Mobility Assistance and Human Aware Navigation

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Motivation and Problem

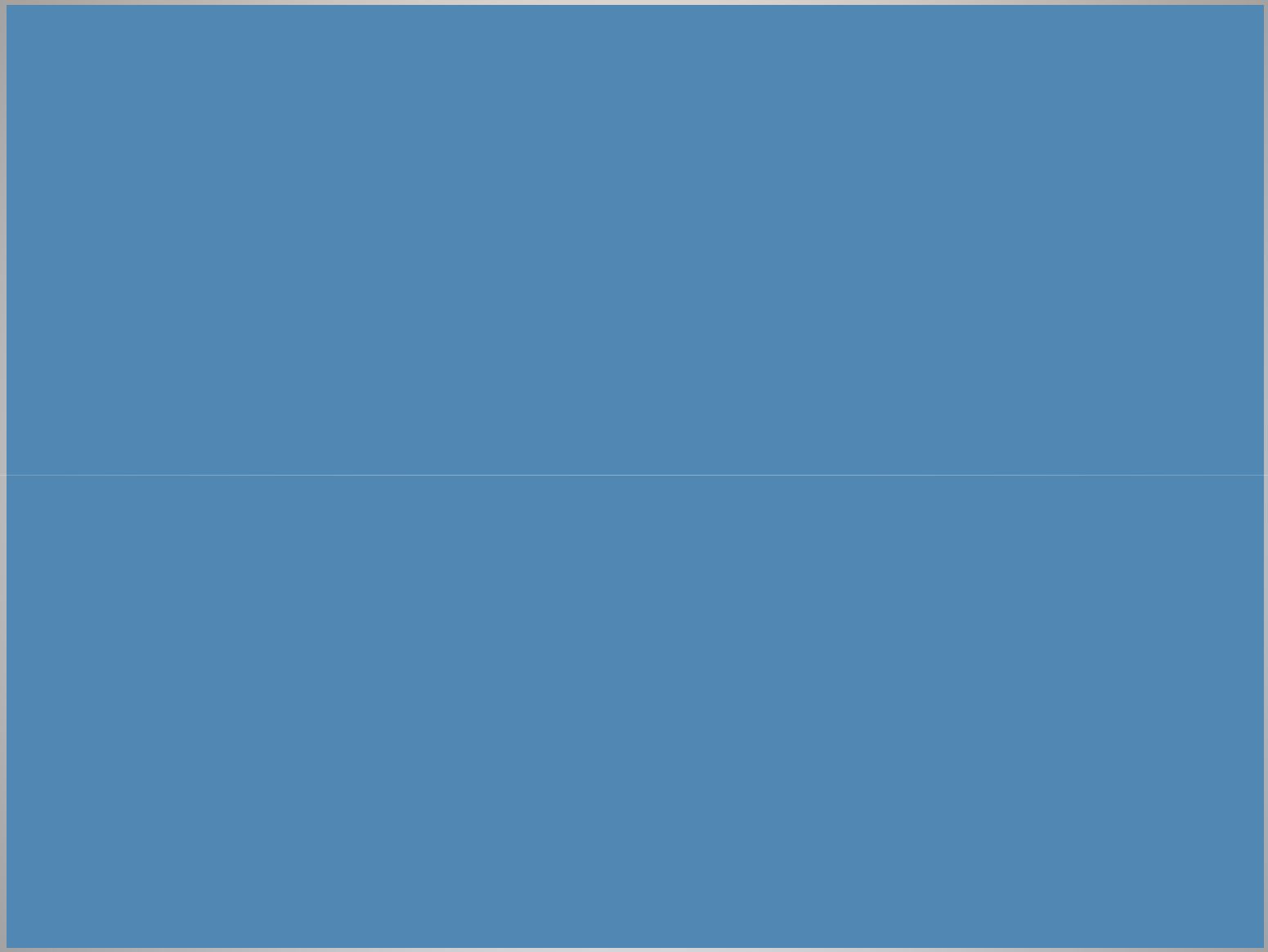
- Transport for people with reduced mobility using a robotic transportation system adapted to dynamic and human populated environments

- Navigation must take into account :
  - Partial and uncertain knowledge of the environment ;
  - Prediction of agents' behavior ;
  - Comfort and safety ;
  - Social conventions.

Social Robotics

- How humans and robots can better **live**, **work and interact** together
- Main issues:
  - Human **perception**
  - Human **behavior modeling**
  - **Task and action planning in the presence of humans**
  - **Design of socially acceptable human-robot interfaces**
- Methods from robotics may be combined with models from **social psychology and cognitive sciences**

Classical vs Human-aware navigation



Path planning in the presence of humans

- Planning in dynamic environments
  - Partially known environments, uncertainty
  - Need of prediction
- Planning in human populated environments
  - Safety
  - Proxemics
  - Sociality

Use prediction to anticipate
Use proxemics to do not disturb

Outline

- Environment modelling
  - Proxemics: social models and robotic models
  - Prediction of obstacle behaviors
- Human aware navigation
  - Combining social conventions, prediction and planning
  - Leader following.

