The Bremen Autonomous Wheelchair – A Versatile and Safe Mobility Assistant

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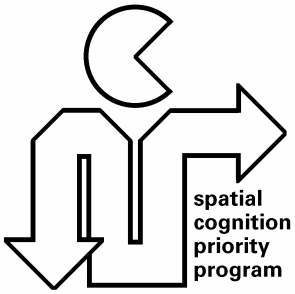

Bremen Institute of Safe Systems
Center of Computing Technology
University of Bremen

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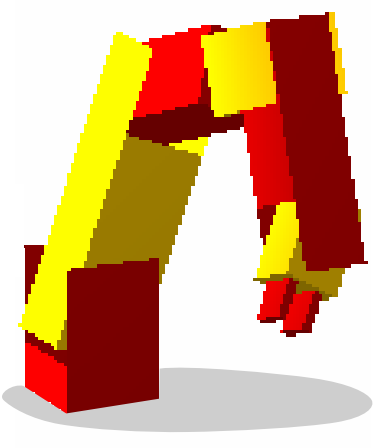
Safety in Robotics



Industrial robotics

Service robotics

Rehabilitation robotics

Increasing safety demands

The Wheelchair “Rolland”

Technical Information

- Meyra Model “Genius 1.522”
- 84 cm/s maximum speed
- Communication via two serial ports

Sensory Equipment

- Internal sensors (speed/steering angle)
- 27 ultrasonic sensors (Nomadic)

On-Board Computer

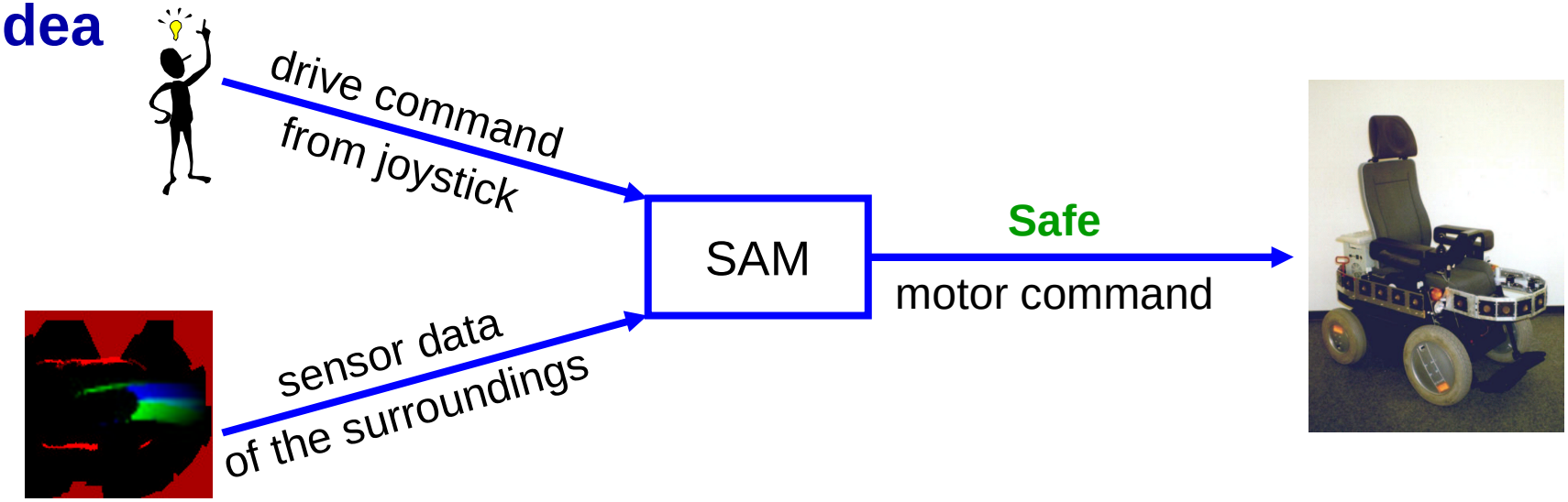
- Industry-PC (Pentium 233)
- QNX (real-time operating system)

Safe Wheelchair – Motivation

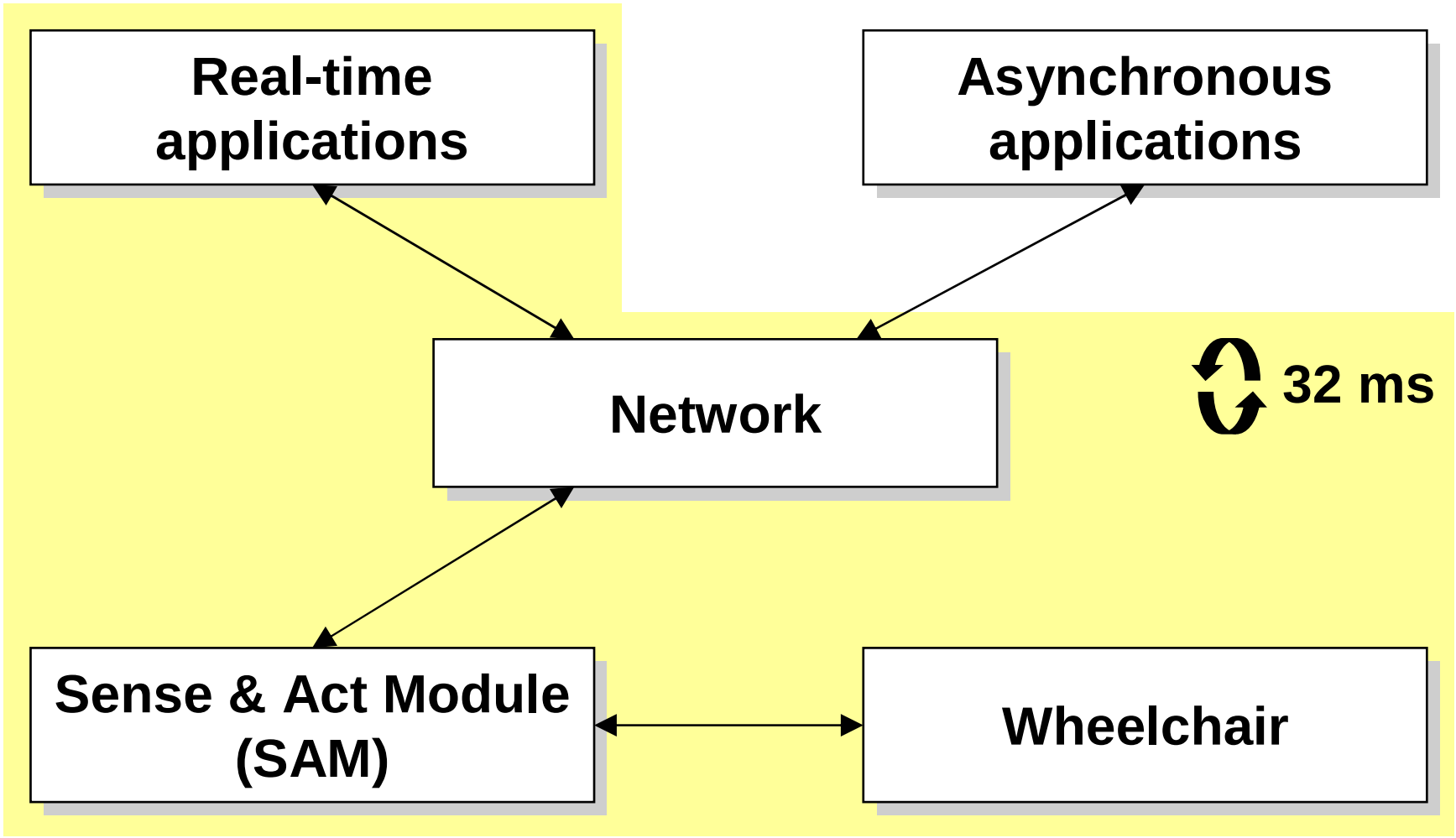
Problem: Safe Driving Is Complex

- Rear swings out
- Accidents caused by user's disease (e.g. spasms)

