

SMART MANUFACTURING

Spring 2021, ISE 789-001/601; 3 credits; Online Delivery; Dr. Binil Starly (bstarly@ncsu.edu)

Purpose: This course is intended to introduce what makes manufacturing machines 'smart' within the realm of 'smart manufacturing'. It introduces some of the key fundamental knowledge necessary to implement 'smart manufacturing' within factory floors. This includes machine communication protocols from PLCs to servers, from the edge device to the cloud. It includes storing this data in databases that can handle data streams. Once this sensor data (from temperature to accelerometer or even still images) are stored, analysis of the time-series data and image data enable factories to be 'monitored' and for quality inspection. All of the concepts and practical implementation will be brought together while working with Raspberry PI – which is affectionately called as 'Raspi'. It will have temperature, accelerometer and a camera to mimic a basic manufacturing machine. While 'smart manufacturing' can contain a number of enabling technology platforms – this course particularly focuses on the information technology/computing aspects within a 'smart' factory.

Course Learning Objectives: By the end of this course, the student will be able to:

- Explain the key technology enablers within a smart manufacturing enabled factory
- Explain the various industrial communication protocols utilized in digitally enabled smart factories
- Demonstrate the usage of databases that capture real-time sensing data from devices.
- Build key software technology stacks through guided projects on the industrial internet of things.
- Prepare, store, analyze time series data analysis techniques.
- Summarize how Deep Neural Networks can be used for Quality Inspection in Factories.
- Solve Machine Vision Problems with OpenCV and PyTorch.

Prerequisites

- Working knowledge of the Python Programming Language to include Numpy and Pandas (you do not need to be an expert).

Any student with Graduate Standing can take this class. Undergraduate students on an ABM (Accelerated Bachelor's to Master's) program can also take this class, with instructor permission.

Hardware Requirements

- A computer with at least 8GB RAM is required. Virtual PCs are available through ISE-VCL.
- A Raspberry PI, SENSEHAT and an Android phone camera. You do not need to buy it. The department will make RPI-4 Modules available for borrowing. These however must be returned before semester ends. I would really encourage you to get a RPI-4 for your own projects. It is extremely useful to learn and build for home projects. A SenseHat Simulator is available and you can complete most graded portions of this class without owning a RPI-4 system of your own.

Textbook Downloads

No required textbook for the course. Since there is no single book available, the instructor will make available references to complement lecture content.

Grading Components:

In-Video Quiz Assessments (10%), Mini-Projects (30%), Research/Technology Paper/Report (30%), Discussion/Case Study Presentation Participation (20%), Class Attendance (10%). I expect most students to be either B+ or above. A+ is reserved for only the very best performers in class (Top 5%). B or below would indicate that the student has not completed key course components.

ONLINE Delivery (PLEASE READ)

- This is a flipped class. This means, all lectures are pre-recorded and can be watched asynchronously at your own pace. I have checkpoints with deadlines to be sure that activities are completed on time though. This is to ensure that students do not procrastinate and keep everything to the last minute.

- In-Class Live Sessions will be used for discussion, student progress presentation, questions and other topics of interest within Smart Manufacturing. ALL Students are expected to participate in at least one session per week. The session times are
 - Tuesday - Thursday: 11.45am to 1.00pm; (These sessions will be recorded and available to everyone)
 - Thursday: 6.30pm – 7.45pm (will not be recorded)
 - Sat: 10.45am -12.00pm (will not be recorded)
 - Wellness Days (No Live Sessions or submission deadlines): Feb 9th and April 15th
- Discussions will be embedded within videos to allow students to ask questions regarding material contained within each video. These discussions can allow other students in the class to respond to queries. Helping out another student improves your own understanding of the concept. Weekly sessions will be used to further clarify questions that you may have. If there are no questions, the instructor will pose questions to bring about a discussion. Discussion participation counts towards 'Class Participation' scores.

