Professor Alberto M. Cuitiño
American Academy of Mechanics
School of Engineering
Rutgers University
98 Brett Road
Piscataway, NJ 08854-8058

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SELECTION OF THE EDITOR

Automatic Control - Can We Do Without It?

Seminar for Students at Bosphorus University, Istanbul, on March 24, 2005

Senol Utku, Sc.D.

Professor (retired), Department of Engineering Sciences, Faculty of Arts and Sciences
Istanbul Technical University, Istanbul, Turkey
&
Professor Emeritus, CEE and CS Departments
Duke University, Durham, NC, USA

Abstract

In this work the similarity between the control systems of living creatures and those of engineered products is discussed. The need for control, the elements of control, the hierarchy and diversity of control, human operator in control loop, open loop and closed-loop automatic controls are shortly reviewed. Then the answer of the question of whether the modern life can continue without the help of automatic control is sought.

1. Introduction

In daily life, the word "control" may bring to the mind an undesirable political attitude for individuals, organizations and nations. Yet the control is essential, in various degrees, for many *systems* and *products*[1] to fulfill their functions.

Consider, as an example, a young person wishing to drive in the busy roads of a large metropolitan area. That person needs to learn not only the efficient use of the means provided in the hardware to control the motion of the motor vehicle, but also all the traffic regulations in order to take advantage of the privilege of driving a motor vehicle without hurting himself/herself, others, the car itself, and all the other properties around. After proving by various tests that the learning process has been successfully completed, that person is granted a driving license to show that he/she can use this privilege by always remembering that the driver is responsible for the consequences of all wrong actions of the driver during the drive.

As the example shows, various levels of control systems are at work here. By continuously observing rapidly changing driving environment, the driver makes successive decisions for the proper use of the means provided in the motor vehicle hardware in order to control the vehicle's motion. By doing so, the driver cooperates with

- The traffic controllers to do their job in controlling the traffic system to function as planned,
- The motor vehicle so that the internal control systems of the motor vehicle start, stop, and function properly, and
- The biological systems in the immediate vicinity of the motor vehicle, such as a running cat or child on the road way or a pedestrian on the crossing, so that they can use their own control systems to protect themselves from impending danger.

In fact, the civilized life requires rules, regulations, and tolerances for all these control systems to work in harmony. This ensures the continual flourishment of our species in a world where our bodies are created to accommodate its slowly changing characteristics and are controlled by its rapid changes.

[1] Without going too much into the semantics of the words, in this paper, the word systems will be used to mean both *systems* and *products*.

Following this introduction, i.e., Section 1, the similarities between biological and engineered systems are briefly observed in Section 2, the necessity of control systems is briefly discussed in Section 3. Section 4 looks into the components of control systems in biological or engineered systems. Diversity in control systems is discussed in Section 5, the use of human operator in the control loop is looked into in Section 6, and the open loop and closed-loop automatic controls are discussed in Sections 7 and 8. With the help of the preceding discussions, the answer of the question of "**Can we do without automatic control?**" is sought in Section 9. The work ends with the conclusions that are drawn from all earlier discussions.

Encouraged by David Hilbert, the distinguished German mathematician of last century, who discussed highly mathematical ideas in his famous work of *The Geometry and the Imagination*[2] without any equation, no mathematical symbolism is used in this work in order to communicate with a widest audience possible. The danger of this is that the words in natural languages can have more than one meaning and thus may cause to multiple interpretations[3]. Being aware of this, the author intends to conduct the seminar in Turkish, and hopes to prevent any possible confusion by providing the English version of the paper with its Turkish translation, as a handout to the participants.

2. Similarities between Biological and Engineered Systems

A biological system is designed by its creator, and an engineered system is designed by human beings. From the control standpoint, biological and engineered systems look alike. It seems human beings learn from the biological systems of nature and they create the engineered systems of their own in order to increase the likelihood of their survival individually and collectively for aeons against natural or man-made dangers.

A biological system, be it a bacteria, or a more advanced organism, tries to keep itself at any desired state as long as possible by using minimal energy. A biological system is provided with

- Appropriate sensors to perceive, perhaps selectively and in quanta, the changes in its immediate environment,
- An explicit or implicit processing system to evaluate the perceived changes in relation to a desired state,
- The means that can be activated to maintain the desired state, and
- The capability of creating its duplicates to ensure the continuation of the species.

