URUS

Ubiquitous Networking Robotics for Urban Settings

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

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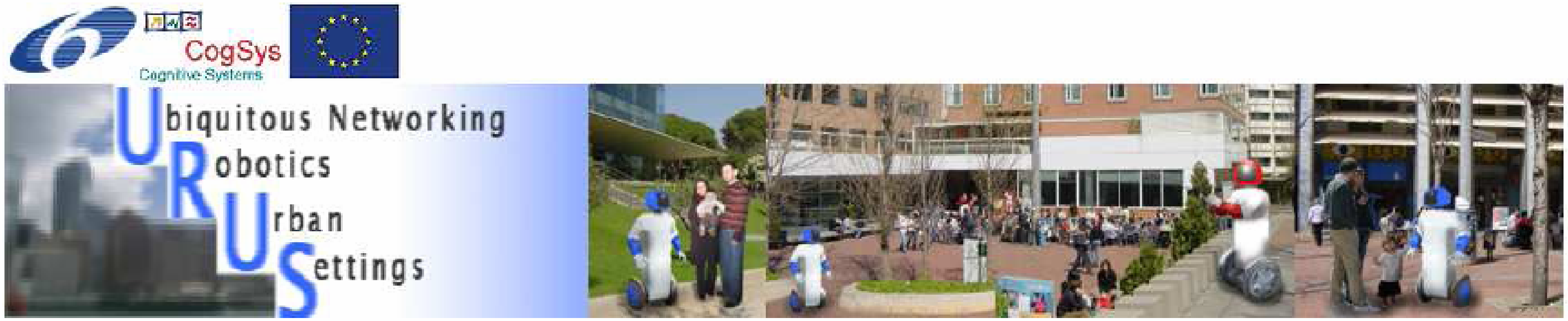
WebSite



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***

  - 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

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

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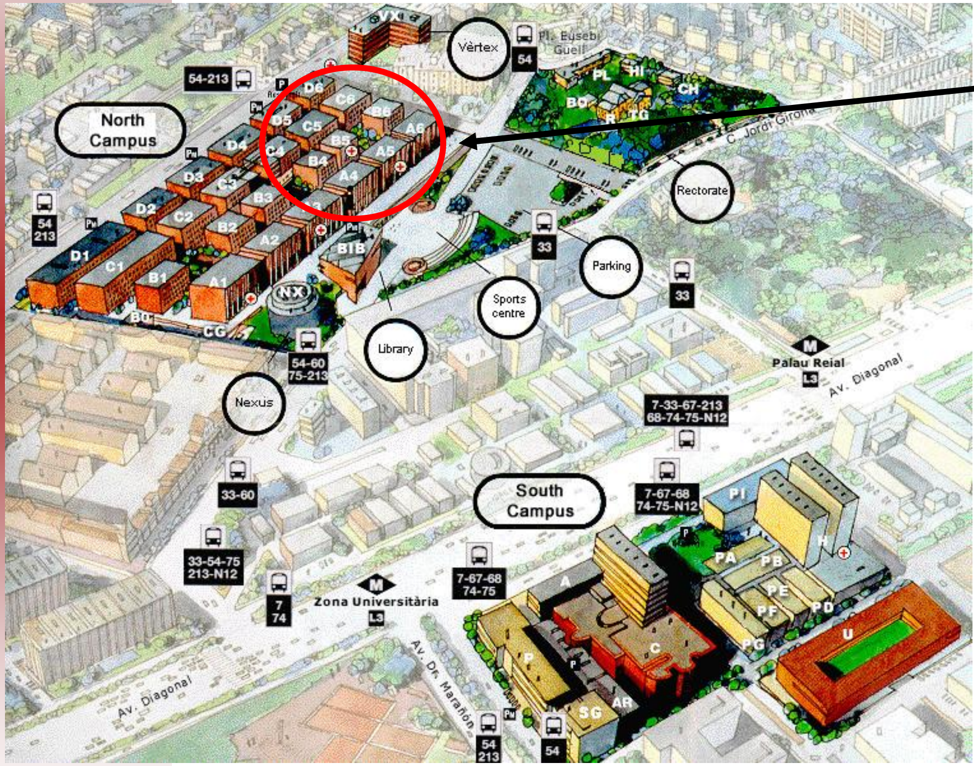
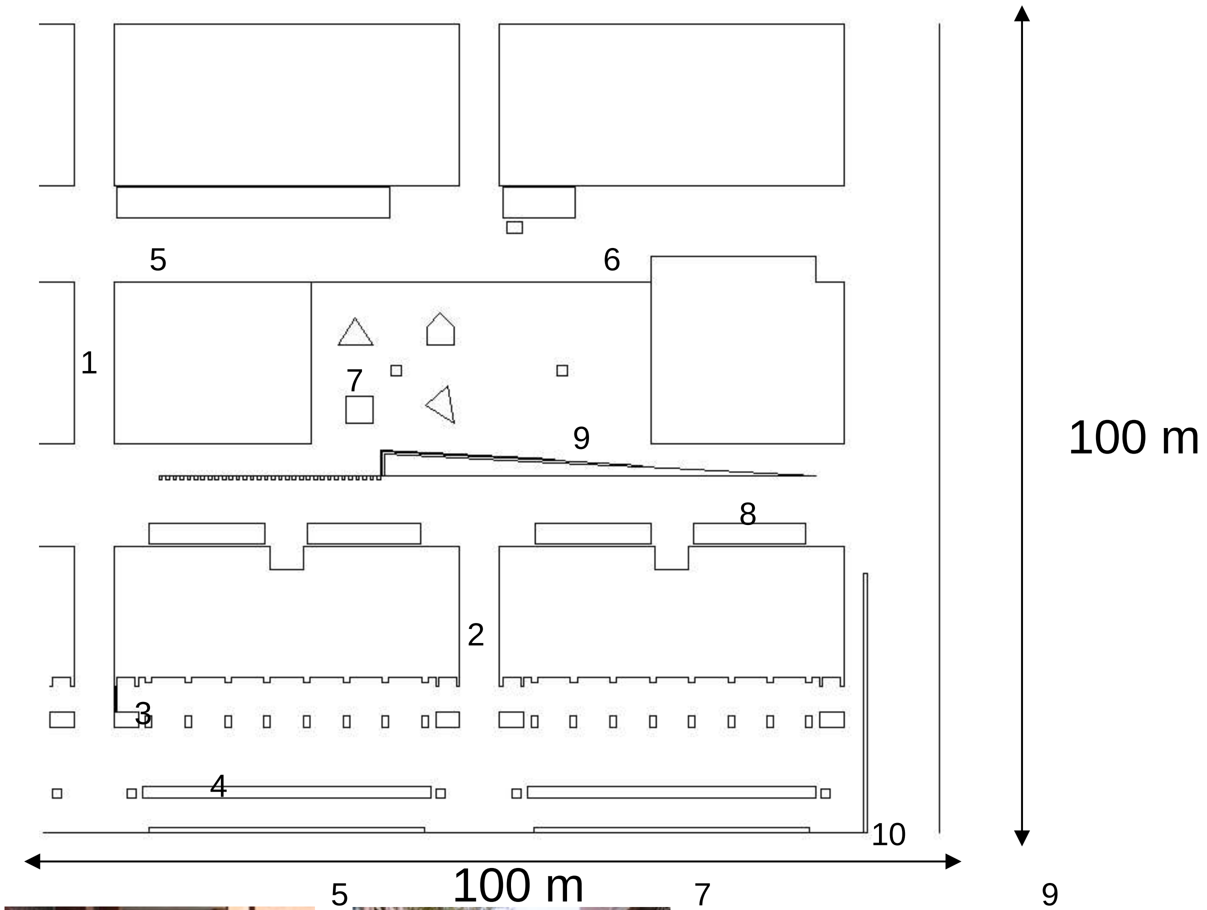
Experiment Locations: Scenario 1



