Self-organized multi-camera system for a fast and easy deployment of service robots in unknown environments

Doctoral Meeting iniciative (CITIUS)

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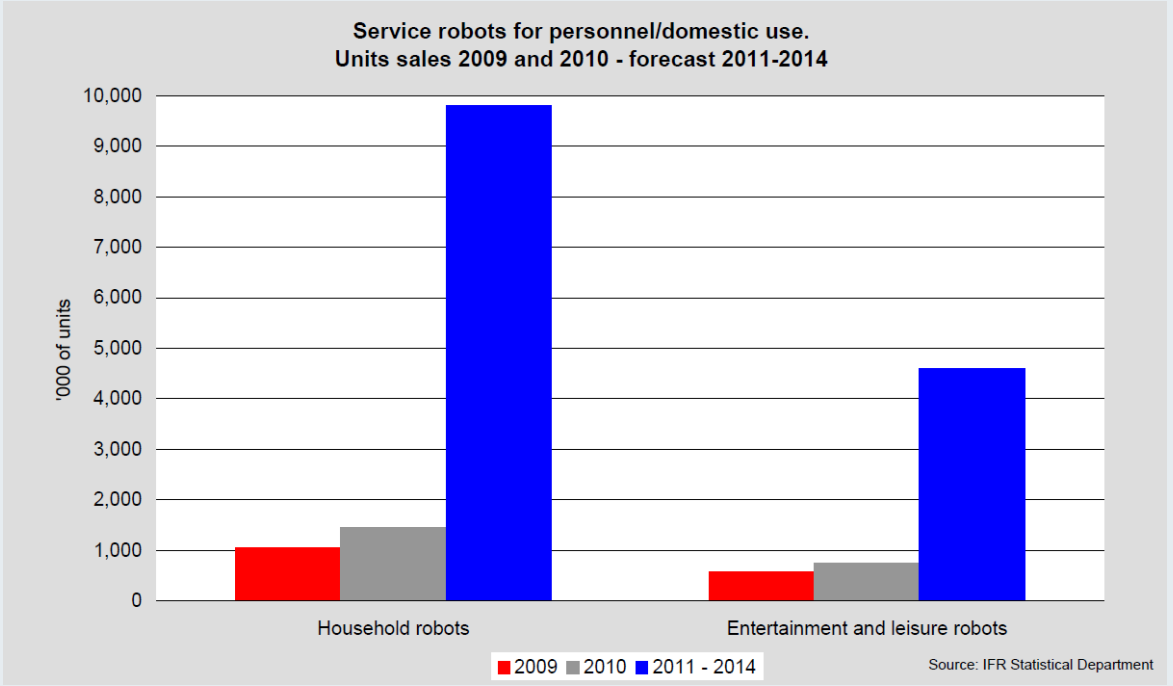
PhD supervisors: Roberto Iglesias Rodríguez and Carlos Vázquez Regueiro

Outline

Outline

Context and motivation - Interest in service robots



- Foresight: ***exponential growth*** in service robots' sales
- Increasing demand to ***take robots to social events***

Context and motivation - Problems

Many ***issues*** to be solved in robotics
We will focus on ***two of them***

Limited perception, limited action, limited initiative

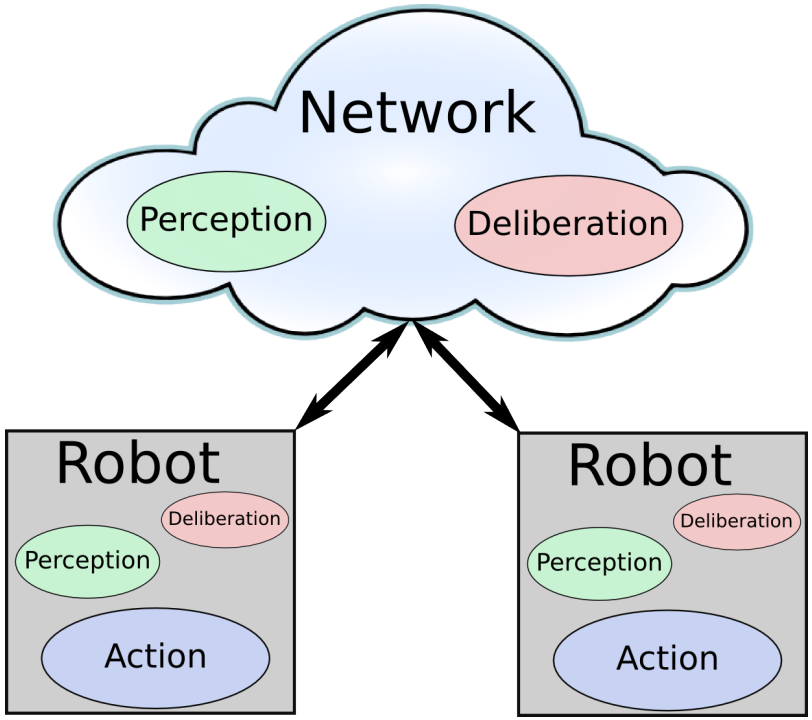
- Typically, robots carry out all the deliberation and action selection based only on their own perceptions.
  - Limits range of events to which they can respond.

Cost of deployment in new environments

- Several days of work in some cases
  - Experts need to tune hardware and software.
  - Experts need to gather and inject knowledge of the environment.

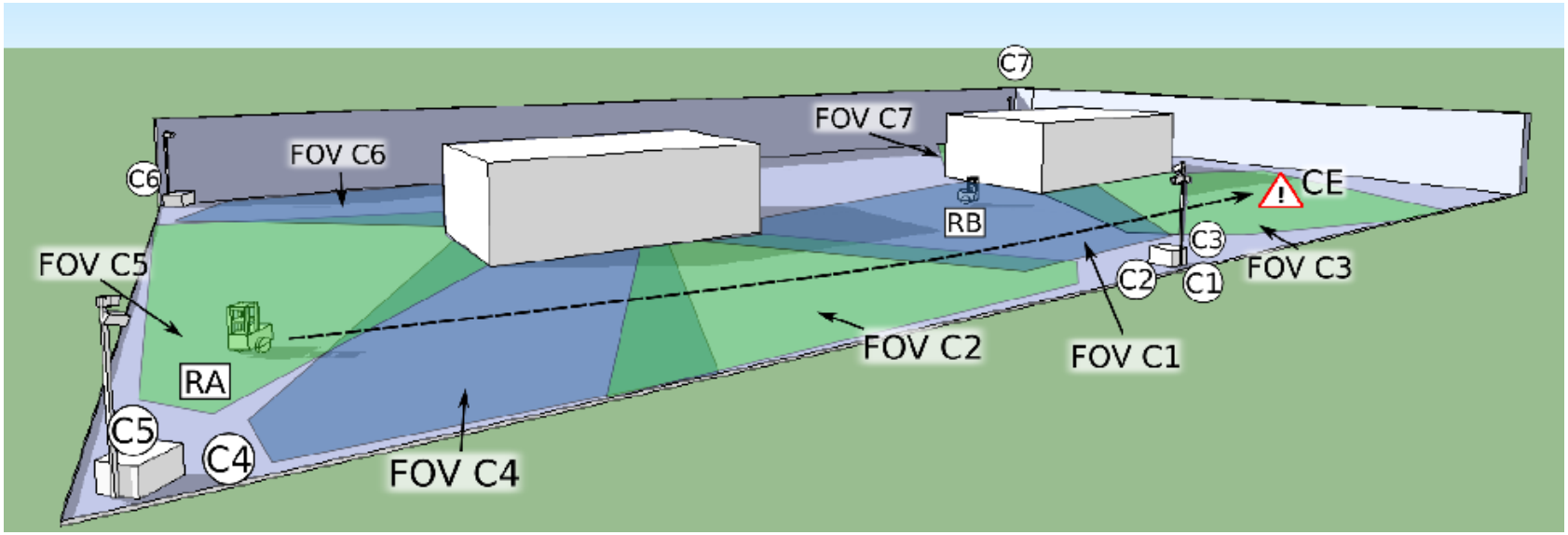
Outline

Research Hypotheses



1. It is feasible to move the deliberation and perception components to networked elements of the environment
2. This will enhance the perception and pro-activity of the robots

Objectives



- Develop an intelligent space of robots and cameras. The cameras:
  - Detect events requiring the robots' presence (Call Events).
  - Support the robot navigation even in absence of maps.
- No dependence on assumptions or knowledge of the environment.
- Robust to deal with the uncontrolled and unpredictable.
- Fast and easy to deploy.