Humans can create many of their engineered systems by imitating the biological and/or other systems that they can observe and using the available technology, in order to increase their life-span individually or collectively.

Many familiar engineered systems are passive systems. Passive systems, once they are created, remain unchanged, until the benefit from their usefulness drop below the cost of repairing, renewing, updating, or replacing with a more advanced system. These systems are designed to endure the changes in their environment all through their design life, safely and without intervention. If their usefulness decrease by time, and their repair or duplication cannot be made easily and economically, they may be replaced with better systems taking advantage of advancing technology and economy. Almost all of the engineered systems before the start of Twentieth Century were passive systems, such as roads, railroads, waterway, houses, etc. One tends to believe as if they were modeled after the passive systems of animals of lower intelligence, such as beehives, ant dwellings, ant trails, beaver dams, spider webs, etc. .

Some other engineered systems imitate biological systems, partially or extensively[4], in order to extend their useful life in their changing environment. These systems are designed basically like the passive

[2] *The Geometry and the Imagination*, English Translation of "*Ansch Auliche Geometrie* by D. Hilbert and S. Cohn-Vossen, 1932, Springer Verlag, Berlin", Chelsea Publishing Company, New York, 1952.

[3] This was observed by Jacques Derrida, famous deconstructionist French philosopher, as he was trying to understand Jean Jacques Rousseau from texts written in French during Rousseau's time, and by linguist Chomsky at M.I.T. who witnessed and probably smiled at the computer translation of the Russian daily newspaper Pravda by IBM 704 computer of M.I.T.'s Computation Center, in the late 1950's.

[4] We will not talk about self-generating systems in this work.

systems, except for they are provided with tools that can help them to adapt to the changing environment, either with human help or autonomously, or both. Such systems are called intelligent systems. They include observation systems, communication networks, modern motor vehicles, power networks, research and industrial robots, etc.

3. Necessity of Control Systems

All biological systems possess appropriate **sensors** to perceive the change in the environment, appropriate **processors** to evaluate what it takes to minimize a possible adverse effect emanating from the perceived change, and appropriate implementation tools called **actuators** to implement the evaluation. In a biological system, the sensors, the processors and the actuators are connected in a loop that makes the control system of the biological system. It is the capacity of the control system that makes us say, for example, "a very intelligent animal", "an intelligent animal" or "a dumb animal", etc. It is the control system that makes a biological system live efficiently and safely. Without their control systems, biological systems cease to exist in a world that continuously changes. In other words, life exists so long as it adapts to its ever-changing environment.

Since the imitation is in human nature, and the modern technology is available for us to create control systems suitable for our passive systems, we may expect more intelligent systems in use in our modern life. However, there are factors that slow down the wider acceptance of intelligent engineered systems. These are basically the same as those related to many new commercial products:

- Individuals prefer the products that they are familiar with.
- Individuals prefer user-friendly products.
- Individuals prefer less costly products.
- Individuals prefer reliable products.
- Individuals prefer products with longer useful lifetime.
- Individuals prefer products that do not mess up their environment.
- Individuals prefer products that serve them without ever hurting them.
- Individuals prefer products with minimal maintenance.
- Individual prefer products that can be replaced easily and with small cost.

On the basis of these and other similar criteria, there is a long and difficult time for the wider acceptance of intelligent engineered systems over the corresponding passive ones. Intelligent engineered systems will be readily accepted only if there is no corresponding passive system for the job.

Luckily, modern life with ever increasing human population of the world requires intelligent engineered systems for many functions in our collective life that is becoming increasingly complex with increasing population. Intelligent engineered systems, in turn, require control systems.

4. Control Systems

Before we start describing a control system, it is beneficial if we discuss briefly the control system of a biological entity. For example, let us discuss the driver we referred to in Section 1.

The driver has ears to hear, eyes to see, a skin to feel, a tongue to taste and a nose to smell. These are the sensors that make him/her aware of some of the changes in his/her environment. The driver has also a brain to record the information he/she gains throughout his/her life. A quantum[5] of sensory information that is obtained by the sensors is carried to the brain through the nerve system. As it is stored there, consciously and/or unconsciously it is also evaluated with respect to the desired state defined by the driver's will, or with respect to a default state defined by instincts. As a result of this comparison a plan materializes in the drivers mind that is ready for implementation by the driver's muscular system. The brain issues neural signals to the muscles to implement the plan. This process is repeated by the ensuing quantum of sensory information and/or by the driver's updated will.