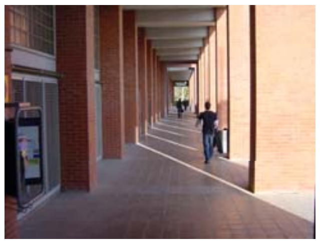
Zone Campus Nord, UPC

Zone
Campus Nord, UPC



1

3



5

7

9

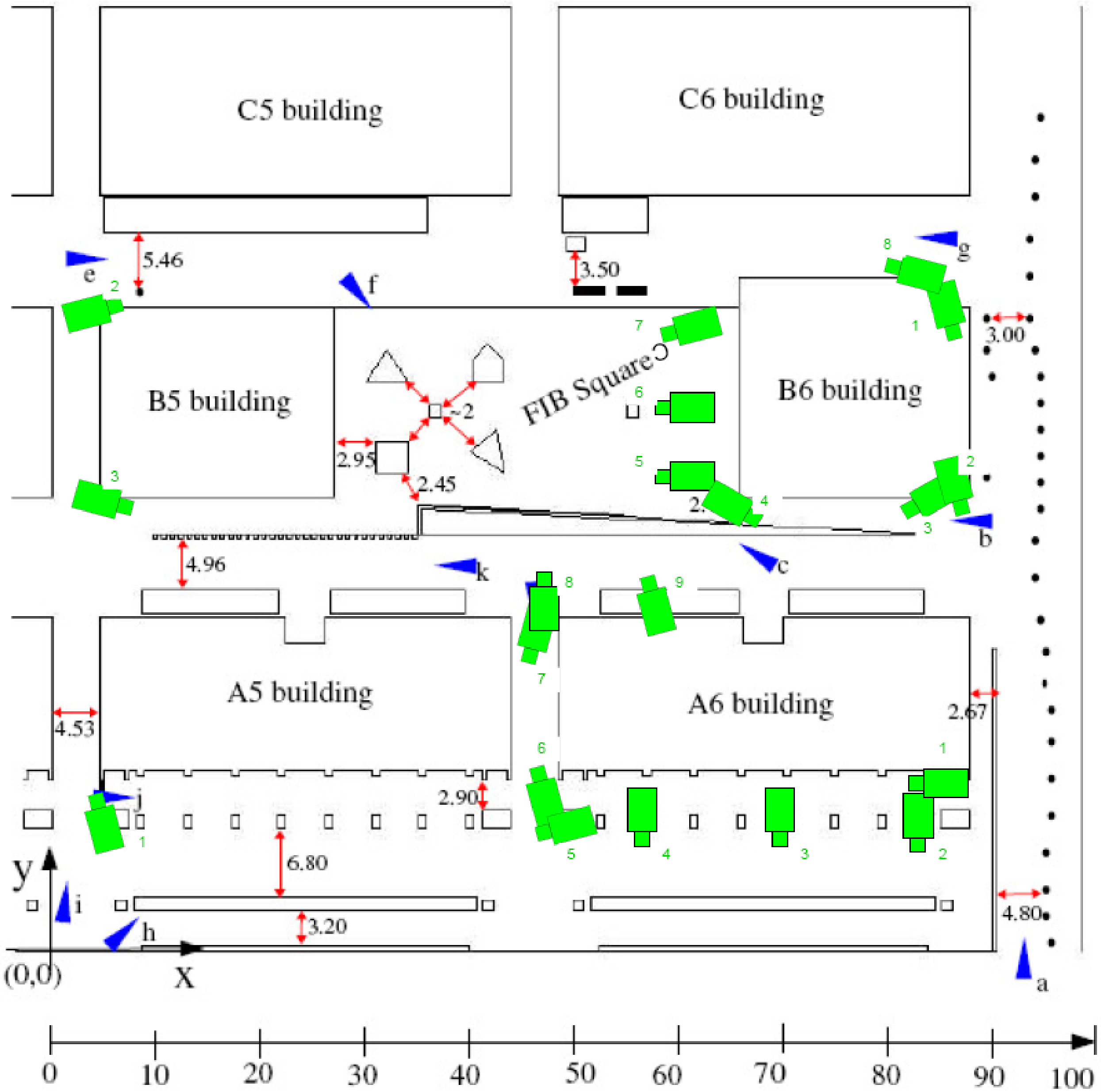
2

4

6

8

10



C5 building
C6 building
B5 building
B6 building
FIB Square
A5 building
A6 building
5.46
3.50
3.00
2.95
2.45
~2
4.96
4.53
2.90
6.80
3.20
2.67
4.80
e
f
g
b
c
k
j
i
h
a
y
x
(0,0)
0
10
20
30
40
50
60
70
80
90
100

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

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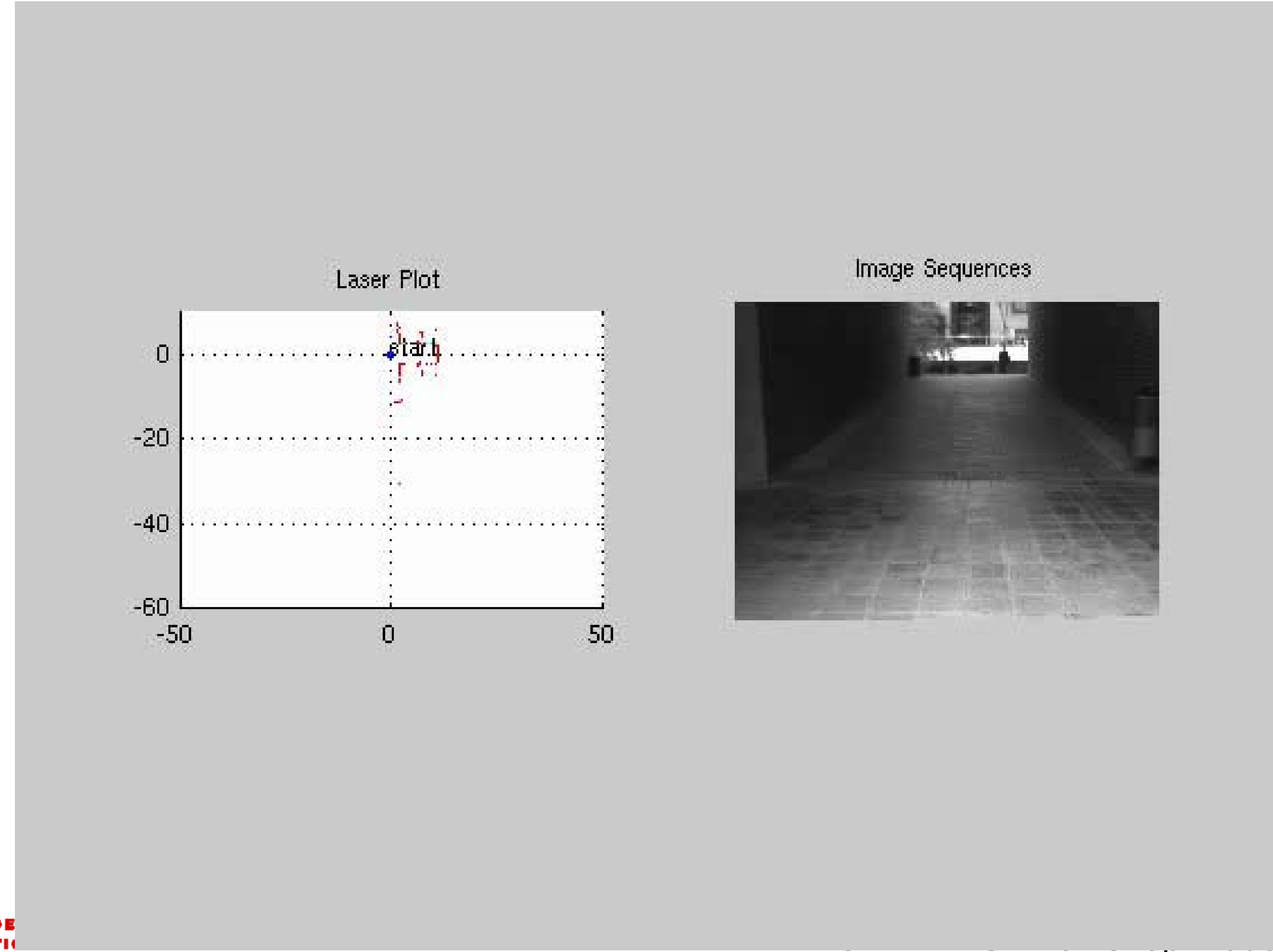
Some Videos of Scenario 1



