Future Trends in Mechatronic Engineering

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Abstract

1. The Importance of Technological Innovation for Economic Progress

Over the past 50 years, technological innovation (see Figure 1) has accounted for over one-third of the growth of the largest economy, the USA, in the world. The pace of innovation around the developed world is increasing dramatically in recent years owing to technological developments in communications, computerization, the Internet, etc., and the resulting globalization of markets and the global distribution of the processes of new product realization (concept development, design, prototyping, manufacture, and servicing).

Some are genuinely concerned (to the extent of being frightened) with the increasing pace of innovation. For instance, as suggested by von Braun [1] "[s]uppliers of new products replacing previous ones should bear in mind that they are also reducing, or even destroying, the assets of customers, either their own or some other supplier's. This "creative destruction" is perhaps not exactly what Schumpeter [2, 3] had in mind when he was extolling the virtues of innovation at the beginning of this century." However, the majority opines that innovation, when taken in its broadest sense, can become the force that could "liberate humanity in general from the preventable evil called poverty [4]". In any case, it is generally accepted that we cannot ignore the onward march of technological innovation.

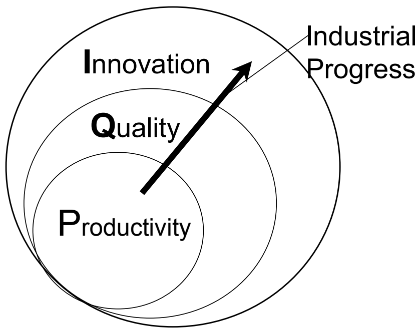

Figure 1 P→Q→I Competitive Strategies

Innovation may be defined as "new ways of delivering customer value [5]." Often the outcome of innovation appears in the form of a new process, product, or service. However, in many cases, the development of new services is a consequence of the availability of new processes and products—e.g. the development of the Internet has resulted in a radical expansion and transformation of service industry). The new services become part of "an emerging industrial value-adding structure that supplies functionality around a new basic technology system [6]."

When a corporation is mainly competing on the basis of superior productivity (functional capability/input) and quality, the focus is on process innovation (in addition to strategic issues related to organization, human resource development, marketing, etc.). However, as the corporation forges ahead towards competing on the basis of innovation, more and more attention needs to be paid to product innovation.

2. Changes in the Nature of Technological Processes and Products

In the era prior to the invention of the electromagnetic induction dynamo (1830-40) by Michael Faraday, all 'machines' (technological processes and products) were mechanical ('M-') in nature, i.e., composed essentially of mechanical units. Since mechanical units exhibit large inertia, machines of this era tended to be large, cumbersome, slow, 'uni-functional' and 'non-user friendly (difficult to control and maintain)'. However, it sufficed for the innovators of such machines to be well versed in mechanical sciences and arts.

