Real-time distributed object computing

Research at UFRGS

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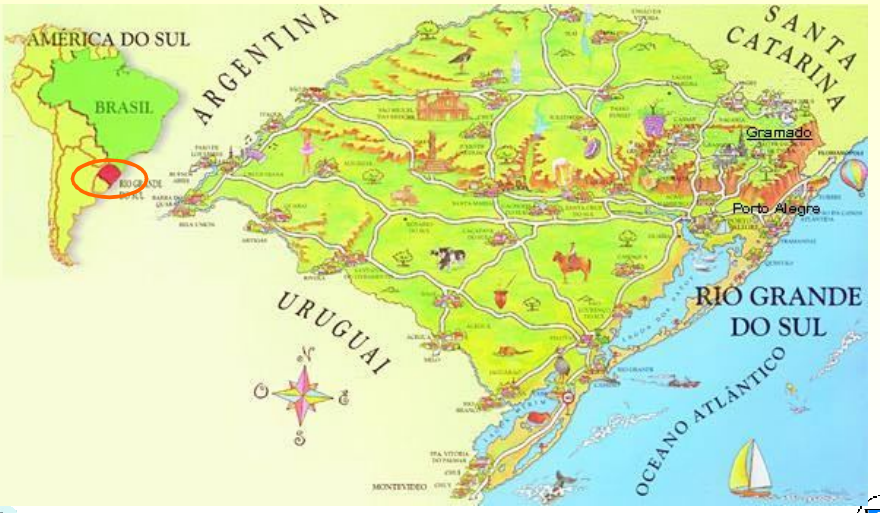
Outline

- Introduction (speaker, RS/Brazil, UFRGS)
- Research areas at UFRGS/GCAR
  - MDE methodology for the development of distributed embedded real-time systems
  - Dynamic Load-Balancing for Computation-Intensive Applications over a Heterogeneous Platform
  - Mixed-reality applied to intelligent maintenance systems
- Q&A

Speaker

- Professor UFRGS – Brazil – Electrical Engineering
- Vice-Dean School of Engineering
- PhD Industrial Automation EE – Univ Stuttgart Germany – 1995
- Sabbatical – United Technologies Research Center – Hartford/CT/USA (Carrier, Otis, Sikorsky, Pratt-Whitney, Hamilton Sundstrand) – Group Leader – Embedded Information Devices – 2000/2001
- Technical Director CETA SENAI/RS Brazil 2002/2009
- TC Chair IFAC TC5.1 Manufacturing Plant automation
- President - Brazilian Automation Society
- Associate Editor – Control Engineering Practice Journal - Elsevier

Rio Grande do Sul



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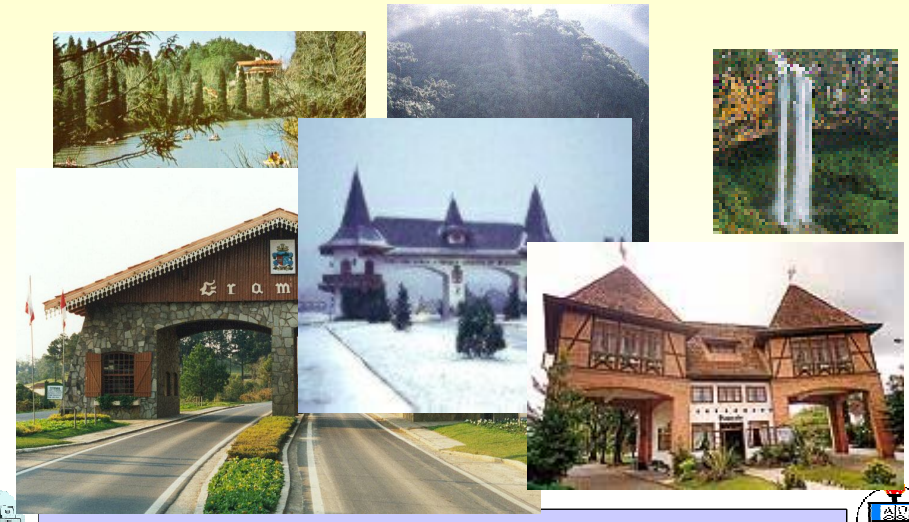
Porto Alegre

Porto Alegre

Gramado - Rio Grande do Sul

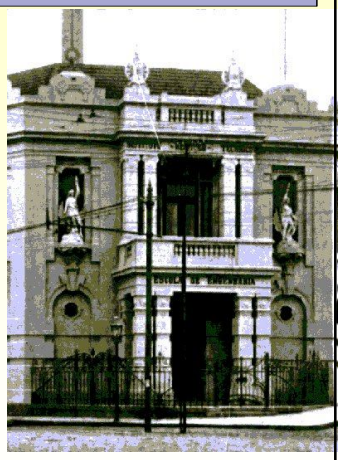


UFRGS

- Created in 1895
- ~70 undergrad programs
- Faculty: 2300 (85% full time)
- Students: ~30 000 (~18 000 undergrad)
- 4 Campus in Porto Alegre/RS
- One of the top 5 universities in Brazil

Electrical Engineering Department

- **School of Engineering**
  - **Created in 1896**
  - **13 undergrad, 6 grad. Programs**
  - **Teaching staff: ~230**
  - **Students: ~ 6000**
- **Electrical Engineering Department**
  - **created in 1946**
  - **Teaching staff: 43 members**
  - **~900 undergrad students, 120 grad students**



GCAR-UFRGS

- Control, Automation and Robotics Group
- 10 Faculty members + ~25 PhD students + ~30 MSc students
- Automation:
  - industrial + building automation applications
  - Real-time distributed embedded computing

