Cooperative Environment Perception in the URUS project

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Index

- The URUS project
- Experiment locations an experiments
- Cooperative Environment Perception
  - Calibration of cameras
  - Cooperative perception in URUS
  - Tracking with fixed cameras
  - Delay-stated information filter for decentralized cooperative tracking
  - Data association based on mutual information
  - People detection under cast shadows
  - Active cooperative perception

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URUS project

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: Steward service in public spaces

URUS Partners

Institut de Robótica i Informática Industria (IRI)
Universitat Politécnica de Catalunya (UPC)

Centre National de la Recherche Scientifique/ LAAS

Eidgenössische Technische Hochschule/ ETHZ

Asociación de Investigación y Cooperación Industrial de Andalucia/ AICIA

Scuola Superiore di Studi Universitari e di Perfezionamento Sant'Anna/ SSSA

Universidad de Zaragoza/ UniZar

Instituto Superior Técnico/ IST

University of Surrey/ UniS

Urban Ecology Agency of Barcelona/ UbEc

Telefónica I+D/ TID

RoboTech / RT

Experiment Locations

UPC Campus Nord

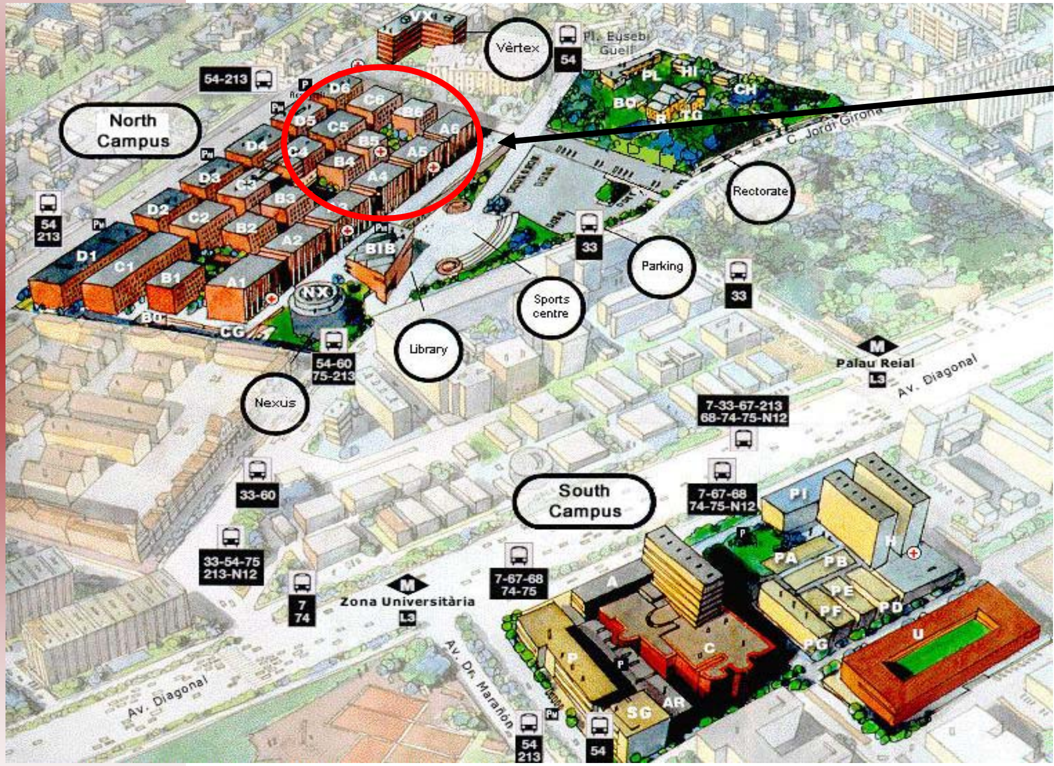
Gràcia Superblock

Espanya Industrial
Superblock (planned)

22@ Campus
Audiovisual
Superblock
(in development)

Ribera
Superblock

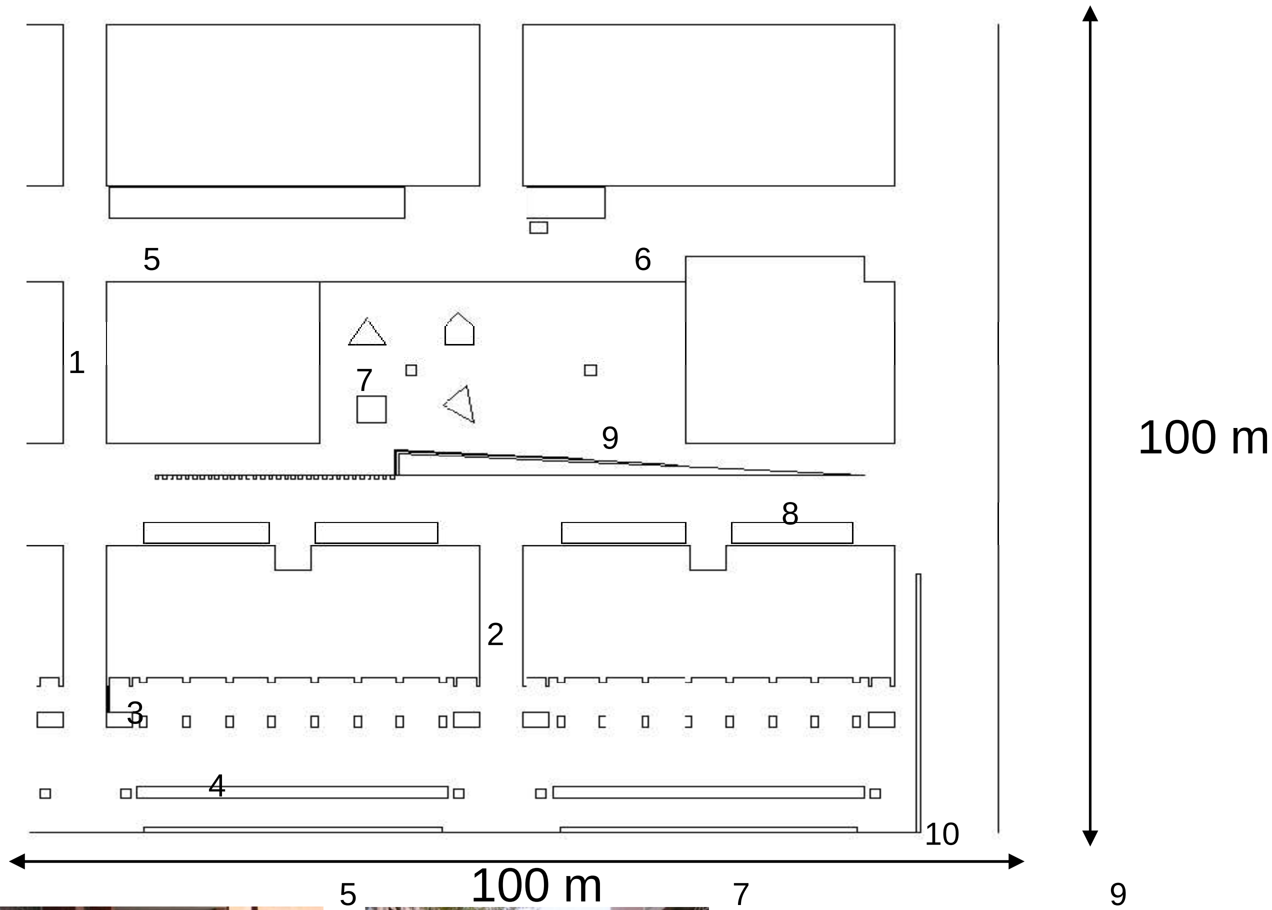
Experiment Locations: Scenario 1
UPC



Zone Campus Nord, UPC

Barcelona ROBOT Lab

Barcelona ROBOT Lab
Campus Nord, UPC



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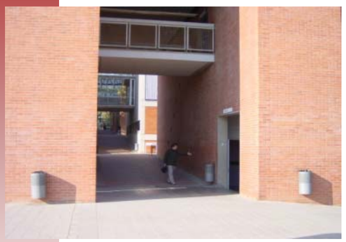

