Navitronics and Nautomatics - A New Challenges for Navigation

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Abstract

The advantage of the latest technical development in the field of automation, electronics, telecommunications, informatics, geomatics and global position fixing techniques, achievement in data storing, processing, analysing, transferring and visualisation must be taken into account and applied to the maritime technology in the very near future. We should build new e-Navigation era using those technologies [16]. In the paper the Author proposes to introduce and define two new terms: navitronics - formed by analogy to mechatronics, and nautomatics - created by analogy to geomatics and telematics to be combination of those two disciplines in navigational applications.

Keywords: Navigation, Telematics, Geomatics, Mechatronics, *e*-Navigation, ECS/ECDIS, INS/IBS, GPS/GNSS.

1. Introduction

The Author expects numerous interpretations associated with proposed new terms. He expects that the definitions of navitronics and nautomatics will be continuously evolving. An acceptable draft definition of navitronics could be "the synergistic integration of navigational systems with electronics and intelligent computer control in the design and manufacturing of maritime transportation and industrial products and processes". Thus, navitronics can be viewed as a fundamental design philosophy applicable to a wide range of navigational products and processes.

Nautomatics includes a wide range of activities, from the acquisition and analysis of site-specific spatial data in navigation and development surveys to the maritime application of GIS-ECDIS/ECS, world-wide electronic navigational chart data base WEND, satellite, telecommunication, and remote sensing technologies in environmental management. It includes hydrographic surveying, nautical charting, ocean mapping, wireless communications, GPS tracking, anti-collision and automatic steering - all come under the nautomatics umbrella. It is the combination of safe navigation, telecommunications and information processing.

2. Mechatronics

Mechatronics is the synergistic combination of mechanical engineering ("mecha" for mechanisms), electronic engineering ("tronics" for electronics), and software engineering. The purpose of this interdisciplinary engineering field is the study of automata from an engineering perspective and serves the purposes of controlling advanced hybrid systems.

2.1 Synergy

Synergy or synergism (from the Greek synergos meaning working together, circa 1660) refers to the phenomenon in which two or more discrete influences or agents acting together create an effect greater than the sum of the effects each is able to create independently. Synergism stems from the 1657 theological doctrine that human will cooperates with divine grace in regeneration. The term began to be used in the broader, non-theological, sense by 1925. In the 1960s it was first used to describe supposed economies of scale in business, reappearing in the 1990s as a common business buzzword [1],[3]. Synergy can also mean [6]:

- A mutually advantageous conjunction where the whole is greater than the sum of the parts.
- A dynamic state in which combined action is favoured over the sum of individual component actions.
- Behaviour of whole systems unpredicted by the behaviour of their parts taken separately. More accurately known as emergent behaviour.

2.2 Mechatronics - the Philosophy in Engineering Technology

Mechatronics is centred on mechanics, electronics and computing which, combined, make possible the generation of simpler, more economical, reliable and versatile systems. The word "mechatronics" was first coined by Mr. Tetsuro Mori, a senior engineer of the Japanese company Yaskawa, in 1969, and the company was granted the trademark rights on the word in 1971. The word soon received broad acceptance in industry and, in order to allow its free use, Yaskawa elected to abandon its rights on the word in 1982 [15]. Mechatronics may alternatively be referred to as "electromechanical systems" or less often as "control and automation engineering" [7].

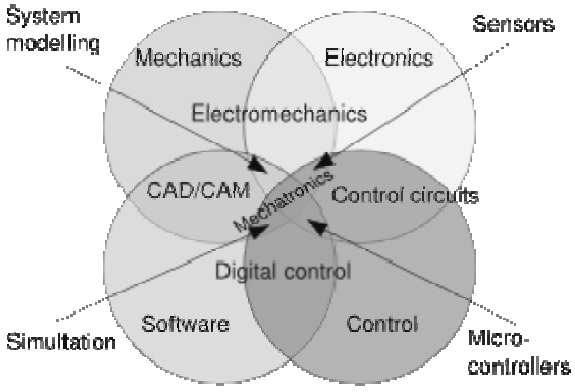

Figure 1. A typical mechatronics diagram - the synergistic combination of several engineering disciplines. Interdisciplinary engineering field of advanced hybrid systems [5],[13]