1. Robots must respect social zones

Proxemics: Social and Robotic models

Proxemics: human management of space

- Concepts taken from the area of social sciences
- Consider the psychological comfort
- Resulting from factors like
  - Distance
  - Orientation
  - Focus of attention

Proxemics: human management of space

Personal Space

[Hall,1966] [Hayduk,1981]

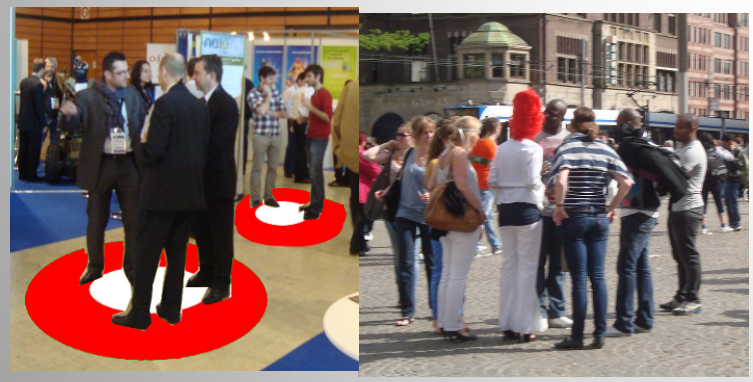
Information process Space

[Kitazawa and Fujiyama, 2010]

Activity Space

[Lindner,2011]

Interaction Space



[Kendon,2010]

Affordance Space

Human management of space

- Personal Space [3]

Zone around the human body that people feel is “their space”. In that zone others cannot intrude without arousing discomfort.

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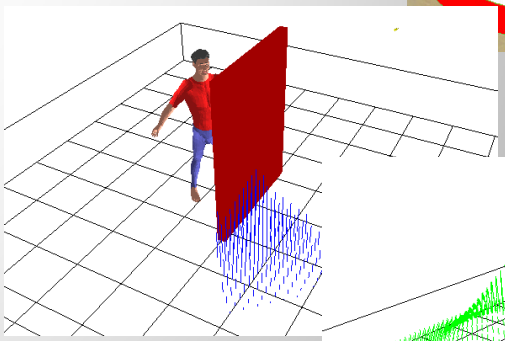
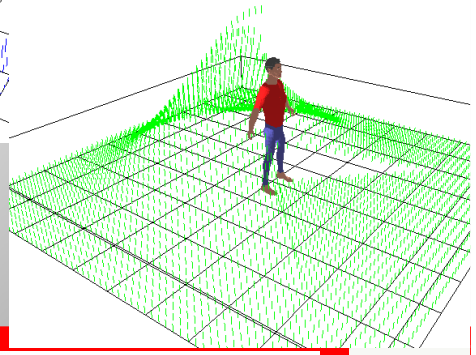
- **Visibility and Hidden Zone spaces**