There are modern control systems that are very similar to the biological control system of the driver, crudely described above. A modern control of this type also has sensors and the means of passing sensory information to its on-board computer. The on-board computer is capable of evaluating the sensory information just received, with respect to a desired state considered for the system, and then it computes the signals that are to be sent to the system's actuators for implementation in order to keep the system in the desired state. Similar to its biological model, the basic

[5] The nerves transmit information in discrete pulses and/or packages, i.e., in quanta.

process is repeated cyclically. The number of cycles per second is called the control frequency and the time for a cycle is called the control cycle time. The control cycle time is a function of how fast the observed environment is changing.

Many modern control systems use digital[6] computers instead of the analogue[7] computers. The use of digital computers increased the capabilities of control systems greatly and decreased their cost. In digital control systems the analogue sensory data need to be digitized and the computed control signals need to be in analogue form since the actuators are in general analogue devices. These do not cause any difficulty, since the analogue-to-digital and the digital-to-analogue converters are widely and economically available in the market place. For these reasons, in many jobs, the digital control systems are favored over the analogue ones.

5. Diversity in Control Systems

There are other digital control systems, which are different then the one described above. Since the driver mentioned in Section 1 is basically an autonomous system, that is, a system that can function as he/she pleases, the corresponding engineered system is an autonomous robot, like the Honda robot, which is being frequently shown in television advertisements recently. The digital control system described in the previous section is more suited to the Hondo robot. They fall into the category of closed-loop control systems that is discussed further in Section 8.

The control system of an industrial robot arm that repeats the same actions on and on again is quite different. In these systems, sensory information may be used only to improve the performance of the robot arm, but, theoretically, is not necessary. The actions of the robot arm are obtained by playing back the recordings of the desired motion of the robot arm. These type of control systems fall into the category of open-loop control systems. For example, the ATM machines (Automatic Teller Machine) that many of us use daily constitute a good example of open-loop control system. A more obvious example of the open loop control systems is a personal computer executing a non-recursive code.

In many control systems the on-board computer is replaced with human operator, which may risk the safe operation of the controlled system because of several fundamental limitations of human species, such as the narrowness of the bands of functionality of their anatomy, physiology, psychology, and ethics. Human beings are very good in learning and creativity but rather inefficient in carrying out routine processes. Perhaps, the widespread availability of microprocessors at extremely low prices and their ubiquitous use in every phase of modern life are caused by the implicit or explicit realization of this fact.

It is interesting to study the history of civilizations from the control point of view. In the **sensor-processor-actuator** loop of a control system, the human operator has been used for any one, or two, or three item(s) in the loop. These will be looked into in the next section. The modern technology is providing more capable alternatives than the human operator for each of the three control items to increase the efficiency of the control system. This trend may encourage people to direct their attention towards what is their real strength: learning and creativity.

6. Human Operator in Control Loop

As mentioned in the previous section, depending upon the objective of the control system, human operators can function, as sensors, and/or as actuators, and/or as on-board processor. With the advent of power tools, the fields where human beings can function as actuators are rapidly dwindling. All things considered, the cost of human operators as actuators is becoming very large compared to machines, as far as maintenance, energy requirements, precision, and ethical understandings are concerned. We use tractors and other machinery in agriculture, bulldozers and other machinery in construction, power cutters and grinders in tunneling and mining, machine tooling in making precision equipments and chirurgic operations, and robots for space and underwater works.

