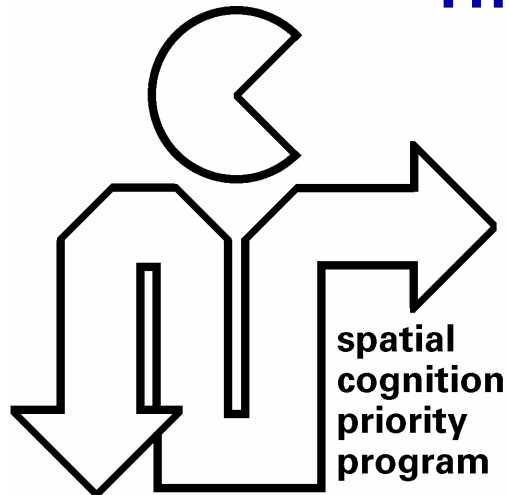


Navigation and Routemark Detection of the Bremen Autonomous Wheelchair

Thomas Röfer and Rolf Müller

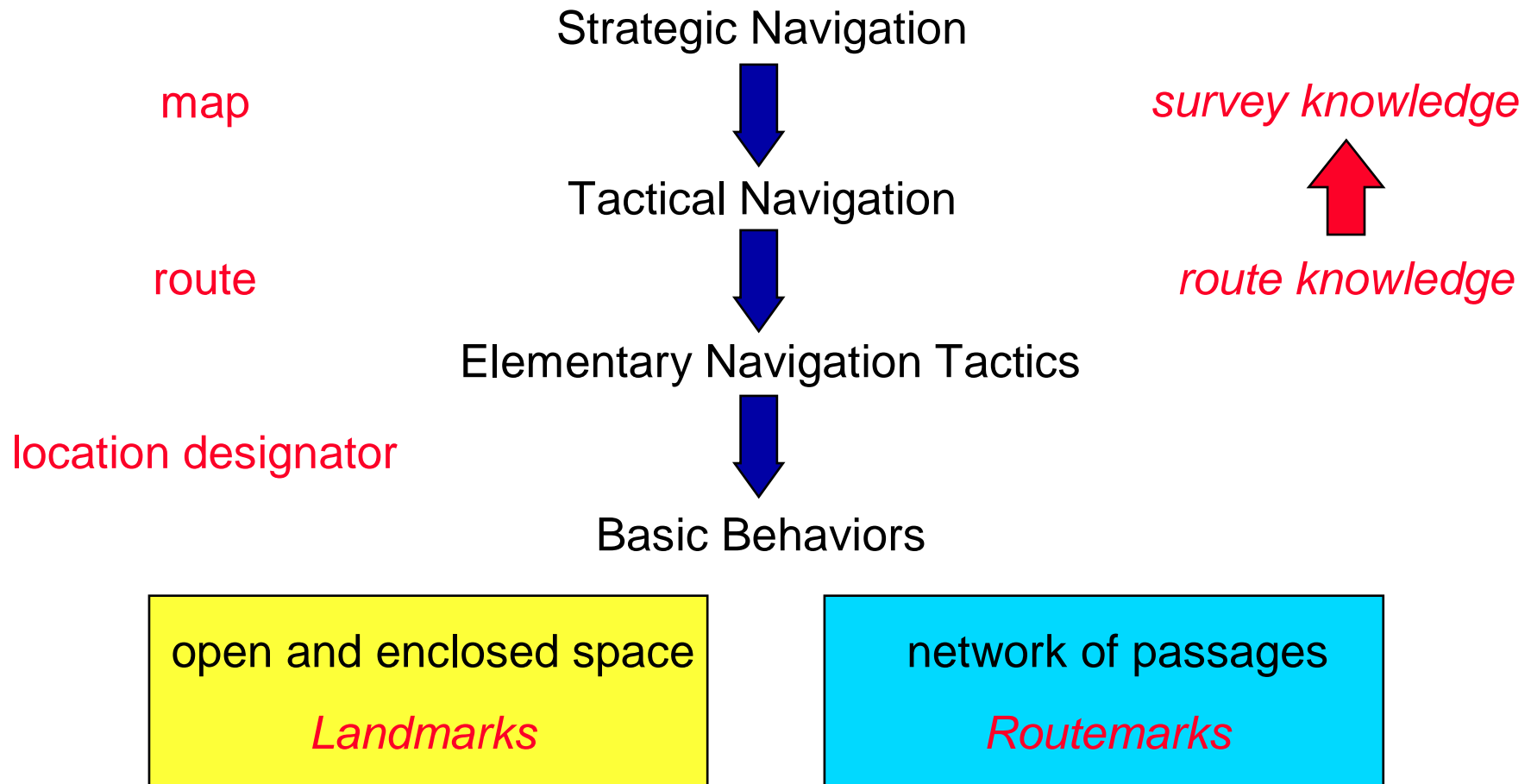


Bremen Institute for Safe and Secure Systems
Center for Computing Technology

University of Bremen

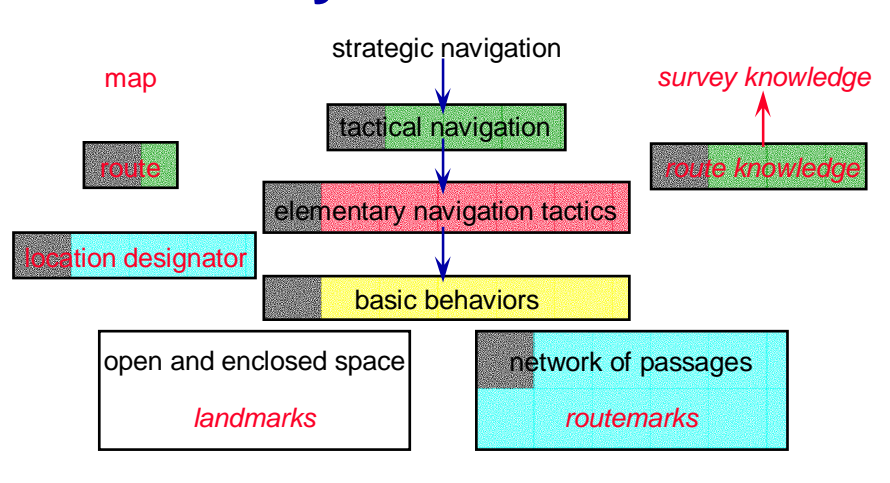
A Taxonomy

Hierarchy of Elementary and Higher-Order Behaviors



Application to Wheelchair Experiments

