Perspectives to Robotics
- trends, challenges and partial solutions

Martin Törngren
Professor in Embedded Control Systems, ICES director
Division of Mechatronics, KTH – Royal Institute of Technology

Joint work with Sagar Behere, Jan Wikander, Jad Elkhoury, Frederic Loiret and Ahsan Qamar
Robotics - a stimulating area!

• Why, what, how, when, where, business models?

• Enabler or threat?
Evolving robots
Robotics research and product perspective

- Vision
- Sensing, estimation and control
- Dynamics
- Project Management
- Quality
- Maintenance, After-market
- Production/parameterization
- Software
- ECU/electronics
- Diagnostics, Support tools
- Mechanical components
- CAD, PDM
- Architecture Networking
  - CAN database
- Integration tests
- Safety
- Power
  - Propulsion
- Thermal
- Robotics research and product perspective

Martin Törngren – KTH; Robotics @ KTH September 27 2013
Main messages

• Robotics evolution shares many traits with automotive and aerospace:
  – Cyber-physical systems
  – Safety, complexity, autonomy

• Engineering techniques have a hard time to deal with current systems
  – Needs for new theory and methodology

• Partial solutions
  – Viewpoint integration
  – Architecting and reference architectures
Outline

• Perspectives
  – Trends and challenges

• Challenges and partial solutions
  – Integrated design and optimization
  – Viewpoint integration
  – Architecting

• Conclusions
Towards a new scale of integration

Social media
- WWW
- Mobile internet
- Google
- Facebook
- Twitter

Internet
- GSM
- GPS
- iPhone
- Android
- Smartphones

Telecom
- Distributed computing
- CAN
- Ethernet
- VoIP

Wired
- Internet
- Social media
- Computation
- Analog and digital

Wireless
- Telecom
- CAN
- Ethernet
- WLAN
- Bluetooth
- Zigbee
- WirelessHART

Computation
- Microprocessor
- MEMS
- Multicore
- Motes

Ubiquitous computing
- Smart dust
- Internet of Things
- Cyber-physical systems
- Cloud computing
- The swarm

Martin Törmgren – KTH; Robotics @ KTH September 27 2013
Robotics, Automotive, Aerospace, ... - common trends and challenges

• Common functionalities
• Functional growth, increasing autonomy
• Increasing scale through networking
  – SW platforms: Orocos, Autosar, IMA/Arinc, ...
• Safety related; evolving safety standards
• Complexity challenge
  – Cost efficient verification
  – Interoperability
  – Lifecycle management
• Paradigm shift
Autonomy/automation paradox and trade-off

- Finding the right level of automation
- Automation may not be the best solution:
  - Degrading skills of human operators
- Humans are fallible, and should therefore be designed “out” of the system vs. Design teams are fallible, therefore humans are required in the system
Challenges/barriers and barriers

**Technological**
- Sensors and actuators
- Smart components
- Packaging/integration
- New computing technology
- Control methods
- Software/platforms
- Tools
- Wireless communication

**Organizational/Business**
- Performance!
- Scale, safety, security!
- Risks & costs!
- Sustainability!

**Societal**
- Societal impact
- Legislation
- Standards
- Education

**Push**
- Theory and Engineering methodology

**Pull**
- Energy
- Transportation
- Healthcare
- Competitive production
- Comfort
- Entertainment
Outline

• Perspectives
• Challenges and partial solutions
  – Integrated design and optimization
  – Viewpoint integration
  – Architecting
• Conclusions
A robotics growth area: healthcare, elderly, assistive devices

Design challenges

- Low weight
- Ergonomics
- Safety/softness
- Transducers
- Energy consumption
- Low cost
- Usability
- User interfaces
- Physical integration
- Attractiveness
- Modularity
- Comfort
- Business models
- Legislation
- Reliability

Martin Törngren – KTH; Robotics @ KTH September 27 2013
Better support for decision making is needed

Support for model based decision making

CAD
System design
Dynamics & Control
Software
Electronics
Production
Optimization

Martin Törngren – KTH; Robotics @ KTH September 27 2013
Multi domain design and optimization

Structural element models
Actuator models
Transmission models
Sensor models
Controller models

Select components and configure

Dynamic component properties
Algebraic performance models

E.g.
- System weight
- Energy consumption
- System costs

E.g.
- Torque/velocity profile
- Path following accuracy
- Closed loop dynamics

Optimization criteria

Requirements

Concept generation

Multi-domain design and optimization
Integrating Viewpoints

- Sensing, estimation and control
- Vehicle dynamics
- Project Management
- Quality
- Maintenance, After-market
- Production/parameterization
- Diagnostics, Support tools
- Mechanical components
- CAD, PDM
- Software
- ECU/electronics
- Architecture Networking
- CAN database
- Integration tests
- Safety
- Power
- Propulsion
- Thermal
- Software
- ECU/electronics
- Architecture Networking
- CAN database
- Integration tests
- Safety
- Power
- Propulsion
- Thermal

Martin Törngren – KTH; Robotics @ KTH September 27 2013
Source: "Integrating Viewpoints" J. of Mechatronics, To appear 2013 Törngren et. al
Embedded systems evolution

Complexity ceiling!
Fusing of architectural concepts from AI, dependable and RT control
Evolvability towards autonomy
Feature interaction

Source: Juarez et. al – Modeling feature interactions in the automotive domain.
Architecting

Assurance of key qualities
Analyzability, composability
Principles, reference architectures and styles
Reference architecture: Cooperative driving

Conclusions

• Robots are Cyber-Physical Systems
  – Shares many traits with automotive and aerospace:
    – SoS, safety, complexity, autonomy
• Engineering techniques have a hard time to deal with current systems
  – Needs for new theory and methodology
• Partial solutions
  – Viewpoint integration
  – Architecting and reference architectures
  – Efforts including networking across traditional domains!