# Cyber-Physical Systems

Dept. of Computer Science Research Day

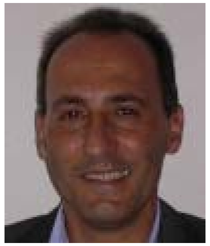
April 11, 2017

# Topics

- Embedded systems design
- Networked embedded systems design
- Embedded systems verification
- Networking systems
- AI and Robotics

# Embedded Systems Design

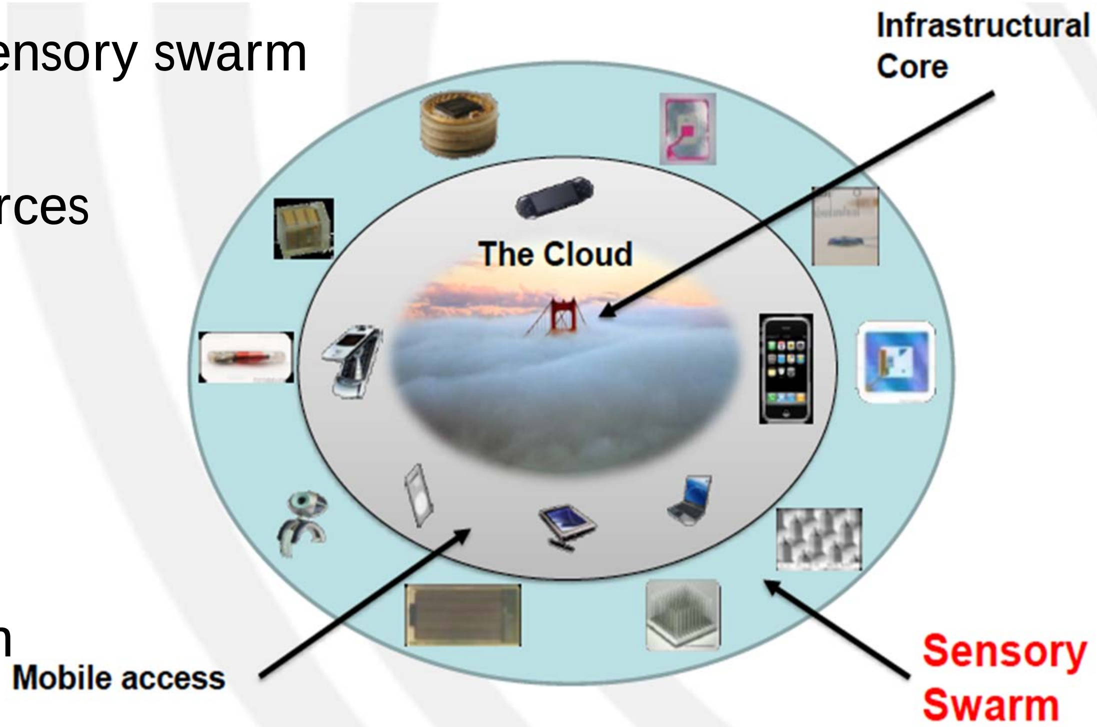
Nicola Bombieri, Franco Fummi, Graziano Pravadelli, Davide Quaglia

# The Emerging IT Scene

## A continuous of:

- smart devices: the sensory swarm
- interconnection
- computational resources




## Open issues:

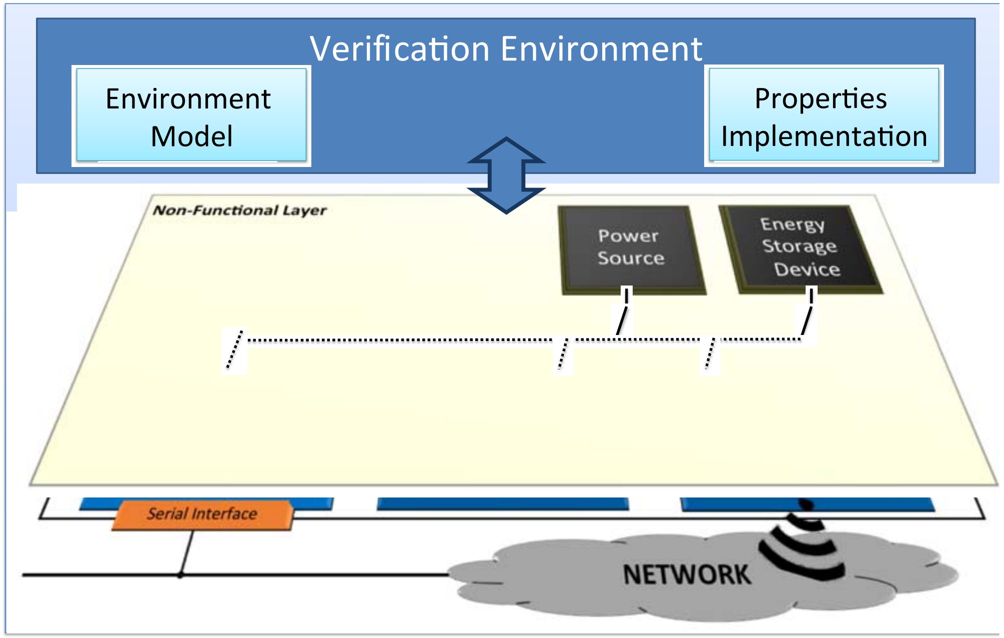
- Modeling
- Design
- Validation
- Interfaces generation

