Board 345: NSF ATE: Internet of Things Education Project

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Gary J. Mullett, a Professor of Electronics Technology and the present Department Chair of the Advanced Engineering Technologies (AET) Group, presently teaches advanced technology topics at Springfield Technical Community College (STCC) located in Springfield, MA. A long-time faculty member and consultant to local business and industry, Mullett has provided leadership and initiated numerous program and/or curriculum reforms as either the Chair or Co-Department Chair of the four technology degree programs that formerly constituted the Electronics Group and now continues in that position for the AET Group. Since the mid-1990s, he has been very active in the National Science Foundation's ATE and CCLI programs as a knowledge leader in the wireless telecommunications field. A co-founder of the National Center for Telecommunications Technologies (subsequently the ICT Center) located at STCC, Mullett also played a principal role in the development of the innovative and long running Verizon NextStep employee training program that led to a two-year associates degree in telecommunications for hundreds of the companies' employees. The author of two, technician oriented, textbooks, Wireless Telecommunications Systems and Networks and Basic Telecommunications – The Physical Layer, Mullett did both his undergraduate and graduate work (in microwave Remote Sensing) in the ECE Department at the University of Massachusetts at Amherst where he also taught the undergraduate sequence of courses in electromagnetics. He has presented at numerous local, regional, and national conferences and also internationally on telecommunications and wireless topics and on the status of the education of electronics technicians at the two-year college level. His current interests are; the development of novel and innovative systems-level approaches to the education of technicians, uses of the emerging field of networked embedded controllers and sensor/actuator networks, and wirelessly enabled cyber-physical system applications in the context of the Internet of Things (IoT) and Industry 4.0.

Internet of Things Education Project

Abstract
An ongoing convergence of technologies has given rise to the rapid implementation of the next generation of uses of the Internet. These Internet applications/systems are commonly known as the Internet of Things (IoT). These IoT functions incorporate networks of advanced sensors and actuators, embedded intelligence, and present-day networking technologies to provide for the exchange of data over the Internet with other network connected devices and systems in what is now called machine-to-machine (M2M) communications. In many cases, this technology gives rise to novel and innovative cyber-physical control systems that were not previously possible. In fact, IoT technology has the potential to affect nearly every aspect of human endeavor and commerce by increasing system efficiency and reducing energy consumption of almost all types of industrial activities. Furthermore, IoT can provide real-time monitoring of the nation's infrastructure and environment and has the real potential to improve public health, safety, and national security.
Today, society is on the cusp of Industry 4.0 and, at the same time, the rapid electrification of the world in the attempt to stem climate change by adopting alternative energy sources (solar, wind, etc.) and reducing fossil fuel usage. The transition to Industry 4.0 is in great part facilitated by IoT applications that enable many supportive and essential industrial functions. The steady integration of IoT applications into industrial environments results in increasing automation, the improvement of timely communications and self-monitoring and increasing the use of smart machines that can analyze and diagnose process issues without the need for humane intervention. Likewise, the integration of alternative energy sources and the transition to electric and autonomous vehicles, advanced batteries, power storage, microgrids and smart grids, and carbon removal initiatives will all be enabled and made more efficient through the use of IoT applications.

This NSF ATE project has developed IoT curriculum and a one-year Certificate of Completion in IoT technology. It is believed that these curricula materials may be readily adopted by the various advanced manufacturing support technologies (e.g. Mechatronics, Robotics, Automation, Electrical/Electronics, Photonics, Nano, Metrology, etc.) taught at the two-year college level. This poster session presentation will highlight the significant outcomes of this ongoing ATE project.

Introduction
Now heading towards the middle of this new decade, the world has started to move beyond a pandemic and entered a new post-pandemic era of how society lives, works, and interacts. The Internet has facilitated many of these dramatic changes that deal with how we associate with each other and it would appear that it will be instrumental in implementing future societal changes as well. Likewise, technology has also been changing rapidly and applications enabled by the Internet have been a primary driver of these changes. In particular, the Internet of Things

(IoT) has been at the forefront of a great number of new technology initiatives that deal with machine-to-machine (M2M) interactions. Today society is on the cusp of Industry 4.0 and at the same time is in the midst of a movement to implement the rapid electrification of the world in an attempt to mitigate climate change by adopting alternative energy sources (solar, wind, hydro, etc.) and reducing/eliminating fossil fuel usage. Additionally, the promise of machine learning (ML) and eventually Artificial Intelligence (AI) in the near future has given rise to increased optimism that technology might be able to solve some of the "grand challenges" of modern society.

