Workshop development for New frontier of mechatronics for mobility, energy, and production engineering

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Abstract

Mechatronics matches the new trend of convergence research [1] for deep integration across disciplines such as mechanics, electronics, control theory, robotics, and production manufacturing, and is also inspired by its active means of addressing a specific challenge or opportunity for societal needs. The most current applications of mechatronics include e-mobility, connected and autonomous vehicles (CAV), robotics, and unmanned aerial vehicle (UAV). The growing mechatronics industries demand high quality workforces with multidiscipline knowledge and training. In this paper we present the working processes and activities of a current one-year ECR: PEER (EHR Core Research: Production Engineering Education and Research) project funded by NSF organizing two workshops held by two institutes. These workshops are to solicit and synthesize insights from experts in the academic, for-profit, and non-profit sectors to describe the future and education of production in mechatronics. Each workshop is planned to be two days, where the first day will be dedicated to the topics of workforce education and training in mechatronics. The topics in the second day will be slightly different based on the expertise and locations of the two institutes. One will focus on the mechatronics technologies in production engineering for alternative energy and ground mobility, and the other will concentrate on aerospace, alternative energy, and the corresponding applications. Both workshops will also address the current technical development of teaching methods and tools for mechatronics. Social impacts of mechatronics technology, expansion of diversity and participation of underrepresented groups will be discussed in the workshops. We expect to have the results of the workshops to present in the annual ASEE conference in June.

Introduction

Mechatronics is a multidisciplinary engineering science that integrates elements of mechanics, electronics, control theory, robotics, computer, telecommunications, power and production manufacturing. The new convergence research [1] emphasized integrating knowledge, methods, and expertise from different disciplines and forming novel frameworks to catalyze scientific discovery and innovation; not just multidisciplinary (including more than one discipline), but interdisciplinary (integrating disciplines) and further transdisciplinary (grand synthesis of disciplines). Mechatronics matches this new trend of convergence engineering for deep integration across disciplines and is also inspired by its active means of addressing a specific challenge or opportunity for societal needs. On the other hand, the growing mechatronics demands high quality workforces with multidiscipline knowledge and training in the industries. This paper is to report the preparation process of an NSF funded project addressing and promoting workforce development in mechatronics and its production engineering applications by developing and holding workshops. The project will be developed by two institutions: Division of Engineering Technology at Wayne State University (WSU), Departments of Chemical Engineering and Mechanical & Aerospace Engineering of California State University, Long Beach (CSULB). The workshops will discuss the education systems and pathways for workforce development in mechatronics; pedagogies, tools, and assessment methods for learning; technological progress in mechatronics; and societal impacts such as workforce diversity.

Figure 1 is a diagram demonstrating the elements creating mechatronics. Including the knowledge of electric/electronic engineering, mechanical engineering, control theory, and computer science, a mechatronics system is a complex device powered by electrical and/or mechanical power sources, detecting the environment by sensors whose signals are sent to microcontrollers/computers through transducers, to react and achieve one or multiple tasks automatically by driving a series of actuators and mechanical parts using control theories. The applications of mechatronics cover many fields, including automotive, aerospace, medical, manufacturing, defense, and consumer products. A cyber-physical system is a computer-controlled mechatronics system tightly connected to internet with physical and software components deeply intertwined. The most current applications in automotive are e-mobility (electric vehicles, EV) and connected and autonomous vehicles (CAV); in manufacturing are robotics and smart-factory; and in aerospace are drones, unmanned aerial vehicle (UAV), and advanced avionics.