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2

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6

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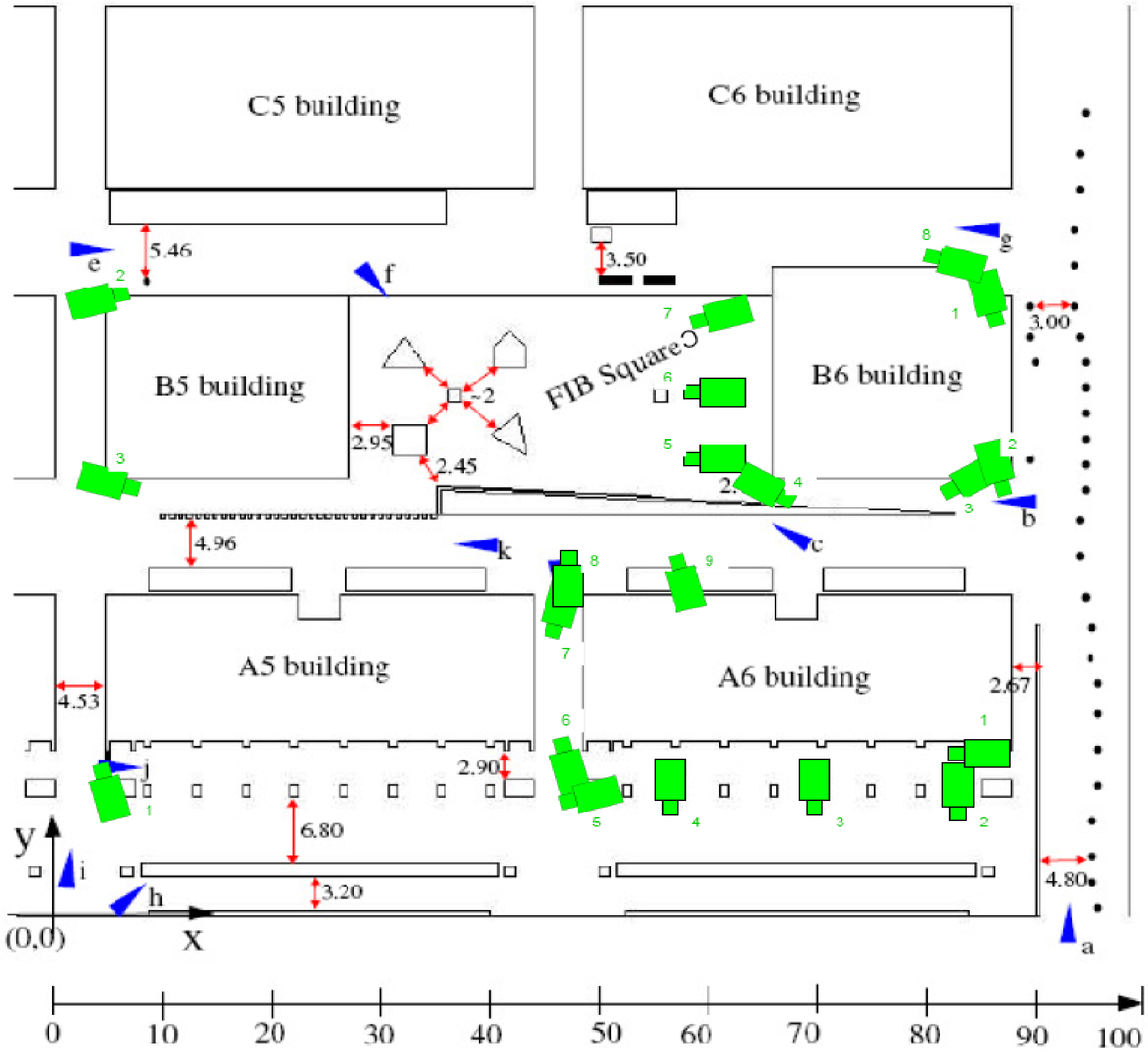

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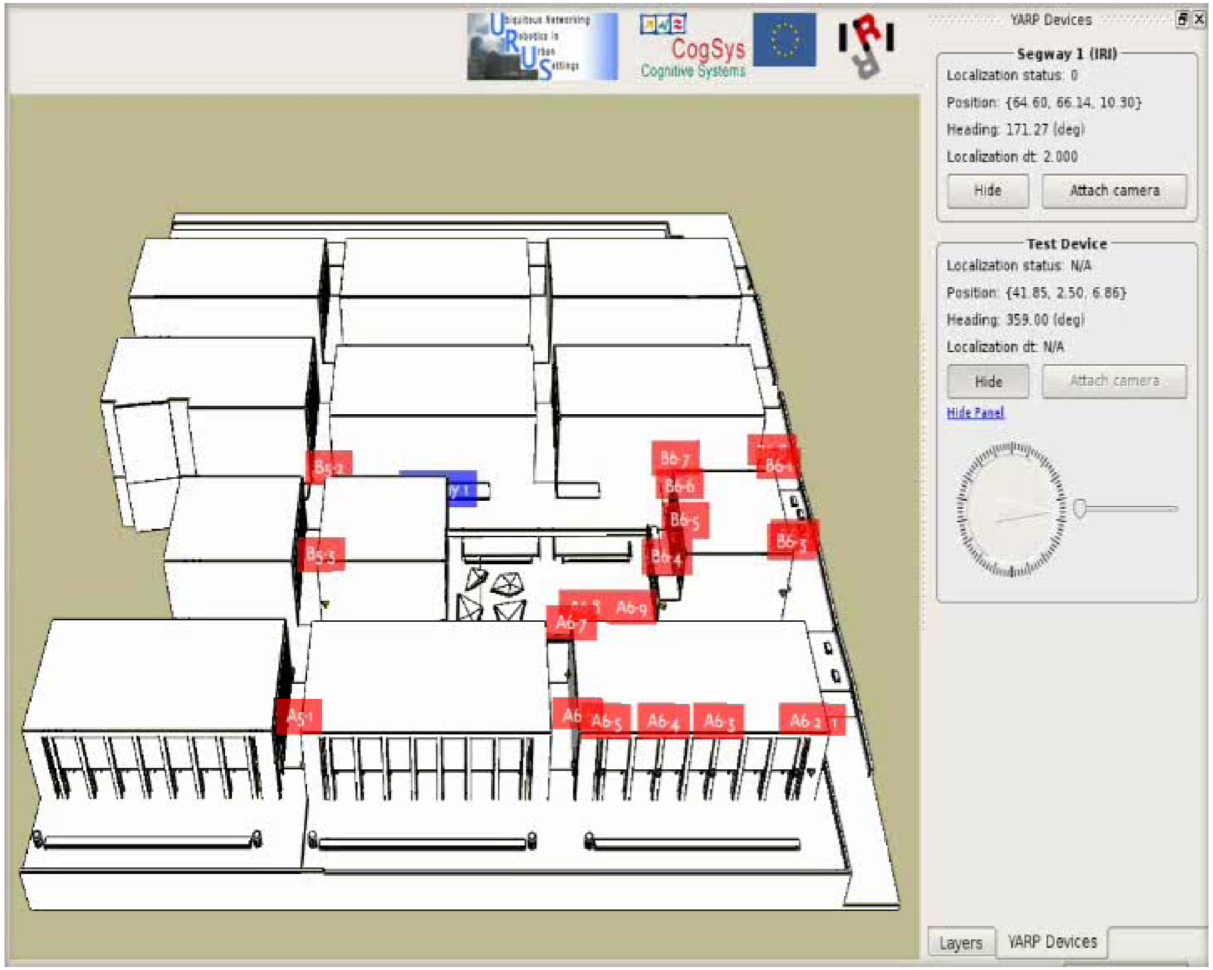
Experiment Location: Scenario 1 UPC