Idea



Safe Wheelchair – System Architecture



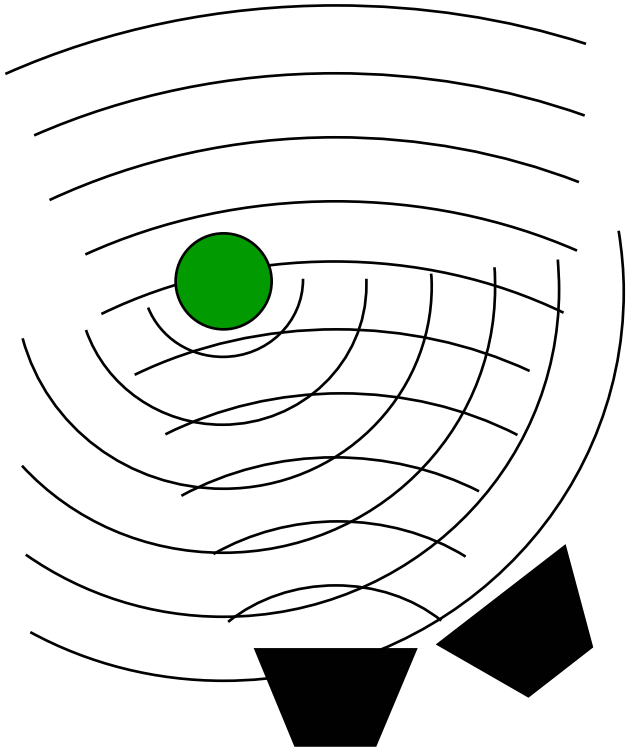
Sonar Sensors in Mobile Robots

Pros

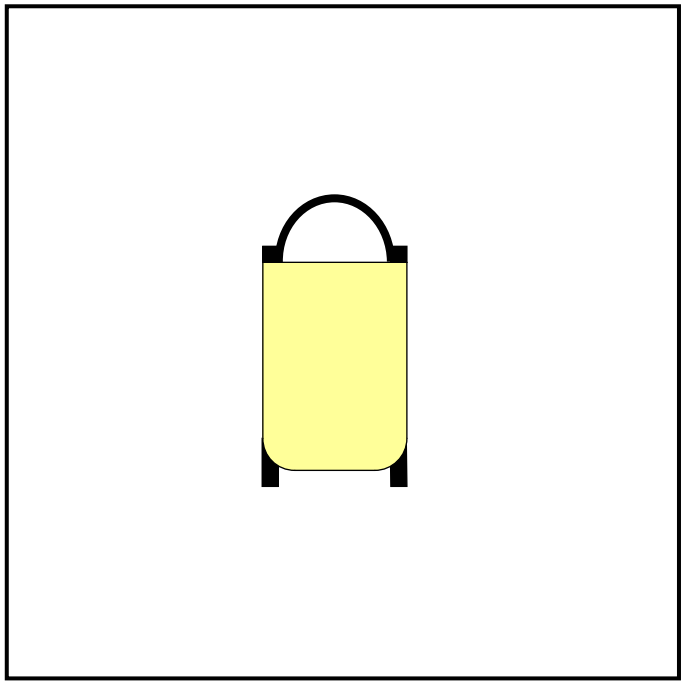
- Small
- Cheap
- Good Range Resolution

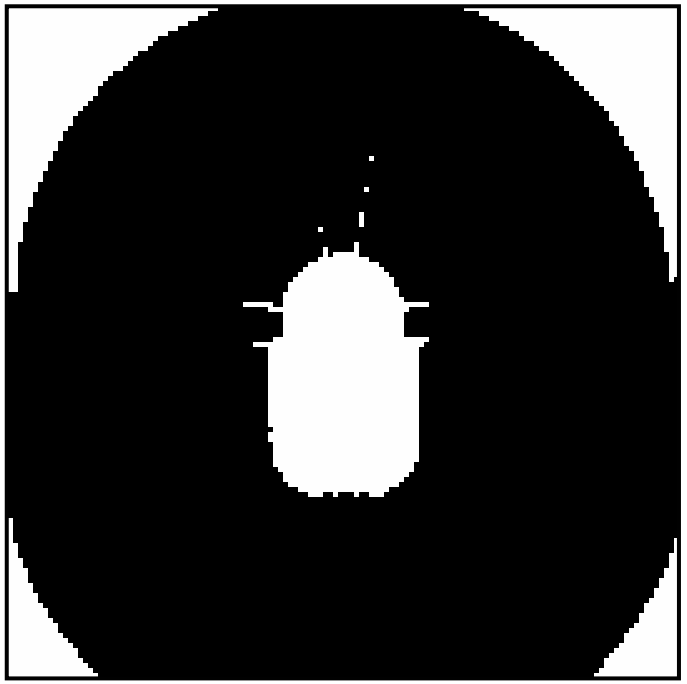
Cons

- Low Angular Resolution
- Specular Reflections
- Cross-Talks
- Blindness in immediate surrounding area