Context: general purpose guide robot

Outline

Methodology: Task planning - Iterative development

1. First challenge. ***Field Of View overlap assumption***.
   - Hardware and software design and development of cameras and robots.
   - Robot detection from cameras.
   - Naive neighbourhood and call event detection.
2. Second challenge. ***Remove FOV overlap assumption and increase robustness***.
   - Increase number of sources of information.
   - Increase robots' intelligence.
3. Third challenge. ***Integration with tour-guide robot***
   - Call event detection: gesture recognition, person detection, group detection.
   - Neighbourhood detection: analysis of people's movement.
   - Final product: development of a tour-guide robot demonstrator (in collab. with **Victor Alvarez**).

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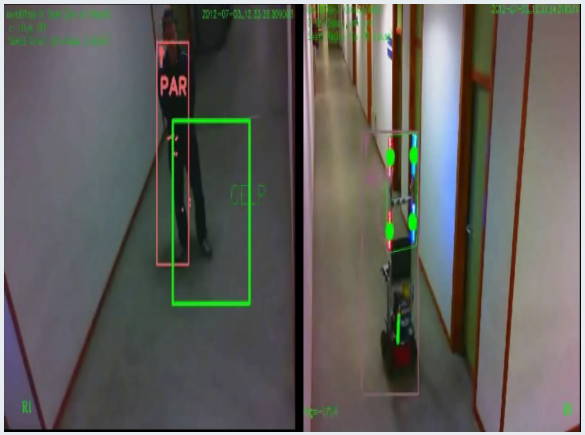
Methodology: Methods & tools - Computer Vision

Robot detection

Person detection

Group detection

Zone detection



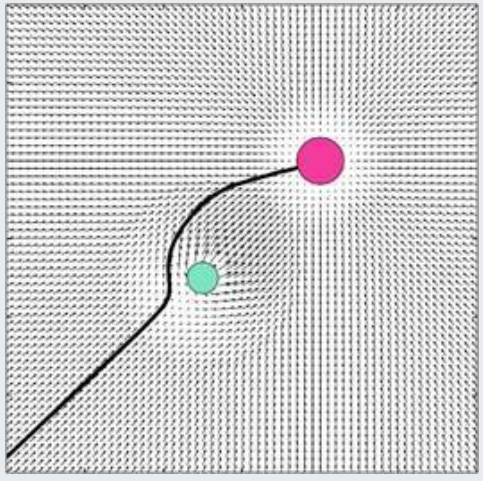
Gesture detection

Others

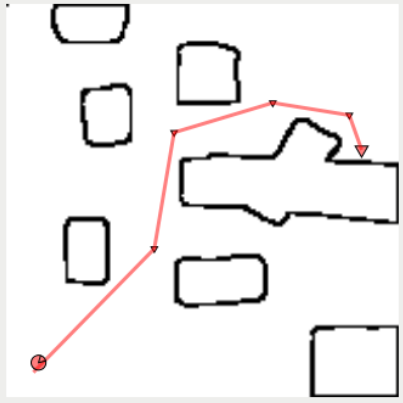
- Robot pose estimation
- Trajectory analysis
- Person re-identification
- ...

Methodology: Methods & tools - Robotics

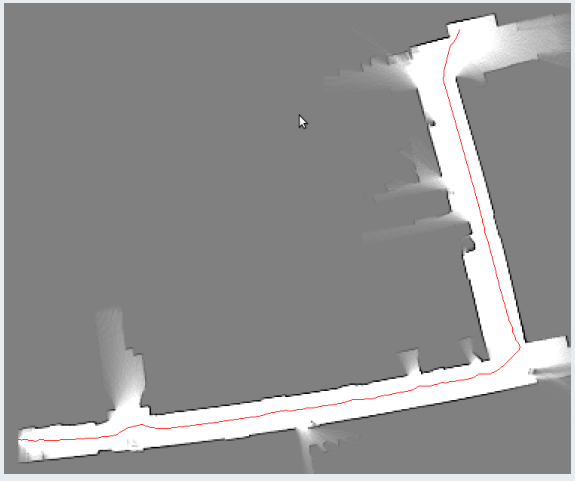
Navigation



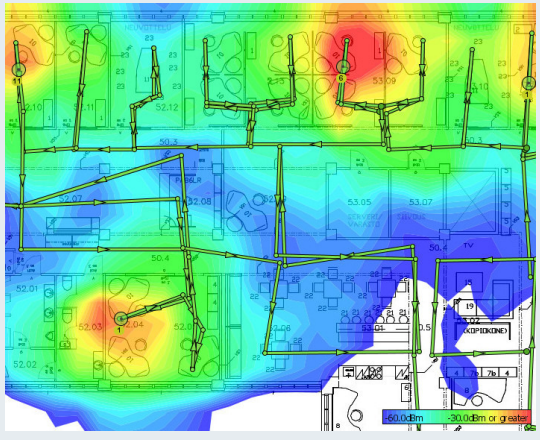
Path planning



SLAM



WIFI localization



Others

- Sensor Fusion
- Learning ...

Methodology: Validation

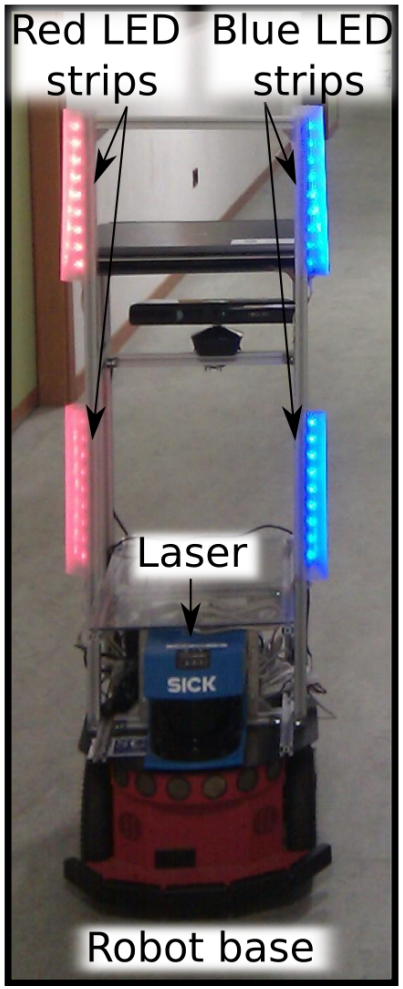
1. Qualitative validation $\rightarrow$ iterative prototype evolution
   - Daily use of the system.
   - Visual inspection of robot behaviours.
   - Feedback from real-world events: ETSE, DOMUS, IES Rosalia de Castro.
2. Quantitative validation: statistical data analysis.
   - Computer Vision algorithms.
   - Robot behaviours.

