A View of Network Robot Systems in Urban Areas in Europe

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European FP6 Projects Related to NRS

FP6 project Acronym	Urban robot	Safe, dependable, cooperating with humans	Networking	Title / Application
RA-NRS	X	X	X	*Research Atelier on Network Robot Systems*: Road Map of Network Robot Systems
AWARE	X	X	X	*Platform for Autonomous self-deploying and operation of Wirelesssensor-actuator networks cooperating with AeRial objEcts:* Filming, and Disaster Management/Civil Security
CommRob		X	X	*Advanced Robot Behavior and High-level Multimodal Communication with and Among Robots*: Consumer applications
Dusbot	X	X	X	*Networked and Cooperating Robotics in Urban Hygiene*: Urban hygiene, vacuum clean, garbage collector,..
Guardians	X	X	X	*Group of Unmanned Assistant Robots Deployed In Aggregative Navigation supported by Scent detection:* Search and Rescue
IRPS		X	X	*Intelligent robotic porter system:* Porter guiding system for airports
IWARD		X	X	*Intelligent Robot Swarm for Attendance, Recognition, Cleaning and Delivery*: Healthcare
ROBOSWARM			X	*Knowledge Environment for Interacting Robot Swarm*: Service robot, open knowledge environment
URUS	X	X	X	*Ubiquitous Networking Robotics for Urban Settings*: Cognitive network architecture, surveillance, urban transportation

Research Atelier on Network Robot Systems

Home | Committee | Associated Members | Other Initiatives | Projects | Events | Publications | Private Area | Contact

Project Summary

The Research Atelier on Network Robot Systems (NRS) was created the 15th of December of 2005 within the EURON II (European Robotics Network) for a period of 1 year, with three purposes in mind: to generate a Roadmap of the NRS in Europe; to start a NRS community in Europe; and to disseminate the results of the Research Atelier among research institutions and companies, trough scientific and technological channels. This WEB has to be an open window to people interested in NRS.

We consider Network Robot Systems as groups of artificial autonomous systems that are mobile and make important use of wireless communication among them or with the environment and natural systems in order to fulfil their task.

Typical examples are:

- Networked robot teams
- Networked robot-human teams
- Robots networked with the environment

Research Atelier Events

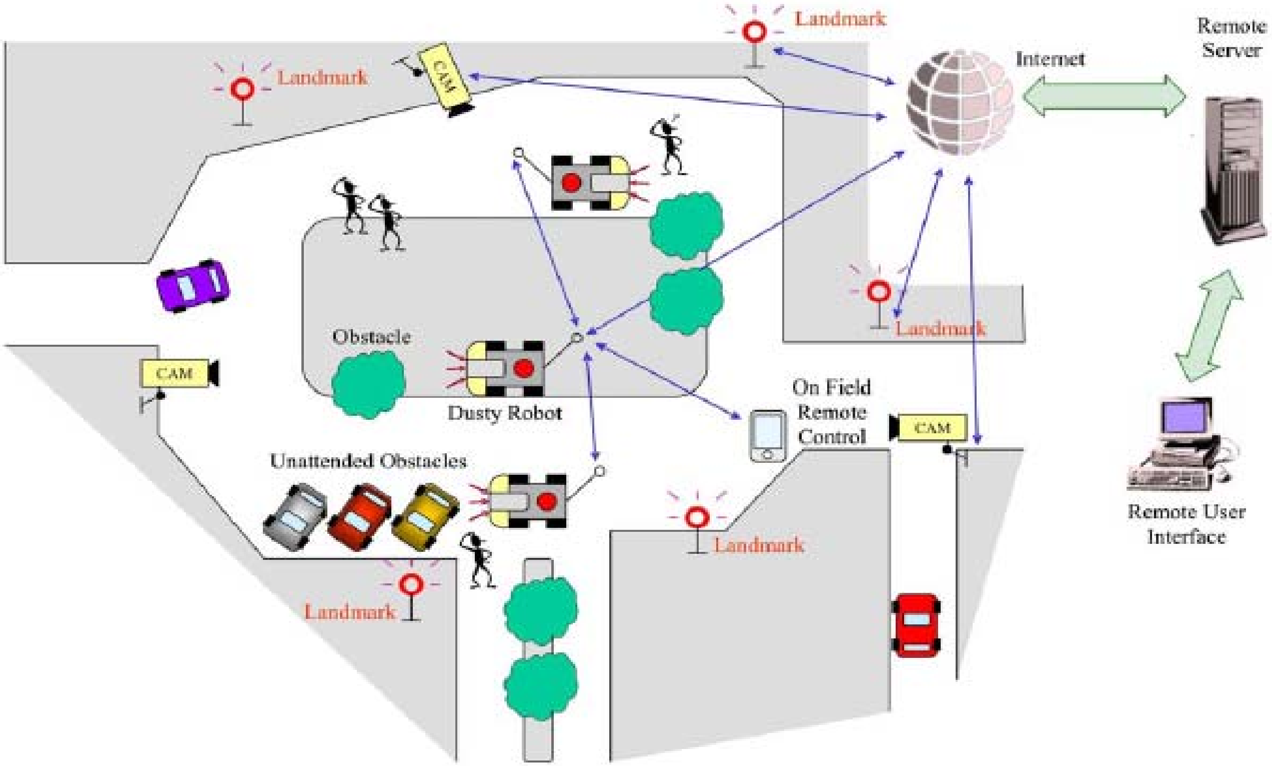
- 21-12-05 Kick-Off technical meeting at Barcelona (Spain)
- 17-03-06 NRS technical meeting at Palermo in conjunction with EURON II annual meeting (Italy)
- 15-05-06 Workshop: "Network Robot Systems:Toward Intelligent Robotic Systems Integrated with Environments" at Orlando (US) ICRA06

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

DustBot

Networked and Cooperating Robotics in Urban Hygiene

Objectives: The DustBot project is aimed at designing, developing and testing a system for improving the management of urban hygiene, based on a network of autonomous and cooperating robots, embedded in an Ambient Intelligence infrastructure.



DustBot

Networked and Cooperating Robotics in Urban Hygiene

DustClean Robot

DustCart Robot

CSIC UPC

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Guardians

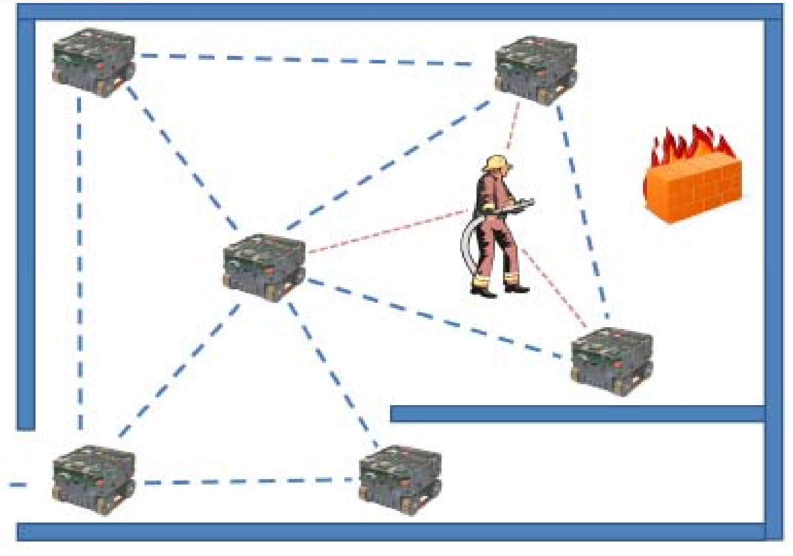
Group of Unmanned Assistant Robots Deployed In Aggregative Navigation supported by Scent detection

Objectives: The GUARDIANS are a swarm of autonomous robots applied to navigate and search an urban ground. The project's central example is an industrial warehouse in smoke, as proposed by the Fire and Rescue Service. The robots warn of toxic chemicals, provide and maintain mobile communication links, infer localization information and assist in searching. They enhance operational safety and speed and thus indirectly save lives.

http://www.shu.ac.uk/mmvl/research/guardians/

Guardians

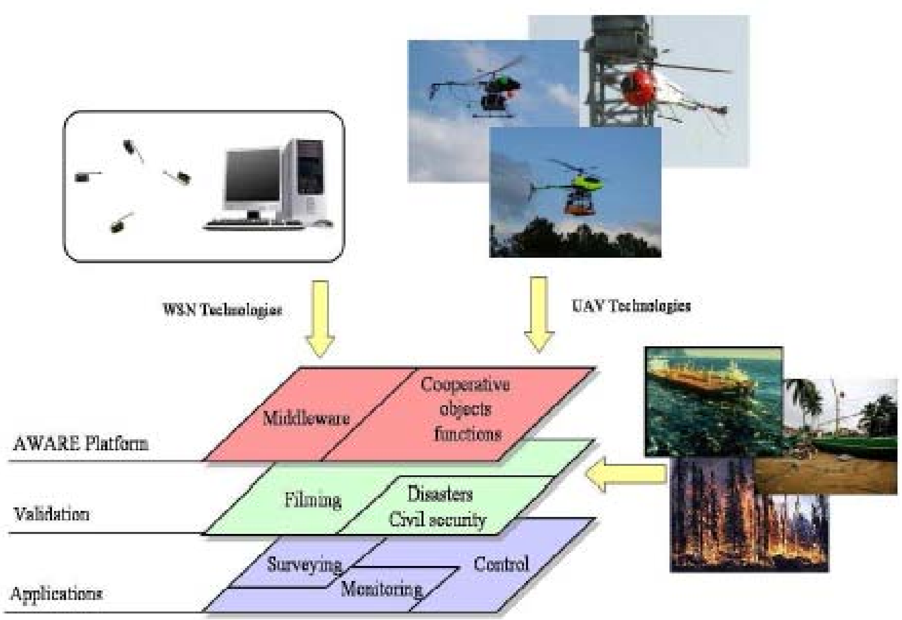
Group of Unmanned Assistant Robots Deployed In Aggregative Navigation supported by Scent detection



AWARE

Platform for Autonomous self-deploying and operation of Wireless sensor-actuator networks cooperating with AeRial objEcts

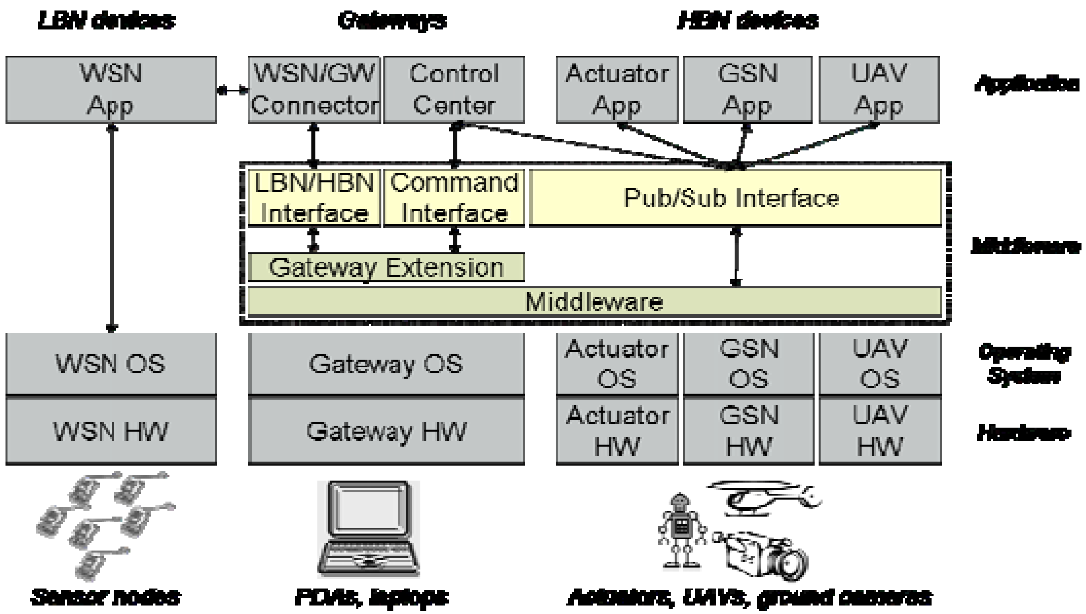
Objectives: This project is devoted to the design, development and experimentation of a platform providing the middleware and the functionalities required for the cooperation among aerial flying vehicles and a ground sensor-actuator wireless network with mobile nodes.



http://grvc.us.es/aware/

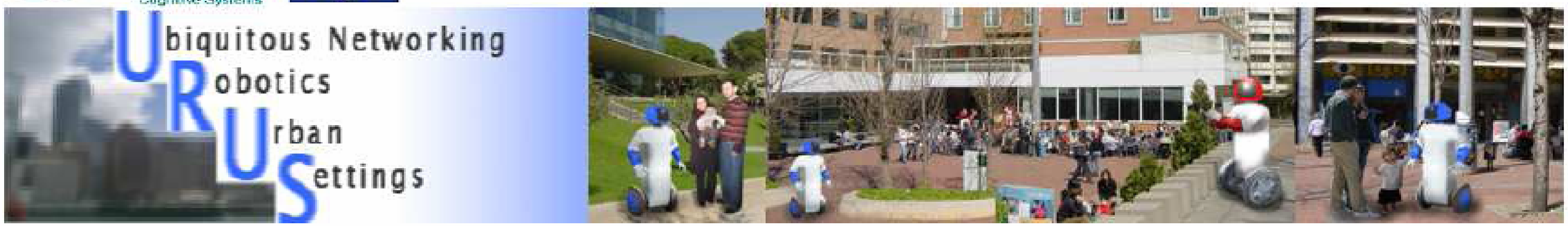
AWARE

Platform for Autonomous self-deploying and operation of Wireless sensor-actuator networks cooperating with AeRial objEcts