Human beings are also being used less and less as sensors. The range of usefulness of human sensors for the individual human being is extremely well adjusted. However, depending upon the objective of the control system, human operators as sensors may become a handicap because of the weakness inherent to Homo sapiens as shortly touched in the previous

[6] The term "digital computers" refers to machines that process discrete data. Presently in the world few words have wider usage than the word "digital".
[7] The term "analogue computers" refers to machines that process non-discrete data.

section. For example we cannot see outside a certain frequency range of electro-magnetic radiations. Likewise we cannot hear outside a certain frequency range of mechanical vibrations. It is impossible for us to feel temperatures below, say, -10^{o}C or above 80^{o}C, and distinguish impedances of a piece of granite rock and a chunk of iron. We cannot observe events that take place within a blink of eye. A human operator, because of human handicaps mentioned earlier, cannot reliably convey what he/she observed for serious processing[8]. Since the technology is providing many powerful sensors economically, there is no place for human operators as sensors in control loops, except for very simple jobs. With the modern sensors, we can see our heart working, our brain trying to solve a mathematical problem, the thermal processes taking place on the surface of the Sun, the planets of Saturn, the planets of a small star in the Andromeda galaxy, …

A human operator as the on-board computer of the control systems of many intelligent systems has been the only way until the computer era started by late Nineteen Forties. As faster machines with larger memories become available, the need for human operators is decreasing rapidly. However there are still many intelligent systems that require control systems with human operator as the on-board computer. The advantage of human operators is that they can use not only their brain as a processor but also use their sensing organs as sensors. For example, consider the driver and the motor vehicle system discussed shortly in Section 1. Suppose the motor vehicle is an automobile functioning as a taxicab. The taxidriver-taxicab is an intelligent engineered system with a control system where the human operator plays the role of "on-board computer and sensors" with higher authority. Suppose the job of this intelligent system is to take a customer from point A and drive him to point B. The human operator helps the taxicab, i.e., the intelligent system, to complete the trip, safely, economically and quickly by using all his/her previous knowledge represented by his/her driving license, his/her experience in the area containing points A and B, and his/her own sensory information about the continuously changing environment. Those of us who can appreciate the breakthroughs in sensor, communication, processing and actuation technologies, can feel that the time is closer than many think, when going from point A to point B even in a large metropolitan area, safely, economically and quickly can be completely automated both for both personal or public transportations of all kinds (railed, laned, sea, or air).

As another example of intelligent systems where human operator included in the control loop, is a ferryboat that allows motor vehicles and their passengers to embark at point A and to disembark at point B. The captain of the ferryboat with information previously stored and/or continuously fed during the trip into his/her brain, can help the boat to complete the trip safely, economically, and in time. However, there are no technical difficulties even now for the ferryboat to do the job autonomously like the drones being used in Iraq or Afghanistan for military purposes, or like the research robot vehicles Spirit and Opportunity[9] on the Martian surface.

7. Open-loop Automatic Control

As mentioned earlier the industrial robot arm is a good example of open loop automatic control. Here classical **sense-process-actuate** loop is modified as **playback-process-actuate**, that is, the sensing is replaced by playing back. In an industrial robot arm, such as puma robot arm, the time histories of the degrees of freedom of the motion are prerecorded from a virtual[10] or actual trajectory of the arm. Then, in place of sensing the trajectory of the arm, the recorded information is played back in successive steps. At each step, the processor computes or copies the controls from the played information and actuates the appropriate actuators in the proper amount to move the arm along the desired trajectory at the desired speed. For additional precision, sensor input may be routed to the processor to overcome occasional real time difficulties.

[8] We usually perceive the images on the retina after they pass through the filters of our mind, which are created with our life-long experiences. By showing successively two pictures that are almost the same but different in finite number of details, Dr. Güven Güzeldere (Assoc. Professor of Philosophy and Assoc. Professor of Psychological and Brain Sciences and of Neurobiology, Duke University; also '86 graduate of Computer Engineering of Bogazici University) surprised me in an interdepartmental talk in 1999, that I was more an aeronautical engineer familiar with the jet engines than a shopping person in a vegetable and fruit bazaar. I could recognize immediately that an engine was missing in one pair of pictures, but could not see the difference in tomatoes in the other pair that he showed us in the seminar.

[9] See *Scientific American*, March 2004 Issue, pp. 24-29.

[10] Simulated, but not imaginary.

We all know about the last year's Istanbul-Ankara fast train accident where the human operators failed to adjust the speed of the train according to the posted signs. With the present technology, it is rather trivial undertaking to run the train over the existing tracks by an open loop automatic control scheme by playing back the speed and the sign records of a careful run of the train from Istanbul to Ankara (and Ankara to Istanbul for the return trip). For safety, sensor input may be routed to the processor to overcome the real time changes in the sign and/or rail system.