Since its introduction in the 1970's, mechatronics has been continually evolving. Consequently, there have been numerous definitions and interpretations associated with this term. The word has taken a wider meaning since then and is now widely being used as a technical jargon to describe a philosophy in engineering technology, more than the technology itself. For this wider concept of mechatronics, a number of definitions has been proposed in the literature, differing in the particular characteristics that the definition is intended to emphasize. A widely accepted and the most commonly used definition of mechatronics is "the synergistic integration of mechanical engineering with electronics and intelligent computer control in the design and manufacturing of industrial products and processes". Thus, mechatronics can be viewed as a fundamental design philosophy applicable to a wide range of products and processes.

2.3 Mechatronic Modules

Engineering cybernetics deals with the question of control engineering of mechatronic systems. It is used to control or regulate such a system. A component-based paradigm is a form of distributed control production system which utilises a CAN (Controller Area Network) or LAN (Local Area Network) to link autonomous mechatronic modules. Through collaboration the mechatronic modules perform the production goals and inherit flexible and agile manufacturing properties in the production scheme. Modern production equipment consists of mechatronic modules that are integrated according to a control architecture. The most known architectures involve hierarchy, polyarchy, heterarchy and hybrid. The methods for achieving a technical effect are described by control algorithms, which may or may not utilize formal methods in their design. Hybrid-systems important to Mechatronics include production systems, synergy-drives, planetary-rovers, automotive subsystems such as anti-lock braking systems, spin-assist and every day equipment such as autofocus cameras, video, hard disks, CD-players, washing machines, lego-matics etc.

A typical mechatronic engineering degree would involve classes in engineering mathematics, mechanics, machine component design, mechanical design, thermodynamics, circuits and systems, electronics and communications, control theory, digital signal processing, power engineering, and robotics [9].

2.4 Mechatronics, an Interdisciplinary Sphere of Activity

Mechatronics is an interdisciplinary field of engineering which is based on the classical disciplines mechanical engineering, electrical engineering and computer science. Mechatronic systems are determined by the fact that they record, process and interpret signals from their environment and execute appropriate tasks.

The goal is to extend and supplement mechanical systems with sensors and microcomputers to build intelligent and capable products. Components for such systems emerge from mechanics, electronics and computer technology. Methods to combine these components emerge from systems theory, control, and information technology. The fact that such a system detects changes in its environment with sensors, and reacts to these changes after processing the information, distinguishes it from more conventional machines. Examples of mechatronic systems include robots, controlled combustion engines, anti-blocking breaking systems for vehicles and airplanes, contact free magnetic bearings, active vibration isolation, machine tools with self adapting tools, automatic suspension technology for transportation, micromechanical grippers etc. Typical for such a system is the high degree of system knowledge and software, which is necessary for its development, construction and deployment.

3. Navitronics

Modern navigational systems are characterized by the extensive integration of sensors, electronics, and computers in their operational environment. This integration is essential to meet the increasing demands of customers on the functionality, flexibility, and reliability of industrial and commercial products. A typical example is the modern merchant, navy, fishing or leisure vessel. Compared to its predecessor just twenty years ago, a modern vessel provides a much higher level of ride comfort, handling safety, efficiency and fuel economy. Navigational systems: IBS, INS, ECDIS/ECS, GPS/GNSS, AIS, VDR, Radar/ ARPA, Log/Compass, Echosounder, Autopilot - all of these inventions required a multifunctional, interdisciplinary design and manufacturing approach which can be best described as navitronics, the term created by analogy to mechatronics.

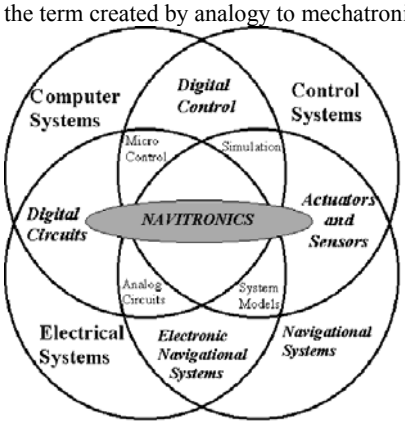

Figure 2. A typical navitronics diagram

The following is a list of subject areas that should be part of the education of an engineer specializing in navitronics:

Navigational Systems:
- Fundamentals of geodesy and cartography (including hydrography and topography)
- Fundamentals of navigation
- Navigational systems: INS/ IBS, ECDIS/ECS, GPS/GNSS, Radar, ARPA, AIS, Log/Compass, Echo sounder, Autopilot, VDR, etc.

