The Entanglement of Control and IT: Intelligent Control in Mechatronics

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(With acknowledgments to Randy Glasbergen)

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Where is Istanbul? In Asia or Europe?

BOTH! It is the only city in the world on two continents!

Robert College was founded in Istanbul on September 16, 1863. On September 10, 1971, Bogazici University was officially established on what had been the Robert College campus for over one hundred years.

Enrollment:
TOTAL: 11206
Undergraduate: 8587
Graduate: 2619
The student community includes 456 foreign students from 45 different countries.

Department of Electrical and Electronics Engng.

• The most prestigious department in Turkey (one has to be among the top 700 or so out of more than a million).
• ABET accredited.
• BUEE currently has 25 faculty members, 22 teaching assistants, and several technical staff serving around 300 undergraduate students.
Okyay Kaynak’s presentation

Impact of Information Technology on Manufacturing

Before 1970
70s and 80s
90s - Present
Future

- Mechanical
- Electrical
- Software

Source: Dr. Sujeet Chand, Rockwell Automation (IFAC World Congress 2005)

The Dozens of Computers that Make Modern Cars Go

- The electronic systems in modern cars and trucks are packed with up to 100 million lines of computer code, more than in some jet fighters.
- “It would be easy to say the modern car is a computer on wheels, but it’s more like 30 or more computers on wheels,” said Bruce Emaus, the chairman of SAE International’s embedded software standards committee.
- Even basic vehicles have at least 30 of these microprocessor-controlled devices, known as electronic control units, and some luxury cars have as many as 100.

The Evolution of Technology

Hunting/Survival to 10 K BC
Agricultural Revolution 10 K BC to 1800 AD
Industrial Revolution 1800 to 1960
Information Revolution 1960 to 2015
Nano, Biotec, Cogno???

Industrial Revolution

- First Phase (1780-1840): UK centered
  - Steam Turbine
  - Textile Engineering
  - Machine building
- Second Phase (1840-1900): Europe Centered (Ingiltere, Almanya, Fransa)
  - Railways
  - Iron and Steel Industry
- Third Phase (1900-1950): North America Centered
  - Electrical Machines
  - Chemical Industry
  - Automotive Engineering
  - Durable Household Goods
- Fourth Phase (1950-1960): Pacific (Japan, California) Centered
  - Synthetics
  - Organic chemicals
  - Computers

The Next Industrial Revolution

- Fifth Revolution (2015 - ??): Based in Developing World?
  - China? India?
  - Nanotechnology
  - Molecular Manufacturing

20th century

- First half: Hardware dominated
- Early second half: Software dominated
- Last 10-15 years: Fusion of technologies
  - Optics and electronics: Optoelectronics
  - Electronics, mechanics and intelligent computer control: Mechatronics
  - Communication and computers: IT
  - IT and Biology: Bioinformatics
  - ?????
Okyay Kaynak’s presentation

**Hardware Age**

**Software Age**

**Information Age**

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**Erosion of Boundaries in the Information Age**

- Between industrial sectors,
- Between products and services,
- Between producers and users,
- Between IT, communications, media, consumer electronics,
- Between IT and non-IT industries,
- In R&D between academia and industry between disciplines, between theoretical and applied research.

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**Trend**

- Advances at the edge of traditional disciplines
- Connections between different disciplines becoming the core of technologies (not multi, not inter but transdisciplinary)

**Convergence**

-blurring

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**NBIC(S)**

- The convergence of Information Technology, Cognitive Science, Nanotechnology, Biotechnology and sometimes (Sociology)

**Convergence Fuels convergence**

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**The Era of Tera!**

| **Worldwide Optical Content** | 103 TB |
| **Worldwide Printed Content** | 1,633 TB |
| **U.S. Broadcast Media** | 14,893 TB |
| **Worldwide Filmed Content** | 420,234 TB |
| **Internet** | 532,897 TB |
| **Worldwide Magnetic Content** | 4,999,230 TB |
| **World Telephony Calls** | 17,905,340 TB |
| **Electronic Flow of New Info** | 17,905,340 TB |

- Byte = 8 bits, Kilobyte = 10^3, Megabyte = 10^6, Giga = 10^9, Tera = 10^12, Peta = 10^15, Exa = 10^18, Zetta = 10^21, Yotta = 10^24
It is the study of mind and intelligence embracing philosophy, artificial intelligence, neuroscience, linguistics, anthropology.
The Era of Zetta!

