning.
6. Use real industrial datasets (e.g., water treatment, LPBF additive manufacturing) to build, evaluate, and interpret ML models for anomaly detection, predictive analytics, and quality monitoring.
7. Describe cybersecurity risks and defenses in manufacturing CPS.
8. Critically reflect on workforce, organizational, and societal implications of adopting smart manufacturing systems.
9. Reflect on cross-sector adoption of smart system concepts, recognizing how tools such as the digital thread, ML pipelines, and cybersecurity frameworks can be applied beyond manufacturing in other industrial domains (e.g., energy, healthcare, water, aerospace).

Additional Outcomes for Graduate Students:

In addition to the abovementioned learning outcomes, graduate students should be able:

1. Review and synthesize relevant literature in smart manufacturing and industrial ML.
2. Learn the basics of academic writing and deliver a final report in the form of an academic paper.

Accountability Statement:

You may expect to achieve these outcomes only if you honor all course policies, attend classes regularly, complete all assigned work in good faith and on time, and meet all other course expectations.

COURSE MATERIALS

- Lecture notes are the primary source materials for this course.
- Other supplemental readings and resources – available through university's libraries and online subscriptions or otherwise "free".

CLASS STRUCTURE PARTICIPATION POLICY

The format of the course is a combination of lecture, in-class discussion, individual projects, and group projects. Student attendance and active participation in class discussions and team projects is vital to the learning process. As such, **in-person attendance is REQUIRED AND GRADED** for on-campus students while fully watching the recorded classes is required and graded for remote students. A Zoom link will be provided to remote students for optional attendance of the live class.

General Policies

- The UA's policy concerning Class Attendance, Participation, and Administrative Drops is available at: [ATTENDANCE POLICIES AND PRACTICES | Dean of Students Office](#).
- The UA policy regarding absences for any sincerely held religious belief, observance or practice will be accommodated where reasonable, [Religious Accommodation Policy | UA Policy](#). The calendar of religious holidays can be found at [Calendar of Religious Holidays | Office of the Registrar](#).
- Absences for groups of more than three students that are pre-approved by the UA Dean of Students (or Dean Designee) will be honored. See: [Attendance Policy | UA Policy](#).
- Non-attendance for any reason does **not** guarantee an automatic extension of due dates or rescheduling of examinations/assessments. Please communicate and coordinate any request directly with your instructor.

Course-Specific Policies

- If a student needs to miss less than three classes in a row for ANY reason, the student **DOES NOT** need to contact the course instructor because the class has a **“three absent classes with NO penalty”** policy; that is three absent classes of course attendance points will be dropped for all students (no questions asked) to account for short-term absences for ANY reason. However, it is the student's responsibility to be aware of all the materials covered in the missed class as it will absolutely affect your progress towards the following classes.
- If you must miss three or more classes in a row, please directly contact the Dean of Students Office DOS-deanofstudents@email.arizona.edu to share documentation about the challenges you are facing. The Dean of Students Office will communicate the situation to the course instructor, and then the student can communicate with the course instructor to discuss what needs to be done to receive attendance points for the missed classes.
- Please note that during the lectures students may be assigned to smaller groups to work together on in-class assignments which can be a very valuable learning and engagement experience that you will miss by not attending in addition to losing the attendance and in-class assignment grades themselves.
- On-campus students must attend the **full** 75-minute lecture in-person while remote students must fully watch the 75-minute lectures.

ASSIGNMENTS AND EXAMINATIONS

Class Attendance

- Class attendance is required in all classes for on-campus students and accounts for 5% of the course grade.
- Fully watching each week's class recordings before the following week is required for remote students and accounts for 5% of the course grade.
- Attendance checks may not be collected every class and will be collected randomly throughout the semester.
- The class has a **“three absent classes with NO penalty”** policy; that is three absent classes of course attendance points will be dropped for all students (no questions asked) to account for short-term absences for ANY reason. However, it is the student's responsibility to be aware of all the materials covered in the missed class as it will absolutely affect your progress towards the following classes.

Quizzes

- The quizzes will focus on concepts and material discussed in class, homework, and/or extra work assignments to ensure achievement of learning outcomes of the course.
- Their purpose is mainly to give you an indication of your understanding of the class material throughout the semester.

Homework and Discussions

- This includes assignments related to class lectures, take-home exercises, in-class exercises, and discussion topics on D2L where students will reflect on their learning and be asked to read and interact with other students' reflections.
- The purpose of those assignments is to prepare you for the quizzes and projects, provide additional opportunities to practice and deepen your understanding of the material, and give you an indication of your understanding of the class material throughout the semester.

Course Projects

- All students will be asked to work individually and in groups on two course projects covering the topics of "Simulation-Driven Design" and "Smart Process Design & Industrial Machine Learning".
- Graduate students will be required to work on a third individual project to read and analyze a research paper and then present it.
- More details on the course projects' scope, deliverables, and timeline will be shared during the semester.