Experiment Location: Inauguration

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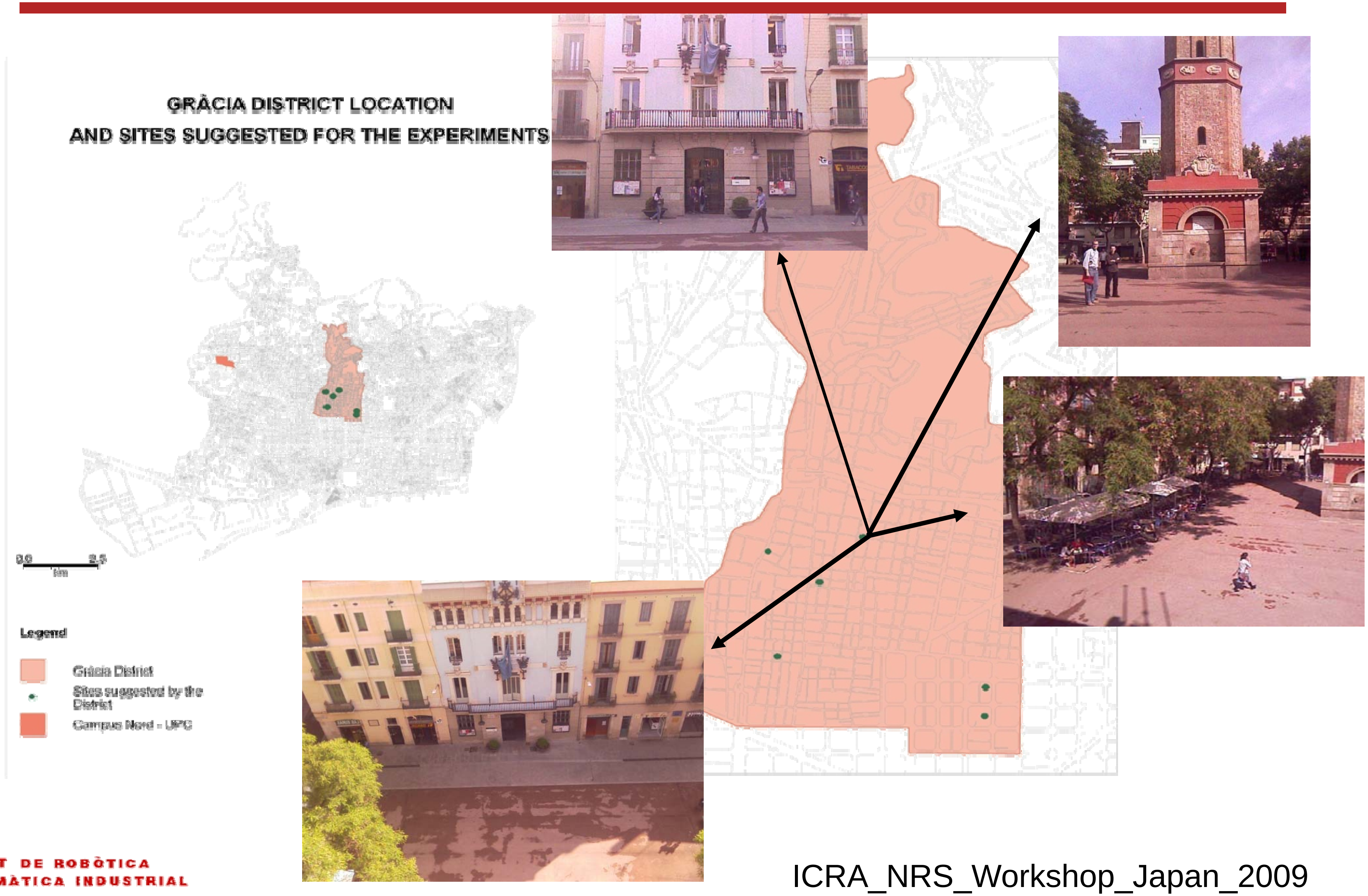
Experiment Location: Scenario 2
Gracia District