Zones around a person that he/she can not see

Entering into these spaces causes discomfort to people

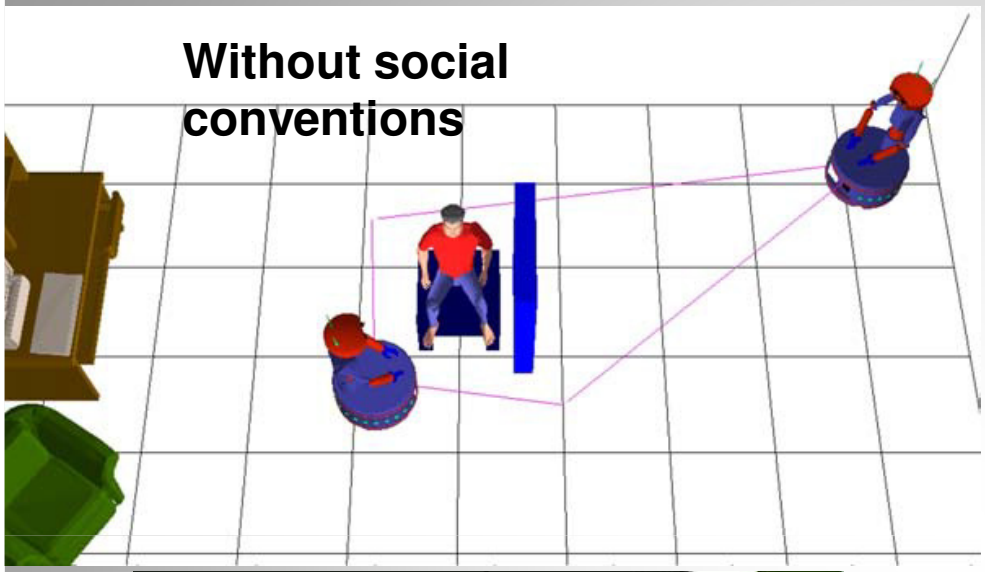


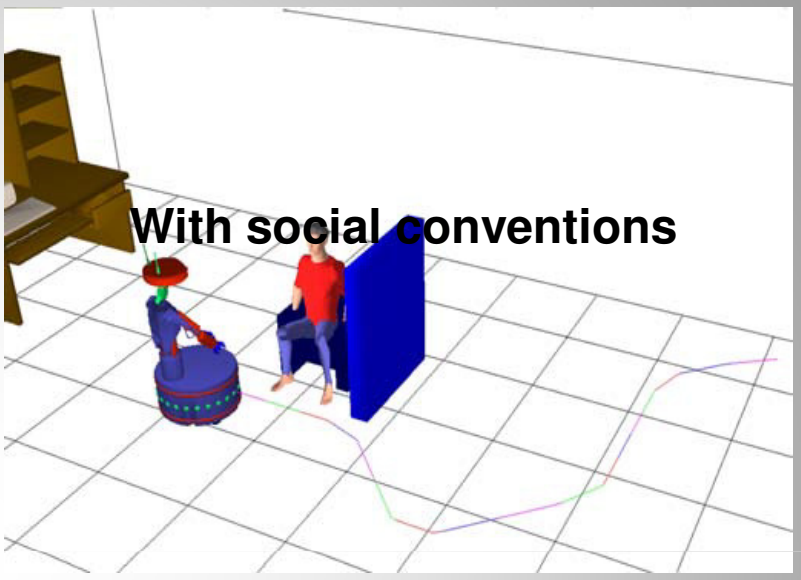


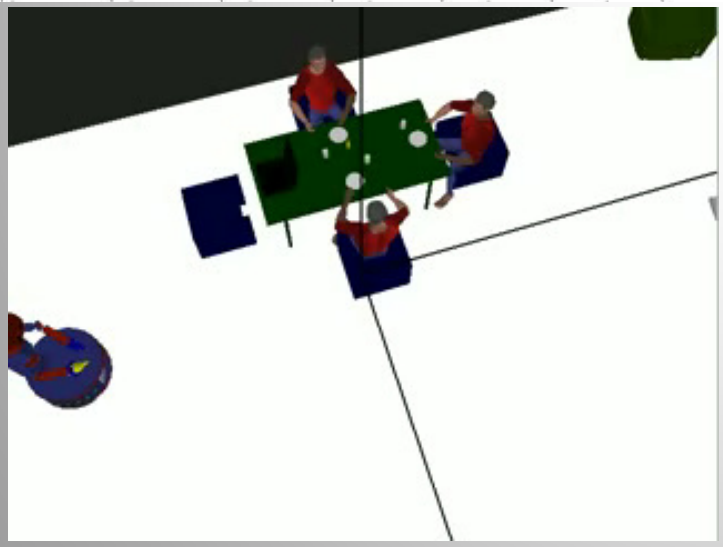
[3] Hayduk, L. A. (1978). Personal space: An evaluative and orienting overview. Psychological Bulletin .

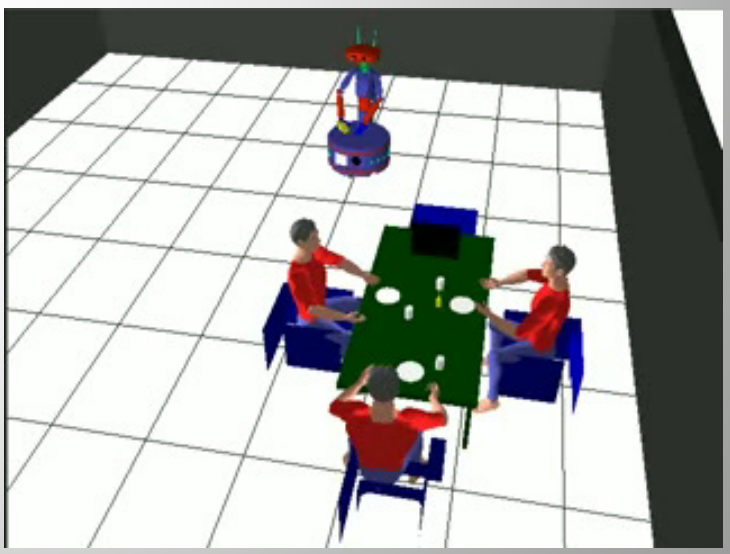
[4] Kendon, A. (2010). Spacing and orientation in co-present interaction. In Development of Multimodal Interfaces: Active Listening and Synchrony, volume 5967 of Lecture Notes in Computer Science .

Human-aware navigation: respecting visibility [not INRIA but LAAS - Sisbot 2008]



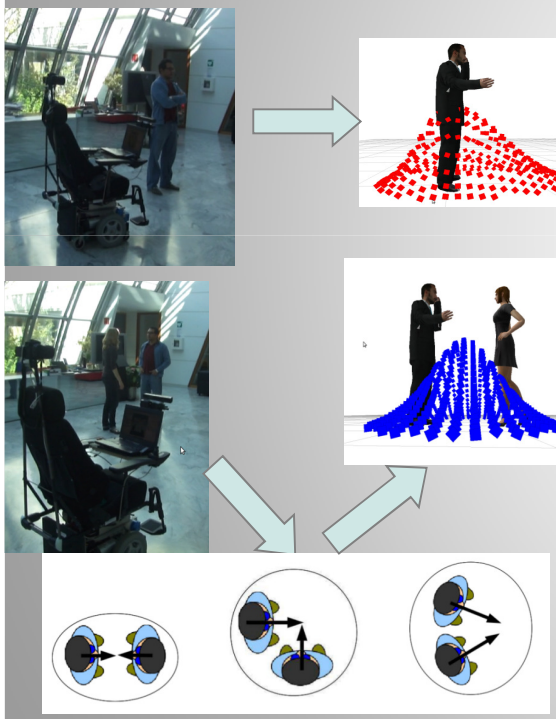




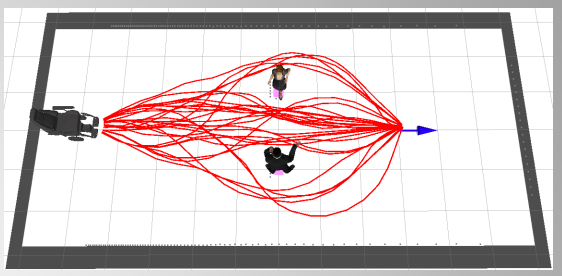


The Social Filter [Rios-Spalanzani 2011]