Electrical Systems:
- Energy conversion
- Power electronics
- Sensors
- Interfacing

Computer Systems:
- Basic computer systems
- Basic computer programming
- Real-time computer systems
- Micro-controllers
- Interfacing
- Software engineering

Control Systems:
- System modelling and simulation
- Basic control systems
- Digital control systems
- Robotics and automation
- Intelligent systems

Navitronics is synergic design of computer controlled electro-navigational systems. Navitronic design encompasses many of the topics associated with traditional engineering disciplines, as illustrated in the diagram below (figure 3).

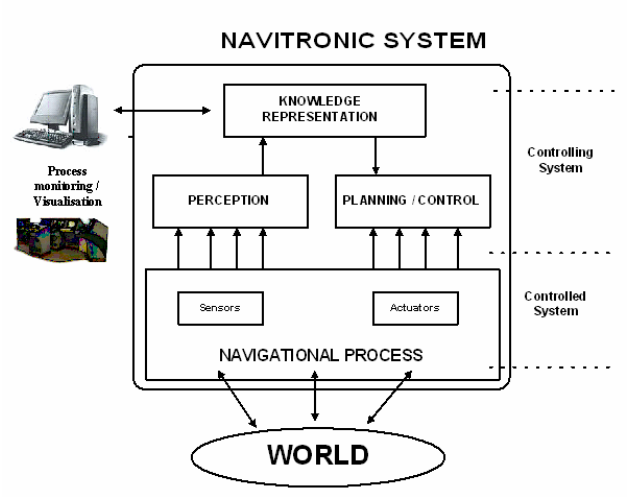

Figure 3. The architecture of navitronics system

4. Geomatics

Geomatics is a field of activities which, using a systemic approach, integrates all the means used to acquire and manage spatial data required as part of scientific, administrative, legal and technical operations involved in the process of the production and management of spatial information.

The definition of geomatics is evolving. A working definition might be "the art, science and technologies related to the management of geographically-referenced information." Geomatics includes a wide range of activities, from the acquisition and analysis of site-specific spatial data in engineering and development surveys to the application of Geographic Information Systems (GIS) and remote sensing technologies in environmental management. It includes cadastral surveying, hydrographic surveying, and ocean mapping, and it plays an important role in land administration and land use management.

The science of Geomatics is the modern scientific term referring to the integrated approach of measurement, analysis, management, storage, retrieval and display of the descriptions and location of Earth-based data, often termed spatial data. These data come from many sources, including earth orbiting satellites, air and sea-borne sensors and ground based instruments. It is processed and manipulated with state-of-the-art information technology using computer software and hardware. It has applications in all disciplines which depend on spatial data, including environmental studies, planning, engineering, navigation, geology and geophysics, oceanography, land development and land ownership and tourism. It is thus fundamental to all the geoscience disciplines which use spatially related data.

Geomatics comprises the science, engineering, and art involved in collecting and managing geographically-referenced information. Geographical information plays an important role in activities such as environmental monitoring, management of land and marine resources, and real estate transactions. The word has been adopted by several international bodies including the International Standards Organisation (ISO).

4.1 Definition of Geomatics

Geomatics, also known as geoinformatics, is the science and technology of gathering, analysing, interpreting, distributing and using geographic information.

Geomatics is the discipline of gathering, storing, processing, and delivering of geographic information, or spatially referenced information.

The term "Geomatics" applies both to science and technology, and integrates the following more specific disciplines and technologies:

- geodesy,
- surveying,
- mapping sciences,
- positioning,
- navigation,
- cartography (hydrography),
- computer systems,
- remote sensing,
- information systems,
- computer graphics,
- photogrammetry,
- land management,
- environmental visualisation,
- Geographic Information Systems (GIS),
- Global Positioning System (GPS).

An alternative view is that geomatics is the measurement and survey component of the broader field of geographic information systems.

