Digital Factory – A Technology Show Case for Teaching and Research in Digital Manufacturing

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Abstract: With the advancing digital technology and information tools in networking, the core of manufacturing activities has shifted from the physical production of goods to the systematic processing of knowledge. The competitiveness of tomorrow's manufacturing enterprise lies in the operation of such digital factory in parallel with the physical one. This change in manufacturing in the digital age is taking place not only in Hong Kong but worldwide. This paper describes the development of establishing a digital factory laboratory in the Department of Industrial and Systems Engineering of The Hong Kong Polytechnic University. The Digital Factory is a focus for teaching, research and technology transfer in the area of digital manufacturing. The paper also describes an application case of virtual manufacturing in which computer simulation models of a production line of an AC motor are developed for investigation.

Keywords: Digital Factory; Virtual Reality; Simulation Models

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1 Introduction

With the impact of information technology and computer networking, the core of manufacturing activities has shifted from physical production to systematic processing of information [1]. To cater for this change, manufacturers today must be well versed with the computer applications in manufacturing. This couples with the advent of high-resolution graphics, high-speed computing, and user integration devices; virtual manufacturing has emerged as a major new technology in recent years [2].

The impact for the change is particularly prominent for Hong Kong and the region. As Professor WB Lee pointed out in his earmark proposal report for establishing a Digital Factory in The Hong Kong Polytechnic University [3], the rich experience in entrepreneurship and in managing a dispersed manufacturing network in the Pearl River Delta (PRD) among SMEs in Hong Kong is un-parallel in other parts of the world. Despite such success, the rapid development in communication technologies has reduced the competitive advantage of Hong Kong using Guangdong province as a low cost production centre. Future progress depends on the adaptation of the advanced internetworking and digital technology in managing the complex production network in the PRD and worldwide, shortening the product development cycle and serving better the customer needs. Further value added will not come from the physical manufacturing but from exploiting the virtual value chain in the "digital factory" behind in the processing of information and knowledge.

2 Digital Factory Development

Following an overwhelming success of a forum in 1999 on Digital Factory organised by the Department of Industrial and Systems Engineering of The Hong Kong Polytechnic University, the department planned to establish a Digital Factory to train engineering professionals to work efficiently in the changing manufacturing industry. The development of Digital Factory has the support from Microsoft (HK) and five other leading software developers with a donation of over fifty million HK dollar worth software in the CADCAM areas. The objectives of the Digital Factory is to provide a digital and graphic-based simulation environment for students and researchers to work in the virtual manufacturing activities in order to develop, plan, experiment, and optimise product and process designs prior to real production.

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2.1 Facilities of Digital Factory

There are fifty desktop computers installed with latest state-of-the-art software in e-manufacturing. The computers are located in three work cells in the laboratory, namely: Digital Design, Virtual Manufacturing and Collaborative Work cells. A virtual reality (VR) visualization system is installed in the laboratory. It consists of a high-performance projection table (Figure 1) for display of crystal clear images from a high-resolution computer workstation. The outstanding image quality makes the VR system a product of choice for 3D simulation and analysis. To further support the digital design activities, a 3D digital camera together with a free-form printer which produces 3D solid prototypes, makes a good platform for facilitating work in digital product development.

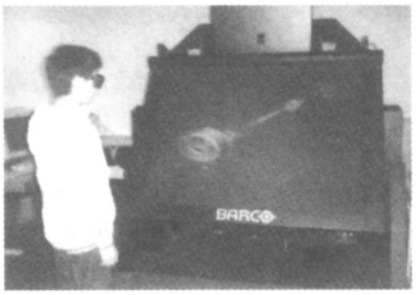


Figure 1 Projection table display unit of the Virtual Reality system

3 Industrial Collaboration

The University encourages collaboration with industry for projects that accomplish problem solving for both industrial and academic needs. The department has been working closely with its industrial partners in various natures of investigation in manufacturing. Digital Factory plays a vital role in this. What follows describes an industrial project in collaboration with an industrial consumer product manufacturer.

3.1 Honeywell Project

The collaborative industrial partner of this project is Honeywell consumer product manufacturing company. They have a subsidiary plant in Shenzhen of China, manufacturing consumer products such as electrical fans, dehumidifiers, moisturisers, heaters, etc. for which AC motors are the main components for power transmission. The objectives of this collaboration project is to build simulation models for the whole manufacturing cycle of the AC motor, which includes the motor design analysis, assembly sequence planning, production planning, operation simulations, workplace designs and suggestion of plant layouts. It is hoped that the generated simulation models can facilitate improvement of the product and process design and thus enhancing the productivity in manufacturing the motor.

3.2 Simulation models

Some developed simulation models are described in the followings. As the work covers a wide scope of manufacturing activities of the motor and for the sake of company secrecy, not all developed models are illustrated and discussed in details. The development of the simulation models were based on the application of an e-manufacturing software called Tecnomatix EMPower [4].