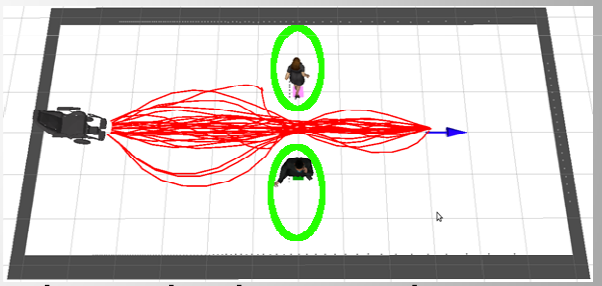
From the models of social conventions, a Risk of disturbance is included as part of the Risk of Collision in the RiskRRT algorithm.



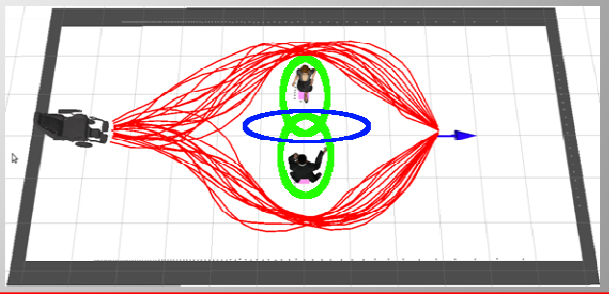
- Planning without Social Filter



Planning with Social Filter back to back



viz a viz: interaction zone



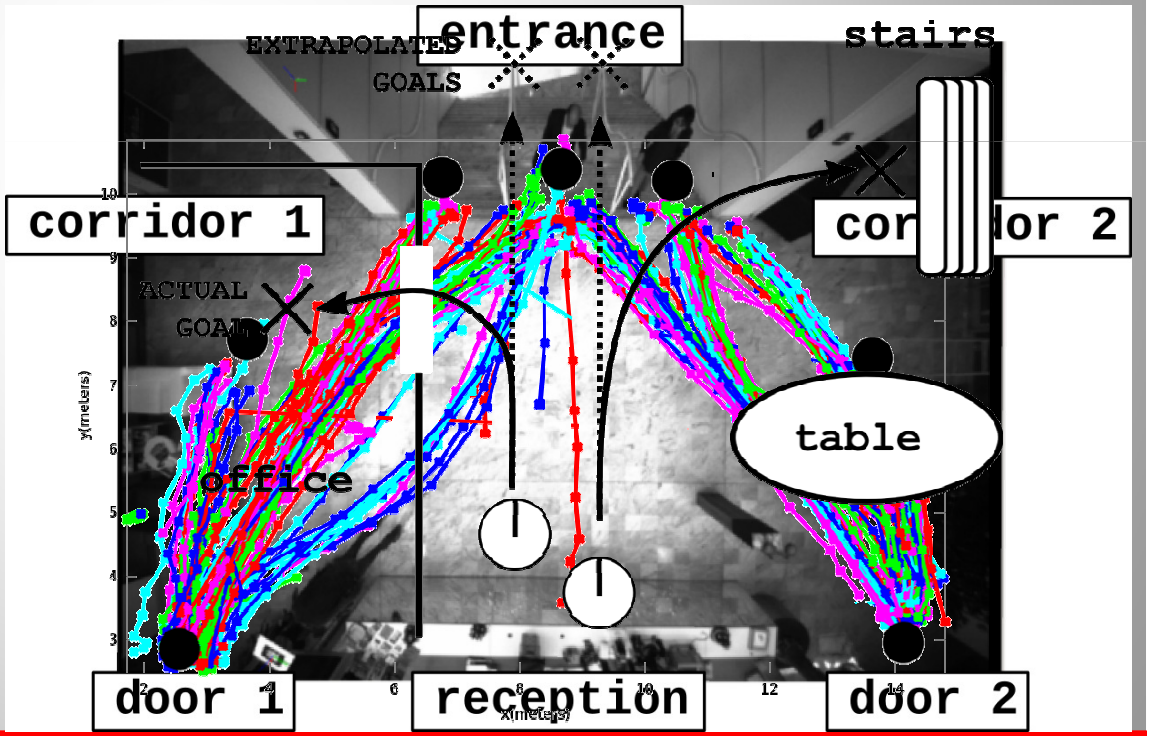
2. Robots need to anticipate

Prediction of obstacles' trajectories

Trajectory prediction

- Humans do not move at random, instead they follow typical paths
- Modeling typical paths:
  - Gaussian Processes [Tay 2007, Ellis 2009, Kim 2011]
  - Growing Hidden Markov Models [Vasquez 2009]