## Possible answer:

- Moving design techniques from the single embedded system to the swarm

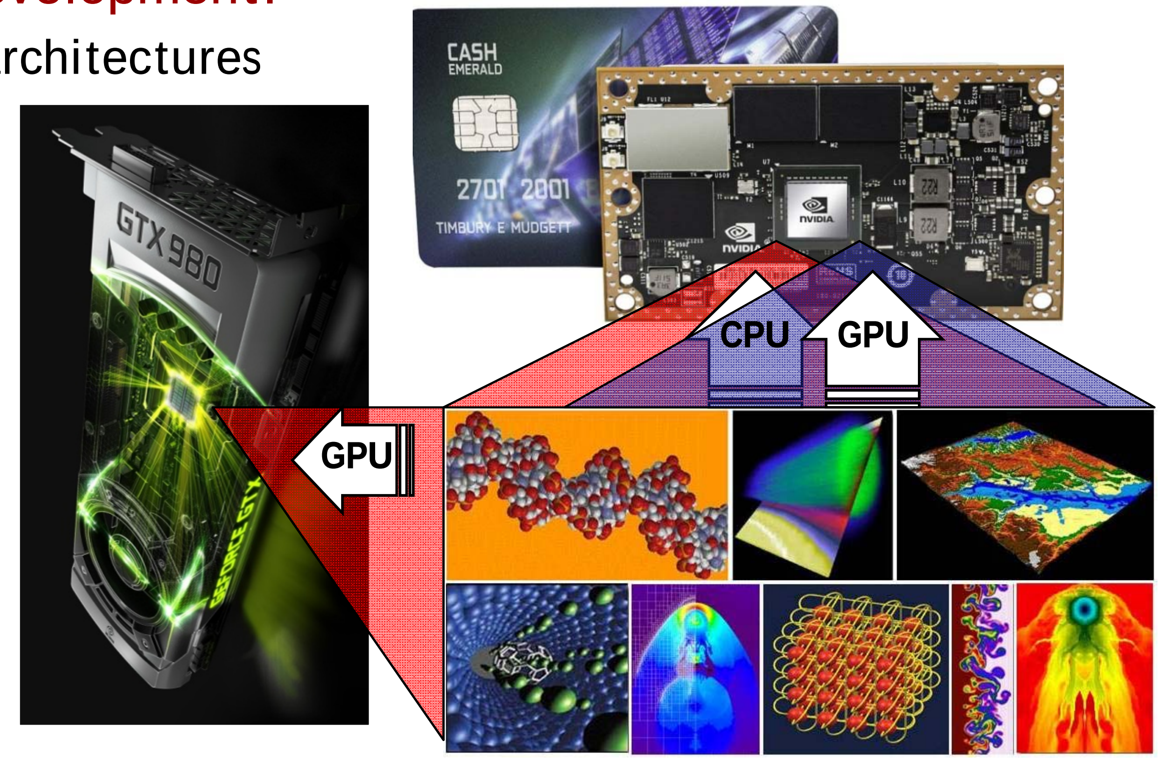
# Virtual Platform Composition

- A virtual platform is a simulation model of an actual platform. It is fundamental for:
  - concurrent hardware software co-design
  - design space exploration
  - design validation
- Investigated issues:
  - Automatic translation of heterogeneous models into an homogeneous representation
  - Fast simulation
  - Re-design
  - Interfaces generation



# Parallel Embedded Software

- Synergism of parallelism in the algorithm, application program and computer architecture development.
  - Parallelism and parallel architectures
    - CUDA, OpenCL, OpenACC
    - OpenMP, MPI
    - Performance analysis
    - Optimization



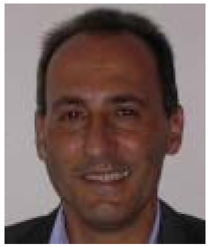

- <u>Investigated issues:</u>
  - GPU programming
  - Heterogeneous CPU-GPU architectures
  - Power-aware performance tuning

# Large Related EU Projects

- ANGEL
  - mobile gateway for sensors network
- VERTIGO
  - HW formal verification
- COCONUT
  - embedded systems design and verification
- C4C
  - control for coordination of distributed systems
- TOUCHMORE
  - correct software generation for multicore platform
- COMPLEX
  - codesign and power management in PLatform-based design
- SMAC
  - smart components and Smart Systems integration
- CONTREX
  - design of embedded mixed-criticality control systems