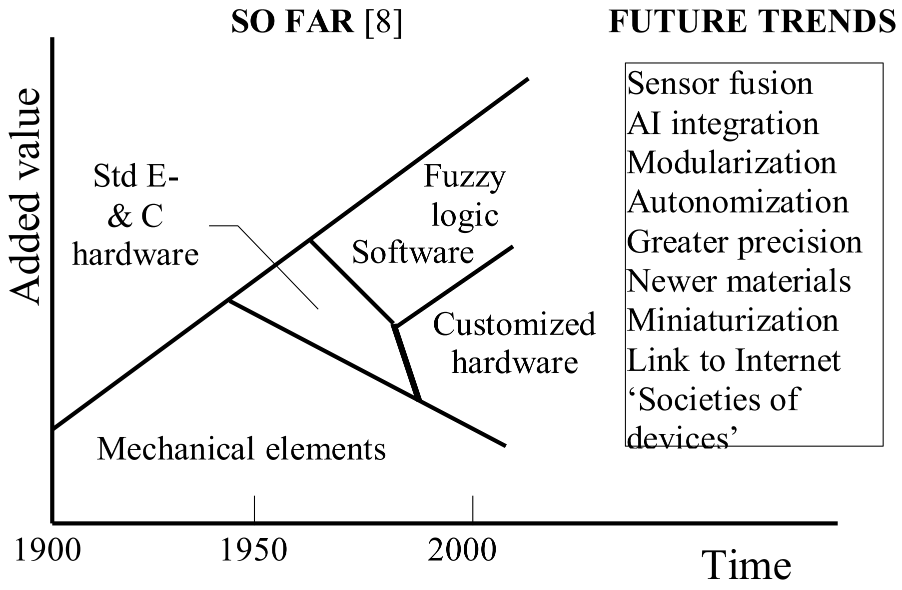

Figure Trends in Mechatronics

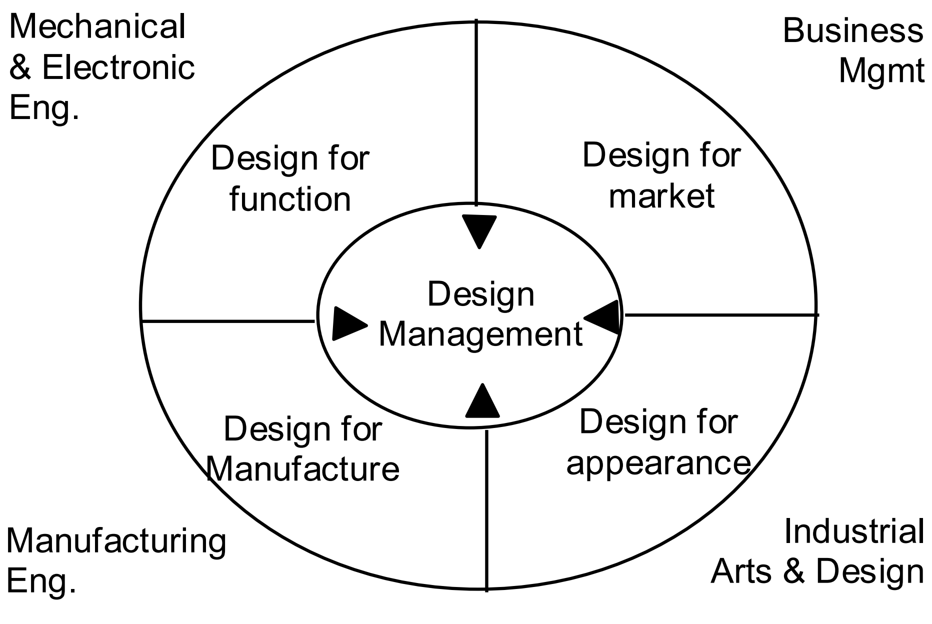

Figure The Role of Design Management []

By the late 19th century, since electrical ('E1-') energy can be transmitted and transformed much more easily than mechanical energy, the energy receiving and manipulating units within machines (technological processes and products) started being replaced by functionally comparable electric units. As a result, machines became more compact, controllable and user-friendly.

A technological transformation occurred with the advent of analog electronic ('E2-') valves in the earlier half of the last century. This transformation accelerated after the 1950s owing to the development of transistors, digital electronics and power electronics ('E3-'). Wherever possible, electrical functional units were replaced by such electronic units so as to attain several orders superior performance in terms of size, controllability and user-friendliness. The synergistic combination of E1-, E2-, and E3-technologies may be called the E-technology (electrical/electronic technologies).

The second half of the last century saw a dramatic transformation technological processes and products owing to the rapid extension of earlier successes in electronic technologies towards the development of a bewildering array of digital computational units (computers): general purpose integrated chips (IC), application specific ICs (ASIC), microprocessors (μP), etc. These functional units are now so small in size (miniaturized) that thy can embedded within the functional units. Such units will be referred to as belonging to 'C-' technology in the rest of this paper.

