URUS
Ubiquitous Networking Robotics for Urban Settings

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http://www-iri-upc.es/groups/lrobots

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WebSite

http://www-iri.upc.es/urus

Project Objectives

- **Objectives:**
  - The main objective is to develop an adaptable network robot architecture which integrates the basic functionalities required for a network robot system to do urban tasks

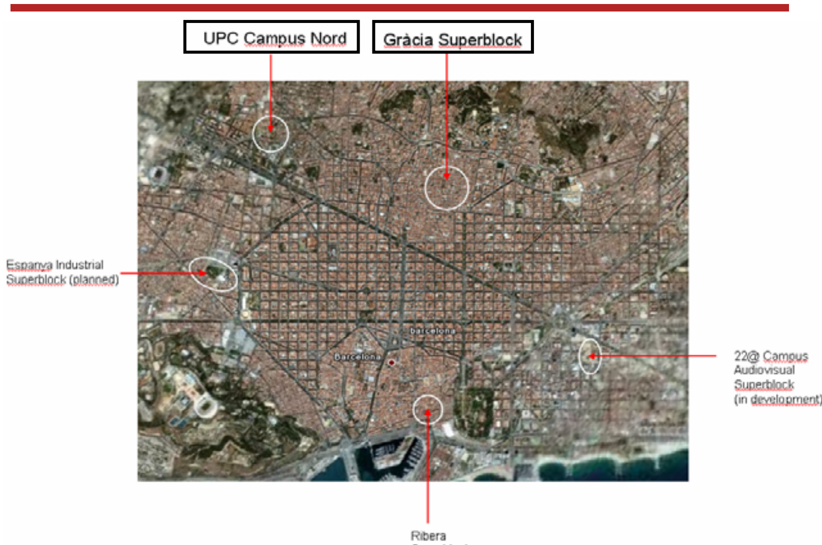
- ***1. Scientific and technological objectives***
  - City rules and requirements due to robots in Urban areas
  - Cooperative localization and navigation
  - Cooperative environment perception
  - Cooperative map building and updating
  - Human robot interaction
  - Multi-task allocation
  - Wireless communication in Network Robots

- ***2. Experiment objectives***
  - Guiding and transportation of people
  - Surveillance: Evacuation of people

URUS Partners

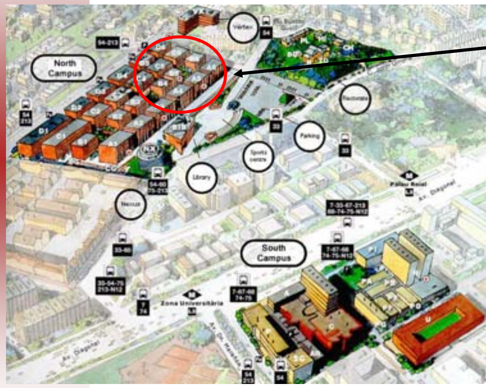
Participant Role*	Country	Participant name	Participant short name
Coordinator Research Partner	Spain	Technical University of Catalonia (Institute of Robotics) Alberto Sanfeliu	UPC
Research Partner	France	Centre National de la Recherche Scientifique Rachid Alami / Raja Chatila	LAAS
Research Partner	Switzerland	Eidgenössische Technische Hochschule Roland Siegward	ETHZ
Research Partner	Spain	Asociación de Investigación y Coop. Indus. de Andalucia Anibal Ollero	AICIA
Research Partner	Italy	Scuola Superiore di Studi Universitari e di Perfezionamento Sant'Anna Paolo Dario	SSSA
Research Partner	Spain	Universidad de Zaragoza Luis Montano	UniZar
Research Partner	Portugal	Instituto Superior Técnico Joao Sequeira / Jose Santos Victor	IST
Research Partner	UK	University of Surrey John_Illingworth	UniS
Agency Partner	Spain	Urban Ecology Agency of Barcelona Salvador Rueda	UbEc
Industrial Partner	Spain	Telefónica I+D Xavier_Kirchner	TID
Industrial Partner	Italy	RoboTech Nicola Canelli	RT