# Networked embedded systems design

Franco Fummi, Davide Quaglia, Damiano Carra

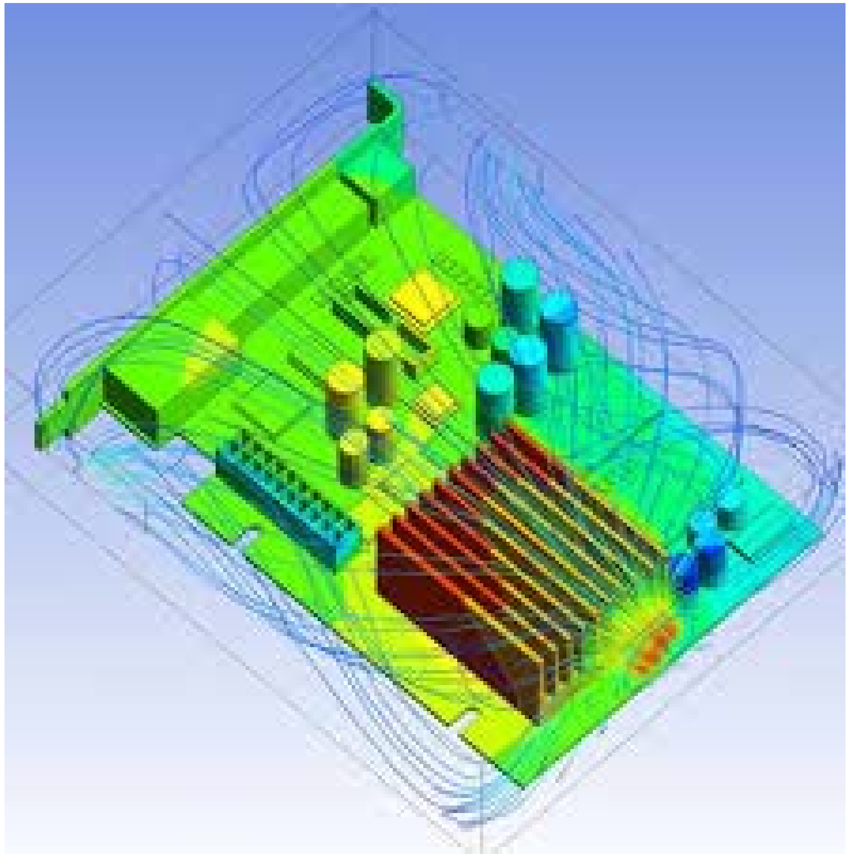


# Networked Embedded Systems

- Networked embedded systems (NES) are small, intelligent, embedded systems able to communicate each other and with Internet
- Key terms
  - Internet of Things
  - Machine-to-machine
  - Smart systems

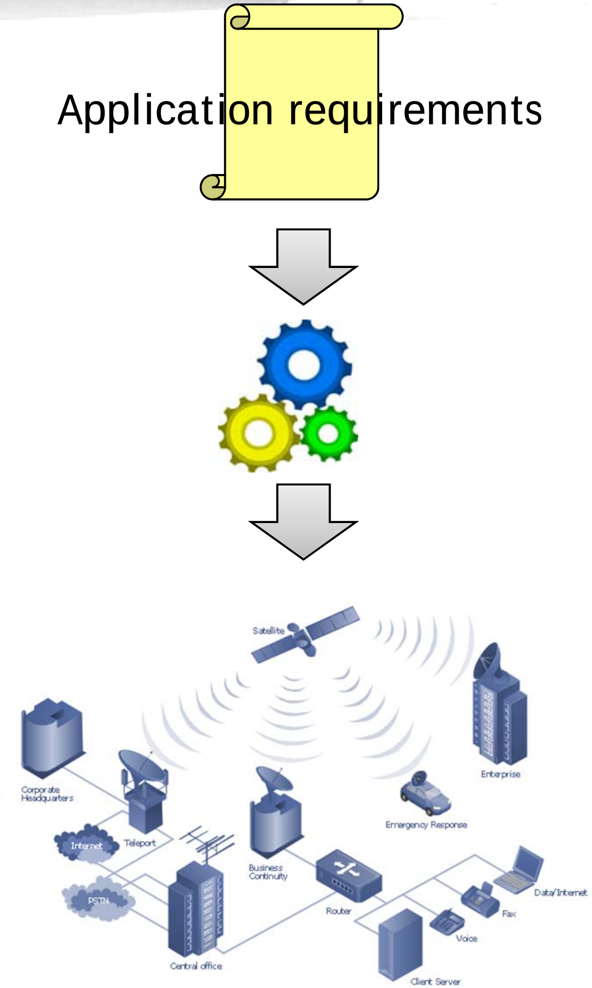
# Modeling & Simulation of NES

- This research topic regards the creation of **models** and **simulation** of
  - Digital hardware
  - Network (e.g., WiFi)
  - Analogue hardware
  - MEMS
  - Physical components belonging to several domains: mechanical, thermal, optical, etc.
- Languages
  - UML
  - SystemC



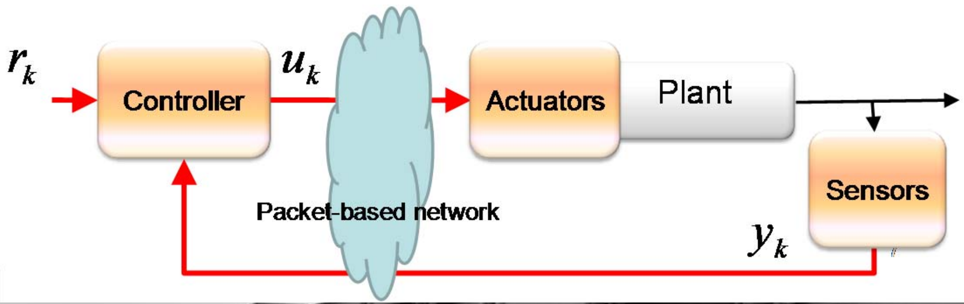
# Network synthesis

- Automatic methodology to design the network infrastructure
  - Topology
  - Nodes (number, type)
  - Channel types
  - Protocols
- Needed to address the challenging size of future’s networks
- Optimal allocation of resources with respect to given metrics (e.g., cost, bandwidth, delay, robustness)