UFRGS/GCAR

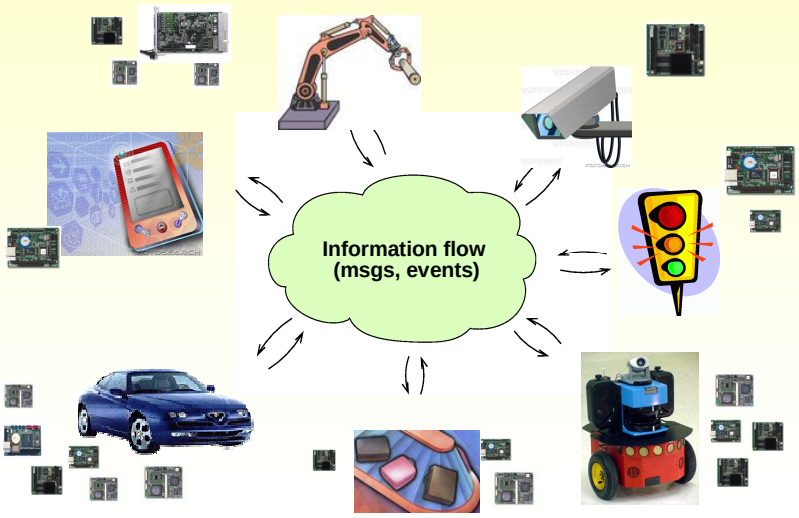
- Research area:
  Real-time distributed embedded (ubiquitous) systems
  cyber-physical systems
- Development methods (model-driven engineering – MDE)
  - Req Specification: UML, AO
  - Design: DSE
  - Implementation: Hw/Sw codesign, reconfigurable architectures

Research Topics

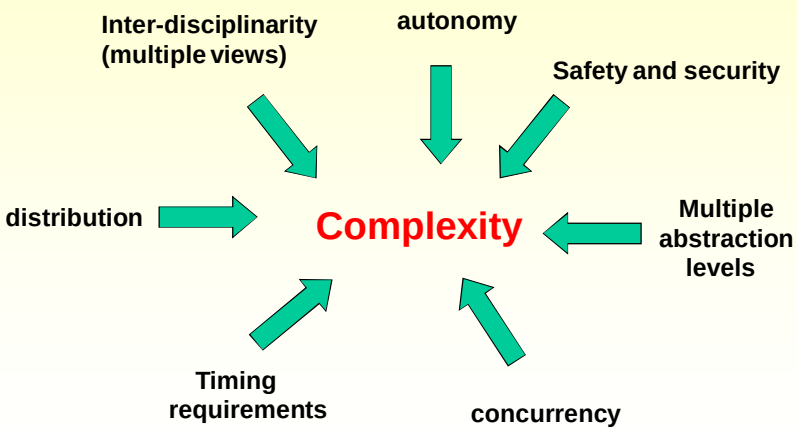
- Distributed/Networked and Embedded Real-Time Systems
- Application areas: Industrial + Building Automation
- Use of Object-Oriented Concepts
- Goals:
  - System Engineering for Embedded, Distributed RT-systems
  - Tool Support (Integrated Environment)
  - From Requirements Engineering to (Hw/Sw)-Implementation

RT-Embedded Systems

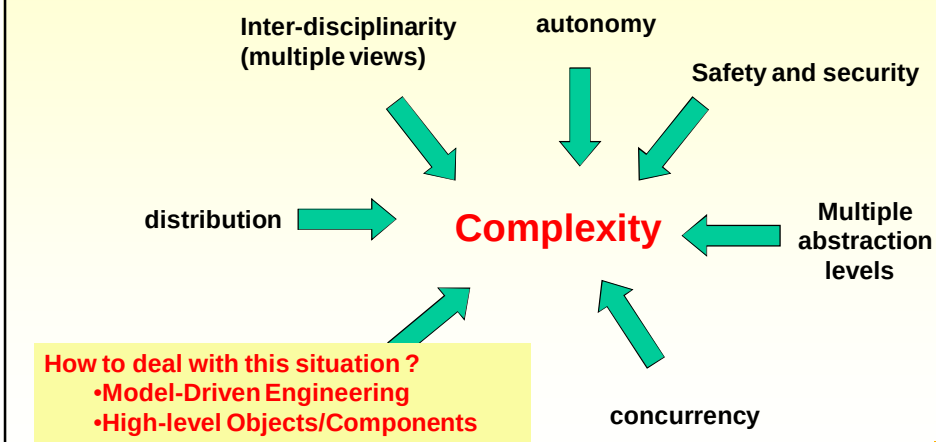
Distributed RT embedded systems



DRES in Industrial Automation: Challenges



DRES in Industrial Automation: Challenges



How to deal with this situation ?
- Model-Driven Engineering
- High-level Objects/Components
- Middleware

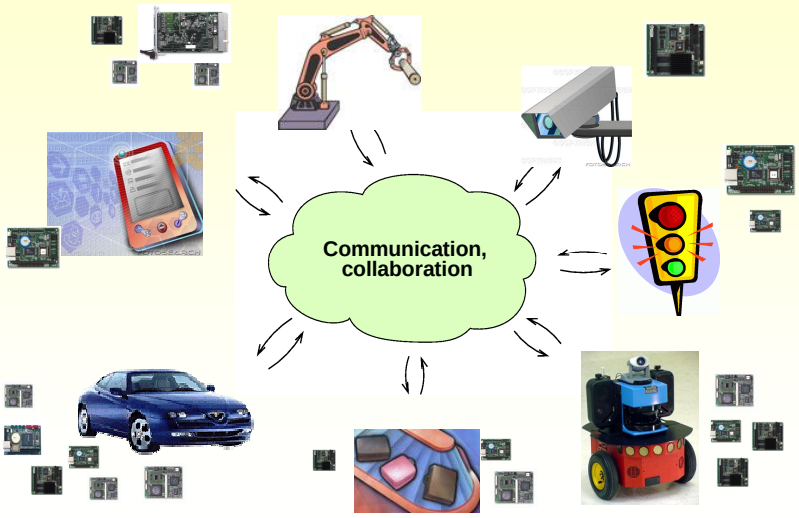
My Research Topics

- Distributed/Networked and Embedded Real-Time Systems
- Application areas: Industrial + Building Automation
- Use of Object-Oriented Concepts
- Goals:
  - System Engineering for Embedded, Distributed RT-systems
  - Tool Support (Integrated Environment)
  - From Requirements Engineering to Implementation