Taxonomy



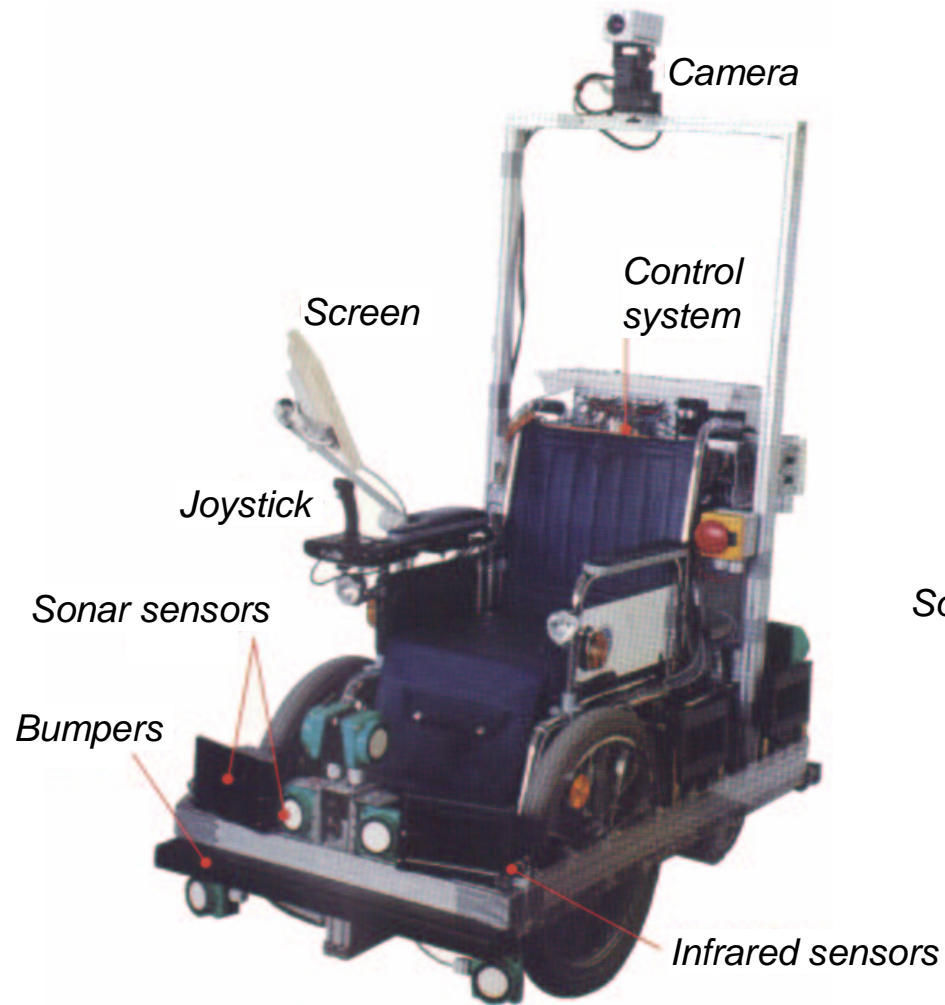
route-following

teaching

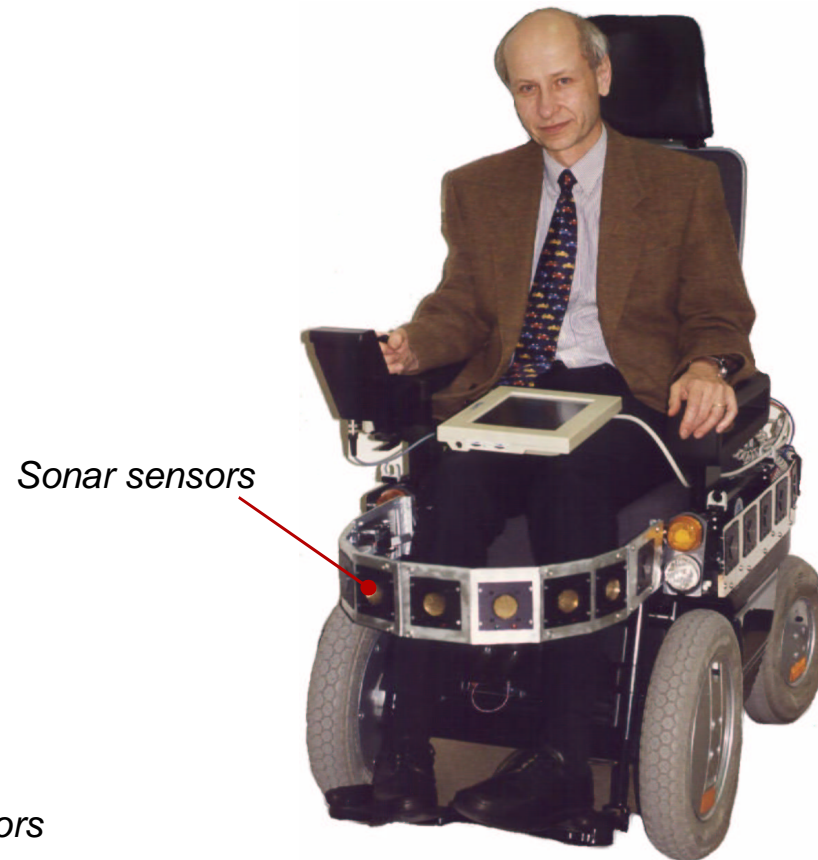
basic behaviors

routemark
constellations

The Bremen Autonomous Wheelchairs

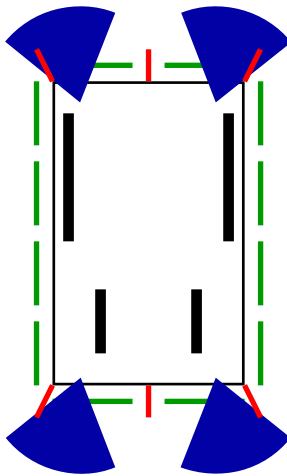


Rolland

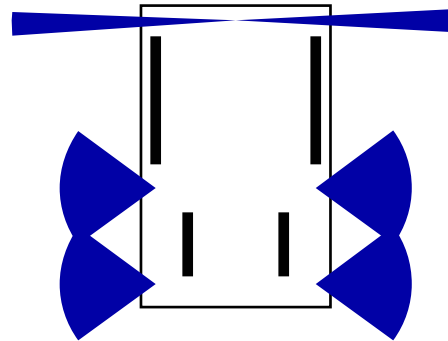


Sensor Control Subsystems

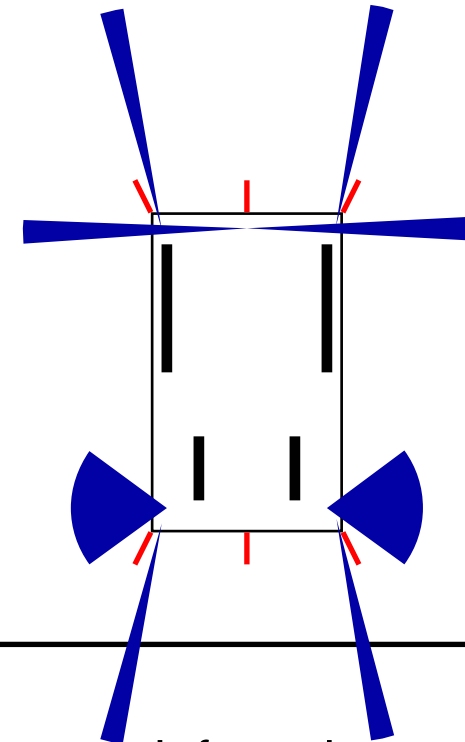
Collision Detection



Steering Restriction