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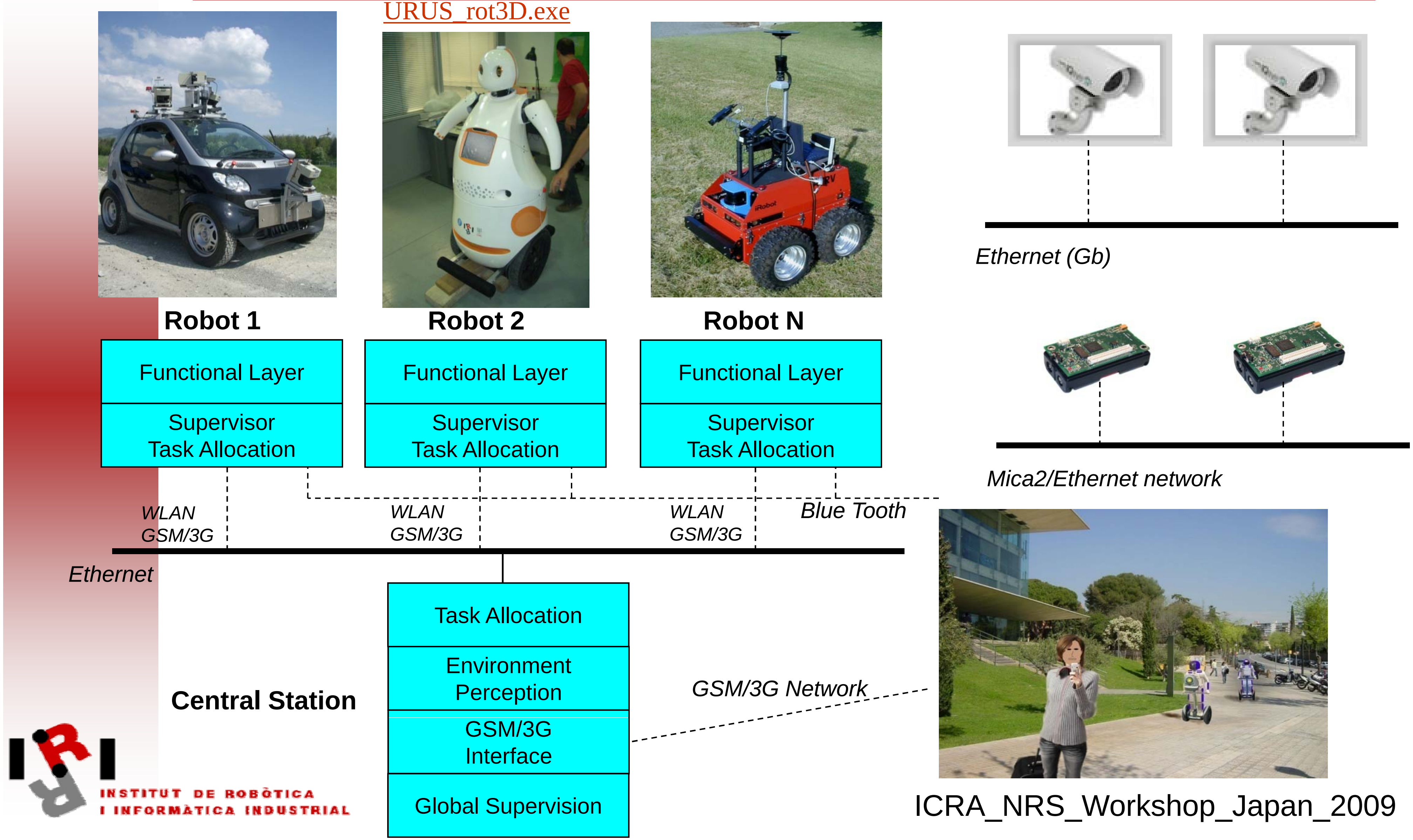
Global Architecture



Robots in Experiment Site 1

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
    - Steward service in public spaces.
  - 4.- Map building

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Cooperative Environment Perception

Cooperative Environment Perception

Cooperative perception using:

• embedded and own sensors

• fusion techniques and technologies

Cooperative environment perception

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Cooperative Environment Perception: Objectives

- **Objective:**
  - Design and develop a cooperative system for environment perception and active cooperation with robots and humans
  - General but focused on the experiments
- **Network Robot System:** several robots, cameras and other networked sensors
- **Topics:**
  - Calibration of cameras
  - Image processing for tracking
  - Information fusion and data association
  - Active cooperative perception

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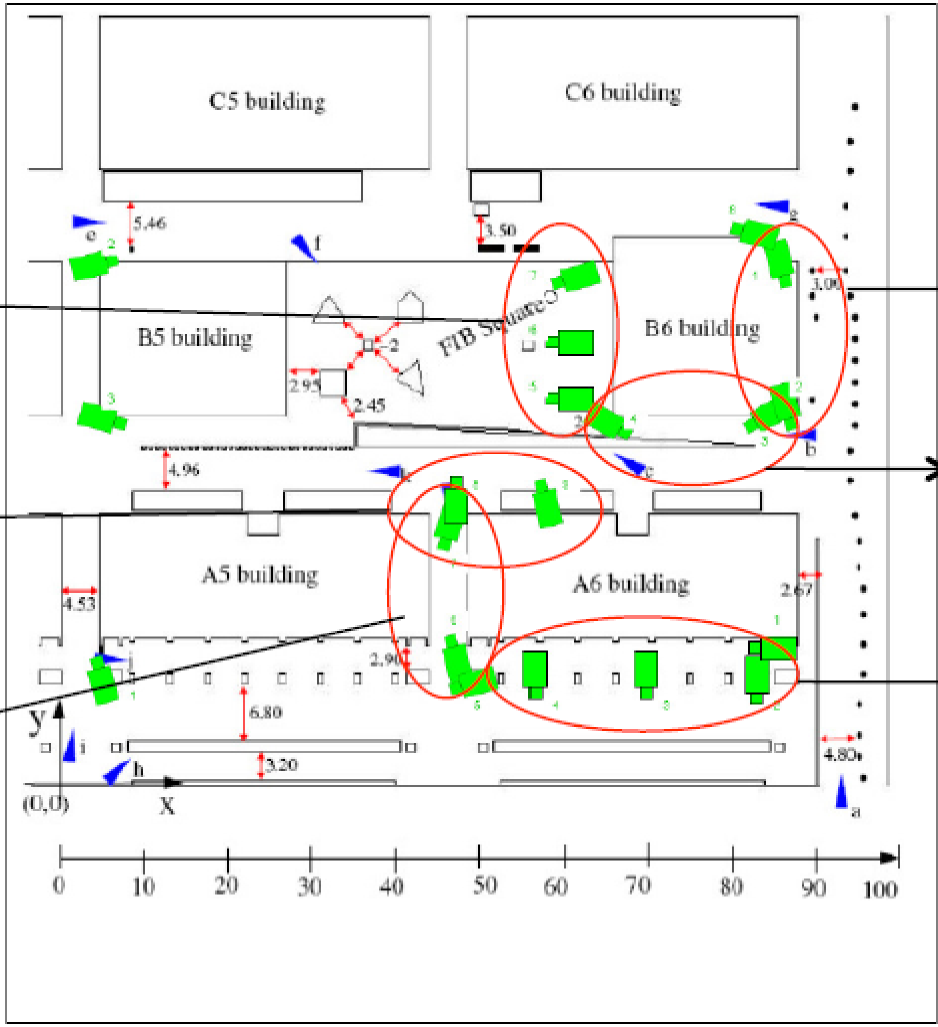
Calibration of Cameras