- DRTOC (Distributed Real-time Object Computing) is a key paradigm for cooperative, distributed embedded real-time systems
- Issues to be addressed:
  - Timing requirements
  - Embedded platforms with restricted performance and tight memory resources (design space exploration)
  - Rise up abstraction level and improve reuse
  - Industrial Communication protocols

RT-Embedded Systems

Distributed RT embedded systems



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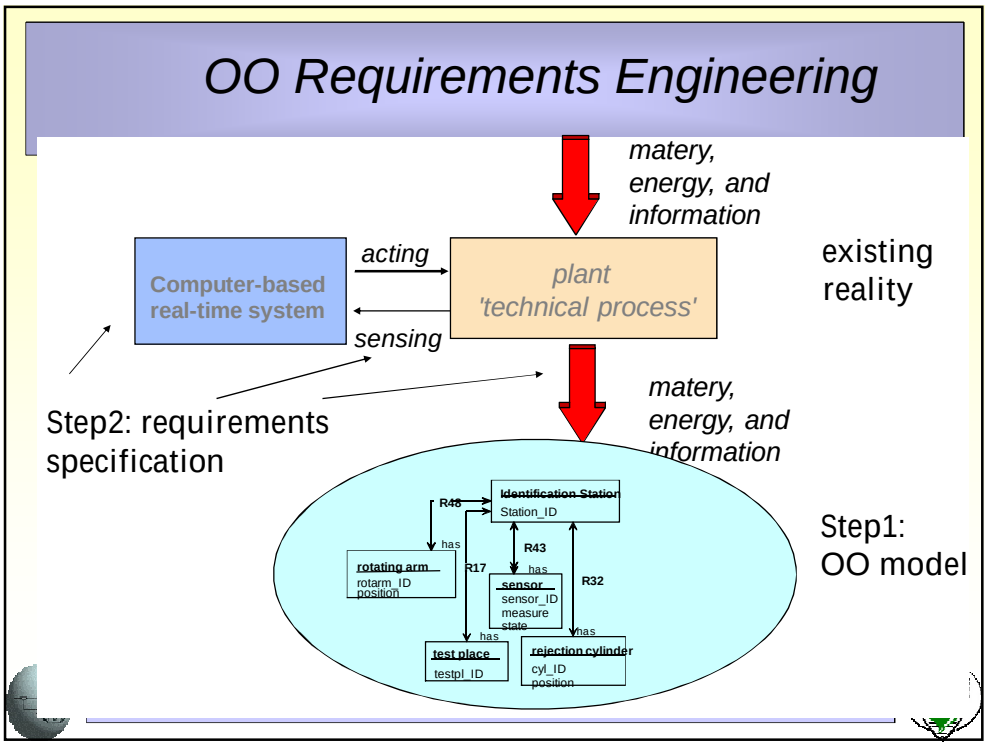
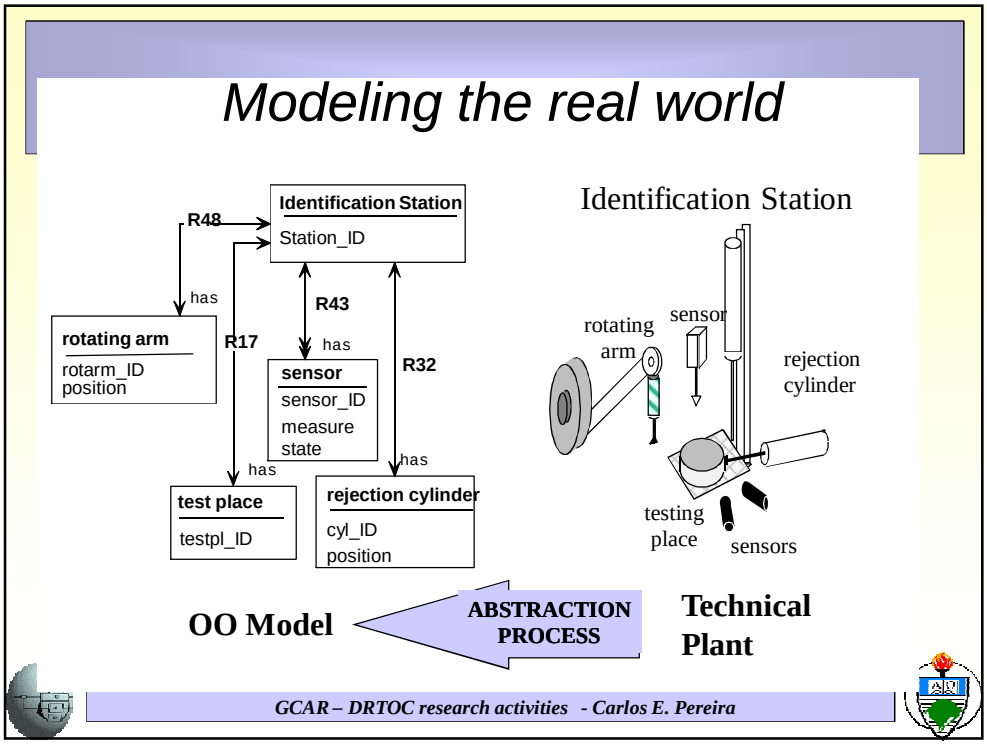

OO Requirements Engineering
matery, energy, and information
Computer-based real-time system
acting
sensing
plant 'technical process'
existing reality
Step2: requirements specification
matery, energy, and information
Step1: OO model
Identification Station
Station_ID
R48
R43
R17
R32
has
rotating arm
rotarm_ID
position
sensor
sensor_ID
measure
state
test place
testpl_ID
rejection cylinder
cyl_ID
position


