SFWE 411/511: Software for Industrial Control Systems
Course Syllabus

Instructor Information

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Course Description

The increased connectivity due to the rise of the Internet and the growth of smart connected devices (Internet of Things) has brought rapid changes in cyber physical systems operational in many areas including manufacturing, healthcare, transportation, power system, home automation, etc. These changes, dubbed as the Fourth Industrial Revolution (4IR), amalgamate artificial intelligence, advanced robotics, smart sensors, and communication networks, blurring lines between the physical, digital, and biological worlds to automate industrial processes. At the forefront of this revolution are connected Industrial Control Systems (ICS), a group of control systems and associated instrumentation, which include the devices, systems, networks, and controls used to operate and/or automate industrial processes. As ICS and automation become more critical components of our digital world, it will be critical for engineers to know to design, develop, control, and manage these ICS. Moreover, the engineers will not just design and develop optimized ICS; they will also have to ensure their security from cyberattacks.

This course will train the students on Industrial Control Systems and their software, ensuring a complete understanding of ICS design, development, control, management, and cybersecurity concepts.

This course will cover the following topics:

- Industrial Control Systems Architecture and Networks
- Programmable Logic Controllers
- Human Machine Interfaces
- Ladder Logic
- Industrial Control System Security

This course will evaluate the student's performance with homework, labs, knowledge checks, midterm exams, semester projects, and a comprehensive final exam. The labs, offered through the Cybersecurity Lab as a Service (CLaaS) environment, enable the students to learn hands-on the ICS

software concepts learned in class. The semester project will require the students to work in teams of three or four to apply the concept learned in class to design, manage, manage and secure an ICS.

Course Objectives:

During this course:

1. The students will be introduced to Industrial Control Systems (ICS), showcasing the need for ICS, and the different critical components in an ICS.
2. The students will learn about Programmable Logic Controllers (PLC), PLC components, types, and applications.
3. The students will learn ladder logic, understanding ladder logic code design, syntax, and structuring. Using ladder logic, students will learn to program PLC's to design and build different Industrial Control Systems with varying degrees of automation.
4. The students will learn about SCADA systems and Human Machine Interfaces. Using their understanding of ICS, PLCs, ladder logic, and SCADA systems, the students will learn to monitor ICS operations, this objective will be effectively showcased through the labs, and final project.
5. The students will learn about ICS networks, and networking protocols like ENIP, Modbus, and DNP3. This will allow the students to understand the SCADA systems behaviors, measured and evaluated through the class labs and final project.
6. The students will learn ICS cybersecurity, by learning of attack vectors to target the ICS, and the techniques used to secure the ICS from cyberattacks.
7. The students will learn concepts of digital twins and their applications in ICS. Students will be showcased and introduced to high fidelity digital twins, their creation, and applications in ICS management and security.

Expected Learning Outcomes:

Upon the completion of this course, students should be able to:

1. Design and develop secure Industrial Control Systems, capable of automating digital systems including industrial manufacturing processes. [ABET Student Outcome 1, ABET Student Outcome 2, ABET Student Outcome 7].
2. Design and develop secure ladder logic code for PLCs, code that is optimized to perform the targeted operations without vulnerabilities like buffer overflows, or injection attacks. [ABET Student Outcome 4, ABET Student Outcome 5].
3. Design and develop secure SCADA systems and Human Machine Interfaces to monitor the ICS and its operations. [ABET Student Outcome 4, ABET Student Outcome 5].
4. Analyze, and Review ICS networks, understanding their functionality, optimizing, and securing their operations. [ABET Student Outcome 3, ABET Student Outcome 4, ABET Student Outcome 5, ABET Student Outcome 6].
5. Review and understand the use of Digital Twins to manage ICS operation in digital systems such as manufacturing floors. [ABET Student Outcome 1, ABET Student Outcome 2, ABET Student Outcome 5, ABET Student Outcome 7].
6. Graduate students only: Design and develop optimized ICS systems (with ICS networks) while ensuring their secure operations

7. Graduate students only: Design and develop Digital Twins to manage ICS operations in digital systems like manufacturing floors.

Course Prerequisites:

The prerequisites for this course are: ECE 275 and SFWE 401

Course Format and Teaching Methods:

This course is structured around weekly progress. It will include a combination of lectures, online labs, and small groups activities focused on experiential learning, in-class discussions, and individual assessments. The expected weekly progress is outlined in the course schedule. At a minimum it is recommended that students keep up with coursework by following the outlined course schedule on D2L. Note the **DUE DATES** on course deliverables are all posted on D2L.

This course is architected to engage and demonstrate key concepts of the materials covered using collaborative and active learning strategies. Students will watch pre-recorded lecture materials that have interactive features integrated into the materials. Interactive instructional technologies (Cybersecurity Lab as a Service (CLaaS), PlayPosit, Perusall, etc.) and industry-relevant software development tools will be used to allow students to demonstrate and self-assess their progress toward and achievement of course learning outcomes. Students will break into small teams to work on activities that demonstrate the key principles covered in the lectures.

