Flanders’ MECHATRONICS Technology Centre (FMTC)

Preparing for a Career in the Innovative Industry of the Future
7 maart 2012
Roadmap of talk

+ Introduction of FMTC
+ R&D strategy of FMTC
+ Badminton robot as demonstrator
+ The role of PhD in FMTC
Flandres’ Mechatronics Technology Centre

+ **FMTC vzw:**
  - Non-profit organization
  - Started in 2003 with support of Agoria
  - In 2011: +4.8 M€ turnover with +35 staff
  - Membership for companies with R&D in Flanders

+ **Our competence: Mechatronics**
  = integration of electronics and software in mechanical systems

+ **Our business: Application oriented research projects**

+ **Our market: Machine building and mechatronic component industry**
Our members

Metal processing machines
- Bekaert
- LVD

Textile machines
- Gilbos
- Picamol
- Van De Wiele

Compressors
- Atlas Copco

Agricultural and food machines
- CNH
- BEST

Gearboxes & transmissions
- Dana
- Hansen

Transportation
- Televic

Specific assembly machines
- LVAH
- Ninix Technologies

- Terumo

Supporting technologies
- Bluways
- Induct

Associated members
- AGORIA
- PMA
- Sirris

INNOVATING TOGETHER FOR SUPERIOR MACHINES
Market trends lead to... intelligent machines

Market Trends:
• Higher Productivity
• Better Energy-efficiency
• Less waste
• Increased Comfort for operator
• Safer
• Increased Modularity
• Increased Flexibility
• Shorter design cycles
• Improved Reliability
• Additional Services

Enabling competence domains:
• modeling & control
• communications & software
• monitoring & diagnostics
Our mission

“Jointly develop and improve generic mechatronic competences and technologies to strengthen the competitive edge of its partner companies”
Top Competences in 3 Technological Clusters

**Modeling & Control**
- Physical modeling
- Control design
- Drive Solutions

**Communications & Software**
- Communication
- Control SW Engineering
- Control Platform Solutions

**Monitoring & Diagnostics**
- Complex Event Process
- Fault Diagnostics & Isolation
- Diagnostic Solutions

Top Competence:
- Energy-efficient EM drive lines
- Wireless control Systems
- Smart self-diagnostics
Cluster Modeling & Control

+ Physical Modeling
  - Simplified dynamic analysis
  - Vibration & Noise Analysis
  - Energy Flow Analysis
  - Coupling with FEM

+ Control Design
  - System Identification & classical feedback
  - Gain-Scheduling, Learning Control
  - Selection tool for Optimal Control

+ Drive Solutions
  - Experience in EM-Actuators, Piezo, Lin.motor
  - Novel sensors & control integrated
  - Method for Energy-Efficient motor selection
  - Power Electronics & Energy storage
Cluster Communication & Software

+ **Communication**
  - Fieldbusses: e.g. CAN synchronization
  - Ethernet-Fieldbusses: e.g. Ethercat
  - Wireless: Bluetooth, Zigbee, WiMedia
  - Wireless Autonomous sensors

+ **Control Software Engineering**
  - Open Source OROCOS framework
  - Custom controllers for safety applications based on PLC Open

+ **Control Platform Solutions**
  - Machine emulators + debugging
  - Requirement Management Process supported by Excel-Enterprise Architect (SysML)
Cluster Monitoring & Diagnostics

+ **Complex event processing**
  - LogAn: Preprocessing & analysis of log-files and tool for pattern definition,

+ **Fault Detection & Isolation**
  - Process and supporting tools for data driven Fault Detection & Isolation

+ **Diagnostic Solutions**
  - SW Tools: On-line SW anomaly detection
    => Weaving machine
  - Solutions: On-line connection integrity
    => Temperature sensor, pressure sensor
  - Solution for on-line diagnostics of pulse based speed sensor
  - Solutions for Optimized Con. Based Maint.
    => Packaging machines & Printers
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FMTC bridges the research gap between academia and industry

Universities & Research Institutes
E.g. PMA

Fundamental Research

Strategic Research

Top Competences
Joint Projects
Bilateral Projects

Consulting Centers
E.g. SIRRIS

Joint Projects
Consultancy

Companies

8

48

370

ytp = year to product
6 ytp
4 ytp
2 ytp

INNOVATING TOGETHER FOR SUPERIOR MACHINES
Joint Projects: demand-driven

+/- 40 project ideas

Visionary seminars

Clustering

idea fair

+/- 7 projects

Selection

1st User Groups

Company Interest

Advising Board

2nd User Groups

Company Interest

1 year cycle

INNOVATING TOGETHER FOR SUPERIOR MACHINES
Joint Projects: unique partnership model

Steering commission per project

Participating companies

cases

Results

bilateral contracts

Cooperation & IPR Policies

PMA & other Research Centers

cooperation

Joint Project

Definition

Evaluation
Cases and demonstrators convince people of the use of the technology

- It can actually work in real-life.
- Implementation issues become clear.
- It can also work on our application.
- End users or marketing can experience the technology.
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Why a badminton robot?