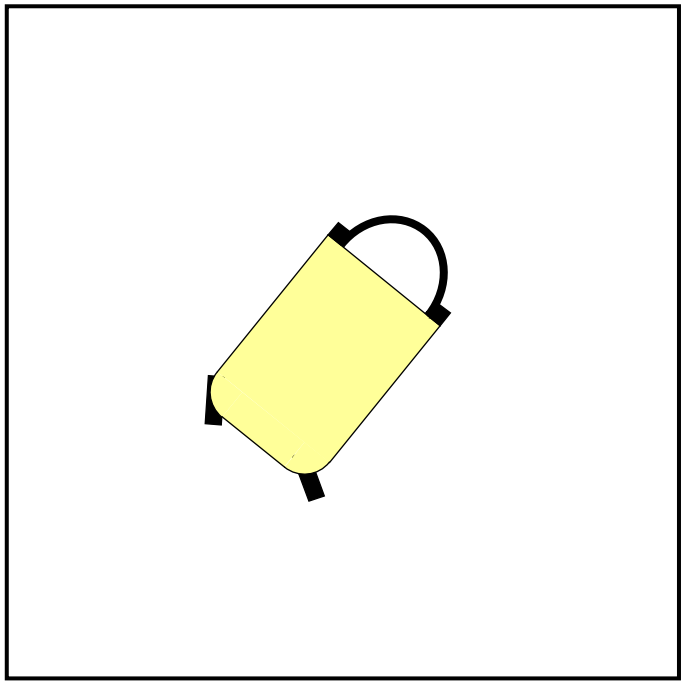


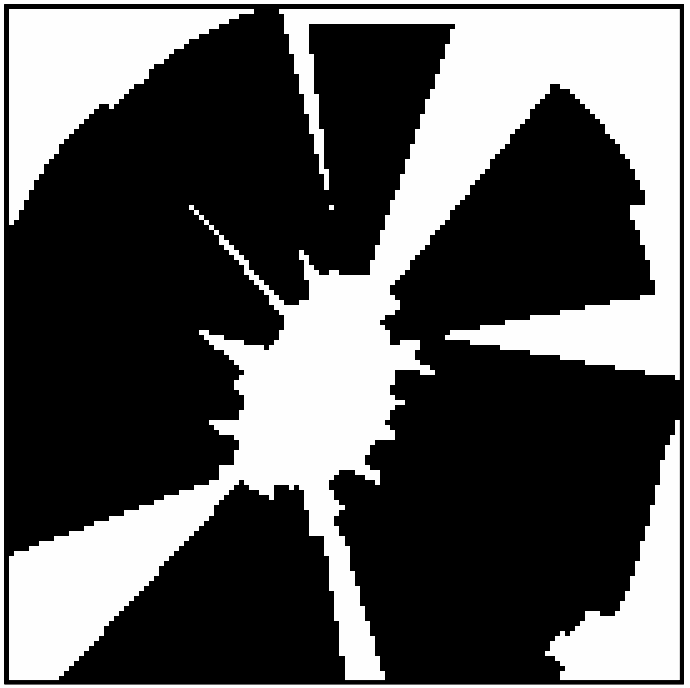
Static Fire Sequence





Static Fire Sequence during Motion





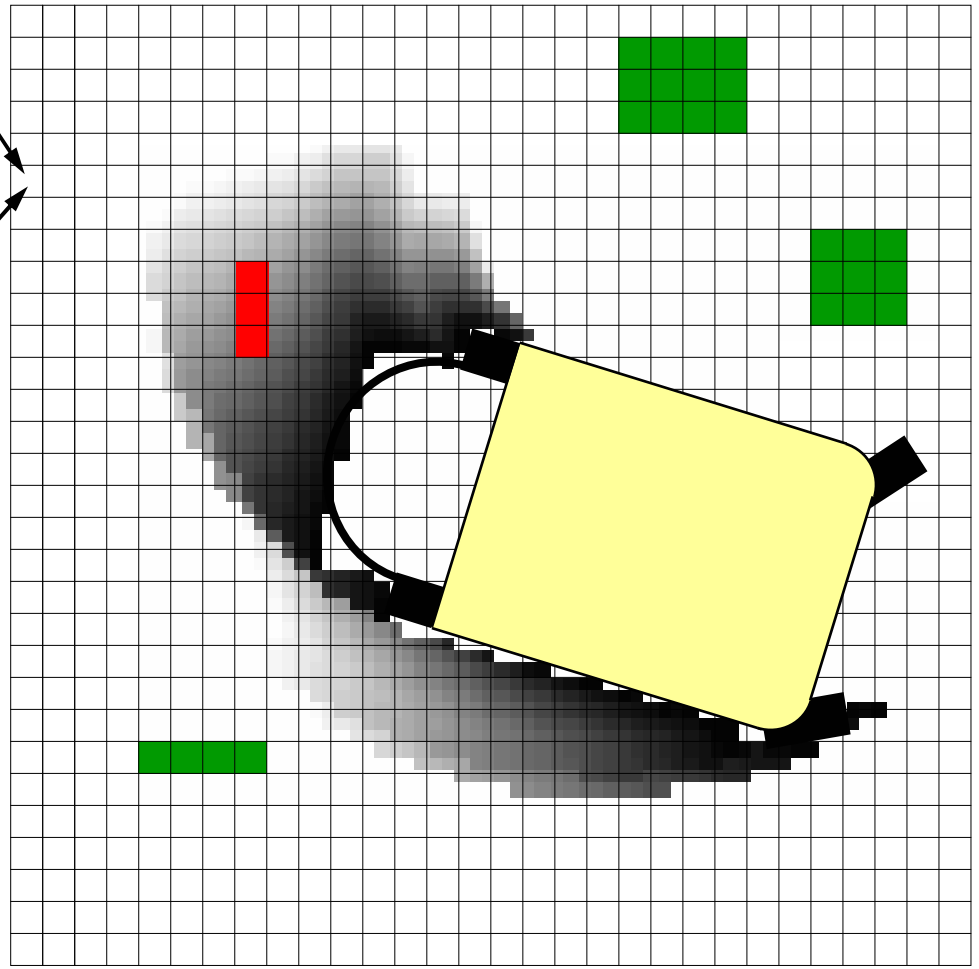
Safe Wheelchair – Local Obstacle Map

Age of Measurement

Occupancy of Cell

- Never Measured
- Empty
- Obstacle Supposed
- Obstacle Confirmed

Danger of Collision!



Safe Wheelchair – Measuring on Demand

Searching

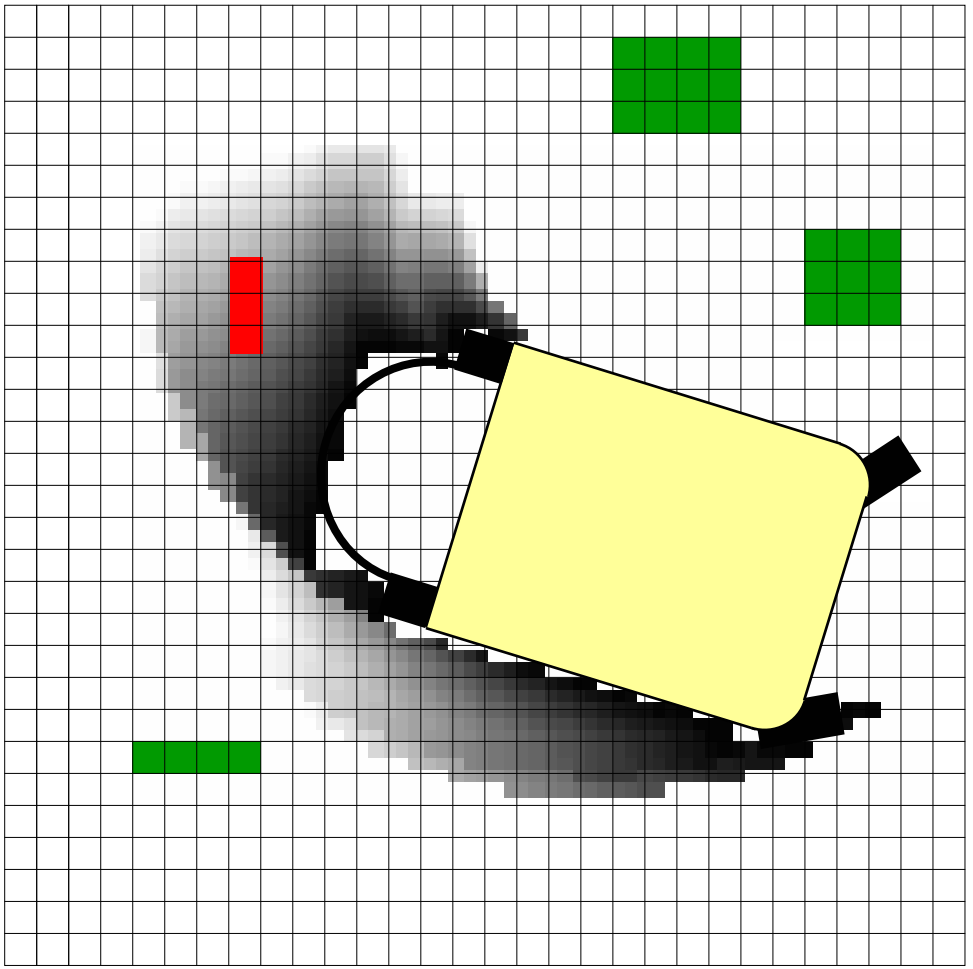
- Only relevant area
- Up to the closest obstacle already known

Sensor Selection (per Side)

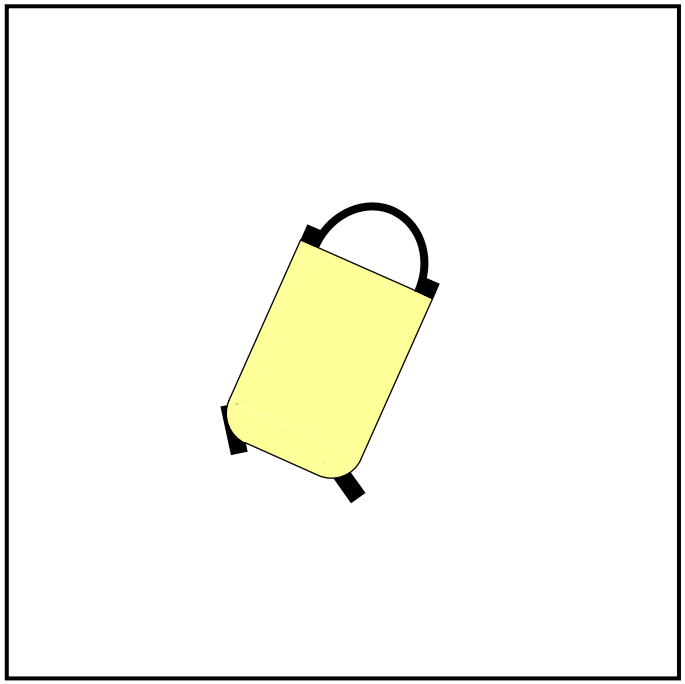
- Fire sensor that looks towards the cell that has not been measured for the longest time
- If this is more than one sensor, fire the one not been used for the longest time