Lecture Outline:

Part 1 Smart Manufacturing Lecture Content

- What makes manufacturing 'Smart' ? Case Studies and Industrial Analysis
- Enabling Technology Concepts, Technical Terms and Standards
- Understanding of Technology Enablers within the Smart manufacturing software stack
- Software Platform Architecture for Digital Factories

Part 2 Streaming Data from Device to the Cloud with "Raspi"

- Data Management for IIOT Foundations using MQTT
- SQL Databases for Smart Manufacturing using PostgreSQL
- Cloud Computing and Web Services through RESTful Interfaces
- Core Concepts of Cloud Architecture for Smart Manufacturing

Part 3 Smart Factory Floor Information Technology / Operational Technology System

- Industrial Ethernet Communication Enablers
- Factory Floor IT Systems
- Integration of IT-OT Systems via Edge Computing Layers

Part 4 Analyzing Sensor Data through Time-Series Analysis for 'Raspi'

- Time-Series Analysis techniques.
- Using Time-Series Analysis to analyze sensor data.
- Auto-regressive Processes, Yule-Walker Equations

Part 5 Machine Vision for Quality Inspection

- Image Processing for Computer Vision (Linear Image processing, Model Fitting, Frequency Domain)
- Image Feature Detection, Descriptors and Model Fitting
- Deep Neural Networks for Machine Vision in Manufacturing.

Part 6 Application Discussion of 'Smart Manufacturing'

- AI in Manufacturing
- AI Culture in Manufacturing Workforce
- Augmented/Virtual Reality in Smart Factories
- Key Technology Companies and Products in AI for Manufacturing Space

COURSE AGENDA

Note: this syllabus is not a contract and can be altered at any point with advanced notice to accommodate the educational goals of the Course

The following timeline agenda can be used as a guide to complete course learning material and hands-on guided project activity. The hard deadlines are highlighted as checkpoints through the semester to ensure timely completion of core activities.

Date	Week	LECTURE TOPIC
Jan	Wk 3	Part 1: Getting Started <ul style="list-style-type: none"> Course Content Review Software Installation Smart Manufacturing Concept, Technology Enablers, Benefits First Coding Exercise
	Wk 4	Part 2: Streaming Data from Device to the Cloud (10hrs) <ul style="list-style-type: none"> Data Management for IIoT Foundations
	Jan 31st	Checkpoint 1: Installation of Needed Software. Get it Working
Feb	Wk 1	Part 2: Streaming Data from Device to the Cloud <ul style="list-style-type: none"> SQL Databases for Industrial Internet of Things Cloud Computing and Web Services Core Concepts of Cloud Architecture for Smart Manufacturing
	Wk2	
	Wk 3	
	Feb 14th	Checkpoint 2: Raspi Simulator to MQTT Broker to Subscriber to PostGRESQL DB to Plotly Dash and Live on Heroku
Wk 4	Part – 3 Smart Factory Floor Information Technology/Operational Technology System (5hrs) <ul style="list-style-type: none"> Industrial Ethernet Communication Protocols Factory Floor IT Systems Integration of IT-OT Systems 	
Mar	Wk 1	Checkpoint 3: Get a Real Raspi to stream its sensor data to an application interface through EdgeX computing framework Checkpoint 4: Initial draft submission of Paper/Report
	Mar 7th	
	Wk 2	Part 4: Time Series Analysis (7.5hrs) <ul style="list-style-type: none"> Querying and Modeling Time Series Data in Databases Time-Series Analysis – 1 Time-Series Analysis – 2 Time-Series Analysis - 3
	Wk 3	
	Wk 4	
Mar 30th	Checkpoint 5: A 50% completed draft submission of Paper/Report.	
Wk 5	Part 5: Machine Vision for Quality Inspection with OpenCV and PyTorch (7.5hrs) <ul style="list-style-type: none"> Image Processing Basics Object Detection Feature Detection Neural Networks Object Detection with Deep Neural Networks 	
Apr	Wk 1	Checkpoint 6: Train a DNN classifier to label manufactured objects
	Wk 2	
	Apr 19th	
	Wk 3	Part 6: AI in Smart Manufacturing (1hr) <ul style="list-style-type: none"> AI Strategy for Business Value in Manufacturing Building an AI Culture within the Manufacturing Workforce Key Technology Companies and Products in the AI Space within Manufacturing Challenges of AI in Manufacturing
Apr 30th	Checkpoint 7: Research Paper or Technical Project Report DUE	

COURSE DELIVERY and HOMEWORK SUBMISSION

All Lectures and Tutorials will be uploaded to Moodle with videos posted to Panopto. The instructor will provide reading references and web tutorials to enhance the learning in class. Mini-project submission will be through Moodle. Grades will be periodically posted on Moodle.