As discussed earlier, to run a non-recursive computer code in a digital computer is also an open loop control as far as the computer system is concerned. When the control of the machine is transferred to a non-recursive code, the whole system acts according to the wishes of the code's creator to produce the planned output. Any commercially available software controls a **computer system**[11] in the open control mode, according to the instructions contained in the software, once the control of the machine is transferred to the software.

This example may bring to the mind the question of if the operating systems used in the computers are open loop control systems. In fact, they are. For example, the Windows operating system is an open loop control system to regulate the executions of software in personal computers[12].

Many modern factories are run in open loop control mode in order to lessen the accidents and increase the production efficiency obeying the rules and regulations compatible with international standards. The complexity of modern life shared by more than six billion people in outrageously unfair amounts forces the industry more and more to automate itself in the open loop control mode. Probably large-scale disasters like Bhopal, Three Miles Island, Chernobyl, Exxon Valdez, and recently the Indonesian Tsunami are increasing the rate with which we employ automation in the open loop control mode.

8. Closed-loop Automatic Control

This type of control is useful for applications when one cannot make any reasonably safe estimate of the system's environment in the future. It requires the knowledge of the desired state of the system for the present and also for the future.

For each sufficiently small time increment sensors **measure** the deviations from the desired state and route this information to the on-board processor with appropriate software to **assess** what it takes by the available actuators to bring the system back into its desired state, and then the processor activates the actuators with the assessed amount(s) to **implement** the correction. This measure-assess-implement cycle is repeated with a rate that depends on the rate of change of the environment, the corrective power of the actuators, the assessment speed of the processor, and the communication time among control elements consisting of sensors, processor, and actuators.

The inverse relation between the measured deviation (also called sensor **input**) and the assessed amounts for implementation (also called **control**) is called **control law**. In systems where the change in state can be described by a single scalar input $\otimes y$, and the corresponding control by a single output $\otimes u$, the simplest control law may be expressed as $\otimes u = g \otimes y$ where g[13] is a scalar that can be obtained by trial and error experiments of the technician in charge of the device. Control systems involving a single control variable are called **single variable control** systems.

When the incremental input is a vector with n components, then the corresponding output will also have to be a vector with n components. This is called **multi-variable control**. In multi-variable control, the simplest control law requires the determination of an

[11] Which is an **adaptive electrical network** that changes its connections in real time according to the code it is executing. This brings to mind the **adaptive mechanical networks** that can change many of the mechanical network attributes in real time. For a discussion of adaptive mechanical networks, see "***Adaptive Structures***, *Senol Utku, CRC Press 1998, New York*".

[12] The author remembers his first experience with the IBM704 computer in the computation center of MIT during 1958-59 academic year. At that time the users used to punch their instructions on IBM cards. The deck of cards, called programs, were given to the machine's human-operator, who, in turn, run the programs on the "early come early served" basis, each time by reinitializing the machine, loading the program, hitting the start button, and waiting for the "halt" signal on the consol in order to repeat the process for the next program. IBM Corporation soon found out that to use a human-operator for the task was too expensive. IBM replaced the human-operator with an operating software. The human operator was not reliable and capable for the orderly run of their fast and expensive machines.

[13] The first letter of word "gain", which is widely used in control literature.

nxn coefficient matrix, which is not a trivial problem. If the mathematical relationships defining the state of the system as a function of time, i.e., the equations of state are known, the control law may be obtained from the equations of state.

Most biological systems use closed-loop multi-variable control systems. For biological systems the desired state may be expressed as a multi-component vector and it is defined by the motto of "live as long as possible by using as small energy as possible". At the pinnacle of biological systems sit Homo sapiens sapiens. Since they have larger brains, they have a much better processor to cope better with the changes in their environment by using minimal energy. Since their creation, they learned the advantages of living together, cooperation, making tools, recording individual experiences in external media and thus transferring individual knowledge and know-how to future generations. It is only in human species that individual life experiences are passed to ensuing generations by non-hereditary means. With the accumulated information in the external media, human beings are now capable of creating multi-variable closed- loop controlled systems like themselves.