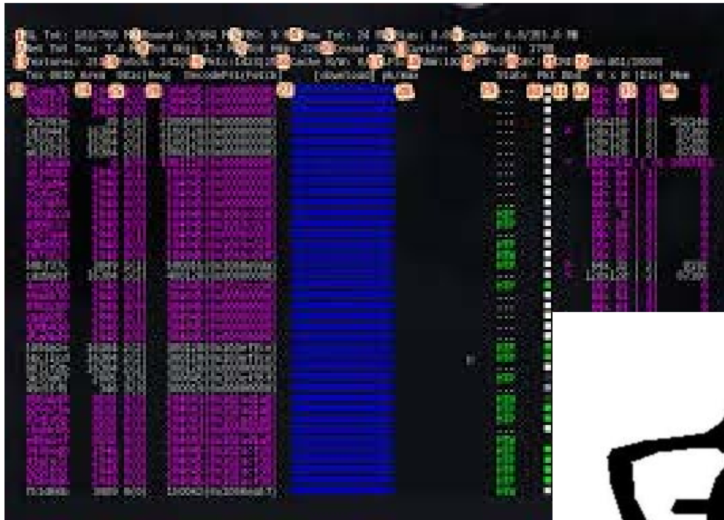
# Design and Verification of Networked Control Systems

- Physical systems controlled through a packet-based network
- Applications
  - Tele-operation
  - Automotive
- Joint design of the controller and of the network
- Security concerns



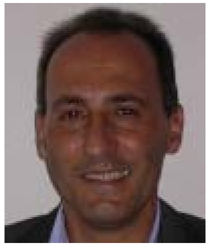
# Verification of network software

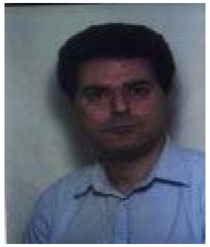
- Many network aspects are implemented as software
  - Protocols
  - Software-defined radio
  - Software-defined network
  - Network function virtualization
- Automatic verification of network-related SW implementation through observation of
  - Simulation traces
  - Actual behavior



# Embedded Systems Verification

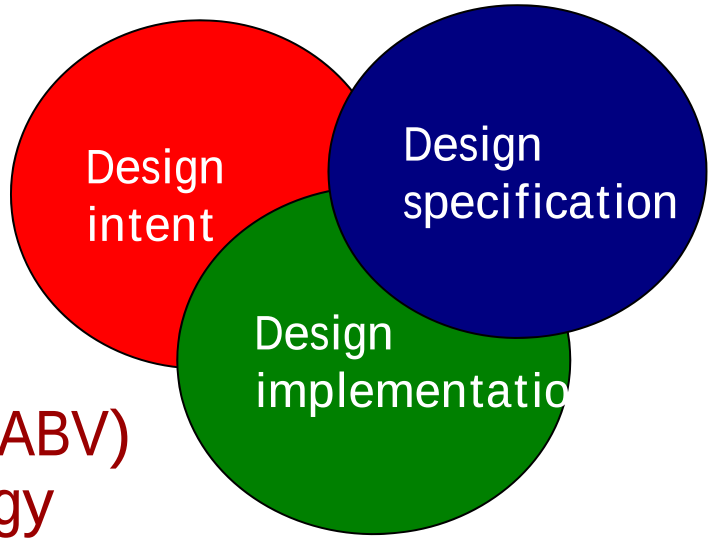
Franco Fummi, Graziano Pravadelli, Tiziano Villa





