1. INTRODUCTION

Product-process design in product development creates a design entity in accordance with the market-related, functional, technical, manufacturing, ergonomic and aesthetic requirements. It is a very complex process involving many sophisticated procedures, and requires a team of designers and engineers with different aspects of knowledge and experience to work together. In recent years, computer-aided design and manufacturing (CAD/CAM) and product data management (PDM) and their integration have been the focal research areas in advancing design and manufacturing automation. Many CAD systems have incorporated some of the functional requirements necessary to support integrated design, e.g., direct interface to analytical, parametric feature-based design or CAM (such as Pro/Engineer and CADDS), and other design techniques. However, most of existing CAD systems still adopt the traditional design methods with various design activities being carried out sequentially. The integration of the design activities and product life cycle issues have not yet been taken into account sufficiently and intelligently. The sequential and non-intelligent approaches are costly, tedious, and could not help in optimizing the product-process design. They are also used relatively late in the design process, in general, during the detailed design phase, and no intelligent and collaborative actions between designers or participants are supported. This means that the designer has no CAD and collaboration support

*This work was conducted by the author during his tenure at Nanyang Technological University and Institute of Manufacturing Technology, Singapore.
during the early conceptual design phase; the downstream processes such as manu-
ufacturing or fabrication and assembly are considered very late in the design process;
and the modifications imposed by these considerations are done when their econom-
ic consequences are worst. In order to obtain the economically and ergonomically
viable design solutions, product design, process planning, economic and ergonomic
analysis and evaluation should be carried out concurrently [132, 210]. Concurrent en-
gineering emphasizes the early consideration of downstream requirements in the early
design stages. Critical to concurrent engineering is the maintenance of information
consistency between participants and the rapid handling, exchange and propagation of
design information or events. It is imperative that an integrated design system addresses
these issues. Further, in order to reduce training costs and support a broad spectrum
of designers, the integrated design system needs to provide a single system image that
gives users a consistent and easy-to-use interface.

There is also an increasing need for human decision operations for solving engi-
neering problems where the more traditional analytical approaches alone would fail.
This can be seen in tremendous interests in: (a) advancing the engineering applications
and development of artificial intelligence; and (b) integrating artificial intelligence
more harmoniously with the human intelligence for maximum benefits. In as much as
human decision processes in design, control, production and management can be
understood and emulated, non-analytical skills are increasingly automated using such
tools as expert systems, soft computing, neuro-computing, and evolutionary computa-
tion in order to expedite advanced design, automation and manufacturing [213].
Therefore, an integrated intelligent engineering environment and system to provide
information for rapid and intelligent decision-making throughout the entire design
should be developed to aid the designers [152].

This chapter first reviews the relevant literature on the development of methodolo-
gies and systems for intelligent design of products and processes. The emphasis of this
review is on the latest application of artificial intelligence and integrated intelligent
systems for concurrent integration and collaboration of the design of a product and its
related processes. Then it presents a generic integrated intelligent framework and its
implementations for the design of products and processes. Based on the review findings,
the problems in the distributed & integrated collaborative intelligent product-process
design which remain unsolved or need further research are summarized.

2. OVERVIEW OF EVOLUTION OF PRODUCT-PROCESS
DESIGN METHODOLOGIES

The development of a product can be characterized by its functions and manufacturing
processes. The production processes are largely dictated by the design of individual parts
and assemblies. The design department accounts for only 12% of the manufacturing
costs, but it is responsible for 75% of the manufacturing costs as it determines the
production process, and the selection of material, tolerances and dimensions. Since
the industrial revolution, product design has undergone many different phase changes.
A number of product-process design methodologies may be deduced to evolve in
parallel with each other. Figure 1 shows these phase changes, from manual design,