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How Mechatronics is Essential in Future for Living a Flexible and Reliable Life

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ABSTRACT

The process of seeking, from the outset, to provide definite engineering system solutions are naturally explained by mechatronics. These processes are integrally linked to the integrating technologies associated with the seasoned mechanical, electrical, and computer-based disciplines. Huge technological opportunities are presented by mechatronics, as demonstrated by the emergence of sophisticated devices like ever-tinier compact disc players and camcorders. Adopting a standard single-disciplinary or combinational strategy would never have made these feasible. Because of this, mechanics is by definition a philosophy - a basic way of looking at and doing things - rather than a subject, science, or technology in and of itself. As such, it necessitates a cohesive strategy to its delivery. The conventional western methodology has depended on identity unique to a specific discipline and evolving approaches based on add-on technologies. However, mechatronic solutions necessitate the employment of integrated teams of workers who are all working toward the same objective. As a result, the mechatronics engineer can relate to the theory of systems thinking. a "product" of mechanics that is the result of methodical processing as opposed to piecemeal processing. Therefore, instead of compromising a "engineered" solution, it aims to maximize it. The method by which it is accomplished is well described by the mechatronics philosophy. This realization easily lends itself to the idea of "total quality," which is something that western industrialized nations have just recently begun to strive for. However, in the field of mechanics, the manner in which system-based solutions are to be implemented already implies quality. sought, as well as the strategies employed to get there. It is hoped that business and industry will recognize and strive toward mechatronics for what it represents: complete synergy.

Introduction

In 1969, Yaskawa, a senior engineer at a Japanese business [1], coined the term "mechatronics," combining the terms "mecha" for mechanisms and "tronics" for electronics. The company was given trademark rights to the term in 1971. The news quickly arrived wide acceptability in the industry and Yaskawa's decision to give up on it in order to permit its unrestricted use his 1982 rights to the word. Since then, the definition of the word has expanded, and it is now is frequently used as a technical jargon term to refer to an engineering philosophy technology—more so than the actual technology. Regarding this broader notion of mechatronics, several definitions with varying specific properties have been proposed in scientific literature which the purpose of each definition is intended to emphasize. The most widely utilized one highlights synergy: In the design and production of goods and processes, mechatronics is the synergistic integration of mechanical engineering, electronics, and intelligent computer control.

There have been three phases in the evolution of mechatronics. The first phase is based on the years this term was first used. The technologies utilized in mechatronic systems evolved at this time mostly on their own. A significant example of the synergistic integration of many technologies that began in the early 1980s is optoelectronics, which is the merging of electronics and optics. During those years, the idea of hardware/software co-design also began to take shape. Since the early 1990s, the third and final stage can also be seen as the start of the mechatronic age. The third's most noteworthy feature