Navigation



| tactile sensors

▶ ultrasonic sensors



— infrared sensors

Local Obstacle Map

Short Term Memory

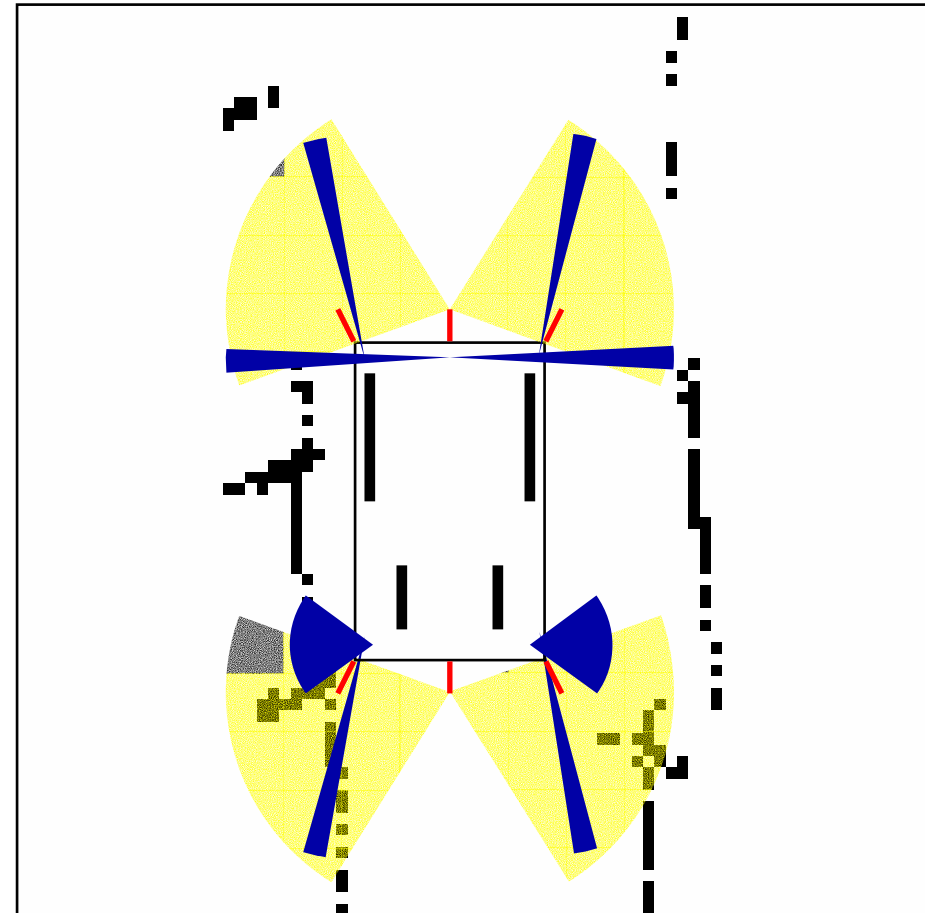
- stores local surroundings of the wheelchair
- size 4 x 4 m²
- entries purged after 30 seconds to cope with dynamic obstacles

Input

-  • 6 narrow-angle and 2 wide-angle ultrasonic sensors
-  • 6 infrared sensors

Output

-  • 4 “virtual sensors”