Modeling the real world
Identification Station
Station_ID
R48
R43
R17
R32
has
rotating arm
rotarm_ID
position
sensor
sensor_ID
measure
state
test place
testpl_ID
rejection cylinder
cyl_ID
position
Identification Station
rotating arm
sensor
rejection cylinder
testing place
sensors
OO Model
ABSTRACTION PROCESS
Technical Plant
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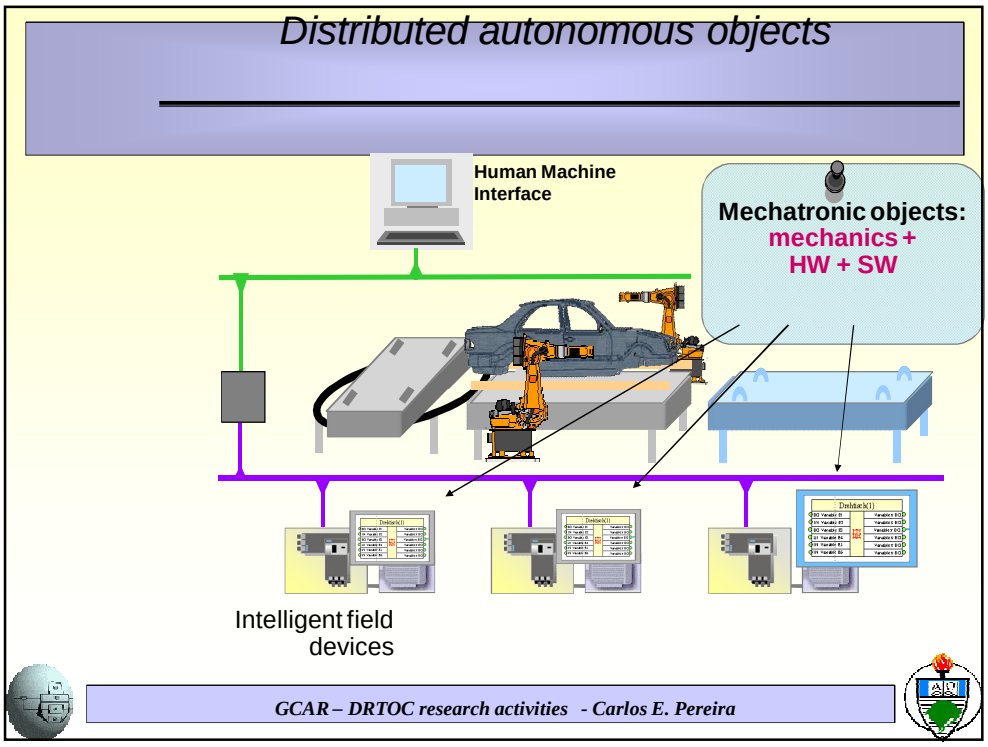