GHMM Training

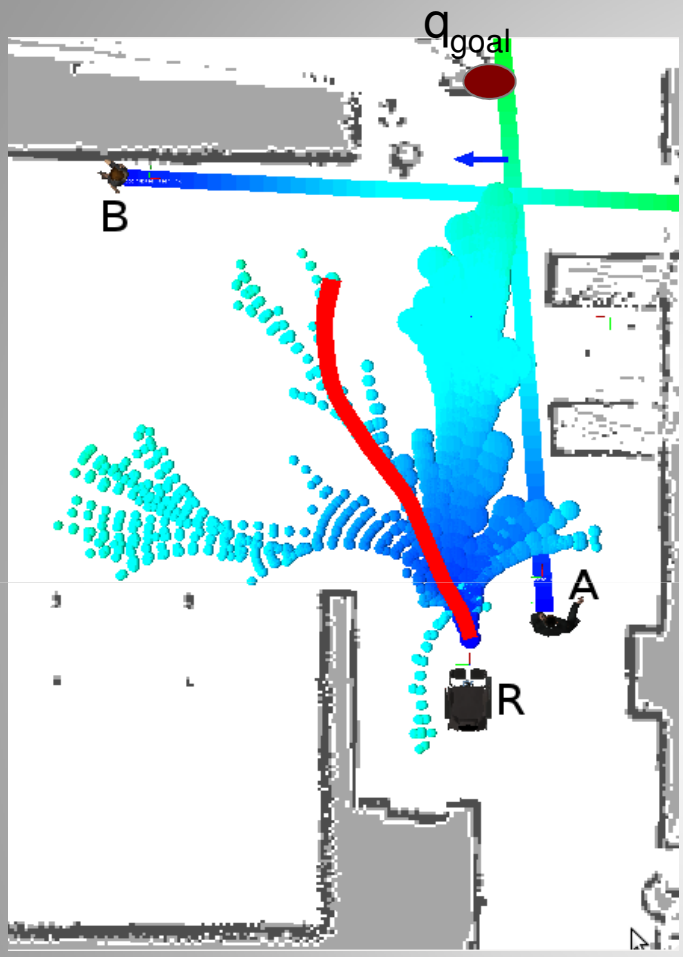


3. Human aware Navigation

The RiskRRT algorithm

Fulgenzi C., Spalanzani A., Laugier C., **"Probabilistic motion planning among moving obstacles following typical motion patterns."**. IEEE/RSJ International Conference on Intelligent RObots and Systems, 2009.

RiskRRT planner: illustration



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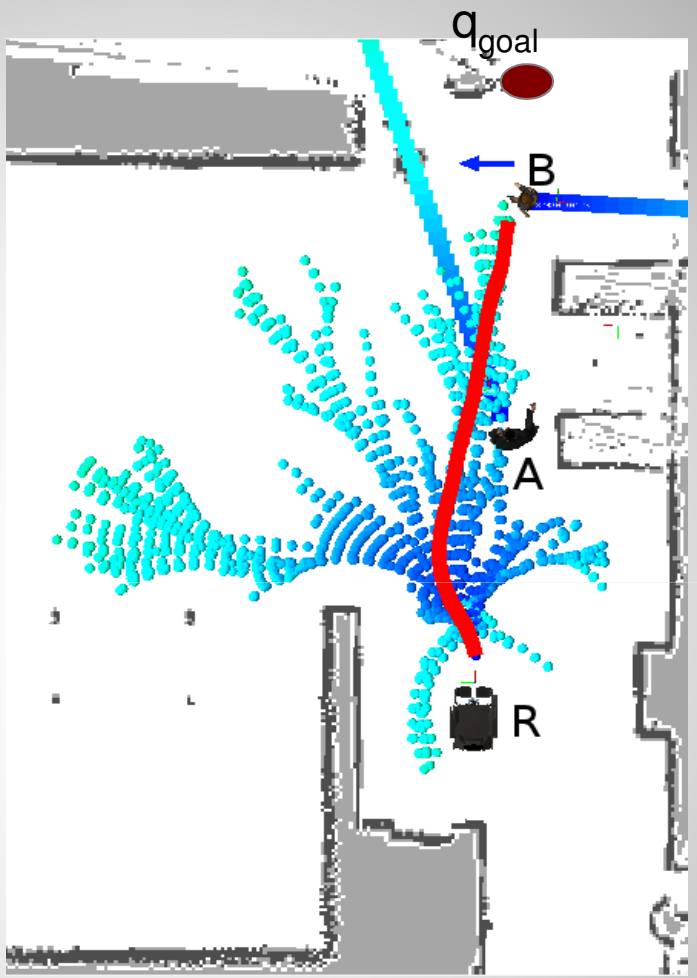

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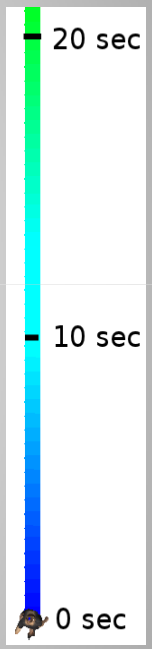