ASSIGNMENT SUBMISSION by EOL Students

All homework assignment submission will take place through Moodle or through software collaborate features directly to the Instructors. Discussion boards will be opened up by the instructors to have suitable online discussions between instructors, on-campus students and online students.

This Course uses Standard NCSU Letter Grading:

97	≤	A+	≤	100
93	≤	A	<	97
90	≤	A-	<	93
87	≤	B+	<	90
83	≤	B	<	87
80	≤	B-	<	83
77	≤	C+	<	80
73	≤	C	<	77
70	≤	C-	<	73
67	≤	D+	<	70
63	≤	D	<	67
60	≤	D-	<	63
0	≤	F	<	60

Diversity, Equity and Inclusion (DEI) Initiative @NC State ISE

The Edward P. Fitts Department of Industrial & Systems Engineering seeks to create a learning environment that supports a diversity of thoughts, perspectives and experiences while honoring the identities (including but not limited to race, gender, class, sexuality, religion, ability, etc.) of our students. To do so, we must acknowledge the inherent dignity and value of every person and strive to maintain a climate for work and learning based on mutual respect and understanding.

While we fully support and encourage open expression as a part of the process of academic discourse, we should engage one another with civility, sensitivity and cordiality. In affirming our common humanity, we reject all forms of prejudice, discrimination and bias. The process of learning often requires difficult and uncomfortable conversations that challenge our beliefs or the status quo. These new perspectives deepen our understanding, strengthen our community and propel our innovation. Only through thoughtful engagement can we create an environment of inclusive excellence for all. As faculty, staff and students we will navigate these challenges through dialogue, education, training, and development while adhering to our shared principles and community values.

Accommodations for Disabilities

Any student in this course, who has a disability which may prevent him/her from fully participating in class activities, should contact the instructor personally. Reasonable accommodations will be made for students with verifiable disabilities. In order to take advantage of available accommodations, student must register with the Disability Services Office (<http://www.ncsu.edu/dso>), 919-515-7653. For more information on NC State's policy on working with students with disabilities, please see the Academic Accommodations for Students with Disabilities Regulation at <http://policies.ncsu.edu/regulation/reg-02-20-01>.

Non-Discrimination Policy

NC State University provides equality of opportunity in education and employment for all students and employees. Accordingly, NC State affirms its commitment to maintain a work environment for all employees and an academic environment for all students that is free from all forms of discrimination. Discrimination based on race, color, religion, creed, sex, national origin, age, disability, veteran status, or sexual orientation is a violation of state and federal law and/or NC State University policy and will not be tolerated. Harassment of any person (either in the form of quid pro quo or creation of a hostile environment) based on race, color, religion, creed, sex, national origin, age, disability, veteran status, or sexual orientation also is a violation of state and federal law and/or NC State University policy and will not be tolerated. Retaliation against any person who complains about discrimination is also prohibited. NC State's policies and regulations covering discrimination, harassment, and retaliation may be accessed at <http://policies.ncsu.edu/policy/pol-04-25-05> or http://www.ncsu.edu/equal_op/. Any person who feels that he or she has been the subject of prohibited discrimination, harassment, or retaliation should contact the Office for Equal Opportunity (OEO) at 919-515-3148.

Students in Stress/Distress

As members of the NC State Wolfpack community, we each share a personal responsibility to express concern for one another and to ensure that this classroom and the campus as a whole remains a safe environment for learning. Occasionally, you may come across a fellow classmate whose personal behavior concerns or worries you. When this is the case, I would encourage you to report this behavior to the NC State Students of Concern website: <http://studentsofconcern.ncsu.edu/>. Although you can report anonymously, it is preferred that you share your contact information so they can follow-up with you personally.