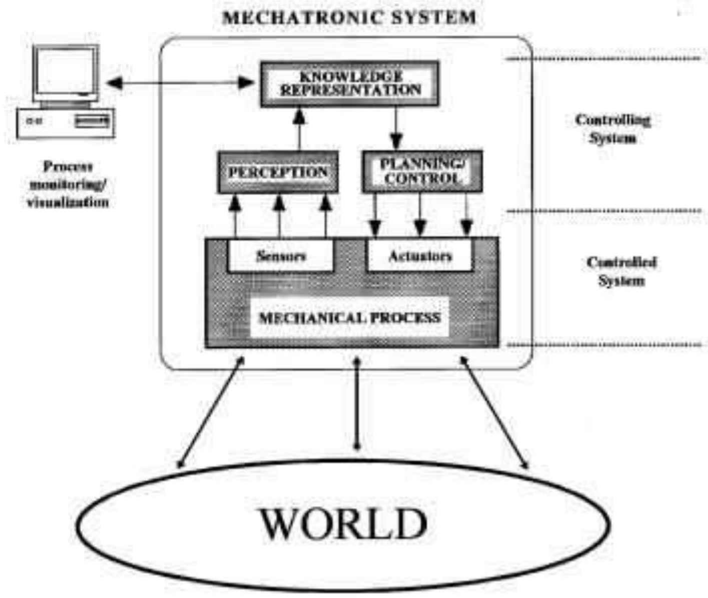

Figure 1: Mechatronic system architecture

As illustrated in Figure 1, a mechatronic system consists of two primary parts. Through all of its sensors and actuators, the mechanical process that makes up the controlled system interacts with the outside world. Three subsystems of the controlling system—used for planning, control, knowledge representation, and perception—are what set the mechatronic system apart. Usually, the subsystem that handles planning and control has intelligence. Thus, computational intelligence techniques are used to plan a course of action that will allow the controlled system to accomplish any given goal based on data collected from the sensors. Artificial neural networks, fuzzy logic, probabilistic reasoning, and conventional microprocessors are a few of the subsystem's information processing and decision-making capabilities.

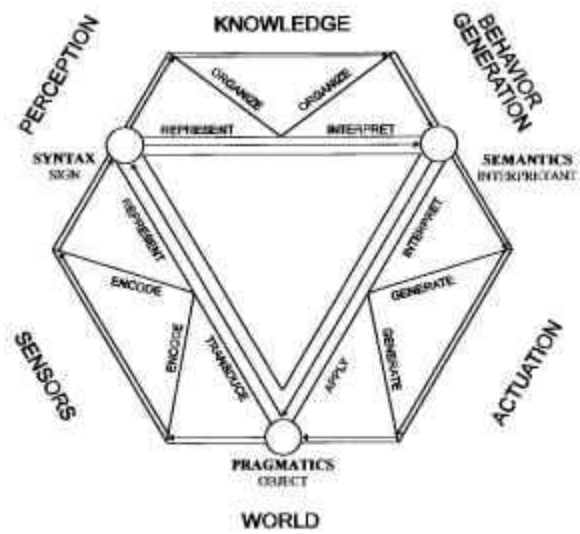

Figure 2: The functional diagram of semiotics

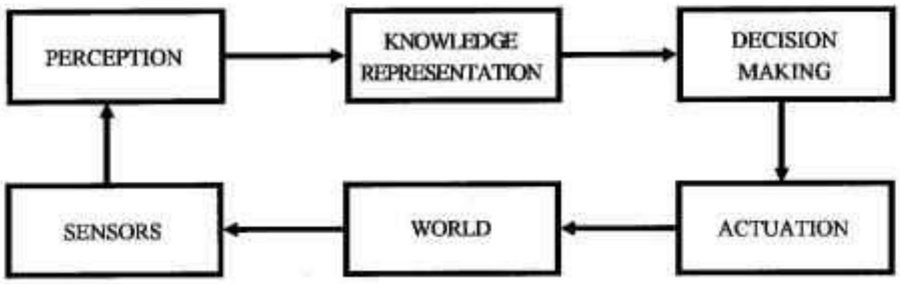

Figure 3: The six-box diagram of behavior formation

A more expansive idea known as "semiotics" has recently been put up as a fresh paradigm for research in the twenty-first century. It is described as a theoretical area that examines and creates formal instruments for gathering, representing, organizing, creating and improving, communicating, and using knowledge. Figure 2's functional depiction of semiotics illustrates the connection between semiotics and mechatronics since it differs from Figure 1's and is more descriptive. The same graphic, which is shown as a six-box diagram, may be used to explain how mechatronic systems and live things generate their behaviors. The six-box design in Figure 3 may be placed into each box to represent a multiresolutional hierarchy. Certain definitions of mechatronics have been published in journals, and reviews of international congresses. After reviewing the aforementioned definitions, the following unique formulation is suggested.

In order to design and produce innovative machines, systems, modules, and complexes of machines with cognitive control over their functional movements, mechatronics is the study of the synergistic fusion of precise mechatronic units, electronic, electro technical, and computer components [2].