AWARE System overview and middleware

URUS project
Ubiquitous Networking Robotics in Urban Settings



http://urus.upc.es

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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***
  - Specifications 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

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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

UPC Campus Nord

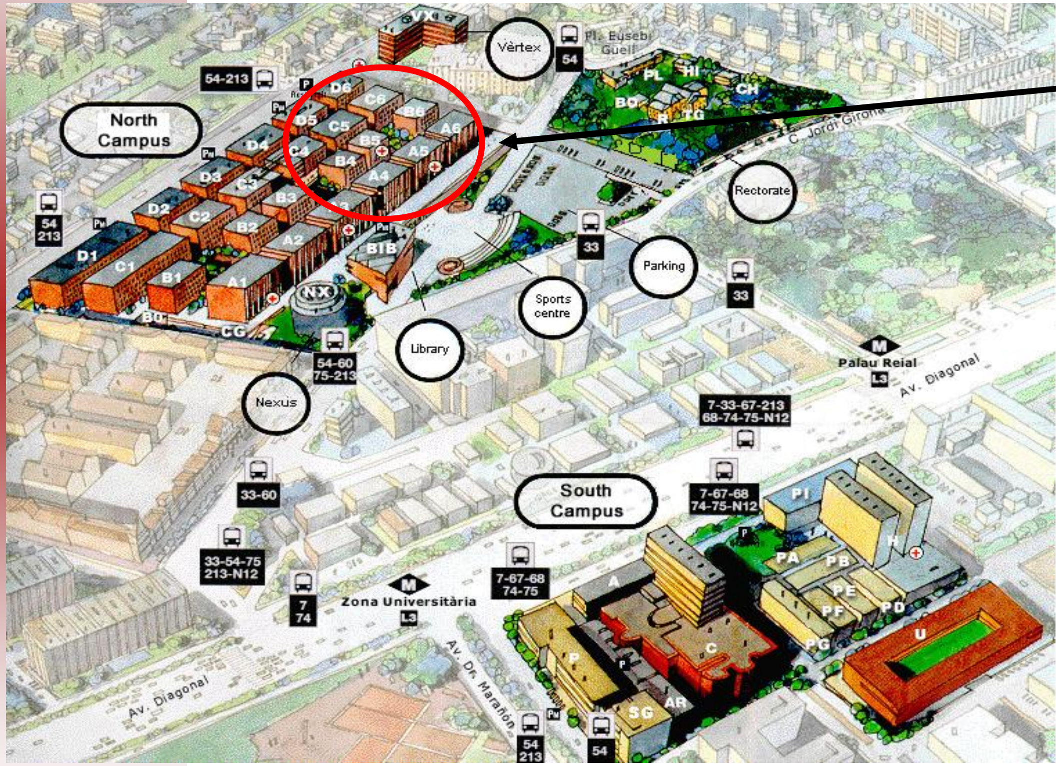
Gràcia Superblock

Espanya Industrial Superblock (planned)

22@ Campus Audiovisual Superblock (in development)

Ribera Superblock

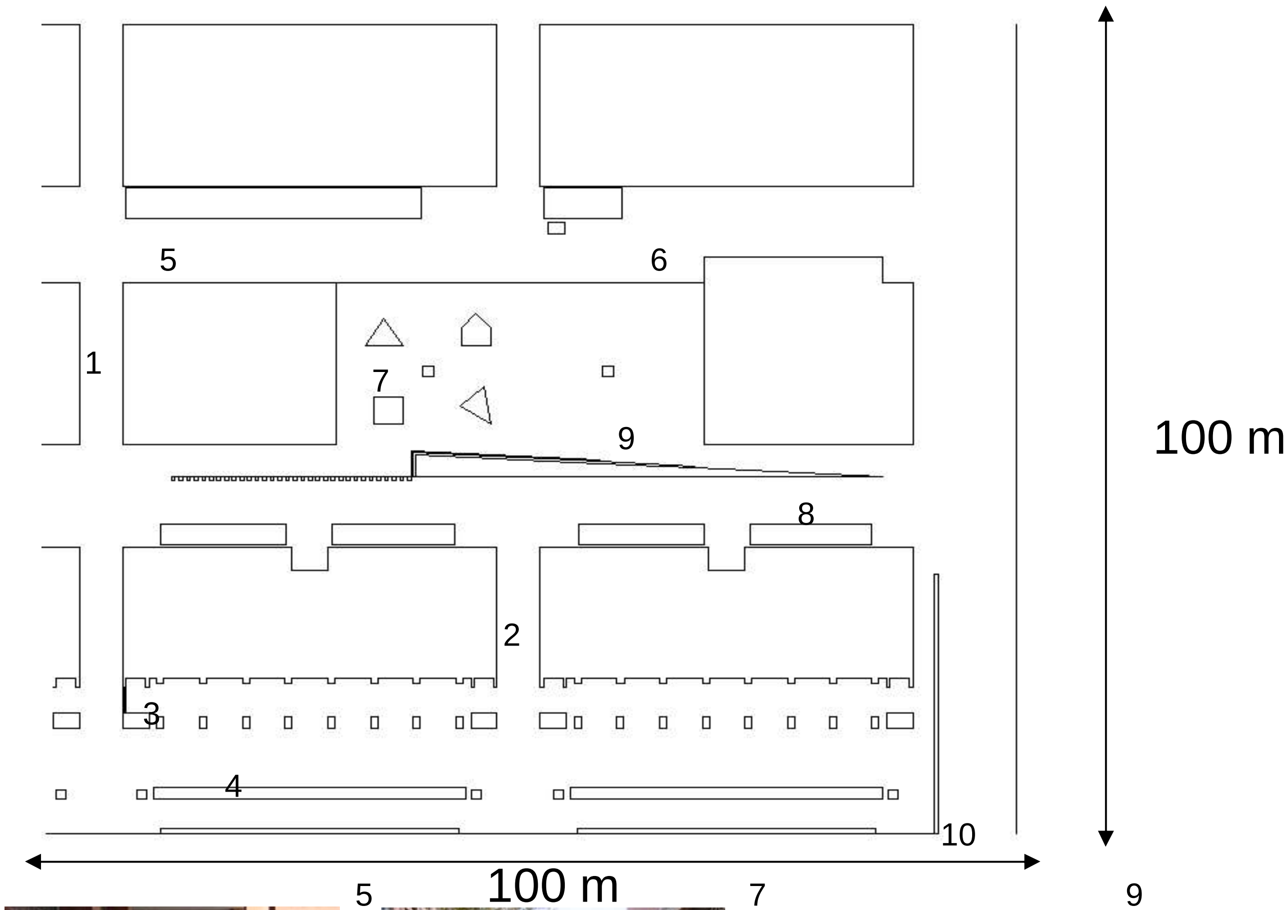
Experiment Locations: Scenario 1
UPC



Zone Campus Nord, UPC

Barcelona Tech Robot Lab

Zone
Campus Nord, UPC



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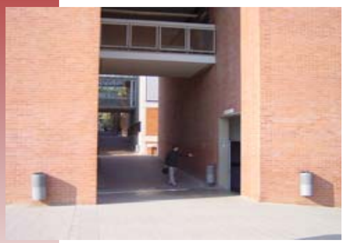

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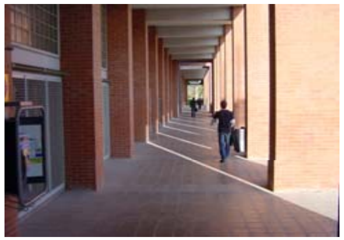

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7


9

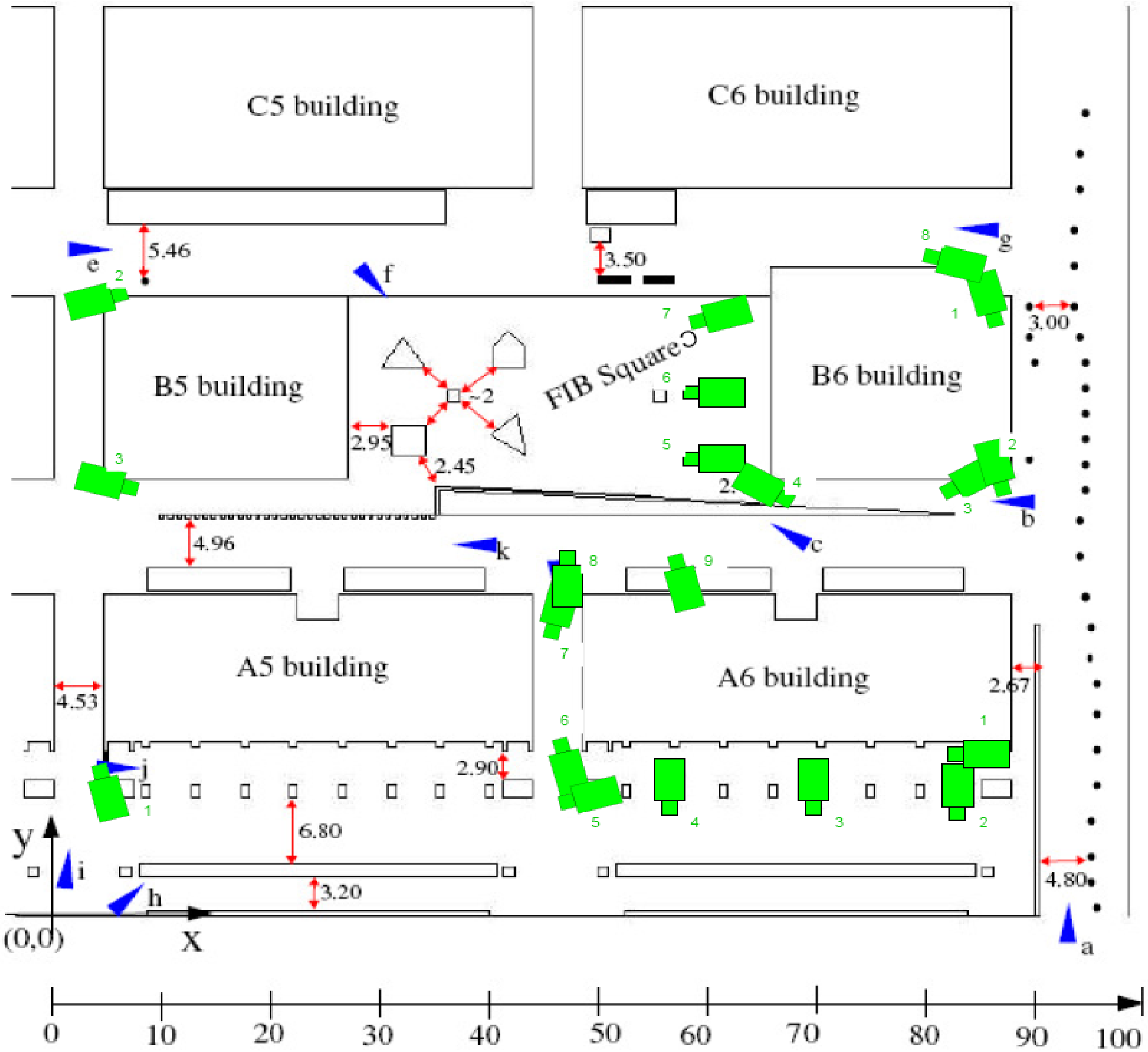

2


4


6


8


10

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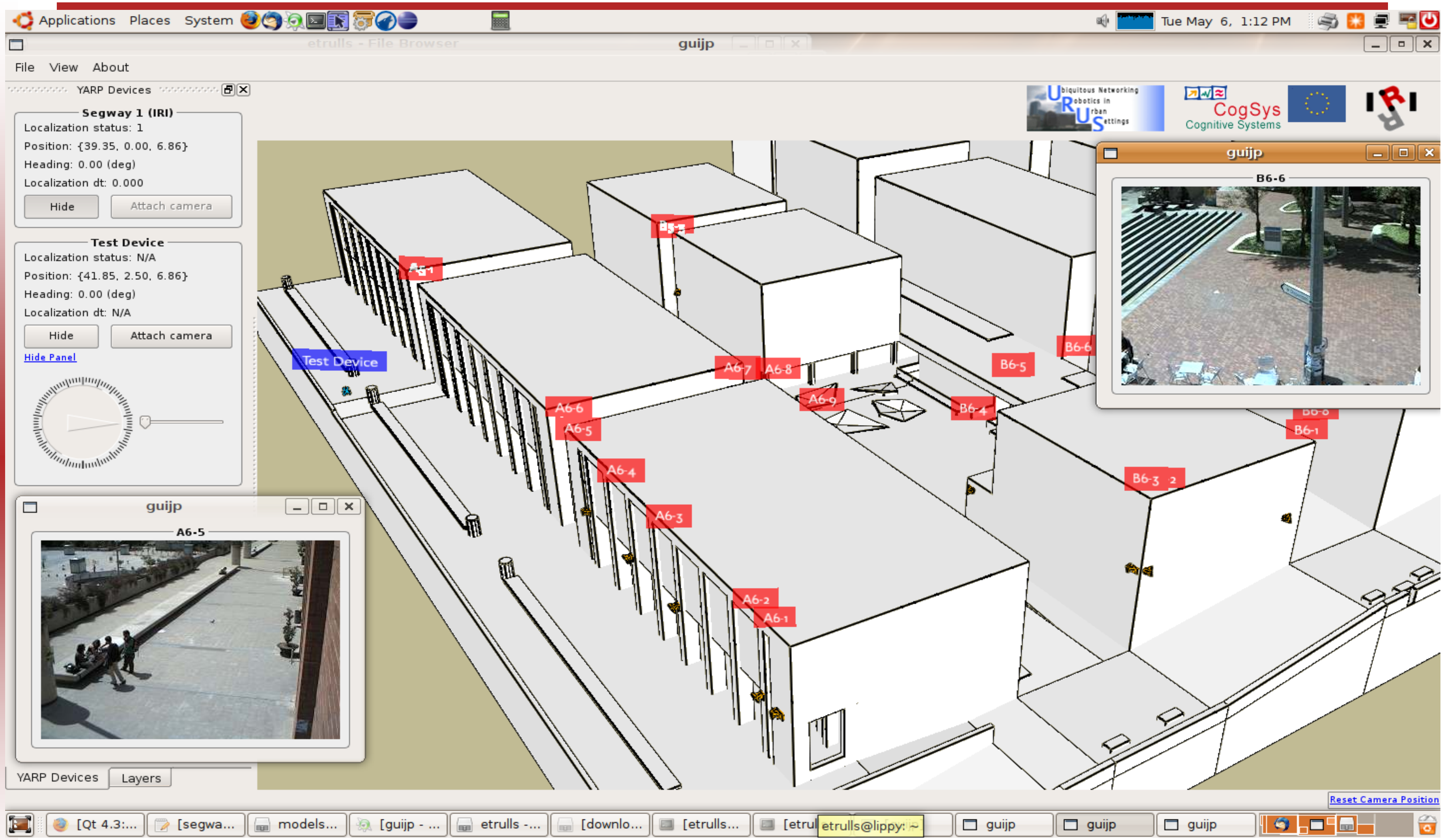
Experiment Location: Scenario 1 UPC