Hardware and Robots

Robot 1

Robot 2

Robot N

Robot 1	Robot 2	Robot N
Functional Layer	Functional Layer	Functional Layer
Supervisor Task Allocation	Supervisor Task Allocation	Supervisor Task Allocation
Wifi	*Wifi*	*Wifi*

Ethernet

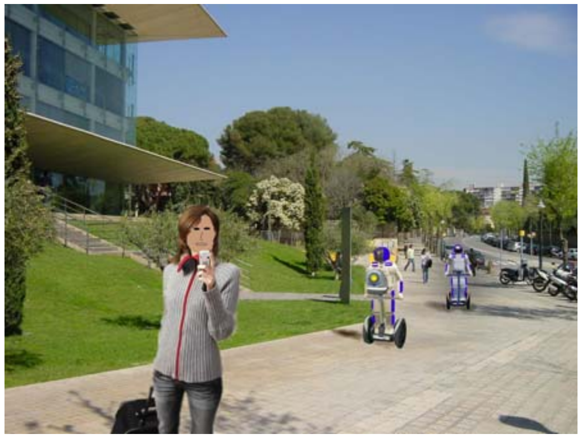
Wifi *Wifi*

Ethernet

Central Station

- Task Allocation
- Environment Perception
- GSM Interface
- Global Supervision

GSM Network



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Scientific and Technological Achievements

Specifications in Urban areas

- Analysis of the urban scenarios for the experiments at all levels (geographical, social and architectonically etc).

- Study of some elements that could be relevant for the city –as the monitoring of some aspects of the environment.

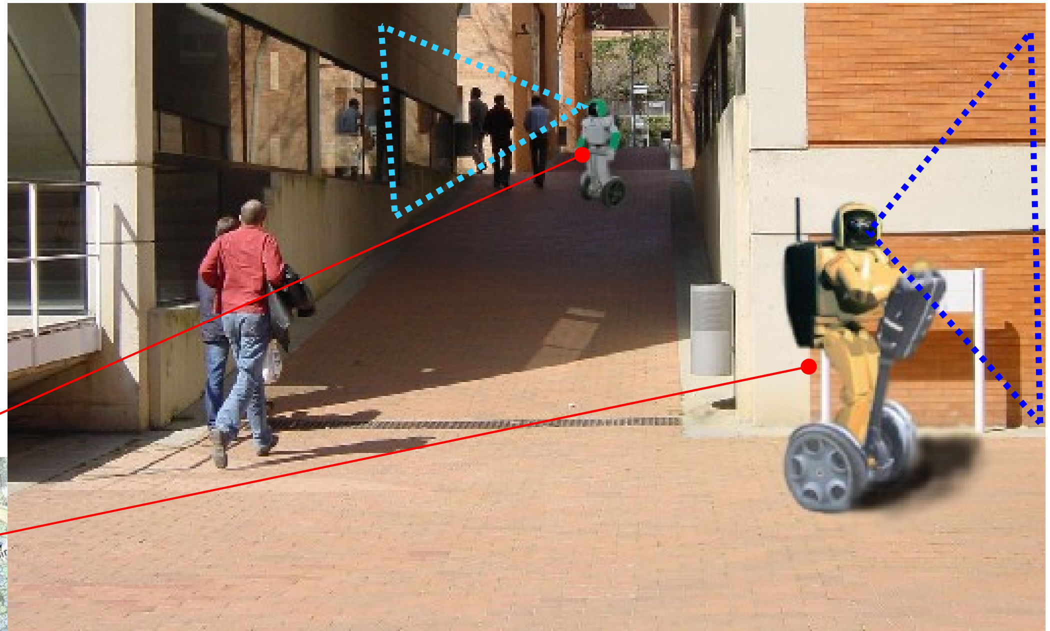
Cooperative Localization and Navigation

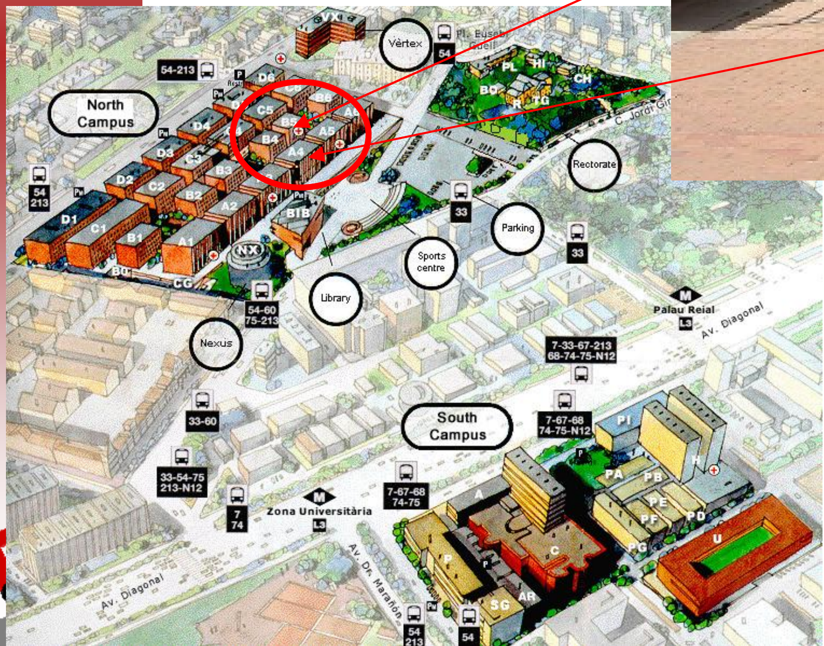
Localization using:

- GIS
- multiple robots
- ubiquitous sensors

Navigation:

- Using GIS
- Own and embedded sensors





Cooperative Localization and Navigation

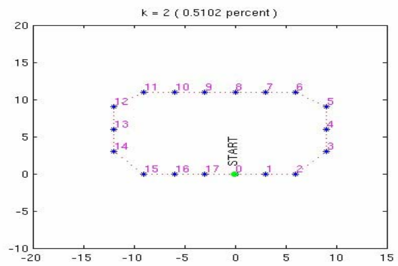
- **Cooperative Localization**
  - Single robot localization has been implemented on the different platforms.
  - Implicit multi robot localization has been carried out by acquiring data on site and building platform-specific maps.
- **Cooperative Navigation**
  - Single robot path planning has been solved by applying the E* motion planning algorithm
  - The cooperative unifies formation maintenance, leader following and obstacle avoidance. The approach has been validated experimentally in obstacle-free environments.
- **Integration**
  - Integration efforts have centred on porting partner’s tool sets to the YARP platform