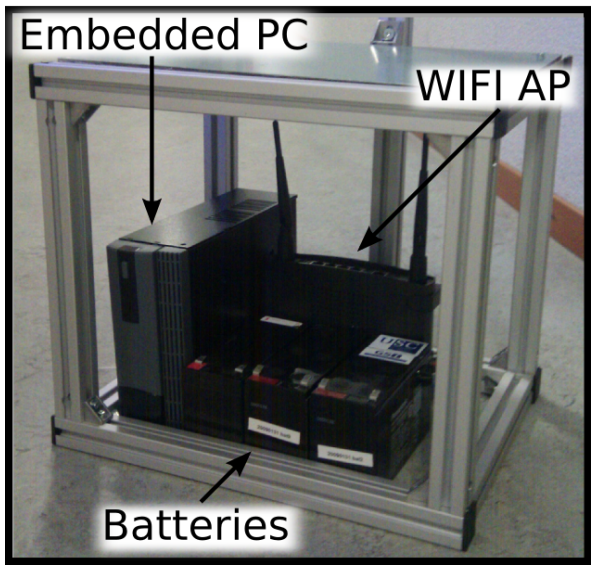
Outline

1st CHALLENGE

Construction of physical agents
Design & implementation of controllers: coordination protocol.
Computer Vision: robot detection.

Physical agents





Robots

- Pioneer 3DX.
- Active marker.
- Laser
- Sonar

Cameras

- USB cameras.
- Processing unit: laptop or embedded PC.
- WIFI communication.
- Batteries.

Camera and robot controllers

Camera

- Detect robot
- Establish neighbourhood relationships from visual info
- Detect events requiring the presence of robots (e.g. gesture detection)
- Route planning
- Support robot navigation