+ **GOAL:** demonstrate new FMTC technologies on a global demonstrator
+ **Demonstrator requirements:**
  - Linear and rotation movements
  - High-rate sensors (e.g. camera’s) in the control loop
  - Dynamic process with changing working conditions
  - Simple process
  - High PR value
  - Relevant for the members
  - Possibility to expand it to several machines
Why a badminton robot?

There are robots that can play soccer, table tennis, tennis, cricket, baseball, golf, kendo) but no badminton robots have ever been made.
Top level design flow for demonstrator

1. Requirements
2. Concept Design
3. Detailed Subsystem Design
4. Implementation
5. Integration
Badminton robot requirements

+ Capable of returning at least 90% of badminton shuttlecocks when the following constraints are fulfilled:
  - the shuttles stay below 4m height
  - the opponent plays in such a tempo that the robot has 1s reaction time, from the moment the shuttle is launched by the opponent until it hits the shuttle back
  - the opponent plays within the reach range of the robot

+ Use a regular badminton racket
+ Use a regular shuttlecock
Badminton facts

+ Court size (single): 13.40 m x 5.18 m
+ Top speed of the shuttlecock: 115 m/s
+ Speed of the badminton racket head can vary between 2 and 50 m/s
+ Maximum acceleration of the badminton racket: 3000 m/s²
+ Maximum Angular velocity of the badminton racket head: 80 rad/s
+ Maximum Angular acceleration of the badminton racket head: 4700 rad/s²
+ Energy consumption: 400 cal/h
Use Case diagrams are used to refine specifications

- List all possible scenarios
- Identify stakeholders
- Identify system boundaries
- Describe use cases (text)
Project requirements can be captured in SYSML
Top level design flow for demonstrator

- Requirements
- Concept Design
- Detailed Subsystem Design
- Implementation
- Integration
Ideal concept: wheeled badminton robot
Wheeled badminton robot is not realistic

- Assume 1s reaction time
- Badminton field in diagonal = ±8m.
- Robot needs to travel minimum 4m in 1s.
- Max acceleration & deceleration profile: max acceleration has to be ±15 m/s².
- Performance cannot be reached with state of the art mobile platforms (±2 m/s² max. acceleration, ±5 m/s top speed).

foto: Tech United Eindhoven
Realistic concept with limited reach
Divide design in 3 logical components

Localization – return the relative position of the shuttle with respect to the robot

Interception – determine the time & position where the robot will intercept the shuttle

Actuation – Place robot in position and perform hit back
Top level design flow for demonstrator

- Requirements
  - Concept Design
    - Detailed Subsystem Design
    - Implementation
  - Localization
  - Interception
  - Actuation
- Integration
Actuation SubSystem

Axis 1

Axis 2

Linear Axis
Actuation Subsystem

Axis 1

Axis 2

Axis 1

Axis 2
Electrical Case and wires

- Ethercat
- Fieldbus
- Drives
- Wire harness
Top level design flow for demonstrator

- **Requirements**
- **Concept Design**
- **Detailed Subsystem Design**
- **Implementation**
- **Integration**
Hardware/Software view of system

- **Optical system**
  - Image processing PC (RT LabView)
  - Central controller PC (RT Linux)
  - Drives and motors

- **Commands**
  - TCP
  - UDP

- **Shuttle positions**
  - UDP

- **Calibration PC** (Windows)

- **Hardware**
  - LabView
  - OROCOS
  - Ethercat
  - RS232
  - TCP
  - UDP

- **Software**
  - Calibration PC (Windows)
  - Image processing PC (RT LabView)
  - Central controller PC (RT Linux)
  - Drives and motors

**INNOVATING TOGETHER FOR SUPERIOR MACHINES**

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Software Complexity

+ **OROCOS**
  - Classes 18
  - Code Lines 4,012
  - Files 27
  - Functions 233

+ **Matlab**
  - Code Lines 3,492
  - Files 57

+ **RTW – controller**
  - Code Lines 25,909
  - Files 78

+ **Labview**
  - # of nodes 8799
  - structures 719
  - diagrams 1792
  - controls 717
  - indicators 559
The result
Project Management Facts

+ Kickoff meeting: 15 January 2009
+ Working robot: 10 March 2010
+ Effort: 760 persondays.
+ 17 persons effectively worked on the project.
+ Documented design alternatives: 98 (22 selected).
+ Purchase orders: 50 (it does not include small expenses).
+ 21 suppliers.
+ Major reliability issues: Cable connectors on the mobile platform
+ Consumables: 3 rackets so far
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PhDs and FMTC ...

+ Status 1/3/2012: 15 staff with PhD.
+ Why are PhDs good?
  - Scientific expertise.
  - Able to handle complex tasks.
  - Can work independently.
  - Can present work.
+ What makes a great PhD?
  - Cooperate in teams.
  - Answer also why questions.
  - Understand context: cost, alternatives, freedom to operate, ROI
  - Reduce threshold to use your work.
  - Convince users with real-life demonstrations.
We will continue to hire great PhDs!!

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