The term geomatics is fairly young, apparently being coined by B. Dubuisson in 1969. It is commonly defined to include the tools & techniques used in land surveying, remote sensing, Geographic Information Systems (GIS), Global Positioning System (GPS), and related forms of earth mapping. Originally used in Canada, because it is similar in French and English, the term geomatics has been adopted by the International Organization for Standardization, the Royal Institution of Chartered Surveyors, and many other international authorities, although some (especially in the United States) have shown a preference for the term “geospatial technology”.

The precise definition of geomatics is still in flux. One of acceptable definitions can be found on the University of Calgary's web page [12]:

> "Geomatics Engineering is a modern discipline, which integrates acquisition, modelling, analysis, and management of spatially referenced data, i.e. data identified according to their locations. Based on the scientific framework of geodesy, it uses terrestrial, marine, airborne, and satellite-based sensors to acquire spatial and other data. It includes the process of transforming spatially referenced data from different sources into common information systems with well-defined accuracy characteristics."

A Geospatial network is a network of collaborating resources for sharing and coordinating geographical data, and data tied to geographical references. One example of such a network is the GIS Consortium's effort to provide "ready global access to geographic information" in a framework named the Open Geospatial Network.

A number of University Departments which were once titled Surveying, Survey Engineering or Topographic Science have re-titled themselves as Geomatics or Geomatic Engineering.

The rapid progress, and increased visibility, of geomatics since 1990s has been made possible by advances in computer technology, computer science, and software engineering, as well as airborne and space observation technologies.

4.2 Geographical Information Systems

The idea of GIS is not new. In the mid-1960s it was recognised that digital computers could be used quite effectively to map out and analyze the vast quantities of information being

collected. The resulting statistical and cost-benefit analyses were used to develop management plans for large rural areas. One of the conclusions of the initial effort was that computerisation was going to be the best alternative for developing these management plans, in spite of the primitive computers of that time and their high costs. This new kind of 'computerisation' was called 'geographic information system'. Since that time geography and GIS have enjoyed an especially close relationship.

The main boost towards an integrated transportation scenario may well come from the rapidly-evolving Geographic Information Systems (GIS) which are now gaining credence around the world. There are various justifications for creating these giant data-sets, which share a common spatial referencing facility to enable instant comparisons of related data. It is quite possible, given adequate input, to correlate demographic facts about urban deprivation, the incidence of a notificable disease, to monitor economic progress or define the extent of industrial pollution. GISs therefore appeal to administrators in central government and local authorities, with special merits in planning the physical infrastructure and public services. Links to computer aided design systems used by civil engineers, architects and town planners already exist, and environmental analysis tasks are also feasible. The secret lies in the effective organization of the data, based on the concept that everything occupies a specific place, and can be uniquely identified by classifications and cross-references.

The initial impetus for developing a marine speciality in GIS was the need to automate the production of nautical charts and to more efficiently manage the huge amounts of data that are now capable of being collected at sea. The GIS can provide the data management tool for all the digital hydrographic survey data, providing the functionality to store, retrieve and query information in the underlying database. The database can contain such information as survey parameters and settings.

Definition: A geographic information system is:

- a computer software system (with supporting hardware),
- that manages data pertaining to land, water, and air resources,
- such that one can store and retrieve such geographic information,
- as well as analyze stored information or additional parameters derived from stored information.

Geographic information has been the basic information for navigation at land and at sea as well as for military and administrative purposes since the early beginnings of our culture. Since these early days maps and charts have been used both for displaying the information and as analogue databases, containing the geo referenced data in a graphically fixed form.

GIS is in effect any computer-based system which display graphical information with some intelligence, and it can be argued that an integrated navigation system is a GIS.

GIS is a special-purpose digital database in which a common spatial coordinate system is the primary means of reference. Comprehensive GIS require a means of:

- data input, from maps, aerial photos, satellites, surveys, and other sources,
- data storage, retrieval, and query,
- data transformation, analysis, and modelling, including spatial statistics,
- data reporting, such as maps, reports, and plans.