Experiment Locations



Experiment Locations: Scenario 1

Zone Campus Nord, UPC



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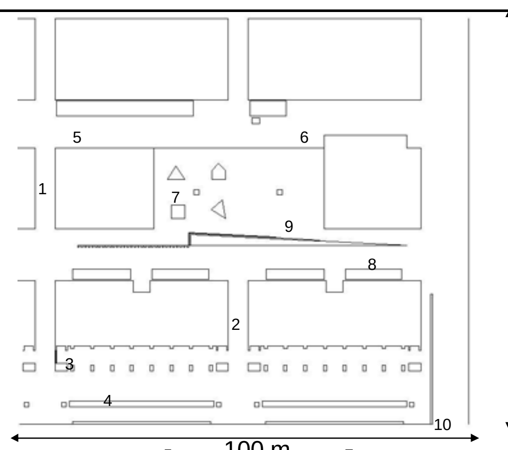
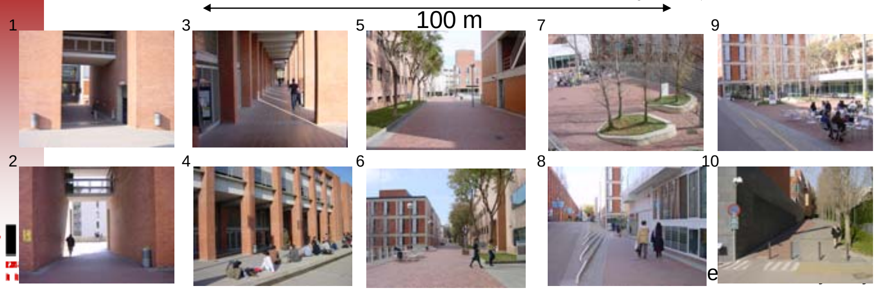
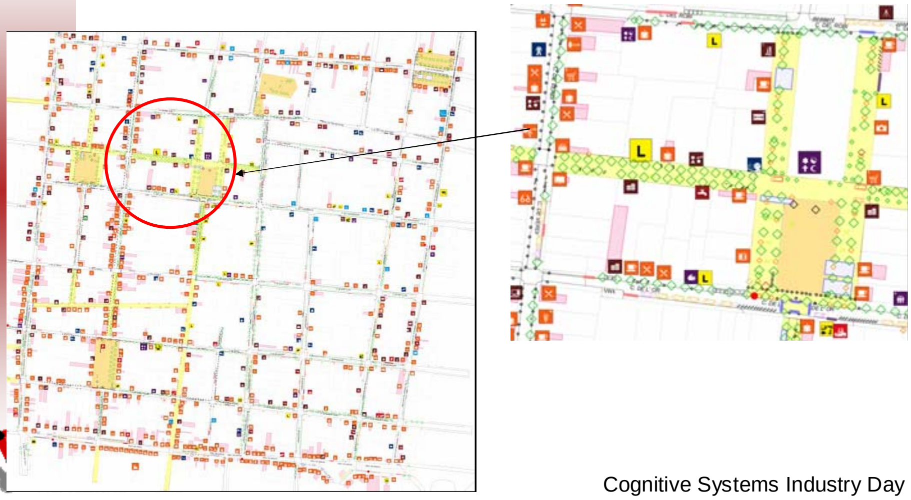
Zone Campus Nord, UPC



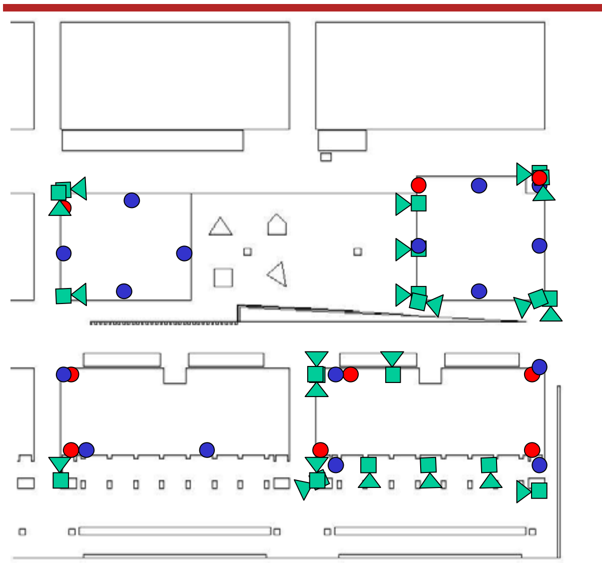


Experiment Locations: Scenario 2

Zone
Gracia District



Infrastructure for Scenario 1



- Potential positions of cameras

Potential positions of access points (Wifi)