1. Mechatronics is the study of unique conceptual and methodological approaches to the creation of devices having distinctly novel characteristics. It is crucial to stress that this method is quite general and may be used with devices and systems of diverse objectives. But it's important to remember that the only way to keep high It is important for mechatronic system (MS) control quality to consider the peculiarity of a particular operated a thing. Studying mechatronics in accordance with its specializations makes sense. possess certain categories of industrial machinery and procedures as their topics;

2. The concept places special emphasis on how components work together when integrated into mechatronic products. To achieve a goal, two people working together create synergy. It is crucial to note that the later system's components not only enhance one another but also provide qualitatively new qualities to the system because of how they are combined. In mechatronics, every flow of power and information is focused on achieving a single, predetermined movement;

3. Integrated mechatronic components are always selected during the design phase, and the required technical and engineering assistance is given during the manufacturing and application phases. It clarifies a key distinction between traditional and mechatronics. when a user must, at his or her own discretion, combine various mechanical, electronic, and information-operating devices from different producers into one system;

4. Concurrent engineering methods, or methods for parallel designing, act as methodological foundation for developing mechatronic systems. Traditionally, machines are designed with computer control sequential design of sensor, electrical, mechanical, and computer components is completed prior to selecting interface blocks for the system. The parallel paradigm designing is the synthesis of every system component concurrently and in relation to one another;

5. The primary subjects of mechatronics research are: mechatronic modules, which are typically movable on a single controlled coordinate; these modules are built into complex modular systems as though they were functional cubes;

6. Mechatronic systems are designed to carry out a predetermined movement, according to the definition. The problem-focused, or defined by the declaration of a specific applicable task, qualitative standards of MS movement performance are implemented. The moving of a target component of the technological machine's working body—such as a machining tool—is what makes automated mechanical engineering operations specific. As a result, coordination between different external processes and spatial MS movement is required. Control of the working body's force contact with the object being machined, diagnosis and management of MS key components, and management of Such processes can include additional technical effects (thermal, electric, and electrochemical) on the object at combined processing methods, operating complex delivery auxiliary devices (conveyors, loading devices), and receiving signals from electro-automatic devices (valves, relays, switches). Functional motions are those such complex and synchronized MS movements;

7. Advanced intelligent control techniques are employed in current MS to ensure superior performance in carrying out intricate and accurate actions. These techniques are based on novel theories of actual theory management, contemporary hardware and software, and theoretical approaches to the synthesis of operated MS movements. Since mechatronics is a relatively new field of modern science, it lacks clearly defined

bodies, categorization criteria, and vocabulary. It is essential to reveal the concepts of new building principles and machine development trends that involve computer-controlled movement. It won't take long for all concepts and definitions to be developed.

Modern Trends of Mechatronic Systems Development

The amount of MS produced worldwide is continuously rising and extending into new areas. These days, mechatronic systems and modules are widely used in the following fields:

- Machine-tool construction and equipment for automation of technological processes;
- Robotics (industrial and special);
- Aviation, space and military techniques;
- Motor car construction (for example, anti blocking brake system (ABS), systems of car movement stabilization and automatic parking);
- Non-conventional vehicles (electro bicycles, cargo carriages, electro scooters, invalid carriages);
- Office equipment (for example, copy and fax machines);
- Computer facilities (for example, printers, plotters, disk drives);
- Medical equipment (rehabilitation, clinical, service);
- Home appliances (washing, sewing and other machines);
- Micro machines (for medicine, biotechnology, means of telecommunications);
- Control and measuring devices and machines;
- Photo and video equipment;
- Simulators for training of pilots and operators;
- Show-industry (sound and illumination systems).

A number of factors, chief among them the following, contributed to the rapid development of mechatronics as a new scientific and technical direction in the 1990s: global industrial development trends; the development of fundamental basic and mechatronic methodology (the base scientific ideas, essentially new technical and technological decisions); and the activity of experts in research and education. In the area under consideration, the following shift trends and global market requirements can be identified:

- The requirement that equipment be produced and maintained in accordance with the global system of quality standards outlined in ISO 9000;
- Internationalization of scientific and technical production market and, as a consequence;
- Necessity for active introduction of forms and methods of international engineering and putting new technologies into practice;
- Increasing role of small and average industrial enterprises in economy owing to their ability to quick and flexible reaction to changing requirements of the market;
- Rapid development of computer systems and technologies, telecommunications, especially in the countries of the European Community. Intellectualization of mechanical movement control systems and technological functions of modern machines appear as a consequence of this common tendency.