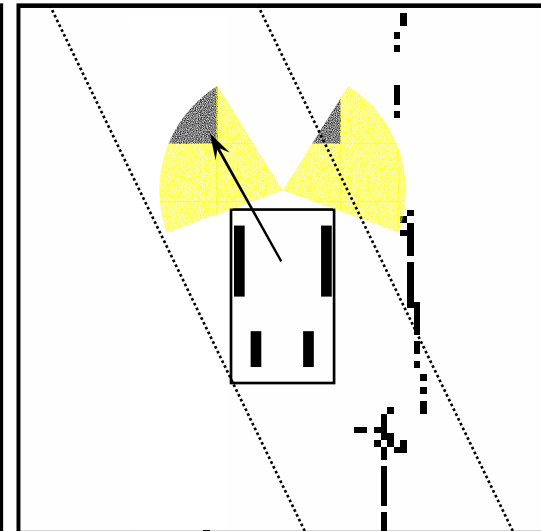
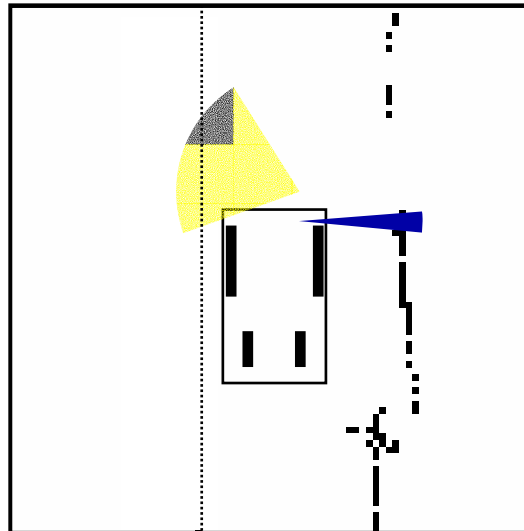
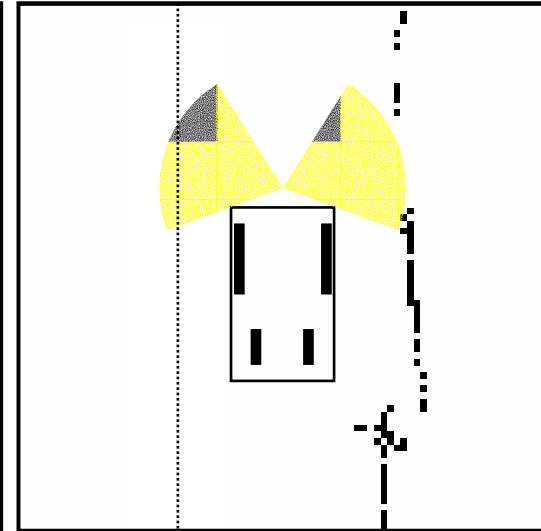
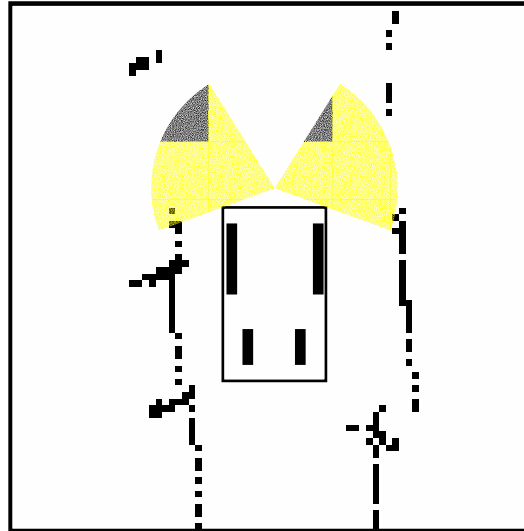
Basic Behaviors

Behaviors

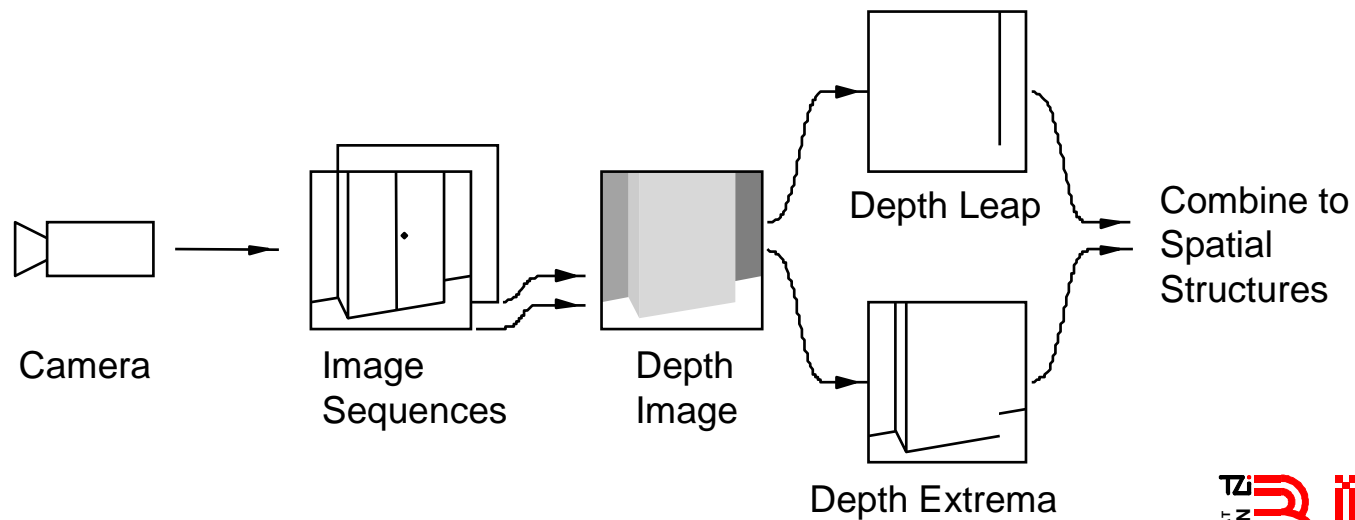
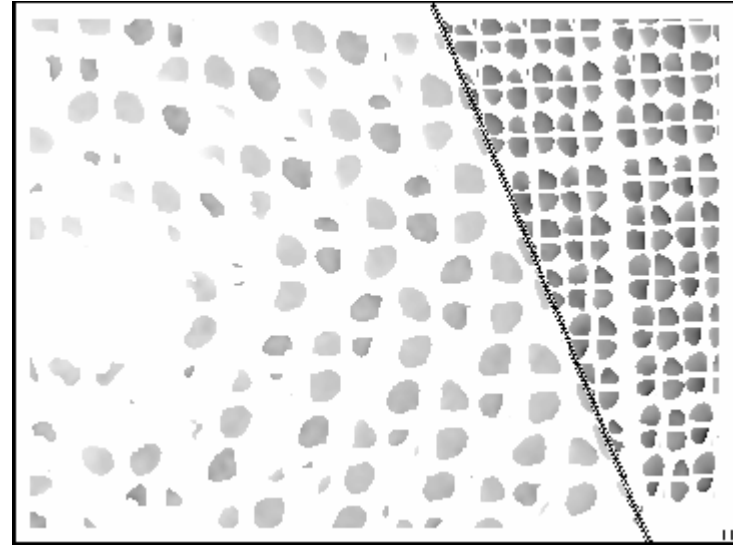
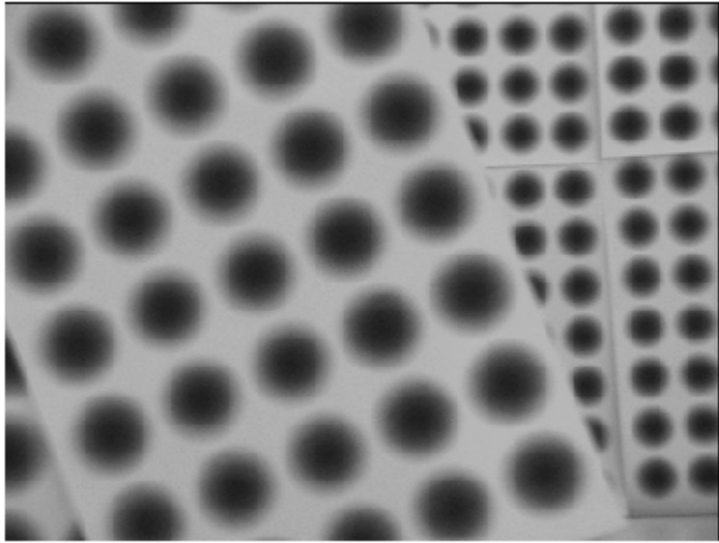
- wall-centering
- wall-following left/right
- turning into left/right door
- direction-following forwards/backwards
- stop