SubNet
cameras 4,5 & 6

SubNet
cameras 15 &16

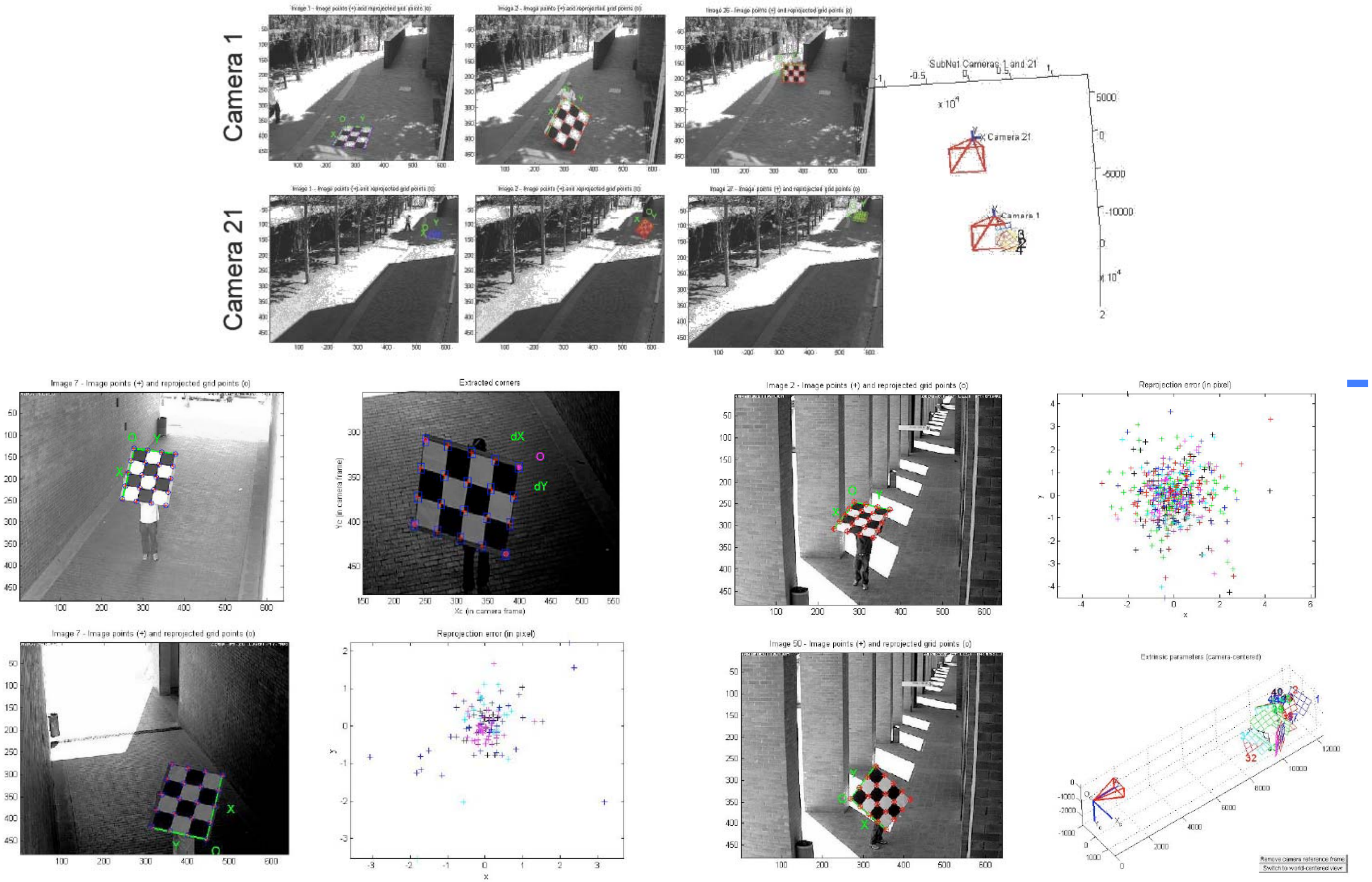
SubNet
cameras 13 &
14

SubNet
cameras 1 & 21

SubNet
cameras 2 & 3

SubNet
cameras 9 ,10 &
11

Calibration of Cameras



Cooperative Perception in URUS

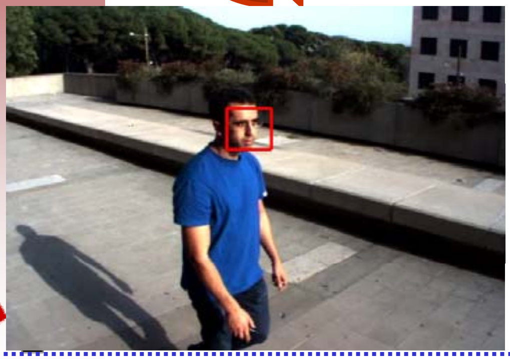
- Cooperative person tracking in URUS
- Decentralized estimation between robots, camera network and WSN

Information channels

Data association → Data fusion

Local Processing | Active Perception

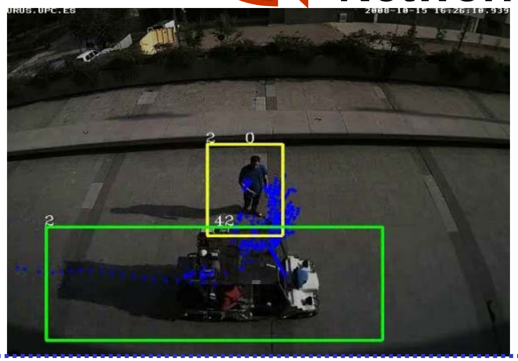
Robot



Data association → Data fusion

Local Processing | Active Perception

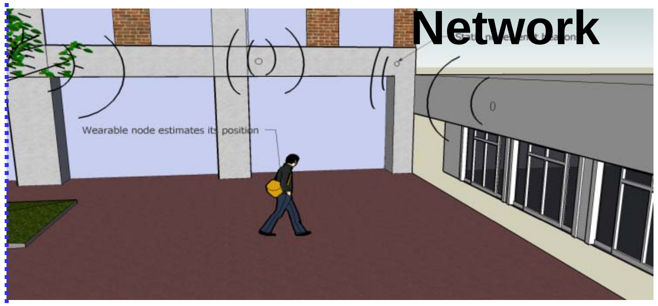
Camera Network



Data association → Data fusion

Local Processing | Active Perception

Wireless Sensor Network



Tracking- Fixed Camera Network

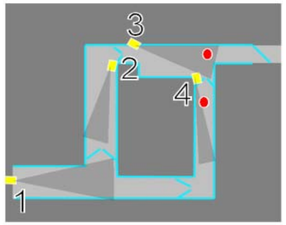
- Objectives:
  - To track people/robots across static camera network

- Approach:
  - Learn probabilistic relationship between cameras on-the-fly
  - Use learnt relationship to increase accuracy of object handover between cameras

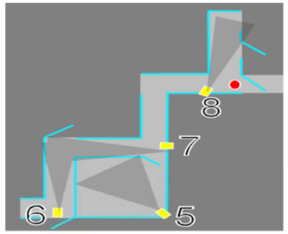
People Tracking with Fixed Cameras

- Motivations:
  - Large numbers of cameras
  - No continuous human monitoring
  - Provide improved viewpoint for ground based robots

- Inter Camera Person Tracking
  - Follow target objects accurately in and between cameras
  - Multiple cameras spatially separated.
  - Uncalibrated, non-overlapping
  - Links regions between camera
  - No a priori data, learns about its environment
  - Improves accuracy as data becomes available



top floor



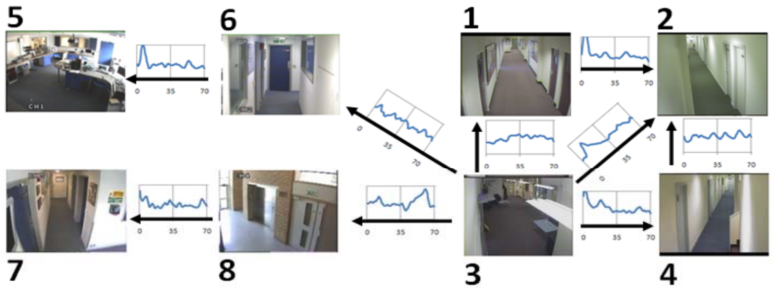
lower floor

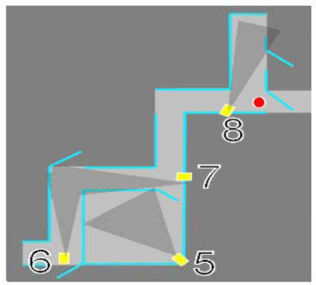
Cross Camera Tracking Approach

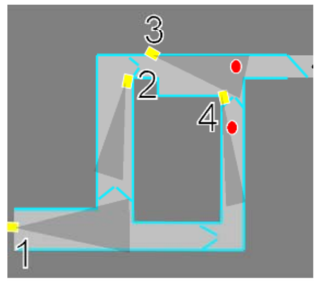
- Learns region relationships
- Weak Cues
- Colour, Shape, Temporal
- Learns consistent patterns
- Learns Entry/Exit regions
- Real Time (25fps)