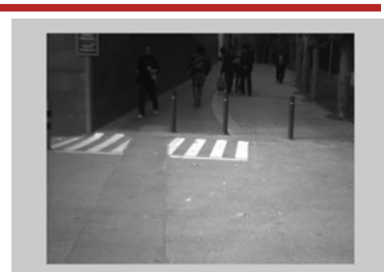
Potential positions of Mica2

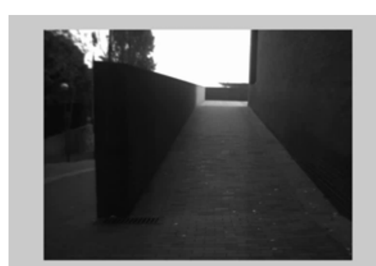
Some Videos of Scenario 1

Large video showing the new Segway Robot Platform for URUS developed at UPC during a data acquisition run.

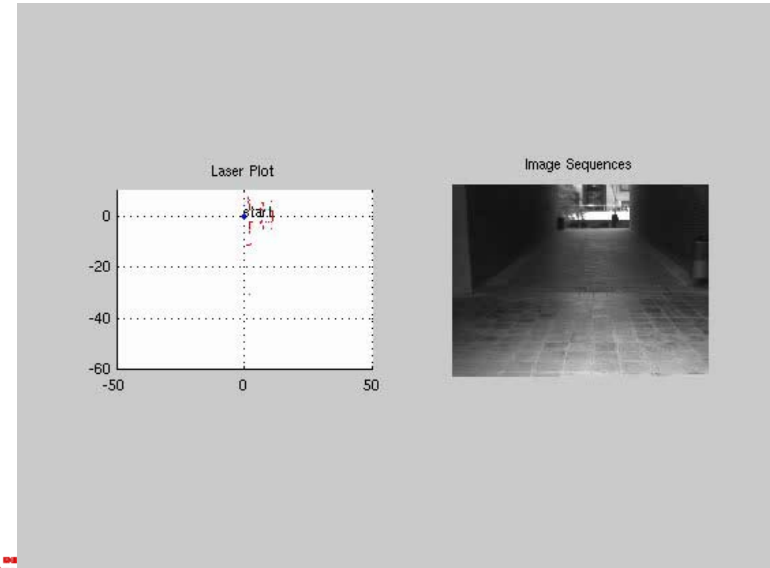
Video: SANYO088.MP4 y SmartAndSegway.mpg

Some Videos of Scenario 1





Some Videos of Scenario 1



Hardware and Robots

Robot 1

Robot 2

Robot N

Functional Layer
Supervisor Task Allocation

Wifi

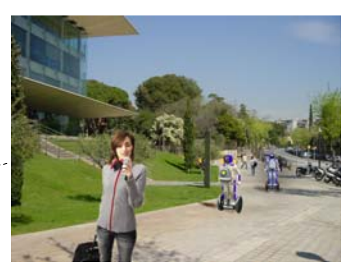
Ethernet

Ethernet

Central Station

Task Allocation
Environment Perception
GSM Interface
Global Supervision

GSM Network



Scientific and Technological Objectives

City rules and requirements due to robots in Urban areas

- **Objectives:**
  - To analyze the city requirements to use robots in urban areas, for example, easy mobility, reserve areas for robot loading and unloading, etc.
  - To study and modify, if necessary, city rules with respect to placement of sensors, robot security issues, etc.
  - To analyze and modify, if necessary, city rules with respect to people security and privacy.
  - To study city zones for pedestrians (superblocks) where the services can be given by robots.
  - To study sensor deployment in robots for measuring environment conditions

Cooperative Localization and Navigation

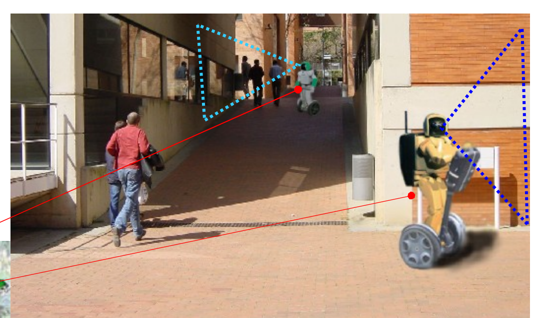
- **Objective:**
- To extend the navigation capabilities of the robots by:
  - Combining techniques of absolute localization
  - Using embedded and wearable sensors to localize robots and people
  - Developing centralized and distributed methods to collaboratively, move in a given area and localize robots or people
  - Integrating planning, reactive techniques and safety considerations
  - Keeping intelligent formations

in dynamic environments, in particular for urban settings.

