Incorporating Robotic Simulation Technology into the Undergraduate Curriculum of Robotics and Industrial Automation

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Abstract

Simulation technology has not only fundamentally changed the way of conducting integrated product design and process development in industries, but also provided educators with new approaches to enhance the learning environment for the best engineering education in schools. This paper describes the authors' initial experience of incorporating robotic workcell simulation technology into the undergraduate coursework of robotics and automation. This includes the discussions about the significant impacts of robotic simulation technology on the processes of learning and conducting robotic workcell design in both industries and schools. The practice has shown that robotic simulation software is an excellent tool for people to study and develop methods of fast product design, manufacturing process planning, and plant floor/cell control support.

I. Introduction

Rapid deployment has been proven by many companies to be successful solutions for meeting the immense demand of product changes. This procedure integrates concepts, tools, and methods of fast product design, manufacturing process planning, and plant floor/cell control support [1]. Among the important technologies for implementing this solution is simulation [2]. Companies such as General Motors, Ford, and Chrysler have used simulation technology to lower the costs and shorten the product development life cycle. Their practice demonstrates that current simulation packages are capable of providing an interactive and accurate virtual environment with which designers can model and evaluate designed products and processes for low cost and reliable solutions, and without delaying production time and risking equipment damage [2,3,4,5].

Currently, in automotive industries the high demand for implementing rapid deployment technology through simulation has already created a growing shortage of qualified employees who can carry out virtual engineering design. At the same time, the educators from Michigan's high schools, colleges and universities have also recognized the changes, challenges, and demands faced by today's automotive industries. They believe that learning rapid deployment technology is important to Michigan's students as they are preparing for their careers in high-tech industry [6].

Incorporating concepts, tools, and methods of rapid deployment technology such as simulation into current curricula and programs of engineering technology requires the academic study of the changes, challenges and demands faced by today's industries. Along with the efforts of curriculum development, state-of-the-art hardware and software components must be available to enhance the capability of existing teaching and laboratory facilities. Often undergraduate students in engineering technology programs graduate and leave for industries without enough knowledge and experience about rapid deployment technologies due to limited laboratory facilities and inadequate financial resources. Partly addressing these issues, this paper describes the authors' initial experience of incorporating the state-of-the-art robotic simulation technology into the undergraduate curriculum of robotics and automation in the Department of Industrial and Engineering Technology (IET) at Central Michigan University (CMU). The purpose of this project is to enhance the existing learning environment for IET undergraduate students to learn rapid deployment technology for integrated engineering design and automation solutions.

In section 2, the existing curriculum of robotics and automation at CMU is reviewed. Strength and weakness of the curriculum are analyzed. Section 3 provides an overview of Deneb's IGRIP robotic simulation software. Section 4 discusses the impacts of robotic simulation technology on robotic workcell design in industry. Section 5 discusses the impacts of the robotic simulation technology on the education of robotics and automation in school. Section 6 presents the conclusion.

II. IET Robotics/Automation Courses and Laboratory

The coursework of robotics and automation at CMU has been primarily developed for two purposes: (1) meeting growing demands of automation in automotive industries; and (2) enhancing the mechanical, electronics, and manufacturing engineering technology programs at IET department.

The course IET 375, " *Robotics*, " has been designed as a study of fundamentals of robotics such as a robot's classification, programming, and control. The educational robots (i.e. Scorbot ER III) in the IET robotics/automation laboratory have been used to aid the study. Comparing to industrial robots, educational robots provide students with a safer learning environment with which students are able to work closely with the robots performing observations, measures, and programming. However, early models of educational robot like Scorbot RE III have very limited capabilities in programming and motion control.

The course IET 576, " *Industrial Automation*," has been designed as a continuity of course IET 375, supplying students with the hands-on experience of applying industrial robots for automated manufacturing. Currently, the course has integrated studies of industrial robots, programmable logic control (PLCs), and robotic workcell design with the aid of an integrated robotic workcell at IET Robotics/Automation laboratory. For example, five industrial GMF robots and associated peripheral devices such as conveyors, grippers, fixtures and pallets in the workcell allow students to develop simple industrial robot applications. Six packages of RXLogic 5 provide students with the capability of programming Allen Bradley PLC 5 controller for cell control support. The final project in course IET 576 requires students to integrate all hardware and software components for designing integrated robotic workcell.