Requirements for Credit-Only (S/U) Grading

In order to receive a grade of S, students are required to take all exams and quizzes, complete all assignments, and earn a grade of C- or better. Conversion from letter grading to credit only (S/U) grading is subject to university deadlines. Refer to the Registration and Records calendar for deadlines related to grading. For more details, refer to <http://policies.ncsu.edu/regulation/reg-02-20-15>.

Requirements for Auditors (AU)

Information about and requirements for auditing a course can be found at <http://policies.ncsu.edu/regulation/reg-02-20-04>. To audit this course, the students are expected to watch all videos and complete mini-project guided projects.

Policies on Incomplete Grades

If an extended deadline is not authorized by the instructor or department, an unfinished incomplete grade will automatically change to an F after either (a) the end of the next regular semester in which the student is enrolled (not including summer sessions), or (b) the end of 12 months if the student is not enrolled, whichever is shorter. Incompletes that change to F will count as an attempted course on

transcripts. The burden of fulfilling an incomplete grade is the responsibility of the student. The university policy on incomplete grades is located at <http://policies.ncsu.edu/regulation/reg-02-50-3>.

Academic Integrity

Students are required to comply with the university policy on academic integrity found in the Code of Student Conduct found at <http://policies.ncsu.edu/policy/pol-11-35-01>. See Page 5 for Department of Industrial and Systems Engineering policies.

Academic Honesty

See <http://policies.ncsu.edu/policy/pol-11-35-01> for a detailed explanation of academic honesty.

Honor Pledge

Your signature on any test or assignment indicates "I have neither given nor received unauthorized aid on this test or assignment."

COVID-19 CONSIDERATIONS

Due to the Coronavirus pandemic, public health measures have been implemented across campus. Students should stay current with these practices and expectations through the Protect the Pack website (<https://www.ncsu.edu/coronavirus/>). The sections below provide expectations and conduct related to COVID-19 issues.

Health and Participation in Class

We are most concerned about your health and the health of your classmates and instructors/TAs.

- If you test positive for COVID-19, or are told by a healthcare provider that you are presumed positive for the virus, please work with your instructor on health accommodations and follow other university guidelines, including self-reporting: <https://healthypack.dasa.ncsu.edu/coronavirus/>. Self-reporting is not only to help provide support to you, but also to assist in contact tracing for containing the spread of the virus.
- If you feel unwell, even if you have not been knowingly exposed to COVID-19, please do not come to class.
- If you are in quarantine, have been notified that you may have been exposed to COVID-19, or have a personal or family situation related to COVID-19 that prevents you from attending this course in person (or synchronously), please connect with your instructor to discuss the situation and make alternative plans, as necessary.
- If you need to make a request for an academic consideration related to COVID-19, such as a discussion about possible options for remote learning, please talk with your instructor for the appropriate process to make a COVID-19 request.

Health and Well-Being Resources

These are difficult times, and academic and personal stress is a natural result. Everyone is encouraged to take care of themselves and their peers. If you need additional support, there are many resources on campus to help you:

- Counseling Center (<https://counseling.dasa.ncsu.edu/>)
- Health Center (<https://healthypack.dasa.ncsu.edu/>)
- If the personal behavior of a classmate concerns or worries you, either for the classmate's well-being or yours, we encourage you to report this behavior to the NC State CARES team: (<https://advising.dasa.ncsu.edu/resources-for-advisors/advisors-toolkit/cares/>)
- If you or someone you know are experiencing food, housing or financial insecurity, please see the Pack Essentials Program (<https://dasa.ncsu.edu/pack-essentials/>).

Community Standards related to COVID-19

We are all responsible for protecting ourselves and our community. Please see the community expectations (link TBD) and Rule 04.21.01 regarding Personal Safety Requirements Related to COVID-19 <https://policies.ncsu.edu/rule/rul-04-21-01/>

Course Expectations Related to COVID-19:

- Personal Protective Equipment: As a member of the NC State academic community you are required to follow all university guidelines for personal safety with face coverings, physical distancing, and sanitation. **Face coverings are required in this class and in all NC State buildings.** Face coverings should be worn to cover the nose and mouth and be close fitting to the face with minimal gaps on the sides. In addition, students are responsible for keeping their course/work area clean.

