CHAPTER 12: APPLICATIONS OF VIRTUAL REALITY IN CIM

12.1. What is Virtual Reality?

The current demand to reduce the time and cost involved in taking a product from conceptualisation to production has forced companies to turn to new and emerging technologies in the area of manufacturing. One such technology is virtual reality (VR). The origins of virtual reality can be traced as far back at least as “the ultimate display”. Virtual reality allows a user to step through the computer screen into a three-dimensional (3D) world. The user can look at, move around, and interact with these worlds as if they were real. The primary concept behind VR is that of illusion. VR is where a Virtual World - a three dimensional environments or scenario created on a computer - can be freely explored, experienced and examined in real time.

12.1.1 Virtual Manufacturing

With the advance of computer technology, VR systems could contribute efficiently in various applications. Virtual manufacturing (VM) is one of the applications of applying VR technology in manufacturing applications. Virtual manufacturing is defined as a computer system which is capable of generating information about the structure, status, and behaviour of a manufacturing system as can be observed in a real manufacturing environment. The vision of virtual manufacturing is to provide a capability to “manufacture in the computer”. That means VM will provide a modeling and simulation environment so powerful that the fabrication/assembly of any product, including the associated manufacturing processes, can be simulated in the computer.

There are currently, vast amount of VR software packages available on the market, which can be used to develop virtual environments for different applications (e.g. Superscape VRT and SENSE8). Moreover, software packages have been developed for virtual applications in manufacturing (e.g. DELMIA). DELMIA package (See Figure 12.1) provides authoring applications that can be used to develop and create virtual manufacturing environment to address process planning, cost estimation, factory layout, ergonomics, robotics, machining, inspection, factory simulation, and production management.

12.2. Virtual reality applications in manufacturing

Manufacturing industries are the most important contributors to prosperity in the industrialised countries. However, it is becoming increasingly difficult to meet customers’ demands and to compete. The advances in virtual reality technology in the last decade have provided the impetus for applying VR to different engineering applications such as product design, modelling, shop floor controls, process simulation, manufacturing planning, training, testing and verification. VR holds great potential in manufacturing applications to solve problems before being employed in practical manufacturing thereby preventing costly mistakes.

Virtual reality applications in manufacturing have been classified into three groups; operations management, manufacturing processes, and design. A brief description of every group and its relevant subgroups will be provided in the coming sections.
12.2.1. Design

Virtual reality may play a very significant role in design a new product. VR technology has been applied into two different applications in design; design and prototyping. VR provides a virtual environment for the designers in the conceptual design stage of designing a new product; the designer could produce a 3D “sketch” of a product in the virtual environment. At this stage, functional experimentation of mechanical features such as hinges, assembly, etc. could be performed to evaluate the conceptual design and modifications could be made as required. Once the designers are satisfied with their design, then the design could be detailed to make the necessary modifications. In the product development process, prototyping is an essential step. Prototypes represent important features of a product, which are to be investigated, evaluated, and improved. Virtual prototyping could be used before building the physical prototype to prove design alternatives, to do engineering analysis, manufacturing planning, support management decisions, and to get feedback on a new product from prospective customers. The virtual environment for prototyping should include.

(a) Functionality: the virtual prototype should be clearly defined and realistically simulated to address product functionality and dynamic behavior.

(b) Human interaction: the human functions involved must be realistically simulated, or the human must be included in the simulation.

(c) Environment: an offline computer simulation of the functions can be carried out, or a combination of computer offline and real-time simulation can be carried out.

12.2.2. Operations management

Operations management has been classified into three categories; planning, simulation and training. The benefits of applying VR technology to these categories...
Due to the necessity of a smarter factory planning; Virtual reality is a useful method to improve the understanding of the plans and to support interdisciplinary discussions. Virtual reality-based training is the world’s most advanced method of teaching manufacturing skills and processes to employees. Using cutting-edge VR technology, training takes place in a realistic, simulated version of the actual facility, complete with the actions, sights, and sounds of the plant floor.

12.2.3. Manufacturing processes
Manufacturing processes has been classified into three different areas; machining, assembly, and inspection.

12.2.3.1. Machining

Virtual machining mainly deals with cutting processes such as turning, milling, drilling, and grinding, etc. The VM technology is used to study the factors affecting the quality, machining time of the material removal process as well as the relative motion between the tool and the workpiece. Fig. 12.2 shows an engineer uses a Virtual reality “semi-immersive environment” to simulate the use of a hexapod machine tool.

University of Bath in Bath has developed an interactive virtual shop floor containing a three axis numerical control milling machine and a five axis robot for painting. The user can mount a workpiece on the milling machine, choose a tool and perform direct machining operations, such as axial movements or predefined sequences.