3.2.1 Virtual Assembly

The motor was analysed for its assemblability of parts. Different ways and paths of assembling the parts were explored by fixing points along which assembly paths were defined. Assembly time was outputted at the end of each assembly path analysis. The one with the shortest assembly time highlighted the optimal path. An assembly sequence

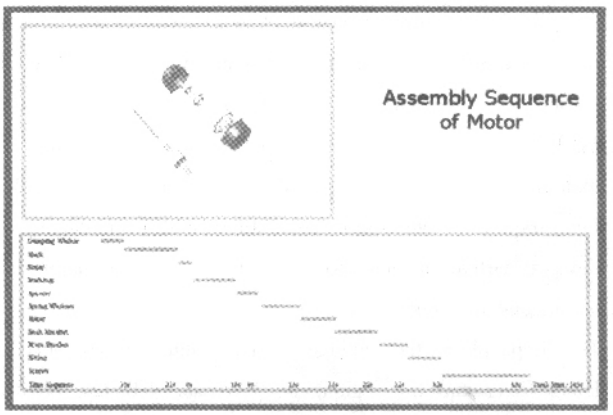
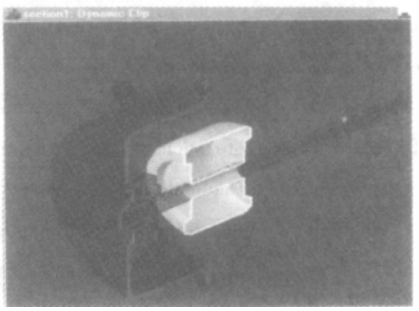


Figure 2 Assembly sequence of the motor parts



Tigure 3 Shaft turns red to highlight collision occurred as it is inserted into the rotor for assembly

plan of the optimal path can be automatically generated at the end of evaluation. The assembly sequence plan for the motor assembly is shown as a Grantt chart format in Figure 2.

As parts are analysed for assemblability, they are also checked for detection of any collisions occurred during the assembly processes. This helps to design the parts sizes for assembly as well as to validate the workability of the assembly paths. Figure 3 shows collision occurs when the oversized shaft is inserted into the rotor hole.

3.2.2 Workplace Design

With the additional application of a Human module of the e-manufacturing software, manual operations can be simulated. The design of the workplace was developed initially either by extracting models of equipment and facilities from the system library or by creating from user definitions. The models of the machines, equipment and human operators were then inserted and positioned on a layout that virtually emulates the real environment. Kinematics and relative motion features among the models are defined. The simulation models of the workplace were then set in animation, which imitate the operations in motion. A simulation model of the workplace design for assembling parts of the motor is shown in Figure 4. Further studies of the operations of the workplace can lead to investigations into ergonomics of human motion, Method Time Measurement (MTM) and cost and time analysis.

3.2.3 Plant Layout Simulation

The layout of the plant for producing the motor was modelled. Execution of the simulation of the plant layout model

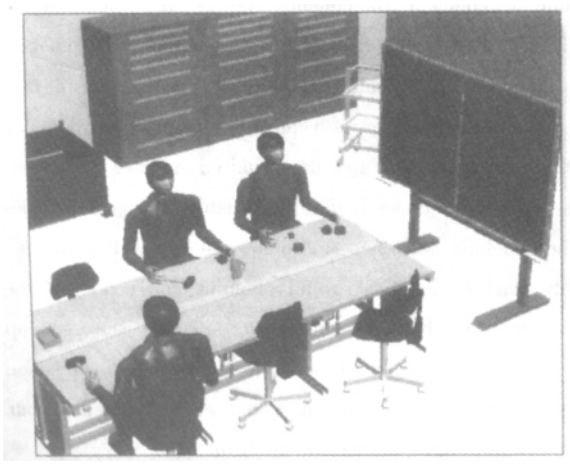


Figure 4 Workplace simulation of assembly of motor

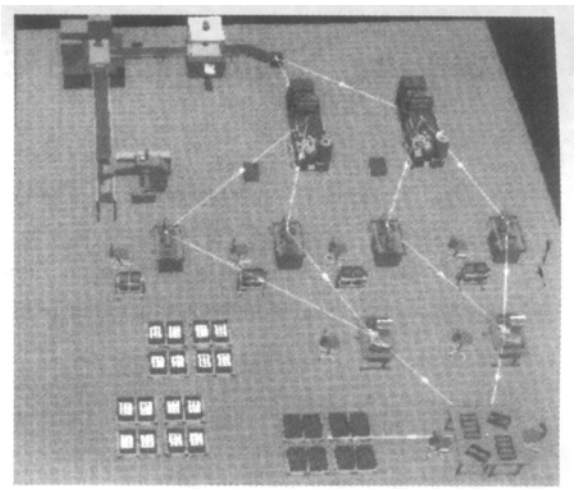


Figure 5 The Throughput and Bottleneck Analysis

highlights its productivity efficiency. The simulation outputs on machine utilisation, throughput time and production rate help to identify the locations of bottlenecks. The plant can then be rearranged and re-analysed with layouts of different positioning of facilities, addition or subtraction of equipment and/or operators. With these iterative evaluations, an optimised layout will be generated. An example of a plant layout for the rotor production section is illustrated in Figure 5.

4 Results and Conclusion

The simulation models were built and were given to the company for comments. It is envisaged that alterations will be made to the models in order to improve the productivity of the designs concerned. An e-manufacture software was used to construct the simulation models. Another module of the software has been recently acquired by the department. It is hoped that with the aid of this software module, the analytical capability of simulation can further be empowered in achieving an optimised design that serves the production requirements.

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