Mode of operation

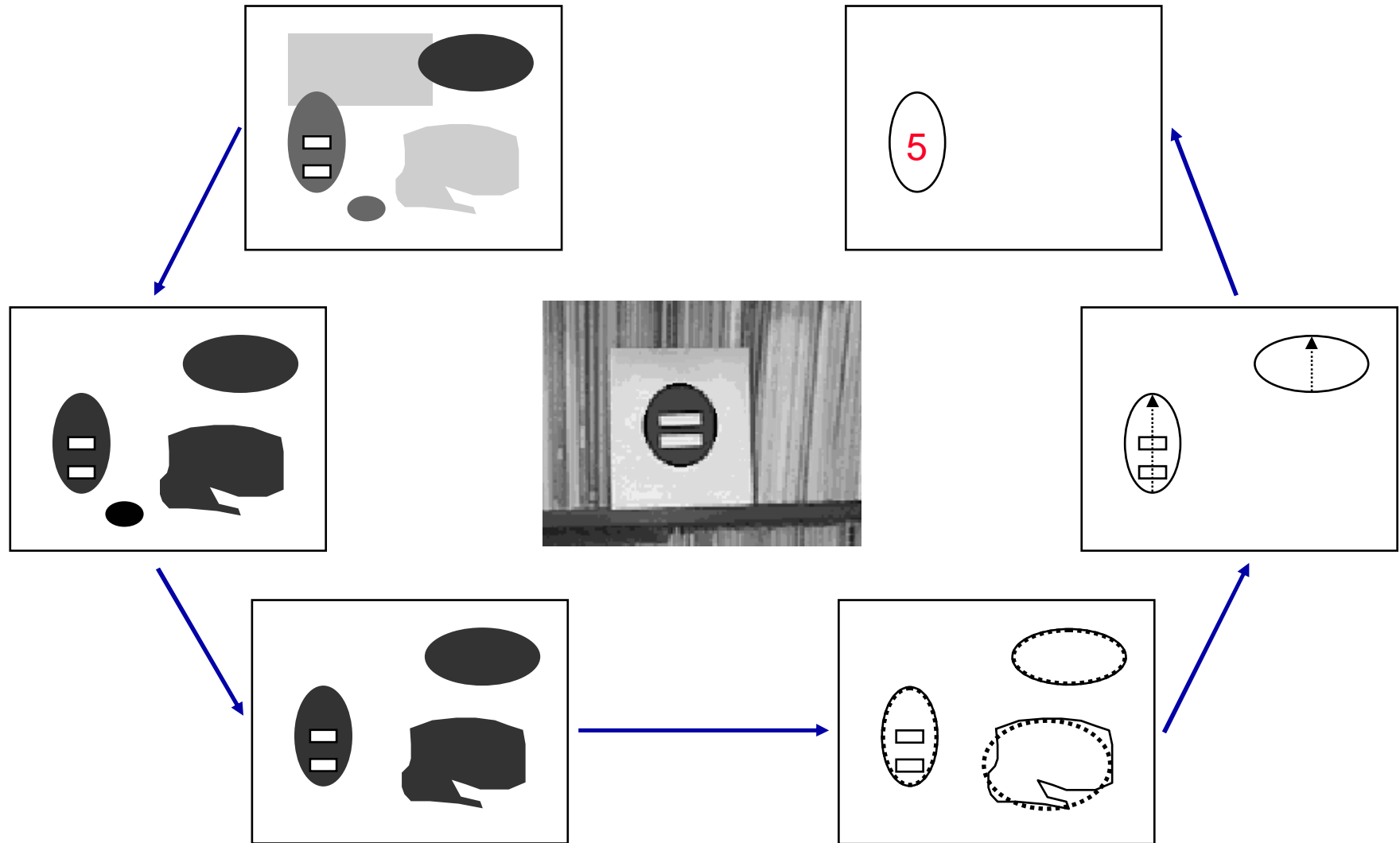
- forward until collision
- then 50 cm back
- forward again



