CHAPTER 1

INTRODUCTION

1.1 BACKGROUND AND OBJECTIVES

Manufacturing enterprises play an important role in improving the economic environment of a country. The capability of producing high quality products with shorter delivery times and the ability to produce according to diverse customer requirements have become the characteristics of order-qualifiers for manufacturing industries. The new generation of advanced manufacturing system is forcing a shift from mass production to mass customization and the ability to manufacture in small batches (Ming et al. 1998). Manufacturing companies need to be flexible, adaptive, and responsive to changes, proactive and be able to produce a variety of products in a short time at a lower cost (Nagalingam et al. 1999). Optimization models and algorithms, decision support systems and computerized analysis tools are examples of approaches implemented by companies in an attempt to improve their operational performance and remain competitive under the threat of increasing competition. Implementing Advanced Manufacturing Technologies (AMTs) is an effective approach towards solving the problems (Lin 1976). It provides opportunities to achieve the competitive advantage for an intermediate to long-term time frame (Sohal 1997). The traditional, fragmented approach to increasing manufacturing efficiency has resulted in "islands of automation" in factories. Usually the domains of Advanced Manufacturing Systems are used in Computer Integrated Manufacturing (CIM). CIM refers to a global approach in
an industrial environment, which aims to improve the industrial performances (Alfieri and Brandimarate 1997) and make use of the enhanced computer power and computing technologies.

In the early factory system, mechanization facilitated mass production to meet the consumer's demands for improved products (in 1900). Transfer lines and fixed automation were created to facilitate mass production (in 1930). This results in the development of programmable automation. Numerical control was developed as an innovative approach to programmable automation in 1950. With the developments in commercially available computer technology, the application of computers in manufacturing started to emerge in generating a variety of new technologies [beginning of Computer Aided Design (CAD) and developments in Numerical Control (NC): such as Computer Numerical Control (CNC), Direct Numerical Control (DNC) in 1955 and developments in CAD, application of Computer Aided Manufacturing (CAM) based systems, introduction of the concept of CIM in 1970], all of which are collectively named as AMTs (Nagalingam and Lin 1999). AMTs provide flexibility as well as data driven computer integration for a manufacturing organisation, where the manufacturing technology utilised is intelligent enough to process the activities with less human intervention. The need for integration has evolved (by the advanced systems in CAM, Computer Aided Process Planning (CAPP), Computer Aided Quality Control (CAQC), Shop Floor Control (SFC) Flexible Manufacturing systems (FMS) and CIM in 1980's) in response to the problems faced by traditional manufacturing processes of industrial automation. These islands of automation did not facilitate communication between the functional units. Hence manufacturing enterprise could not be integrated.
In order to integrate islands of automation, the United States Air Force initiated the Integrated Computer Aided Manufacturing (ICAM) program in 1983 (Foston et al 1991). The European Strategic Programme for Research and development in Information Technologies (ESPRIT) Consortium AMICE (European Computer Integrated Manufacturing Architecture - in reverse) initiated the CIMOSA (Computer Integrated Manufacturing Open System Architecture) concepts in 1983 (ESPRIT 1993). The advanced Information Technology (IT) road map for the European manufacturing industry initiative was launched by Daimler Benz in 1993, for technological integration through the development of integration platforms, and the usage of generic networked enterprise (re)engineering methodologies. International Standards related to CIM such as Electronic Data Interchange (EDI), Distributed Office Application Model (DOAM), Manufacturing Automation Protocol (MAP), Technical and Office Protocol (TOP), Open Distribution Processing (ODP), Open System Interconnection (OSI) and Standard for Exchange of Product Data (STEP) started to bridge the communication gap.