Cooperative Localization and Navigation

Localization using:
- GIS
- multiple robots
- ubiquitous sensors

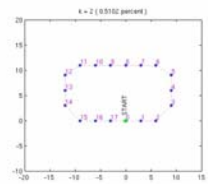
Navigation:
- Using GIS
- Own and embedded sensors



Cooperative Localization and Navigation

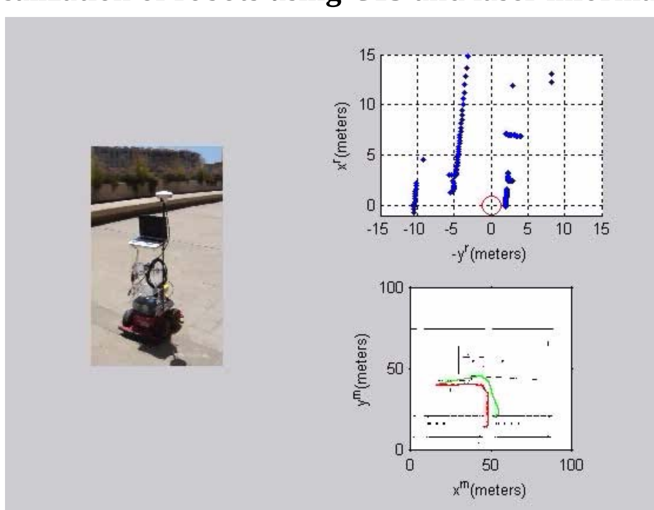
Fusion of odometry and visual odometry with an information filter. [Andrade, et al. IAV2007]

Video: SLAM_29Janallfast.avi



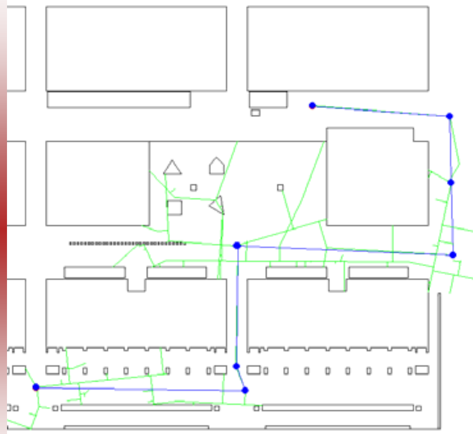
Cooperative Localization and Navigation

Localization of robots using GIS and laser information



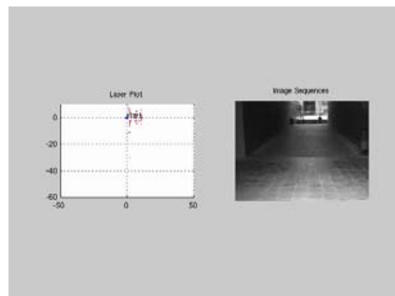
Cooperative Localization and Navigation

Navigation using path planning and sensor information



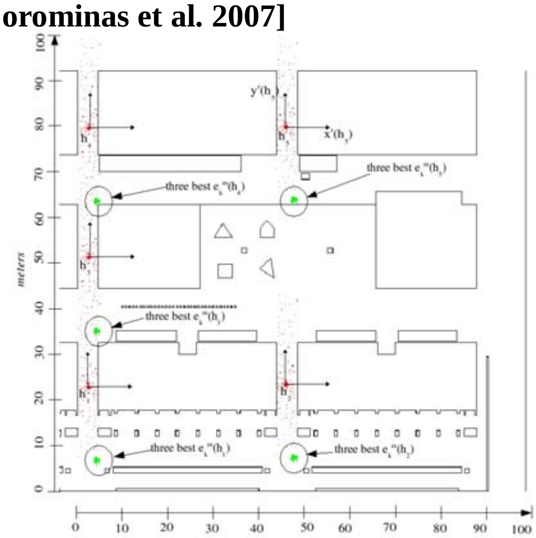
Path planning

Navigation with laser



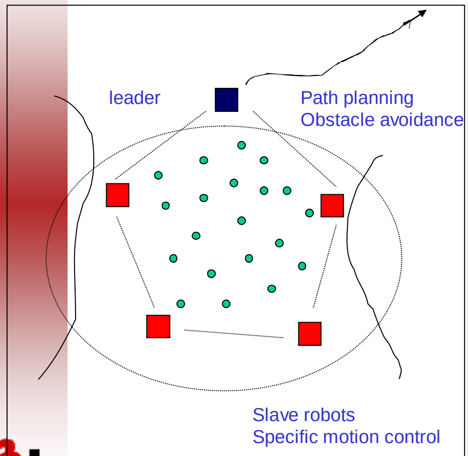
Cooperative Localization and Navigation

Auto-localization using probabilistic model [Corominas et al. 2007]