Distributed autonomous objects
Human Machine Interface
Mechatronic objects:
mechanics +
HW + SW
Intelligent field devices
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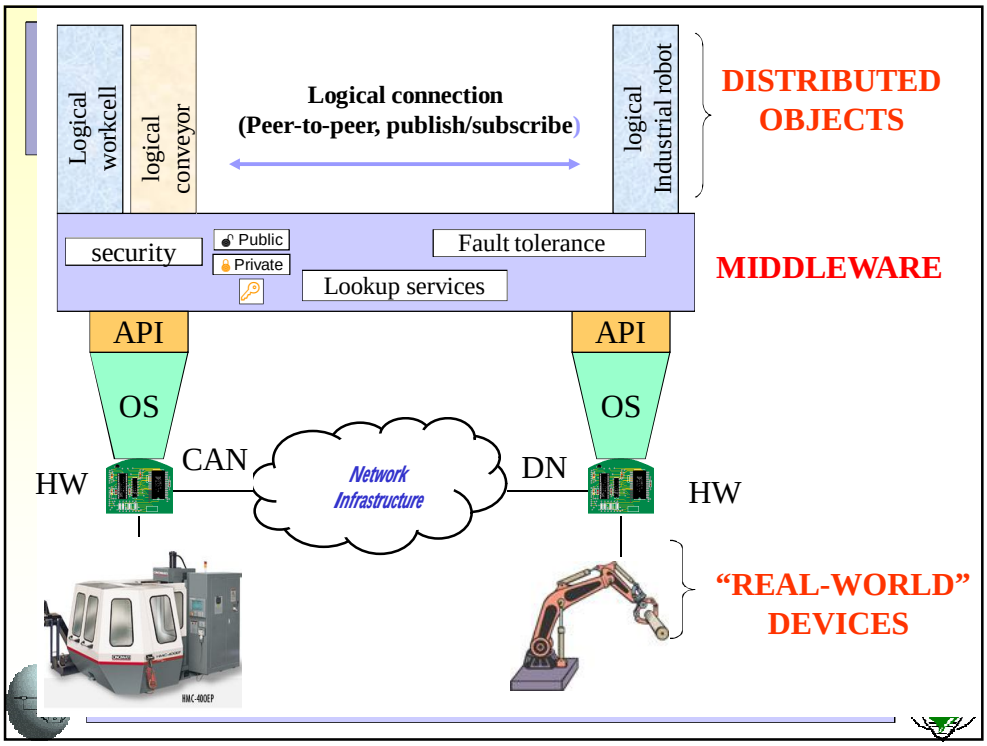
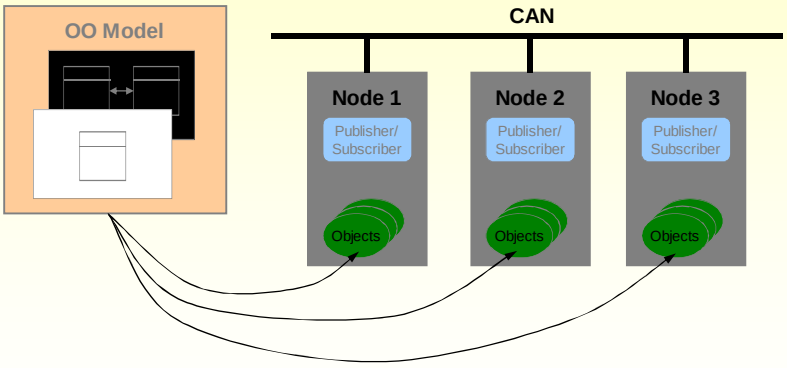
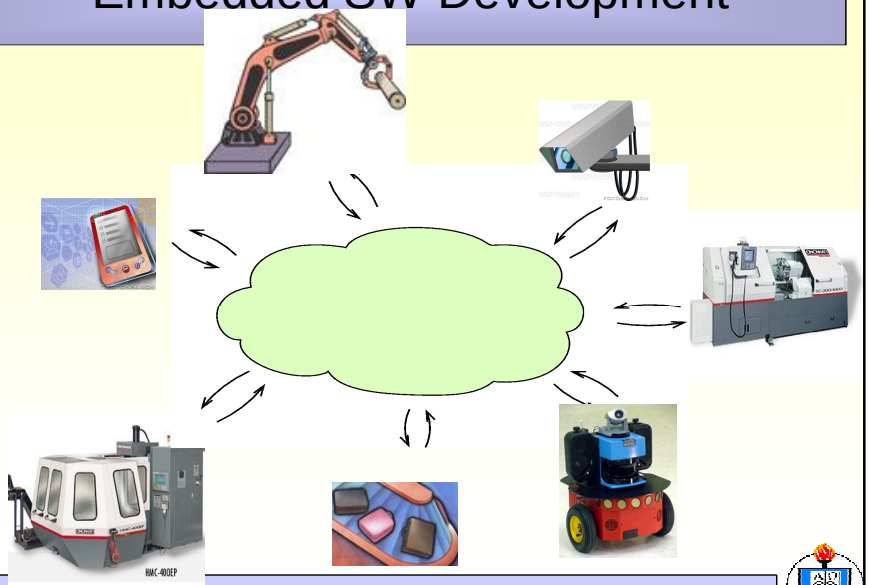
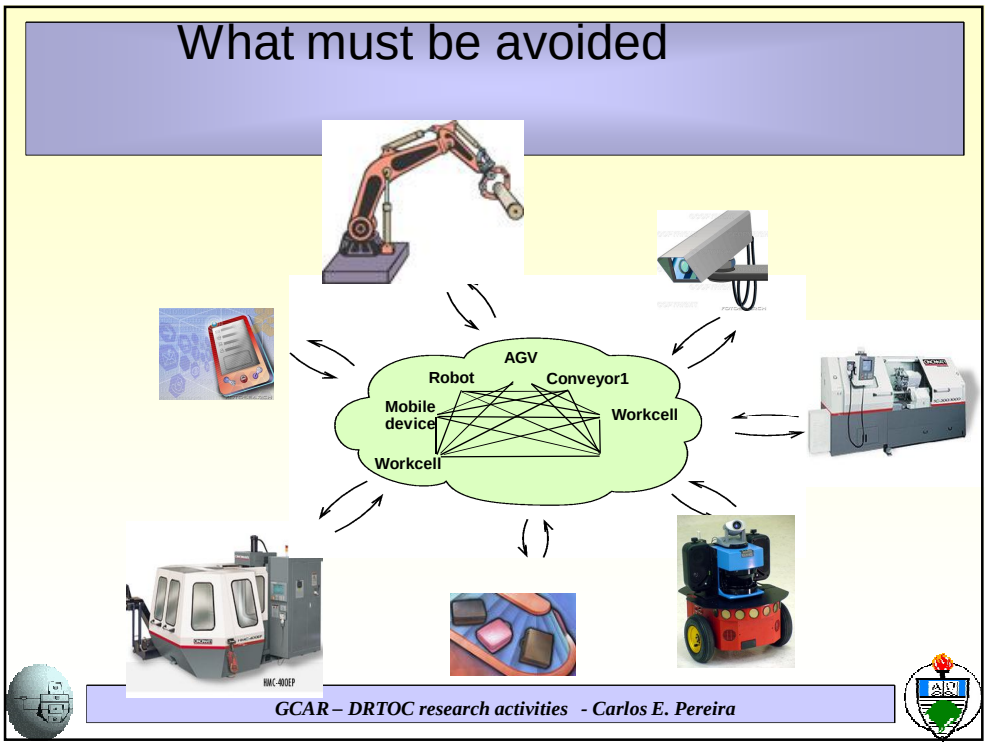