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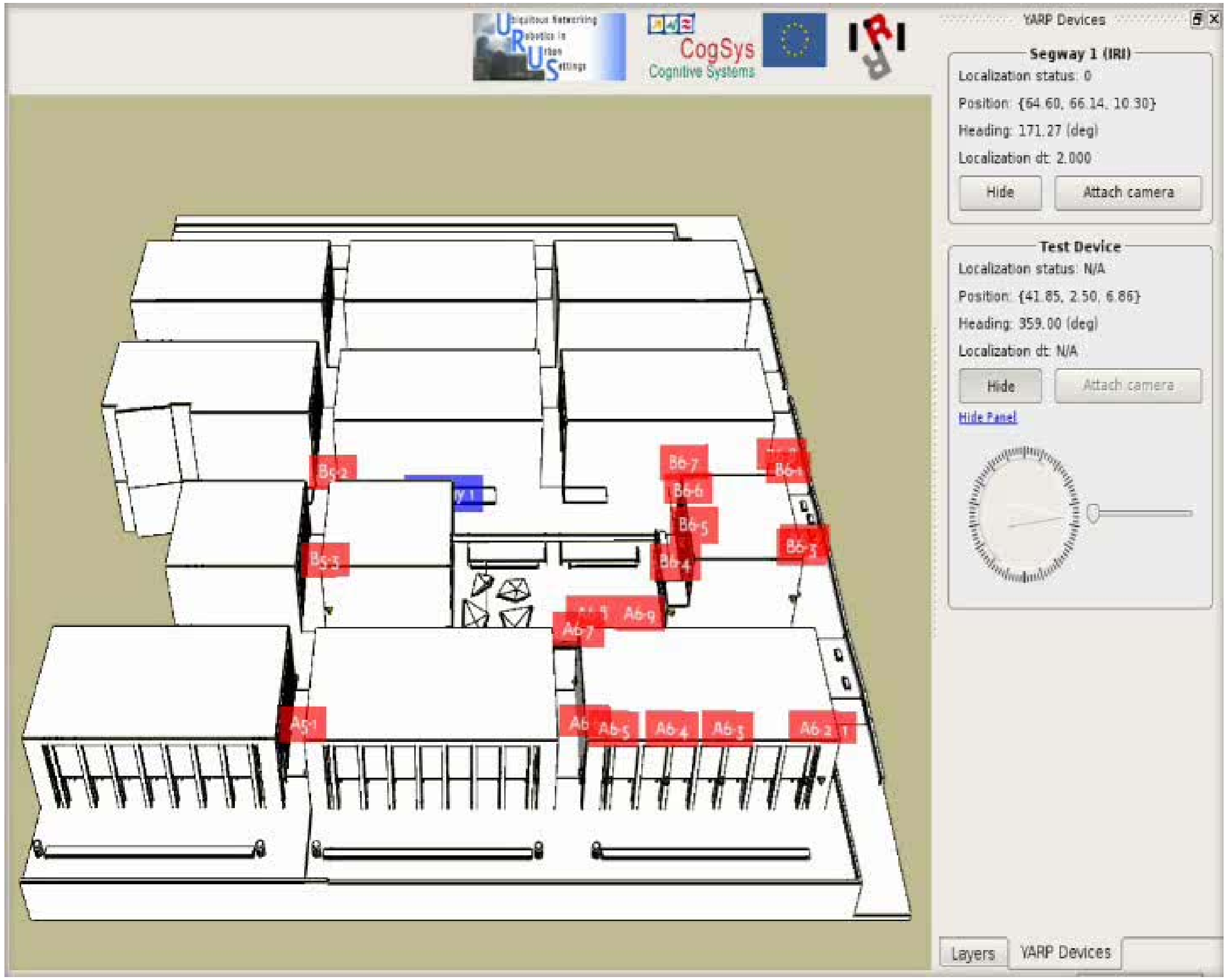
Experiment Location: Scenario 1
UPC



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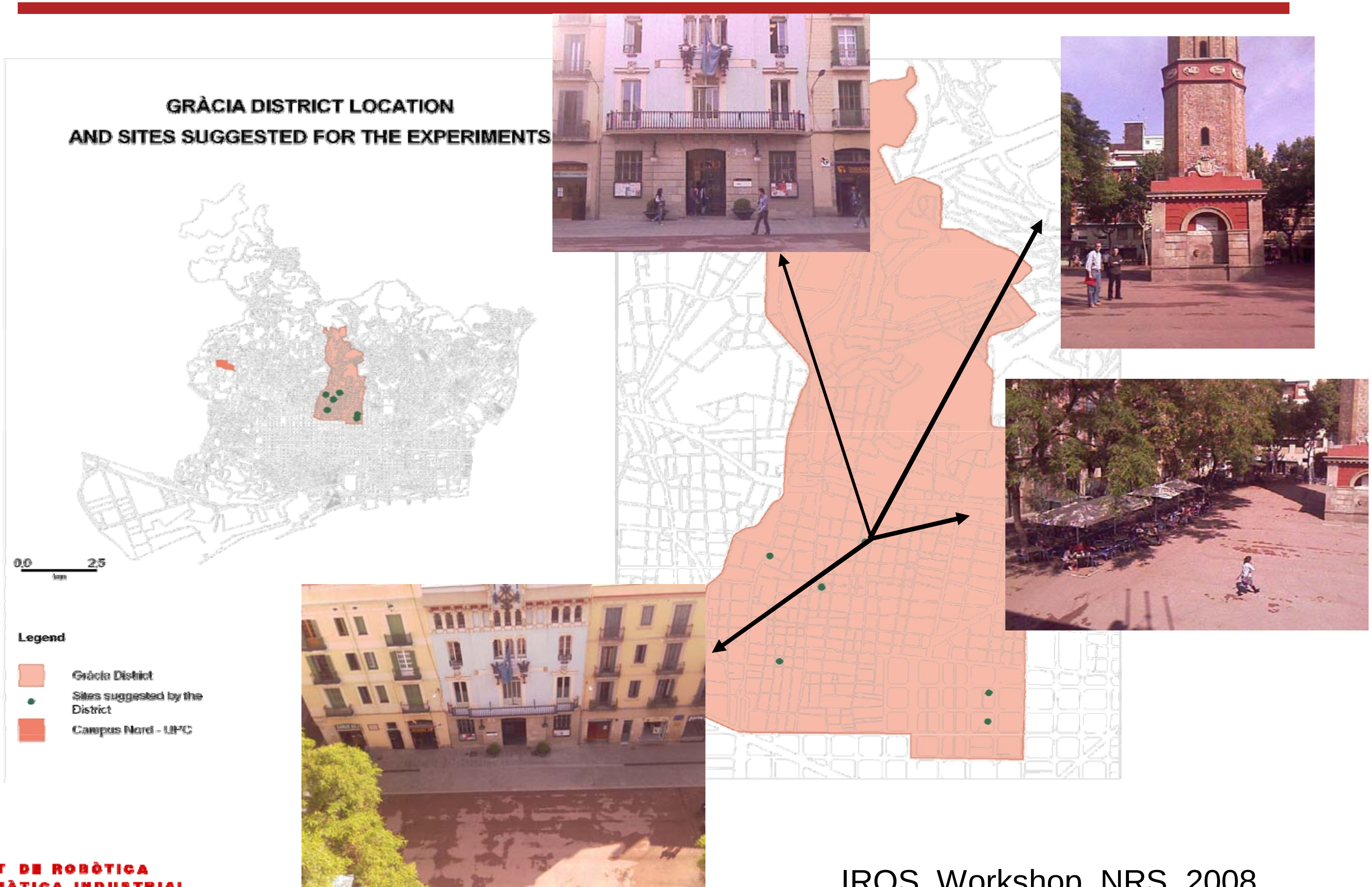
Experiment Location: Scenario 2
Gracia District



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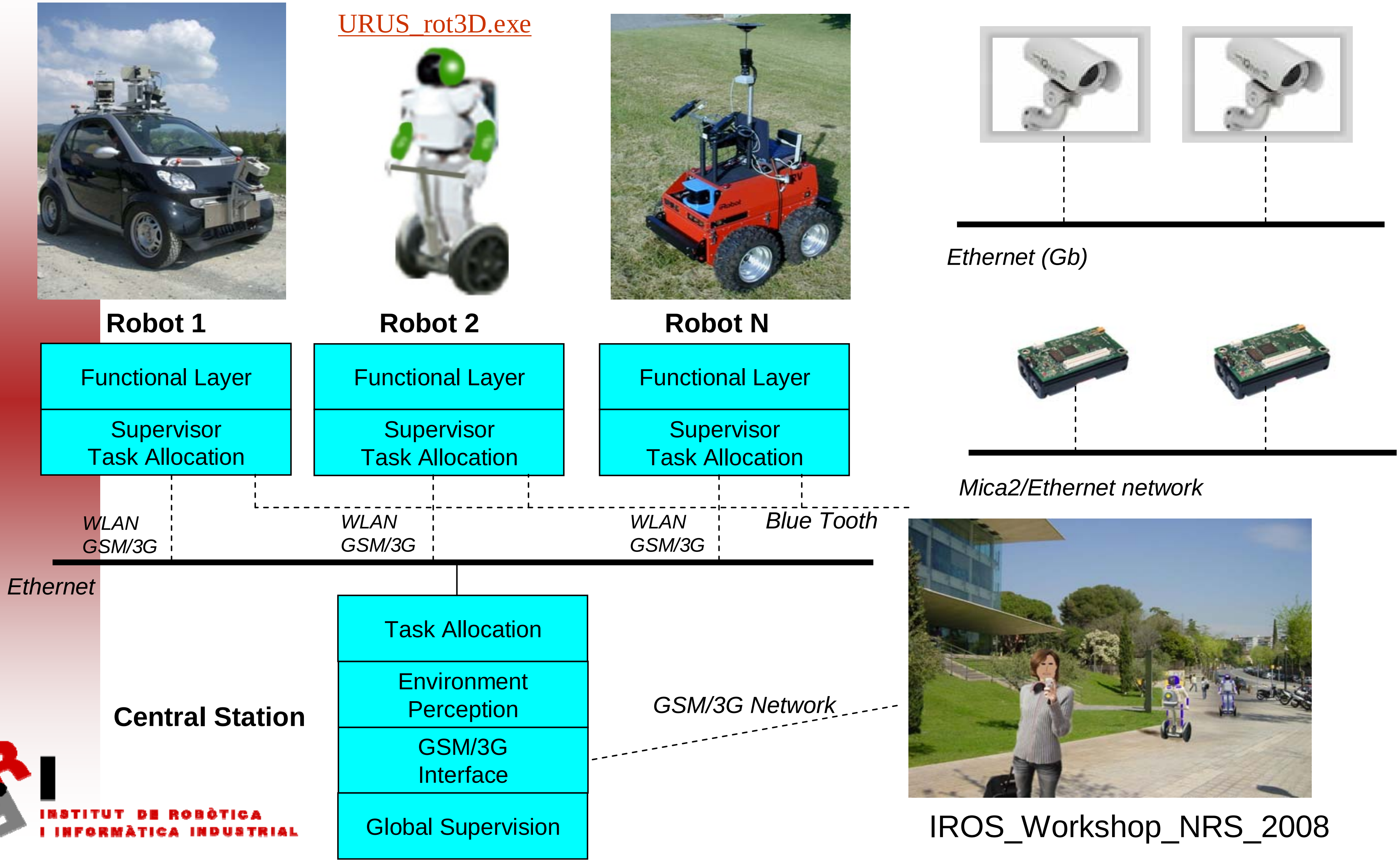
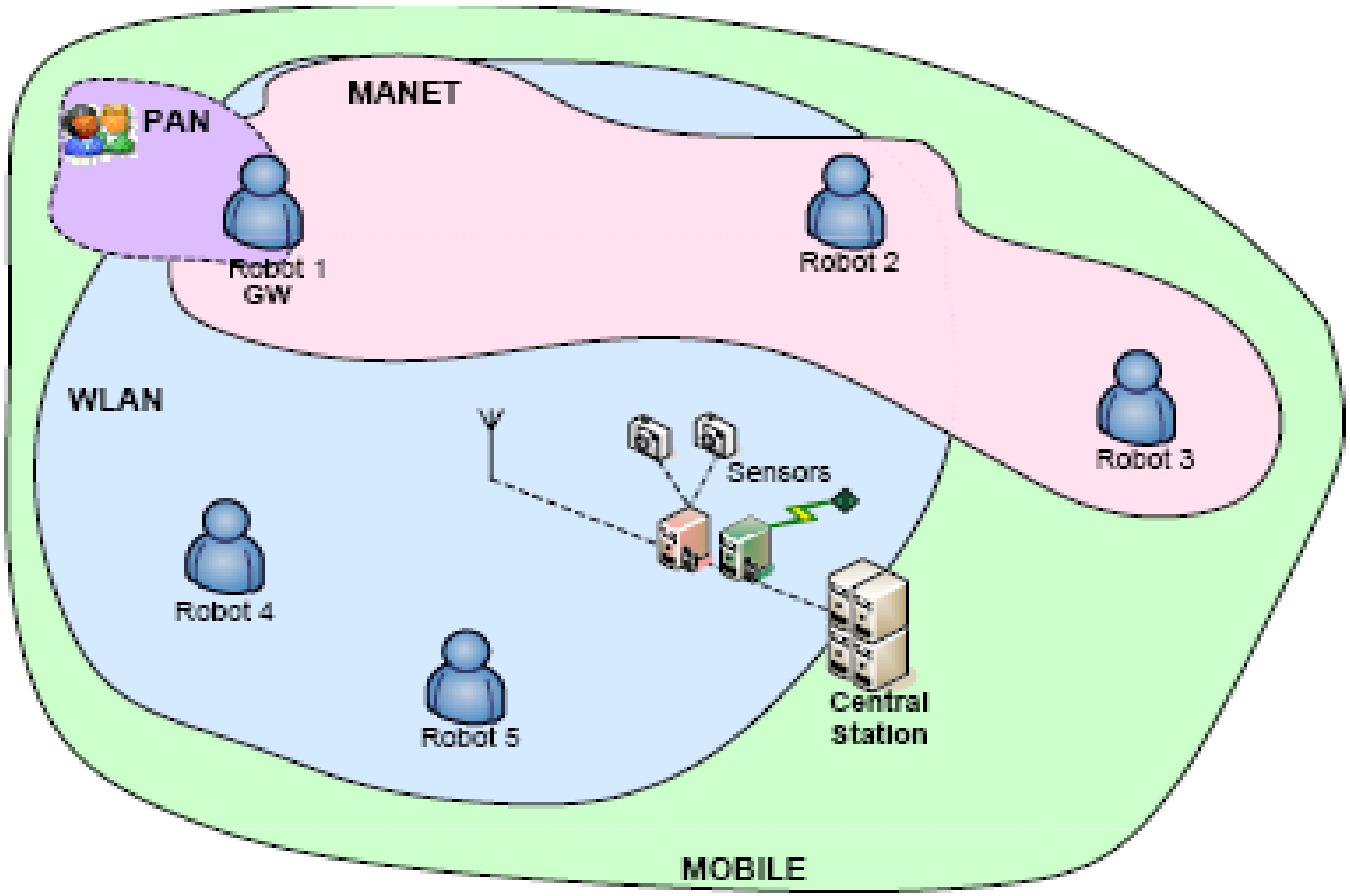
Global Architecture