Cooperative Localization and Navigation

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

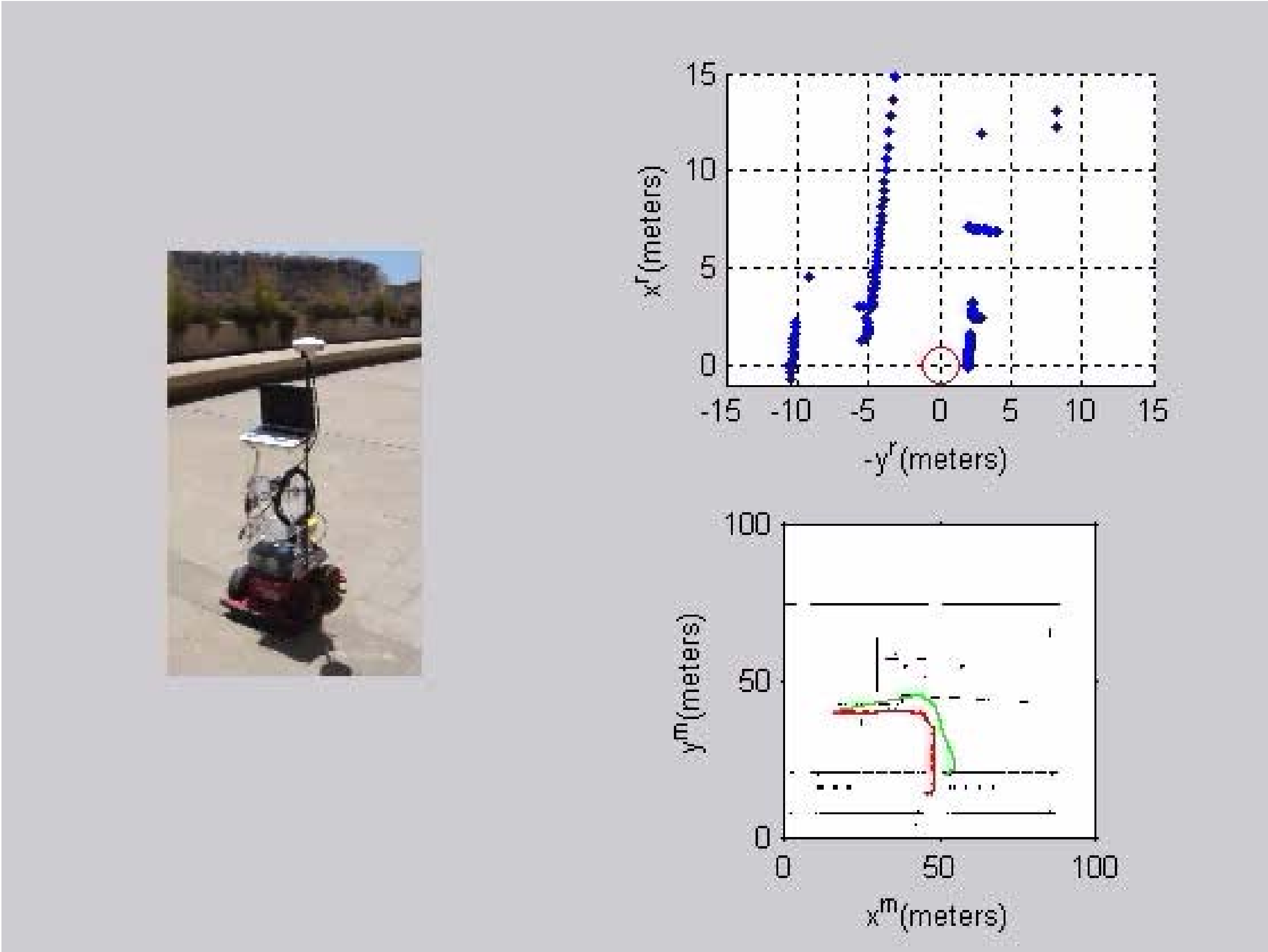
New technique to robot localization purely from vision data, based on two criteria: closeness of robot pose estimates, and information gain.

Video: SLAM_29Janallfast.avi



Cooperative Localization and Navigation

Localization of robots using GIS and laser information



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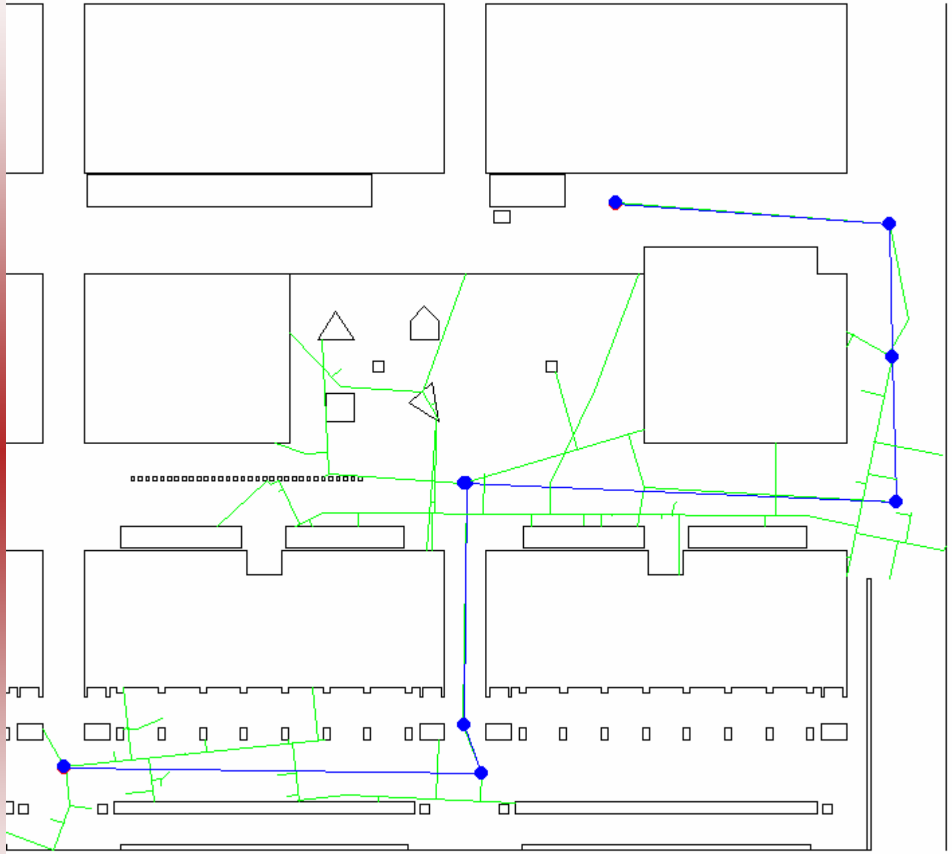
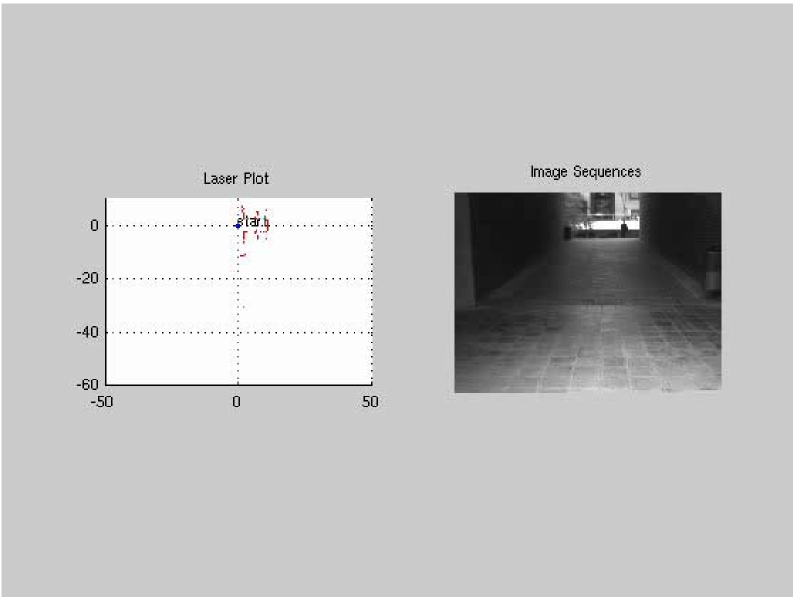
Cooperative Localization and Navigation

