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Internet of Things Education Project (IoTEP)

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Gary J. Mullett, a Professor of Electronics Technology and Department Chair, presently teaches in the Applied Engineering Technology Group 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 curriculum reforms as either the Chair or Co-Department Chair of the four technology degree programs that constituted the former Electronics Group. Since the mid-1990s, he has been active in the NSF's ATE and CCLI programs as a knowledge leader in the wireless telecommunications field. A co-founder of the long running National Center for Telecommunications Technologies (then the ICT Center) located at STCC, Mullett also played a principle role in the development of the innovative and long running Verizon NextStep employee training program. The author of two text books, Basic Telecommunications – The Physical Layer and Wireless Telecommunications Systems and Networks, Mullett did both his undergraduate and graduate work (in 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, applications of the emerging field of wired and wireless networked embedded controllers and sensor/actuator networks, and cyber-physical system applications in the context of the Internet of Things (IoT).

Internet of Things Education Project

Abstract

A convergence of technologies has given rise to the rapid deployment of applications/systems commonly known as the Internet of Things (IoT). These IoT applications incorporate networks of advanced sensors and actuators, embedded intelligence, and present-day networking technologies to provide the exchange of data over the Internet with other devices and systems. In many cases, this technology gives rise to control systems that were not previously possible and also provides the needed platform to implement innovative cyber-physical systems that can have wide-scale impact on everyday activities. 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. Furthermore, it also can provide real-time monitoring of the nation's infrastructure and environment and has the potential to improve public health, safety, and national security.

To address the lack of educational materials and expertise available pertaining to this emerging technology paradigm, this NSF ATE project has four main objectives: First, it is creating and testing relevant interdisciplinary IoT learning material in electronics, computing, and networking that can be used to improve the skill sets of a developing IoT workforce; Second, it is broadly disseminating the materials produced through established networks such as the NSF Advanced Technological Education Centers; Third, the project has develop 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 about the IoT. 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.

Introduction

As we enter the decade of the 2020s, the Internet has facilitated a dramatic change in how we live. This has never been made more obvious to us than by the circumstances brought on by the COVID-19 pandemic. Our nation’s move to wholesale on-line learning and remote work would not have been possible without the technologic advances of the last two decades. Powerful PCs and improved operating systems, high-resolution inexpensive cameras, Smart phones that provide mobility, and high-speed wireless Internet access have all become ubiquitous parts of our lives and have allowed us to adapt to threats to our public safety and well-being brought about by the pandemic. There is another transformation that is being expedited by the Internet that is not as obvious but will be extremely impactful nonetheless. This is the adoption of technology that incorporates 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 devices and systems. This convergence of technologies is commonly known as the Internet of Things or IoT. What is different about this emerging paradigm is that most of the Internet traffic produced is from machine-to-machine (also known as M2M) and is thus not like previous Internet uses which were primarily driven by human needs for social interactions or desires for entertainment or information. Many of the applications of IoT technology give rise to control systems heretofore not possible and to next generation control systems known as cyber-physical systems. These cyber-

physical control systems will probably be the most impactful as they can be used to control small individual systems or over-laid on geographically large areas and therefore have relevance to things like the electrical grid, transportation systems, and other large scale human enterprises [1].

A Potential Problem

For some time now, many of the world's leading technology companies have been touting this new technology paradigm with ads about the "smarter planet" or 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. A Google search of the "Internet of Things" yields about 5 billion hits and 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 [2] possibilities there has not been a concerted effort by the big tech companies to drive curriculum development with one exception. Cisco Systems has added several overview types of online IoT courses to its offerings to its networking students on its long running Cisco Networking Academy web site [3]. 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. 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 four-year (Covid-19 delayed) 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 four main objectives: first, it will create and test 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 will broadly disseminate the materials produced through established networks such as the NSF Advanced Technological Education Centers; third, the project will develop teacher and faculty expertise in IoT and active-learner technologies through workshops and on-line activities; and lastly, it will attempt 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 started to develop the necessary curriclum 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 [4] 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 [5]. 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 teaching platform. The labs have not been developed for online delivery as of yet except for 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 the second 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. The project team is presently making preparations to deliver on-line workshops to both middle- and high-school STEM teachers and to college faculty during the summer of 2021 and will take a one-year no-cost extension to finish the grant work by the Fall of 2022.

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 2022.

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