Integrating Mechatronics Into a Mechanical Engineering Curriculum

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Abstract - **This paper presents a stepwise method to restructure a traditional mechanical engineering curriculum with a mechatronics theme. The result can be a curriculum with contemporary emphasis, enhanced content, and improved sequencing and coupling of traditional topics including modeling and analysis, computing, electrical circuits and machines, measurements and instrumentation, control theory, and design. Mechatronics provides a natural focus for this restructuring and creates an opportunity to better connect and utilize interesting exercises and design experiences throughout the curriculum. The proposed restructuring method consists of four evolutionary steps that allow manageable incremental changes that can be reasonably coordinated with faculty and laboratory development.**

Also presented is some information on where to find mechatronics-related resources on the Internet. The resources include listings of various definitions and interpretations of the term "mechatronics," links to mechatronics courses and programs in the United States and around the world, links to and information on mechatronics books, references, conferences, and journals, and links to vendors of and instructional material for mechatronics-related products. This information is a valuable resource for mechatronics educators and students.

I. INTRODUCTION

Although an emphasis on mechatronics should not change the fundamental content of a mechanical engineering curriculum, it does provide the opportunity to contemporize some subject matter, enhance content, and improve sequencing of modeling and analysis, computing, electrical circuits and machines, measurements and instrumentation, microprocessors, and design. Furthermore, a central curricular theme of mechatronics provides a better focus to connect the intellectual growth that occurs in undergraduates as they proceed through the four years of an ABET-accredited program. Disjoint, compartmentalized curricular structures that separate curricular topics into unconnected pedagogical packages make it difficult for some students to comprehend and embrace the concept of mechanical engineering system design. Today's students want to see how the foundation studies are germane to the practice of design engineering, and mechatronics provides an excellent focus to inspire and motivate students. A mechatronics theme can help make the mechanical engineering curriculum more stimulating, meaningful, fun, and attractive, and can better prepare students to pursue careers that are characterized by a high degree of innovation and leadership.

It is difficult to dramatically redesign a traditional mechanical engineering curriculum with a mechatronics theme in one revolutionary step. The difficulty is due to the time required to gain consensus among the faculty and administrators, the need to train and/or hire faculty, and the need to develop laboratories that are necessary to assure that teaching and learning meet the new goals of the proposed structure. Ideally, a mechatronics curriculum would be a joint effort between departments of mechanical engineering, electrical engineering, computer engineering, and possibly computer science since mechatronics encompasses all of these disciplines. However, this level of cooperation and integration is often difficult or even impossible at many institutions. What we present here is what we believe is a more manageable approach to enhancing a mechatronics-based mechanical engineering program.

II. CURRICULUM EVOLUTION

As illustrated in the figures below, we present a model for a stepwise change in a mechanical engineering curriculum expanding around the theme of mechatronics. We propose, as one approach, a four-stage evolution that will recast some courses, establish better links between courses, and define new courses. This approach was first described in reference 1 and is presented here in an improved and expanded form.

Fig. 1 shows the typical courses in a mechanical engineering curriculum germane to the field of mechatronics. The course titles come from a past Colorado State University curriculum, but most universities have similar courses. At many institutions, "Intro to Circuits" is taught in an electrical engineering department and "Computer Programming" (e.g., C or FORTRAN) is taught in a computer science department. In our curriculum, "Control Theory" is an elective; however, we strongly encourage students with even a remote interest in mechatronics to take the course. Because control theory is not a required course in our curriculum and will probably remain so, we do not incorporate it into the mechatronics theme as strongly as others might (e.g., see reference 2).

In Fig. 1 and the figures that follow, arrows indicate sequencing of prerequisites and rectangular boxes indicate courses with common subject matter and close linkages. In subsequent figures, a shaded course block indicates that the course is the focus of change or restructuring in the current evolutionary step. In Fig. 1, "Intro to Design" and "Capstone Design" are surrounded by a box since these courses typically already have good linkage since the first is usually in place to support the second.

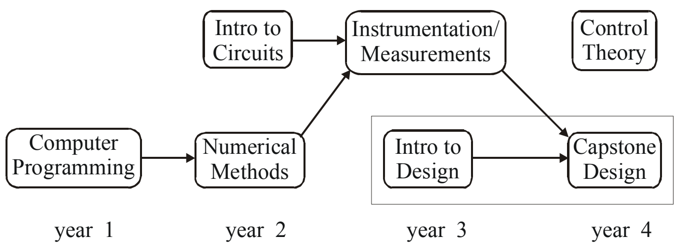

Fig. 1 Typical mechatronics theme foundation courses.