Navigation using path planning and sensor information



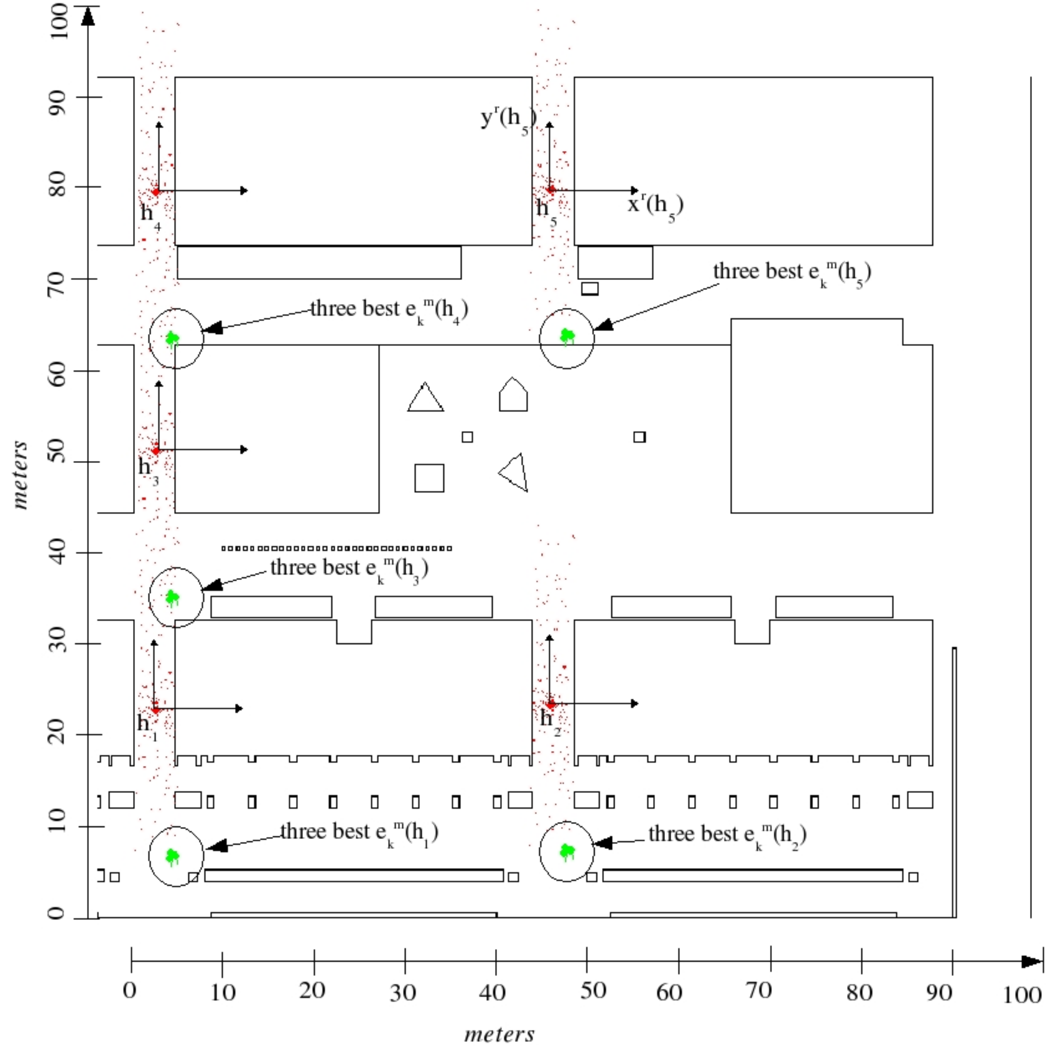
Path planning

Navigation with laser



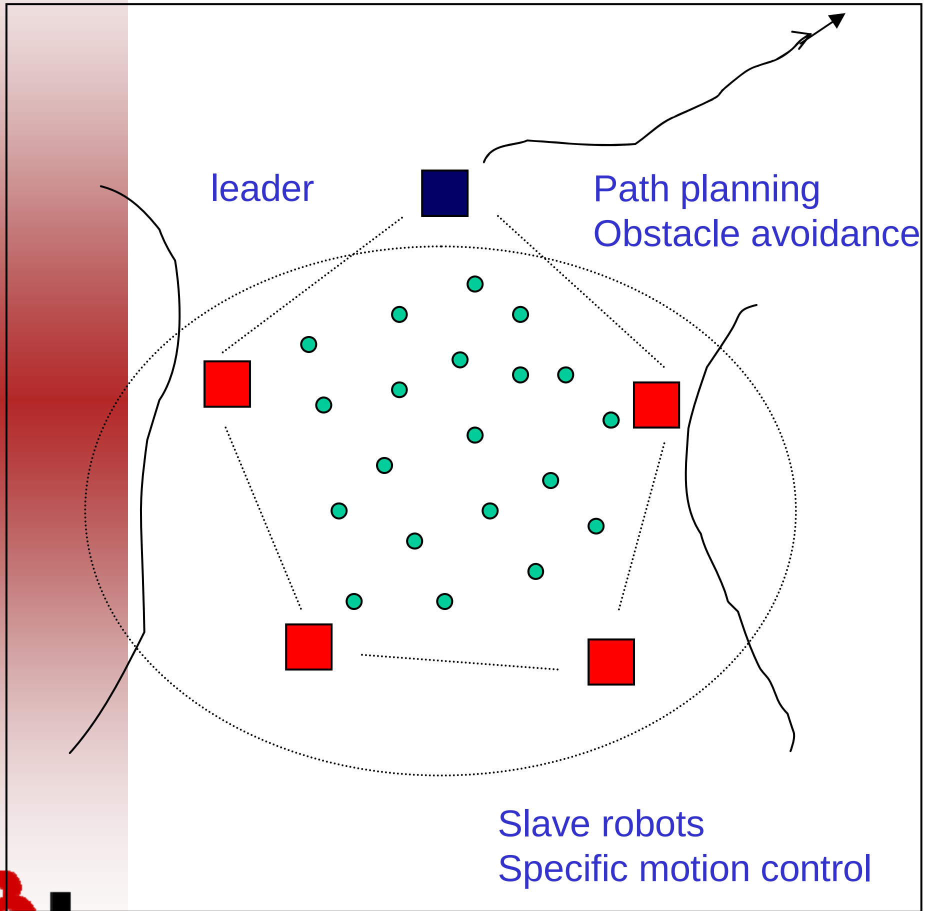
Cooperative Localization and Navigation

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

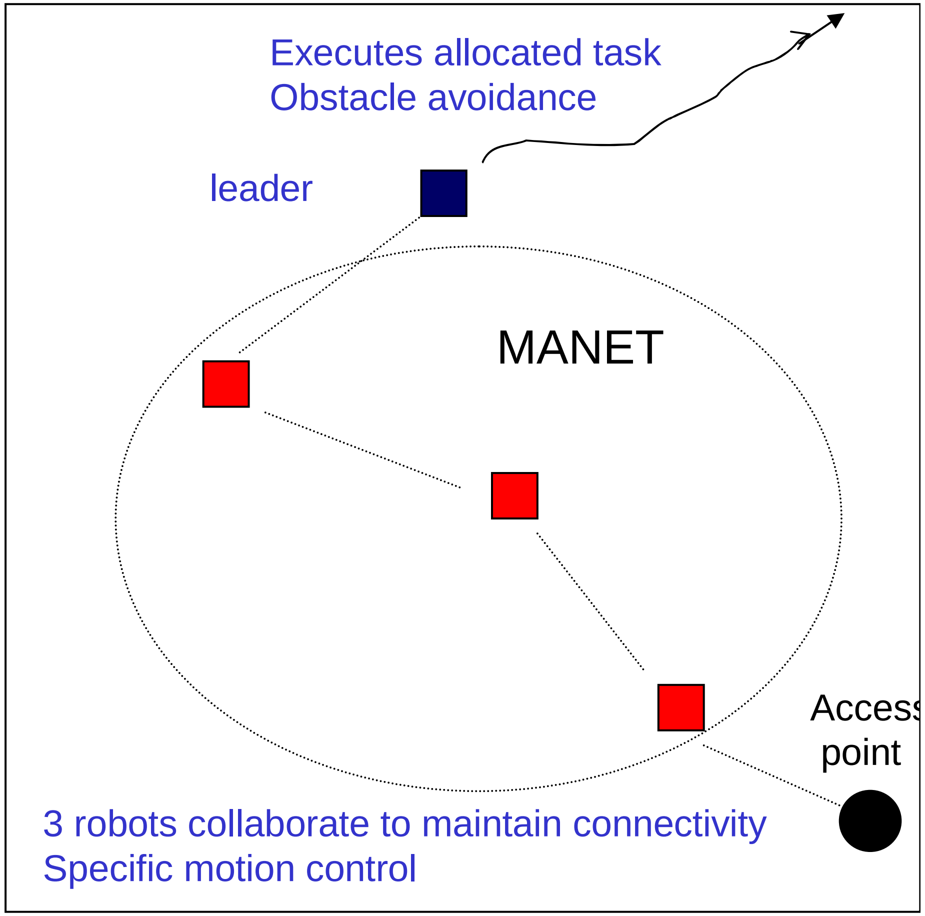


Cooperative Localization and Navigation

Robot formation



Network connectivity



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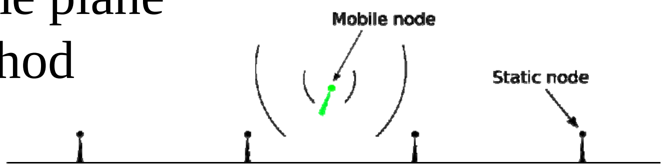
Cooperative Localization and Navigat

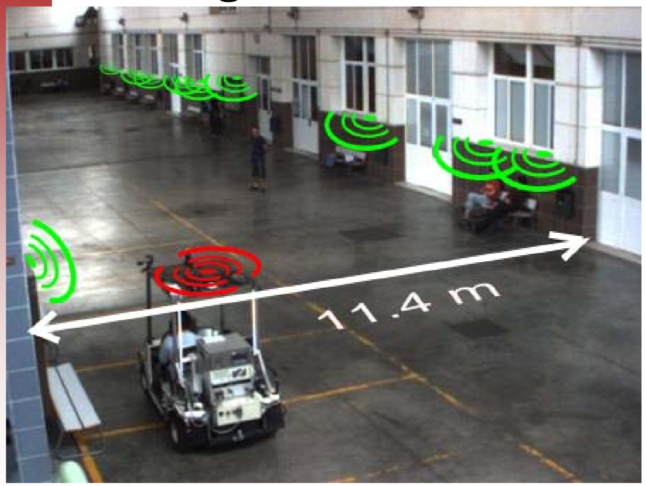
Relative Ranging method

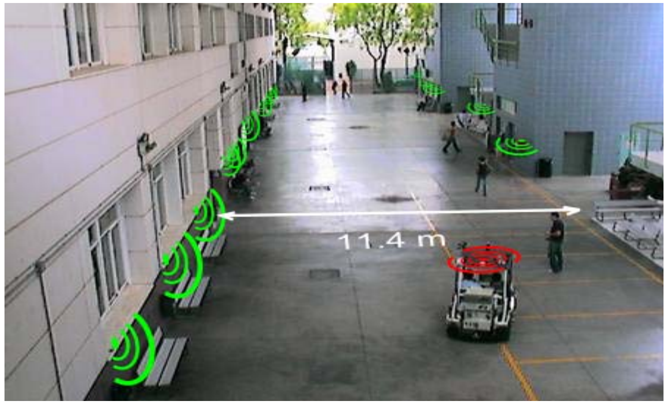
Try to eliminate effect of antenna orientation