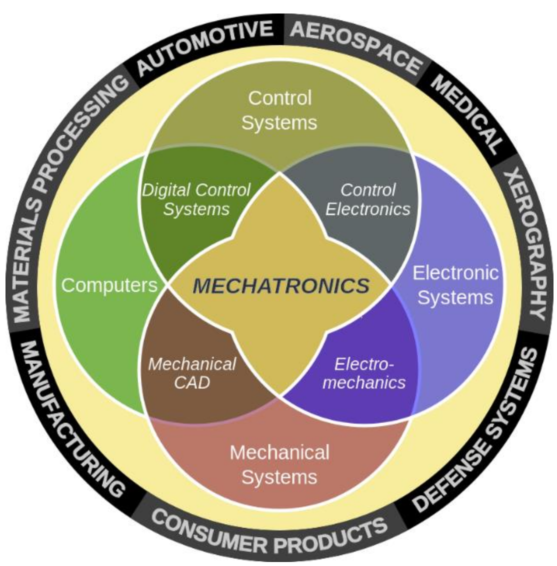

Figure 1 A Euler diagram by K. Craig from RPI's website describes the fields making up mechatronics.

The growing mechatronics industries demand high quality workforces with multidiscipline knowledge and training. These workforces can come from the graduates of colleges and universities, or from laborers substituted by newly introduced automation and robotics in manufacturing doing routine and repeating works that were originally operated by human. These substituted workforces can be included in the mechatronics workforce development by re-entering conventional pathways such as community colleges or taking new pathways such as training programs provided by industries, academic institutions or other professional development organizations. The curricula of two-year colleges and four-year universities should also be reviewed and updated for the coming challenges of mechatronics in production manufacturing. Graduate schools are included in the system for preparing higher level workforces that can carry out fundamental research and explore new technologies in mechatronics. K-12 schools will also play an important role in fostering the next decade workforces for all the STEM areas. Analyzing workforce needs and organizing education resources require data and information from labor statistics agencies. WSU and CSULB are collecting the information from Workforce Development Agency of Michigan [2] and The State of California Labor & Workforce Development Agency (LWDA) of California [3]. WSU has had long term collaboration with Workforce Intelligence Network for Southeast Michigan (WIN) [4] on workforce development in the great Detroit area, and is consulting the Michigan STEM education network (MiSTEM) [5] for K-12 STEM education. We plan to further look for working with the federal statistics agents to collect longitudinal data on factors that influence career pathways, especially for women, underrepresented minorities, veterans, and persons with disabilities.

The development of mechatronics technologies improves the tools for teaching mechatronics as well. In the past years, the most popular devices used in STEM education are the affordable microcontrollers and the peripherals including sensors and actuators. Arduinos, Raspberry Pi, LEGO controllers and many others allow students to create projects by wiring electrical devices and writing codes to control the devices and achieve tasks [6], [7]. These microcontrollers have low costs but perform industry level functions that can be used for prototyping or even commercial products. With wireless communication modules they can be integrated with smart devices and controlled by apps, and further building advanced systems such as cyber-physical systems and internet of things (IOT). These microcontrollers also promote the development of desktop 3D printers, another example of mechatronic systems, which can create customized parts conveniently used in building other mechatronic systems. Extended reality (XR), including virtual reality (VR), augmented reality (AR), substitutional reality, (SR), and mixed reality (MR), is the new technology that has attracted attention in STEM education and workforce training. By creating a virtual world, an educator can simulate a phenomenon by presenting the detailed internal layouts and controlling the simulation steps to improve teaching efficiency. A virtual world accessed by VR devices provides a communication platform for remote education. Many pioneers have investigated the use of XR in teaching [8]-[10] and in professional training by Bosch [11]. Big data technology has a potential to enhance mechatronics teaching environments. Pervasive data collected by sensors in cyber-physical systems or the internet of things can be analyzed and simulated to duplicate the original physical systems in a virtual world. Integrating these duplicated models in VR or AR helps students obtain a physical picture to learn the mechanism and the design of these complicated mechatronics systems.