Obstacle Detection

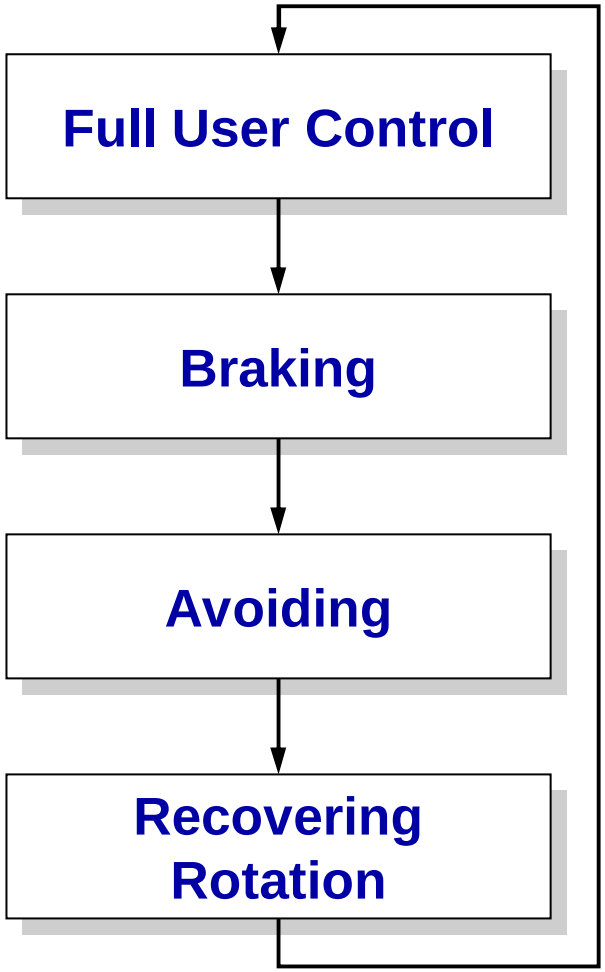
- If an obstacle is detected first, force a re-measurement