Logical workcell
logical conveyor
Logical connection
(Peer-to-peer, publish/subscribe)
logical Industrial robot
DISTRIBUTED OBJECTS
security
Public
Private
Fault tolerance
Lookup services
MIDDLEWARE
API
API
OS
OS
HW
CAN
Network Infrastructure
DN
HW
"REAL-WORLD" DEVICES

RTDOC at low cost microcontroler nodes



DRES in Manufacturing: Embedded SW Development




What must be avoided
AGV
Robot
Conveyor1
Mobile device
Workcell
Workcell
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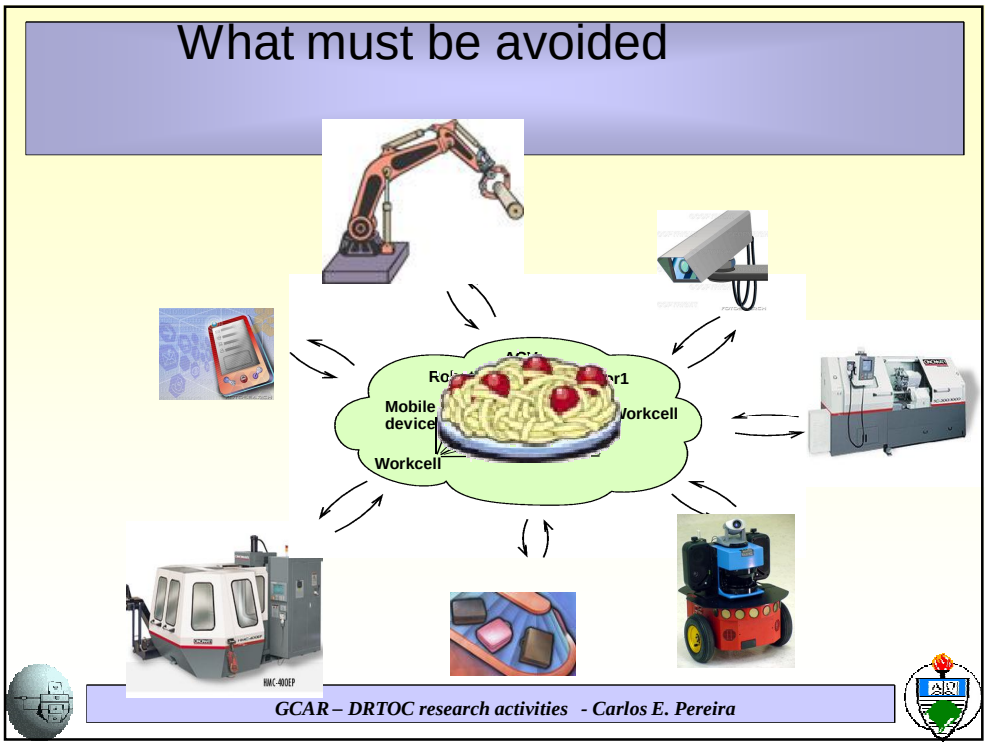
What must be avoided
Mobile device
Workcell
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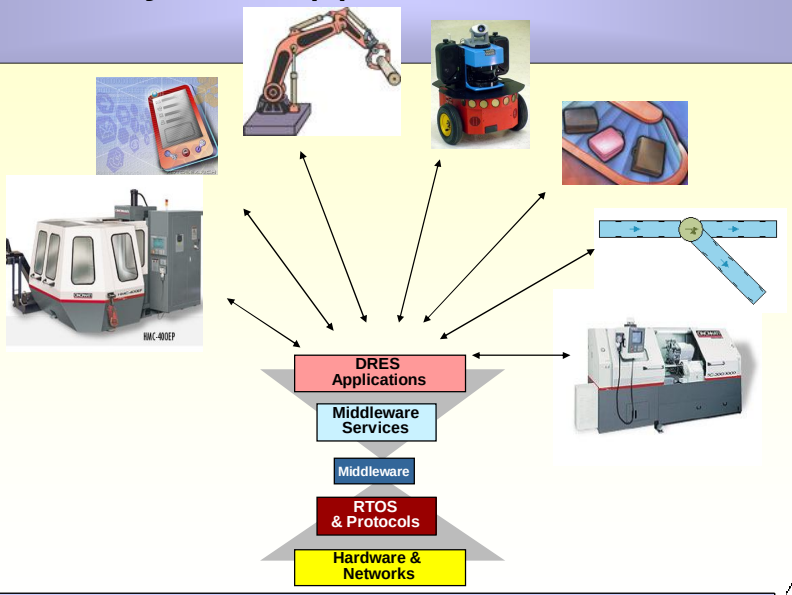
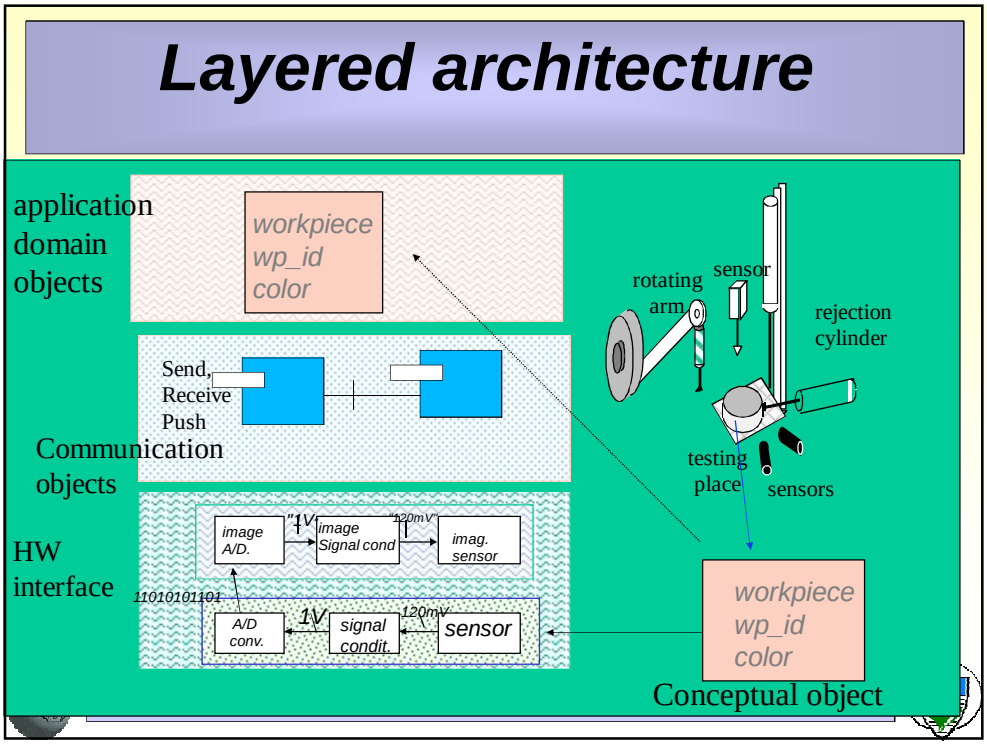
Layered approach: Middleware