Wireless Communication in URUS Project

Communication Systems



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Scientific and Technological Achievements in the 1rst Year of URUS project

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Specifications in Urban areas

- Major urban needs:
  - Transportation of goods (urban merchandise distribution)
  - Transportation of other materials
  - Maintenance service
  - Emergency calls.
  - Security (surveillance)
  - Helping the disabled and people with mobility handicaps to overcome limitations.
  - Data gathering (noise, air pollution, temperature, wind, light conditions).
  - Access to urban information

Specifications in Urban Areas

- Urban requirements for URUS experiments
  - To inform the **local authorities** about the URUS experiment its main goals and features.
  - To arrange the **permissions** that will be necessary to carry out the tests with the help of the local authorites.
  - To gather information about **regulations and laws** concerning different aspects of URUS (robots, cameras, sensors)
  - To **map** the UPC site that has been chosen for the experiments.

- City regulations related to URUS experiment (regulation on the use of thoroughfare and public space in Barcelona approved 27th November 1998 and published the 15th January 1999)
  - Use of public space in general
  - Special Uses
  - Conditions
  - Licenses and permissions

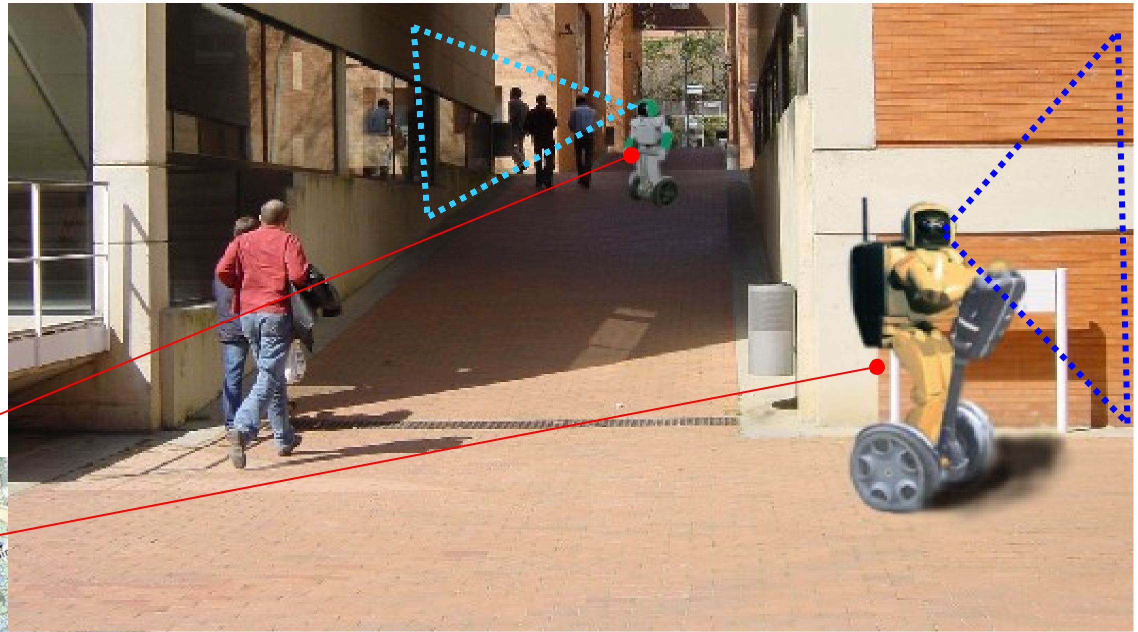
Open Questions to put Robots in Urban Areas

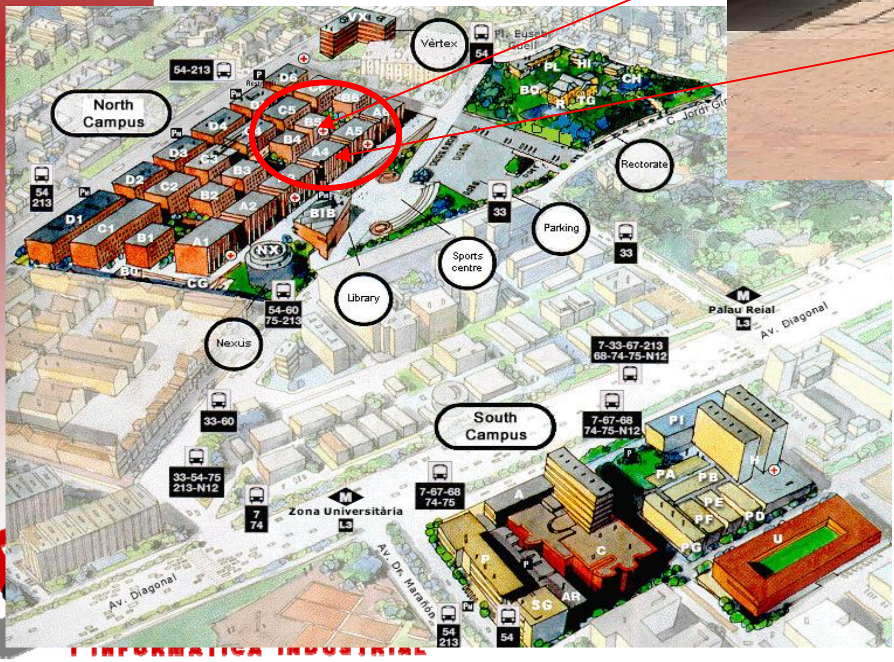
- Is there any on going public debate about robotics and their role in society? At which level is this debate developing? Legal? Social? Economic? Technological?
- What are the main difficulties that have been overcome to put robots in public space?
- Is there any plan or strategic analysis before putting robots in the street? (for instance plans about tasks to do) Paths to follow?
- Do the robots perform any of these tasks: merchandise distribution, surveillance, cleaning? Do they perform some other tasks?
- Has any law or regulation been approved in order than the robots could do tasks in public space?
- Which urban regulations have been modified after they have started doing these tasks?
- What kinds of regulations have been approved? Broad and general? Small and specific? At local, regional or national level?
- How have these specific tasks in public space been established? Who has established them? City council politicians? Public servants? Experts? Citizens? All of them combined?
- What protocols have been developed to keep robots security? (protecting them from eventual attacks)
- Has any conflict with pedestrians emerged? If so, how has it been tackled? What about conflicts with other transports? (bicycles, motorbikes, cars, vans, buses)

Cooperative Localization and Navigation

Localization using:
- GIS, Compass, laser, estereo
- multiple robots
- ubiquitous sensors

Navigation:
- Using GIS, laser, compass
- Own and embedded sensors





Cooperative Localization and Navigation

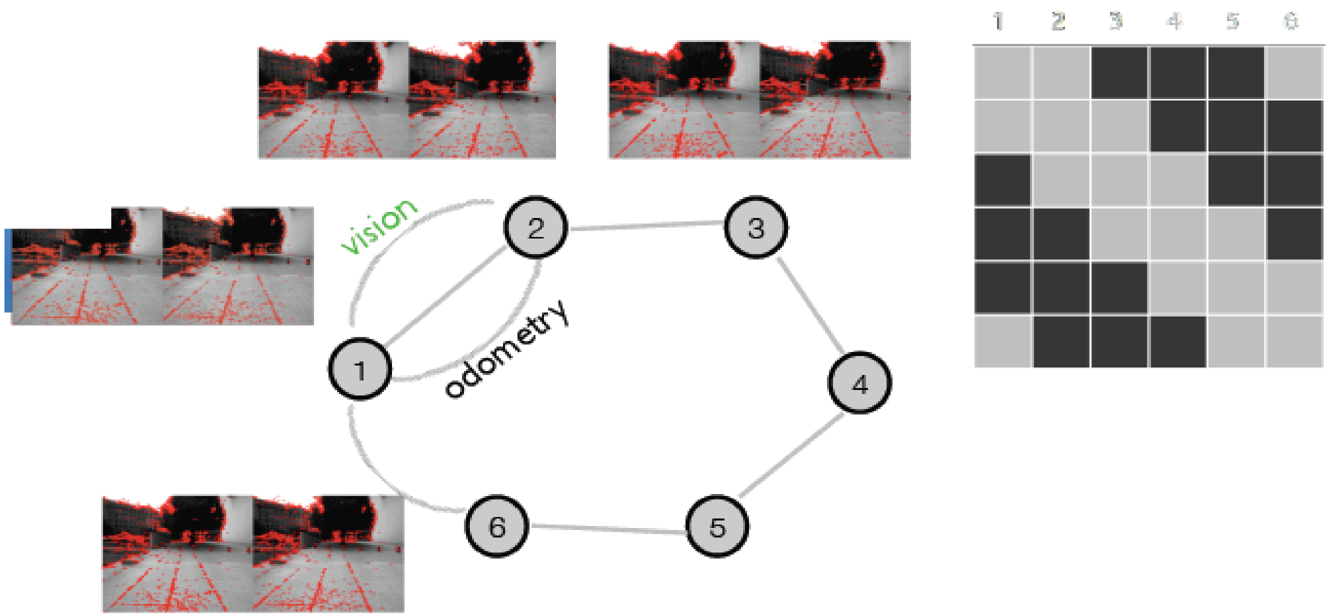
- **Cooperative Localization**
  - Single robot localization has been done fusing diverse sensors (GPS, laser, compass, estereovision, odometry, visual odometry)
  - Cooperative localisation has been accomplished using global probabilistic model based on particle filter methods
- **Cooperative Navigation**
  - Single robot path planning has been solved by applying the E* motion planning algorithm
  - There has been worked in cooperative formation maintenance, leader following and obstacle avoidance. The approach has been validated experimentally in obstacle-free environments.
- **Integration**
  - Integration has been based on YARP platform

Cooperative Localization and Navigation

Segway-robot navigation based on fusing odometry and visual odometry

Video: SANYO088.MP4 and video_SLAM_21Aug_new.avi

$$p(\mathbf{x}) \sim \mathcal{N}(\mathbf{x} : \boldsymbol{\mu}, \boldsymbol{\Sigma}) \sim \mathcal{N}^{-1}(\mathbf{x} : \boldsymbol{\eta}, \boldsymbol{\Lambda})$$