![Figure 12.2: Virtual Machine Tool](image)
12.2.3.2. Assembly

Virtual assembly is a key component of virtual manufacturing and is defined as: “the use of computer tools to make or “assist with” assembly-related engineering decisions through analysis, predictive models, visualisation, and presentation of data without realization of the product or support processes’. In assembly work [18], VM is mainly used to investigate the assembly processes, the mechanical and physical characteristics of the equipment and tooling, the interrelation among different parts and factors affecting the quality based on modeling and simulation. Virtual reality can be used for assembly/disassembly operations. For example, can a human worker assemble a part or a component? And then can the part be disassembled for service and maintenance at latter stages? Other questions need to be addressed, too: is it “difficult” or “easy” to assemble/disassemble a part? How long does it take? How stressful is it in terms of ergonomics? Is there enough room for tools? Figure 12.3 shows a screenshot taken from VR simulations of DELMIA HUMAN Package used in ergonomics analysis in assembly of car body parts.

![Figure 12.3 DELMIA HUMAN Simulations of Work Ergonomics in Assembly](image)

12.2.3.3. Inspection

Virtual inspection makes use of the VM technology to model and simulate the inspection process, and the physical and mechanical properties of the inspection equipment. This aims at studying the inspection methodologies, collision detection, inspection plan, factors affecting the accuracy of the inspection process, etc.
12.3 Example Applications of VR in CIM Systems

12.3.1 DELMIA Packages

DELMIA offers a suite of digital 3D Manufacturing Solutions available in today's marketplace and provides Process Centric technologies that deliver end-to-end solutions dedicated to critical customer manufacturing processes. It covers Powertrain, Final Assembly and Body-in-White in the automotive industry, Airframe Assembly in aerospace and general assembly processes across manufacturing industry segments. DELMIA’s Digital Manufacturing Solutions are built on an open Product, Process and Resource model (PPR) which enables the continuous creation and validation of the manufacturing processes in the context of the product throughout the design phases. The PPR is the foundation to support efficiently the effects of changes through 3D Collaboration. Anyone involved in the manufacturing design has full access to the current Product (“What to produce”), Processes and Resources (“How to produce”) at any point in time. The Seamless integration of our entire portfolio on the PPR hub covers all the facets of the manufacturing engineering process, which allows the capture of manufacturing Knowledge and the reuse of best industrial practices.

PPR Hub: The Product-Process-Resource data collaboration system, called the PPR Hub, is a unique data model for the digital factory that provides storage and management of all product, process, and resource information required for production system design - from product concept through manufacturing implementation (See Fig.4). The DELMIA PPR Hub includes the following DELMIA Packages;

Process Planning
- DELMIA Process Engineer

Process Detailing and Validation
- DELMIA Industrial Engineer
- DELMIA DPM Assembly
- DELMIA DPM SHOP
- DELMIA DPM Body in White
- DELMIA Powertrain
- DELMIA Envision Assembly

Resource Modeling and Simulation
- DELMIA Human
- DELMIA IGRIP & DELMIA ULTRA
- DELMIA Cell Control
- DELMIA Robotics
- DELMIA Virtual NC
- DELMIA Inspect
- DELMIA QUEST

Some of the selected DELMIA Packages are explained below.
12.3.1.1 DELMIA Process Engineer

DELMIA Process Engineer is a tool for process and resource planning, providing a high quality solution for early recognition of process risks, re-use of proven processes, traceable changes and decisions, and access to scattered process knowledge. This comprehensive treatment of the relationships between product, process and manufacturing resource data, including plant layout, helps to avoid planning mistakes and obtain a precise overview, early in the process, of the required investment costs, production space and manpower (See Fig. 12.5).

The main functions of DELMIA Process Engineer are:

- Providing a structured methodology that systematically leads to an optimal solution by considering all process-related costs and analyzing alternatives early in the planning stage
- Presenting a clear view of the overall system performance versus target values during all planning phases
- Reducing risks by the re-use of proven processes
- Supporting multiple users, shortening planning time
- Organizing each project based on the unique structure of the product, processes, resources and plant involved with easily configured project structure
- Customizing the user interface and reporting formats to meet individual user requirements
- Promoting an identical planning environment for all projects
- Providing built-in documentation of the planning history
- Reflecting any data change immediately for all users
- Allowing native integration with other CAD and PDM systems

Figure 12.4: DELMIA PRR Hub
12.3.1.2 DELMIA Industrial Engineer

DELMIA Industrial Engineer is a package that allows users to efficiently and reliably determine the time required to perform a specific job sequence based on commonly used time measurement methods or company-proprietary time standards.

The main functions of DELMIA Industrial Engineer are;

- Quick and efficient generation of time analysis with all common analysis procedures (MTM and WF)
- Capturing and management of estimated and recorded time values
- Creation of user-defined data cards
- Creation of user-defined formulas for determining process times
- Design of user-defined print forms
- Checking of rules for accuracy and totality (MTM-1, UAS, MEK, MTM standard data, WF)
- High productivity through the creation and usage of time macros (library elements) and of analysis templates
- Data compression capability over any number of data levels
- Structured data management into work processes/work stations
- Flexible search mechanisms using key words and search patterns
- Time analysis directly associated with workstation layout
- Automatic updating of time values
- Extensive user configuration options
12.3.1.3 DELMIA DPM Assembly

DELMIA DPM Assembly is an assembly process planning and verification solution for developing manufacturing and maintenance processes (See Fig. 12.6).