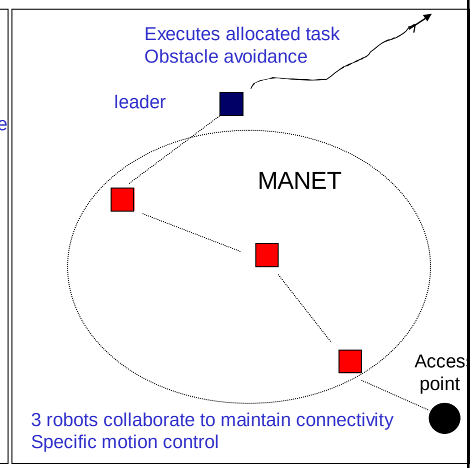


Cooperative Localization and Navigation

Robot formation



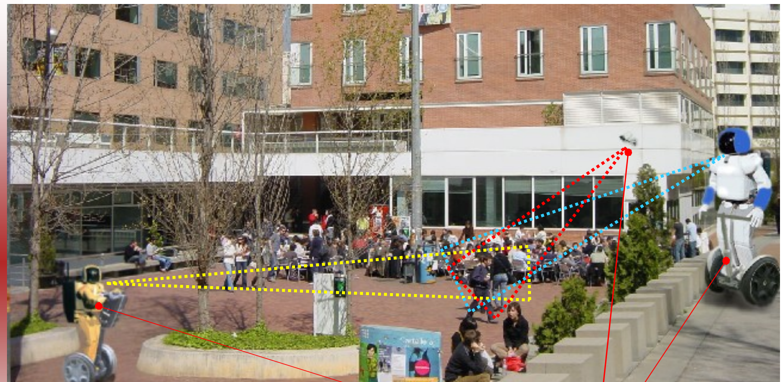
Network connectivity



Cooperative Environment Perception

- **Objective:**
  - To create and maintain a consistent view of the urban world by means of the information provided by the robot sensors and the sensors embedded in the urban environment.
    - Identification of Objects (humans and robots) in multiple cameras
    - Identification of humans in multiple cameras
    - Object Handover - Tracking humans and robots across cameras
    - Identification of events, scenario and situations

Cooperative Environment Perception



Cooperative perception using:
- embedded and own sensors
- fusion techniques and technologies

Cooperative environment perception

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Cooperative Environment Perception

Following a person with environment cameras

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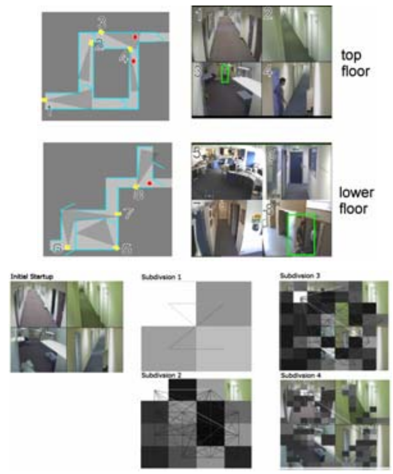
Cooperative Environment Perception

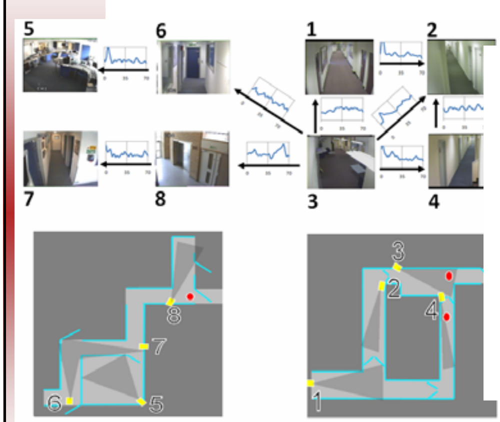
Following several persons with environment cameras