Safe Wheelchair – Dynamic Fire Sequence



Cooperative Obstacle Avoidance



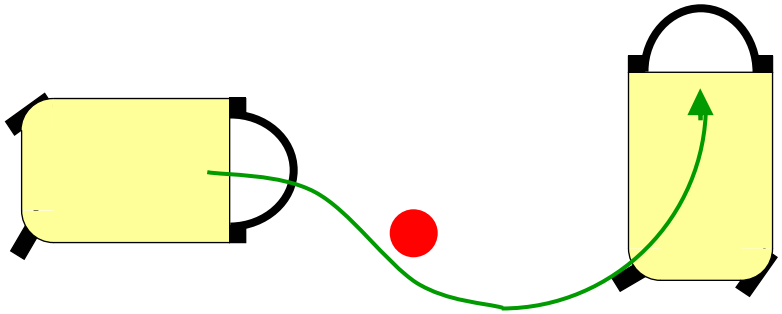
No relevant Obstacles

Obstacle detected, but not avoiding it

Obstacle detected, avoiding it

No relevant obstacles,
user did not intervene

Obstacle Avoidance – Speed



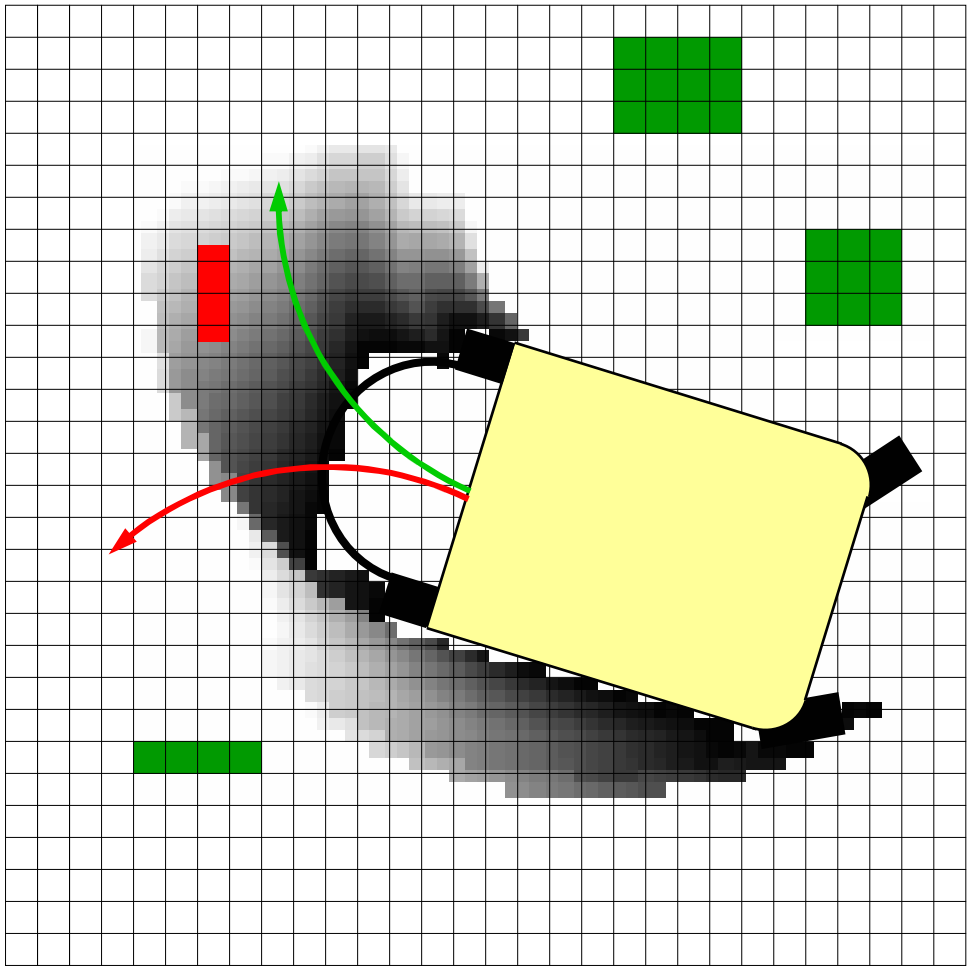
maximum right

maximum left

impossible to avoid

can be avoided even with high speed

Obstacle Avoidance – Direction



Obstacle Avoidance – Demonstration

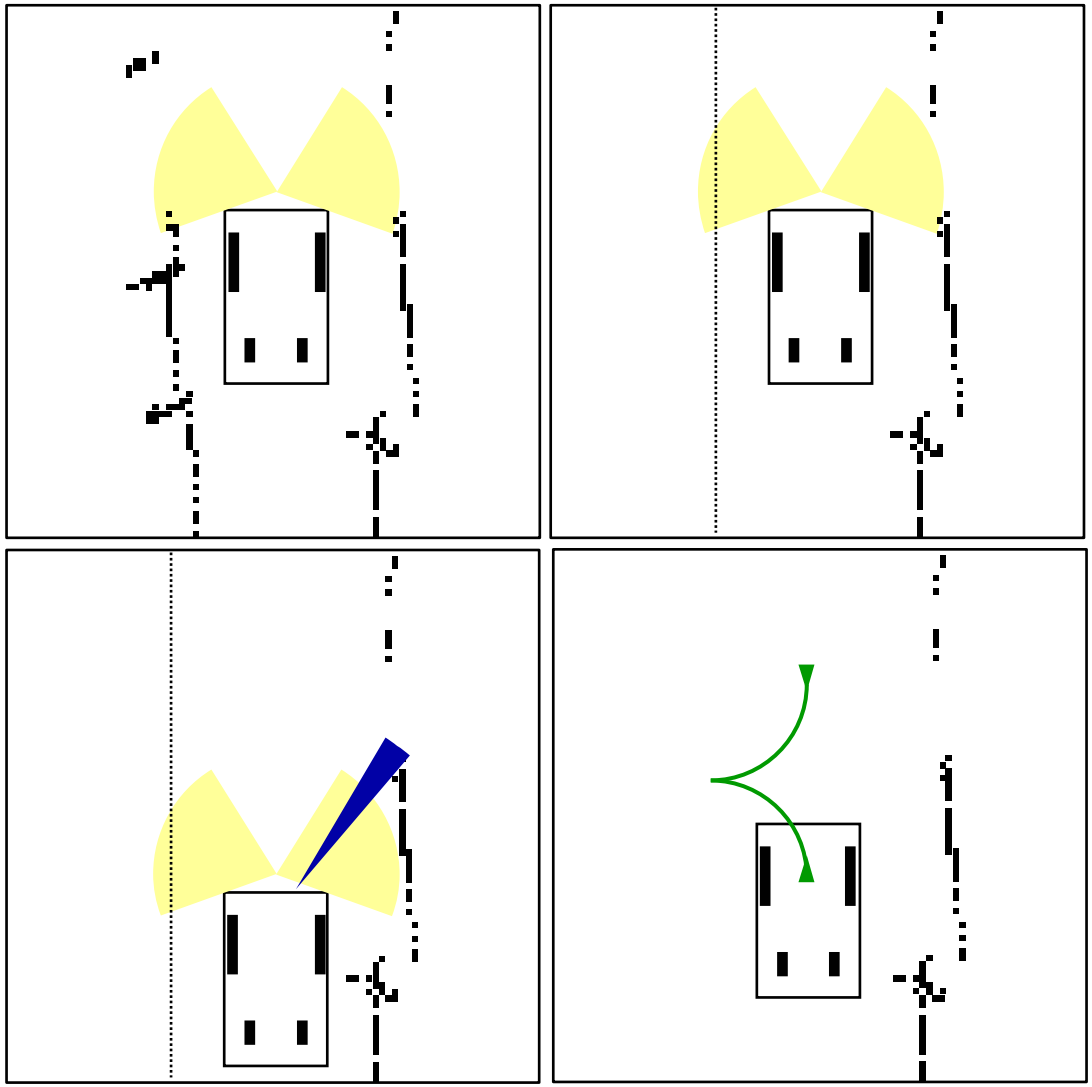
Basic Behaviors

Methods

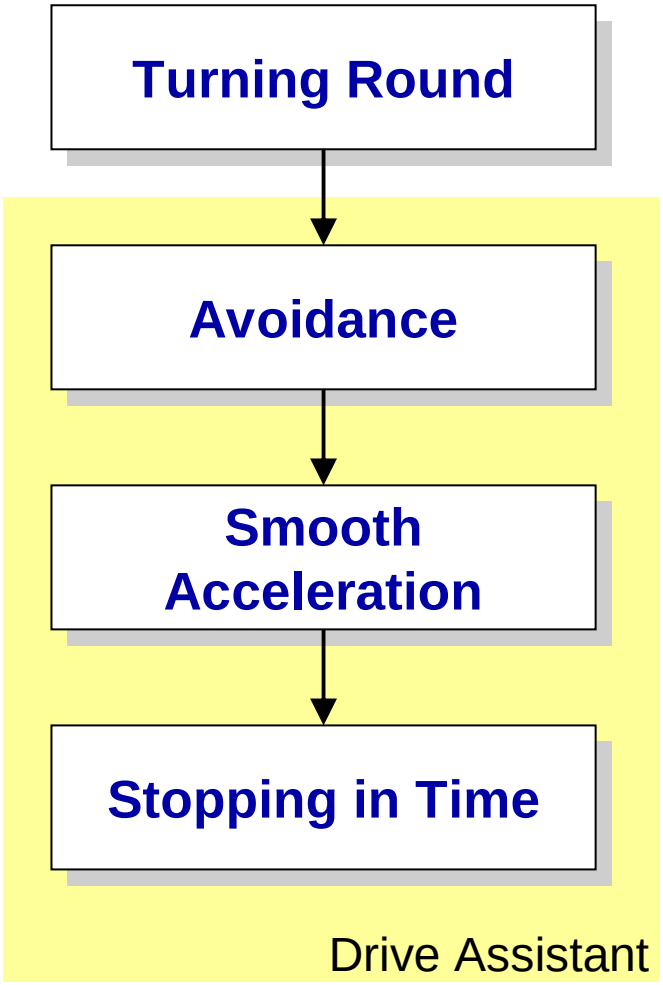
- Local Obstacle Map
- Virtual Sensors

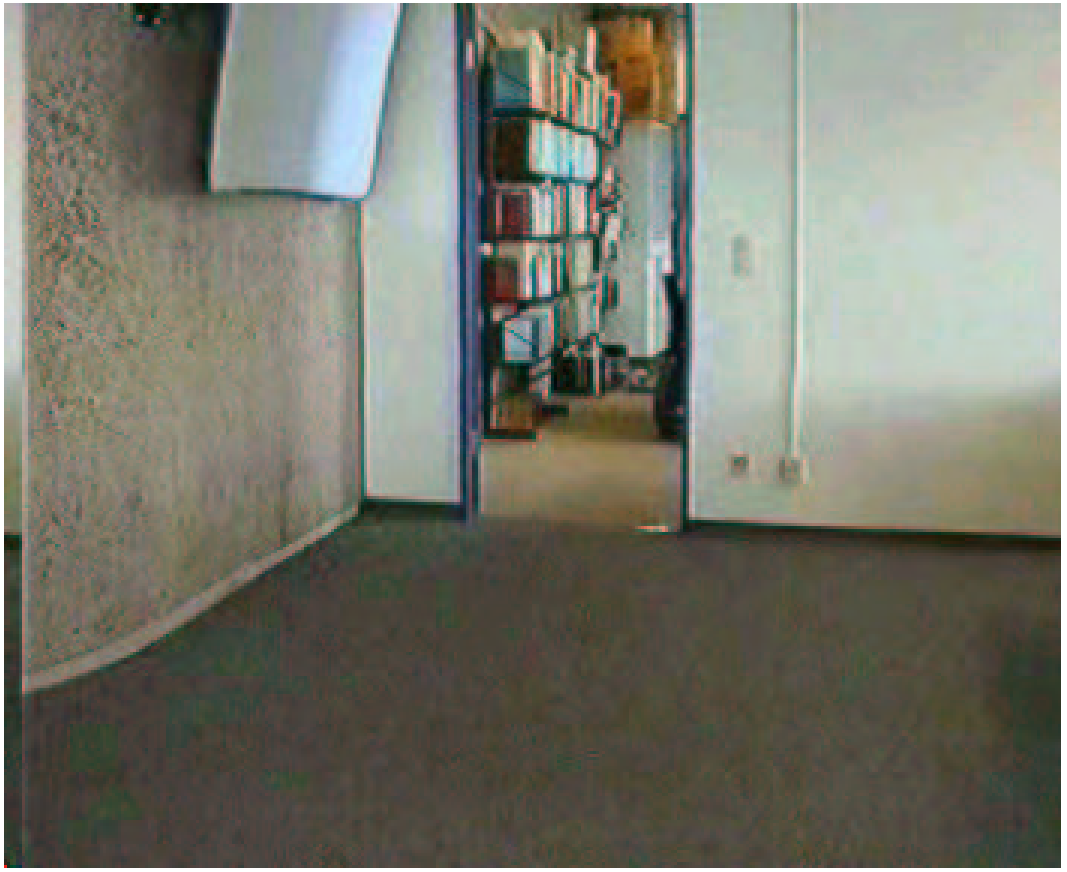
Behaviors

- Forwards and Backwards
  - *Corridor-following*
  - *Wall-following left/right*
- Only Forwards
  - *Turning into the left/right door*
- Automatic
  - *Turning round*
- Miscellaneous
  - *Stop*