Supported by the NSF ECR: PEER program and the Boeing Company, two workshops will be organized to discuss the education systems and pathways for workforce development in mechatronics; pedagogies, tools, and assessment methods for learning; technological progress in mechatronics; and societal impacts such as workforce diversity. One workshop will be held in the Detroit, Michigan area organized by the WSU team and the second workshop will be held in Long Beach, California by the CSULB team. The workshop is planned to be two days, where the first day will be dedicated to the topics of the current workforce situation in industry, the current pathways for workforces, conventional college and university workforce training, and K-12 STEM education preparation in mechatronics. The topics in the second day will be slightly different based on the different locations of the two institutes. In Detroit the topics will focus on the mechatronics technologies for alternative energy and ground mobility, because Detroit is the home of the big three with the production chain of their suppliers. In Long Beach the theme will be aerospace, alternative energy, and the corresponding applications. We present in this paper the motivation, vision, and current progress of the workshop preparation. The workshops were planned to be held in May and June 2020, and the results will be analyzed and presented in the 2020 ASEE conference. The complete results of the workshops will be organized and published on a newly created project website as well as in research papers for dissemination.

Mechatronics and Workforce Development

Mechatronics is a multidisciplinary and interdisciplinary science [12] integrating the knowledge from electronics, mechanics, control theory, robotics, computer, and even biomedical and chemical engineering fields. A mechatronics system is usually an automation combining electrical and mechanical devices that can achieve certain tasks. The demanding of complicated tasks sparks off new mechatronics technology development, where subsequently these newly developed mechatronics technologies inspire novel applications. In the past workforces might just need to master in a certain area which they were originally trained for in the production industry. However, with the increasing complexity of manufacturing systems from the introduction of mechatronics technologies, the workforces are facing challenges of communications with colleagues in other disciplines.

Most of the current workforces were trained from the conventional education system, starting from two-year colleges, then/or directly four-year universities, and ultimately graduate schools for some of them. Schools usually start with few fundamental STEM courses (math, physics, and chemistry) and then concentrate on delivering major courses of certain professional fields and do not have time to include multidisciplinary topics in the curricula. A critical need for an interdisciplinary approach to engineering education should be addressed and emphasized [13]. The insufficiency of interdisciplinary education and its importance to workforce development were claimed by Mayer-Krahmer [14]. Mechatronic innovations are often stimulated by an integrated discipline approach [15], and the full potential of interdisciplinary solutions results from bridging the gap between product technologies and engineering disciplines [14], [16]. Two approaches can strengthen the current college level mechatronics workforce education: first, new pathways in additional to the schools, such as training programs provided by industries and social services organizations, that focus on professional training for empirical practices; and second, curriculum reformation of conventional schools addressing interdisciplinary learning to match current mechatronics workforce needs. Integrating STEM education in K-12 education for development of a STEM-capable workforce had been investigated in [17]. To prepare readiness of K-12 students in the STEM areas, mechatronics is an essential element that new teaching methods and more resources should be researched for introduction to both students and teachers. Finally, all these education and pathway designs for workforce development must surround the industry needs, which will be the center of discussion in the proposed workshop.

In additional to modify and integrate the education systems and strengthen the relationship between schools and industries for STEM workforce development, the technical elements used both in introducing the latest mechatronics technologies or in teaching pedagogies and tools should be addressed. In the workshop, leaders or key personnel of industries and venture companies will be solicited to reveal the current challenges and future trends of both markets and technologies in mechatronics, while university faculty and researchers will be invited to present the latest inventions and research of mechatronics technologies. Engineering education faculty from colleges and university and K-12 teachers will contribute their experiences and idea of new teaching methodologies and tools, especially innovative technologies such as Apps, design software, microcontrollers (Arduino and Raspberry Pi), and extended reality (VR, AR, MR). Furthermore, experts will discuss social and economic impacts and issues risen with mechatronics technology development and the growth of workforce of mechatronics in production industries.