The DELMIA DPM Assembly provides:

> Easy cataloging of best practices and manufacturing resources for future reference
> Development of the sequence of operations, assignment of resources, determination of throughput and cost estimation
> Automatic display of all design changes in the process validation
> Evaluation and feedback of assembly feasibility
> Detection of collisions
> Detailed internal part inspection

12.3.1.4 DELMIA HUMAN

DELMIA Human provides such organizations with a suite of human simulation and Human Factors (HF) tools specifically geared towards understanding, and optimizing, the relationship between humans and the products they manufacture, install, operate and maintain.

Virtually every major automotive, aerospace and heavy engineering manufacturer can benefit from some form of human modeling solutions to support product design and development. Visionary leaders in these companies were the first to seek advanced technology solutions to
better understand the capabilities, as well as limitations, of the people who manufacture, install, operate, maintain and even decommission their products (See Figure 12.7).

This technical toolset for quantifying human-factors studies offers widely recognized benefits found in many areas:

- Leveraging an enterprise’s capabilities to generate intellectual property through international research (proprietary or generic) and in-house knowledge accumulation
- Ensuring that the appropriate level of ergonomics functionality is readily available to designers
- Creating a common human modeling file-format for disseminating human-factors knowledge throughout the enterprise, not just within the engineering and manufacturing units
- Saving time in dealing with human factors and ergonomics, by introducing human factors earlier into the product life cycle.

**Figure 12.7 DELMIA HUMAN Snapshots**

### 12.3.1.5 DELMIA IGRIP

DELMIA IGRIP is a physics-based, scalable robotic simulation solution for modeling and off-line programming of complex multi-device robotic workcells. The system incorporates real world robotic and peripheral equipment, motion attributes, kinematics, dynamics and I/O logic, for producing accurate simulations and programs.

DELMIA IGRIP allows users to:

- Graphically construct workcells for applications such as welding, painting, dispensing, and material removal
- Optimize robot locations, motions and cycle times
- Eliminate costly collisions between robots, parts, tools, fixtures and surroundings
- Reduce implementation costs and robot programming time
12.3.1.5 DELMIA QUEST

DELMIA QUEST is a complete 3D digital factory environment for process flow simulation and analysis. It provides a collaborative environment for industrial and manufacturing engineers and management to virtually develop and prove out manufacturing flow practices.

- Allows experimentation with facility layout, resource allocation, Kaizen practices and alternate scheduling scenarios
- Improves designs, reduces risk and cost and maximizes efficiency, thereby ensuring accuracy and profitability
- Facilitates presentation of results to customers, managers and those in other engineering disciplines
- Provides a single model that can be integrated with existing design tools for use from conceptualization to implementation, including documentation, analysis and communication of results

12.9 DELMIA QUEST Factory Simulation
12.3.2 VCIMLAB – Virtual Reality Based CIM Laboratory Training System

EMU – VCIMLAB Virtual CIM Laboratory is a first version of the complete educational software package, which has been designed and developed to perform education on the principles of automated production using industrial simulations on a virtual environment. The overall system has been developed by EMU – Virtual Laboratory Research group, which is capable of modeling any existing real laboratory system on a virtual environment for education and training purposes. For the development of the software VCIMLAB, a real CIM laboratory that is located at the Industrial Engineering Department of EMU, has been modeled using VR technologies. The reference real model of the VCIMLAB includes industrial robots and several CIM equipment, provided by Intelitek ®. The real and Virtual models of the EMU CIM Laboratory has been shown in Fig.12.2 a-b.

![Real CIM Lab](image1.png) ![Virtual CIM LAB](image2.png)

**Figure 12.10 – a) Real CIM Lab**  **Figure 12.10 – b) Virtual CIM LAB**

The runtime platform of the VCIMLAB v1.0 has been designed as virtual worlds which are loaded as four separate CIM rooms.

The rooms contain virtual robots, CNC machines and peripheral CIM equipment for assembly, storage and material handling based on several industrial products, which are widely available in the market. The virtual equipment used in the software platform has been simulated with all the operating functions of the real devices.

The VCIMLAB Virtual Rooms mainly provide the students,

- An introduction to teaching control, automation and manufacturing techniques.
- Looking at and developing solutions to ‘what if?’ scenarios in real time with intelligent objects.
- Learning how a real robot works including how to program a robot, write sequences and develop script files.
- Experimenting with complex and expensive industrial equipment from a standard PC.
- Recognizing and understanding of relationships between different devices such as a CNC lathe to discover what is involved when another device is introduced.
• Learning of the principles of computer integrated manufacturing (CIM) and the various components involved.

In addition, the VCIMLAB gives teachers the opportunity to introduce their students to computer control in industry. This can be done on different levels in VCIMLAB virtual rooms. The students can get things wrong safely without damaging machinery or work, this allows them to learn from their mistakes and develop their skills and understanding of the process. Using Virtual Reality is a different approach to conventional expensive educational robot laboratories.

![Figure 12.11 VCIMLAB Snapshots](image)

The more information on the specifications and operations of the Virtual Rooms of VCIMLAB can be found on the VCIMLAB lecture notes [4].
REFERENCES TO THIS CHAPTER