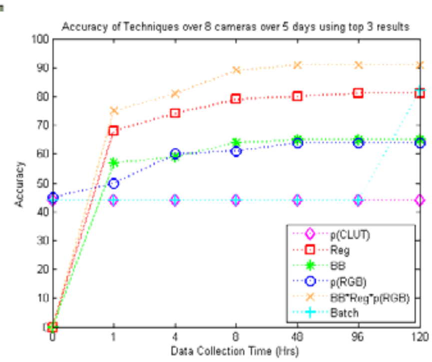
- Inter Camera – uncalibrated, non overlapping
- Learns relationships
  - Weak Cues
    - Colour, Shape, Temporal
    - Learns consistent patterns
  - Learns Entry/Exit regions
- Real Time (25fps)
- Incremental design
  - work immediately
  - improves in accuracy over time



Cooperative Environment Perception

Following several persons with environment cameras





Cooperative Environment Perception

Eliminating shadows in a sequence of images [Scandaliaris et al., 2007]

Original image **Gradient image** **Without shadows image**

Cooperative Environment Perception

Eliminating shadows in a sequence of images [Scandaliaris et al., 2007]

Original image **Gradient image** **Detection image**

Cooperative Environment Perception

- Homogeneus regions in scale-space: Color-blob based approach: Each blob is described by a 3d-normal distribution in RGB color space
- Without any predefined model of a person
- Initial startup: blob to track

Image i

Image i+1

Cooperative Environment Perceptio

Relative Ranging method

Try to eliminate effect of antenna orientation

Suitable for static nodes approximately in the same plane

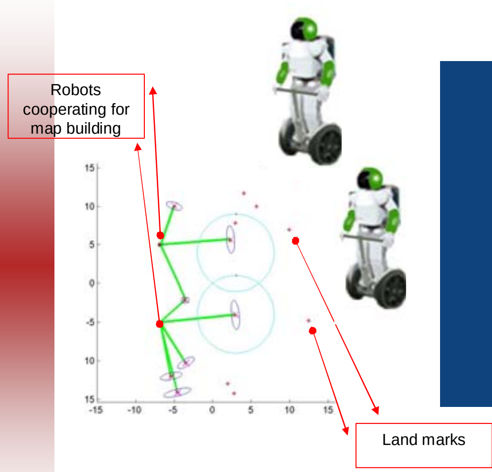
Triangulation using a non-linear least-square method

- Experiments
- ROMEO 4R autonomous robot with onboard WSN node
- Static WSN nodes deployed on campus
  - Average distance between consecutive nodes: 7.18 m

Cooperative Map Building and Updating

- **Objective:**
  - To augment the classical static Simultaneous Localization and Map Building (SLAM) problem to deal with dynamic environments, and to be cooperative using not only a troupe of robots, but all the different elements of the NRS.
    - Various map layers to be exploited during operational phases for localization and navigation purposes.
    - Incidentally, some map-based localization algorithms that can be of use in the project. At least for the set of robots used to build the map layers.
    - The positions and calibration of the camera sensor network.

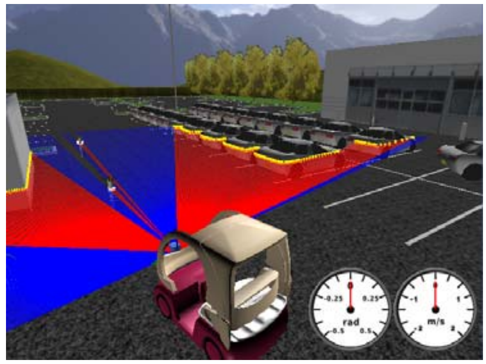
Cooperative Map Building and Updating



Cooperative SLAM:
- Using multiple robots and sensors
- Using control techniques

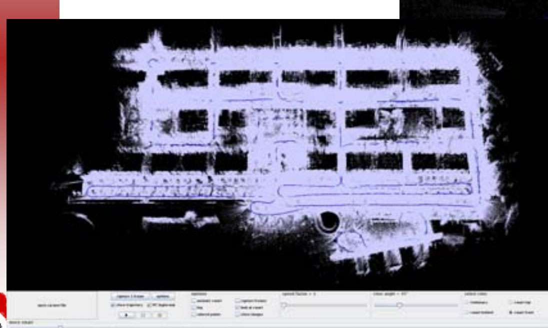
Cooperative Map Building and Updating

3D Map construction using laser beams



Cooperative Map Building and Updating

3D Map construction using laser beams



Video SmartData.mpg

Human Robot Interaction

- **Objective:**
  - To develop a series of tools to have a robust communication interface between robots and persons
    - Develop a user friendly and robust communication scheme
    - Develop a robot head able to generate neck and head motion and facial expressions
    - Develop expressive motions that the robots will use to convey meanings to people