The substantial improvements in computer technologies and increasing competition in the manufacturing industry and subsequent quality improvements have fueled the explosion in information processing equipment (ESPRIT 1993; Anitesh and Byungtae 1997). The mystery is why this massive computer investment has not resulted in measured productivity gains in the service sector. The observation that not every firm that tried CIM was successful and the fact that many manufacturing concerns were significantly declining in their expectations about CIM (Gupta 1996) predicted that CIM required reengineering and needed a modular approach to develop integrated CIM systems.
It would seem that to satisfy the evolving market needs, the manufacturing facilities would need to integrate the plant automation layer with enterprise business systems (Dhinesh et al 2002b) in order to bring their manufacturing facilities under control and to satisfy the demanding supply chain requirements of global e-commerce (which is still evolving). Integrated automation is an essential success factor in automation, control and information systems (Dhinesh et al 2002a). Integrated automation concepts provide the cost-effective answer to production requirements in virtually all areas of industry and eliminate uncertainties, introduce greater reliability, better information flow, decision support infrastructure and increased responsiveness. Integrated automation leads to reuse of existing objects and is based on the integration of different functions of the enterprise into a single optimized model and enable firms to turn environmental treats (rapid market changes, increasing complexity, declining opportunities, economics of sale) into opportunities for gaining a competitive advantage (Siemens 2001). The availability of production data and field data facilitate quick product design changes, resulting in better engineering and quality.

Integrated approach to CIM paves the way for total integration of manufacturing enterprise. The occurrence of changes and disturbances are considered as nominal system behavior, and the manufacturing control system must be able to effectively handle these situations. This thesis contributes to this new approach by seeking inspiration in the structure and the dynamics of complex adaptive systems and develops a methodology for the implementation of Integrated Automation System (IAS).
The main objective of this research is to model and develop an Integrated Automation System with in the domain of CIM. This research also aims to:

- Establish a methodology for the design and implementation of IAS
- Develop an Integrating Infrastructure for IAS
- Develop a holonic control architecture
- Establish data consistencies and functional relationships among enterprise modules
- Design an Integrated Information System and a Knowledge base to control information flow
- Implement a software package to develop an integrated information system
- Establish a method to access the plant data to wireless/mobile devices and
- Develop a CIM model for IAS with reference to an industry.

1.2 RESEARCH ISSUES

Research towards CIM has concentrated on the computerization of individual functions of manufacturing dealing with product and process design, production planning and job execution (such as CAD, CAM, CAPP, SFC, Data management, etc.) and could not represent a complete automation program, but a program for robustness in a hectic production environment. The design of such systems was made in a functional fashion that emphasised local solutions, using closed and self-contained architectures. This, together with the use of heterogeneous databases and incompatible computer operating systems have led
to "islands of automation" which suffer from data inconsistencies and lack of control of functional interactions between manufacturing application systems. However CIM could not cope adequately with unexpected changes of market environments, globalization of markets, variety of customers demand, customer designed products, shortened product lifecycle etc.

The generic internet based utility hook up host computers (which handle high-level decisions) and dedicated process controllers. This gives the controllers various facilities to interact, report, query, and coordinate activities with computers located anywhere in the internet (Fuertes 1999; Jagdale et al 1996). The new possibilities for connectivity, sharing and co-ordination have shifted the way manufacturing enterprises are run (Shaw 2000). Client/Server architecture and groupware tools attempt to coordinate the anarchy created by the Personal Computer (PC) revolution, and provides means also for travelling users who want to connect their own web from anywhere in the world, storing, analyzing, and coordinating their activities (Dessy 1996). Distributed computation technologies motivate scientists and industries to develop modular architectures, distributed and linked through specific networks in contrast to centralized and rigid organizations. Advances in software technology is transforming the world of integration into compatible systems and devices by establishing an open connectivity standard, agreed by manufacturers, which will provide plug-and-play communication and interoperability between field devices, control systems, and enterprise-wide business applications.