Workshop Goal and Objectives

The objectives of holding the workshop for STEM workforce development in mechatronics for production engineering can be summarized into two parts. One is workforce analysis and training methodology, and the other is technology development and impacts. The planned topics surrounding workforce education are:

- New providers and pathways of education and training. The traditional workforce pathways will be reviewed as a starting point to exploring new, innovative, and dynamic education pathways and training providers. Pathways such as formal degrees, short courses, practical training, exams and certificates will be considered, and providers may include social service, charity and veteran professional development organizations.
- Inquiring the needs of industry employers. Industry employer provides the first-hand information of the trend of technology development and the types of workforce needed. Strong and close college-business partnerships are encouraged and new effective and sustained two-way communication and collaboration will be explored.
- Examining college and graduate level education and their impacts on STEM workforce readiness. Review the current curricula and explore new pedagogies and methods including

hands-on, research-based, interdisciplinary, and virtual and remote learning. More internships, apprenticeships, and traineeships for undergraduate and graduate students are essential for students to get ready to start their STEM career after graduation.
- Prepare K-12 education for the farther future workforce needs. The current design of college level workforce training may only satisfy the industry demanding of the coming decade. The challenges of the next decade and beyond may be very different and need to be predicted and addressed in advance to keep US technology leading the world as well as avoid misplacing of the education resources.

The themes for targeting new and prospective mechatronics technology developments are

- The trend of mechatronics systems. The future applications of mechatronics will be discussed, especially the cyber-physical systems and IOT, including ground mobility systems such as connected autonomous vehicles (CAV), alternative energy powered mobile systems, and their peripheral and infrastructures; aerospace systems such as unmanned aerial vehicle (UAV), drones, satellites, planet rovers; energy systems, such as smart grids.
- New research and technologies in mechatronics. The current and prospective research and development in mechatronics will be discussed, both hardware and software. The topics include advanced sensors, embedded systems, actuators, microcontrollers, communications (5G), artificial intelligence (AI), robotics, and alternative energy systems.
- New education technologies for mechatronics. New hardware and software will be introduced to workforce education to face the challenges of new technologies of mechatronics and to match the innovative pedagogies. In additional to traditional hands-on training, extended reality (XR), including Virtual Reality (VR), Augmented Reality (AR), Substitutional Reality, (SR), and Mixed Reality (MR) potentially provide more freedom to cover both theoretical and practical learning, with assistance of other software. The usage of big data technology will also provide large amount of real and well-examined results and experiences to shorten the learning curves.
- Social impacts of new mechatronic technologies: The new mechatronic systems are changing our life. The social impacts including legal regulations, safeties, privacies, economics, and ethics from these new devices need to be addressed. For example, the introduction of CAV needs new traffic regulations, data privacy, and insurance policies. Workforce diversity and equal opportunity for underrepresented groups will be discussed.

Workshop Preparation

1. Advisory Committee

Initiating the development and implementation of all proposed activities requires a system of coordination for exchange of information and resources and effective utilization of institutional strengths. Collaboration among faculty and administrators from both institutions and their industrial partners will be formalized through the creation of an advisory committee. Members from the Joint Industry Advisory Boards of both institutions, especially the ones from industries will be invited to serve and advise the advisory committee. Committee members will meet regularly via net-meetings and teleconference to develop and implement the planned activities and monitor progress of the proposed project.

2. Workshop Agenda

Two workshops are planned for mechatronics workforce development in production manufacturing. The workshop participants are targeting university/college faculty, K-12 teachers, graduate students and researchers in mechatronics related area, as well as technical, administrative, professional development and human resource personnel from industries. One workshop will be held in the Detroit area managed by the WSU team, focusing on mechatronics applications in the ground mobility and alternative energy. The other workshop will occur in the Long Beach area managed by the CSULB team, and it will focus on mechatronics in the aerospace applications. Both workshops will take two days, where one day will focus on mechatronics workforce education systems and pedagogies, and the second day will be dedicated to the current and prospective mechatronics developments and new technologies that can be applied in workforce education. The workshops will be recorded and set up for live streaming to the general public on YouTube and other social media, and at workshop Q&A sessions the live streaming system will turn to a webinar form allowing deep interactions among local and remote participants. If the facility allows, the workshop video will be taken by multiple video cameras to create a real time VR environment for local and remote users equipped with a VR headset. Both WSU and CSULB equip VR laboratories that can support the workshop VR live streaming to demonstrate this technology as an effective tool for teaching. The proposed workshop schedule and topics are shown in Table 1.