Human Robot Interaction

Human robot interaction:
• Combining mobile phones, voice, touch screen

Human Robot Interaction

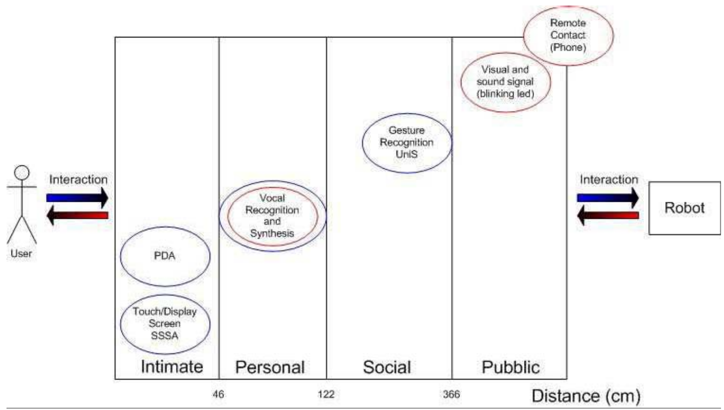
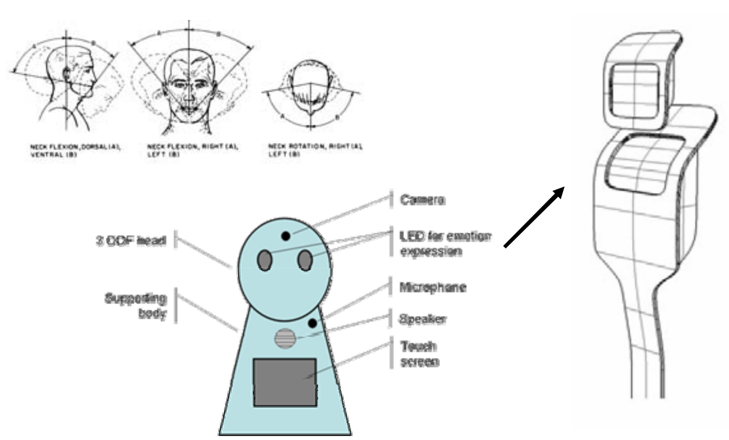


Fig.2: Interaction between the user and the robot across different distances

Human Robot Interaction

Design and features of the head



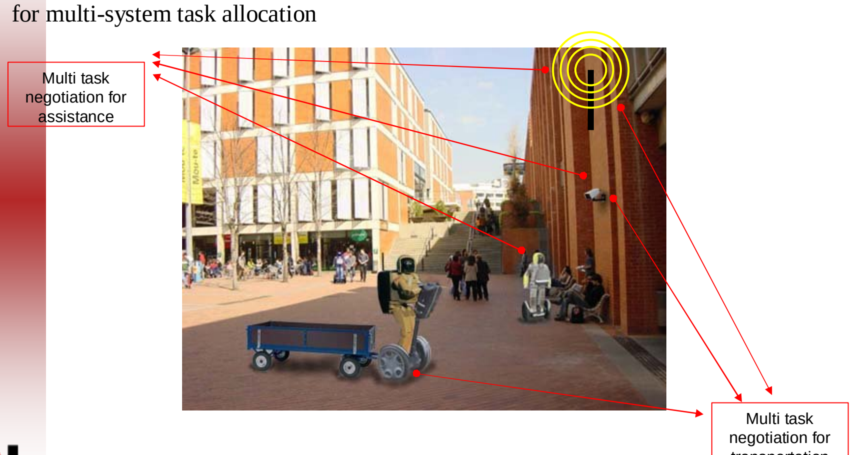
Multi-task Allocation

- **Objective:**
  - The objectives are oriented to the Experiments that will be done in the project.
    - Surveillance:
      - Detecting abnormal situations: possibility of camera detection of crowds, fires or people in the ground.
      - Coordinating and evacuation of a group of people
    - Transportation and guiding of people
      - Transporting: People or cargo is loaded at a meeting point, and transported to a requested unload location.
      - Guiding: A person is lead by a robot to a desired location or transferred to another robot that will continue the guiding, until the final destination is reaches

Multi-task Allocation

Multi-task negotiation:

• Using sub-optimal techniques
for multi-system task allocation



Wireless communication in Network Robots

- **Objective:**
  - To establish a robust wireless communication between robots, humans, sensors and other systems.
  - To improve the communication recovery for robots and humans.
  - To establish a common wireless interactive language and protocol for the communication between humans (by means of mobile phone), robots and ubiquitous sensors.