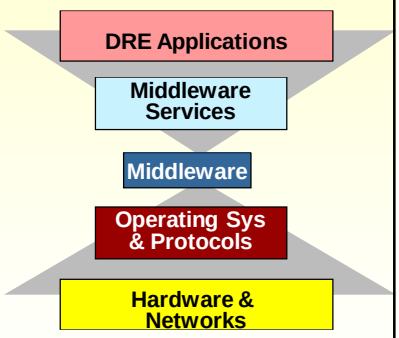


Layered architecture



Middleware

- shields applications from heterogeneous platform *dependencies*
  - *e.g.*, languages, operating systems, networking protocols, hardware
- simplifies development of distributed applications



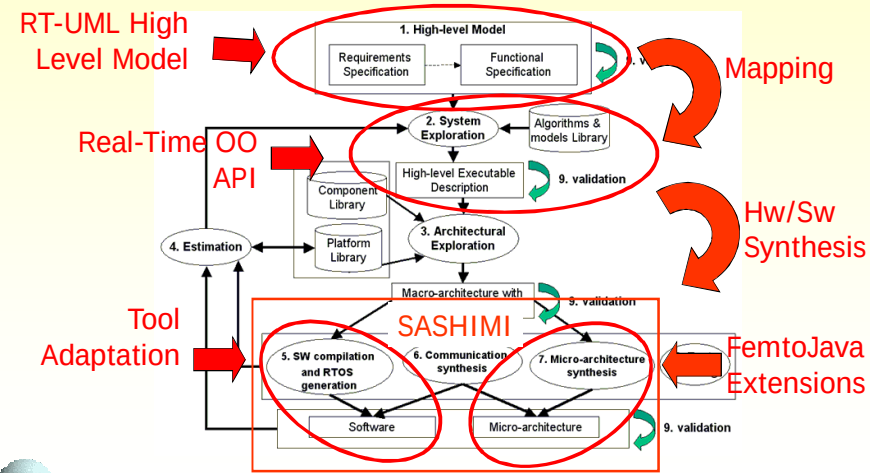
PhD students

- PhD students:
  1. Frederico Schaf – UFRGS + Univ. Bremen: mixed reality and virtual learning environments for control and automation teaching 4th year
  2. Reiner Perozzo – ambient intelligence – service composition 4th year
  3. Danubia Espindola – Intelligent Maintenance Systems + Augmented and Virtual Reality 4th year
  4. Alecio Binotto – UFRGS + Univ. Darmstadt graphical processors for industrial applications (CPU vs. GPU vs. PPU vs. Dedicated hardware) 4th year
  5. Edison Freitas – UFRGS – Univ. Halmstd - aspect orientation applied to early aspects 3rd year
  6. Andre Cavalcante – self-organizing DRTES – 2nd year
  7. Rodrigo Allgayer – wireless sensors networks – 2nd year
  8. Ivan Mueller – wireless communication protocols – 2nd year
  9. Dionisio Doering – real-time image processing – 1st year
  10. Suenoni Paladini – control and automation education – 1st year

Overview research activities

- MDE for DRTES - link
- Wireless Sensor Networks - link
- Load Balancing - link
- Mixed-reality for intelligent maintenance systems - link

SEEP Project Overview



Motivation

Usual approach:

-Given a (fixed) hardware architecture + (full) RTOS, develop real-time embedded software so that final system meets application requirements

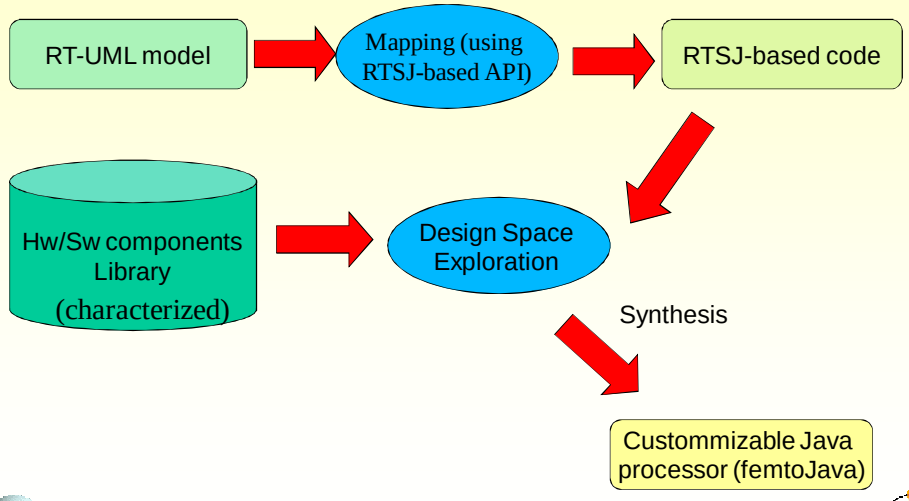
SEEP approach:

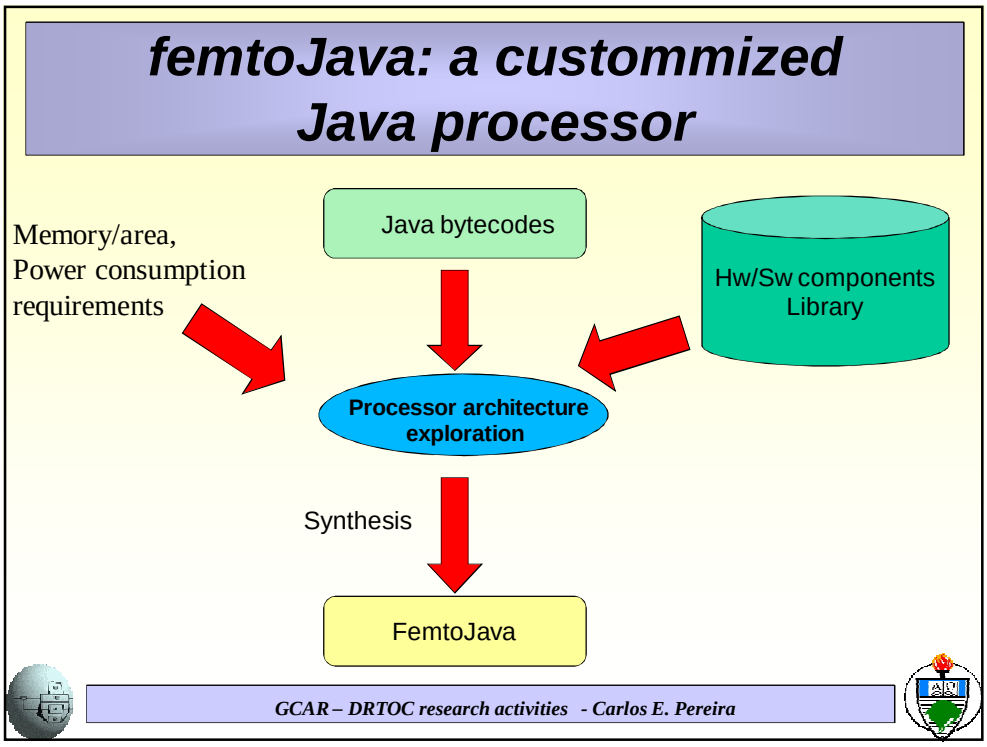
Synthesize **platform** (OS functions + hardware) that best fits to application demands

