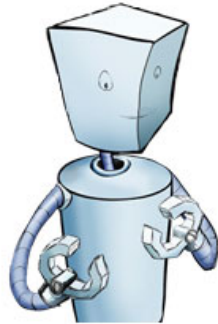


Robots are already among us!



## Experimental learning: How to cope with uncertainty

Paolo Fiorini  
Dipartimento di Informatica  
Università di Verona



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## Summary

- A brief presentation of the Robotics Laboratory at Verona
- Why learning during Search and Rescue operations?
- Machine v/s Robotic learning
- Concepts and architectures of learning by experimentation
- The experimental loop
- Conclusions



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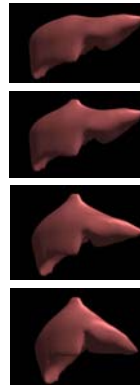
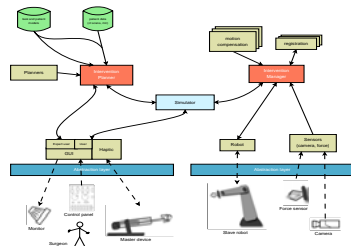
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# Robotics@Verona

- ALTAIR, robotics laboratory (2001)
- Active areas of research:
  - Service Robotics
  - Teleoperation
- Funds: EU Projects on Surgery, Learning, and Standardization



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## Search and Rescue Situations



Inspection



Hurricane



Stabilization



Tsunami



Earthquake



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## Rationale for Learning in S&R Tasks

- Search and Rescue operations occur after significant physical, geographical and structural alterations of the environment

- The known environment configuration and properties are just a hypothesis on the current status of things.

- Robots must learn the new properties of the objects around them
- Robots must verify the validity of a priory knowledge and improve on their built in knowledge



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## Machine and Robotic Learning

- Machine Learning:

- Data generated by unknown processes,
- No influence on data selection,
- No possibility of acquiring more specific data.

- Robotic Learning:

- Robot generates the data to analyze,
- Robot can choose when, where and how to take data
- Robot can refine data collection to improve its knowledge



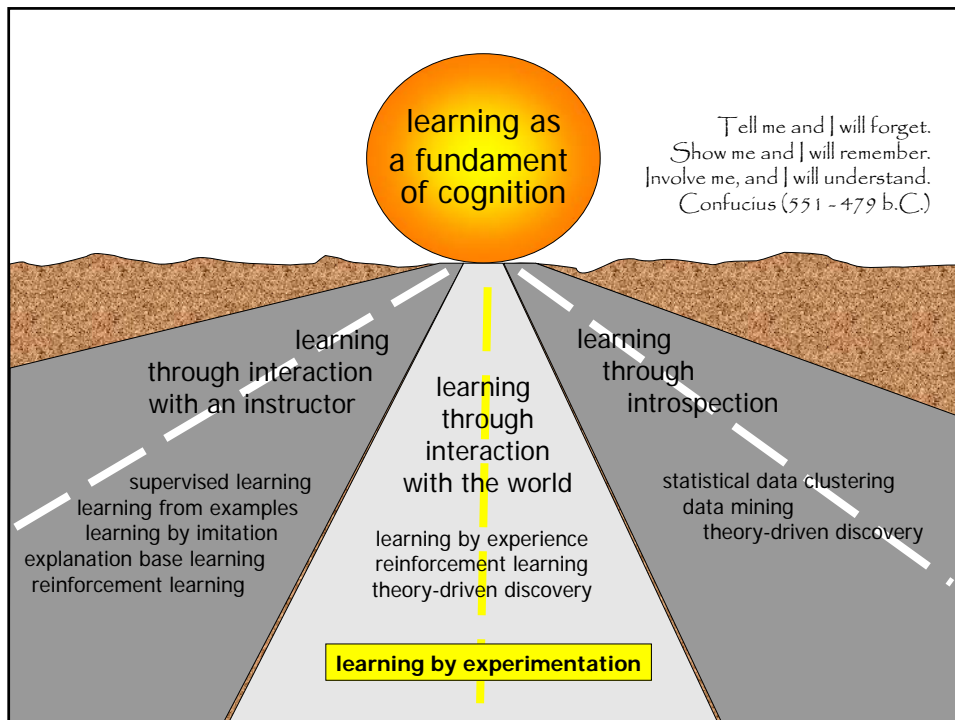
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## The EU Project XPERO