Current and future trends for the use of computers in manufacturing include the control and integration of information flow of a production operation into a computer controlled factory management system. CIM is the goal of tying together these islands into a single coherent system capable of
managing and controlling the entire enterprise operation to adapt themselves at an ever increasing pace to incorporate new technology, new products, new organizational structures, etc. The technical and organizational difficulties of such a massive undertaking requires a modular approach to CIM implementation, with an initial nucleus being gradually expanded by allowing interaction between entities and other systems. Such a totally flexible automation system can be achieved, if the different levels of the automation system (Physical, Application, Business) are totally integrated to form an integrated automation system. The objectives of this research raises several research issues. The major research issues are:

Identification of the Critical Success Factors

This issue is concerned with providing some key factors on the key technologies of information technology, managerial and communication issues that must be addressed for designing and implementing Integrated Automation System. The factors that are critical to the successful implementation of IAS are identified and discussed for the development of totally integrated flexible automation systems.

Modelling of the envisaged IAS

This issue describes the general problems in manufacturing enterprises, and discusses the impact and consequences of the growing internationalization of markets. The need for models to support the design and reorganization of CIM systems that lead to integrated automation and control of manufacturing enterprises are discussed. An approach to the design and implementation of integrated automation system using Computer Integrated
Manufacturing Open System Architecture (CIMOSA) has been presented and the performance has been modeled using Petri-net.

**Development of an Integrating Infrastructure**

The next research issue to be addressed deal with the new advances that have put more demands for CIM integration technology and associated supporting tools. One of these demands is to provide CIM systems with better software architecture, more flexible integration mechanisms, and powerful support platforms. An Integrating Infrastructure (IIS) for IAS implementation has been specified. A research prototype of an integrating infrastructure has been developed for the development, integration and operation of integrated automation system.

**Design of a holonic control Architecture for IAS**

Technological advances in computing technology have made it possible to consider a wide range of possibilities in the design of control architectures. To combine robustness against disturbances and unforeseen changes with performance optimization and predictability, this research task presents a control architecture that has a basic structure of autonomous co-operating local agents that are capable of negotiation with each other in order to achieve production targets and ensure reconfigurability.

**Implementation issues**

The methodologies conceptualized by the above modules have been implemented in a manufacturing industry and the teething troubles have been
rectified. The implementation of the system and the overall performance compared to the earlier system have been evaluated.

1.3 CONTRIBUTIONS OF THIS RESEARCH

Contributions made in the work of this dissertation are listed as follows:

- Identifies the critical success factors for the implementation of Integrated Automation System.
- Establishes a modelling approach for the design and implementation of Integrated Automation System using CIMOSA.
- Develops an Integrating Infrastructure for Integrated Automation System.
- Develops a holonic reference architecture for Integrated Automation System.
- Develops a CIM model for Integrated Automation System.
- Implementation and validation of the above system in a factory.

1.4 THESIS STRUCTURE

Chapter 1 presents the motivations and needs for the design and implementation of Integrated Automation System. This chapter discusses the objectives of this research and the tasks, which were undertaken to realize these objectives. Chapter 2 reviews the current literature relevant to this research. The first section discusses the CIM system architectures. The second section discusses the database frameworks for CIM systems. The third section presents the Knowledge based systems for CIM systems. The fourth section deals with
the system modelling tools and techniques. The fifth section presents a review of holons and agents technology. The sixth section presents a review of enterprise application integration and integrating infrastructure for CIM system.

Chapter 3 presents the research approach. Chapter 4 identifies the Critical Success Factors for the implementation of the Integrated Automation System. Chapter 5 details the modelling of Integrated Automation System. Chapter 6 presents integrating infrastructure system architecture for Integrated Automation System. Chapter 7 presents a holonic control reference architecture for Integrated Automation System. Chapter 8 presents case study and a CIM model. Chapter 9 presents a brief summary of the research and significant accomplishments. This chapter also provides recommendations for future research.

1.5 SUMMARY

This chapter presents the motivation and needs for the design and implementation of IAS. The objectives of this research, the research issues to realize the objectives and the contributions of this research are outlined in this chapter.