W1. Objectives, Challenges, State of the Art, Technologies

- Socio-economic context
- Technological evolution of Robotics & State of the Art
- **New challenges for Robotics in Human Environments**
- Decisional & Control Architecture for Autonomous Mobile Robots & IV
- Sensing technologies: Object Detection
- Sensing technologies: Robot Control & HRI
- Basic technologies for Navigation in Dynamic Human Environments
- Intelligent Vehicles: Context & State of the Art
- Intelligent Vehicles: Technical Challenges & Driving Skills

Introducing Robots in Human Environments brings new Challenges to Robotics

House Keeping

Care Taking

Robot & Human have to safely:

- ✓ Cooperate & Accomplish tasks together
- ✓ Communicate & Interact
- ✓ At least “Co-exist”

Personal Assistant

➔**New concept**:

Socially Acceptable Robot Motions &

➔**New environments**:

Open, Dynamic, Uncertain & Populated by Human Beings

New functionalities have to be developed

Intensive human-robot interactions

Highly dynamic world

Accuracy & increased Safety

➔ *e.g. "Companion robot" operating in " human personal space"*

New functionalities have to be developed

Intensive human-robot interactions

Accuracy & increased Safety

Highly dynamic world

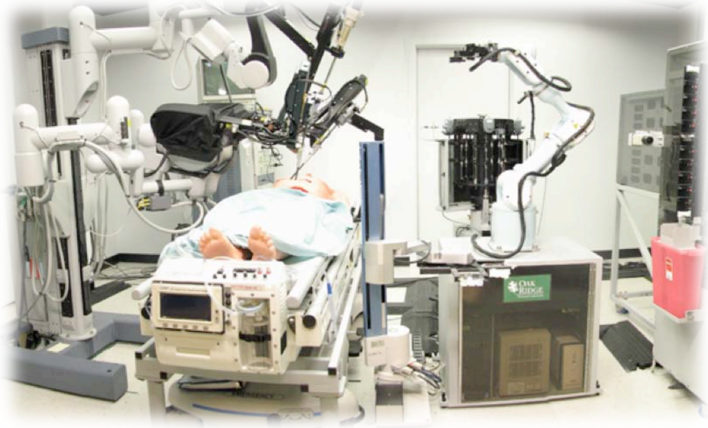
➔ *e.g. "Intelligent Vehicles" operating with / among human beings*

New functionalities have to be developed

Intensive human-robot interactions

Highly dynamic world

Accuracy & increased Safety



➔ *“Surgical robots” operating in close contact with human bodies & organs*

Required technological breakthroughs

- **Motion & action autonomy v/s Shared control**
  - ➔ *Adapted to Dynamic & Open Environments populated by Human Beings*
- **Increased robustness & safety (sensing & control)**
  - ➔ *Dealing with incompleteness & uncertainty (Bayesian models)*
- **Intuitive Programming & Human Robot Interaction**
  - ➔ *Self-learning capabilities & behavior models + Multi-modal interaction*
- **Real-time & Cost constraints**
  - ➔ *Miniaturization & Efficient Embedded systems*

Required technological breakthroughs

Real dynamic world too complex for being fully modeled using classical tools

Complexity & Incompleteness & Uncertainty

Necessity to introduce

Probabilistic Reasoning Approaches

in traditional Decisional & Control Robot Architectures

Two complementary reasoning processes

Geometry, Topology , Kinematics
Motion Models & Algorithms

Dynamic world

Analytical & Statistical data
Sensing data

Geometric & Kinematic reconstruction
SLAM
Motion prediction…

▼

Space & Motion Models

Constrained Motion Planning

Configuration Space
Velocity Space
Differential Flatness …

▼

Motion plan & Navigation controls

Mastering the complexity by using the right ***reasoning level & incremental approaches***

Two complementary reasoning processes

Geometry, Topology , Kinematics
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Space & Motion Models