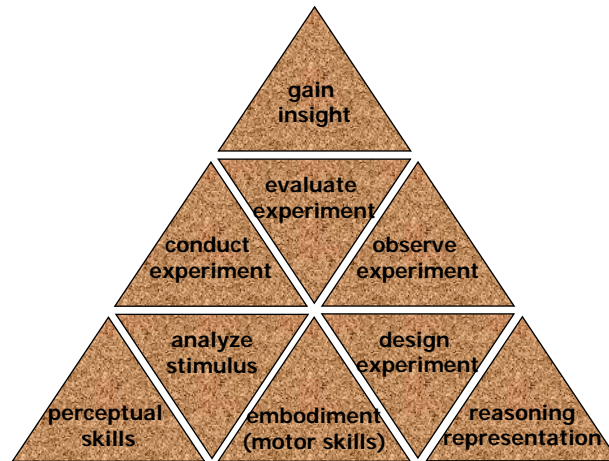
- EU Project of the 6<sup>th</sup> Framework Programme
- Started on April 1<sup>st</sup> 2006
- Including the following partners:
  - University of Bonn-Rhein-Sieg (Germany)
  - Technische Universität Wien (Austria)
  - University of Verona (Italy)
  - University of Ljubljana (Slovenia)
  - American University of Paris (France)
- The objective is to devise methods to learn the properties of objects and characteristics of the environment.



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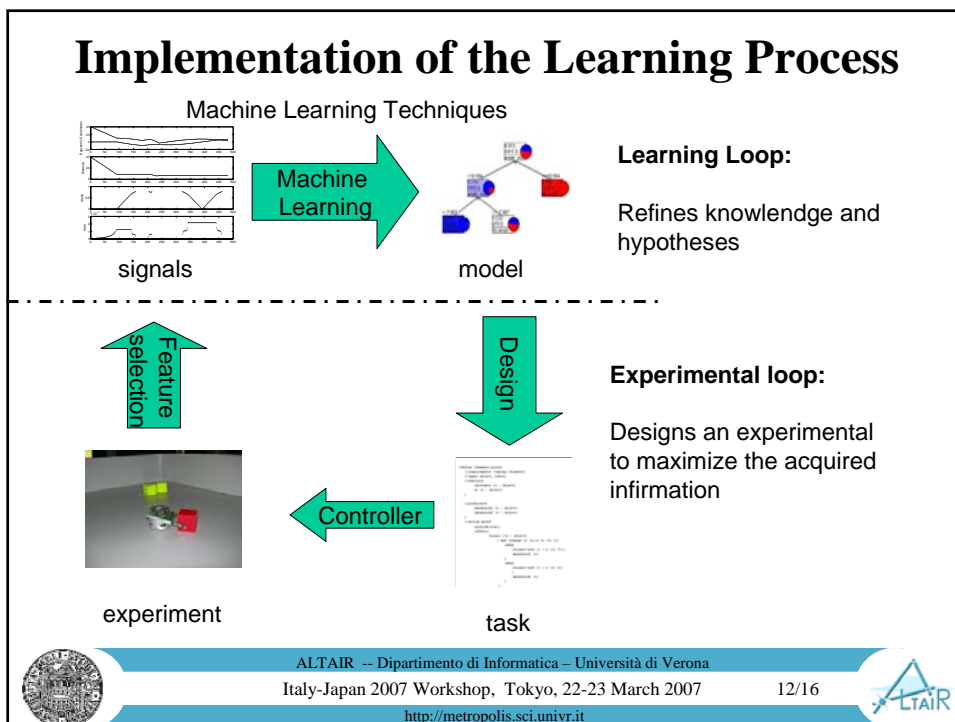
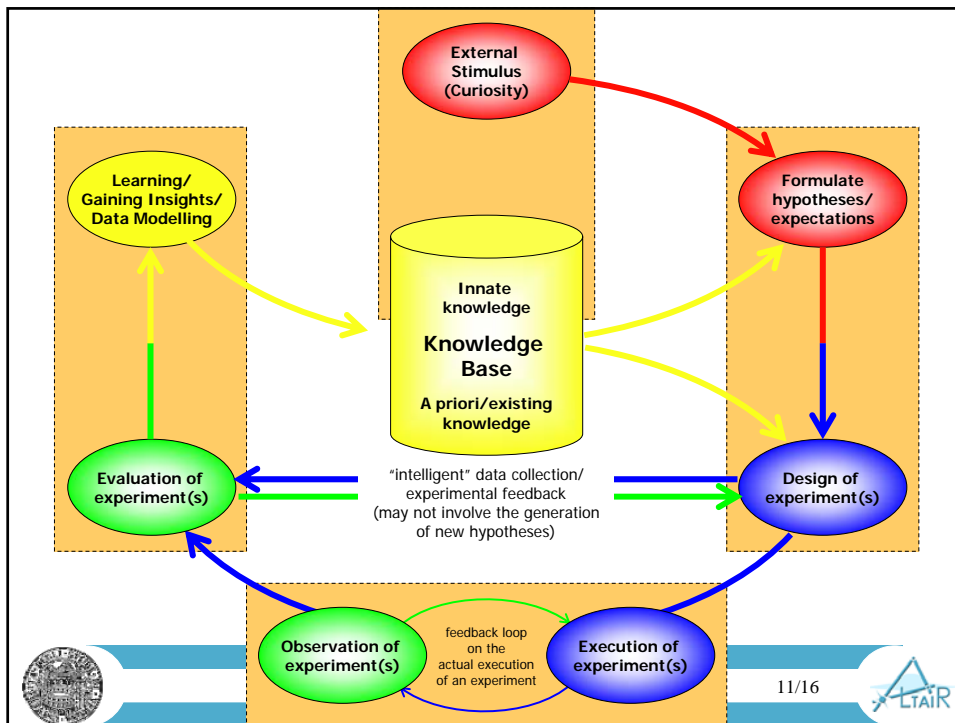
## Concepts of Learning by Experimentation