Semi-Local 3D-marks



Artificial Routemarks





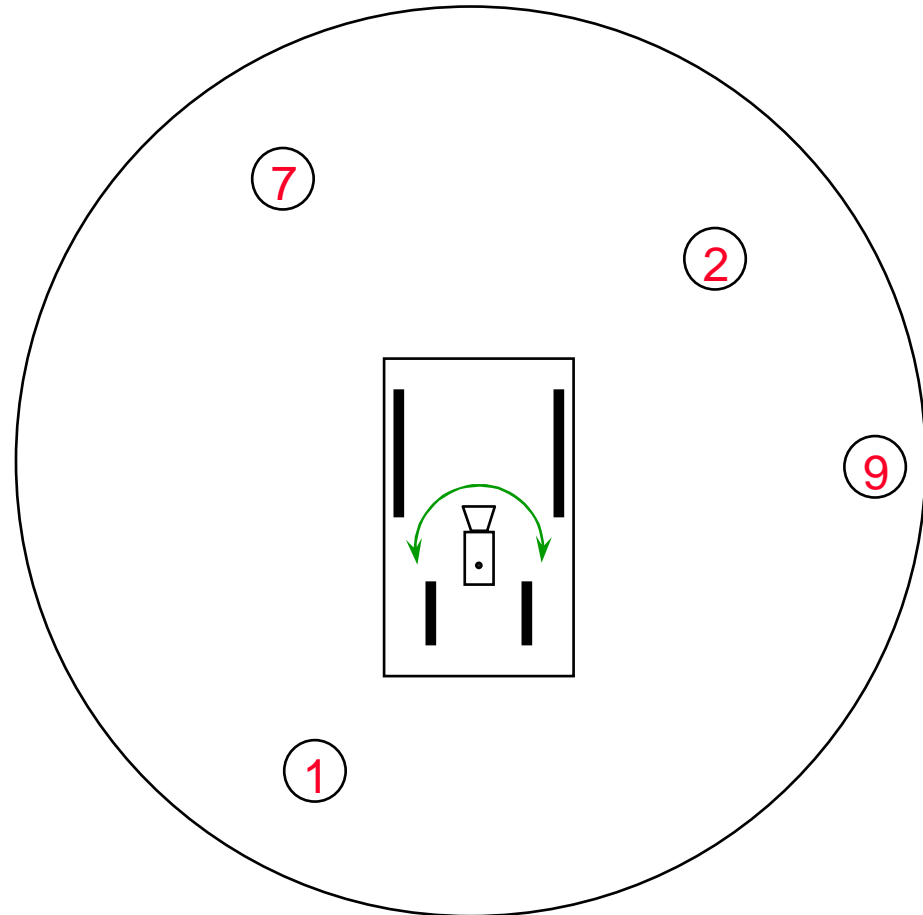
Local Routemark Map

Short Term Memory

- stores routemarks in the local surroundings of the wheelchair
- radius 5 m





Symbols