A, B two pedestrians

q_{goal} Goal of Robot R

Size of nodes is Risk of collision

Principle of the RiskRRT

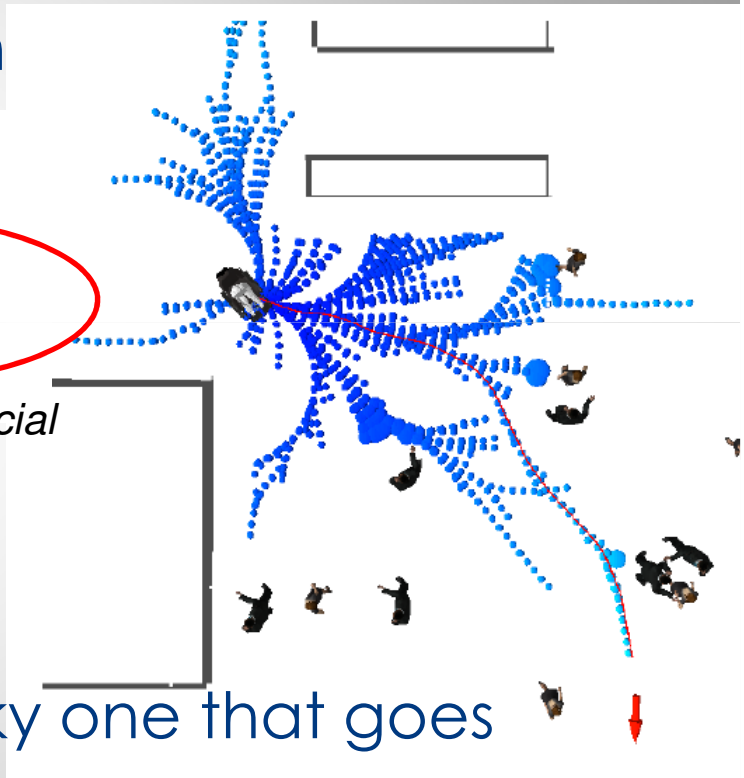
- Trajectories generated thanks to the RRT algorithm [Lavalle 99]
- On each node of the generated path are calculated probabilities of collision

$$P_c = P_{cs} + (1 - P_{cs}) \cdot P_{cd}$$

$$P_{cd} = 1 - \prod_{m=1}^{M} [1 - P_{cd}(o_m)] \prod_{i=1}^{r} [1 - PZ_i]$$

Collisions with the m moving obstacles

Entering the r social zones

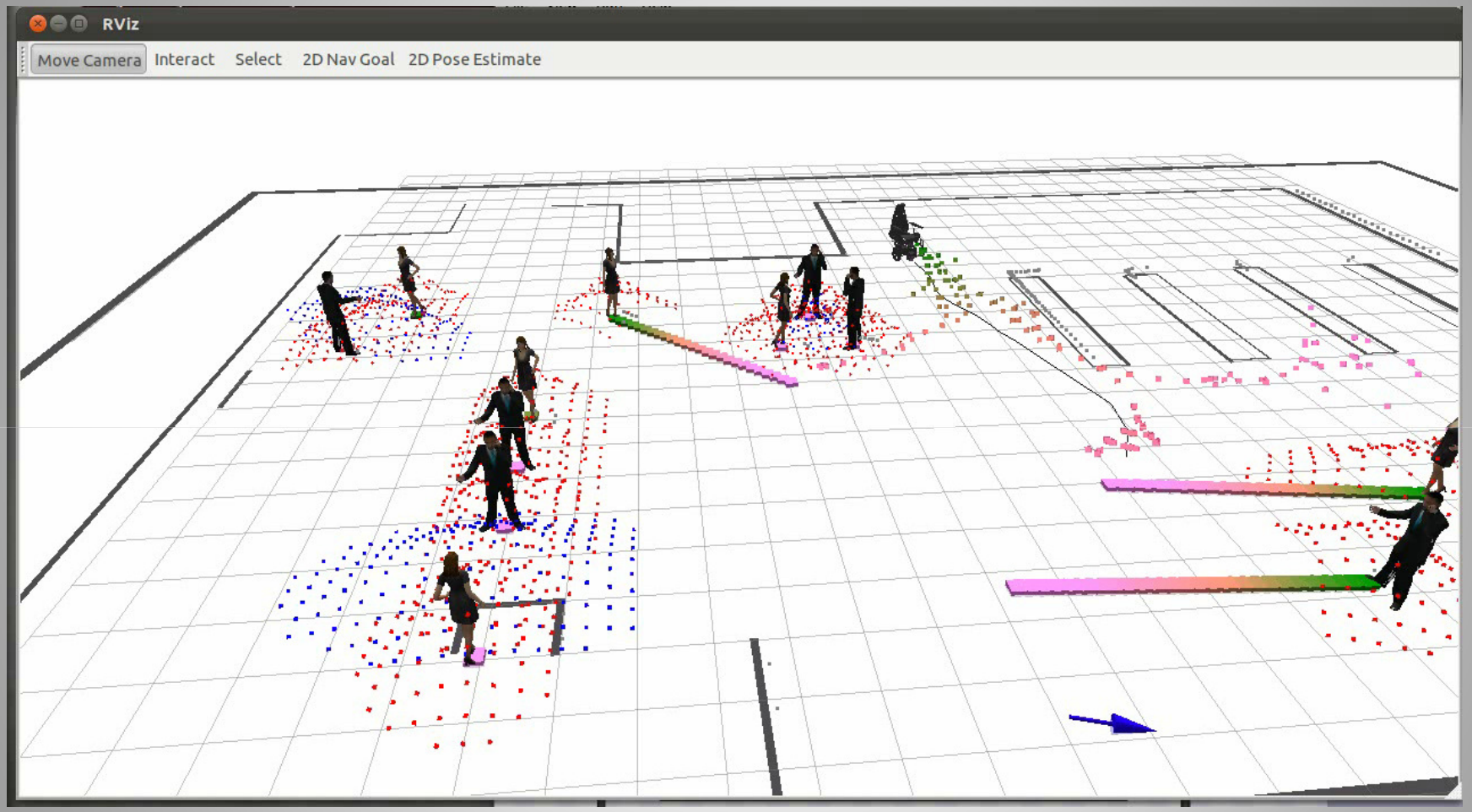


- The chosen trajectory is the less risky one that goes toward the goal

Navigation using prediction

- The future state of the environment is estimated and used to plan safe trajectories
- The chosen trajectory is the less risky one

Navigation using social conventions and prediction



Limitations of this approach

4. Navigating in Populated Environments by Following a Leader

Stein P., Santos V., Spalanzani A., Laugier C., "Navigating in Populated Environments by Following a Leader", International symposium on Robot and Human Interactive Communication, Gyeongiu, Korea, Aug. 2013.