The transition to Industry 4.0 is in great part facilitated by IoT applications that enable many supportive and essential industrial functions. The steady integration of IoT applications into industrial environments results in increasing automation, the improvement of timely communications and self-monitoring and increasing the use of smart machines that can analyze and diagnose process issues without the need for human intervention. Likewise, the integration of alternative energy sources and the transition to electric and autonomous vehicles, advanced batteries, power storage, microgrids and smart grids, and carbon removal initiatives will all be enabled and made more efficient through the use of IoT applications. The present version of Smart Phone technology, 5G, is being driven by M2M applications as contrasted with previous generations concerned with higher data rates. Already, plans to implement 6G smart phone technology by the end of this decade are taking shape and being driven by notions of how ML and AI can be used to enhance the system. Emerging Wi-Fi 7 standards are also being influenced heavily by IoT communication needs. All of these trends give rise to the flourishing of cyber-physical systems that have relevance to things like the electrical grid, transportation systems, and other large scale human enterprises [1].

A Potential Problem

There has been for some time now announcements of this new technology paradigm from the world's major technology companies in their commercial ads. Talking about the "smarter planet" or using similar terms that describe the emerging ecosystem embodied by IoT applications. These companies have become convinced that this newest application of the Internet will be the driving force behind their success for the foreseeable future. In 2019 a Google search of the "Internet of Things" yielded about 3.5 billion hits [2]. Today that number has risen modestly to about 4 billion but there are many more Google search suggestions about IoT sub-topics than ever before. Certainly many, many, commercials for IBM, Cisco, AT&T, Bosch, Intel, Samsung, Microsoft, Amazon, Google, etc. about futuristic IoT applications may be found on YouTube. Descriptive terms for IoT applications such as "machine-to-machine" (M2M), "vehicle-to-vehicle" (V2V), Industry 4.0, and e-healthcare have been coined to refer to possible application space scenarios. But the question arises, as we travel down this path of technological innovation, who will teach the skills needed to deal with the many diverse applications of the Internet of Things? IoT applications typically involve the deployment of sensors and embedded controllers in geographically scattered locations or throughout buildings, homes, factories or other infrastructure. Newly implemented technology systems routinely require maintenance, upkeep, software downloads and, in many cases, there will be a need for field service technicians to perform hands-on maintenance and interventions to keep these systems functional or updated. Applications implemented by IoT technology tend to be, by their very nature, extremely multi-interdisciplinary. These facts would seem to indicate the need for various technology disciplines to work together to find a solution to what would appear to be a growing need for the creation of a workforce for this area in the near future. To be objective, this is a fairly new problem facing the technical education segment of the two-year college space. Typically, most new technological developments have been derived from a discipline specific, legacy technology area and the curricula would only need to be morphed to include the new topic area at the expense of other topics that could be reduced in coverage due to declining importance or maturity due to the continuing advance of technology. Today, with the myriad of projected IoT application areas, this type of solution to bring this emerging interdisciplinary technology into the curriculum of existing programs is no longer an easy task.

Industry and Educational Stakeholders

Although industry has been active in attempting to educate their potential customers about IoT [3] possibilities there has not been a concerted effort by the big tech companies to drive curriculum development with one exception. Cisco Systems added several overview types of online IoT courses to its offerings to its networking students on its long running Cisco Networking Academy web site [4]. However, Cisco is a networking company and has its limitations when it comes to sensor, actuator, and embedded controller hardware expertise which are key components of IoT applications. Furthermore, most IoT applications target operational technology (OT) usages versus Cisco's emphasis on IT applications. Cisco has tended to rely on others for this expertise. Recently Cisco announced that it would no longer support these courses and as of now has not announced any plans for replacement. As far as educational stakeholders are concerned, there is a lack of curricula addressing IoT at the two-year college level with a notable exception being Springfield Technical Community College (STCC) of Springfield, Massachusetts, which now offers a one-year IoT certificate.