The Zettabyte Scale

- Zettabyte
- 120,000 Terabytes or 5,000,000,000,000,000,000,000,000,000,000 bytes
- Capacity of all books ever written
- 200 Terabytes
- A single movie
- 3 Petabytes
- 1,000 Terabytes or 400 million DVDs
- 1 Exabyte
- A complete set of all books ever written
- 5 Exabytes
- 5 Exabytes
- 10 Exabytes
- 1 Zetta byte
- 20,000 CDs or 100 billion DVDs
- Today’s data
- 2 Zetta bytes
- 100,000 CDs or 500 billion DVDs
- What is the future?
- 5 Zetta bytes
- 100,000 CDs or 5,000 billion DVDs
- 10 Zetta bytes
- 200,000 CDs or 10,000 billion DVDs
- 1 Yottabyte
- 1,000,000 CDs or 50,000 billion DVDs

Managing Change in Enterprises

Enterprises need
- Organizational structures to use IT
- Constant professional learning
- Positioning in global market
- Flexibility to act quickly

Mechatronics offers a best practice for synthesis and meeting the challenges.

Many definitions?—Very diverse due to ever changing nature of technologies
- Hailed as “Mechanical Engineer for the 21st Century”
- Becoming increasingly popular in MME courses
- Criticised as “Nothing new but a bundle of existing technologies,” “No original content of technology”

General trends in industry

- Knowledge is the king
- Innovation is essential
- What is rare today becomes a commodity tomorrow
- Products are becoming more complex and system-based with higher performance
- Short design cycles are more common
- Markets are increasingly global and more competitive
- Design teams are a preferred approach
- Customer requirements are getting tougher
- Legislation is more and more demanding

Mechatronics

- UNESCO Chair on Mechatronics
- Boğaziçi University
Definition of Mechatronics in 20th Century

The synergistic integration of mechanical engineering with electronics and intelligent computer control in the design, manufacture and operation of industrial products and processes.

Evolution of Mechatronics (Tomizuka 2000)

Definition of Mechatronics in 21st Century

The synergistic integration of physical systems with information technology and complex-decision making in the design, manufacture and operation of industrial products and processes.

Paradigm Shift

Industrial Electronics

Industrial Informatics

What is Industrial Informatics?

- Industrial Informatics is that collection of principles and techniques that uses information analysis, manipulation, and distribution to achieve higher efficiency, effectiveness, reliability, and/or security within an enterprise.

IEEE Transactions on Industrial Informatics

- Focuses on the knowledge-based factory automation to enhance industrial and manufacturing processes.
- This embraces a collection of techniques that uses information analysis, manipulation, and distribution to achieve higher efficiency, effectiveness, reliability, and/or security within industrial environment. The scope of the Transaction includes latest developments in intelligent and computer control systems, robotics, factory communications and automation, flexible manufacturing, vision systems data acquisition and signal processing.
YOUR KNOWLEDGE IS OUR POWER!!

New Generation of Products in Information Age
- More digital than analogue
- Advanced mechanical components enabled by CAD techniques
- Increasing powers of embedded IT components
- Increased complexity,
  - Greater flexibility
  - More functions
  - Higher MIQ

MIQ - Machine Intelligence Quotient
- IQ stays more or less constant MIQ changes with time and is machine specific
- The dimensions of IQ and MIQ are not the same
- At this moment there is no agreed set of tests to measure the MIQ of a, say fuzzy washing machine

Intelligent Systems Revolution
Man-made systems
- Ability to reason
- Learn from experience
- Make rational decisions without human intervention

What is INTELLIGENCE?
"Intelligence is a mental quality that consists of the abilities to learn from experience, adapt to new situations, understand and handle abstract concepts, and use knowledge to manipulate one’s environment."

Copyright 1996 Randy Glasbergen, www.glasbergen.com
How far have we got?

An Electric Brain Capable of Translating Foreign Languages is Being Built.

An headline from the popular press of 1950

Today’s most intelligent machine is far from being able to do what a child easily does, such as eating food with a knife and fork, peeling an orange, etc.

Why so late?

- The principle tools used in AI are symbol manipulation and predicate logic, not suitable for real-world problems
- The computing power was not available

Prof. Zadeh argues that

Soft Computing based Computational Intelligence should be the basis for the conception, design, deployment of intelligent systems rather than Hard Computing based Artificial Intelligence.

Hard Computing (HC) v. Soft Computing (SC)

<table>
<thead>
<tr>
<th>HC</th>
<th>SC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bivalent Logic</td>
<td>fuzzy Logic</td>
</tr>
<tr>
<td>Numerical analysis</td>
<td>neurocomputing</td>
</tr>
<tr>
<td>Probability theory</td>
<td>genetic computing</td>
</tr>
<tr>
<td>Differential equations</td>
<td>probabilistic reasoning</td>
</tr>
<tr>
<td>Functional analysis</td>
<td>management of uncertainty</td>
</tr>
<tr>
<td>Mathematical programming</td>
<td>evidential reasoning</td>
</tr>
<tr>
<td>Approximation theory</td>
<td>rough sets</td>
</tr>
<tr>
<td>Quantitative, precise, formal</td>
<td>qualitative, imprecise, informal</td>
</tr>
</tbody>
</table>

AI CI

Hard Computing

Soft Computing

FL NN GA

Evolving NN

Optimising Capability

Evolving Fuzzy Neural Network

Neuro-Fuzzy Fuzzy-Neuro

FS Representing Capability

Self-tuning Fuzzy System
What is important about soft computing is that its constituent methodologies are for the most part synergistic and complementary rather than competitive. Thus, in many cases, a higher MIQ can be achieved by employing FL, NC, GC, and PC in combination rather than singly.