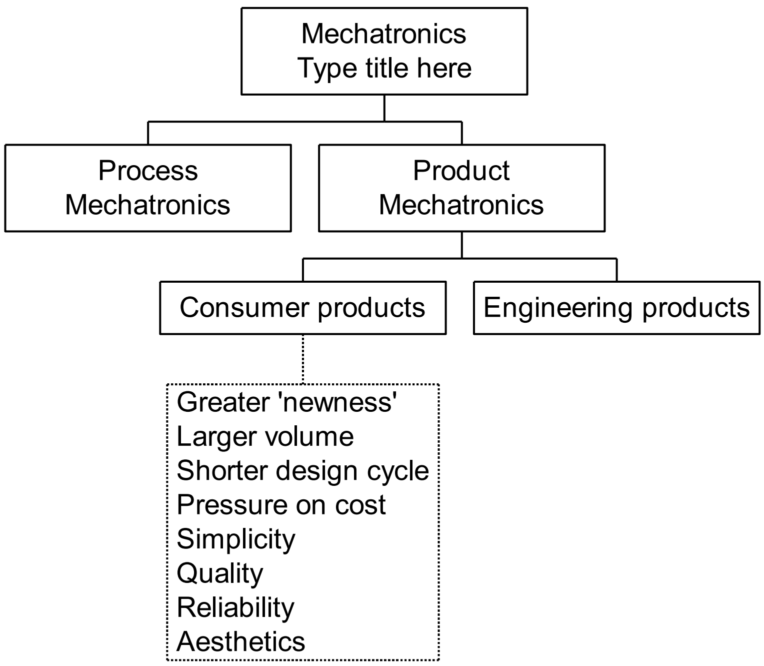

Figure The scope of Mechatronic Engineering

3 What is Mechatronic Engineering

The synergistic combination of M-, E-, and C-technologies eventually led to processes and products that could not be contemplated before [7-12] while attaining unprecedented levels of performance (sees Tables 1 and 2).

Table 1 Some types of mechatronic products (adapted from Dinsdale [7-10])

Type	Examples
Transducers and measuring instrumentation	Ultrasonic receiver Electronic scale
Processing machines	Turning and machining centers Bonding machines Robots
Industrial handlers	Robots Component insertion machines
Drive mechanisms	CD players Printers Disk drives
Interface devices	Keyboards

Table 2 Benefits of mechatronic engineering (adapted from Dinsdale [7-10])

Benefit	**Examples**
Faster response time	Servo-motion controller Camera
Better wear and tear characteristics	Electronic ignition
Miniaturization potential	Camcorder
Easier maintenance and spare part replacement rive mechanisms	Washing machine
Memory and intelligence capabilities	Programmable sequence controllers
Shortened set up time	Computer numerical control (CNC) machines
Data processing and automation	CNC machines
User friendliness	Photocopier
Enhanced accuracy	Electronic calipers

Many modern products use embedded computers (computer-on-a-chip) to provide functionalities hitherto attained exclusively by mechanical means. One may also exploit the ability of a computer to be programmed at will to add new functionalities. For instance, we can create 'smart' products by programming the computer on the basis of fuzzy logic, or by making the computer behave like an artificial neural net (ANN). Thus computer technology offers an opportunity for endless product innovation. Mechatronic engineering is the emerging discipline that supports the development of this class of technological processes and products.

Although USA and Europe had contributed significantly to the M-, E-, and C-technologies described above, it was Japan that fully recognized the strategic importance of the development of mechatronics as a distinct discipline. Indeed, much of Japan's economic success since the 1970s seems to be based on its mastery of mechatronic engineering [13, 14]. However, soon the importance of mechatronic engineering started being recognized elsewhere in the world.

Since mechatronic engineering is an emerging discipline, it is not surprising that many peopleMost The original definition of mechatronics was given by MITI of Japan as “the application of microelectronics a combination of mechanical engineering, electronic control and systems the understood first which According to the Industrial Research and Development Advisory Committee of the European Community, mechatronics is “*a synergistic combination of precision mechanical engineering, electronic [read computer] control and systems thinking in the design of products and manufacturing processes [Dinsdale 90]*.”