NSF Project Goals and Results

The Internet of Things Education Project is a five-year (Covid-19 delayed for two years) NSF ATE project located at Springfield Technical Community College that builds on several prior grants, by the project team, on sensor networks and intelligent infrastructure. These previous projects have facilitated the identification of the basic enabling technologies of IoT. They are: sophisticated embedded controllers; both wired and wireless networking technologies; intelligent sensors and actuators; and reconfigurable software and hardware. To address the lack of educational materials and expertise available pertaining to this emerging technology paradigm, this NSF ATE project has pursued four main objectives: first, it has created and tested relevant interdisciplinary IoT learning material in electronics, computing, and networking that can be used to improve the needed skill sets of a developing IoT workforce; second, it continues to broadly disseminate the materials produced through established networks such as the NSF Advanced Technological Education Centers; third, the project has developed teacher and faculty expertise in IoT and active-learner technologies through workshops and on-line activities; and lastly, it has attempted to interest under-represented groups in STEM fields by recruiting inner city K-12 students into summer workshops. It is vitally important that the United States be at the forefront of the development of this technology and has a workforce that can install, maintain, and update this emerging technology. This project has continued to develop the necessary curriculum needed to provide the skill set necessary for the emerging IoT workforce of the future. In the project's first year, three summer workshops for middle- and high-school STEM teachers and several IoT camps for upper-level K-12 students were offered with numerous teachers turned away due to space limitations. Also, the curriculum for a one-year IoT certificate program was crafted together and passed through the College's curriculum committee. The IoT certificate was originally under the Electronic Systems Engineering Technology (ESET) program but was subsequently moved to be under the Computer Systems Engineering Technology (CSET) program when the ESET program was discontinued by a new college administration. The curriculum for the certificate is shown on the college web site [5] and there are links to the descriptions of the courses.

There are several new courses in the IoT certificate curriculum that have been specifically designed to address the fundamental concepts and theory of the Internet of Things. They are: ELE-111, Internet of Things, ELE-111L, Internet of Things Lab, ELE-128, Internet of Things Networking and Security, ELE-128L, Internet of Things Networking and Security Lab, ELE-230, Wireless Networks, ELE-230L, Wireless Networks Lab, ELE-168, Developing the Things for Internet of Things, and ELE-168L, Developing the Things for Internet of Things Lab. As one can see, all of these courses have a hands-on lab associated with them. The lab activities associated with courses ELE-111 and ELE-128 rely heavily on the Arduino microcontroller and Raspberry PI microprocessor platforms. These device platforms are low cost and are available as kits from various manufacturers that include other parts and components to provide the student a viable lab experience [6]. All of these courses have been now taught at least once except for ELE-168 and ELE-168L. Also, due to the COVID-19 pandemic all the courses except ELE-168 and ELE-168L have been delivered online using the BlackBoard learning management platform. All of the labs have not been developed for online delivery as of yet except for ELE-111L and ELE-128L. Due to Massachusetts state-wide restrictions and the state-of-emergency declared because of COVID-19, work on this NSF project was suspended during both the second and a good portion of the third year of the grant. The project team was tasked with putting all of their normal on-campus course loads on-line in a structured format and then teaching their normal course loads online for the first time during the 2020-2021 academic year. This fact precluded any significant work on the grant. Furthermore, all access to campus was closed until the Spring 2021 semester at which time only limited access became available. A no cost extension was requested for a fourth grant year and teacher workshops were held in person during the summer of 2022. An additional year of a no cost extension was granted for a fifth grant year with more teacher workshops planned for the summer of 2023.

This poster session will present: a more detailed description of the IoT certificate curriculum; allow session attendees a preview of on-line course content; display the contents of the various labs that have been developed to date and the required lab supplies needed to perform the lab activities including using dedicated servers to act as the "cloud"; preview the contents of the various on-line workshops; indicate how the curriculum materials may be used by other technology areas; and we will outline our plans for the completion of the grant deliverables with plans for face-to-face workshops during the summer of 2023.

References:

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