-  • routemark X
-  • camera on turn-table





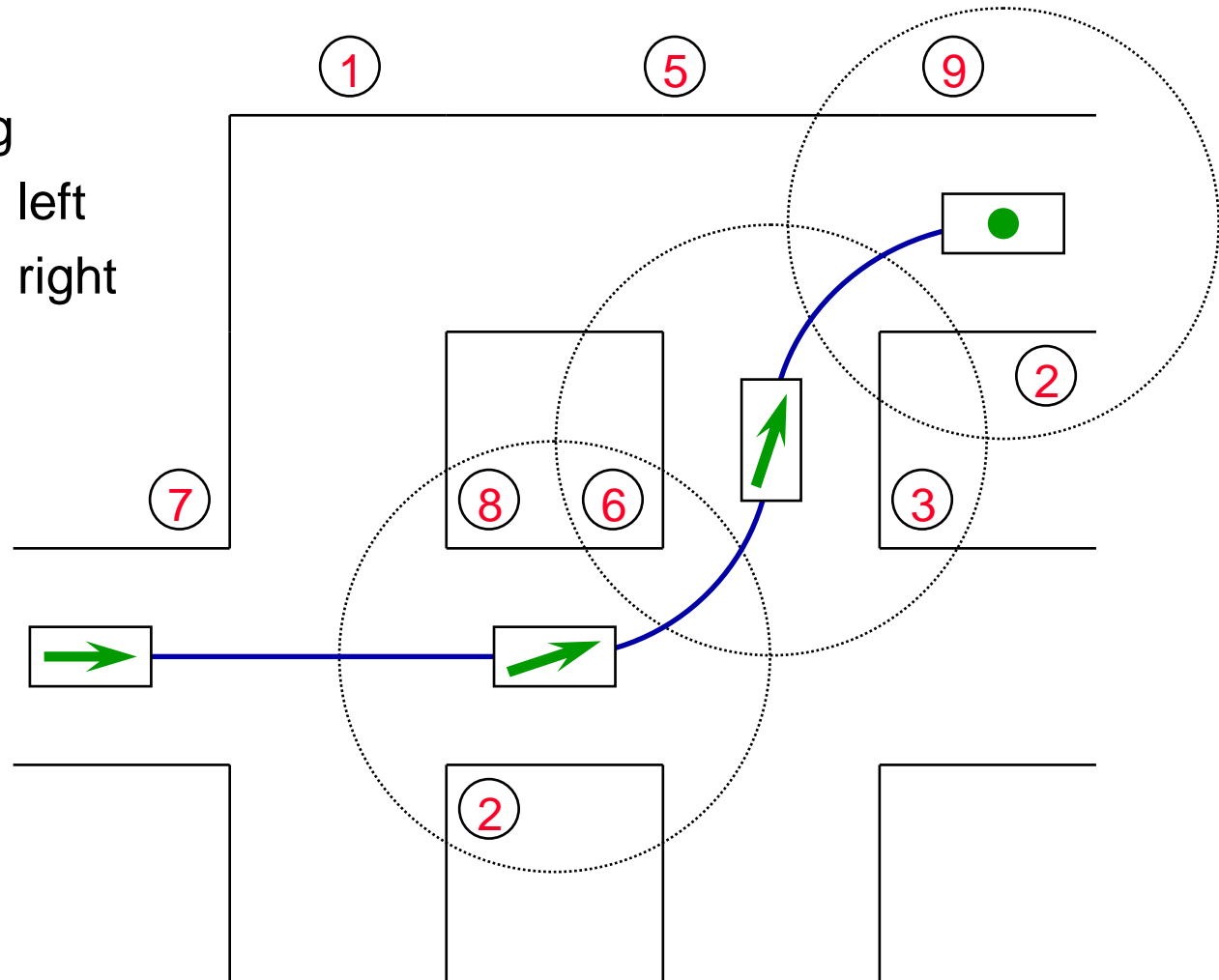
Teaching

Behaviors

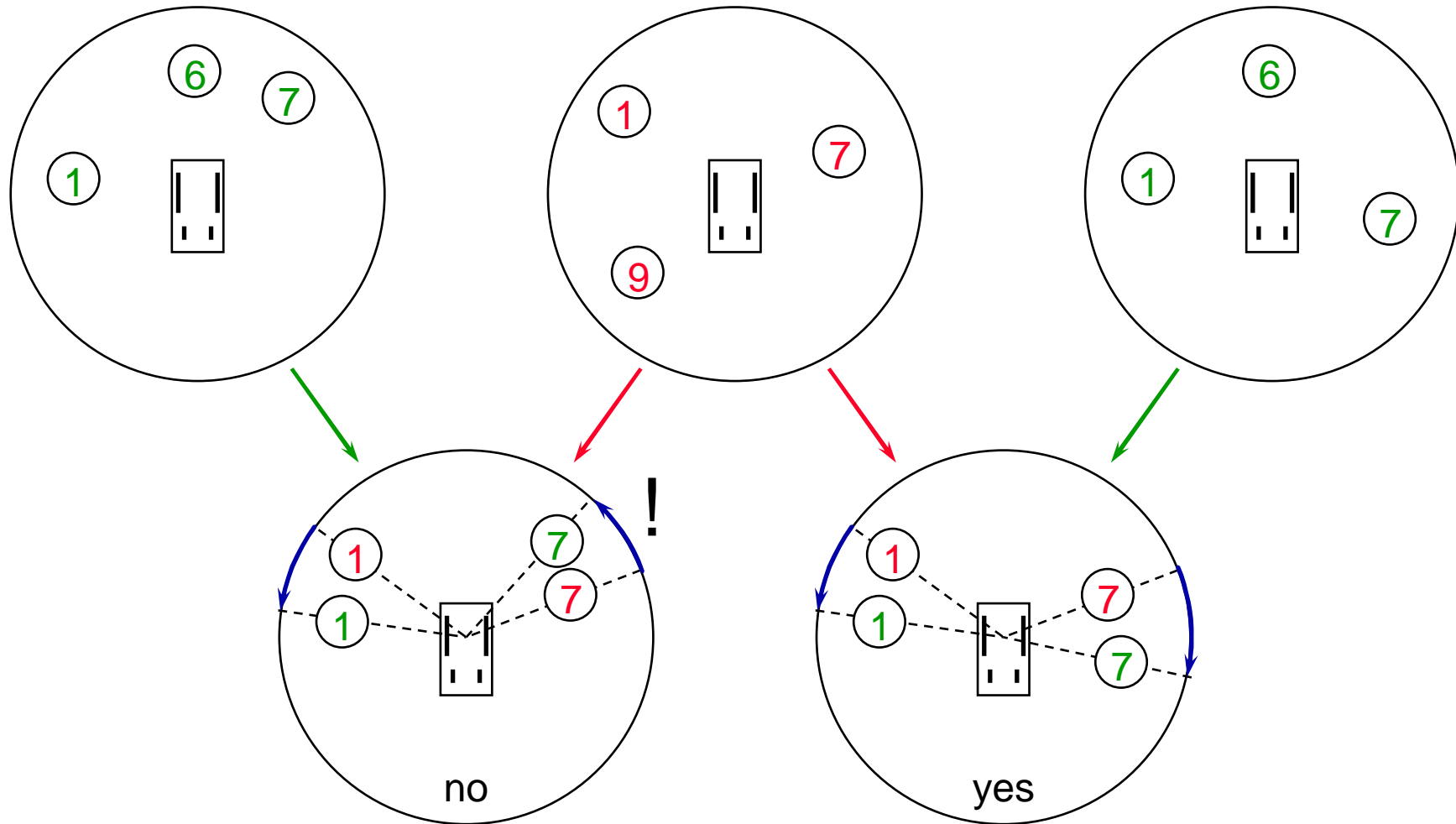
-  • wall-centering
-  • wall-following left
-  • wall-following right
-  • stop