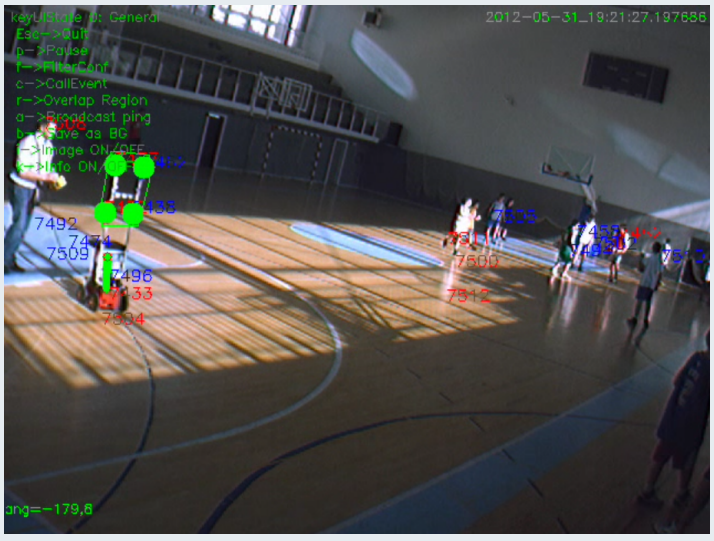
Robot

- Navigate safely

Design: distributed and self-organized

- ***Robust and scalable***

Robot detection and pose estimation



Rejected alternatives: passive markers, IR markers, object detection techniques

Algorithm designed for robot control

- Robust
- Multi-robot
- Fast

Active marker detection

1. Blob detection (colour)
2. Blob tracking (Kalman Filter)
3. Probabilistic pattern matching
4. Pose estimation

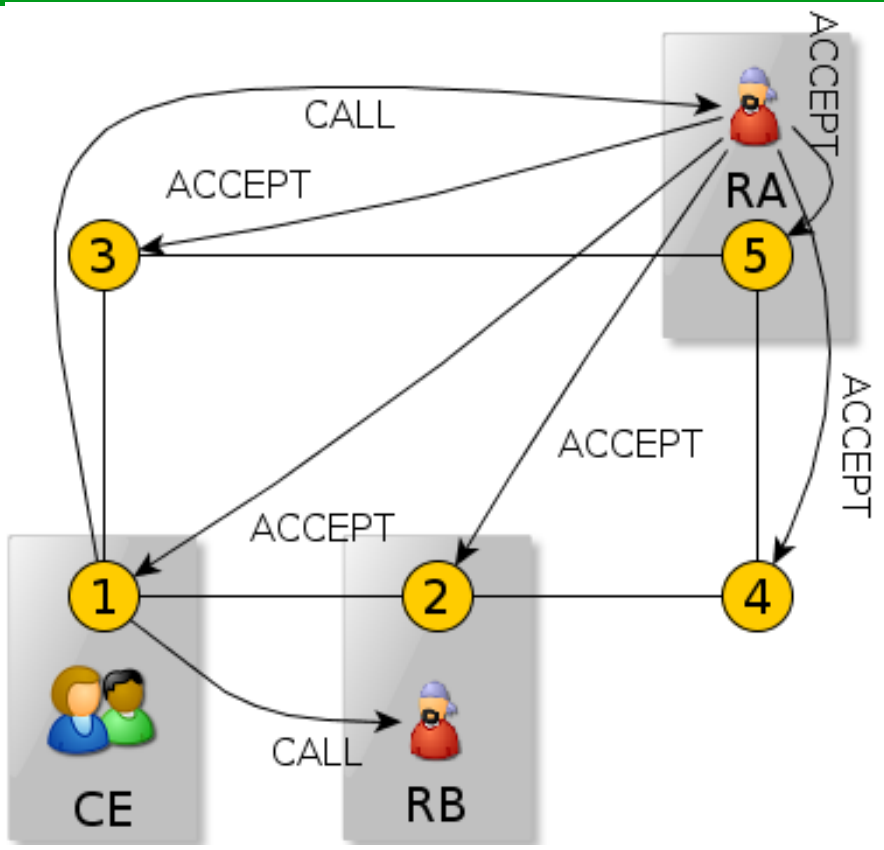
Neighbourhood detection

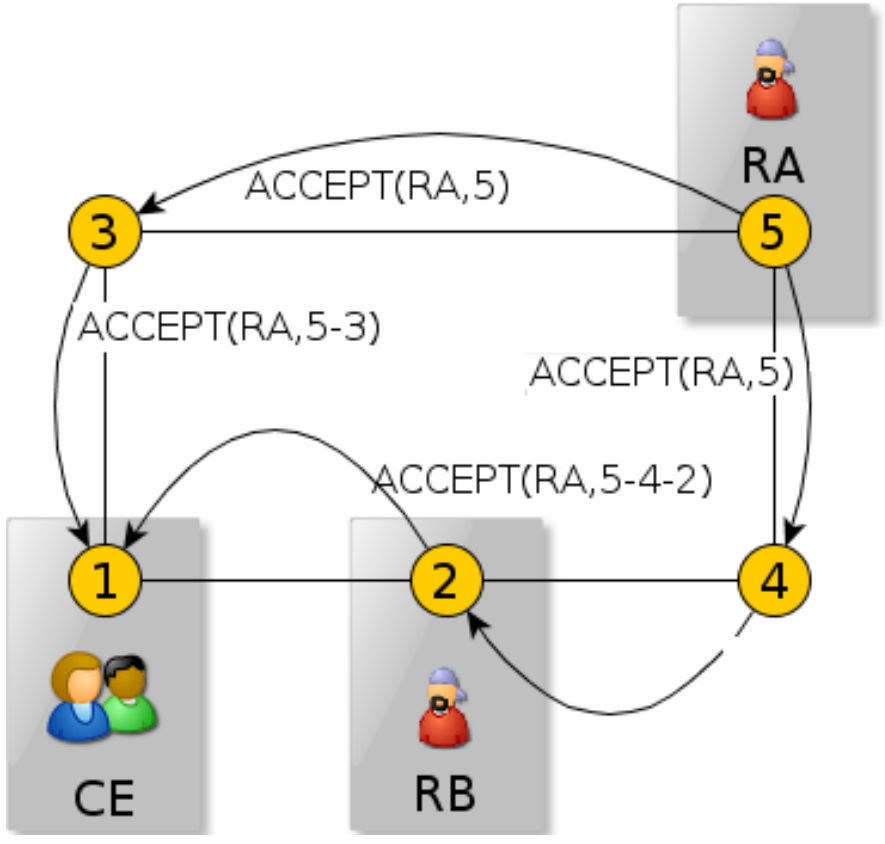
Simultaneous robot detections $\longrightarrow \uparrow$ neighbourhood probability

Isolated robot detections $\longrightarrow \downarrow$ neighbourhood probability

Field of View overlap assumption

Route planning

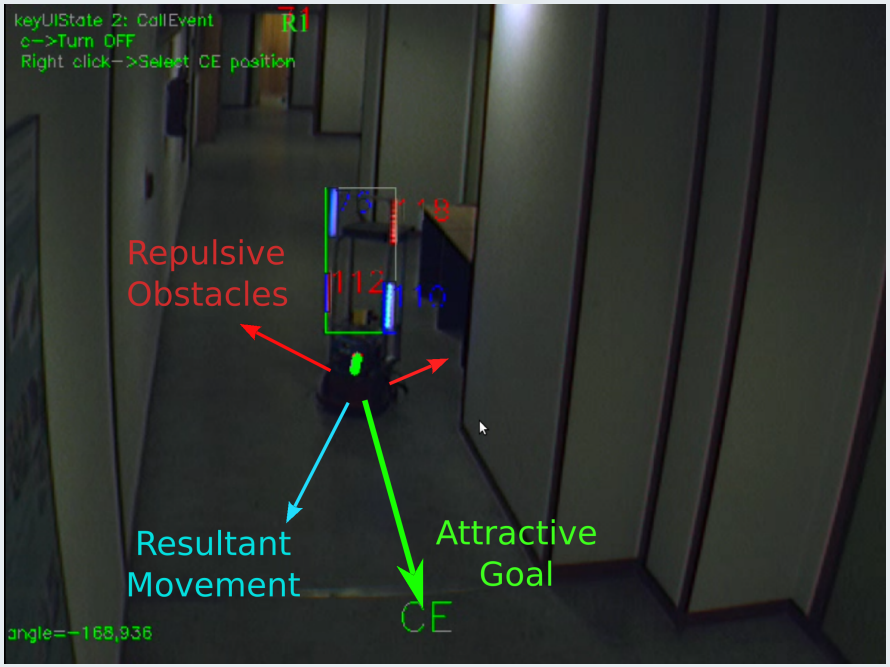


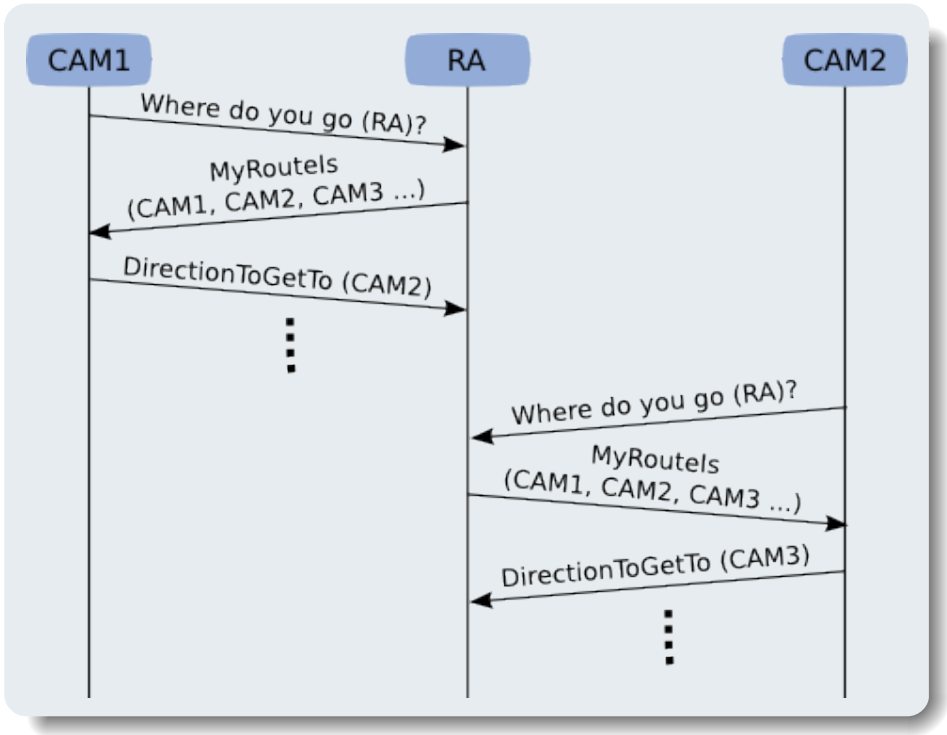


1. Flooding-based
2. Agents do not share neighbouring knowledge → ***independence***
3. No central planner, distributed, ***scalable***