There have been three observations obtained through teaching these two robotics courses. First, the learning process of robotics can be greatly enhanced if students are able to visualize the concepts with real robots. For example, it might be not very difficult for students to understand robot anatomy if they could see step-by-step how different robot arms are structurally configured and assembled with different joint types. However, in reality it is often the case where most concepts of robotics are illustrated in classroom without the aid of real industrial robots. Even if an industrial robot has been used in the laboratory, it is still very difficult for an instructor to discuss basic and advanced robotic concepts with students due to operational constraints and safety concerns. Second, the learning experience can be greatly improved as students are able to see the overlook factors in their robotic experiments. For example, seeing an unexpected physical collision between a robot gripper and a fixture gives them the idea of how to develop a feasible robot path to avoid it. However, unlike other laboratory experiments, making mistakes in setting up or programming an industrial robot under workcell environment is usually not practical because they often result in severe damages to the robots and peripheral equipment. The fear and frustration caused by such mistakes often block students to conducting robotic experiments. Finally, students enrolled in course IET 576 are primarily senior students in mechanical, electronics, and manufacturing engineering technology programs preparing for careers in automotive industries. Although they have developed some specific technical backgrounds and skills in computer-aided design (CAD), electrical circuit analysis, and manufacturing process planning prior to taking course IET 576, they still need to practice how to integrate them into the development of engineering products and processes.

Based upon these observations, it is clear to the authors that the significant missing element in the current coursework of robotics and automation at IET is the state-of-the-art simulation tool that can provide students with a realistic, interactive, and safe learning environment. The authors believe that under this enhanced learning environment, rapid deployment technology can be successfully incorporated into the existing curriculum of robotics and automation at IET

III. Deneb's Robotic Simulation Technology

Deneb's IGRIP (Interactive Graphics Robot Instruction Program) is a user-friendly computer graphics based package for robotic workcell layout design, simulation and off-line programming. The IGRIP User Graphical Interface (GUI) as shown in Figure 1 provides different menu options, each of which defines specific IGRIP functions. Selections of available functions on GUI constitute methods of creating and manipulating workcell simulation models.

Creating a workcell simulation model starts with retrieving a group of IGRIP *Device* models (e.g., robots, conveyors, tables, and end-effetors, etc) from the existing IGRIP libraries and then precisely positioning them in IGRIP workcell layout. Some device models in the workcell store not only geometric information, but also non-geometric information includes kinematics, dynamics, velocity, etc. Besides the availability of most industrial robot models in IGRIP robot library, IGRIP also provides users with two capabilities of creating and adding customized