In feedback systems involving the motions of rigid bodies, such as airplanes, ballistic missiles, etc., there may be at the most 12 state variables, i.e., six velocities and 6 positions. In spite of this small number of state variables, we have lost lots of ballistic missiles[14] and drone airplanes before we managed to closed-loop control the motions of these rigid bodies. The control laws for these systems are obtained by mathematical processes that start with the Newton's laws that are cast as equations of state of the rigid body dynamics.

The autonomous motion control of flexible bodies is a much harder problem since the number of state variables can be extremely large, and the equations of state involve not only the Newton's laws but also the Euclidean geometry and the constitutive laws of material of the flexible body. The autonomous control of motion is necessary in the precision structures such as radiofrequency (RF) antennas[15], Hubble type orbiting telescopes, and also earthbound structures that house precision-instruments and/or nuclear-energy generators.

Multi-variable closed-loop control of non-mechanical systems, such as economics systems, banking systems, judicial systems, medical systems etc., poses a much harder problem, since the equations of state for such systems are either not known or known very little.

9. Can We Do Without Automatic Control?

A happy shepherds man can continue his life without many of the amenities of modern life for a very limited time. He is always under the scare of a wolf attack or extreme cold in the wintertime, or anthrax bacteria, draught and flooding all the time, and he will have terrible time in finding a match to raise a family deprived from medical care. Life is practically impossible without modern amenities.

As we have seen by some examples in earlier sections that the automatic control is the key player in every advanced system of modern times. Stock exchanges, banking systems, economic systems, transportation systems in land, sea, air and space, industrial systems of all kinds, communication systems, entertainment systems are all use automatic control at various levels.

"Why is this happening?" is a more interesting question; since in its answer lies the principle in the creation of living beings every where: "try to live as long as you can by using as little energy as possible". We human beings are social animals with higher intelligence. We have learned long time ago that by organizing our efforts we can get much better efficiencies in solving our collective problems, especially the ones originating from the nature itself. Although improvements are necessary, the results so far are very good. We now can cope with diseases much better, we can communicate better, travel better, learn better, eat better, entertain better so long as we cooperate with the social system. We are much better off than the sheep herdsman trying to live alone.

[14] The V2 missiles during the Second World War are first examples of self-controlled rigid bodies. They were followed by the ballistic missiles of Cold War, and the booster rockets of space age.

[15] A well-known example is the 100 meters by 110 meters offset paraboloidal radio frequency antenna that is known as the Green Bank Telescope in Pocahontas County, West Virginia. U.S.A. One may refer to the Internet site at *http://wwwlocal.gb.nrao.edu/GBT.GBT.hstml* for more information on this remarkable motion and deformation controlled structure.

After the natural forces, our greatest enemy is the population increase. The complexity of our social problems is increasing exponentially. The human population of earth passed the six billion mark. By improved communications, much more people is becoming aware of "dolce vita", i.e., the amenities of modern living, and trying to incorporate some aspects of it to their own lives. We have come to a stage to worry about how to meet the needs of six billion plus individuals. We cannot use the switchboard operators to plug the lines to establish the telephone communication between any two individuals. This would mean about 60 million switchboard operators and probably hundreds of hours wait-time to establish the connection. We had to use automation to establish the connection, and we have done a superb job in connecting almost instantaneously any two cell phones located at any two points on the surface of the earth. From transportation, to car manufacturing, from power distribution to microprocessor production, we have done marvelous things by means of automatic control.

With an ever-increasing rate, the human beings are being excluded from important control loops, because of finiteness of their sensing, processing and physical work capabilities. It takes 13 or so milliseconds before I sense that a hot object is burning my skin. I cannot see anything if the number of photons hitting my eye is less than a certain amount. I am not aware of any electromagnetic radiation outside the range that my eyes are created for. I cannot hear mechanical vibrations with frequencies outside my audible range. My attention span is not continuous and has to be broken by sleep, feed and relaxation cycles. I have to be fed properly, breath proper air. I should not be a subject of accelerations beyond a couple of g's. I cannot bear pressures above 100 meters of water, and less than so many millibars. I can pay attention only one thing at a time, provided that I am not upset. I should not be tempted to do wrong things because I am only a human being with different convictions and beliefs. Knowing all these, I cannot and should not be trained for things that require abilities beyond the ones I have. If you force me, then I may become nasty or scared or act as if I am doing them, and this may cause accidents, hurting not only myself but also many in my vicinity.