Robot navigation

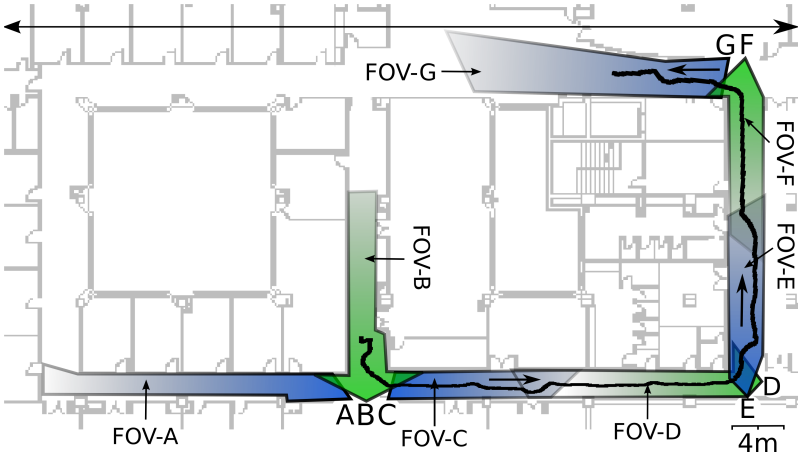
Potential Fields Navigation

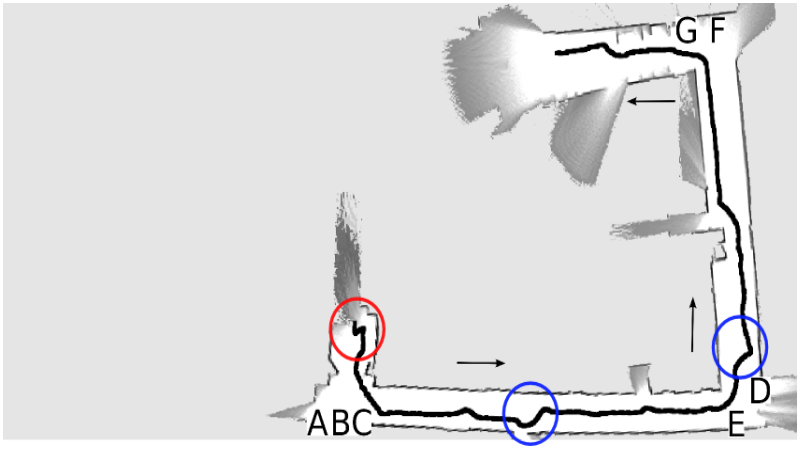


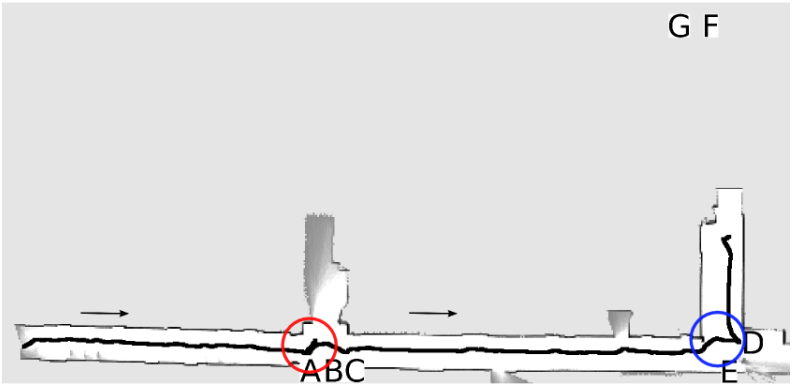


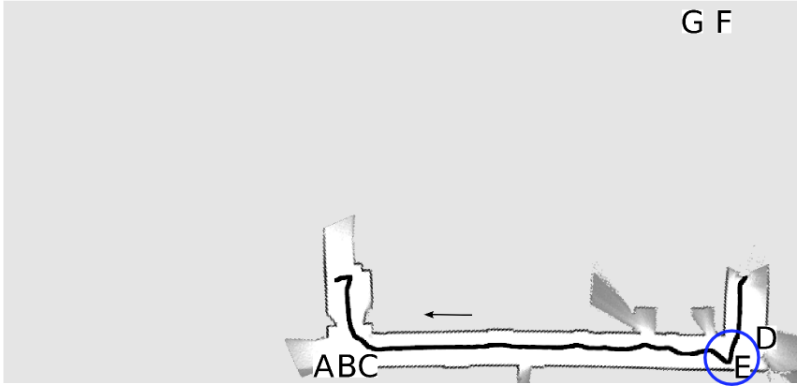
Each camera directs the robot towards the next camera on the route

Robot navigation results - Trajectories









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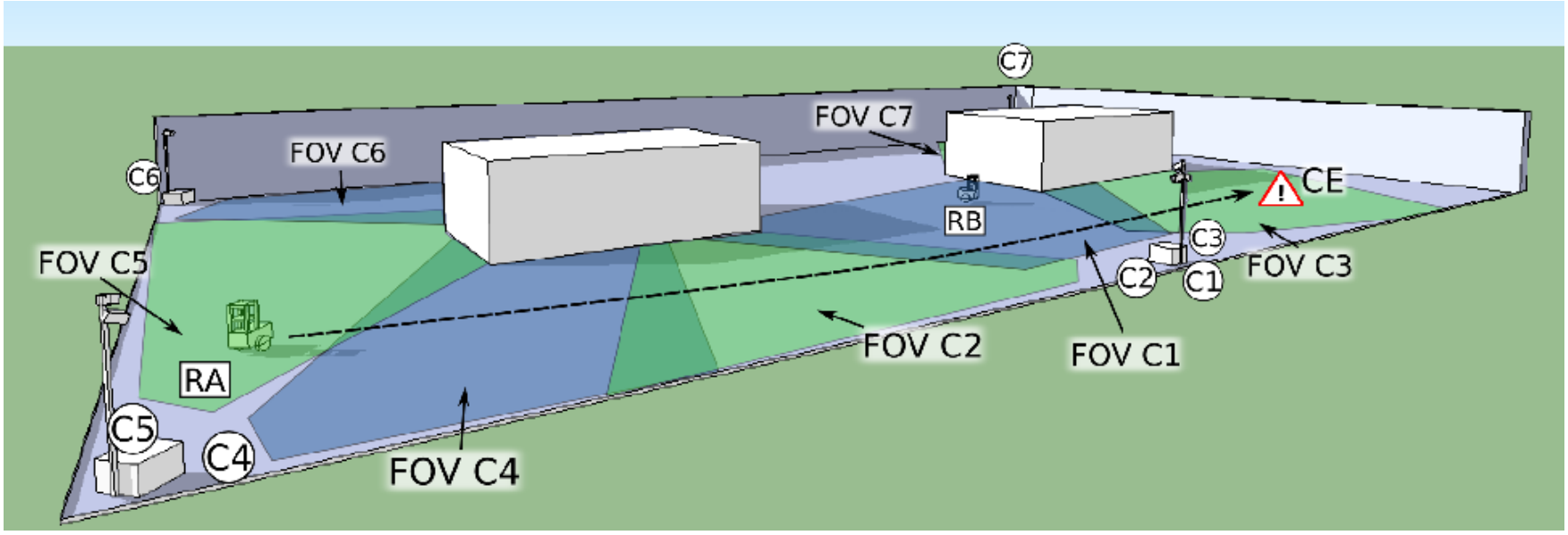
Robot navigation results - Video

2nd CHALLENGE

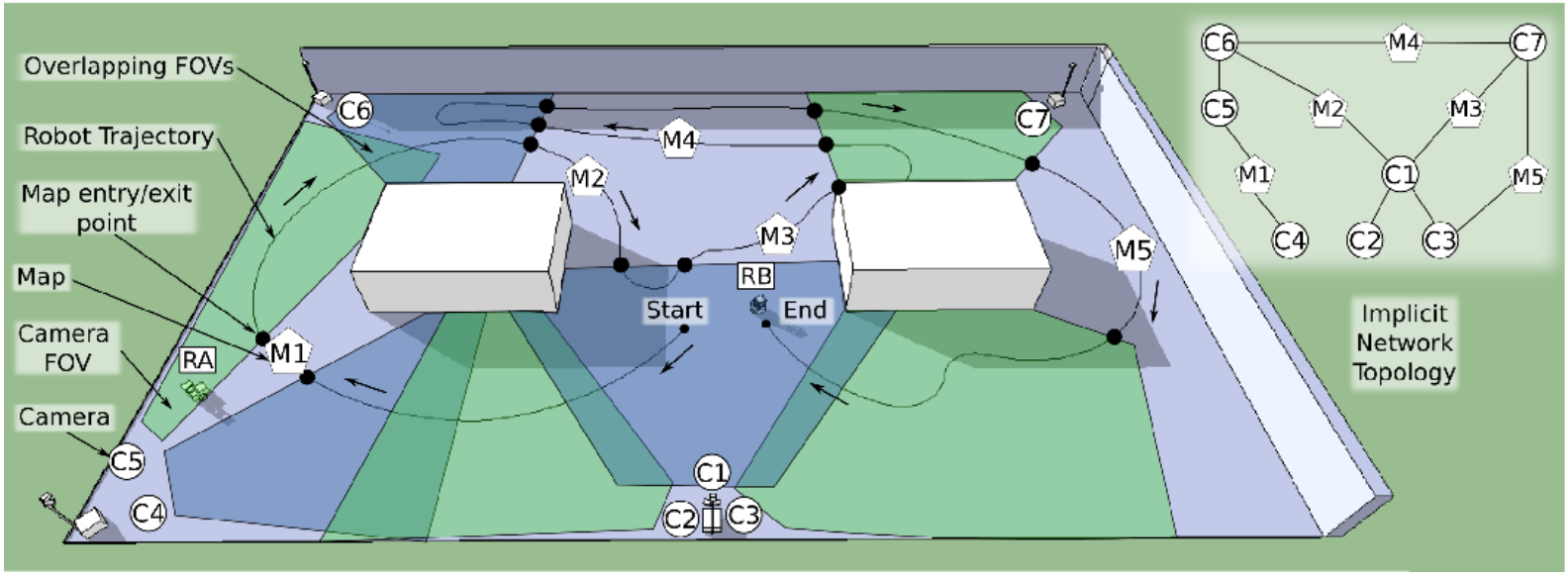
Remove FOV overlap assumption, increase robustness