Future of Mechatronics

Technology is generally a beneficial thing, as demonstrated by the fact that politicians, businesses, institutions, professionals, students, and even children use it virtually daily in their daily conversations. Historically, mechanics has been a somewhat quiet or Although an unseen force in many organizations, technology is a real asset whose power is that it nearly appears transparent to the user when used appropriately. This aims to provide a quick overview of the potential for mechatronics and is broken down into eight categories: difficulties, DIY systems, e-Medicine, manufacturing, nanotechnology, communications, and transportation sophisticated algorithms, as well as a summary. Due to the constantly evolving nature of among the technologies mentioned, the writers have chosen to offer several references as webpages so that readers with an interest in developments

- Challenges: The design of mechatronic systems allows for a reduced time-to-market and shorter product life, promoting increased customer expectations. These systems can now handle various tasks, such as playing music, surfing the web, and serving as alarms. Component technology allows for rapid market entry, affordability, and profitability. Vendors are aware of the global marketplace and are offering trade-in programs to recoup value and disassemble products. The knowledge economy continues to dominate the business world, and technology-based products, including mechatronic systems, have added value in everyday life when used ethically. However, misuse can create societal issues, necessitating regulation and prohibition.

- Home Based Technologies: Home-based systems are increasingly using voice control to initiate or close electromechanical devices, particularly for home help systems. Smart appliances offer assistance with schedules, medication monitoring, and prescription refills. The Roomba™, a robotic vacuum cleaner, has sold 2.5 million units as of January 2008. Personal digital assistants may soon plan daily wardrobes based on schedules. Mechatronic devices also offer enhanced safety and security systems, remote monitoring of home systems, and adapting to a person's lifestyle. These devices can help save time and improve overall living conditions.
- Medicine and health: Mechatronics is crucial in supporting independent living for the elderly and infirmed, allowing them to maintain their independence. It creates a secure environment for monitoring movement, location, and medication schedules, and teleconsultations replace traditional GP services. These technologies allow for better monitoring and care for those who might otherwise need institutional care.
- Transportation: Transportation is undergoing significant changes, with electric hybrid vehicles becoming more popular and hydrogen-based fuel cells emerging as promising technologies. Highway systems are gaining efficiency, with transponders and credit cards allowing vehicles to pay tolls or congestion charges. As vehicles become smarter and incorporate self-parking and collision avoidance systems, guided vehicle technologies may soon auto-pilot cars on special lanes. Advanced mass rapid transit systems are emerging, using mechatronic components to synchronize station stops and train steering. Aeronautics is also seeing advancements, with super jumbo jets like the Airbus 380 carrying 555 passengers with automated takeoff and landing functions. Future autopilot systems may include more intelligence, observing debris and taking remedial action to prevent accidents.
- Manufacturing, Automation and Robotics : Machine intelligence is enabling deep cooperation with humans in various tasks, including heavy work-piece manipulation and autonomous handling of hazardous materials. Advanced manufacturing systems use self-reconfigurable machines that bid on incoming jobs based on availability and proximity. The semiconductor industry is particularly advanced in material handling systems and automated assembly and disassembly.
- Communications: Communications networks link distributed system elements, enabling efficient monitoring of various types of information. Self-organizing sensor networks can form tele-care, health networks, and smart building environments. Advanced communications support collaborative working, swarm robots, and unmanned aerial and sub-sea vehicle operations by facilitating operator interaction and achieving higher functionality levels.
- Nanotechnologies: Nanotechnologies are increasingly being used in various applications, including medical nabobs that perform in vivo procedures to improve lifespan and quality of life. These nabobs can repair damaged DNA, attack viruses and bacteria, remove contaminants, and correct bodily structures. Implanted diagnostic and maintenance Nano systems can facilitate early detection of abnormalities and first-level repair. In the short term, implantable devices like micro-pumps can control drug release based on blood chemistry measurements. Nanotechnology also allows for the synthesis of bespoke materials with inherent properties, such as super-diamond strength and resiliency.
- Advanced Algorithms: Mechatronic systems use computational components for control systems and intelligent self-organization. Neural networks optimize control tasks over time, while particle swarm technology solves scheduling problems. Ant colony optimization (ACO) metaphor forces solution trajectory to forage into new spaces, but coding the swarm's desire to branch out is challenging.
- Artificial Intelligence: Artificial intelligence techniques are expected to significantly impact mechatronics in the coming years. In design, recommender systems and smart databases will help optimize material and facility use, enabling design modification and re-use. Data mining and knowledge discovery will support the development of new solutions and methods. Autonomous decision-making strategies, like those associated with DARPA Grand Challenge and Urban Challenge, will enable the development of smarter systems and products. Self-organizing networks of sensors and devices will form the basis for distributed computing networks at the system level. In medical technology, prostheses will rely on smart integration of drives and actuators with novel sensors. Enhancements in system intelligence will support advanced healthcare strategies, increasing independence for a wide range of individuals.