- Course Attendance: NC State attendance policies can be found at: <https://policies.ncsu.edu/regulation/reg-02-20-03-attendance-regulations/> . Please refer to this course's attendance, absence, and deadline policies for additional details. If you are quarantined or otherwise need to miss class because you have been advised that you may have been exposed to COVID-19, you should not be penalized regarding attendance or class participation. However, you will be expected to develop a plan to keep up with your coursework during any such absences. If you become ill with COVID-19, you should follow the steps outlined in the health and participating section above. COVID 19-related absences will be considered excused; documentation need only involve communication with your instructor.
- Course Meeting Schedule: Be sure to pay attention to any updates to the course schedule as the information in this syllabus may have changed. Please discuss any questions you have with the instructor.
- Classroom Seating: To support efficient, effective contact tracing, please sit in the same seat when possible and take note of who is sitting around you; instructors may also assign seats for this purpose..
- Technology Requirements: This course may require particular technologies to complete coursework. Be sure to review the syllabus for these expectations, and see go.ncsu.edu/syllabus-tech-requirements to find out more about technical requirements for your course. If you need access to additional technological support, please contact the Libraries' Technology Lending Service: <https://www.lib.ncsu.edu/devices>.

Course Delivery Changes Related to COVID-19

Please be aware that the situation regarding COVID-19 is frequently changing, and the delivery mode of this course may need to change accordingly, including from in-person to online. Regardless of the delivery method, we will strive to provide a high-quality learning experience.

Grading/Scheduling Changing Options Related to COVID-19

If the delivery mode has a negative impact on your academic performance in this course, the university has provided tools to potentially reduce the impact:

- Enhanced S/U Grading Option: <https://studentservices.ncsu.edu/your-resources/covid-19/spring2020-sat-grading/>
- Late Drop: <https://studentservices.ncsu.edu/your-resources/covid-19/spring2020-latedrop/>

In some cases, another option may be to request an incomplete in the course. Before using any of these tools, discuss the options with your instructor and your academic advisor. Be aware that if you use the enhanced S/U, you will still need to complete the course and receive at least a C- to pass the course.

Other Important Resources

- Keep Learning: <https://dasa.ncsu.edu/students/keep-learning/>
- Protect the Pack FAQs: <https://www.ncsu.edu/coronavirus/frequently-asked-questions/>
- NC State Protect the Pack Resources for Students: <https://www.ncsu.edu/coronavirus/reactivating-campus/resources-for-students/>
- NC State Keep Learning, tips for students opting to take courses remotely: <https://dasa.ncsu.edu/students/keep-learning/>

- Introduction to Zoom for students:
<https://youtu.be/5LbPzzPbYEw>
- Learning with Moodle, a student's guide to using Moodle:
<https://moodle-projects.wolfware.ncsu.edu/course/view.php?id=226>
- Learning with Panopto
<https://howtovideos.hosted.panopto.com/Panopto/Pages/Folders/DepartmentHome.aspx?folderID=4b9de7ae-0080-4158-8496-a9ba01692c2e>

**Edward P. Fitts Department of Industrial and Systems Engineering
North Carolina State University**

The Department strives to provide an environment conducive to learning and believes strongly in the Code of Student Conduct (POL 11.35.01). The portion below, extracted from POL 11.35.01, is specific to academic misconduct:

8.0 ACADEMIC MISCONDUCT

All members of the University community, students, faculty and other employees, have the responsibility to report academic misconduct to the appropriate authority.

Faculty members must undertake a threshold responsibility for such traditional safeguards as examination security and proctoring and should clearly communicate their academic expectations in the course syllabus. The use of the Pack Pledge, "I have neither given nor received unauthorized aid on this test or assignment," on all syllabi, assignments, examinations, or other academic evaluations is encouraged. Similarly, faculty members should familiarize themselves with the procedures for addressing academic misconduct. The procedures for reporting academic misconduct can be found in [**NCSU REG11.35.02 - Student Discipline Procedures.**](#)

Definitions regarding academic misconduct are set forth in writing in order to give students general notice of prohibited conduct. They should be read broadly and are not designed to define academic misconduct in exhaustive terms. If a student is in doubt regarding any matter relating to the standards of academic integrity in a given course or on a given assignment, that student must consult with the faculty member responsible for the course before presenting the work.