Problems from 1st challenge



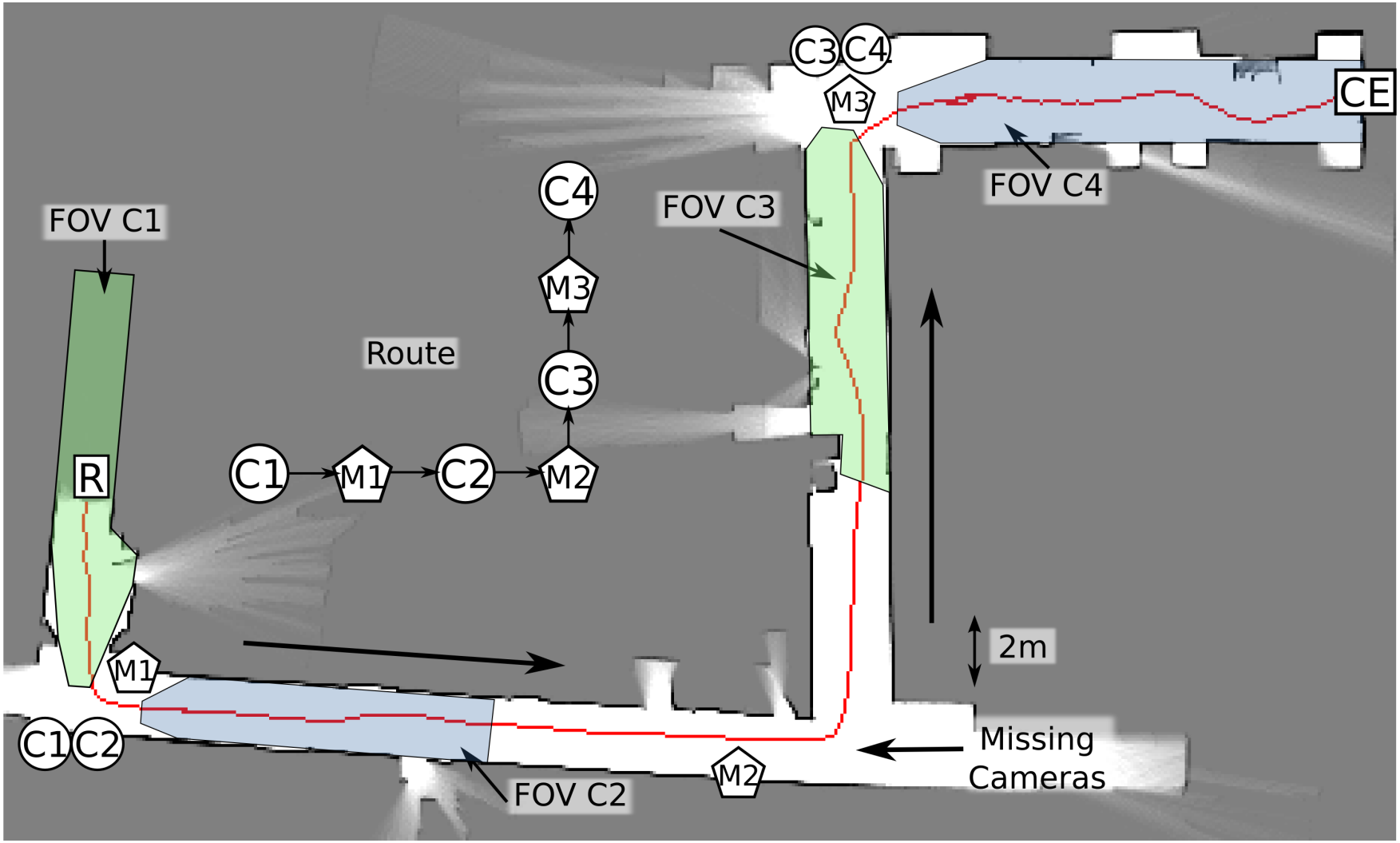
1. FOV overlap needed → ***navigation in non-covered areas?***
2. Robot navigation relies almost exclusively on the camera information → ***Non robust!***

1st approach - Fill the gaps



- Divide and conquer: automatic construction of behaviours to cross non-covered areas.
  - Maps
  - Movement direction
  - Sets of checkpoints
  - ...
- ***Poorer environmental perception***