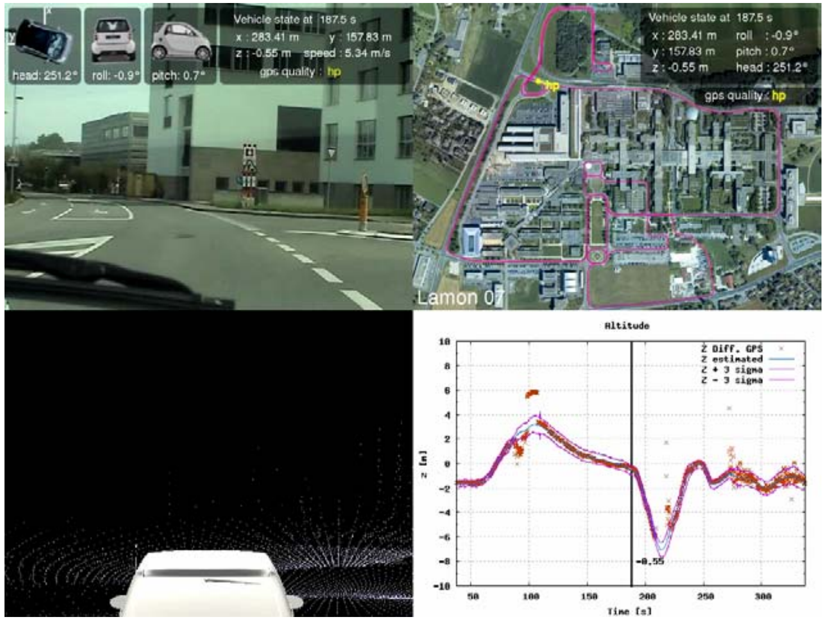


[Ila et al, IROS07]

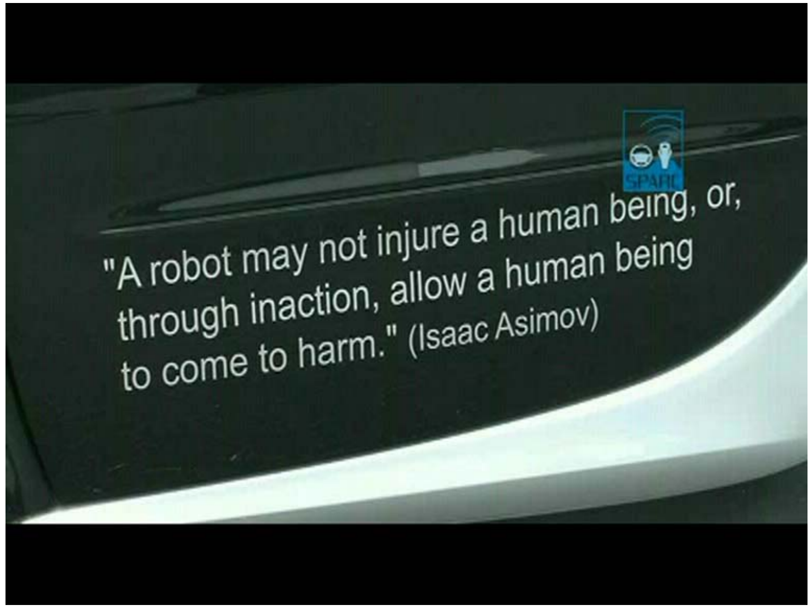
Cooperative Localization and Navigation

Smart navigation based on fusion of sensor information

Video showing Smart Ter at UPC siteVideo: SmartAndSegway.mpg



SmartTer: GPS/IMU/Odometry fusion **[Lamon et al 06].**



Safe RRT-based local planning and obstacle avoidance **[Macek et al 08]**.

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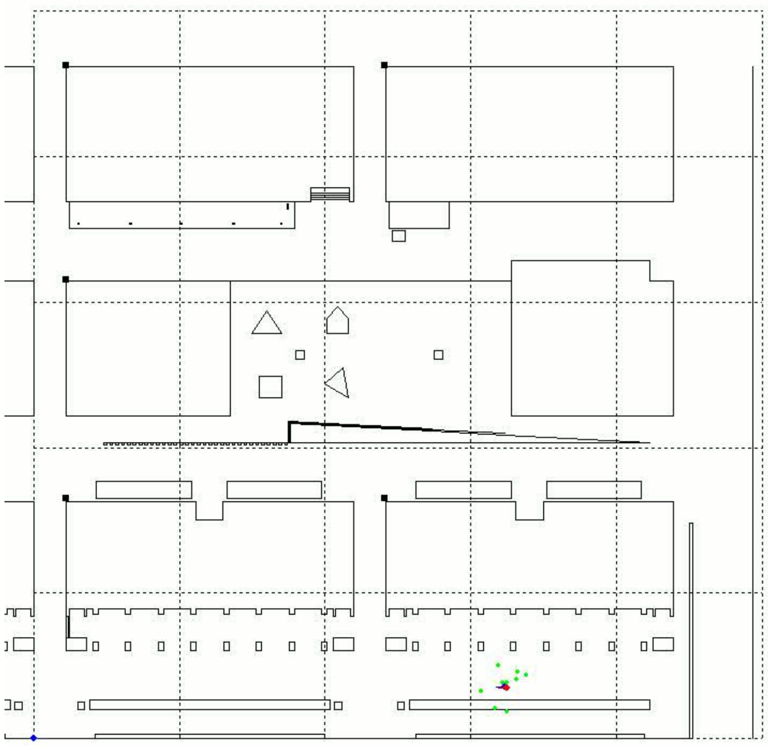
Cooperative Localization and Navigation

Robot localization using active global localisation

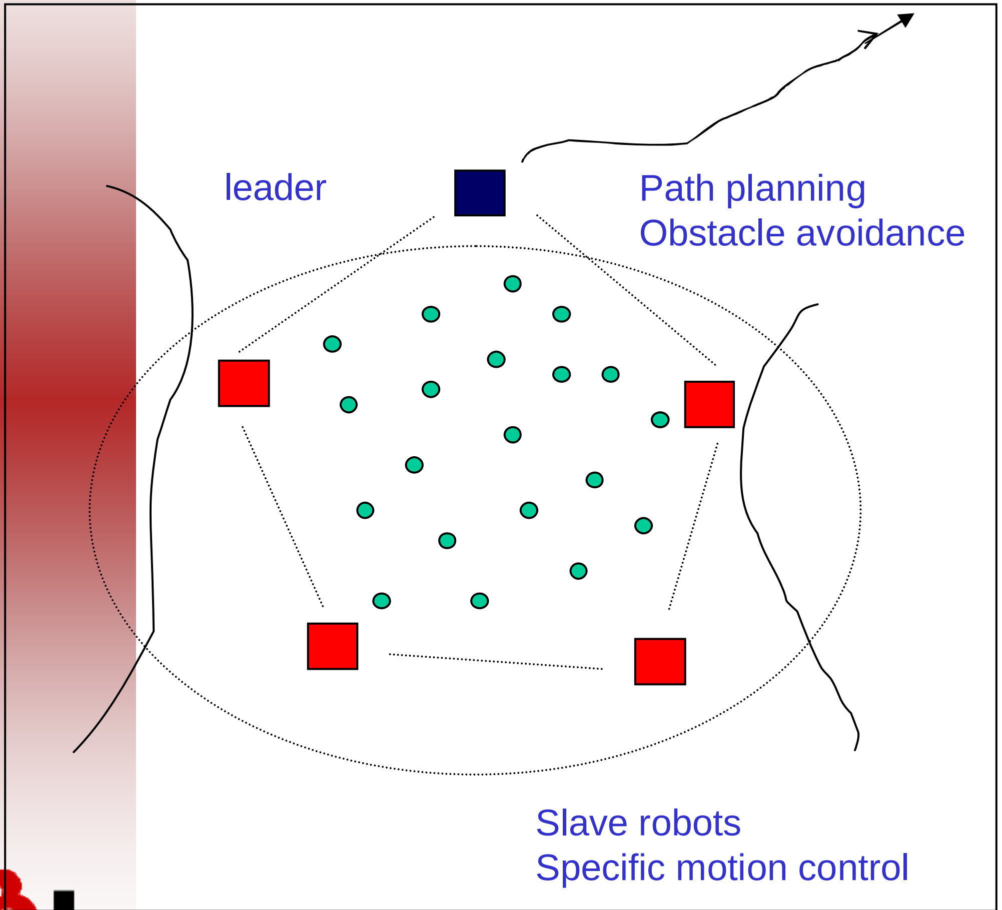
Video: **20080508posTrackingShort.mp4**

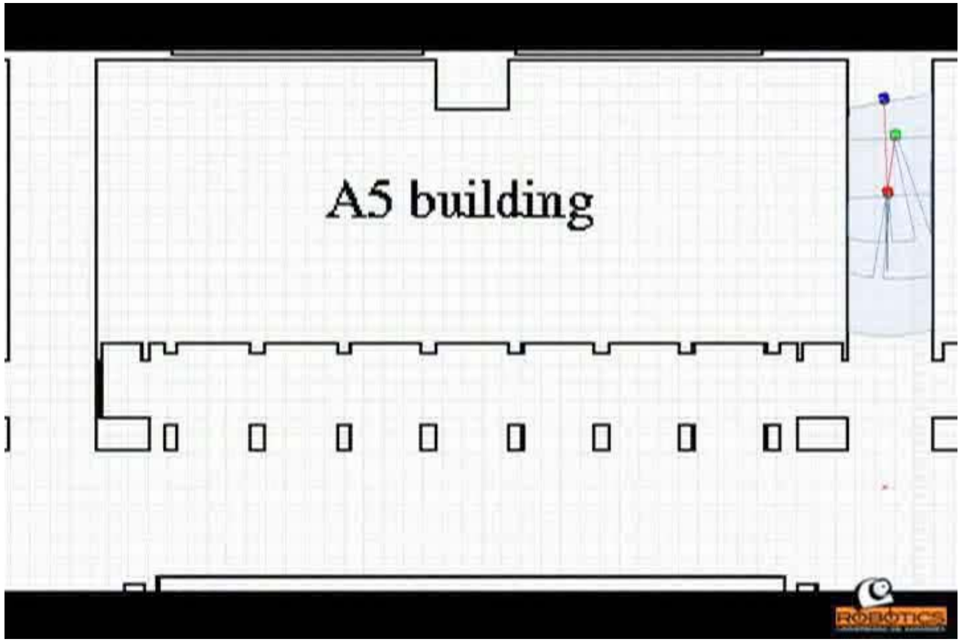


[Corominas et al ICRA08]

Cooperative Localization and Navigation

Robot formation





[Mosteo et al. ICRA08]

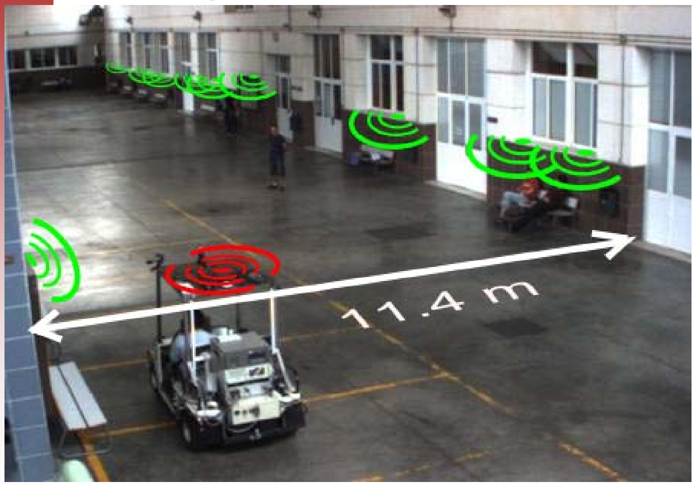
Cooperative Localization and Navigation

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 Environment Perception

Cooperative perception using:

- embedded and own sensors
- fusion techniques and technologies

Cooperative environment perception

Cooperative Environment Perception

- The main framework for cooperative perception has been established:

  Partially Observable Markov Decision Processes (POMDPs)

  as a framework for active cooperative perception.

- Human activity recognition algorithms have been developed and some results have been already obtained using cameras.

- New algorithms for tracking persons have been tested in the scenario.