Capture Video

Building Region links







[A. Gilbert, R. Bowden, 2008]

[A. Gilbert, R. Bowden, 2007]

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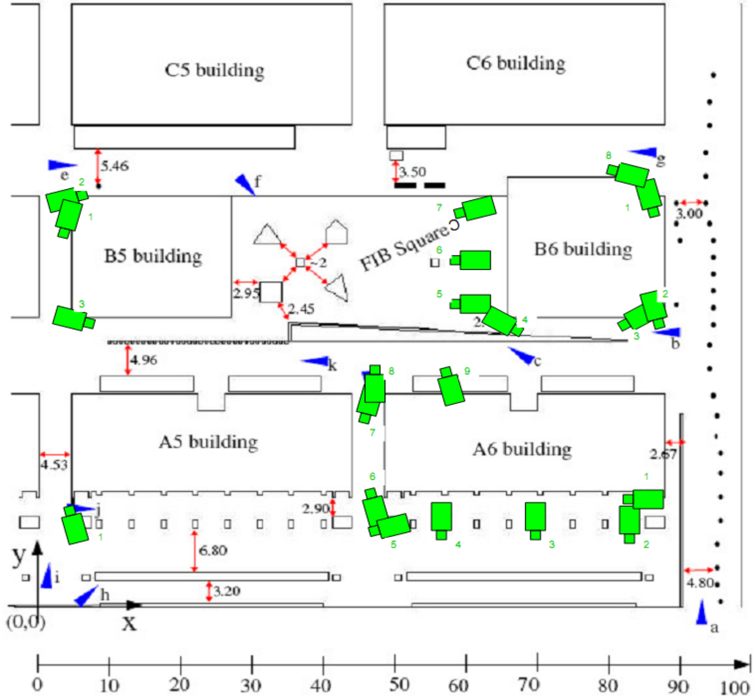
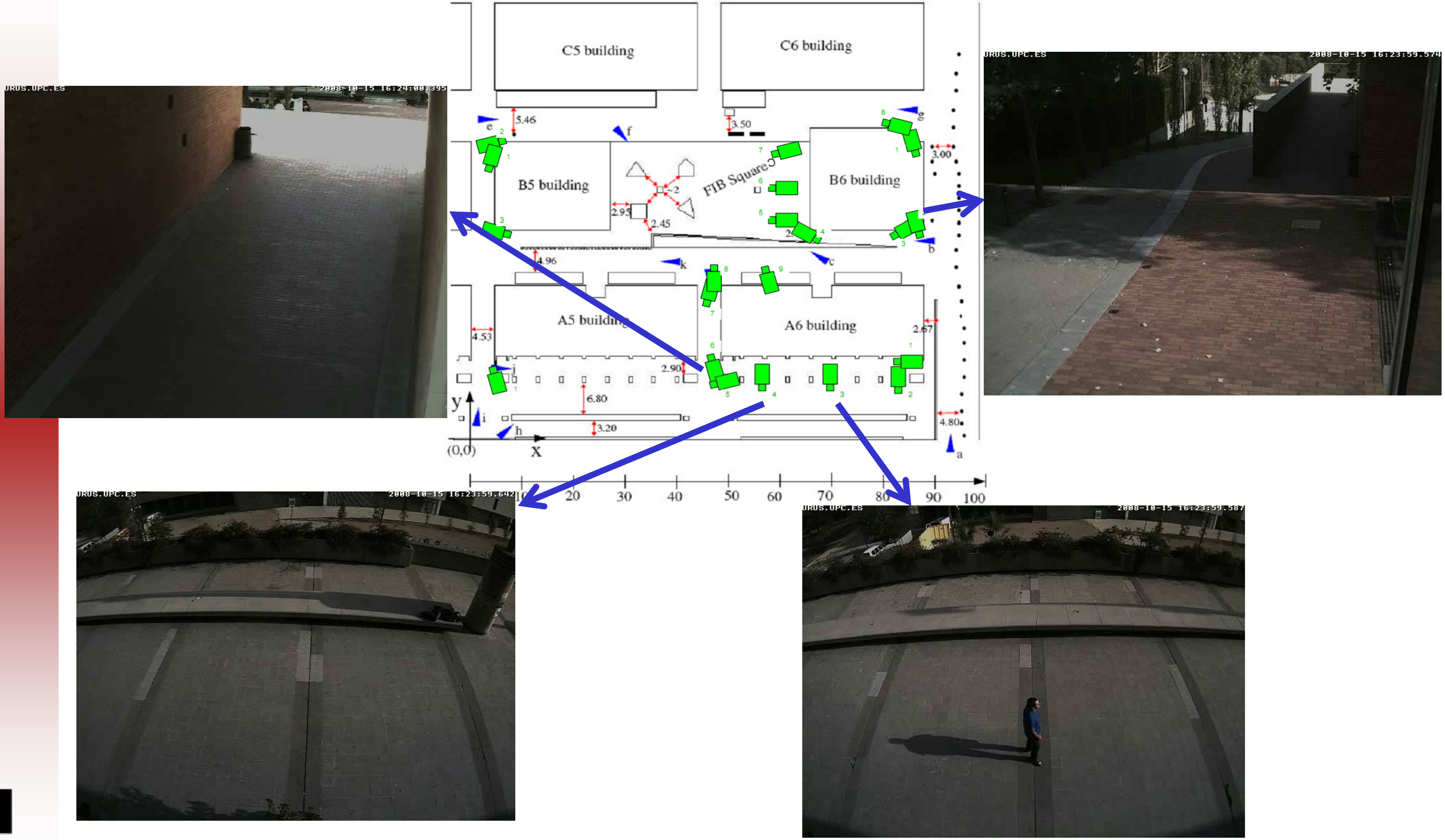
URUS Fixed Camera Network

- 21 cameras with little camera overlap
- Shadows challenging
- Delineates foreground objects from non-stationary background e.g trees