# Verification: why?

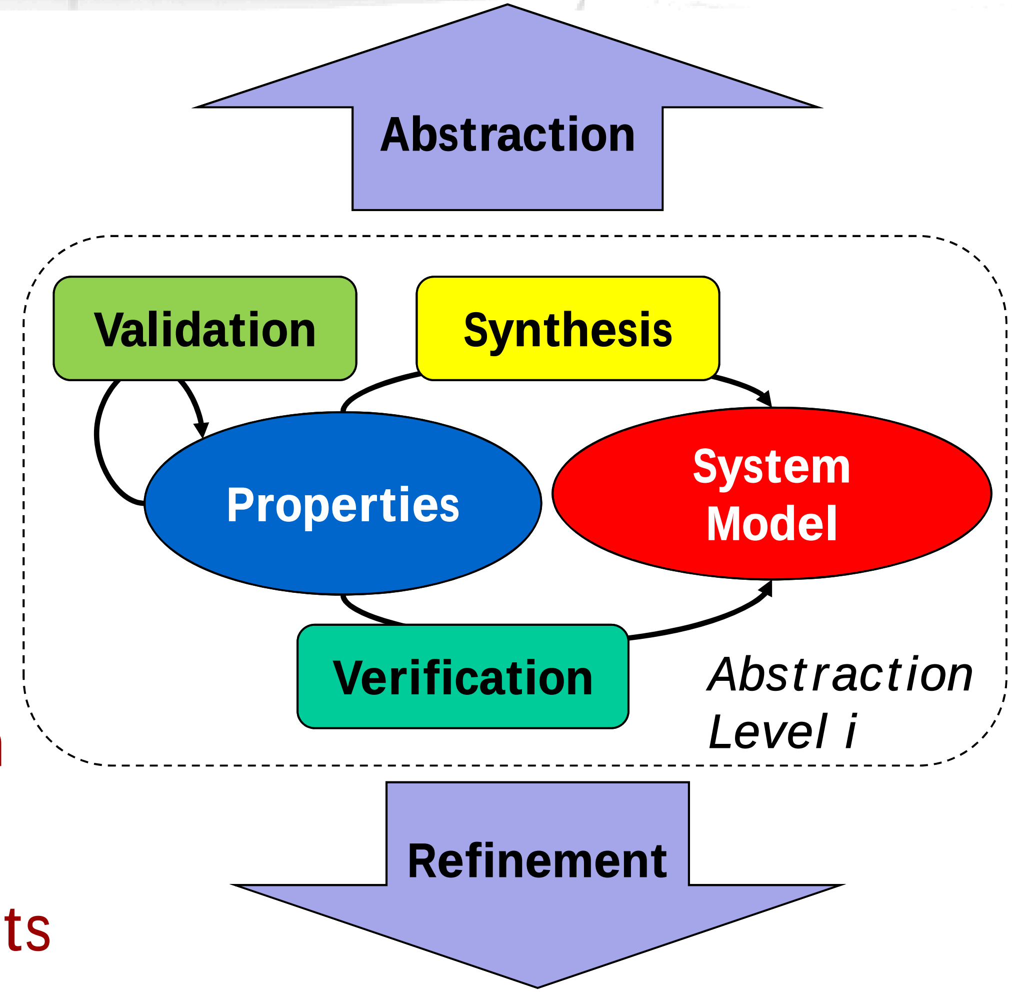
- **(Functional) verification** is the process of determining that the intent of the designer has been correctly implemented and is preserved during the implementation process
  - Does my specification really match my intent?
  - Does my implementation really match my specs?




- Assertion Based Verification (ABV) provides a unified methodology for **unambiguously specifying and verifying** design intents by using formal specifications

# Verification: where?

- Design is a continuous mix of verification, refinement and abstraction
- Verification should not be only a post-refinement step, but it should guide the design with some correct-by-construction refinements



# Spatial assertions: challenges

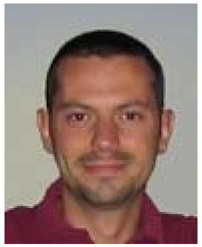
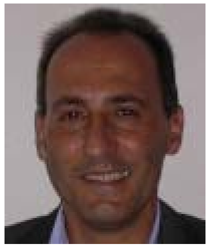
- Deal with approximation error in a formally sound way
- Control of approximation error, especially when non-determinism is considered
- Efficient representation of space regions, due to a significant impact of dimensionality
- Effective convergence for infinite-time reachability calculus
- Combine different approaches to different classes of dynamics

# Temporal assertions: challenges

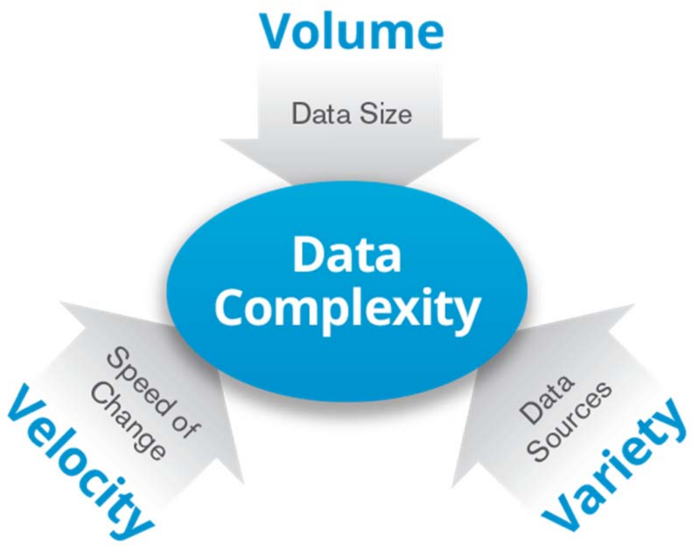
- Automatic generation of assertions
- Automatic abstraction and refinement (reuse) of assertions at different levels (ESL, TLM, RTL)
- Evaluation of the quality of assertions
- Verification of assertions taking care of:
  - dynamic vs. static approaches
  - discrete vs. continuous domains
  - real time constraints
- Non only in the functional domain (power, timing, …)