The most sophisticated maritime application of GIS is ECDIS (Electronic Chart Display and Information System) [17]. ECDIS is an advanced navigation information system, which has been developed to lighten considerably the navigation workload, freeing the mariner for other important navigation-related tasks such as maintaining a safe lookout and for collision avoidance. It is real-time decision aid, which provides the navigator with accurate and reliable information about ship's position and its intended movements in relation to charted navigational features. ECDIS combines satellite position fixing, ship's sensors and other data with a sophisticated electronic database containing chart information.

5. Telematics

Telematics Definition: Using computers in concert with telecommunications systems; The combination of telecommunications and computing (information processing); Data communications between systems and devices.

Originally coined to mean the convergence of telecommunications and information processing, the term later evolved to refer to automation in automobiles. GPS navigation, integrated hands-free cellphones, wireless communications and automatic driving assistance systems all come under the telematics umbrella.

Refers to the broad industry related to using computers in concert with telecommunications systems. This includes dial-up service to the Internet as well as all types of networks that rely on a telecommunications system to transport data.

Telematics is the blending of computers and wireless telecommunications technologies, ostensibly with the goal of efficiently conveying information over vast networks to improve a host of business functions or government-related public services. The most notable example of telematics may be the Internet itself, since it depends on a number of computer networks connected globally through telecommunication backbones.

5.1 Telematics Engineering in Vehicles

Recently, it has been more and more used to mean "automotive telematics," the use of computers and telecommunications to enhance the functionality of motor vehicles, for example, wireless data applications in cars, trucks, buses and vessels.

The term has evolved to refer to systems used in automobiles that combine wireless communication with GPS tracking. The term is further evolving to include a wide range of telecommunication functions that originate or end inside automobiles.

The term has evolved to refer to automobile systems that combine global positioning satellite (GPS) tracking and other wireless communications for automatic roadside assistance and remote diagnostics.

Major automakers are equipping new prototype vehicles with wireless-based services controlled by voice commands. This kind of telematics could enable motorists to perform a variety of wireless functions such as accessing the Internet, receiving or sending e-mail, downloading digital audio and video files, or obtaining "smart" transportation information.

The telematics industry is not limited to automotive applications. Other applications are being studied or developed for monitoring water and air pollution, for medical informatics and health care, and for distance learning. Many European countries are developing uniform policies to integrate telematics applications into government, business and education

5.2 Global Telematics

Global Telematics (founded in 1986) uses the word "telematics" in the broad sense of combining computers and telecommunications, rather than the more recent connotation of "automotive telematics." Computers and telecommunications to improve cars are certainly important, but not the whole story of telematics. Read on for the complete story.

The word "telematics" historically - since 1980 - has meant the blending of computers and telecommunications. Thus, the Internet is an example of telematics, and earlier, the Minitel system in France is an example [12].

Telematics is the English language version of the French word *telematique* - coined by Simon Nora and Alain Minc in the book *L'informatisation de la Societe* (La Documentation Francaise, 1978); translated as *The Computerization of Society* (MIT Press, 1980) [12].

By the mid-1970s, French industries were frightened of IBM and worried about the British experiments in videotext--the (failed) experiment in selling information services to British subjects via their television screens and telephone touchpads. French intellectuals and scientists were beginning to write about the significance of the coming information age. Pressure was mounting on the government and industry to do something more than modernize an antiquated telephone system. In 1978, Simon Nora and Alain Minc submitted a decisive report on "the computerization of society" [4].

Lately, "telematics" has been more and more used to mean "automotive telematics," the use of computers and telecommunications to enhance the functionality of motor vehicles, for example, wireless data applications in cars, trucks, and buses. There have even been attempts by some vendors to narrow the meaning of telematics to what they happen to be selling.

There is a web page called *Telematics Update* that contains many recent news articles on automotive telematics. Global Telematics is a long time supporter of "telematics" for improving how cars and other transportation systems work [14].

6. Nautomatics

In Author's point of view the nautomatics is a field of activities which, using a systemic approach, integrates all the means used to acquire and manage navigational, telecommunications and spatial data required as part of scientific, administrative, legal and technical operations involved in the process of the production, management, processing and analysing of information used to navigation.