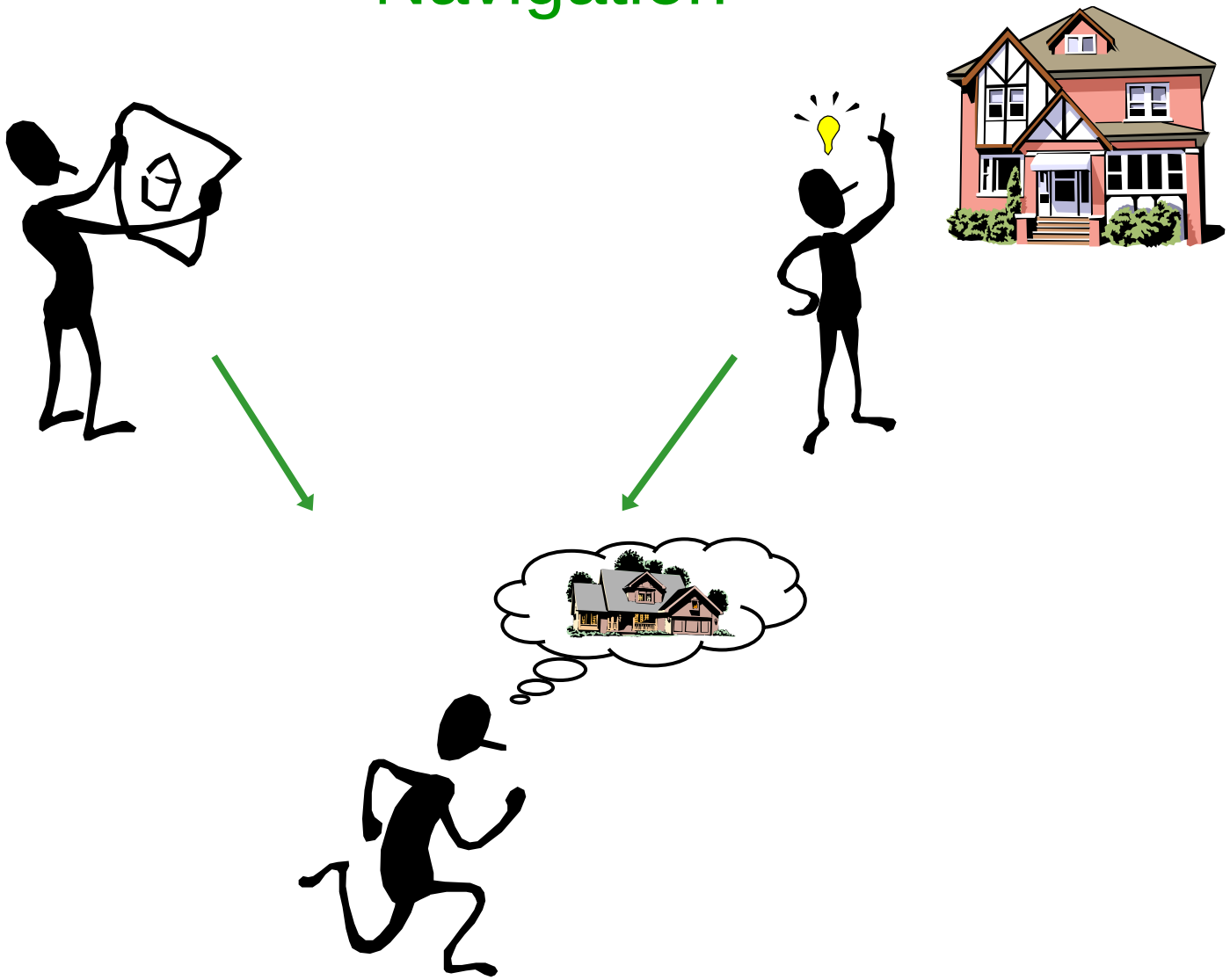


Drive Assistant – Demonstration

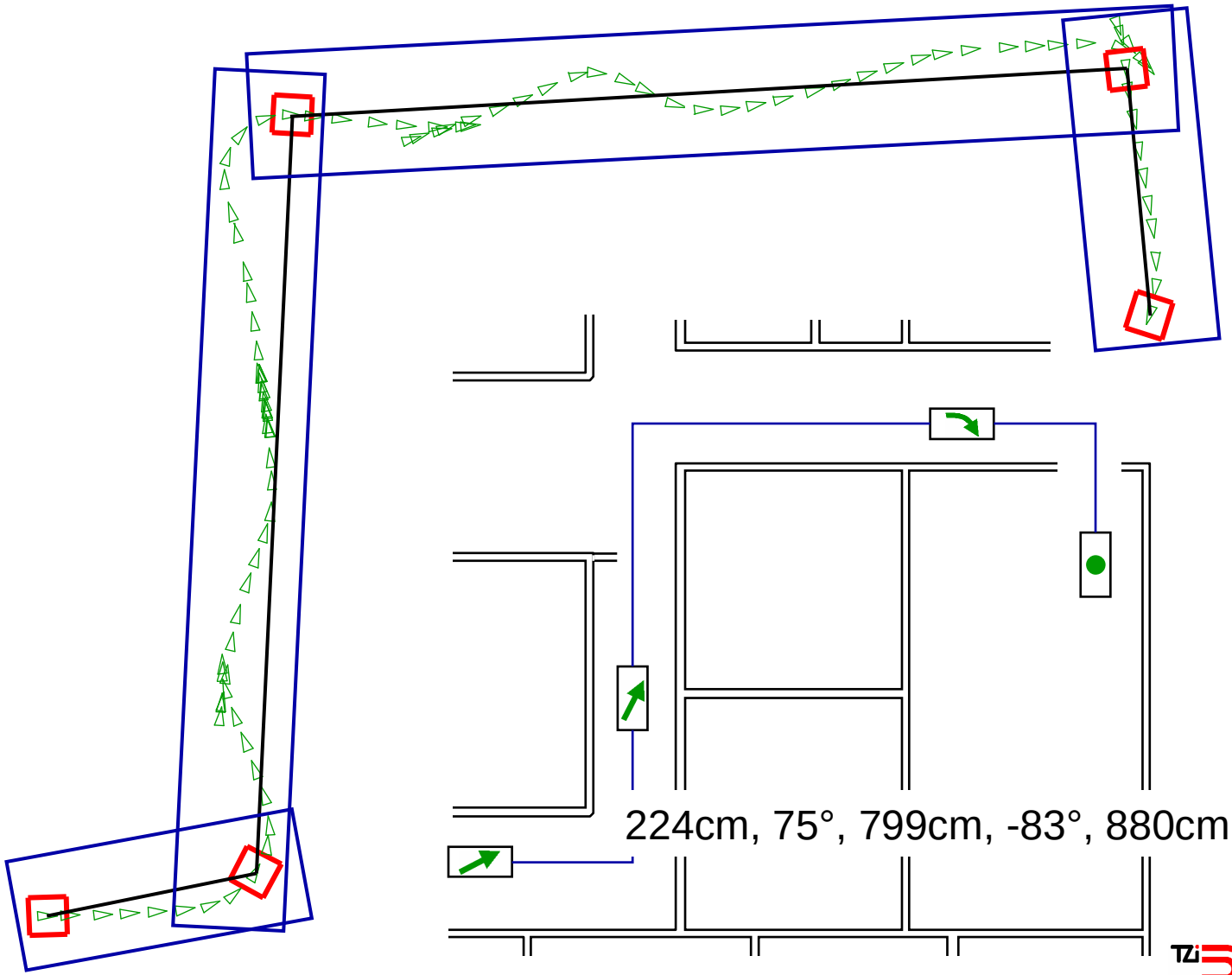




Navigation



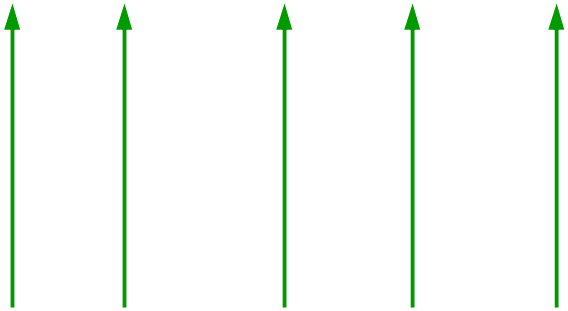
Self-Localization in Routes



224cm, 75°, 799cm, -83°, 880cm, -87°, 260cm

Matching Generalized Tracks

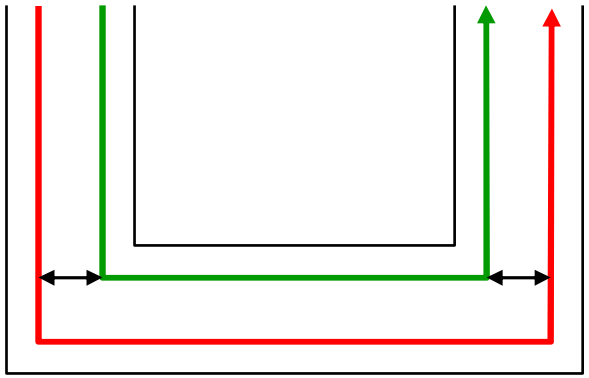
224cm, 75°, 799cm, -83°, 880cm, -87°, 260cm

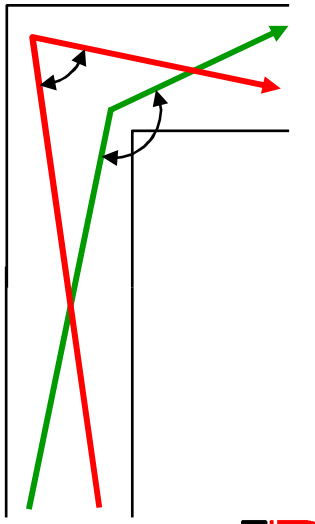


250cm, 85°, 750cm, -91°, 440cm

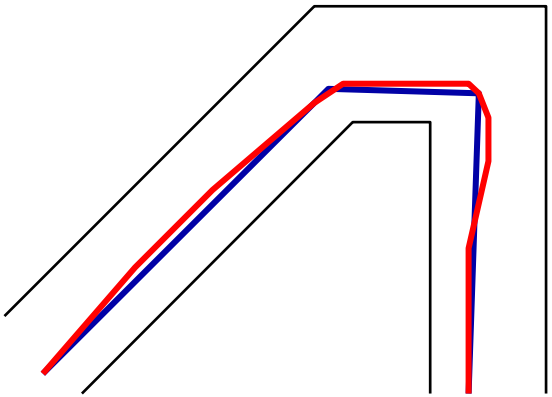
In the third segment,
440 cm from the previous corner