Reconfigurable hardware (RTOS + communication services as SW or HW modules)

Instead of generating code (adapting sw to hw), reconfigure hw (adapt hw to sw)

Design Flow




femtoJava: a custommized Java processor
Memory/area, Power consumption requirements
Java bytecodes
Hw/Sw components Library
Processor architecture exploration
Synthesis
FemtoJava
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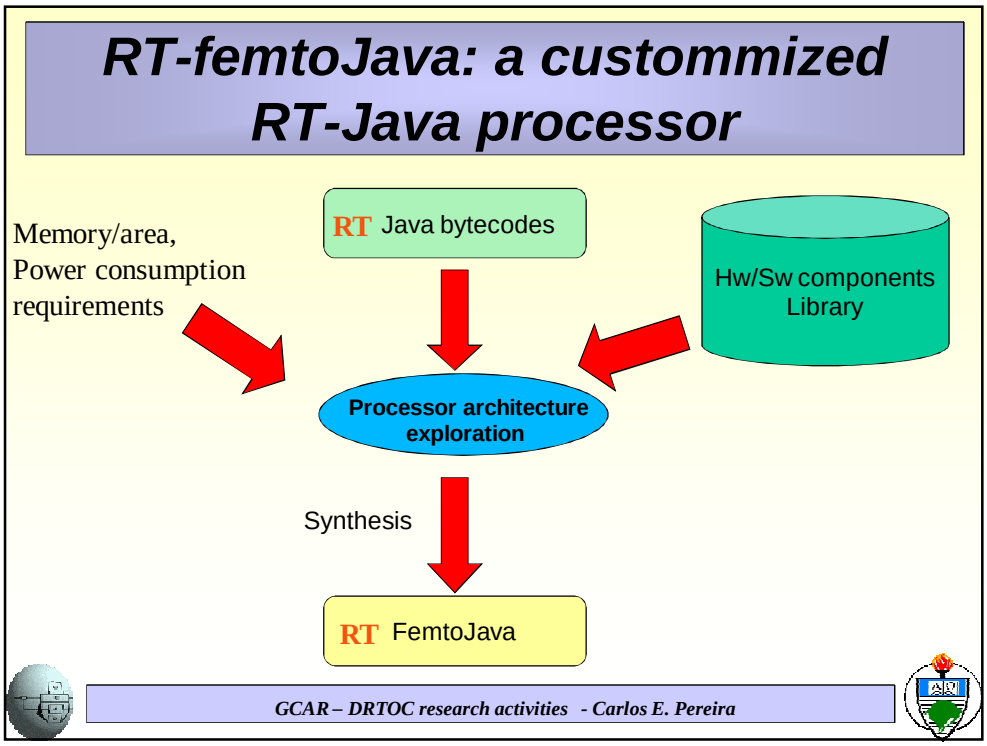
RT-femtoJava: a custommized RT-Java processor
Memory/area, Power consumption requirements
RT Java bytecodes
Hw/Sw components Library
Processor architecture exploration
Synthesis
RT FemtoJava
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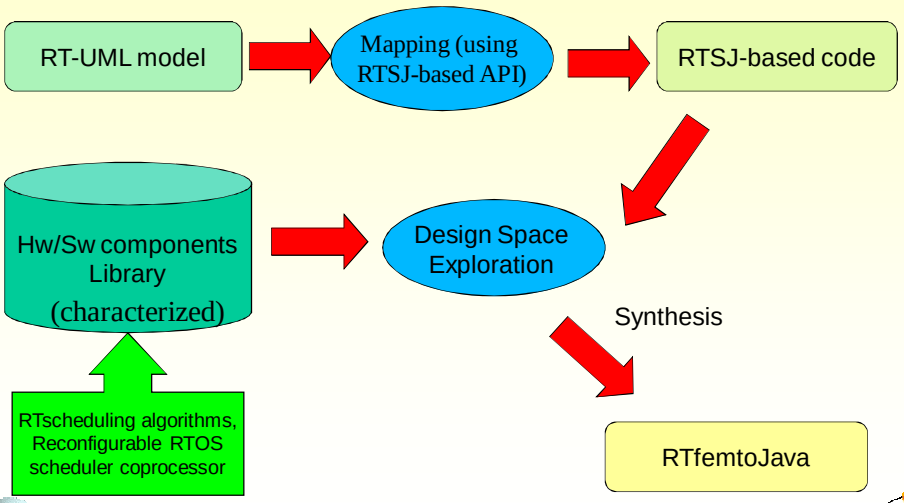
Additional extensions: scheduler as hw or sw



Conclusion

- RTDOC as a key paradigm for developing complex industrial and building automation applications
- Mapping from problem domain to runtime objects using a layered architecture