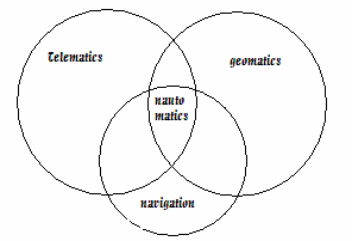

Figure 4. Nautomatics - overlap area of navigation, telematics and geomatics

The Author expects that the definition of nautomatics will be evolving. A working definition might be "the art, science and technologies related to the management of geographically-referenced and navigation-related information." Nautomatics includes a wide range of activities, from the acquisition and analysis of site-specific spatial data in navigation and development surveys to the maritime application of GIS-ECDIS, world-wide electronic chart data base WEND and remote sensing technologies in environmental management. It includes hydrographic surveying, nautical charting, ocean mapping, wireless communications, GPS tracking, anti-collision and automatic steering - all come under the nautomatics umbrella. It is the combination of safe navigation, telecommunications and information processing.

7. An Initial Approach to E-Navigation

The advantage of the latest technical development in the field of automation, electronics, telecommunications, informatics, geomatics and global position fixing techniques, achievement in data storing, processing, analysing, transferring and visualisation must be taken into account and applied to the maritime technology in the very near future. We should build new e-Navigation era using those technologies based on navitronics and nautomatics.

e-Navigation is intended to make safe navigation easier and cheaper [2]:

- e-Navigation is the transmission, manipulation and display of navigational information in electronic formats to support port-to-port operations
- It is needed:
  - to minimise navigational errors, incidents and accidents;
  - to protect people, the marine environment and resources;
  - to improve security;
  - to reduce costs for shipping and coastal states; and
  - to deliver benefits for the commercial shipping industry;
- It can be delivered:
  - using satellite positioning signals underpinned by fail-safe supplementary position signals;
  - displayed in an intelligible and comprehensively integrated format (ECDIS) on board ship and replicated on shore with shore-based monitoring and intervention capability.

The IMO Maritime Safety Committee decided to include, in the work programmes of the NAV and COMSAR Sub-Committees, a high priority item on "Development of an e-navigation strategy", with a target completion date of 2008 and with the NAV Sub-Committee acting as co-ordinator. NAV 52, which met in July 2006 gave preliminary consideration to this important topic. The first step to e-Navigation was done [16].

The aim is to develop a strategic vision for e-navigation, to integrate existing and new navigational tools, in particular electronic tools, in an all-embracing system that will contribute to enhanced navigational safety (with all the positive repercussions this will have on maritime safety overall and environmental protection) while simultaneously reducing the burden on the navigator. As the basic technology for such an innovative step is already available, the challenge lies in ensuring the availability of all the other components of the system, including electronic navigational charts, and in using it effectively in order to simplify, to the benefit of the mariner, the display of the occasional local navigational environment. E-navigation would thus incorporate new technologies in a structured way and ensure that their use is compliant with the various navigational communication technologies and services that are already available, providing an overarching, accurate, secure and cost-effective system with the potential to provide global coverage for ships of all sizes.

8. Conclusion

In the paper Author proposed to use two new terms: navitronics and nautomatics, as an initial approach to e-Navigation development. It is the result of his more than 20 years experience in teaching and research works in the field of maritime navigation, sea transport, hydrography, cartography, geodesy and safety at sea, especially in the field of ECDIS and electronic navigational charts. It was very difficult for him to clearly define in few words his area of interest. Now it is much easier, we can say he is an expert in navitronics and nautomatics.

It has been said that nautomatics can be many things to many people, but they can be generally accepted as the science and technology of acquiring and managing navigational information about our world and its environment. The term represents the rapidly changing and expanding world of navigational information management, which consists of measuring, mapping, geodesy, satellite positioning, hydrography, computer systems, remote sensing, information systems, telecommunications, environmental visualization, computer graphics etc. Navigation information management also includes the various stages of data acquisition, manipulation, display, management and transfer. As you can see it takes a lot of words to explain what it is all about, hence the word nautomatics.

Navitronics is an interdisciplinary field of engineering which is based on the classical disciplines: navigation, electronics and computer science. It is the synergistic combination of navigation ("navi" for navitation systems), electronic engineering ("tronics" for electronics), and software engineering. Navitronic systems are determined by the fact that they record, process and interpret signals from their environment and execute appropriate tasks.

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