Table 1 The two-day workshop agenda

Time		Michigan (WSU)	California (CSULB)
Day 1	Morning Session 1	New education and training providers and pathways	
	Morning Session 2	Inquiring the needs of industry employers	
	Afternoon Session 1	College and graduate level education	
	Afternoon Session 2	K-12 education	
Day 2	Morning Session 1	The trend of mechatronics systems in ground mobility and alternative energy	The trend of mechatronics systems in aerospace and alternative energy applications
	Morning Session 2	New mechatronics research and technologies in ground mobility and alternative energy applications	New mechatronics research and technologies in aerospace and alternative energy applications
	Afternoon Session 1	New education technologies for mechatronics	
	Afternoon Session 2	Social impacts of mechatronics workforce development and technologies, and diversity and equal opportunity.	

3. Implementation Timeline

This project will be started with forming the advisory committee, followed by contacting and inquiring the renowned industry leaders, federal or state workforce administrations and organizations, college and university educators, researchers, and K-12 teachers. After the workshops' time and locations are scheduled, we will start planning the meeting facilities, participants' accommodations, speakers' traffic plans, meals and refreshments, and participant recruiting. The project will be implemented over a period of 12 months, starting from August 1, 2019. The planned implementation schedule is displayed in Table 2. The actual starting date turned out to be October 1 due to NSF administrative reasons, however it basically did not affect the timeline much except the activities proposed in 2019.

Table 2 Project timeline.

Time	Activity
August 2019	Form the advisory committee
September 2019	Look for speakers by contacting industry leaders, federal or state workforce administrations and organizations, college and university educators, researchers, and K-12 teachers
January 2020	Determine the time of the workshops
February 2020	Announce the time and locations of the workshops and start recruiting participants
March 2020	Continue recruiting workshop participants
May 2020	Workshop in City A, MI
June 2020	Workshop in City B, CA
July 2020	Wrap up and report

4. Speaker Arrangements

One or two speakers were expected to present in the eight sessions with eight corresponding topics. We have started contacting and communicating with the potential candidates. The current speaker recruiting arrangements with respect to the topics are:

- New education and training providers and pathways: We targeted leaders in state or region level workforce agents such as Workforce Intelligence Network for SE Michigan (WIN).
- Inquiring the needs of industry employers: Personnel of the human resource and professional development department of companies with workforce training programs in mechatronics would be invited to talk.
- College and graduate level education: Faculty and administrators of community colleges and universities with mechatronics programs are the potential candidates.
- K-12 education: We planned to work with school districts and high school teachers that actively engage in STEM education emphasizing on mechatronics related areas.
- The trend of mechatronics: The targets were the companies with innovations in the pioneer fields of mechatronics, such as connected and autonomous vehicles (CAV) and unmanned aerial vehicles (UAV).
- New mechatronics research and technologies: Faculty or scientists in the universities or research institutions doing the most advanced research in the related fields of

mechatronics would be consulted and invited.
- New education technologies for mechatronics: The venders that provide latest teaching equipment and software, as well as college and university faculty that created new teaching strategies and tools in mechatronics were the targets to inquire.
- Social issues of mechatronics workforce development: We planned to invite the state government education or labor administrators to address the social issues.

Summary

This paper was submitted to review in early February while the workshops were not held yet. The advisory Committee has been formed and the first workshop has been scheduled in May and the second was planned in June currently. We already started inquiring and evaluating the potential workshop facilities as well as contacting the speakers. We expect to have the fruitful results of the mechatronics workforce development workshops to present in the annual ASEE conference in June.

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