NSF ATE funded Initiatives for Artificial Intelligence in Manufacturing Technician Education

Prof. Karen Wosczyna-Birch, National Center for Next Generation Manufacturing

Dr. Karen Wosczyna-Birch has been a champion of engineering and technology education for over 30 years. Since 1995, has served as the State Director of the CT College of Technology (COT) where her leadership has been instrumental in creating nationally recognized seamless pathway programs in engineering and technology between all 12 Connecticut public community colleges (now merged to CT State Community College) with 10 universities and technical and comprehensive high schools. She is also the Executive Director and Principal Investigator of the National Center for Next Generation Manufacturing (NCNGM), a National Science Foundation (NSF) Center of Excellence and a Professor Emeritus in Applied Technology at Connecticut State Community College Tunxis. She has received over $40M in funding from the NSF, including the Computer Science, Mathematics, and Physics Scholarship Program of Central Connecticut S-STEM grant and two grants for international partnership. Karen has implemented strategies resulting in an increase in the enrollment of underrepresented populations in STEM programs at the community colleges.

Karen has received numerous awards for her accomplishments as a professor and for her passion for increasing the diversity of the STEM population including the 2016 Distinguished Service Award from the international honor society Epsilon Pi Tau (EPT), the 2018 CT Women of Innovation Award in the Postsecondary Academic Innovation & Leadership Category, the 2012 New England Board of Higher Education Excellence Award for the State of CT and most recently, the 2020 High Impact Technology Exchange Conference's Innovative Program of the Year Award and the 2021 International Technology Engineering Educators Association (ITEEA) Special Recognition Award and 2025 ITEEA Prakken Professional Cooperation Award. In 2014, she was invited to the White House College Opportunity Summit recognizing leaders like Karen for their commitment to STEM education. She also serves on numerous local and national boards including the Connecticut Technical Education and Career System, Charter Oak State College Academic Council, and Charter Oak State College Business & Technology Committee, and Massachusetts Institute of Technology's TechAMP Advisory Board and Curriculum Committee.

Ms. Wendy Robicheau, National Center for Next Generation Manufacturing

Wendy Robicheau is the Assistant Director for the National Center for Next Generation Manufacturing, funded by the National Science Foundation Advanced Technological Education Program. She began working on NSF ATE grants for the Connecticut State Colleges & Universities System in 2012. Her work on these grants has grown her passion for making students, parents, educators and counselors aware of the educational and career pathways that are possible in STEM fields with an emphasis on advanced manufacturing. She has organized and participated in numerous local, national, and international initiatives over the years where she has both shared and learned about addressing STEM workforce needs and has also published and presented papers for these conferences. Wendy has her M.S. in Student Development in Higher Education from Central Connecticut State University.

Mr. Eric Paul Flynn

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Overview

The integration of smart technologies and AI in higher education and industry is reshaping how students learn, innovate, and prepare for technologically advanced careers. Colleges and universities are embedding AI tools and applications across disciplines from data analytics, programming, and engineering design to equip students with skills directly aligned with industry demand. Through incorporating these technologies into research projects, higher education institutions expose students to every stage of the AI lifecycle from data engineering to model deployment to bridge academic theory and industrial application.

This National Center for Next Generation Manufacturing (NCNGM), funded by the National Science Foundation Advanced Technological Education (NSF ATE), aims to address the need for a highly skilled technician workforce at the two-year college level through its network of advanced manufacturing stakeholders. With the exponential growth of smart technologies, including artificial intelligence (AI), the NCNGM developed new partnerships and initiatives to investigate how AI is used in the manufacturing industry and how it can be implemented in manufacturing technician education. The NCNGM surveyed manufacturing companies to determine how they currently or plan to use AI [1]. According to the survey, AI applications in the manufacturing sector commonly involve data collection and analytics, preprocessing, model training, deployment, and continuous optimization that drive automation, quality control, and decision-making in manufacturing [1].

Student Research Project Program

One way the NCNGM provides real-world manufacturing experiences for students is through the Mechanical & Manufacturing Engineering Technologies (MET^2) Program, a student research project program. The MET^2 Program implements industry-driven team research projects that focus on manufacturing and mechanical engineering technologies. Students are recruited from community colleges and universities in Connecticut for the purpose of learning professional, entrepreneurial, and technical skills in addition to their classroom curriculum. Student teams perform research for projects developed by industry and faculty and then develop prototypes based on their research. Each program begins with the Winter Intersession Workshop where students spend two weeks learning about professional skills including teambuilding and leadership using the DISC behavioral model. They also learn technical skills such as SolidWorks CAD software, 3D printing, and circuit analysis. Students are placed into their teams and when the workshop is over, they work on their team research projects throughout the rest of the semester. Projects are presented to faculty and administrators from the community colleges and universities and industry sponsors at the end of the semester. This paper explores the Year 1 preliminary results from simulated data for a project focused on predictive maintenance for machine tools.