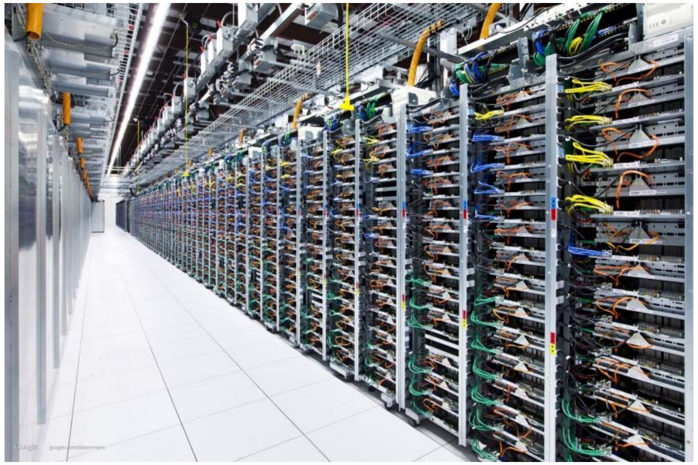
# Networking systems

Damiano Carra, Franco Fummi, Davide Quaglia

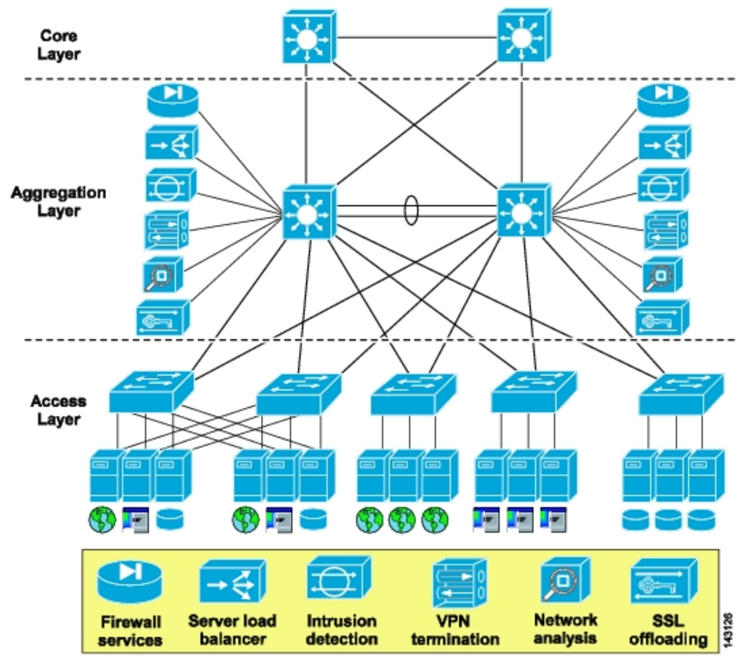
- The increasing size of available data requires new systems able to process it
  - The datacenter as a computer



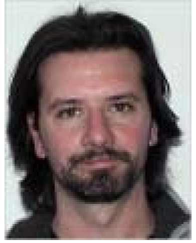
# Datacenter Networking

- Networking inside a datacenter plays a crucial role
- Key problems
  - All-to-all communication
  - Available end-to-end bandwidth
  - Delay



# AI and Robotics

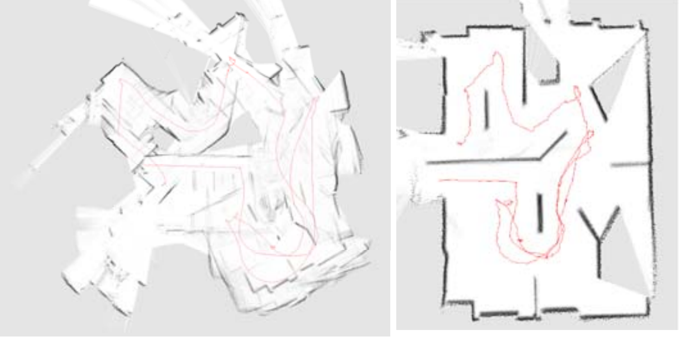
Alessandro Farinelli, Riccardo Muradore, Paolo Fiorini, Andrea Calanca