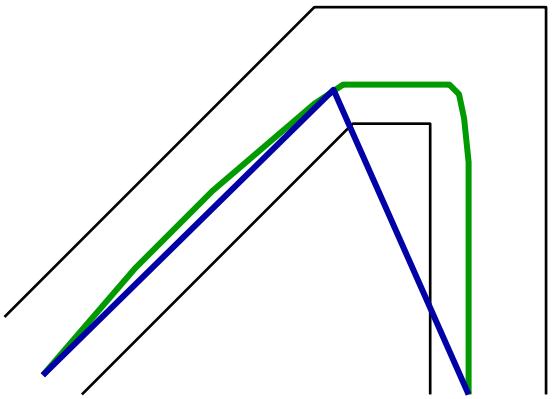
The tracks are incompatible





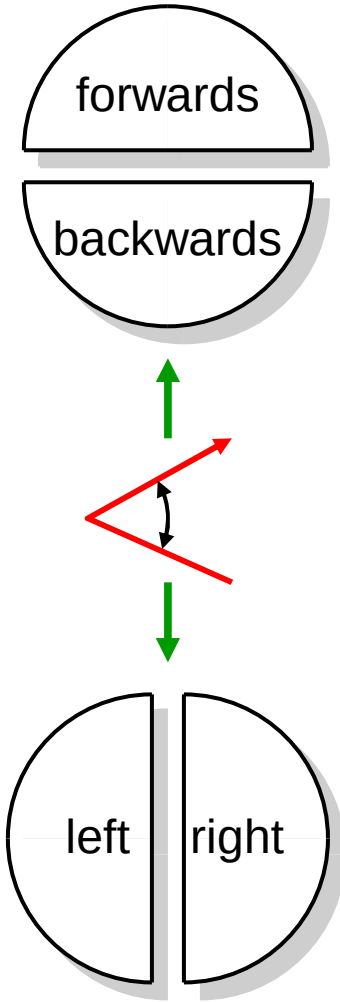
Compensating for Deviations



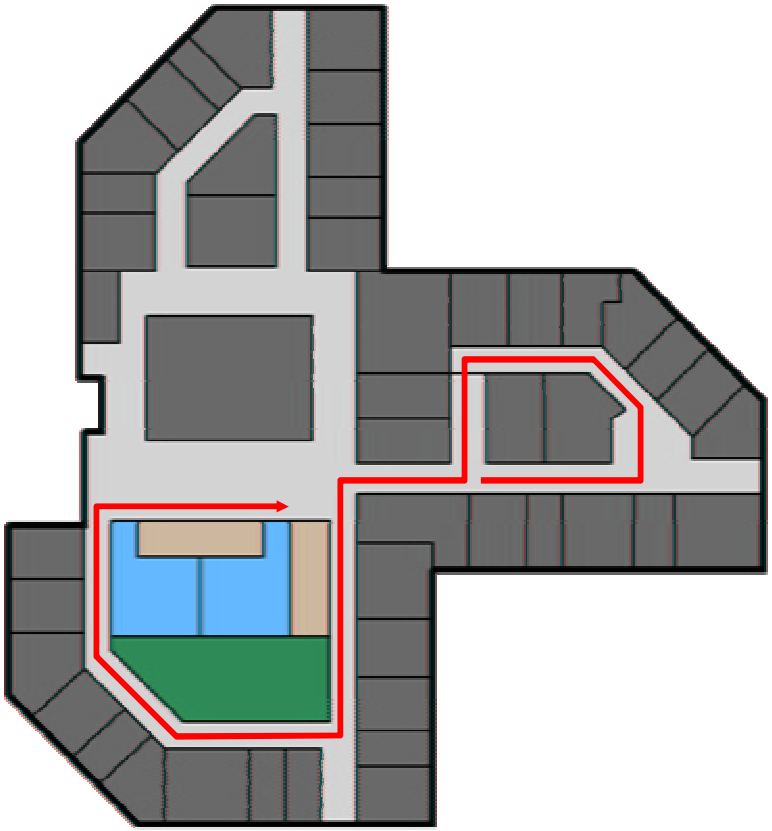


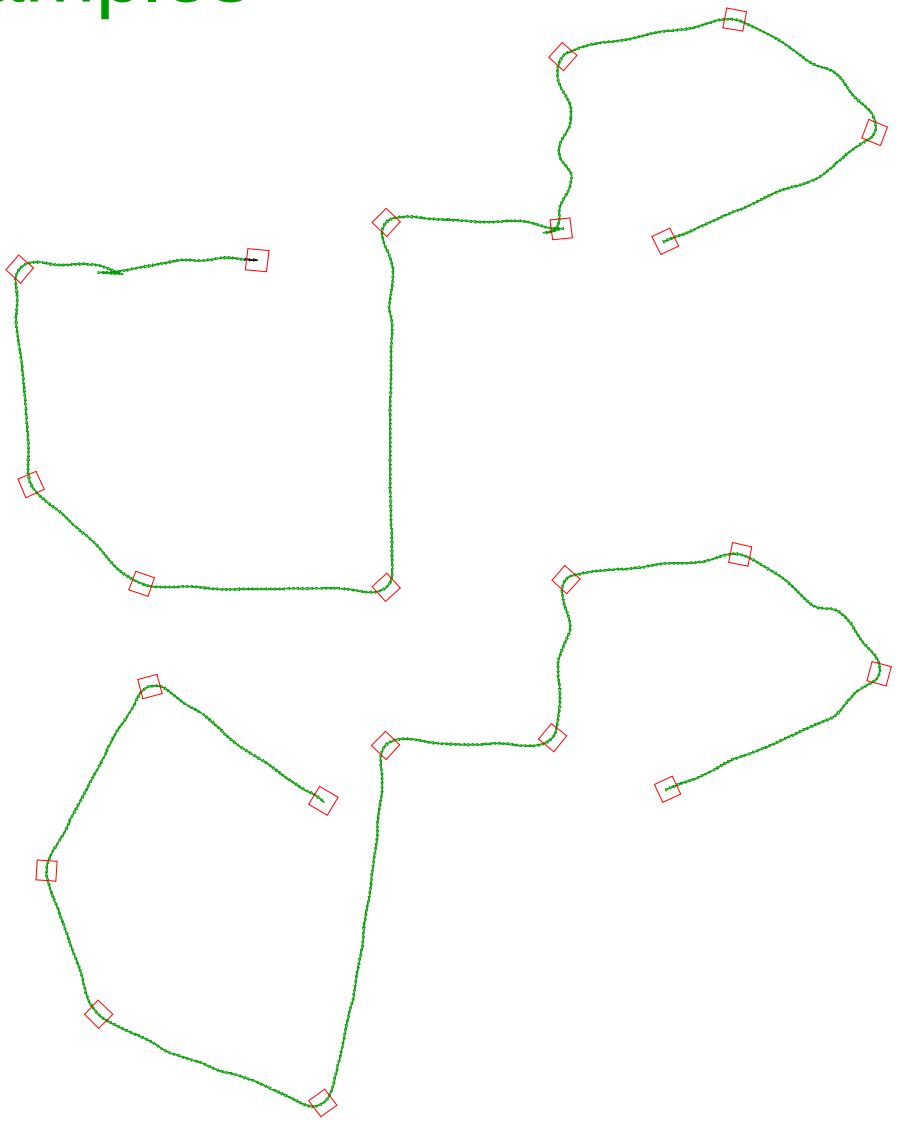
306cm, 45°, 150cm, 83°, 224cm

290cm, 130°, 520cm

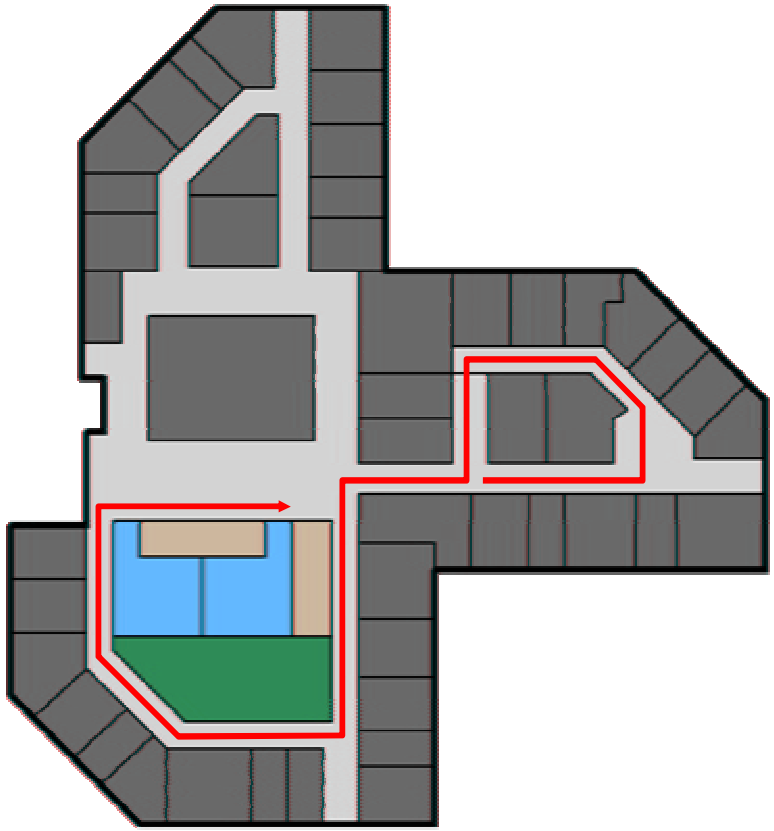


