MECHATRONICS & ENGINEERING DESIGN

Olaf Diegel
Historically......

• Mechatronics grew out of the use of computer based technologies to provide increased levels of performance of mechanical systems.
• The realization from mechanical engineers was that the developments in electronics and software could support significant performance enhancements.
The evolution...

- Mechanical Engineering
- Mechanization
- Electro Mechanical Systems
- Mechatronics
- Information Technology & Software
- Electrical Technology
- Electronics
Evolution of mechatronics

<table>
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<tr>
<th>Product</th>
<th>Mechanics</th>
<th>Electronics</th>
<th>Mechanics</th>
<th>Electronics &amp; IT</th>
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<td>10%</td>
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IEEE Robotics and Automation Magazine 2001
The evolution...

- Electronics and software have continued to develop along their own paths.
- The mechatronics base has remained substantially within the mechanical engineering community.
The evolution...

• The working party on mechatronics in Europe came up with the following definition.

  “Mechatronics is the synergetic combination of precision mechanical engineering, electronic control and systems thinking in the design of products and processes”
Controller/Data Acquisition
- RF transmitter/receiver
- Digital control
- Remote sensing

Sensor:
camera, force sensors
solar panel

Mechanical components
Robot manipulator
Gear box
Rotors, tires, etc

Actuators:
- Servo motors
- DC motors
The evolution...

• An alternative definition took the form

“Mechatronics represents an approach to the design of engineering systems which involves the integration of mechanical engineering, electrical and electronic engineering with software engineering and computer technology at all levels of the design process”
The evolution...

• To call a system a mechatronic system, the product must have the correct **balance** between the design of the system technologies.

• A mechatronic system must truly display the **integration** of its core technologies within any individual system, product or process.

• Not just “bolting on”
The future of mechatronics...

By definition then, mechatronics is not a subject, science or technology per se - it is instead to be regarded as a philosophy – a fundamental way of looking at and doing things, and by its very nature requires a unified approach to its delivery.
The future of mechatronics...
Communication, Collaboration and Integration

- **Communication** is the biggest problem.
- The mechatronic engineer acts as **mediator** or **link** between the technologies and disciplines.
Mechatronic design tools....

- Mechanical Simulation (CAD/CAE/FEA)
- Electronic simulation
- Software simulation
- Physical models
- Mathematical model (don’t forget these!)
• Need proper dynamic modeling + estimation control – not just trials and errors.

Mechatronics Example

• Mechatronic systems have transparency
  – Engine management system
  – User can concentrate on the higher level operations of the system

• The automatic, auto focus camera
  - Auto-focusing
  - Auto-exposure
  - Anti-shaking
AUTOMATIC AUTOFOCUS CAMERA

Drives
- Film advance
- Film rewind
- Shutter
- Focus
- Zoom
- Aperture

Sensors
- Film speed
- Exposure counter
- Focus
- Exposure
- Zoom
- Lens type
- Flash attachment
- Body closure

Flash
- Local processor
- Flash setting
- Zoom
- Exposure data

Flash Interface
- Flash setting
- Shutter speed
- Aperture
- Zoom
- Mechanical coupling

Lens
- Local processor
- Focusing drive
- Aperture control
- Zoom

Lens Interface
- Lens type
- Focus
- Aperture
- Zoom
- Mechanical coupling

Body
- Main processor
- Exposure control
- Focus control
- Film speed
- Film advance
- Film rewind

User
- Selects procedure
- Composes picture

User Interface
- Program select
- Aperture
- Shutter speed
- Overrides
DIGITAL CAMERA can offset blur from a shaky photographer’s hand by rapidly adjusting a lens element or by moving the CCD that records the image (far right).
LENS ELEMENT shifts freely on ball bearings—up, down, left or right—inside a housing, when magnets induce attached coils to move. (Other designs nudge the lens with piezoelectric rods.) Sensors detect the direction and speed of camera jitter, signaling a microprocessor that controls the magnets. For example, if the camera tips down, the microprocessor instructs the lens element to drop, refracting the incoming light upward. A spring anchors the lens in a home position.
CCD is moved up, down, left or right by piezoelectric actuators when directed by a microprocessor, if motion sensors indicate the camera is jiggling. Verification sensors confirm that the CCD has shifted properly. If the camera tips down (below), the CCD drops so light stays centered.
DIGITAL STABILIZATION requires no moving parts. Software crops the incoming image so it covers only 80 to 90 percent of the CCD's pixels. If electronics sense that the camera shakes left, the software adjusts the crop to the right (over available pixels); if it shakes down, the crop moves up.
Mechatronics Decision Making
Mechatronics Decision Making