Tracking Example



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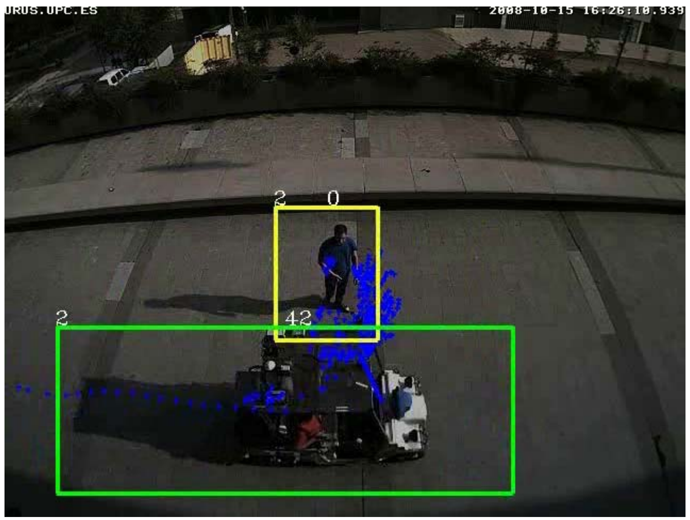
Delayed-State Information Filter for Decentralized Cooperative Tracking

- URUS UPC site
  - Camera network
  - WSN
  - Romeo
- Cooperative guiding experiment
- Simple robot tracker based on mean shift for testing purposes
- Wireless Sensor Network Data



Data Association based on Mutual Information

- Entities with quite different points of view

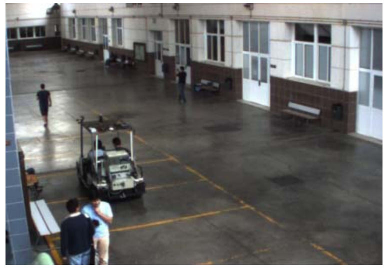
- Data association based on Mutual Information

$$I(X;Y) = \sum_{y \in Y} \sum_{x \in X} p(x,y) \log \left(\frac{p(x,y)}{p_1(x)\, p_2(y)} \right)$$

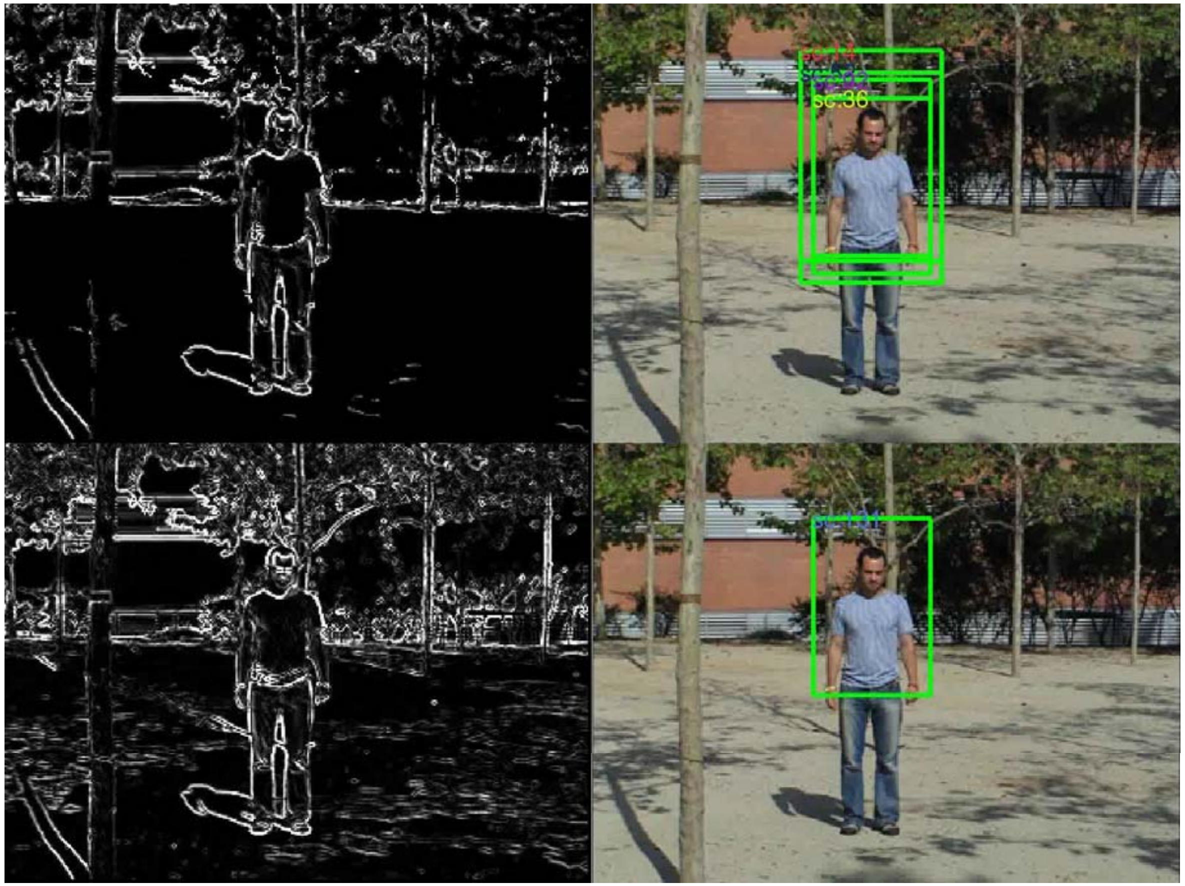
- Track objects on different cameras
  - Compute their velocities

- Match objects that maximize MI between linear velocities
  - Even under unknown coordinate transformations

- Probability distributions computed using Kernel density estimation techniques
  - Parzen windows



People Detection Under Cast Shadows



With Filter

Without Filter

[Villamizar et al., 2009]

Active Cooperative Perception (ACP)

- **Active Perception**: Choose actions for task completion as well as sensory performance.

- **Active Cooperative Perception**: also consider cooperation between robot and camera network.

- **Decision-theoretic approach.**

- **Three scenarios**:
  - Robot meets person (POMDP).
  - Dynamic camera selection (POMDP).
  - Camera-aware robot navigation (MDP).