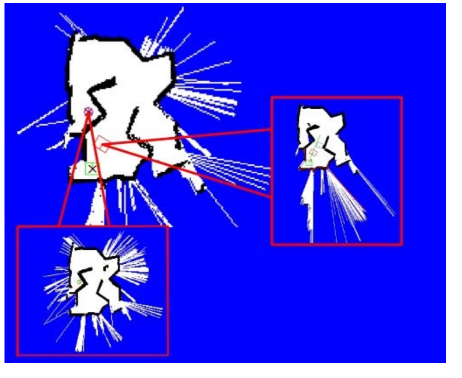

# AI and Robotics

**Algorithms** for **intelligent** robots and multi-robot systems

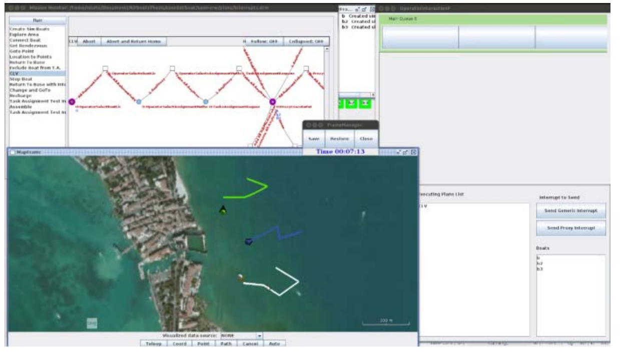
**Noisy perception**



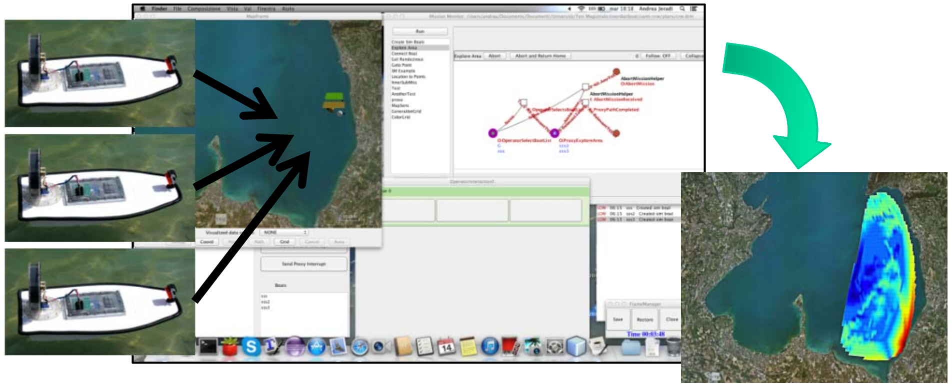
**Distributed knowledge**



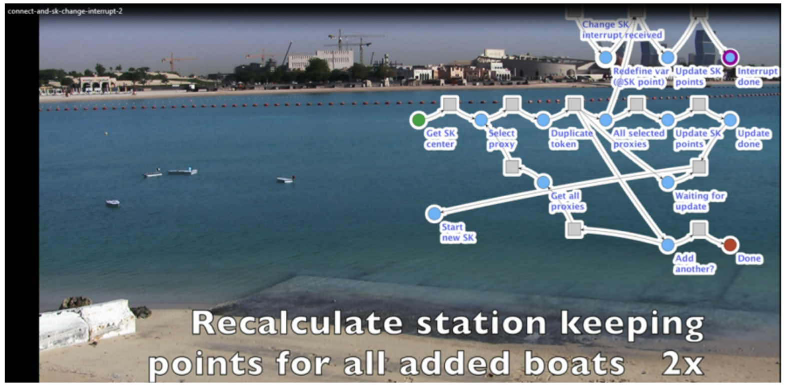
**Interacting with humans**



# AI and Robotics

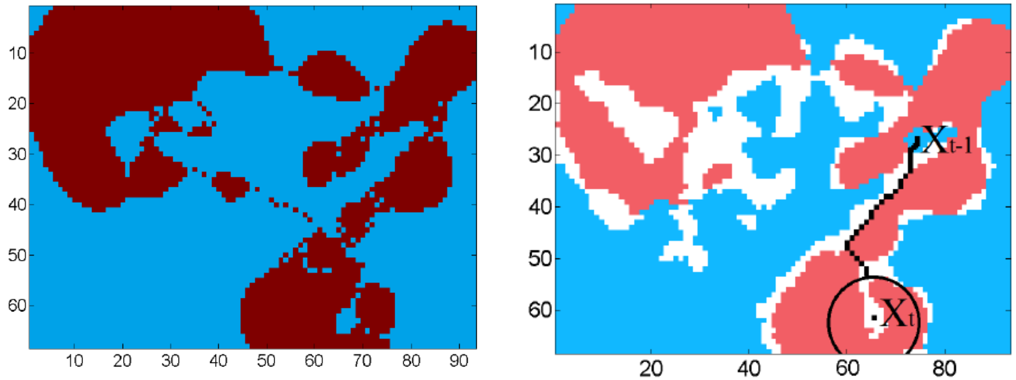


**Environmental monitoring**
**(**INTCATCH H2020 )




**Formal methods for team level control**

**Collaborations:**
CMU (US), Univ. Sapienza (Italy)



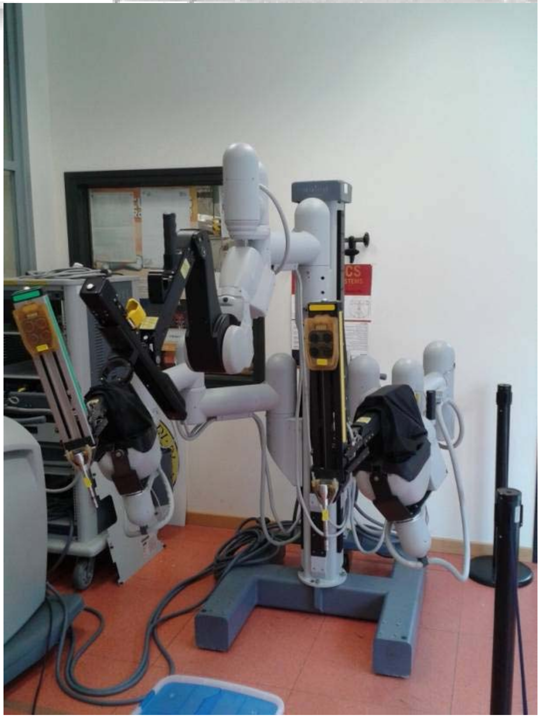
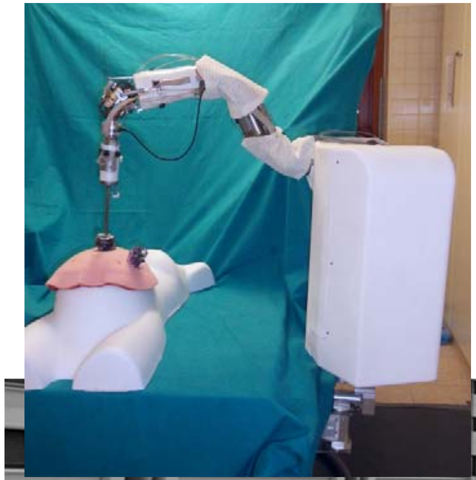