Suitable for static nodes approximately in the same plane
Triangulation using a non-linear least-square method



Experiments

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





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Cooperative Environment Perception

Cooperative perception using:

- embedded and own sensors
- fusion techniques and technologies

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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.

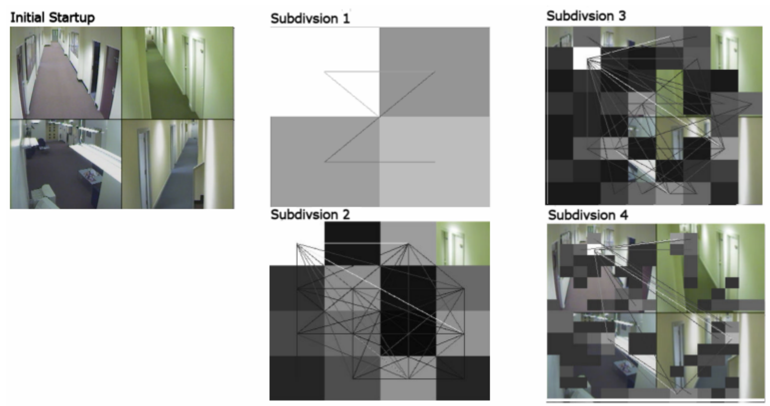
Cooperative Environment Perception

Following a person with environment cameras

Cooperative Environment Perception

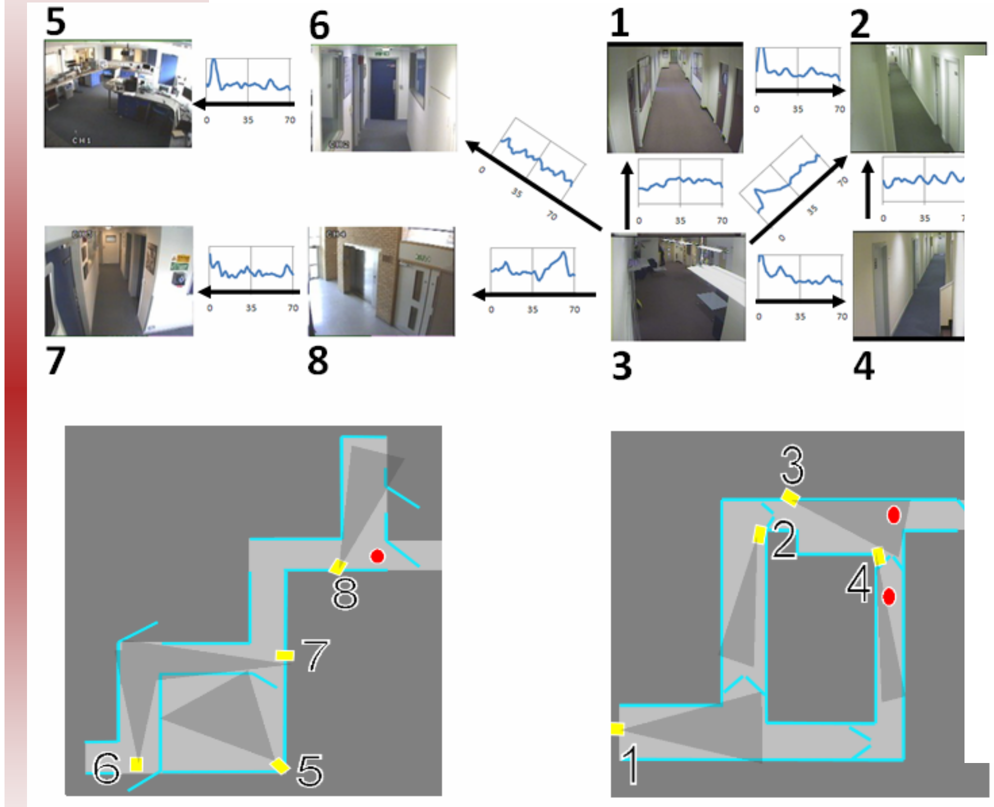
Following several persons with environment cameras