Course Communications:

Announcements and important reminders will be regularly posted on D2L. Log in frequently to check for new announcements, reminders, and information related to the course.

Students are encouraged to reach out to the instructor frequently throughout the semester via in-person lectures, email, phone call, text, office hours, or schedule an in-person or Zoom meeting. Every attempt will be made to respond to any questions or concerns that you may have within 24 hours, if possible (often sooner).

Textbooks:

The textbook recommended for reading in this course:

- Automating Manufacturing Systems with PLCs
  Authors: Hugh Jack
  ISBN-13: 978-0557344255
  ISBN-10: 0557344255

Other Supplemental Readings / References:

Additional supplemental materials will be referenced and provided to students via D2L.

Course Schedule

The following table provides an outline for the topics and objectives that will be covered during each module for this course. Specific dates will be posted on D2L for any given semester.

Module	Topic	Learning Outcomes
1	Introductions of Cyber-Physical Systems in different applications including manufacturing, healthcare, transportation, power system, home automation	• Students will be able to understand Cyber-Physical Systems, their architectures, and applications • Students will be able to explain the Cyber-Physical System Operations
2	Introduction to Industrial Control Systems and Programmable Logic Controllers	• Students will be able to understand and explain the design of Industrial Control Systems • Students will be able to understand and explain the design and working of Programmable Logic Controllers
3	Introduction to Ladder Logic and PLC programming	• Students will be able explain and analyze PLC code written using ladder logic • Students will be able to create new ladder logic code for PLCs
4	SCADA systems and Human Machine Interfaces (HMIs)	• Student will understand, and can explain and analyze the design and structure of SCADA systems • Students will be able to design new SCADA systems and HMI interfaces
5	Industrial Control System communication networks	• Students will be capable of explaining the operations of ICS networks and the associated protocols like ENIP, Modbus, and DNP3 • Students will also be able to design and analyze the operations of new ICS networks built using ENIP, Modbus, DNP3 protocol.
6	Cyber threats on Industrial Control Systems	• Student will be able to explain and understand different cyberattacks and analyze their impacts on ICS

Module	Topic	Learning Outcomes
7	Security of Industrial Control Systems	• Students will understand and be able to explain all the critical concepts associated with ICS security • They will also be able to analyze and design secure ICS
8	Introduction to Digital Twins for ICS	• Students will understand the key concepts on Digital Twins and their applications for ICS

D2L Course Management System

This course uses the University of Arizona's D2L course management system. You are **required** to use D2L with this class and are encouraged to check our D2L class course space daily.

You are also encouraged to have D2L email forwarded to your primary University of Arizona email account. We will use D2L for course assignments, exams, content distribution, and important announcements. The University of Arizona's D2L system is available at: http://D2L.arizona.edu.

Course Assignments and Exams

There will be homework assignments aligned to the outcomes of the module and designed to assess students' progress toward the course outcomes. There will be lab assignments aimed at providing students deeper, practical understanding to the material covered in-class. There will also be graded module-based discussion board prompts; student participation is required. There will be one midterm exam and a final exam. All exams will be timed, administered by the instructor or proctor, and will be available during the regularly scheduled exam time. ***Note: the instructor will give students ample notice of the format, time, and any resulting stipulations about where and how the exams will be administered.***

Final Examination:

The date and time of the final exam or project, along with links to the Final Exam Regulations can be found at https://www.registrar.arizona.edu/courses/final-examination-regulations-and-information, and Final Exam Schedule, http://www.registrar.arizona.edu/schedules/finals.htm

Grade Distribution

The grading distribution for course assignments, class participation, semester project, and exams is as follows:

Homework Assignments (x4):	10%
Note: *Graduate students will be required to answer extra questions focused on design and development aspects of the topics*	
Lab Assignments (x4):	10%
Note: *Graduate students will be required to perform add-on tasks and answer extra questions requiring application and analysis of the concepts*	
Class Participation (x8):	10%
Knowledge Checks:	10%
Midterm Exam (x1):	15%
Semester Project:	25%
Note: *Graduate students will have a more comprehensive set of deliverables focusing on design and development of secure ICS systems, and/or Digital Twins*	
Comprehensive Final Exam:	20%
Total	**100%**

Rubrics will be posted on D2L for all homework assignments.

Grading Scale and Policies:

The following scale will be used to award the final grades:

Percentage	Letter Grade
90% – 100%	A
80% – 89%	B
70% – 79%	C
60% – 69%	D
<60%	E

Homework and labs are due at the time specified in the course schedule and/or D2L content pages. Late homework, labs, and projects will not be accepted without prior approval by the instructor and will receive 0 points.

Subject to change:

The contents of this syllabus are subject to change at the instructor's discretion.

Course Time Zone:

All dates and times mentioned in this course represent Mountain Standard Time (Arizona), which is UTC-7 hours. Arizona does not observe Daylight Savings Time. You can use the following link to get the current local time in Tucson, Arizona: http://www.timeanddate.com/worldclock/city.html?n=393

Academic Policies and Institutional Resources

Academic Policies and Procedures:

As a University of Arizona student, you are expected to become familiar with and abide by the university-wide policies and procedures. You can find complete, up-to-date information at: https://academicaffairs.arizona.edu/syllabus-policies.