Fig. 2 illustrates the first step in the evolution to create an introductory mechatronics course that emphasizes system response, measurement fundamentals, digital and analog electronics, sensors, actuators, and an overview of basic mechatronic system control architectures (e.g., microcontrollers, single board computers, and PLCs). We have previously described early versions of this course at Colorado State University [3, 4]. This course could serve as a replacement for a traditional measurements, instrumentation, and/or modeling course, or it could be a new course. In either case, faculty development in modern electronics and applications may be required to ensure the course's success. Another option may be team teaching the course with colleagues from an electrical engineering department.

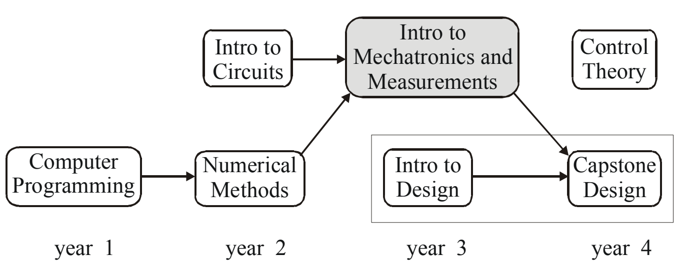

Fig. 2 First step in curriculum evolution.

Fig. 3 illustrates the second step of the evolution to transform a traditional "Intro to Circuits" course to provide a better foundation for the mechatronics course. The transformed course ("Electrical Circuits and Electronics") can include Kirchoff's Laws, ac and dc circuits and sources, computer-aided circuit design and analysis, basic electrical measurements, simple op amp circuits, basic digital circuits, dc motors, optoelectronics, and electrical safety. If possible, the subject matter should be coupled with some laboratory experiences that require building circuits and using the oscilloscope, digital multimeter, and power supplies. Throughout the evolution of the mechatronics theme courses, effort must be devoted to creating laboratory exercises and design projects that are stimulating, somewhat open-ended, and appropriate to previous experience and future context. Although typical "Intro to Circuits" courses are taught by electrical engineering faculty, we recommend that the proposed "Electrical Circuits and Electronics" course be taught within mechanical engineering or team taught with electrical engineering faculty to help provide students better context. We have recently published a textbook [5, 6] that has helped us develop the first and second steps of the evolutionary process.

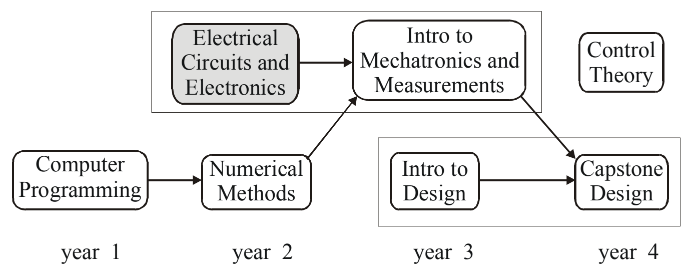

Fig. 3 Second step in curriculum evolution.

Fig. 4 illustrates the third step in the evolution to transform a traditional "Computer Programming" and "Numerical Methods" sequence to better dovetail into the mechatronics theme. This is done by infusing topics related to system modeling and analysis and by introducing the basics of microcomputer control. The "Intro to Computing" course would cover less traditional programming (especially advanced techniques such as sorting and data structures) and cover more the use of application-based analysis tools such as spreadsheets, MathCAD, and MATLAB. This first course could then also include some of the material (e.g., vectors, matrices, root finding, numerical integration) from the original "Numerical Methods" course. This transformation is described elsewhere [7]. The "Applications of Computers" course could then utilize the analysis tools learned in the first course to continue coverage and application of numerical methods. There would also now be time to provide foundations for the mechatronics course: digital representations and number systems, and microcomputer architecture and programming basics. Interesting exercises and design problems involving programming and basic feedback control can also be infused into this second course to help engage and excite the students.

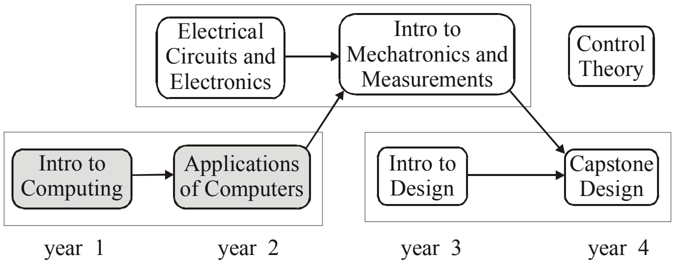

Fig. 4 Third step in curriculum evolution.