What in the future???

Prophetic Statements…

Can become very embarrassing in years to come..

"Heavier than air flying machines are impossible"

Lord Kelvin, 1895

"I think there is a world market for maybe five computers"

Thomas Watson, IBM, 1943
'There is no reason why anyone should have a personal computer in their home'

Ken Olsen, 1977

'640K ought to be enough for everybody'

Bill Gates, 1981

What progress can we expect during the next 10,000 years??

Prophecy?

What progress can we expect during the next 10,000 years??

Futurology?

The End of the Road??

No New Needs..

Today is good enough?

Innovation Getting Harder..

Or too expensive?

The best way to predict the future is to invent it.

Alan Kay
What progress can we expect during the next 10,000 years??

- In computing environment
- In recognition technologies
- Improved MIQ of products
- Biomimicry?
- What??

Needs of the market will be the main driver....

From USA Today
(22 February 2002)

Humanoid Robotics
A driving force??

Manny: a full-scale android body completed by the Pacific Northwest National Laboratory in 1989 for the U.S. Army. Manny sees life-like and has 42 degrees of freedom, but no intelligence or autonomous mobility.

Evolving ASIMO

The Engine of the Information Society

Adaptive Step in Innovative Mobility

UNESCO Chair on Mechatronics
Boğaziçi University

From USA Today
(22 February 2002)
Paradigm Shift in Robotics

From 4D Assignments
(Dirty, Dangerous, Dull and Difficult)

To 4A Assignments
(Automation, Augmentation, Assistance and Autonomous)

Robot Soccer

By the mid-21st century, a team of fully autonomous humanoid robot soccer players shall win the soccer game, complying with the official rules of FIFA, against the winner of the most recent World Cup...

A date has been registered with FIFA: 17 July 2050

Nao - Robocup Edition

Nao has been selected by the International Robocup Committee as the successor of the Sony robot dog Aibo, as the new official platform of the Robocup Standard League.

Thus, the next edition of the Robocup, in July 2008 in Suzhou in China, will feature a 16 university teams from all over the world “Nao League. They will be able to use the excellent cognitive and physical abilities of dozens of Nao (4 in each team) during soccer plays.
43 countries, 400 teams and 3000 participants!

One of the best among the 15 RoboCups that have taken place.

Research Issues in Humanoid Robots

- Perception
- Human-Robot Interaction
- Learning and Adaptive Behaviour
- Legged Locomotion
- Arm control and dexterous manipulation
- Materials
- Energy

Mechatronics / Robotics

Ambient Intelligence

Increased robot-human and robot-machine interaction

Migration of robots out of Shopfloors

- Service Robots, Field Robots
  - Robot Assistants
    (Worker Assistants, Personal robots, cyber-companions)

Societal Challenges

- Usability - Adaptability
- Robustness - Safety

Cognitive Perception

- Perception
- Signal Processing
- Sensor Fusion
- Pattern recognition - 3D modeling

 Artificial Intelligence

- Intelligent agents
- Reasoning
- Memory & knowledge organisation

Understanding Intelligence

What can nature teach us?

- The most successful control systems on earth are biological ones.
- What can we learn from them?
- Conversely, can there be anything that biological science learn from the control-theoretic viewpoint?

Biomimicry?

- Locusts are experts at avoiding collisions. They fly in swarms many millions strong without bumping into each other. Can we learn from their simple neural machinery to design a collision sensor to warn of impending collision using visual information?
- Can we learn from a fly how to land very gracefully as it does at the edge of a plate?
**The Big Dog**

- Will carry up to 400 lbs of gear and enough fuel for missions covering 20 miles and lasting 24 hours;
- The development of LS3 will take 30 months, with first walk out scheduled for 2012.

**LS3 Legged Squad Support Teams**

- Will carry up to 400 lbs of gear and enough fuel for missions covering 20 miles and lasting 24 hours;
- The development of LS3 will take 30 months, with first walk out scheduled for 2012.

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**As we climb up the ladder of knowledge, let us not forget what T. S. Eliot wrote in “The Rock”:**

Where is the life we have lost in living?
Where is the wisdom we have lost in knowledge?
Where is the knowledge we have lost in information?

**What is the meaning of life? I don’t know. The computers are down.**
Thank you for your attention!!