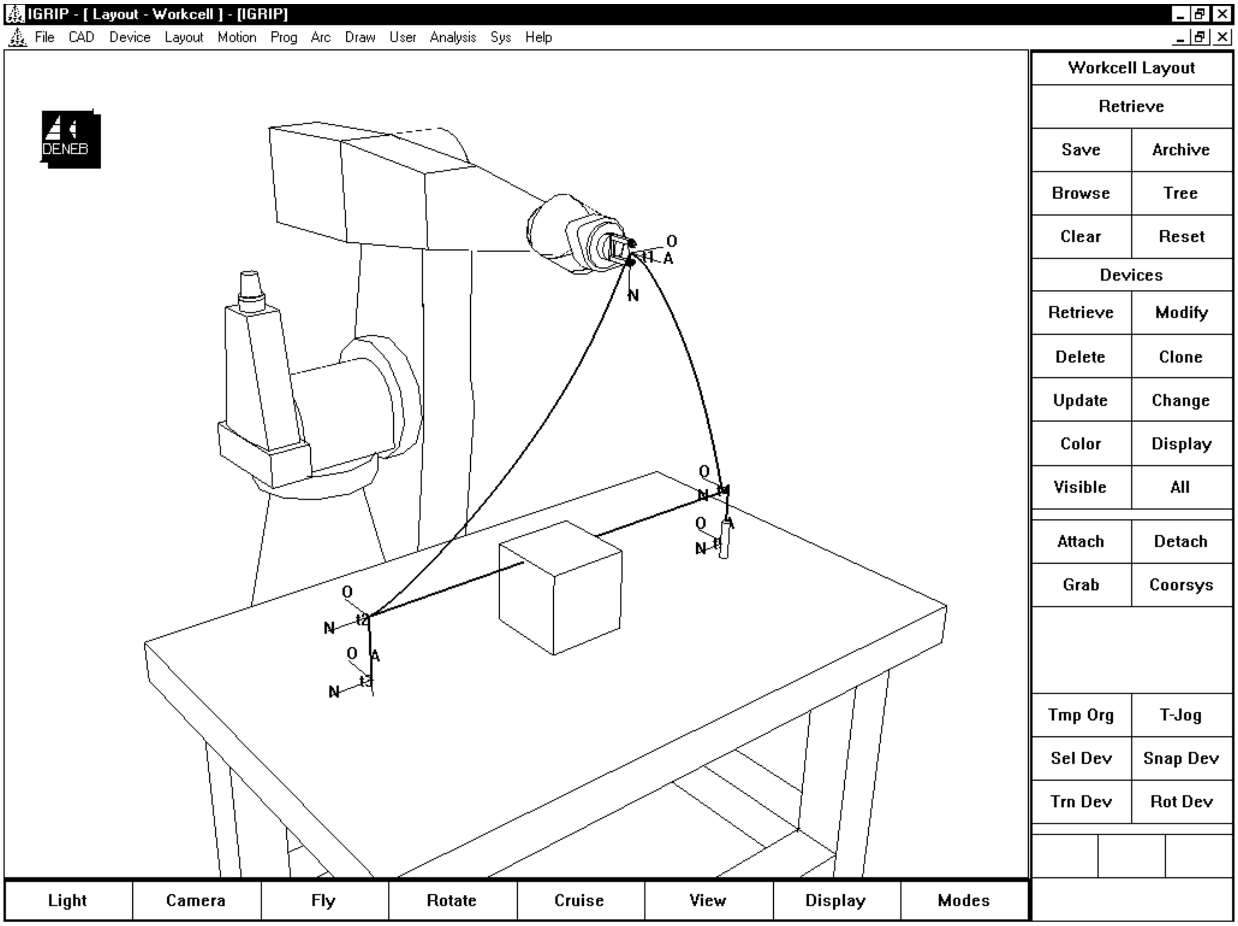

Figure 1 IGRIP User Graphical Interface (UGI)

device models to a new or an existing library. One way is to first model the IGRIP *Parts* using its built-in CAD system and then assemble them into a device model. The other way is to directly import part data generated on other CAD systems into its CAD system via the built-in input data translators such as IGES, VDA, DXF or others (e.g. SDRC, Pro/ENGINEERING, etc).

Once a workcell simulation model has been created, the positions required for programming a robot's path can be specified and modeled as IGRIP *Tag Points*. A Tag Point is a three-dimensional point in space with orientation and other information (e.g. robot configuration) attached to it. Creating a tag point requires creating a *Path* first. Every path must be attached to a device or a part in the workcell. There are different tag-point creation methods available in IGRIP. For example, tag points can be generated individually, and then snapped to a surface or vertex on the device, or translated to a final position with geometric measurement. Or multiple tag points can be generated automatically on specified surfaces, edges, and curves in the workcell model. With the availability of tag points in workcell model, it is possible to jog any device model that has defined inverse kinematics to a tag point.

Users must use IGRIP Graphical Simulation Language (GSL), a structured and Pascal-like procedural language, to program the actions and behavior of individual device model in the workcell. During a GSL program development, users are able to observe immediate program statement executions. The required input/output (I/O) signal interface between devices can also be specified and used in the program simulating interlocks of devices' actions in the workcell. Running workcell simulation model requires loading GSL programs to the devices that have inverse kinematics. During simulation individual GSL program can be viewed and debugged. There are many other IGRIP features available for users to conduct design analysis during a simulation run. For example, if the 'collision check' function is selected, simulation can be halt on a detected collision. Then user may use the world display function to perform detailed analysis to the collision.