GRADING POLICY

The final course grade will be based on the total weighted points and the following scale. Final scores will be calculated to the hundredth decimal and rounded to the nearest whole number (e.g., 89.50 = A and 89.49 = B, no exceptions).

A: 100-90%; **B:** 80-90%; **C:** 70-80%; **D:** 60-70%; **E:** below 60%

For undergraduate students, grades will be assigned based on performance using the following percentages:

Course Requirement	Percentage of Grade
Class Attendance	5%
Quizzes	15%
Homework and Discussions	20%
Course Projects	60%

For graduate students, grades will be assigned based on performance using the following percentages:

Course Requirement	Percentage of Grade
Class Attendance	5%
Quizzes	15%

Homework and Discussions	15%
Course Project	65%

CLASSROOM BEHAVIOR POLICY

To foster a positive learning environment, students and instructors have a shared responsibility. We want a safe, welcoming, and inclusive environment where all of us feel comfortable with each other and where we can challenge ourselves to succeed. To that end, our focus is on the tasks at hand and not on extraneous activities (e.g., texting, chatting, reading a newspaper, making phone calls, web surfing, etc.).

Students are asked to refrain from disruptive conversations with people sitting around them during lecture. Students observed engaging in disruptive activity will be asked to cease this behavior. Those who continue to disrupt the class will be asked to leave lecture or discussion and may be reported to the Dean of Students.

THREATENING BEHAVIOR POLICY

The UA Threatening Behavior by Students Policy prohibits threats of physical harm to any member of the University community, including to oneself. See: [Threatening Behavior by Students Policy | UA Policy](#).

ACCESSIBILITY AND ACCOMMODATIONS

Our goal in this classroom is that learning experiences be as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, please let me know immediately so that we can discuss options. You are also welcome to contact the Disability Resource Center (520-621-3268) to establish reasonable accommodations. For additional information on the Disability Resource Center and reasonable accommodations, please visit <http://drc.arizona.edu>.

CODE OF ACADEMIC INTEGRITY

Students are encouraged to share intellectual views and discuss freely the principles and applications of course materials. However, graded work/exercises must be the product of independent effort unless otherwise instructed. Students are expected to adhere to the UA Code of Academic Integrity as described in the UA General Catalog. See: [Academic Integrity | Dean of Students Office](#).

The University Libraries have some excellent tips for avoiding plagiarism, available at [Avoid plagiarism](#).

UA NONDISCRIMINATION AND ANTI-HARASSMENT POLICY

The University of Arizona is committed to creating and maintaining an environment free of discrimination. In support of this commitment, the University prohibits discrimination, including harassment and retaliation, based on a protected classification, including race, color, religion, sex, national origin, age, disability, veteran status, sexual orientation, gender identity, or genetic information. For more information, including how to report a concern, please see: [Nondiscrimination and Anti-Harassment Policy | UA Policy](#).

Our classroom is a place where everyone is encouraged to express well-formed opinions and their reasons for those opinions. We also want to create a tolerant and open environment where such opinions can be expressed without resorting to bullying or discrimination against others.

ADDITIONAL RESOURCES FOR STUDENTS

UA Academic policies and procedures are available at [All Policies | University of Arizona Catalog](#).

Campus Health: [Home](#) | [Campus Health](#)

Campus Health provides quality medical and mental health care services through virtual and in-person care.
Phone: 520-621-9202

Counseling and Psych Services (CAPS): [Home](#) | [Counseling & Psych Services \(CAPS\)](#)

CAPS provides mental health care, including short-term counseling services. Phone: 520-621-3334

The Dean of Students Office's Student Assistance Program: [Student Assistance](#) | [Dean of Students Office](#)

Student Assistance helps students manage crises, life traumas, and other barriers that impede success. The staff addresses the needs of students who experience issues related to social adjustment, academic challenges, psychological health, physical health, victimization, and relationship issues, through a variety of interventions, referrals, and follow up services.

Email: DOS-deanofstudents@email.arizona.edu

Phone: 520-621-7057

Survivor Advocacy Program: [Welcome](#) | [Survivor Support Services](#)

The Survivor Advocacy Program provides confidential support and advocacy services to student survivors of sexual and gender-based violence. The Program can also advise students about relevant non-UA resources available within the local community for support.

Email: survivoradvocacy@email.arizona.edu

Phone: 520-621-5767

Safety on Campus and in the Classroom

For a list of emergency procedures for all types of incidents, please visit the website of the Critical Incident Response Team (CIRT): [In Case of Emergency](#) | [Emergency Management](#)

Also watch the video available at the university's [EDGE-learning](#) website.

SUBJECT TO CHANGE STATEMENT

Information contained in the course syllabus, other than the grade and absence policy, may be subject to change with advance notice, as deemed appropriate by the instructor.

Students are responsible for all the policies above and for any announcements, assignments, or changes to the syllabus that are announced in class, by e-mail, and/or posted on D2L.