September 2013

Problems

Social interactions depend on context and may be difficult to detect

Predictive approaches may fall into the Freezing Robot Problem

Freezing Robot Problem [Trautman 2010]

In dense environments, due to large future uncertainty, every path generated by the navigation algorithm is expected to result in collision, so the robot stops moving

Proposed Solution

Follow persons, to take advantage of their motion in complex and dynamic environments

Motivation:

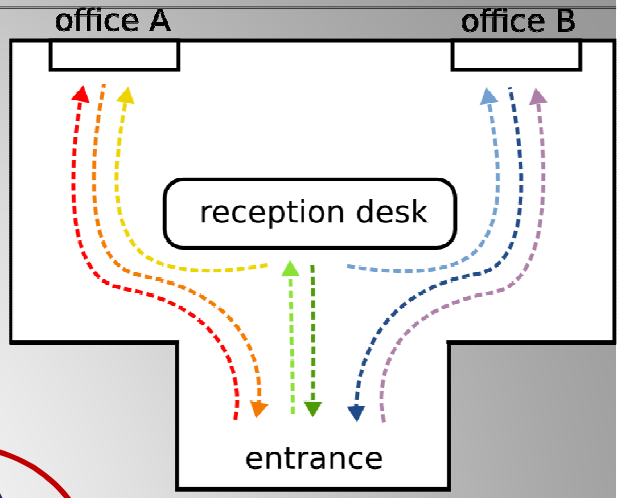
- *People motions can provide information about the environment*
- *Humans can easily navigate in crowded environments*
- *Persons are able to deal with very complex social interactions.*

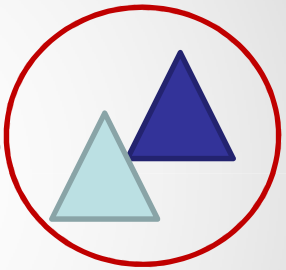
Advantages:

- *Reduce computational cost*
- *Escape Freezing Robot Problem*
- *Better acceptance by humans*
- *Avoid undetected obstacles (e.g. spilled coffee)*

How to Choose a Leader?

- Goal similarity prediction
- Models of typical paths (ghmm, gp)

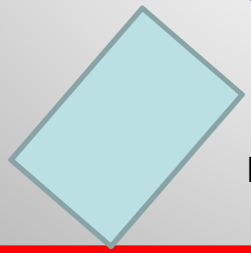




predicted goals

leader candidates

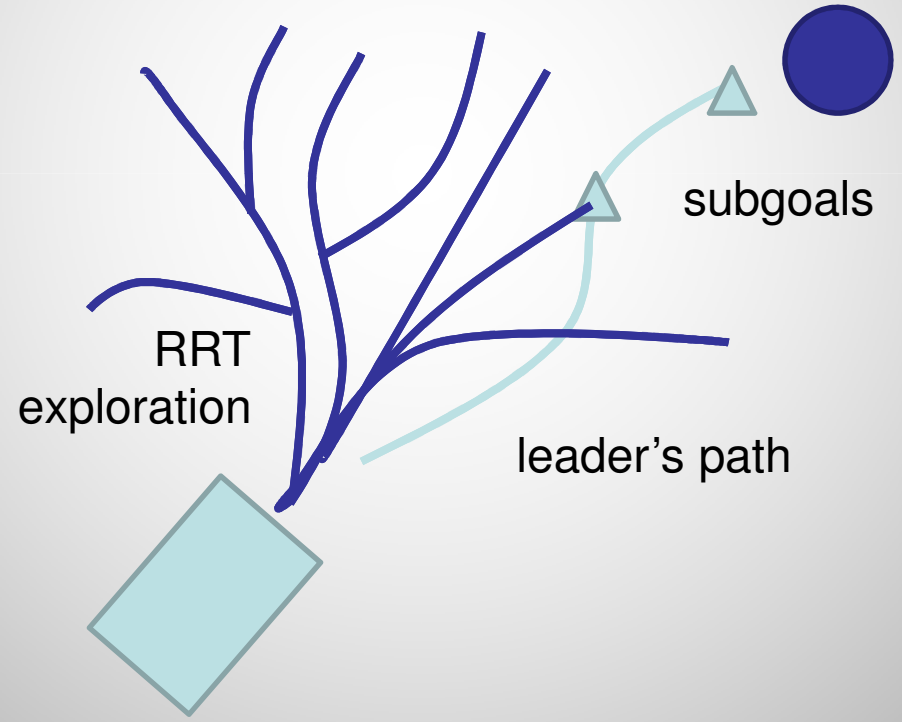
chosen leader



robot

How to Follow a Leader?