Fig. 5 illustrates the fourth and final step in the evolution of the curriculum. The main change here is to include the introductory design methodology course ("Intro to Design") as a prerequisite to the mechatronics course. The design methodology and project management skills taught in the design course, in addition to preparing students for their capstone experience, can also be used to help ensure the success of project activity in the mechatronics course. With this prerequisite, students will be better prepared to focus on the formal design process, planning and scheduling, optimization, computer aided design and other elements necessary to facilitate their design experiences in the mechatronics and the capstone design courses. Another change is to include "Control Theory" as a prerequisite for students wishing to participate in capstone projects involving mechatronic systems with feedback control as a major challenge.

The large box in Fig. 5, by including "Capstone Design," implies that the mechatronics theme and improved integration also enables more sophisticated mechatronics capstone design projects. Another mechanism that can help improve the cohesiveness implied by the large box is to use projects and case studies that continue from one course to the next. Using and building upon the same projects and case studies throughout the theme courses helps improve subject connectivity and continuity and helps provide the students with a "real-world" context.

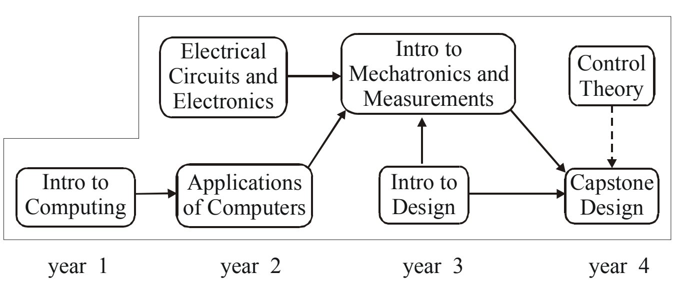

Fig. 5 Fourth step in curriculum evolution.

Throughout the stepwise evolution, we propose replacing or dramatically changing some traditional courses in electrical circuits, computing, instrumentation and measurements, and design methodology to better integrate them around a mechatronics theme. A result is improved course efficiency created by presenting the various topics in a more integrated way with more unified context, which can also result in enhanced student motivation and learning.

III. Internet Resources

As with most topics today, the Internet offers lots of information on mechatronics that can be of assistance to both educators and students. We have created three sites that provide easy access to many of the information and resources available. We briefly describe each here so you will know what is available.

The first site [10] includes a listing of various definitions and interpretations of the term "mechatronics," along with links to their sources. The definition that we use is: "Mechatronics is the interdisciplinary field of engineering dealing with the design of products whose function relies on the integration of mechanical and electronic components coordinated by a control architecture." The second site [11] includes links to mechatronics courses and programs in the United States and around the world. The third site [12], which is the most useful, provides links to vendors and information on: actuators and accessories, books and references, conferences and proceedings, digital signal processors, electronics, IC manufacturers, instrumentation and data acquisition, journals, mechanical and industrial components, motor/motion controllers, microcontrollers, programmable logic controllers, sensors, single board computers and minicontrollers, and small parts. This site also has links to other mechatronics-related sites and to sites useful in finding other product information.

IV. Conclusions

We presented a stepwise method to enhance a mechanical engineering curriculum that responds to current issues in mechatronics, providing students with a major educational theme that will keep them invested in and excited about their learning. The proposed changes result in a curriculum with enhanced content and improved sequencing of foundation mechatronics topics. The goal is not to create a novel "Mechatronics Program;" but rather, to give our mechanical engineering program better focus. Different universities may elect to skip or combine some or all of the incremental changes; however, we did not believe this was manageable for our program. The changes we propose may be integrated in whole or in part by departments based on their strengths and resources. At Colorado State University, we have completed most of steps 1-3 and are currently planning for step 4.

The reasons why we think a mechatronics theme is important in a mechanical engineering curriculum include the following:

- Mechatronics is an important discipline that provides many job opportunities.

- The mechatronics theme allows a better coupling and integration of normally compartmentalized topics.
- Capstone senior design projects have the potential to be more sophisticated.

For descriptions of other programs that have substantial mechatronics components in their curricula, see references 8, 9, and 11. Also, for useful mechatronics-related resources on the Internet, see references 10, 11, and 12.

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