• The OddBot: a simple robotic platform for student use
• Must be cheap to manufacture
• Must be possible for students to manufacture themselves
• Must be easy to modify/hack
Mechatronics Decision Making

• The Brain: Mechatronics systems have some kind of microcontroller used for system intelligence
  – Is intelligence on-board or remote?
  – How many I/Os and motors?
  – Display/LCD?
  – Communication?
  – Memory RAM/ROM?
  – Off-the-shelf or custom made?
  – Power requirements?
Mechatronics Decision Making

Pololu Maestro 6 motor controller

WIFI module

Infocast 3.5” media display
* 454 MHz ARM processor
* 64 MB DDR SDRAM
* 2 GB internal microSD card (some only have 1 GB)
* 3.5” LCD color touchscreen
* 2W mono speaker
* Wi-fi connectivity (802.11 b/g)
* FM radio tuner
Mechatronics Decision Making

- Electromechanical: Every mechatronic system has a combination of electromechanical design and actuation
  - Motors/Actuators
  - Body/Enclosure
  - Sensor mounting
  - Clearances, tolerances and practicalities
Mechatronics Decision Making
Mechatronics Decision Making

• Power: Every mechatronic system has a power supply
  – What voltages do your various electronics need?
  – How much current do you need?
  – In case of OddBot, motor start-up current was too much to supply microcontroller from same supply, so 2 separate battery packs used
Usability: Your mechatronic system must be transparently useable.

– On OddBot, all intelligence resides on robot, so user can control it from any wifi capable device, without needing to download app.

• Python webserver onboard infocast serves webpage to controlling device
• Webpage contains javascript code to control motors
• Webpage address permanently printed on side of OddBot
Other OddBot versions
Other Mechatronics Work

SCVL Cardiovascular Lab
• ATMega microcontroller
• Pump
• Pressure sensor
• Solenoid valve
• Serial communication over USB
• Intelligence for BP contained in SCVL
• Intelligence for data display and calcs contained on PC

• Code written in C for hardware
• Code written in Visual Basic for software
Other Mechatronics Work

Xrystal Blood Pressure Monitor
- Attempt at getting a medical device not to look like a medical device, to help with compliance problem
- Same hardware as SCVL
- Includes PC software that allows downloads from BO, Glucose, Scales so patient can look at health trends
- Code written in Visual Basic for software
Other Mechatronics Work

Smart House Indoor Positioning System
- Investigated many methods to track the position and ID of occupant of Smart House
Innovation in Mechatronics

• Most engineering problems need input from a multitude of disciplines to solve. Mechatronics engineers are therefore ideally suited to this...

• ...Mechatronics is therefore a discipline in which finding creative solutions to engineering problem is an essential skill

• Can creativity and innovation be taught?
What it's all about

PROJECT MODEL

Concept and Initiation  Planning and Development  Implementation  Commissioning and Handover

PRODUCT MODEL

Decision to design product  Develop detailed product brief  Design product according to brief  Get approval and launch manufacturing

IDEA GENERATION MODEL

Preparation: Incubation  Verification
What is creativity?

- Expertise = Learned
- Creative thinking skills = Teachable... to an extent
- Motivation = Manageable

*Creativity*: "the ability to create", where create means "to bring into being, to cause to exist, to produce, or to give rise to". *(OED)*
What is innovation?

US patent & Trademark office: To be patentable, an invention must satisfy the simultaneous criteria of being new, useful and non-obvious.

de Bono stresses that there are three levels of being innovative:
- Bringing into being something that was not there before
- The new thing must have a value
- There has to be something unique or rare about it

Innovation: the introduction of novelties; the alteration of what is established; a rebellion or insurrection. (OED)
Innovation vs Creativity

Creativity

Innovation

Product development

Outputs
- Ideas
- Ideas for Artifacts
- Artifacts
Targeted problem solving

• General Innovation: New ideas that are not related to a specific project

• Innovative Targeted Problem Solving is innovation which is directed at a specific project.
Is following a recipe innovative?