- Leader path tracked
- Samples passed as subgoals
- The RiskRRT plans trajectories

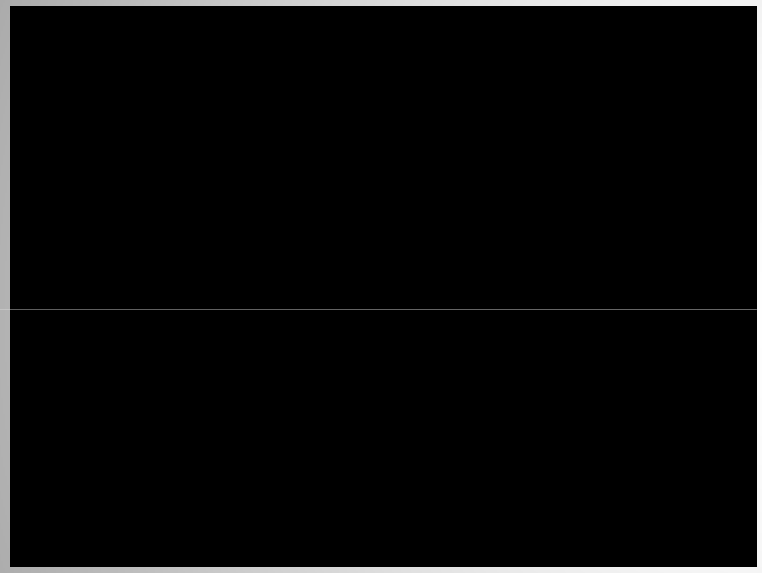


Experiments

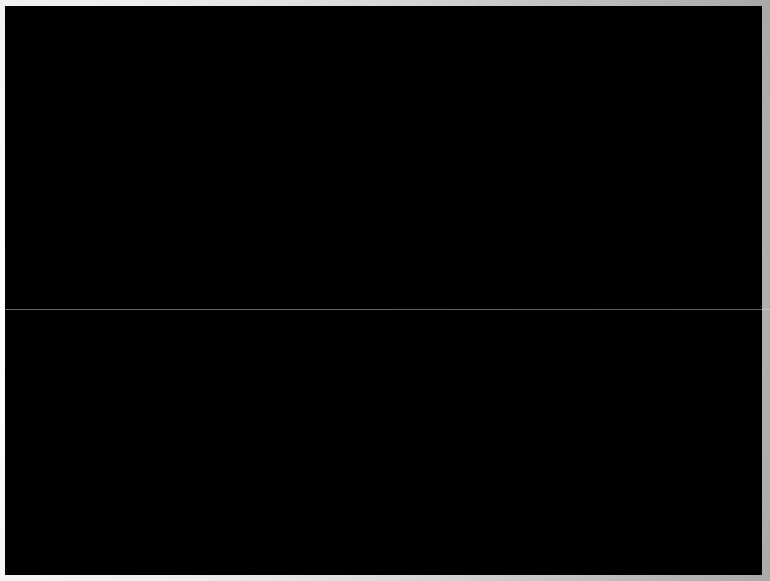
- Simulation Only
- Simulated Robot + Real Data
- GHMM trained with real data
  - Fiducial markers were worn as hats
  - Overhanging camera + wide angle lens
  - People moved among interest points

Experiments: real data + sim

leader **detection and following**



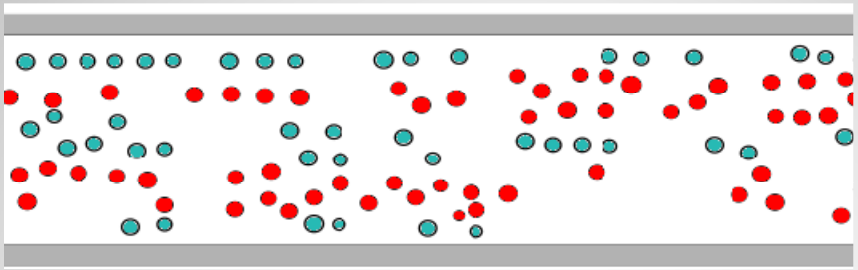
leader **following among people**



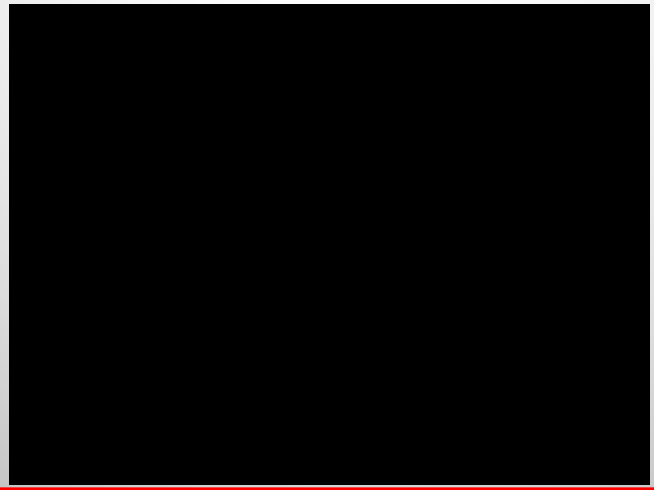
people naturally give room for the leader to pass.
the robot benefits from this space

Navigating among crowds

- Pedestrian Simulator Based on the Social Force Model [Helbing 1995]



- It incorporates reactions of persons to the presence of the robot and of other persons, replicating some situations of the real world



Experiments with Pedestrian Simulator

- Goal: **Leader following** to escape **frozen** situations;
- Reduction of time spent to reach goal, when following a leader;
- Robot becomes part of the human group.

Thank you for your attention !