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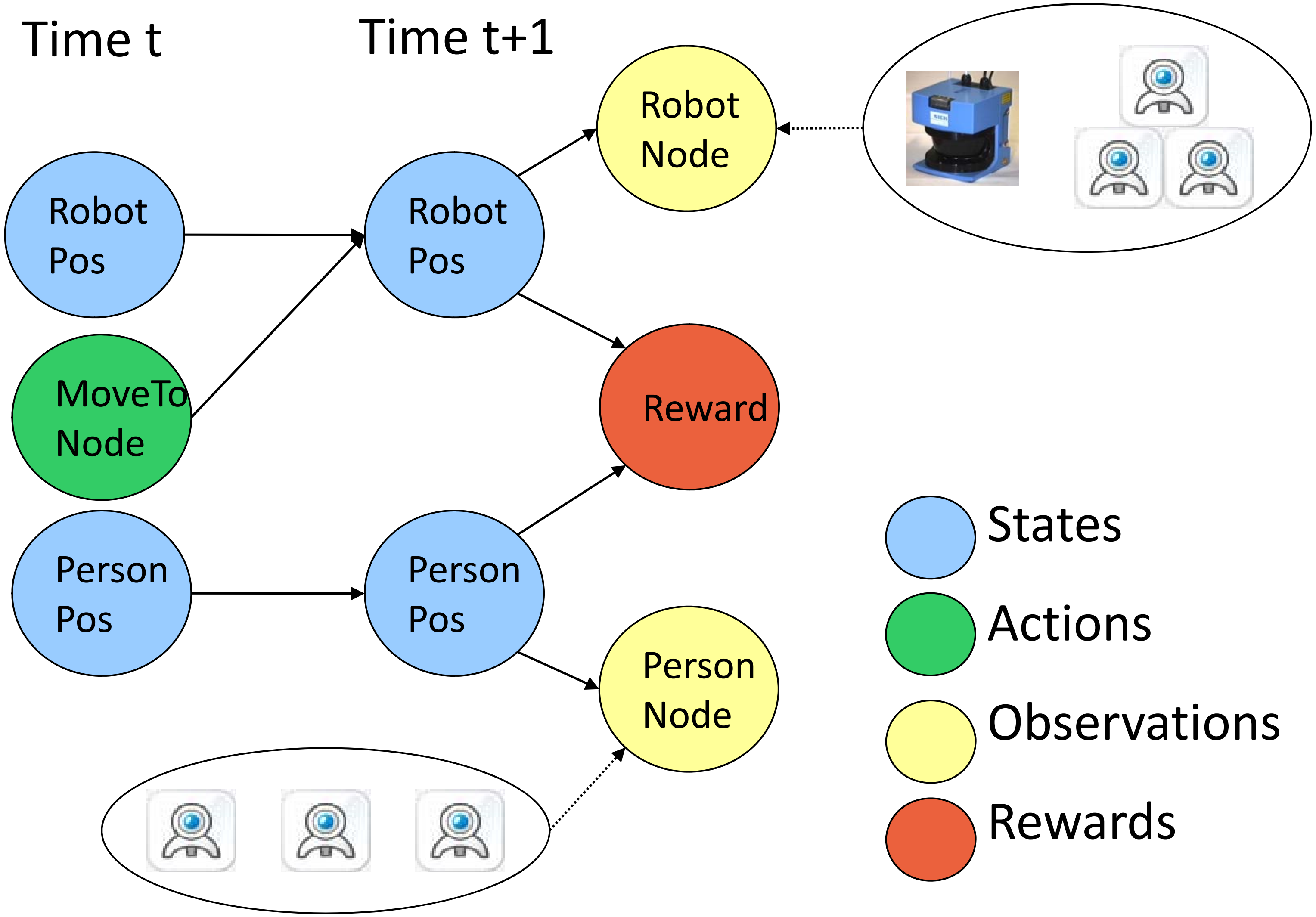
ACP: Robot Meets Person

First POMDP scenario:

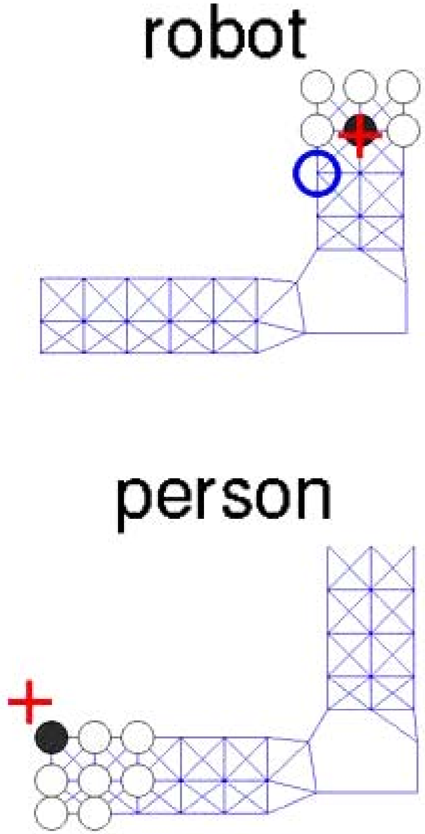
- Robot meets person entering lab.
- Robot moves on a graph (topological map).
- Actions: choose among neighboring nodes.
- Observations are provided by camera network (persolocation in the same graph).
- Goal: to be in the same node as the person.

[M. T. J. Spaan, 2008]

ACP: Robot Meets Person



ACP: Robot Meets Person

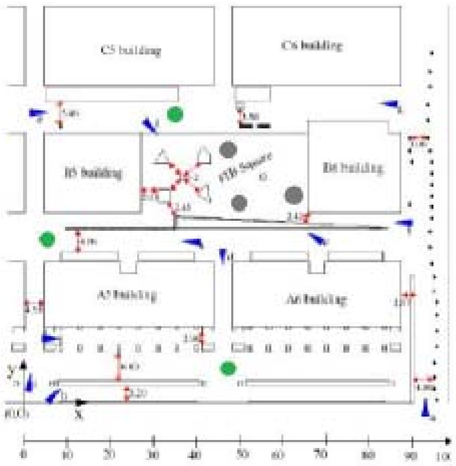


Conclusions

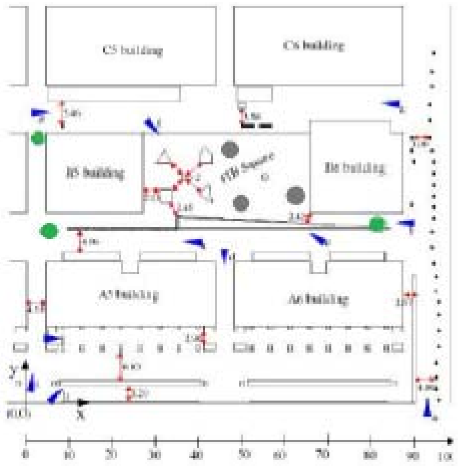
- The URUS project joints together technology of sensors, robots, communication systems and their relation with humans
- The last year of the URUS project will be devoted to experiments: guiding and transportation of people
- Cooperative environment perception is a key element in NRS, due that there have to fuse information from multiple perception systems, for example to track or identify people
- The combination of cooperative perception with robot actions is also a key element of NRS

New Experiment

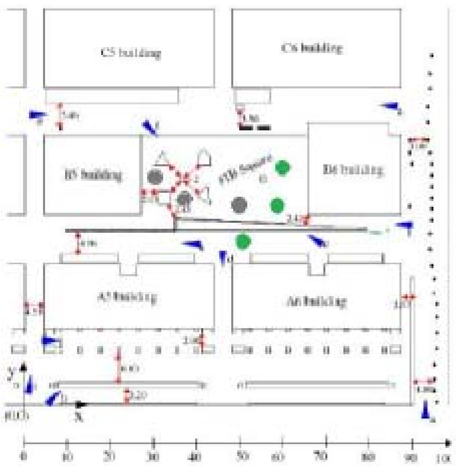
Typical behavior in the updated scenario – Closing the FIB square



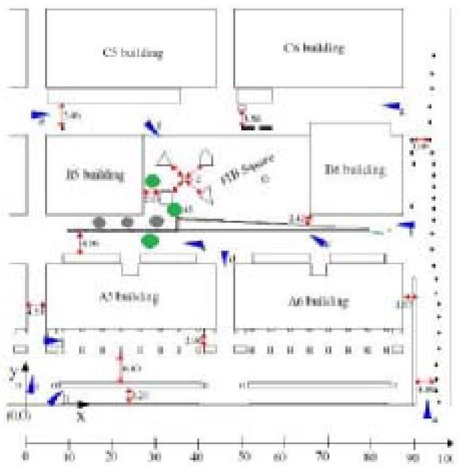
(a)



(b)



(c)



(d)

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