Our undergraduate program in mechatronic engineering was launched in the early 1990s [Venuvinod 93]. The graduates were expected to be different from the traditional specialist mechanical, electronic, or computer engineers. They would know the art and science of achieving the optimum synergy amongst the three basic technologies. This suggested that we had to recognize mechatronics as an integrative discipline. The science part was relatively easy to deal with. We could achieve it merely by including the basics of the three disciplines in the curriculum. The path to the integration of the three basic disciplines (which, hitherto, had remained distinct) was much more difficult. Literature concerning the conceptual structures underlying such synergy was sparse. We sought to resolve this problem by giving a product design orientation to the program. We designed our curriculum such that groups of students (3 to 5 members) could work autonomously over a period of three semesters towards the development of the concept, embodiment design, prototype fabrication, and testing of a mechatronic product. Typical products attempted by our students include a smart household vacuum cleaner, a smart wheel chair for paraplegics, a 4-axis CNC (computer numerical control) turning-cum-milling center, and a ‘smart cart’ to reduce queues in super markets. In parallel, our students also study a course on “Design Management’.

Figure: Modern manufacturing organization

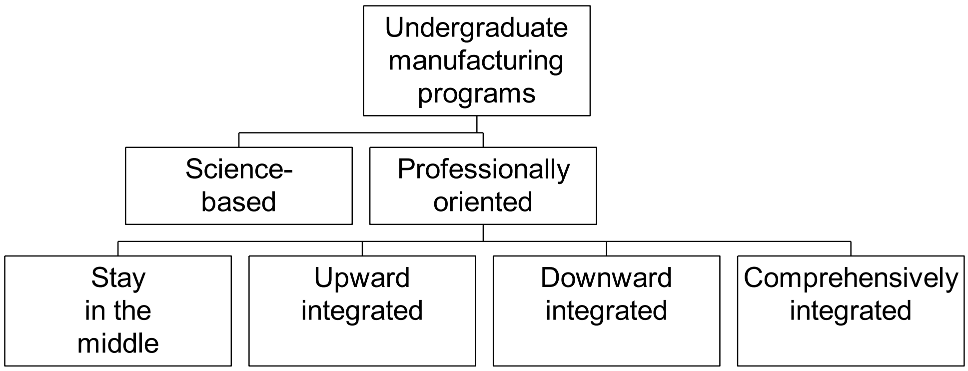

Figure : Prototypes of manufacturing programs

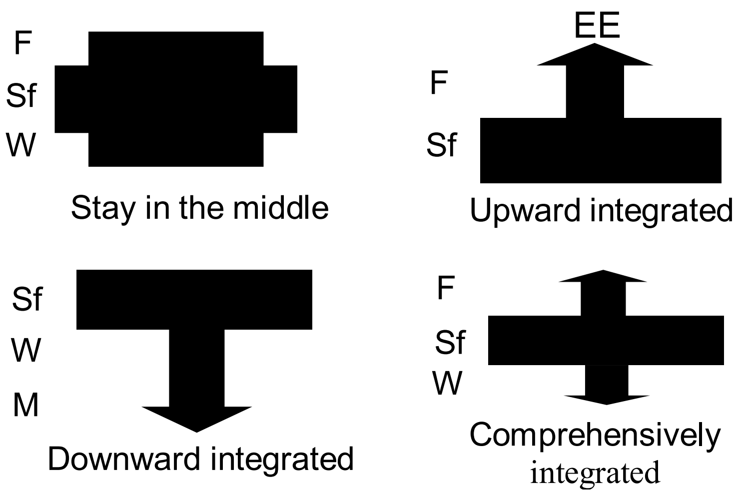

Figure Professionally oriented prototypes

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