Cooperative Environment Perception

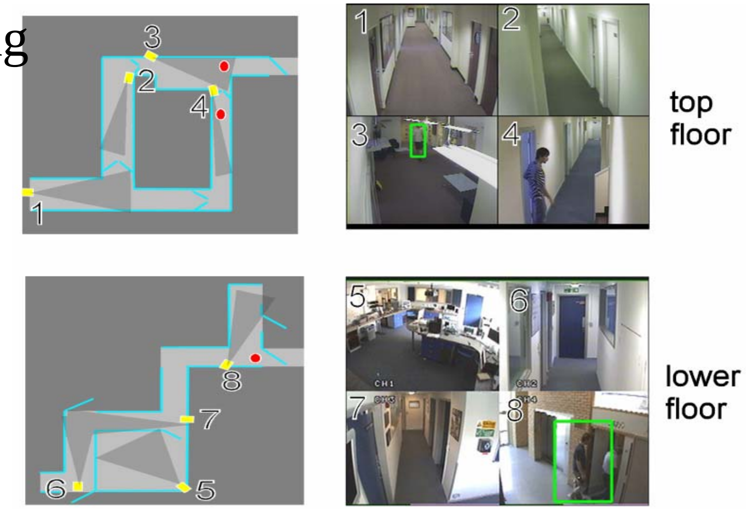
Following a person with environment cameras

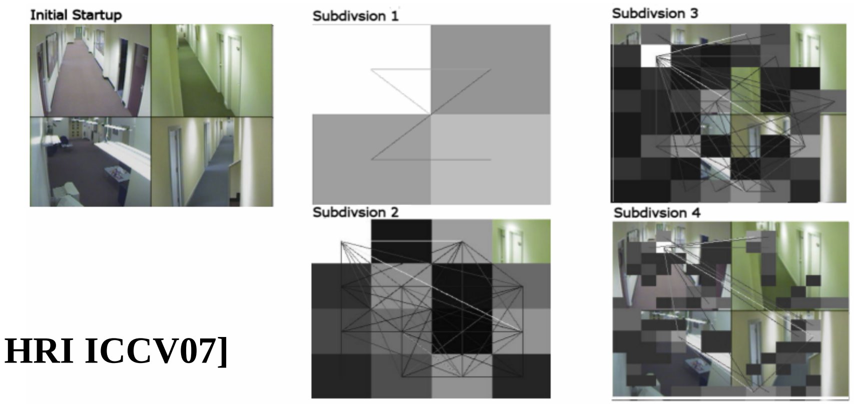
video **videoUrus1.avi**

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

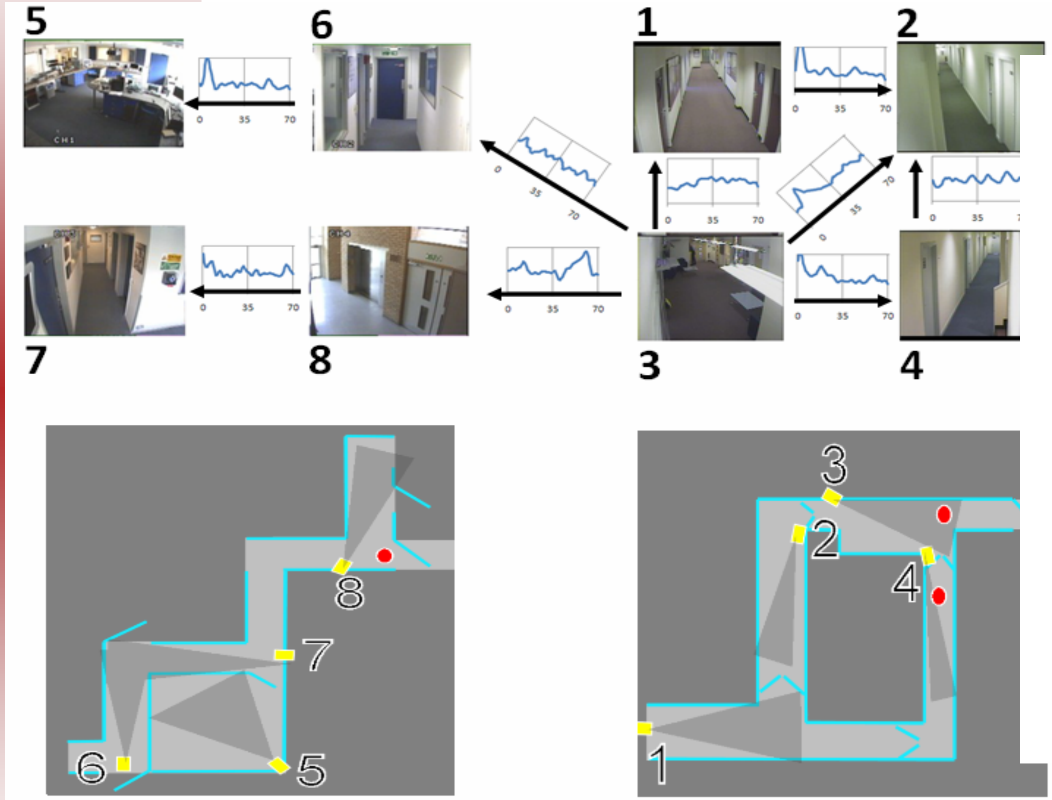


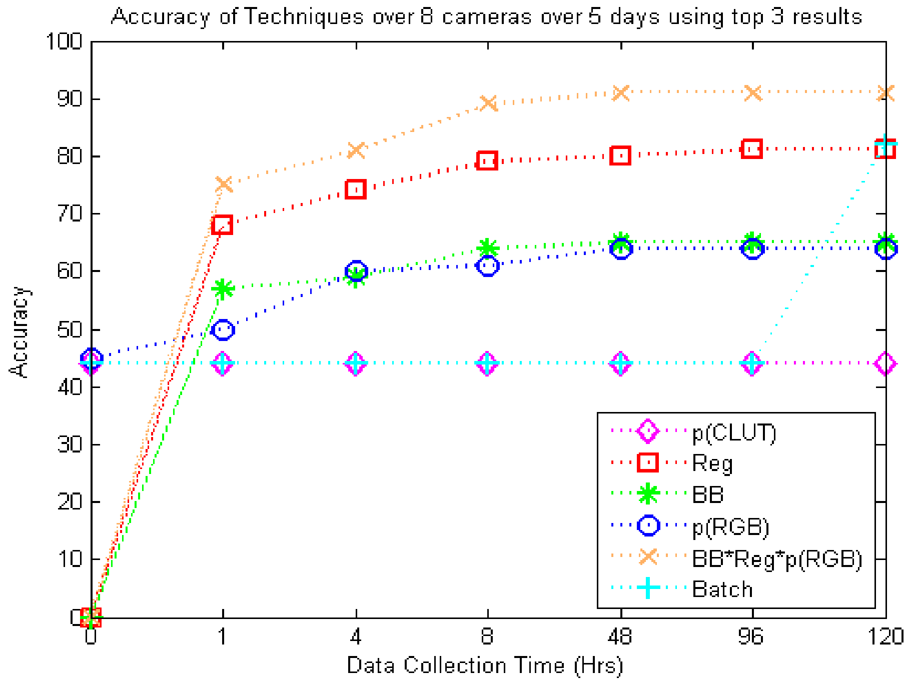


[Gilbert et al., HRI ICCV07]

Cooperative Environment Perception

Following several persons with environment cameras



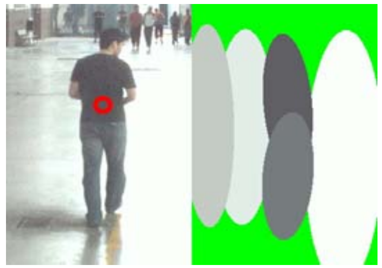


Cooperative Environment Perception

- Homogeneous 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 Perception

Eliminating shadows in a sequence of images

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

[Scandaliaris et al., CIARP207]

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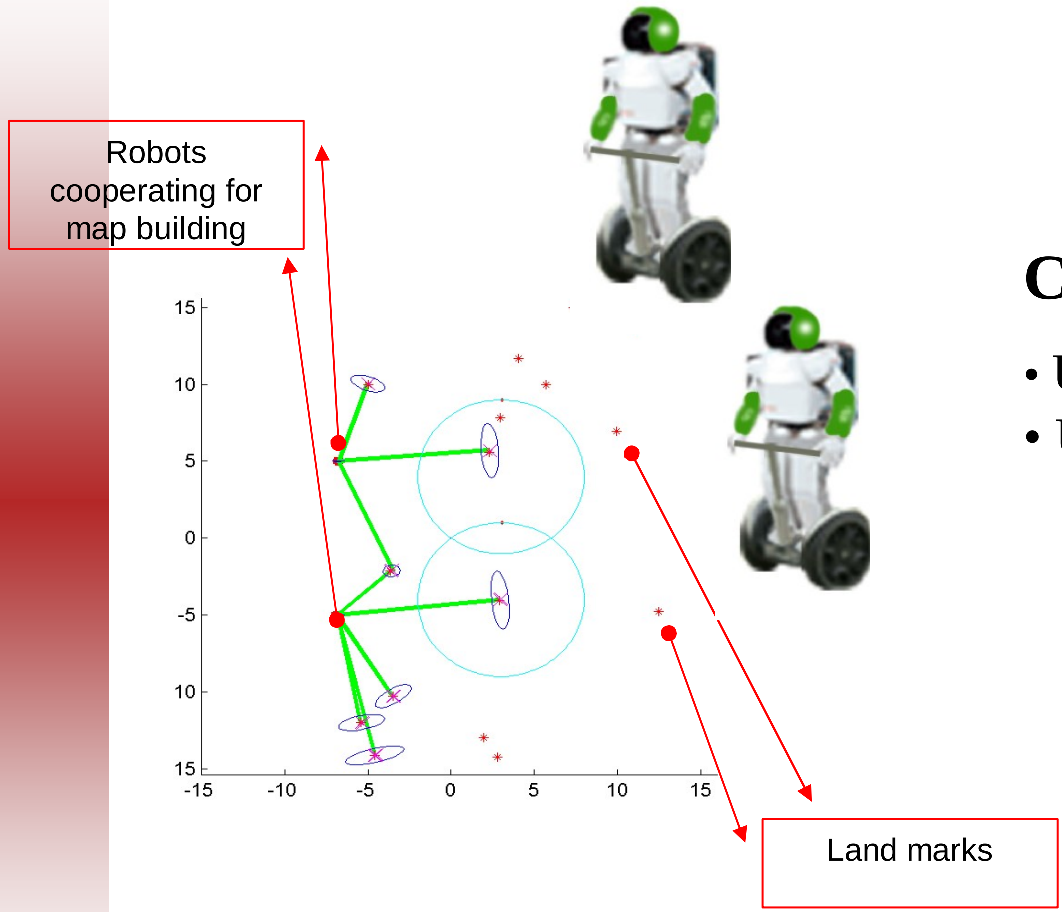
Cooperative Map Building and Updating



Cooperative Map Building:

- Using multiple robots and sensors
- Using control techniques

Cooperative Map Building and Updating

- We have preliminary results on mapping the UPC North campus using 3D range data from the EHTZ's SmartTer platform.

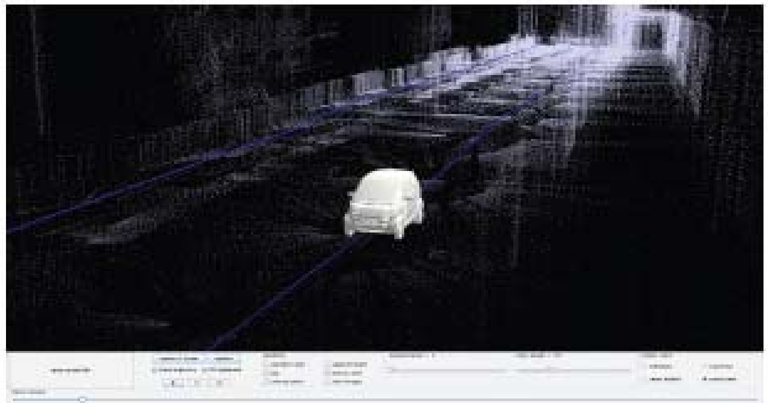
- The experiments conducted in July 2007 consisted in a series of runs, both inside and around the campus, gathering information from two rotating Sick laser scanners and using the platform's global localization module.

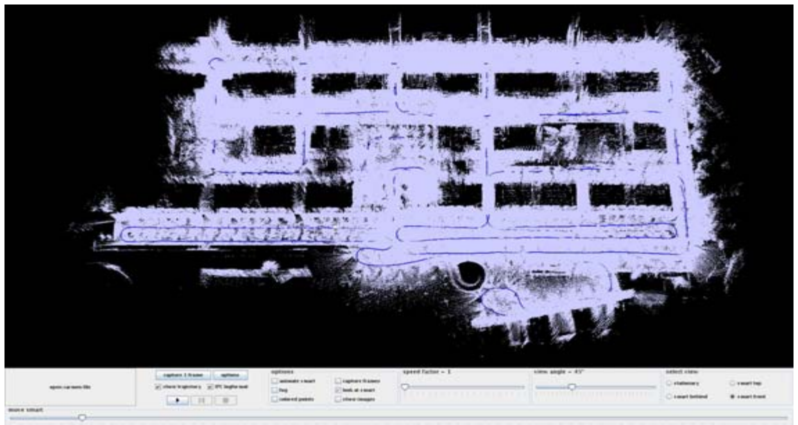
Cooperative Map Building and Updating

3D Map construction doing by Smart Ter robot

Video SmartData.mpg

(a) Localization sensors (b) Environment sensors



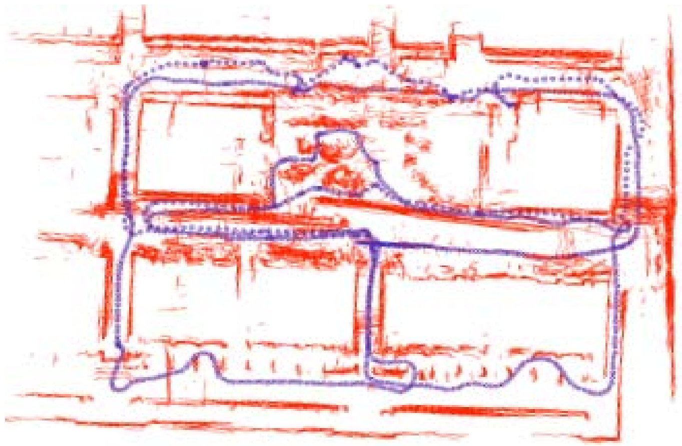


Cooperative Map Building and Updating

Video showing trasversability map building based on 3D odometry and stereovision Data robot