IGRIP simulation package also supports translating simulation programs into robot-native languages for downloading to actual robot controllers. This procedure, referred to as IGRIP off-line programming, may also include a phase of simulation verification relative to the physical workcell.

IV. Robotic Workcell Design Using Simulation

Many of the largest users of robotic production equipment, predominantly in the automotive sector, are well aware of the benefits that effective simulation technology can offer to their robotic systems. First, designing a robotic workcell using simulation system eliminates the guesswork from a concept. For example, directly importing CAD design data of parts and devices to robotic simulation system allows designers to simulate the accurate operational behavior of robots and their placement in the workcell without assumptions. By the time when a design has been completed, robots in the workcell are able to reach all desired positions and perform specified operations at each position. Designers can also offer optimum solutions to their designs via having evaluated alternatives. 'Right first time' is a reality without having to have physical models of products, robots and peripheral devices. Furthermore, as modifications are made to parts, the process of incorporating modifications into the simulation model of a workcell is mush easier and faster comparing to making changes to a real workcell.

Second, robotic simulation software takes the process of robot programming away from teaching a real robot on-line via teach pendant. For example, teaching required positions on-line for a spot welding application usually takes an operator many hours to complete. This includes chalking spot weld positions on the physical parts and jogging the robot to each specified position via teach pendant and visual observation for recording. However, in robot simulation all required welding points can be easily and accurately generated on corresponding models of the workpiece at one time via multiple tag points.

Finally, robotic simulation software brings the designers a safe working environment. Whether designing a new workcell, optimizing its performance, or making modifications to an operational workcell, developing and testing required programs can be safely carried out. Indeed, collisions can be tested within the virtual environment at no cost to equipment and programmers, in contrast to the potential disasters if the same tests occurred in the real workcell.

V. Learning Robotics through Simulation

With a growing library of virtual industrial robot models in robotic simulation software and ever-faster desktop PCs and workstations, it is not surprising that education and training sectors have begun adopting simulation as a tool to aid the teaching and training of robotics and automation. First, robot simulation software makes it possible for instructor to elaborate robotic concepts via virtual industrial robots and workcells in classroom. These concepts include a robot's configurations, path planing, programming, input and output (I/O) control, etc.

Second, the availability of robotic simulation software in schools allows students to integrate their knowledge and skills into the process of engineering design and automation deployment. For example, students who have developed CAD skills from engineering design courses are able to create CAD models of parts, grippers, fixtures, conveyors, etc. for robotic workcell simulation models used in robotics courses. Students may also apply their knowledge about manufacturing process planning and plant layout for improved robotic workcells where material handing and welding applications can be successfully conducted. Obviously, the experience that students obtained by going through these interdisciplinary design stages greatly improves their understanding about integrated product design and process development.

Finally, incorporating manufacturing simulation technology into the existing engineering technology programs may also bring many other potential benefits to schools and industries. As more and more companies are moving toward integrated product design and process development, CAD and simulation become the key technologies to successfully accomplish this goal. Both industry experts and educators have already observed that the high demand to such new skills could result in the shortage of qualified employees. The resolution to this potential challenge faced by today's industry is through school education and industrial training. For example, with the availability of robotic simulation software and developed curriculum in universities and colleges, early education to manufacturing engineering technology can be offered to high school students through summer camps, workshops, etc. Practice shows that students' early exposure to manufacturing simulation technology can help them understand what manufacturing is and purse careers in manufacturing engineering technology in the future. The universities and colleges that have the availability of manufacturing simulation packages may also directly conduct industrial training for industries to meet their demands in applying manufacturing simulation technology.

VI. Conclusion

As a state-of-the-art tool of rapid deployment technology, robotic simulation has not only fundamentally changed the way of conducting robotic workcell design in industry, but also provided educators with new approaches to enhance the existing learning environment for the best education in robotics and automation. Under such a realistic, flexible, interactive, and safe learning environment, students are able to better understand a robot's anatomy, programming, control, and application. Robotic simulation software also provides faculties and students with the possibilities of conducting collaborative teaching and laboratory activities for integrated engineering design and automation solutions.

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