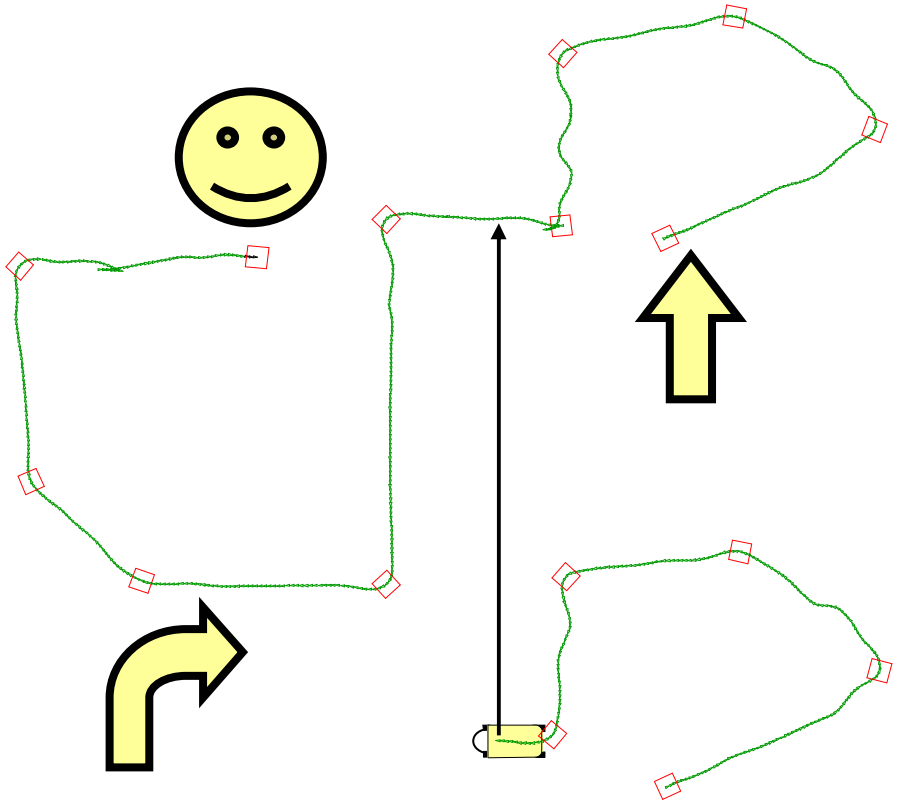
Examples



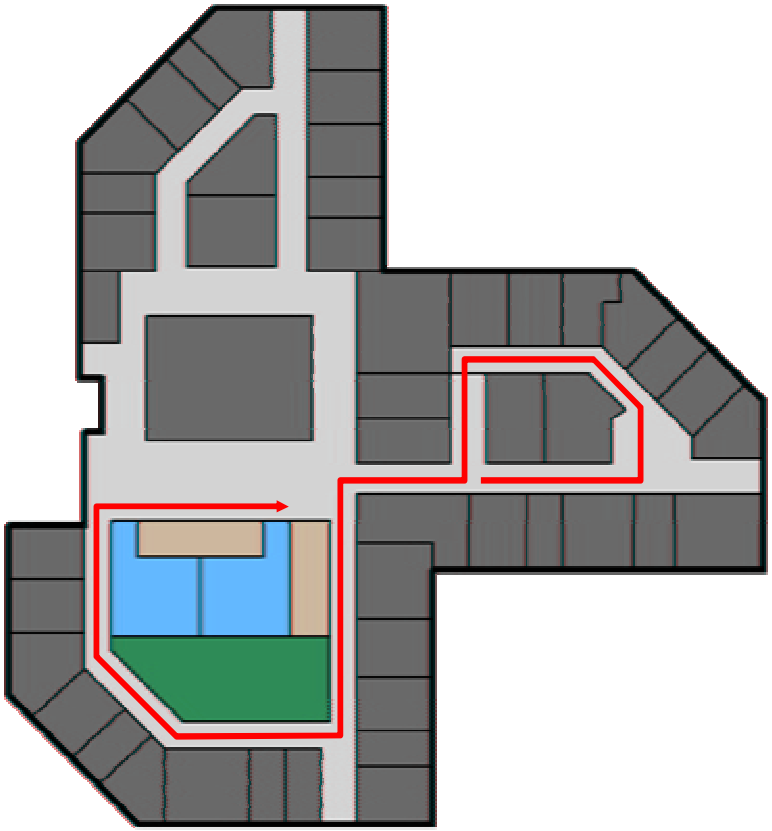


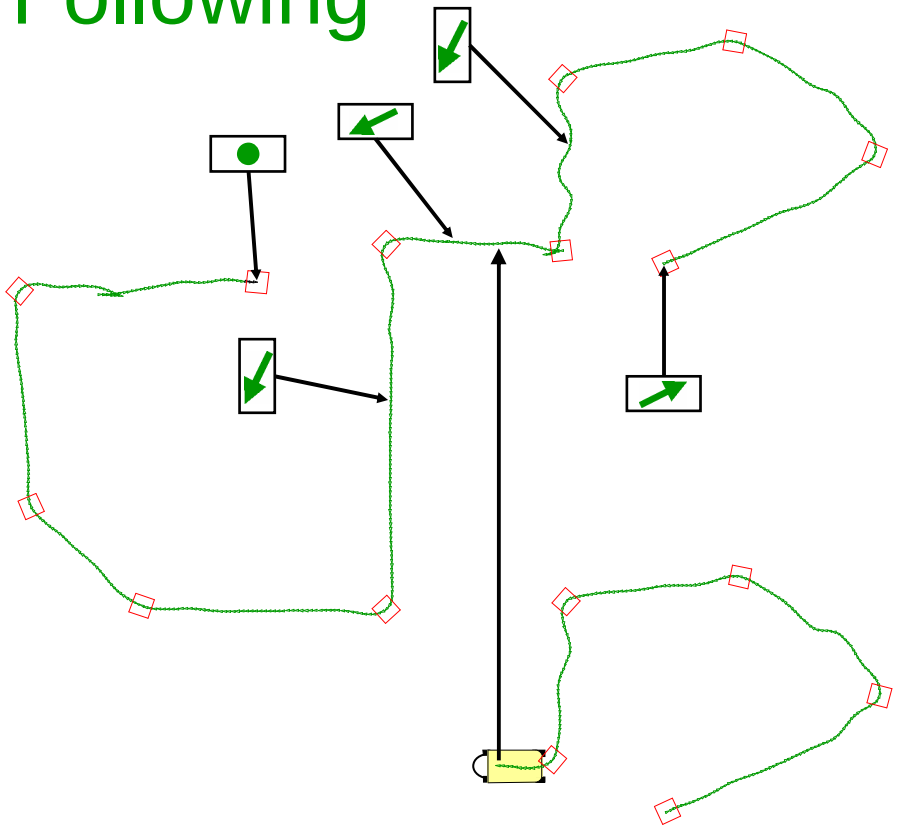
Route Assistant





Route Following





Route Following – Demonstration

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Summary and Outlook