Constrained Motion Planning

Differential Flatness,
Velocity Space…

Motion plan
& Navigation controls

Mastering the complexity by using the right reasoning level & incremental approaches

Uncertainty & Incompleteness
Bayesian Reasoning

Incompleteness

Prior Knowledge
+
Experimental Data
=
Probabilistic Representation

Maximum Entropy Principle

$$\Sigma P_i \log(P_i)$$

Uncertainty

Bayesian Inference
(NP-Hard [Cooper 90]
Heuristics & Optimization)

P(AB|C) = P(A|C) P(B|AC)= P(B|C) P(A|BC)
P(A|C) + P(¬A|C) = 1

Queries
& Decision Process

Taking explicitly into account the hidden variables & uncertainty at the reasoning level

Successful large scale experiments in Human Environments

Tour-guide robots *(Swiss National Exhibition Expo 2002)*

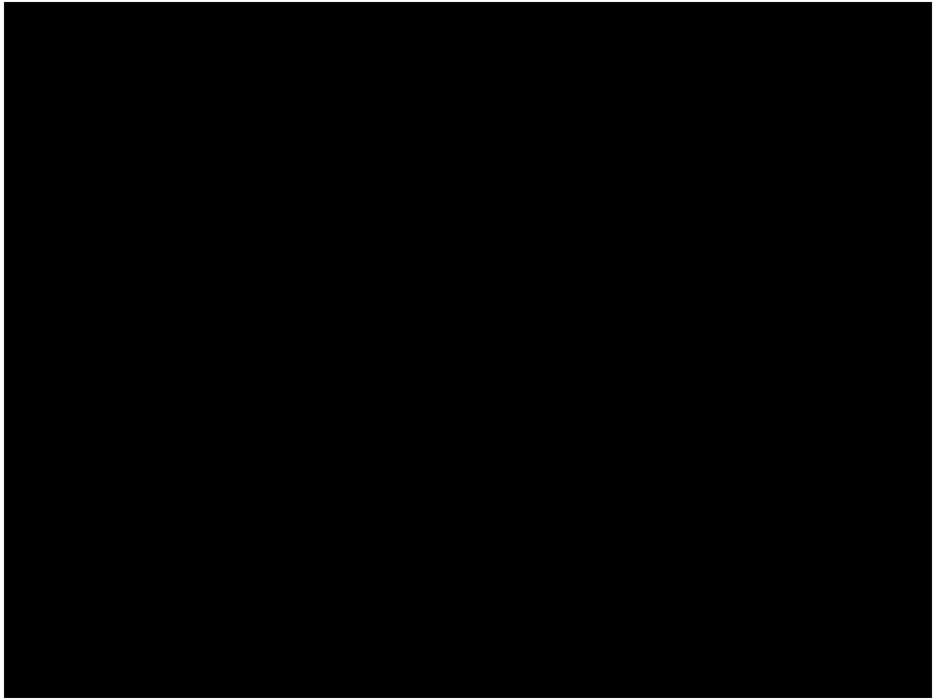
BlueBotics SA
&
EPFL Autonomous Systems Lab

- 4 Months, Daily operation, Up to 12h/day, Up to 11 robots simultaneously
- 13 300 hours Operation time, 3 300 km Traveled distance, 680 000 Visitors
- Mainly "natural" interactions with children, No accident

Successful large scale experiments in Human Environments

CyberCars Public Experiments *(Inria & EU Partners)*

- Several experiments in public areas
- Some CyberCars products in commercial use *(e.g. Robosoft, 2GetThere…)*



Floriade 2002 - Amsterdam

Successful large scale experiments in Human Environments

DARPA Urban Challenge 2007

- **96 km** through urban environment
- **50** manned & unmanned **vehicles**
- **35 teams for qualification,** 11 selected teams, 6 vehicles finished the race
- **Road map** provides a few days before the race
- **Mission** (checkpoints) given 5mn before the race
- Several **incidents/accidents** during the event

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