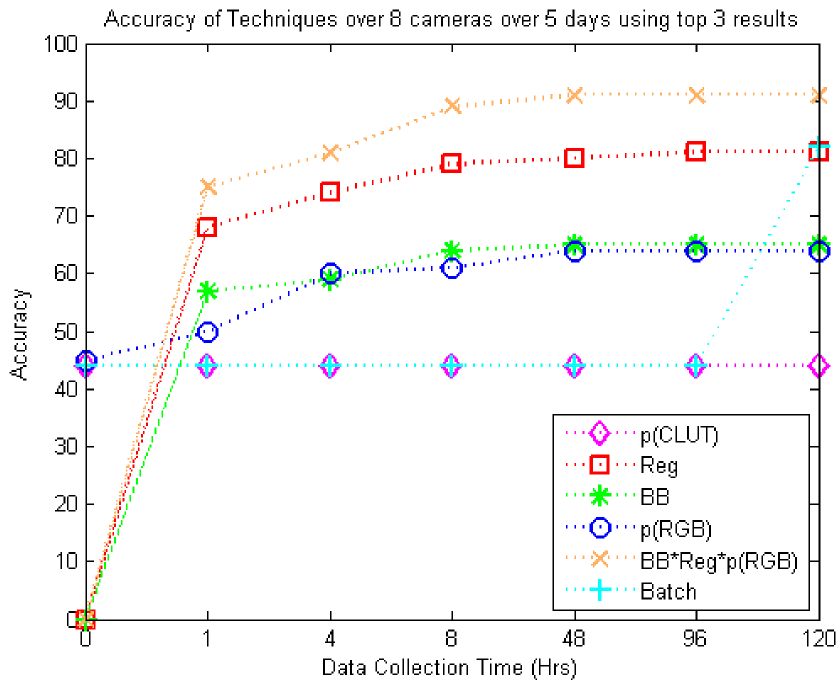
- Inter Camera – uncalibrated, non overlapping
- Learns relationships
  - Weak Cues
    - Colour, Shape, Temporal
    - Learns consistent patterns
  - Learns Entry/Exit regions
- Real Time (25fps)
- Incremental design
  - work immediately
  - improves in accuracy over time



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

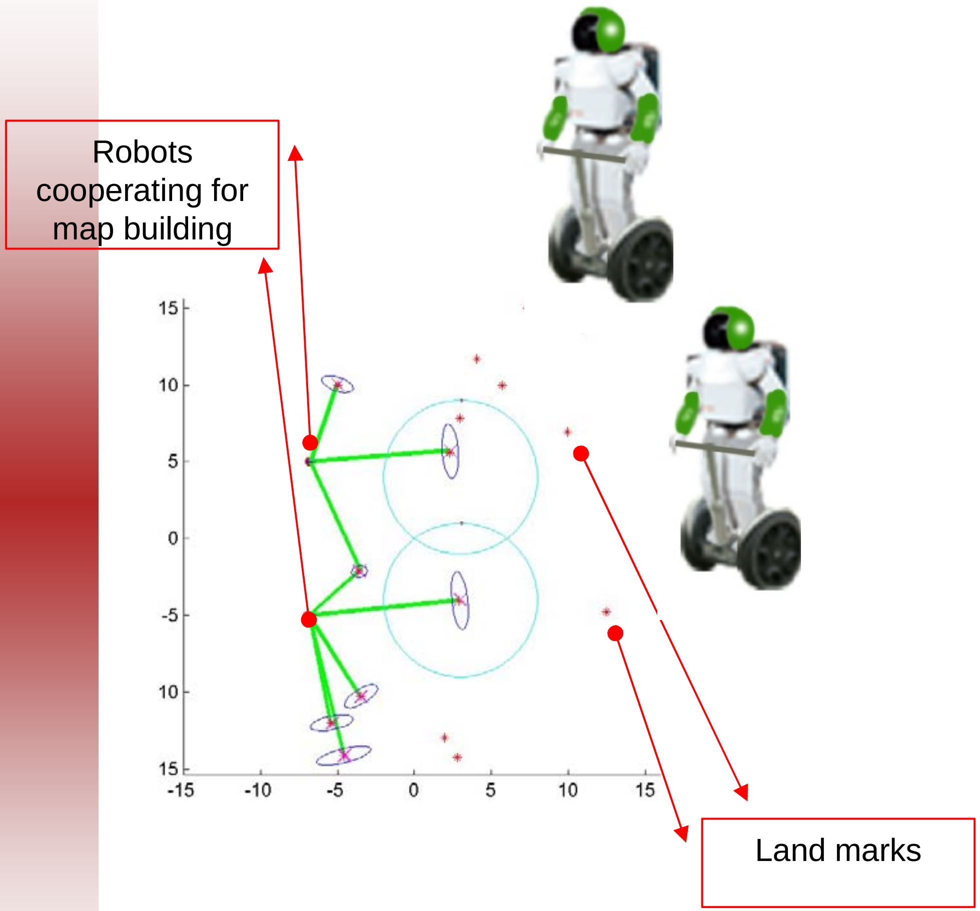
Cooperative Environment Perception

- 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 Map Building and Updating



Cooperative SLAM:

- Using multiple robots and sensors
- Using control techniques

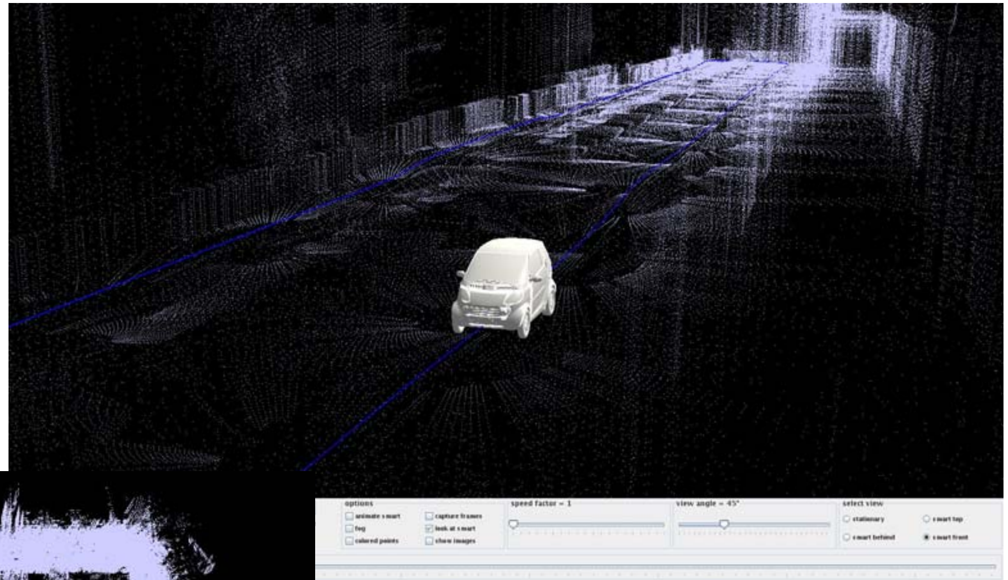
Cooperative Map Building and Updating

- We have preliminary results on mapping the UPC nord 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 using laser beams