Video: serie04-1000-3000-dtm.mov

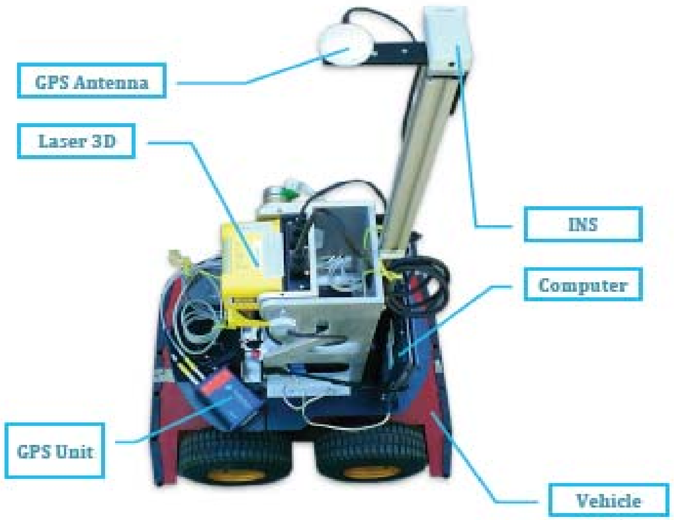
Video: serie04-1000-2260-classif.mov

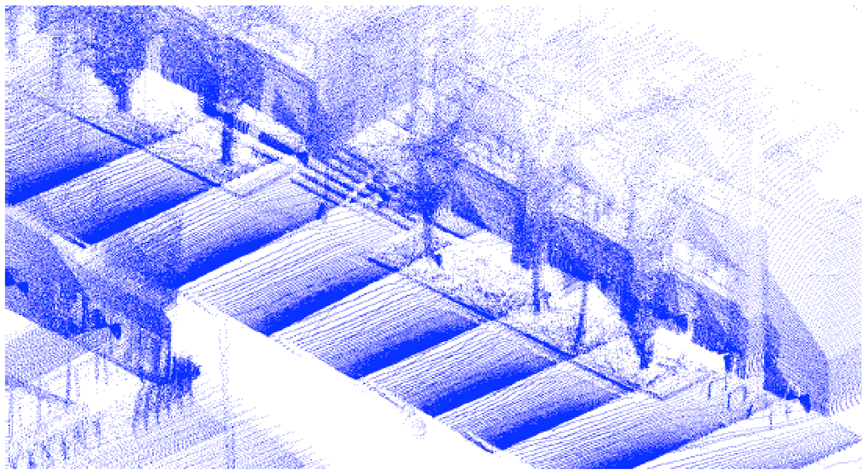


Reprojection of raw laser data on
the basis of 2D odometry estimates
Final position error < 1m

Cooperative Map Building and Updating

UPC 3D ranger scan





Human Robot Interaction

Human robot interaction:

- Combining mobile phones, voice, touch screen

Communication by voice and touch screen

Communication by voice

Communication between robots and humans trough the mobile phone

Human Robot Interaction

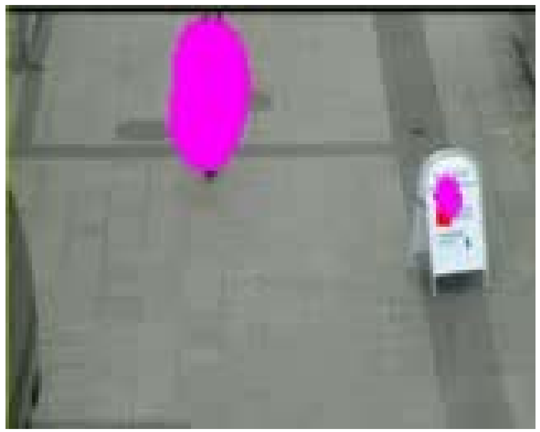
- Analysis of the specifications for human-robot interaction (HRI) aspects required by the experiments considered in the project:
  - the selection of the admissible gestures that form the basic language for interaction between humans and robots
  - the selection of the adequate features for the robot head that simplify the interaction with human (e.g., the ability to generate multiple facial expressions)
  - the selection of adequate technological tools for interaction (e.g., cellphones, touchscreen, and communication media between the interaction devices and the robots).

Human Robot Interaction

Gesture detection

Boxing detection

Waving detection



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Human Robot Interaction

Robotic Head

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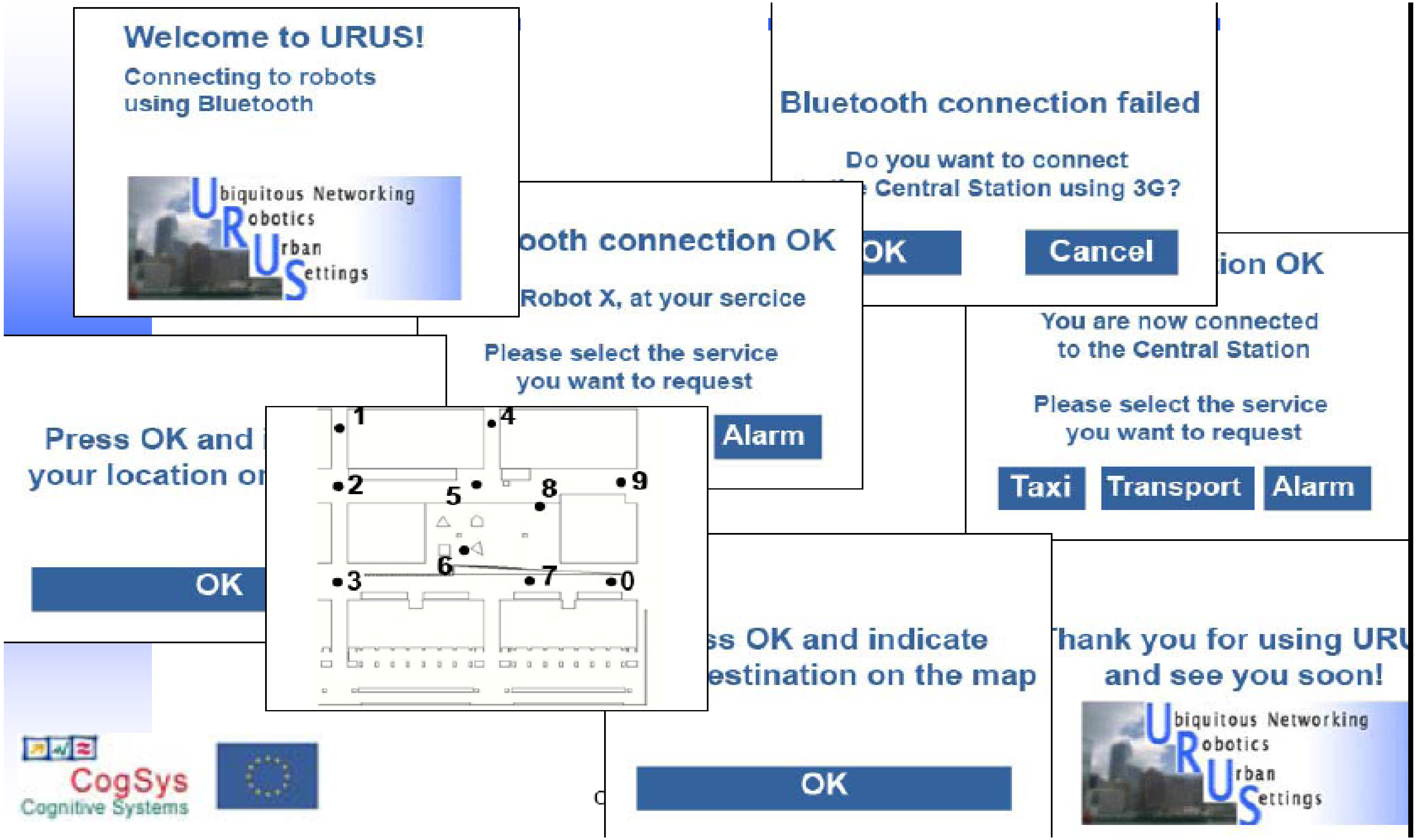
Human Robot Interaction

Emotion expressions

Human Robot Interaction

GUI look & feel

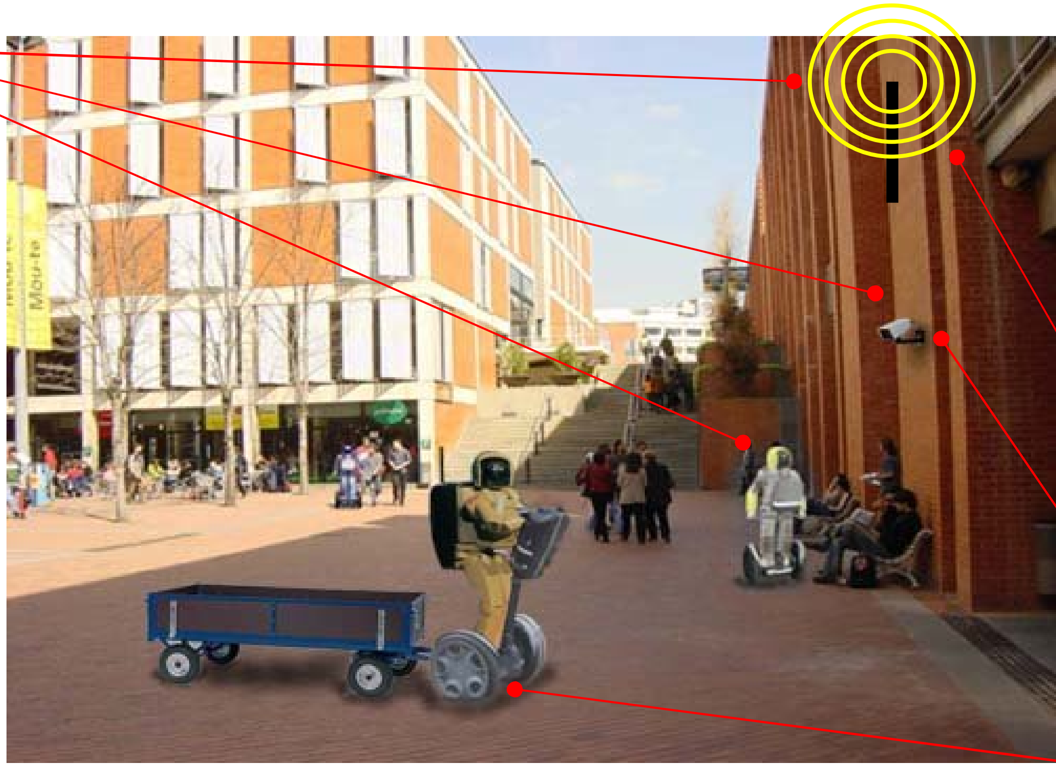


Multi-task Allocation

Multi-task negotiation:

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

Multi task negotiation for assistance



Multi task negotiation for transportation

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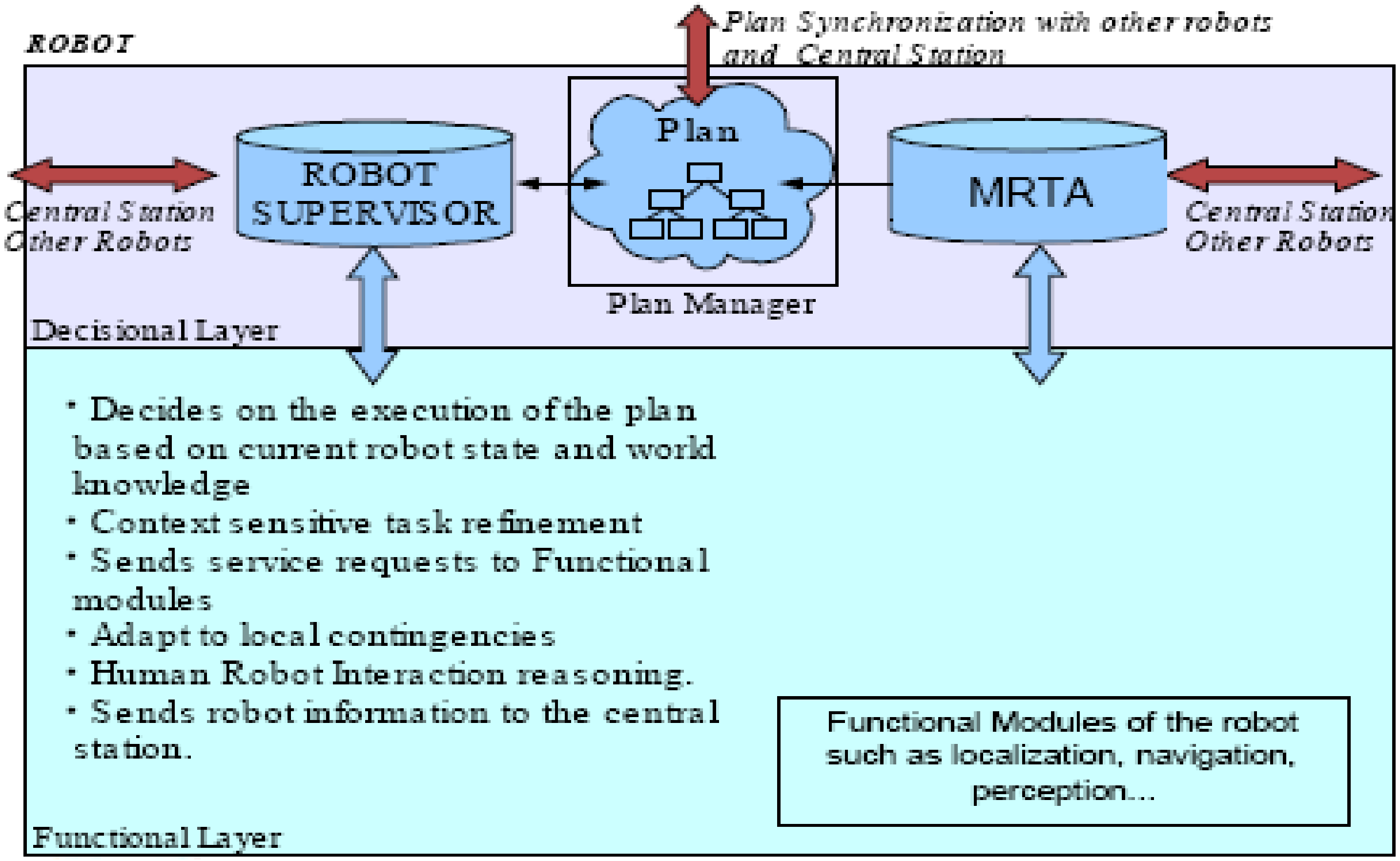
Multi-task Allocation

- Two kinds of results have been reached:
  - The first one addresses the case in which no network constraints exist.
    - Fully working infrastructure network is operative and robots are able to communicate and move without restrictions in the workspace.
    - In this case, the entire robotic workforce may be executing user tasks at full capacity.
  - The second kind of results addresses the case in which the infrastructure network is not operative or out of range.
    - Robots can only use ad-hoc, robot-to-robot communication channels to convey any necessary information to its destination.
    - In this case, some robots may be used not to execute user tasks, but to act as bridge nodes between the robots executing user tasks in out of range areas and the infrastructure network in which the central station and other robots communicate.