Emerging and Future Trend of Mechatronics

The complexity of devices and systems has significantly increased, necessitating a system-level approach to mechatronics design. This approach combines mechanical and control design, simplifies testing, and reuses algorithms within the final embedded delivery framework. This trend is driven by investments in medical, life sciences, renewable energy, and industrial machinery. By splitting the design process into parallel threads, engineers can create virtual prototypes faster, minimizing development time and costs, and promoting cooperation between design teams. A good mechatronics design process includes built-in design instruments, which device vendors like National Instruments have invested in promoting this approach. These interfaces ensure smooth communication between different devices, allowing engineers to build virtual implementations of their systems with a smooth path to embedded hardware and reuse code. Algorithms need to be implemented on embedded hardware during prototyping and deployment. Engineers can shorten production time during deployment by developing a component-level tailored control system to reduce costs and deploy on embedded commercial-off-the-shelf (COTS) systems. "System ready" subsystems are mostly used for prototyping or as a delivery platform to check consumer acceptance before cost-optimized custom designs are designed. In recent years, there has been a move towards customizable embedded platforms, providing the versatility of a custom configuration and rapid deployment associated with COTS hardware. National Instruments launched the RIO (reconfigurable I/O) platform seven years ago, which has evolved and is currently used in robust embedded hardware and system-level items of an industrial scale. Software plays a crucial role in mechatronics and embedded systems of the future, offering a system-level view of various design factors and abstracting the complexities of the latest technologies. Three major future trends in mechatronics include the ghost of computing, hidden life of data, and future of fear.