Video SmartData.mpg

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Human Robot Interaction

Human robot interaction:

- Combining mobile phones, voice, touch screen

Communication by voice and touch screen

Communication by voice

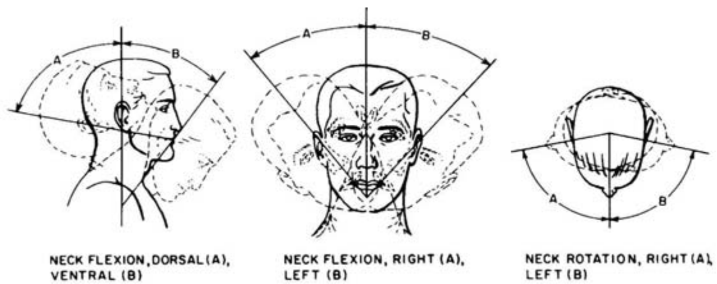
Communication between robots and humans trough the mobile phone

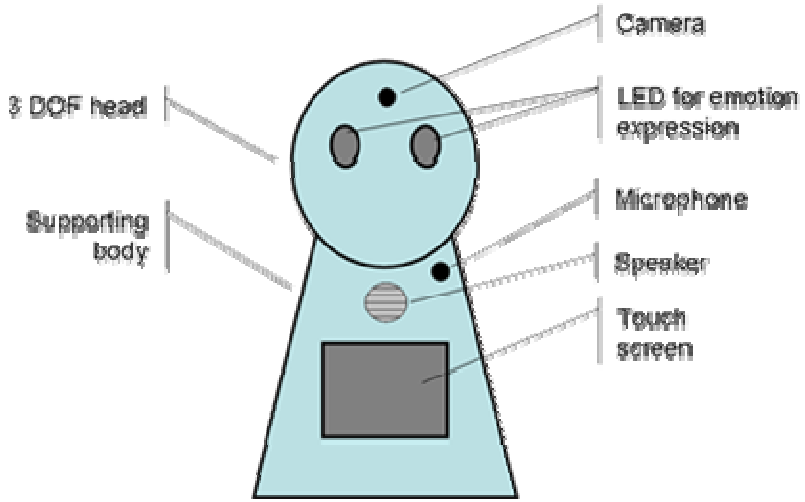
Human Robot Interaction

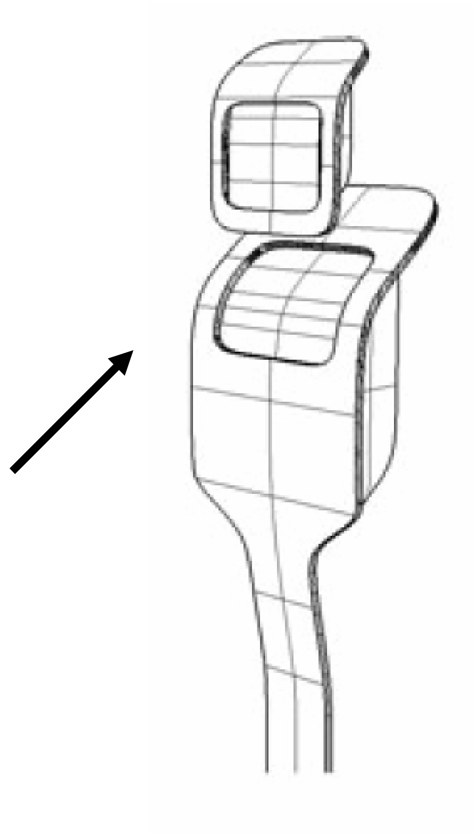
- Analysis of the specifications for human-robot interaction (HRI) aspects required by the experiments considered in the project:
  - the selection of the adequate features for the robot head that simplify the interaction with human (e.g., the ability to generate multiple facial expressions)
  - the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

Design and features of the head







Multi-task Allocation

Multi-task negotiation:

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

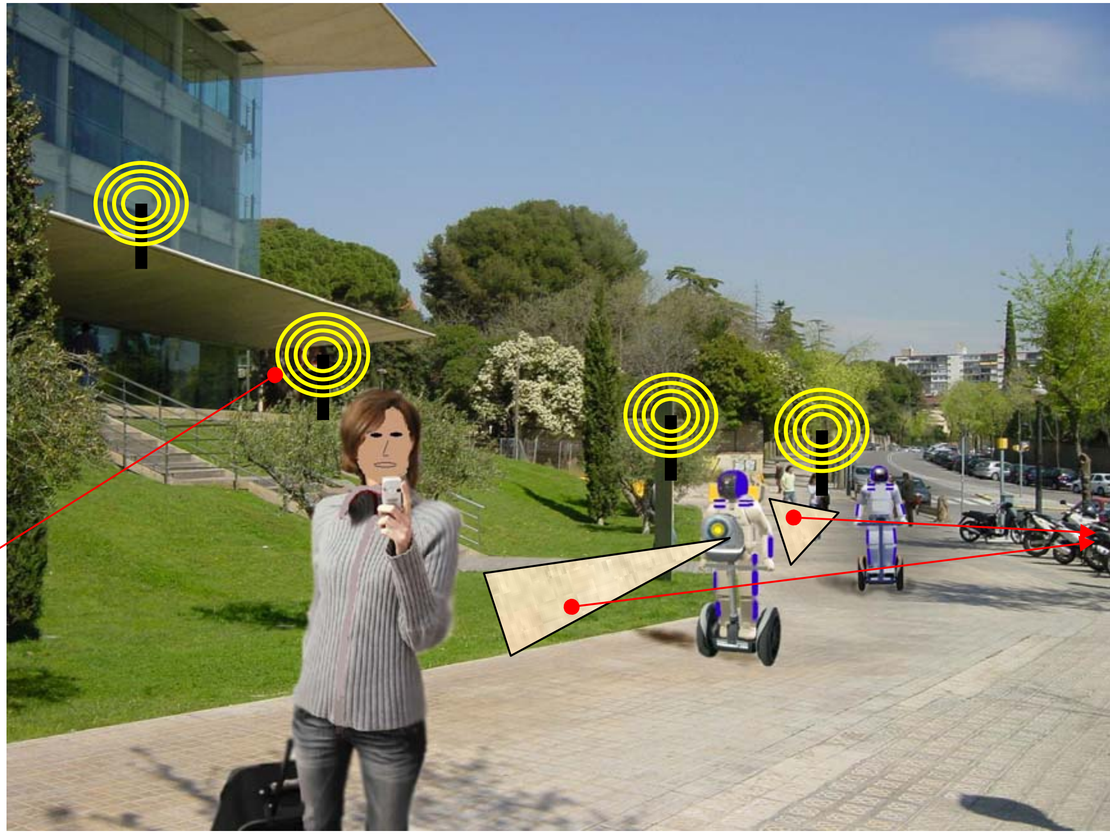
Multi-task Allocation

- 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.

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

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

Cameras and ubiquitous sensors

Robots with intelligent head and mobility

People with mobile phones and RDFI

Wireless and network communication

Robots for transportation of people and goods

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)