Course Policies

Make-up exams:

A make-up exam may only be given under extraordinary circumstances. The student requesting a make-up exam should contact the instructor well in advance and provide *written* documentation for the reason that he/she will not be able to attend the regularly scheduled exam. It is up to the discretion of the instructor to accept the justification provided by the student.

Requests for incompletes (I) and withdrawal (W) must be made in accordance with University policies which are available at http://catalog.arizona.edu/2015-16/policies/grade.htm#I and

http://catalog.arizona.edu/2015-16/policies/grade.htm#W respectively.

Dispute of Grade Policy:

You can dispute any grade that you receive within two weeks that the grade has been awarded.

Incomplete (I) or Withdrawal (W):

Requests for incomplete (I) or withdrawal (W) must be made in accordance with University policies, which are available at http://catalog.arizona.edu/policy/grades-and-grading-system#incomplete and http://catalog.arizona.edu/policy/grades-and-grading-system#Withdrawal respectively.

Classroom Behavior Policy:

To foster a positive learning environment, students and the instructor 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.).

Online Collaboration/Netiquette:

In this course, you will primarily communicate with the instructor and peers through a variety of tools such as discussion forums, Jamboard, email, and other forms of web conferencing. The following guidelines will enable everyone in the course to participate and collaborate in a productive, safe environment.

- Be professional, courteous, and respectful as you would in a physical classroom.
- Online communication lacks the nonverbal cues that provide much of the meaning and nuances in face- to-face conversations. Choose your words carefully, phrase your sentences clearly, and stay on topic.
- It is expected that students may disagree with the research presented or the opinions of their fellow classmates. To disagree is fine but to disparage others' views is unacceptable. All comments should be kept civil and thoughtful. Remember that this course abides by university policies regarding disruptive behavior: http://policy.arizona.edu/education-and-student-affairs/disruptive-behavior-instructional-setting
- Compose your messages and posts in a word processing tool and check your spelling and grammar before submitting your post / email.

Statement of copyrighted materials:

All lecture notes, lectures, study guides and other course materials disseminated by the instructor to the students, whether in class or online, are original materials and reflect intellectual property of the instructor or author of those works (with the exception of other published reference materials – i.e. course textbooks). All readings, study guides, lecture notes and handouts are intended for individual use by students. You may not distribute or reproduce these materials for commercial purposes without the express written consent of the instructor. Students who sell or distribute these materials for any use other than their own are in violation of the University's Intellectual Property Policy (available at http://ogc.arizona.edu/node/16). Violations of the instructor's copyright may result in course sanctions and violate the Code of Academic Integrity.

Student Support:

The instructor is available to assist with **content-related** issues. You may, at any time, email the instructor. This course also provides an ***Ask the Instructor*** discussion forum within the D2L environment. You are encouraged to post content-related questions to this forum at any time, especially for things that will benefit all students. *(It is not recommended that you use this forum for individual questions that are specific to your work or performance in the class.)* This forum will be monitored on a regular basis and the instructor will respond in a timely fashion. It is common for other students to participate in answering questions posted in the ***Ask the Instructor*** forum. You should feel free to contribute to the solution if you can provide knowledge or guidance related to the question.

The following are guidelines for requesting support:

- **General Course Questions:** Use the ***Ask the Instructor*** discussion forum for questions regarding course materials or policy.
- **Personal Course Questions**: Email the instructor to discuss grades or personal concern.
- **D2L Support Questions**: Email mailto:d2l@arizona.edu

Accommodations for Students with Disabilities:

At the University of Arizona, we strive to make learning experiences as accessible as possible. If you anticipate or experience barriers based on disability or pregnancy, please contact the Disability Resource Center (520-621-3268, https://drc.arizona.edu/)to establish reasonable accommodations.

See http://drc.arizona.edu/instructors/syllabus-statement.

Library Support:

The University of Arizona Libraries provides the research tools you need at any time. For an abbreviated list of resources directly related to a specific course, select the **Library Tools** link (located in the Tools drop down on the left of the screen within the Course Navigation bar).

Course Grievance Policy:

In case of grievances with a course component or grading, students are encouraged to first try and resolve the issue with the instructors. If you feel the issue is not resolved satisfactorily, please send an email to https://registrar.arizona.edu/faculty-staff-resources/grading/grading-policies/grade-appeal.

Course Surveys and Evaluations:

Near the end of each semester / session, students will receive an invitation via email to complete an online course survey associated with this course administered by the Office of Instruction and Assessment thru the UA Student Course Survey (SCS) tool. Refer to the Student Support website associated with the Student Course Surveys (https://scs.arizona.edu/content/5).

Your feedback is extremely valuable and will be used to make changes and enhancements to the course to better meet student needs in the future.

Additional Resources for Students (recommended links):

- Student Assistance and Advocacy information is available at: http://deanofstudents.arizona.edu/student-assistance/students/student-assistance
- Confidentiality of Student Records: http://www.registrar.arizona.edu/ferpa/default.htm