Although we humans are weak in many areas, we are extremely creative and resourceful in many other areas that count. By taking advantage of the creative thinking of preceding generations, we have created computers, around the middle of the preceding century, that could do arithmetic operations with a couple of kilo flops[16] rate. That was enough for us engineers to switch to numerical[17] solutions of very difficult partial differential equations instead of trying to obtain solutions in terms of previously tabulated functions of calculus[18]. We developed algorithms to solve many mathematical problems with the basic **retrieve-process-store** cycles of digital computers. At the time I retired from Duke University in 2002, we were talking about machines in the upper Giga flops rate. According to *New Horizons for Information Technology*, a publication of *Scientific American*, we are now talking not about Tera flops, not about Peta flops, but about above Peta flops rates. These fast computation rates, of course exert pressures on digital automatic control schemes with **sense-process-actuate** cycles. The needs created by population increase, coupled with advances in communication technologies and the pressures exerted by fast advancing digital computer technology are, luckily, creating an environment that excludes me and my fellow humans altogether in most of the routine operations of collective life.

Luckily, I can do many things with my natural abilities and live a happy and contributing life, and leave the things beyond my abilities to the automated systems that work for public good.

The time is almost here for human beings to spend more time to take care and to teach each other for social harmony, to create appropriate psychological and ethical medium for social life, to improve their physical and mental capabilities for personal satisfaction, and to output individually and collectively their creations for individual and collective good.

In short, the information provided in the earlier sections may convince us that the modern collective life cannot continue without automatic control.

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[16] Floating point operations per second
[17] But not digital
[18] In 1960, during the open defense of my doctoral dissertation in M.I.T.'s Civil Engineering Department, "***Use of Digital Computers in the Stress Analysis of Thin Shells***", I remember this observation had upset, to my chagrin, my Elasticity Professor Eric Reissner in the Mathematics Department.

10. Conclusions

Owing to the global consciousness of our species, our habitat and our limited individual abilities, we have to use autonomous systems more. The wider use of control systems requires a basic understanding of automatic control by all, and deeper knowledge of control theories by professionals, just as it was for the digital computers some 50 years ago.

BOOK ANNOUNCEMENT

New Book Announcement: Fluid Structure Interaction and Moving Boundary Problems

WIT Press has announced the recent publication of Fluid Structure Interaction and Moving Boundary Problems. The book consists of over 60 papers presented at Fluid Structure Interaction: Incorporating an International Seminar on Computational Modeling and Experimental Measurements of Free and Moving Boundary Problems, which was held September 19-23, 2005, in La Coruña, Spain. The contributions included will be of particular interest to structural, offshore, naval and earthquake engineers. The book is divided into two parts. The first part deals with Fluid Structure Interaction problems and the second with Moving Boundary studies. The papers are organized into the following sections: Fluid Structure Interaction: Advances in interaction problems in CFD; Cavitation effects in turbo machines and pumps; Computational methods; Fluid and biological tissue interaction; Fluid pipeline interactions; Hydrodynamic forces; Mechanics of cables, risers and moorings; Offshore structures and ship dynamics; Response of structures including fluid dynamics; Structure response to severe shock and blast loading; Wind effects on bridges and towers. Moving Boundaries: Free surface flows; Computational fluid mechanics; Phase change; and Advanced computational simulation.

Fluid Structure Interaction and Moving Boundary Problems is Volume 84 in WIT Press's WIT Transactions on the Built Environment. Abstracts (free) and full text ($30 per paper) of individual papers in the book are available through the electronic edition of the Transactions at http://library.witpress.com/.

A post-conference report for the FLUID STRUCTURE INTERACTION 2005 conference is available at http://www.wessex.ac.uk/conferences/2005/fsi05/index.html. Full contents details on the book can be found at http://www.witpressusa.com/acatalog/0276.html.

Book Information:

Title:	Fluid Structure Interaction and Moving Boundary Problems
Edited by:	S. CHAKRABARTI, Offshore Structure Analysis Inc., USA, S. HERNANDEZ, University of Coruña, Spain; and C.A. BREBBIA, Wessex Institute of Technology, UK
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