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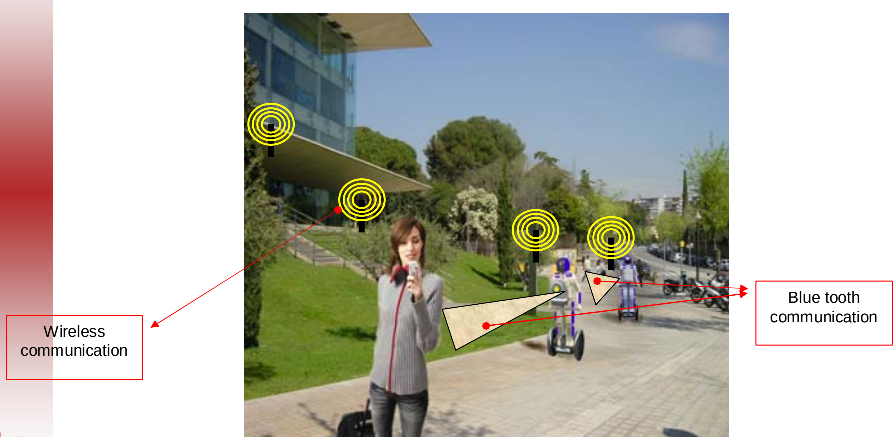
Wireless communication in Network Robots

Wireless communication:
• Combining wireless techniques
for robust communication



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Experiments

- **Urban experiments:**
  - 1.- Transportation of people and goods
    - Transporting people and goods
      - Taxi service requested via the phone
      - User request the service directly
  - 2.- Guiding people
    - Guiding a person with one robot
  - 3.- Surveillance
    - Coordinate evacuation of a group of people
  - 4.- Map building

Guiding and Transportation

URUS Potential Technologies for Industrial Applications (some examples)

- NRS architecture for robot tasks in Urban Sites
  - System architecture
  - Module communication methods among NRS sensors, robots and humans, using YARP
- Cooperative Localization and Navigation
  - Robust methods for cooperative localization (fusion of techniques, Zig-bee)
  - Robust method for cooperative self-localization
  - Robust method for robot navigation using NRS

URUS Potential Technologies for Industrial Applications (some examples)

- Cooperative environment perception
  - Tracking people using environment cameras and robots
  - Detection of people and robots using environment cameras and robots
- Cooperative map building
  - Integration of multiple levels of maps for navigation and localization
  - Combining sensor information and GIS by SLAM
- Task allocation
  - New methods for robot task allocation in the robots and the central station

Cognitive Systems Industry Day

URUS Potential Technologies for Industrial Applications (some examples)

- Communication
  - Proxy elements for combining multiple wireless communication protocols
  - Robot communication recovery techniques
- Human-robot interaction
  - Development of a friendly head for human-robot interaction in outdoors
  - New programs to use mobile phones for human-robot interaction
- **New Urban Site in Barcelona for testing Network Robot Systems**

Conclusions

- I the first year of the project (2007) we have analyzed the specifications, build part of the infrastructure and developed some techniques.
- Between 2007 and 2008 we will develop the techniques and in 2009 we will do the experiments
- The project face several problems, for example
  - The development of cooperative techniques among heterogeneous robots
  - Working with technologies that still do not allow to solve problems in dynamic and outdoors scenarios (communication, dynamic range of the cameras, etc.)
  - Robot-human interaction in outdoors scenarios

Some References

Sanfeliu and J. Andrade-Cetto, *Ubiquitous networking robotics in urban settings*. Workshop on Network Robot Systems. Toward Intelligent Robotic Systems Integrated with Environment. Proc. of 2006 IEEE/RSJ International Conference on Intelligence Robots and Systems (IROS2006), Beijing, China, Oct. 10-13, 2006.

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Special Issue on

Network Robot Systems (NRS)

A. Sanfeliu, N. Hagita and A. Saffioti
Co-Editors

Robotics and Autonomous System Journal

(It will appear half of 2008)

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