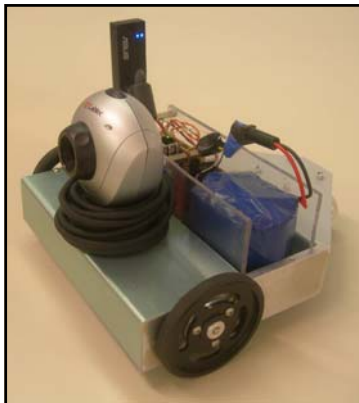


## The Robotic Learning Process

- Two main functional processes:
  - **Experiment loop:**
    - the robot designs an experiment, plans it, and carries out its execution
    - techniques of control, signal processing, and embedded systems are applied
  - **Learning loop:**
    - the robot examines the data, validates them, and extracts new knowledge.
    - techniques of machine learning and pattern recognition







## The Experimental Loop

- Consists of several cascaded steps:

- **Experiment Designer:** constructs an abstract experiment from the current set of hypotheses and world knowledge

- **Experiment Planner:** maps the abstract experiment into a temporal sequence of actions and sensing matching pre/post-conditions
  - **Experiment Embodier:** maps the task into the actions of a specific robot
  - **Functional level:** executes the actions and collects the data generated



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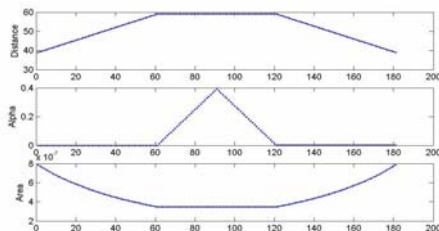
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## The Experiment Designer

- The objective of this step is to identify how to span the space (*actions X sensing*), as to maximize the data information
- For example: modeling the distance of a 2-dof robot to a sphere



Robot can move forward and backward, and rotate the camera. First data collected by random motion.

Machine Learning

**Preliminary Hypothesis**  
 $Area = K / (Dist^2)$



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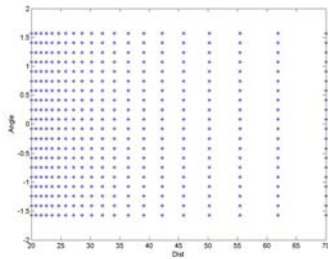
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## Data Pool Refinement

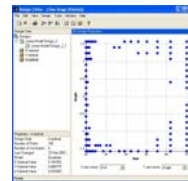
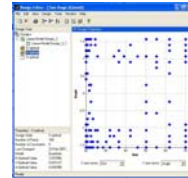
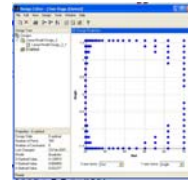
- Normally, the (*actions X sensing*) space that satisfies the preliminary hypothesis is very large, it is necessary to extract points with maximum information.



$$D_{eff} = \frac{\log_e(\det(X' X))}{k}$$

$$V_{eff} = \frac{1}{n_c} \sum_j x_j'(X_c' X_c)x_j$$

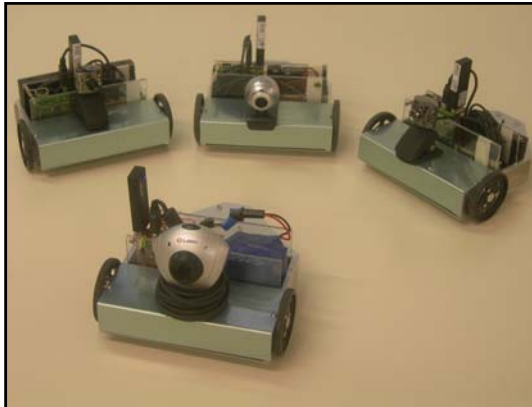
$$A_{eff} = \text{trace}((X' X)^{-1})$$



## Conclusions and Future Work

- Instrumental to all robotic activities that deal with unstructured environments is **Learning by Experimentation**.
- Thanks to EU fundings, the project XPERO is developing the learning framework by combining methods from robotics and machine learning.
- At the end of the first year we are testing the first simple process, with various mobile robots. In the next two years we will address more complex learning examples.
- IEEE-IFRR Summer School on Robotics Learning, September 24-29 Lazise (Verona – Italy)





**Thanks for  
Your Attention**



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