Multi-task Allocation

Supervisor

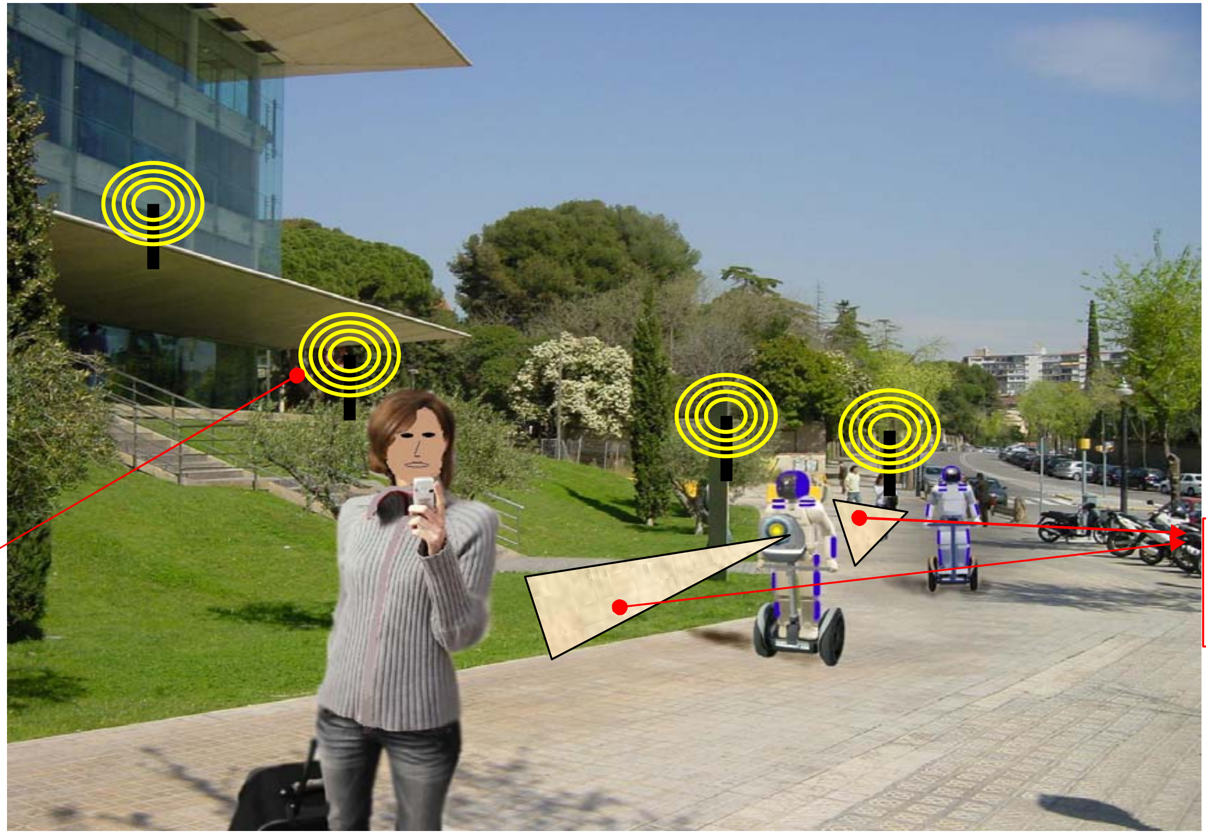


Wireless communication in Network Robots

Wireless communication:

- Combining wireless techniques for robust communication

Wireless communication



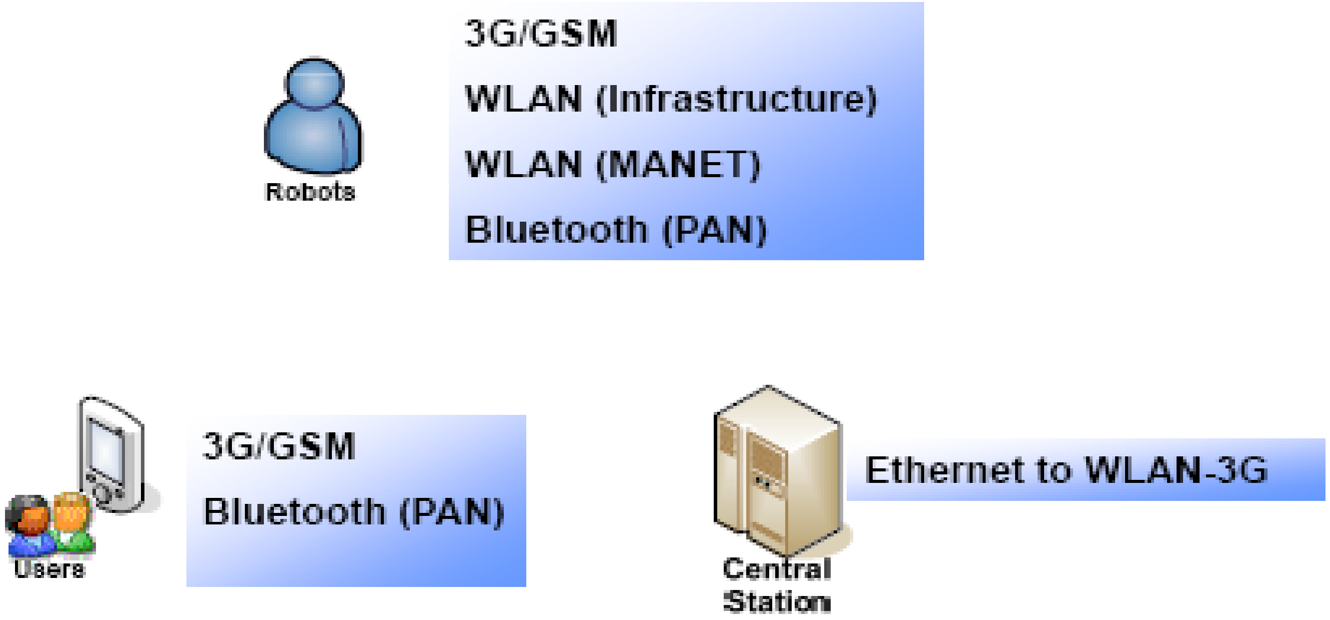
Blue tooth communication

Wireless communication in Network Robots

- The flexibility and cost of IEEE 802.11 and Bluetooth (for robot to robot and user to robot communications respectively) has been preferred over cellular commercial solutions, keeping the latter as backup mechanism.
- Creation of a software component to deal with the integration with the internal communications framework and external communications using multiple network interfaces.
- Definition of a protocol to manage real-time communications in ad-hoc networks that will be used to allow communications between robots.
- Development of a method to map the position of the nodes of the Wireless Sensor Network (WSN) by using the signal strength received from a mobile robot that carries one node

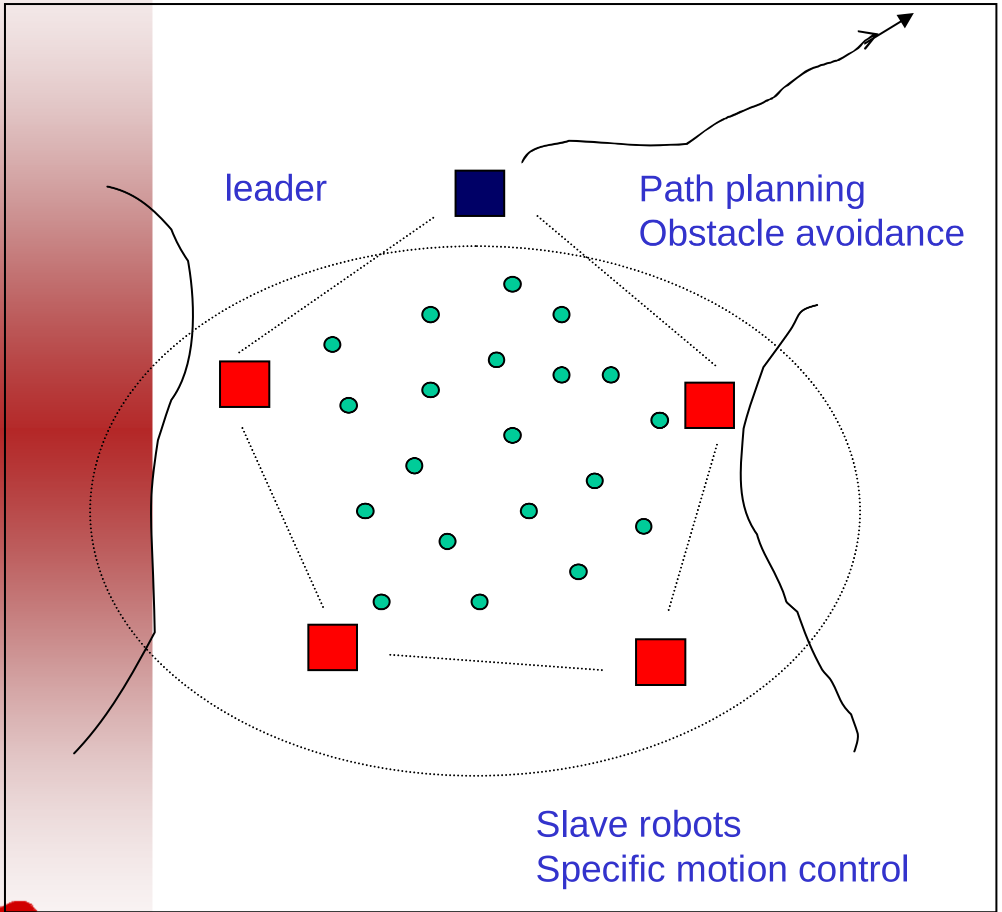
Wireless communication in Network Robots

Interfaces

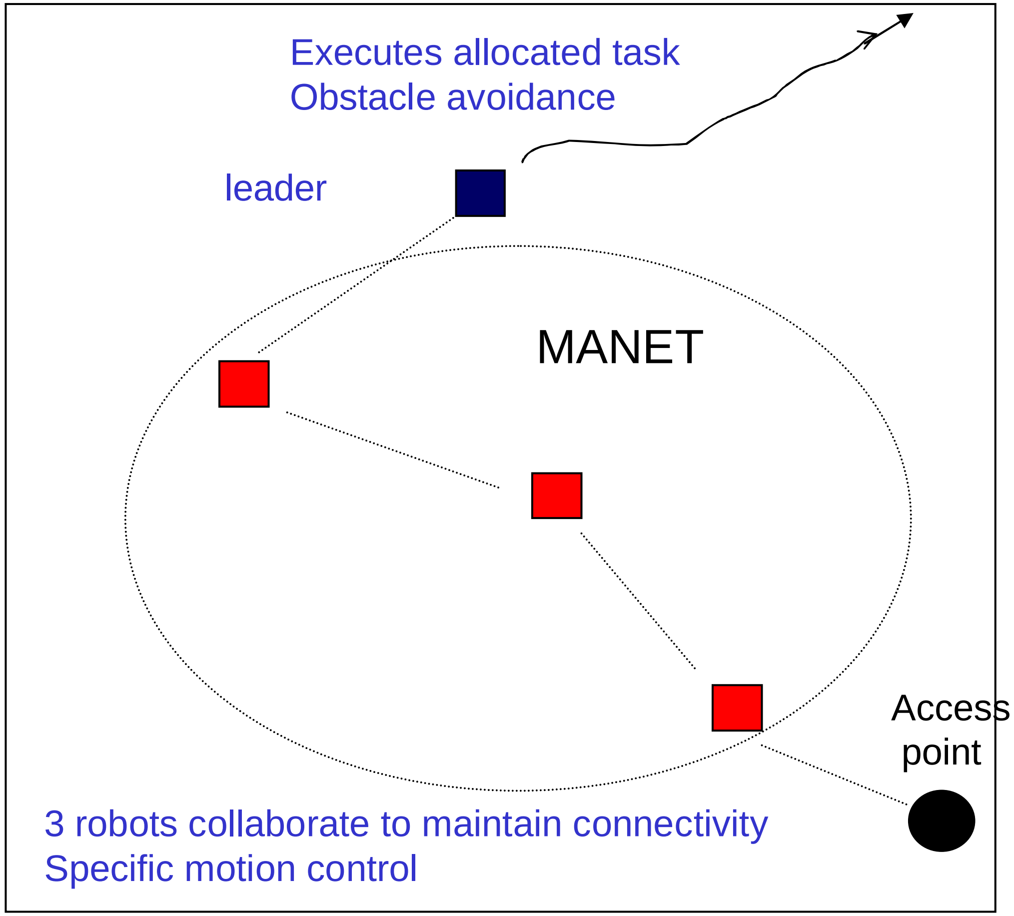


Wireless communication in Network Robots

Robot formation



Network connectivity



[Mosteo et al ICRA08]

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