**Informative paths for classifications**

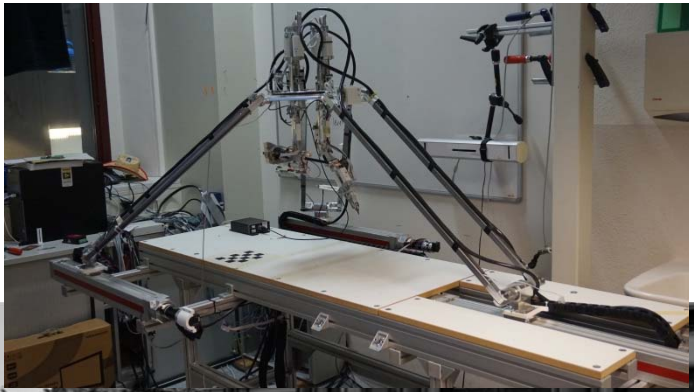
## Lab. Altair

- CV2 piano -2
- Windows, Linux
- Mobile robots
- Fixed robots
- Sensors
- Haptic devices
- Tracking devices
- UltraSound machine
- da Vinci surgical robot

# Robotic Surgery

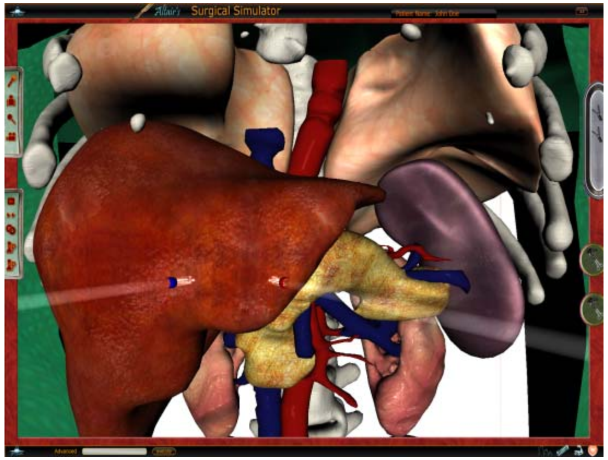
- Robotic Surgery
  - Patient safety
  - Surgeon training
  - Automatic task execution
  - Robot control
  - Sensor data fusion

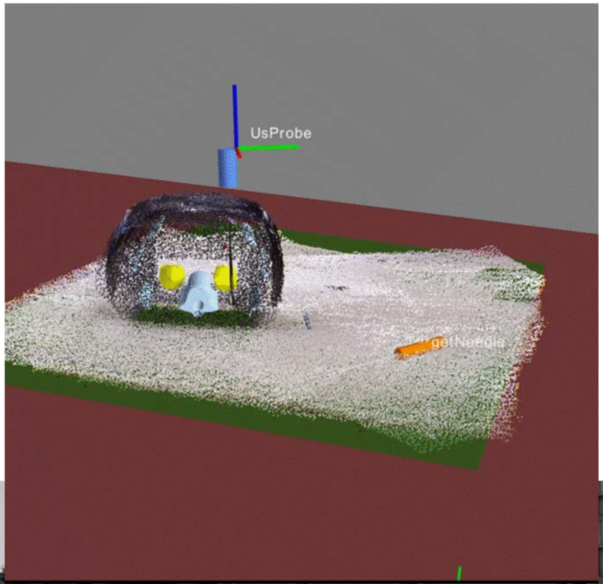






# Organ modelling

- Organ modelling
  - Medical image analysis
  - Organ property measure
  - Virtual organ development
  - Deformable model analysis
  - Organ registration

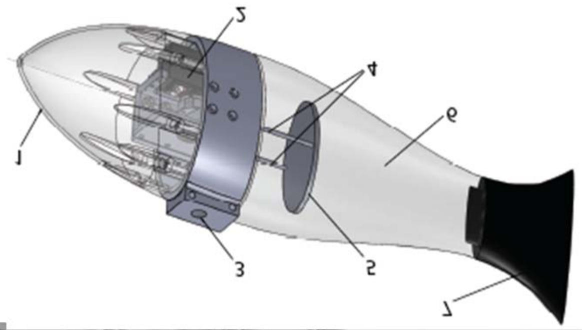


# Rehabilitation and Bio-inspired

- Rehabilitation

- Bio-inspired robots
  - Morphological computing
  - Flow image analysis
  - Biological experiments
  - Computatonal fluid dynamics



# Research areas

- Teaching with Robots
  - Mobile robots
  - Drones

# EU Projects

- MEDICATE (FP5) The control of prescribed medications
- XPERO (FP6) Robot learning by exploration
- ROSTA (FP7) Robotic standards
- ACCUROBAS (FP7) Accurate robotic assistant
- SAFROS (FP7) Patient safety in robotic surgery
- ISUR (FP7) Intelligent surgical robotics
- EUROSURGE (FP7) European robotic surgery
- EDUFILL (FP7) Robotic teaching
- ROBIOPSY (Italy-USA cooperation) Robotic Prostate Biopsy
- MURAB (H2020) MRI and Ultrasound Robotic Assisted Biopsy
- INTCATCH (H2020) Teams of intelligent robots for water monitoring

safros
Patient Safety in Robotic Surgery

I-Sur
INTELLIGENT SURGICAL ROBOTICS

ESurge

MURAB

INTCATCH 2020