1st approach - Results



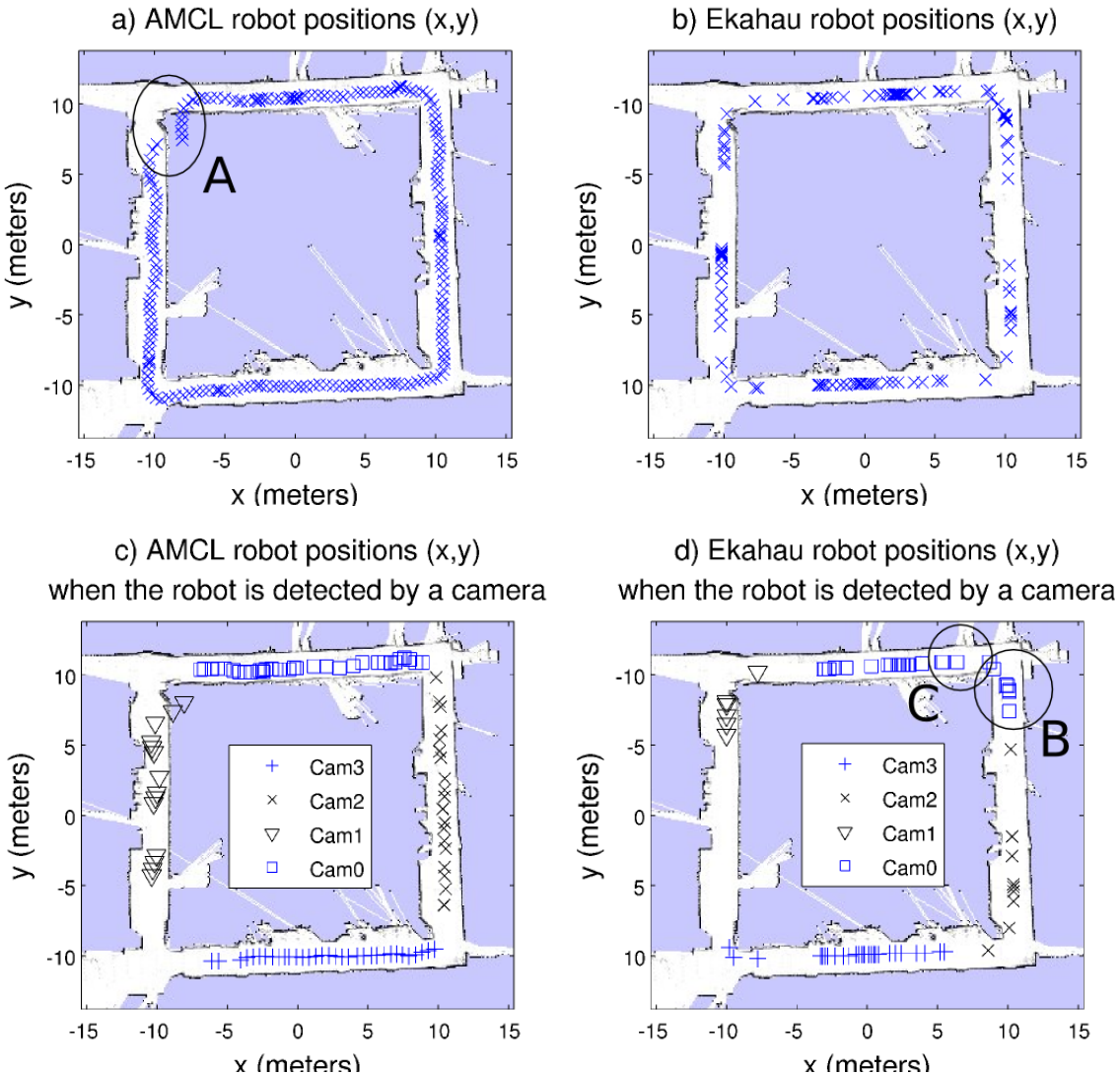
2nd approach - Multiple information sources

Use complementary and redundant information sources:

- Cameras: position and orientation.
- Map-based Probabilistic Localization: position and orientation.
- WIFI Localization System: position.
- Electronic compass: orientation.

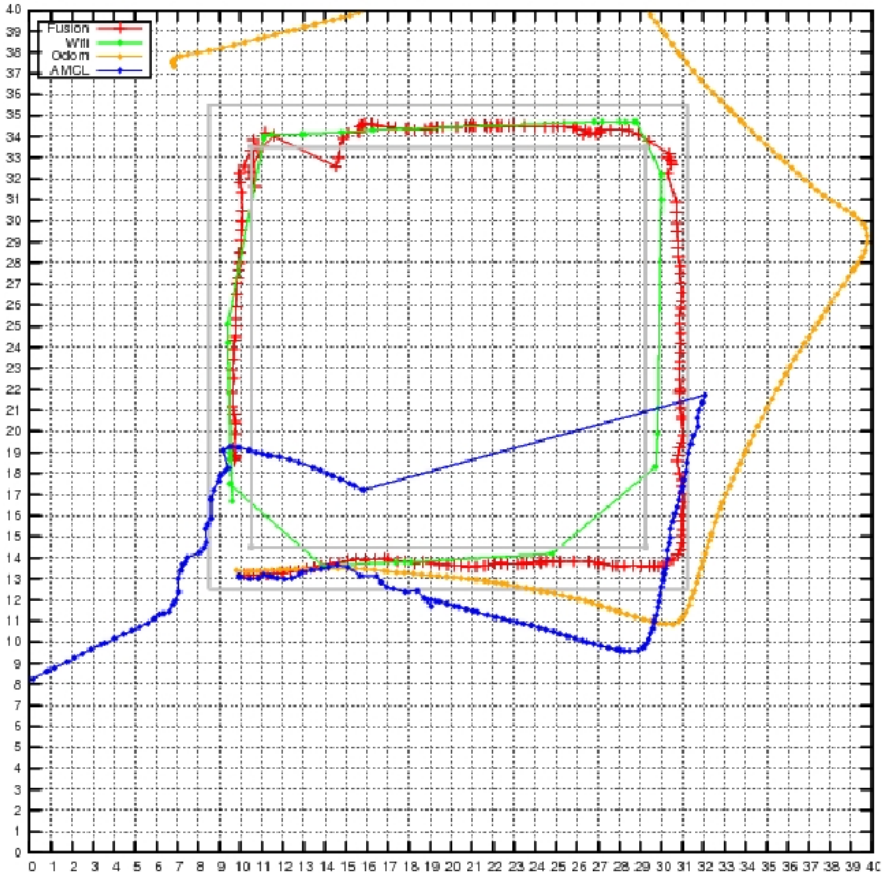
	Camera	WIFI	Map	All together
Oclussions (e.g. people moving around)	FAIL	OK	FAIL	OK
Robot out of FOV	FAIL	OK	OK	OK
Challenging illumination	FAIL	OK	OK	OK
Communication Failure	FAIL	FAIL	OK	OK
Electro-magnetical Interferences	OK	FAIL	OK	OK

2nd approach - Information sources validation



- Map-based localization: ***high data rate***, ***accurate***, ***needs initial estimation***.
- WIFI localization: ***low data rate***, ***non-stable periodicity***, ***low precission***, ***trustworthy rough estimate***.
- Compass: ***drift***, ***trustworthy rough estimate***.

2nd approach - Information sources fusion



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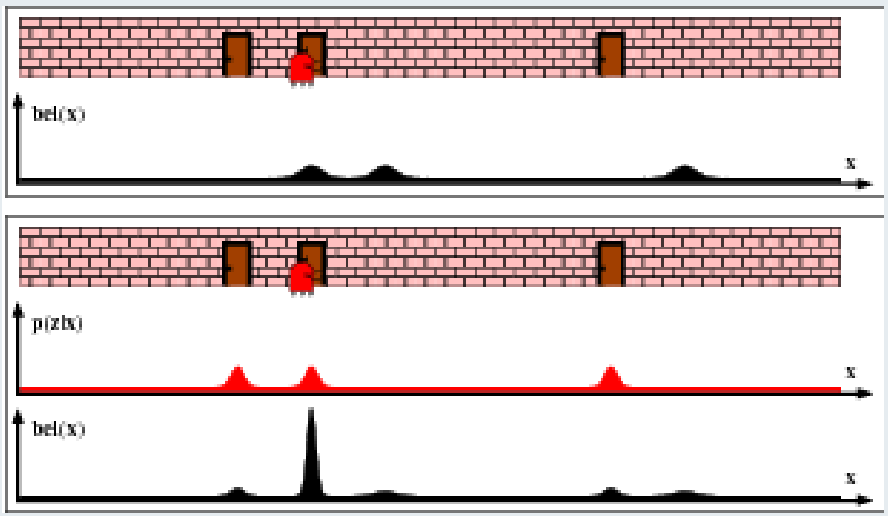
Bayesian Inference