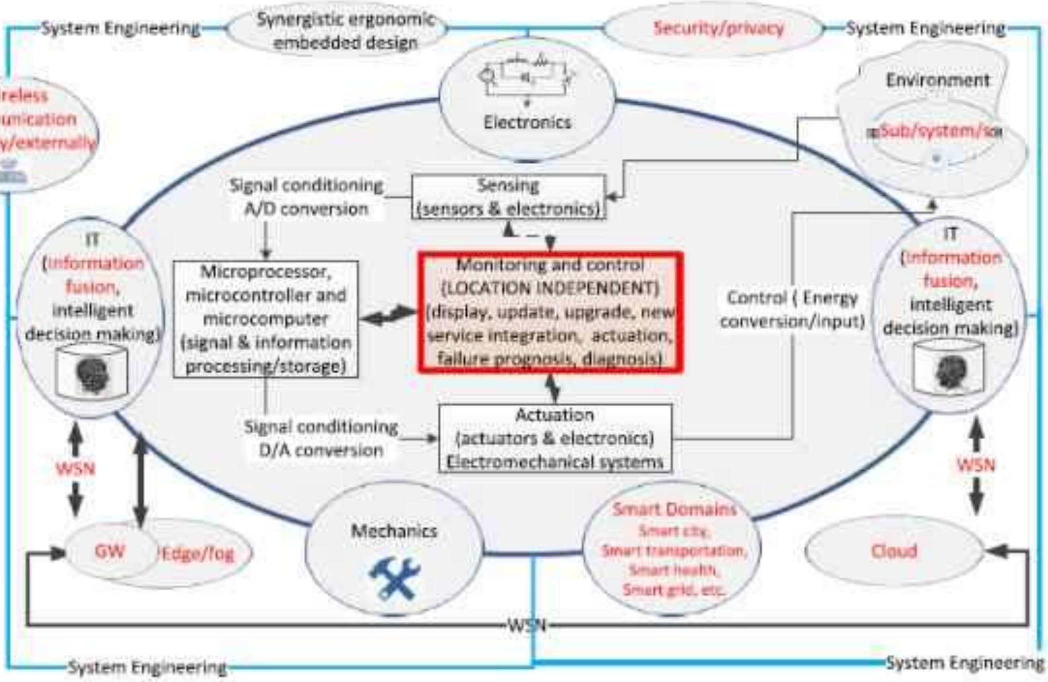

Figure 4. Advanced Mechatronic system and its interaction with the environment

Reliability-adaptive systems

Reliability-adaptive systems are defined by two requirements: reliability observation and system influence. Reliability observation requires the ability to estimate reliability measures for multiple instants of operation and update them permanently. Stochastic reliability measures are used in this context. System influence consists of several points, including transferring the system to a state that results in more reliable operation, operating individual systems within a fleet to react on their own reliability properties, considering system control aspects, reconfiguring redundant components, and accurately estimating the time to preventive maintenance. One way to implement reliability-adaptivity is to use the Safety and Reliability Control Engineering-Concept (SRCE-Concept), which contains a closed loop for controlling system reliability. However, early introductory papers state that some necessary connections cannot be given due to its non-pure technical approach. Wol08 suggests using model predictive control and a model of degradation behavior, but this concept prioritizes reliability over other aspects of system operation. Degradation models exist for some faults, but modeling degradation becomes a challenging task, making implementation of such control schemes infeasible. The paper presents a method for modeling reliability control systems, aiming to create a closed description of reliability and system dynamics that can be treated using general or dedicated methods from system analysis and control theory. However, forming such a system model is challenging and error-prone. The paper introduces classifications for prognostics and health management schemes into four types of increasing complexity and capability. The paper proposes a new type 5, which requires adaptation of the individual system based on type 1 to 4 data, encompassing reliability-adaptive systems. This type 5 system directly builds on all properties of the lower types, increasing system complexity and development efficiency. The paper also discusses self-optimization techniques as an approach for implementing suitable control strategies. To be interesting for practical usage, the new method needs to be generalizable and adaptable to a multitude of systems with minimal effort. Developing a new method based on self-optimization is a promising approach, as it allows for adapting system behavior and operating in optimal working points.

Enhanced multi-level dependability concept

The multi-level dependability concept, introduced in [GRS09b, p. 61] and [KSR12, p. 6], allows self-optimizing systems to change their behavior based on current dependability, such as reliability. It classifies the system state into four levels, with the first level assuming that dependability does not need to be considered when selecting current system behavior. Level four is special, as the sole goal of the system is to reach a safe state. In [SMD+12], an example for usage and setup of the multi-level dependability concept is given. The remaining life of railway wheel flanges is used as the main factor for degrading reliability. Continuous control would be advantageous in this case, as it takes time-dependancy into account and compensates early, yet only as much as required to reach the desired usable lifetime. The original definition assumes that dependability is a minor aspect of system operation, but reliability controlled operation aims to find an optimal compromise between reliability and system performance. Without considering system reliability, system performance could be worse than necessary for maintenance or early failure. To meet these classifications when using reliability control, the levels need to be redefined. Level I is characterized by a safe, normal state where performance and dependability objectives are balanced. Dependability does not need to be prioritized overly, and countermeasures against undesired events are not required. Level II is when a threat is detected, leading to behavior adaptation and maintaining system operation dependable but impairing other objectives. Levels III and IV are not the subject of this thesis, which focuses on continuous control for levels I and II.

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