1 stick (4 ounces) butter, plus a little for buttering the molds
4 squares (4 ounces) bittersweet chocolate, preferably Valrhona
2 eggs
2 egg yolks
1/4 cup sugar
2 teaspoons flour, plus a little more for dusting

- Is it creative to use a recipe to create something new?
- How much does a recipe have to be modified before it is creative to use it?
What about a thinking style?

Göring’s Vermeer
By Hans Van Meegeren

• Is painting through the eyes of a cubist the same as following a recipe?
Innovation is not magic

Though the results of innovation may be about the new, the processes involved in innovation are about the old

“We cannot imagine anything whatsoever, only things constructed out of existing knowledge. I cannot imagine a colour beyond my visual experience” (G Smith, 1998)

• All innovation is based on knowledge
• An innovative idea consists in finding a novel use for an existing object or concept
• The method for arriving at a solution can be analysed in hindsight.
It all comes from what we know...
How the mind works

Environmental Input → Sensory Registers (Visual, Auditory, Haptic) → Short-term Memory (Buffer, Scanner) → Long-term Memory (Permanent Memory Store) → Response Output

Need to achieve Something → Data input (Keyboard, Mouse, Scanner, GUI, etc.) → Data Screen Printout, etc. → Short-term storage (RAM, Software) → Permanent storage (Hard Disk)

Short-Term Memory

• Simultaneous data input limited to 7 events
• The goldfish syndrome: Input remains active for 10 ~ 20 seconds
• 7 elements can be simultaneously retained in STM
• Scanning process recognises validity of data and if required refreshes it, or puts it in long-term memory.
• Data in STM is used to recall data from LTM
Long-term Memory

- A dynamic structured hierarchical tree of knowledge
- Each extra node requires an additional 0.75msecs
- Node links can be of greater, or lesser strength and vary with time.
- Nodes can be ‘chunked’ into memory clusters which are instantaneously retrievable. (2 x 2 = 4, images)
Some fun with numbers

• 7 items in short term memory allows for 127 new combinations (or 5913 if we include permutations)
• In 1 second we can scan 1333 items in LTM and process them in STM
• In 1 second we have the potential for 169,291 innovations (7,882,029 if we include permutations)
So, why isn’t it easy?

- Gestalt Theory: Law of Prägnanz states that psychological organisation will always be as concise, simple and unified as immediate events permit
- Innovative thinking is hard work!
- Our education acts as a barrier to Innovation

(Wertheimer, Köhler, Koffka, 1924)
Law of Prägnanz

• What do you see?
The barrier to Innovation

Functional fixedness is the effect of only being able to see something for what we have traditionally been taught it is by our education, environment, culture, etc.

(Maier, 1931)
Overcoming Functional Fixedness

• Alternative uses for a brick
• Break it down into the properties that make it up
• Weight, rectangular, retains heat, Small enough to be picked up in one hand, rough texture, porous, does not conduct electricity, does not burn, etc.
How does this apply to me?

- The brain can only deal with small amounts of data at once, so we often break things down to have less to deal with.
- Imagery is often used, as one image can replace many other stimuli.
- There are 3 separate, equally sized boxes, and inside each box there are 2 separate, small boxes, and inside each of the small boxes there are 4 even smaller boxes. How many boxes are there together?
Design Breakdown Structure

The DBS is a graphical decomposition technique, but used in reverse. One has identified the properties that our solution requires, and one is looking for the “brick” or solution that will fulfil those properties in a novel way.
THE END
PROBLEM SPACE

SOLUTION SPACE

CONSTRAINT MANAGEMENT
Theory of constraints

• A troup of boy scouts is on a field trip
• The path is only wide enough for a single file
• All the scouts travel at different speeds
• As always, there is a slow kid. Lets call him Herbie.
• Depending on where Herbie is, different things happen...
Herbie in the middle?

Herbie at the back?

Herbie at the front?

Herbie unloaded & all holding hands?
So how does this relate to production, or running a business?
Theory of constraints steps

Step 1: Identify the system's constraints.

Step 2: Decide how to exploit the system's constraints.

Step 3: Subordinate everything else to the above decision until the constrain is no longer a constraint.

Step 4: Avoid Inertia - go back to step 1 and identify the new constraint.