$$P(x|obs) \propto P(obs|x)P(x)$$

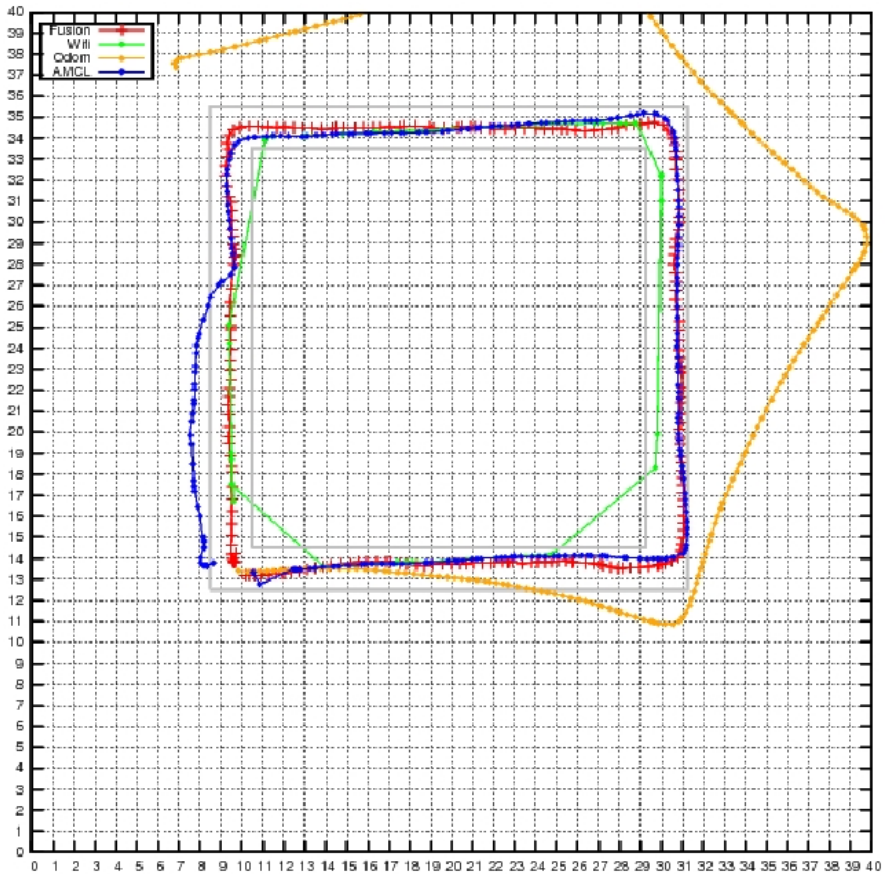


Particle-Filter (Monte-Carlo)

$$Particle_k = \{x_k, w_k\}$$
$$w_k = \sum_{sensors} \alpha_s P(obs_s|x_k)$$
$$x = \sum_{particles} w_k x_k$$

In collaboration with David Santos, Cristina Gamallo, Victor Alvarez

2nd approach - Information sources fusion



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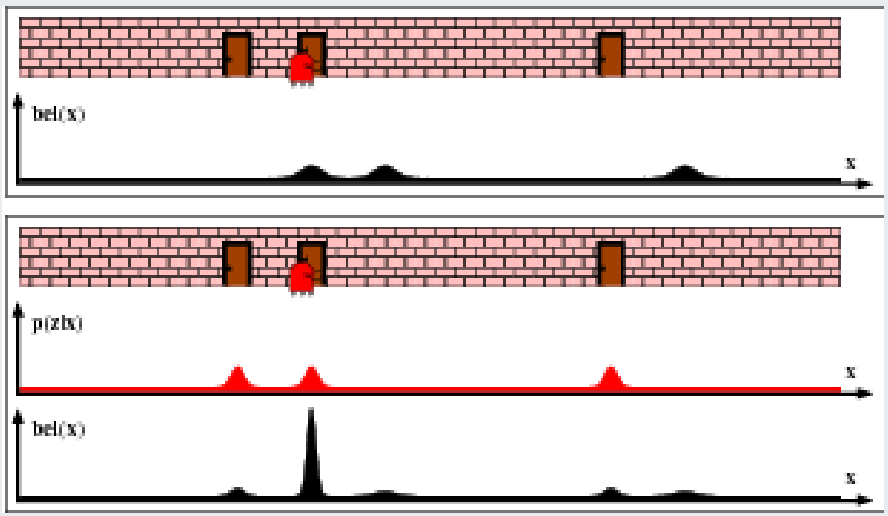

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3rd CHALLENGE

Current and future work

Current and future work

1. Call event detection: detection of gestures and groups of persons.
2. Neighbourhood detection: person re-identification, people trajectory analysis.
3. Integration with tour-guide robot (collab. Victor Alvarez).

Outline

Collaborations

CITIUS

Graduate students

- Victor Alvarez
- David Santos
- Cristina Gamallo
- Jose M. Abuin
- Ignacio Cabado

Lecturer

- Xose Manuel Pardo
- Eva Cernadas

Intelligent Systems Research Center - U. of Ulster (N. Ireland)

- Kevin Curran
- Eoghan Barr

Outline

Publications

JCR Journals

1. A. Canedo-Rodriguez, R. Iglesias, C. V. Regueiro, V. Alvarez-Santos, X. M. Pardo, "Self-organized multi-camera network for a fast and easy deployment of ubiquitous robots in unknown environments", **Under review in Sensors**.
2. Adrian Canedo-Rodriguez, Carlos V. Regueiro, Roberto Iglesias, V. Alvarez-Santos and Xose Manuel Pardo, "Self-organized multi-camera network for ubiquitous robot deployment in unknown environments". **Robotics and Autonomous Systems**, 2012.
3. V. Alvarez-Santos , R. Iglesias , X.M. Pardo , C. V. Regueiro, A. Canedo-Rodriguez, "Gesture based interaction with voice feedback for a guide robot", **Journal of Visual Communication and Image Representation**.
4. V. Alvarez-Santos, X.M. Pardo, R. Iglesias, A. Canedo-Rodriguez and C.V. Regueiro, "Feature analysis for human recognition and discrimination: Application to a person-following behaviour in a mobile robot". **Robotics and Autonomous Systems**.

Journals with other quality indicators

1. Canedo-Rodriguez, A.; Alvarez-Santos, V.; Regueiro, C.V.; Pardo, X.M. and Iglesias, R., "Multi-agent system for fast deployment of a guide robot in unknown environments". Special Issue on Advances on Physical Agents. **Journal of Physical Agents**.

Publications

Conferences

1. Adrian Canedo-Rodriguez, David Santos-Saavedra, V. Alvarez-Santos, Carlos V. Regueiro, Roberto Iglesias and Xose Manuel Pardo, "Analysis of different localization systems suitable for a fast and easy deployment of robots in diverse environments". **WAF2012**.
2. Canedo-Rodriguez, A.; Alvarez-Santos, V.; Regueiro, C.V.; Pardo, X.M. and Iglesias, R., "Multi-agent system for fast deployment of a guide robot in unknown environments". **WAF2011**.
3. A. Canedo-Rodriguez, Roberto Iglesias, Carlos V. Regueiro, V. Alvarez-Santos, X. M. Pardo, "Self-organized Multi-agent System for Robot Deployment in Unknown Environments", **IWINAC 2011**.
4. V. Alvarez-Santos, Roberto Iglesias, Xose Manuel Pardo, Carlos V. Regueiro, Adrian Canedo-Rodriguez, "Gesture based interface with voice feedback for a guide robot". **WAF2012**.
5. V. Alvarez-Santos, X. M. Pardo, R. Iglesias, A. Canedo-Rodriguez, C. V. Regueiro, "Online Feature Weighting for Human Discrimination in a Person Following Robot", **IWINAC 2011**.

Thank you very much!!