8.1 Aiding and Abetting

Aiding and abetting others to cheat or plagiarize is as detrimental to the scholarly community as engaging in the acts themselves. Aiding and abetting others to cheat or plagiarize includes, but is not limited to, the following:

- (a) Giving unauthorized assistance to another or others during a test or evaluation;
- (b) Posing as another student in order to meet a course or graduation requirement;
- (c) Providing specific information about a recently given test, examination, or assignment to a student who thereby gains an unfair advantage in an academic evaluation;
- (d) Providing aid to another person, knowing such aid is expressly prohibited by the faculty member, in the research, preparation, creation, writing, performing, or publication of work to be submitted for academic evaluation;
- (e) Permitting one's academic work to be represented as the work of another; or
- (f) Sharing or distributing academic materials, including class notes, in violation of the [**UNC Policy Manual 500.2 – Patent and Copyright Policies**](#) or [**NCSU REG01.25.02 – Copyright Infringement – Policy Statement.**](#)

8.2 Cheating

Cheating is the giving, taking, or presenting of information or material by a student that unethically or fraudulently aids oneself or another person on any work which is to be considered in the determination of a grade or the completion of academic requirements or the enhancement of that student's record or academic career. Cheating includes, but is not limited, to the following actions:

- (a) Copying from someone else's assignment, examination, or other academic exercise;
- (b) Possessing, buying, selling, removing, receiving, or using, at any time or in any manner not prescribed by the faculty member, any information related to an instrument of academic evaluation;
- (c) Using materials, equipment, or assistance in connection with an assignment, examination, or other academic exercise which have not been authorized by the faculty member, including but not limited to, notes, calculator, or other technology;

- (d) Obtaining or attempting to obtain, in a dishonest manner, any material relating to a student's academic work;
- (e) Working with another or others in completing an assignment, examination, or other academic exercise when the faculty member has required independent and unaided action;
- (f) Attempting to influence or change an academic evaluation, grade, or record by unfair means;
- (g) Permitting another individual to substitute for one's self in an academic evaluation;
- (h) Marking or submitting an examination or evaluation material in a manner designed to deceive the grading system;
- (i) Failing to comply with a specific condition of academic integrity which has been clearly announced in a particular course;
- (j) Submitting, without prior permission of the faculty member, any work by a student which has at any time been submitted in identical or similar form by that student in fulfillment of any other academic requirement at any institution;
- (k) Submitting of material in whole or part for academic evaluation that has been prepared by another individual(s);
- (l) Submitting data which have been altered or contrived in such a way as to be deliberately misleading; or
- (m) Providing false information to the University in any manner to achieve an unfair advantage, enhance one's record, or complete a requirement.

8.3 Destruction or Removal of Academic Materials

The destruction or removal of academic materials denies access to, and prevents the ability to develop the full potential of, scholarly resources. Prohibited acts under this section include, but are not limited to, the following:

- (a) Removing or attempting to remove, destroy, steal, or make inaccessible library or other academic material without authorization; or
- (b) Willfully damaging the academic work or efforts of another.

8.4 Plagiarism

Plagiarism is the use or close imitation of the language and thoughts of another and the representation of the other's work as their own. The act of submitting work for evaluation or to meet a requirement is regarded as assurance that the work is the result of the student's own thought and study, produced without assistance, and stated in that student's own words, except as quotation marks, references, or footnotes acknowledge the use of other sources. Any ideas or materials taken from another source for either written or oral use must be fully and correctly acknowledged. Submission of work used previously must first be approved by the faculty member. Plagiarism includes, but is not limited, to the following actions:

- (a) Representing the work of others as his or her own; or
- (b) Submitting written materials without proper attribution or acknowledgment of the source.

I have read, understand, and agree to abide by the Code of Student Conduct.

Name (Printed)

Signature

Date