Method

The NCNGM tasked a team of students from Connecticut State Community College and the University of Bridgeport with completing different stages of a research project that would result in simulating and implementing zero down time (ZDT) analysis on a computer numerical control (CNC) machine. According to a report from Deloitte, "Agentic AI systems can monitor industrial equipment health, anticipate failures, diagnose root causes, and proactively schedule maintenance – keeping equipment running smoothly and reducing maintenance costs." [2]. This also translates to educating students in advanced manufacturing skills because having a virtual model allows a safe way for students to learn and correct mistakes [3]. In this case, data is used to mimic a machine crash, rather than faculty having to physically crash an expensive CNC machine in real life. The team first focused on prompt engineering for overall research on ZDT and how to use AI to predict future performance on clean data through database programming. Using the OpenAI platform, a set of AI-simulated test data was established to reflect real-world CNC machine sensor data recording spindle current load [4]. They began by simulating a 100-point data set. Figure 1 represents an example of this simulation in which spindle load is being estimated during a traditional three-cut machining process consisting of end mill, side feed, and conservative cut. The tool spindle is held at approximately 20% load baseline representing 2500 rotations per minute with no material cutting, often referred to as "cutting air." The tool then enters the workpiece and there is a steady increase in spindle load representing normal material contact, a normal increase in cutting stress as axial load increases, and a normal decrease in load as the tool disengages the workpiece. This is repeated three times. The simulated data was then run a second time to introduce a machine crash or broken tool. After three appropriate cuts we see a fourth peak, represented in orange. A broken tool, possibly caused by a programming error in G-code, is represented by a much narrower time impulse, or spike. This matches real-world crash behavior in which the tool contacts the material at too high of a feed rate. Interestingly, the spindle load does not peak at much higher than a traditional cut, but the time pulse is much narrower indicating rapid contact, tool breakage, and a rapid decrease in load (no cut condition). Examples of prompts used for the simulation included, but were not limited to:

"Simulate 100 data points for real-world sensor data on a three-axis Tormach CNC spindle - such as current load for a normal part - with three normal data spikes replicating three cuts in 6061 aluminum at conservative feeds and speeds."

"Now, simulate a machine crash and hide it in the data – making sure to fit this crash simulation data within the same sample size."

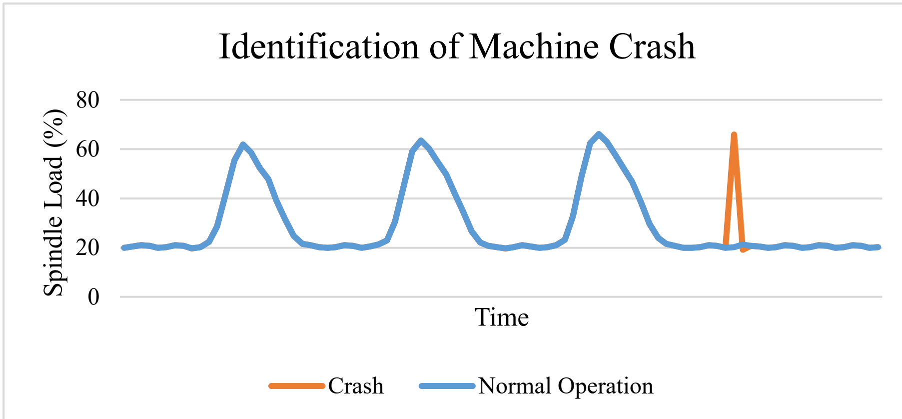

Fig. 1. Example of data from CNC machine crash simulated in OpenAI. [4]

The team will continue to experiment with prompts in OpenAI throughout the project to simulate data for additional variables that can occur with a CNC machine such as non-invasive spindle motor current sensing, spindle rotational speed, structure-borne vibration, and localized thermal response.

The next steps for the team are to choose the sensors to acquire raw data in the real-world, clean the data using AI-prompted database programming, and use applied AI to predict the health of various CNC machine components. These is occurring throughout the Spring 2025 semester and will be reported in a subsequent paper that includes documentation of operating conditions, maintenance events, and model results will be required to demonstrate how AI can support predictive maintenance decisions in a real manufacturing environment.

Results

The initial AI simulations found that the key difference between normal cutting and a machine crash is not directly related to peak spindle load, but to the time transient behavior of the signal. Normal cutting events show a gradual rise and fall in load as the tool engages and disengages material, producing a smooth, sustained load profile over multiple samples. In contrast, crash events exhibit a highly impulsive transient, which is a rapid, out-of-context spike followed by an immediate unload, often occurring within the same load magnitude range as normal cuts. This demonstrates that crashes are best identified by their rate of change and temporal signature, rather than absolute load level alone. This would not traditionally be cataloged by the machine but can be detected by an AI system that monitors real-time sensor data. Having students measure sensor data from an in-use industrial CNC machine introduces them to real-world variables of manufacturing such as the effect of feeds and speeds on tool and machine wear. They are introduced to the “sounds” of machining to qualitatively understand what makes a good cut versus a bad cut. Understanding the numerous variables such as load, vibration, and temperature that directly affect machine performance and longevity can be an experience not often found within a textbook or educational lab.

Therefore, by establishing that machining anomalies are most accurately identified through transient signal behavior rather than absolute load values, and by reinforcing this understanding through direct, real-world sensor interaction, it is evident that this combined AI-driven and experiential approach provides both a technically sound and validated framework. It was shown that these methods are not only authentic but represent real-world methods for both dependable machine crash detection on the shop floor, and effective engineering education in modern manufacturing environments.

Discussion

The overall purpose of the NCNGM's research project initiative is to provide students with real-world, industry-driven experiences in addition to their coursework. With the rapid implementation of AI across numerous industries, it is important for students to have experience with AI literacy and applications for the industry in which they will be employed. This research project builds students' AI literacy and allows them to learn industrial applications of AI in manufacturing outlined in the survey funded by the NCNGM through both simulations and hands-on experiences.

Overall, the alignment between academia and industry that the NCNGM facilitates ensures graduates enter the workforce ready to operate, manage, and innovate within AI-integrated systems. The result is a new generation of professionals fluent in the necessary technical elements of AI, capable of supporting next-generation platforms in organizations that depend on automation, analytics, and machine learning to remain competitive in the global marketplace.

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