Routemarks

-  • routemark X
-  • routemark constellation



Autonomous Switching of Behaviors



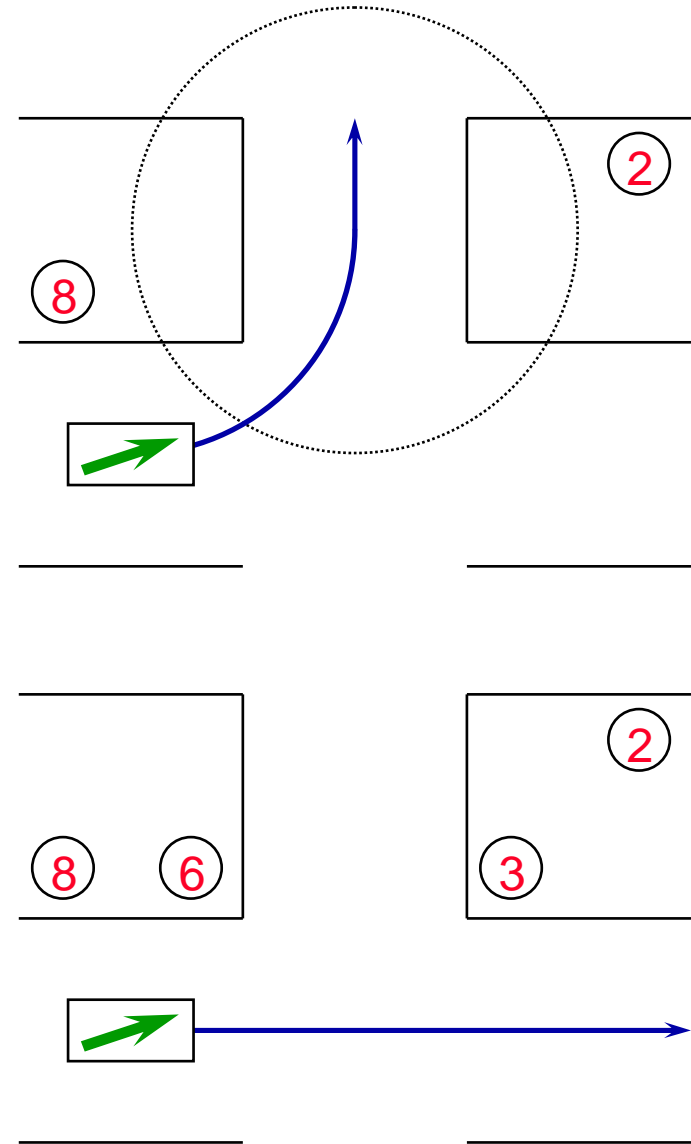
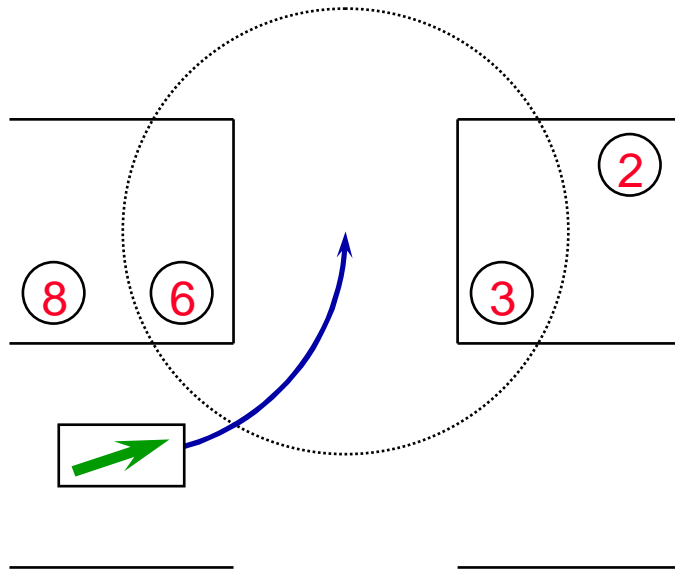
Errors

Possible Errors

- all routemarks are missing
- behavior performed erroneously

Terminating Erroneous Behaviors

- timeout
- other routemarks are found



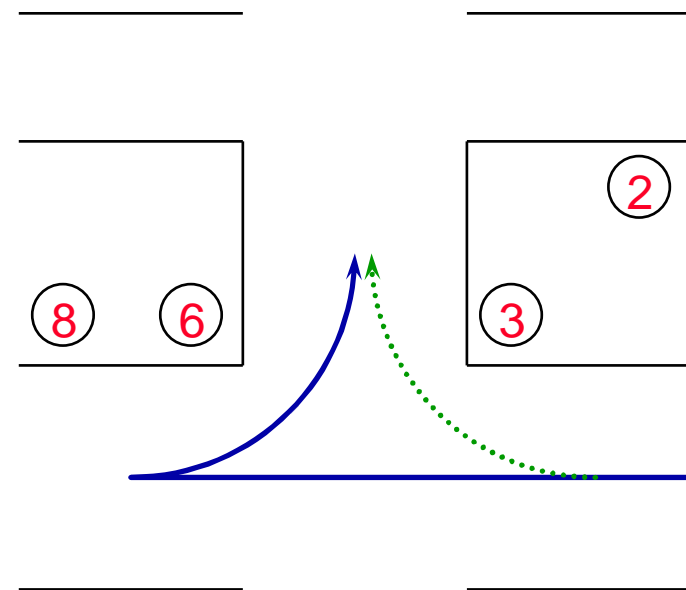
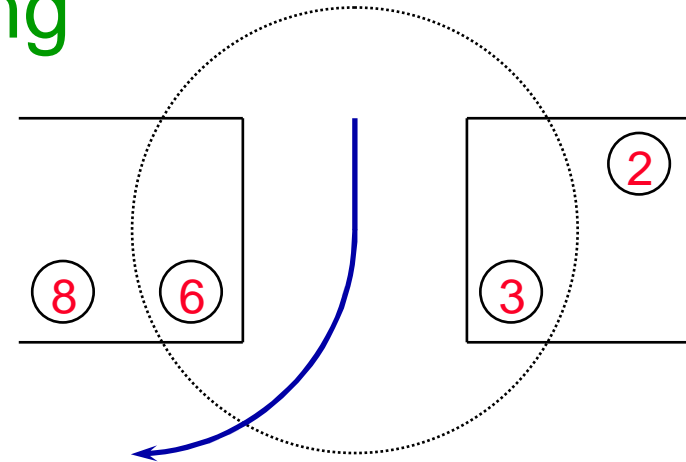
Backtracking

Method

- ←• no inverse behaviors
- threading: recording odometry positions during behavior
- canceling behavior by backtracking recorded positions
- with “direction-following backwards” behavior

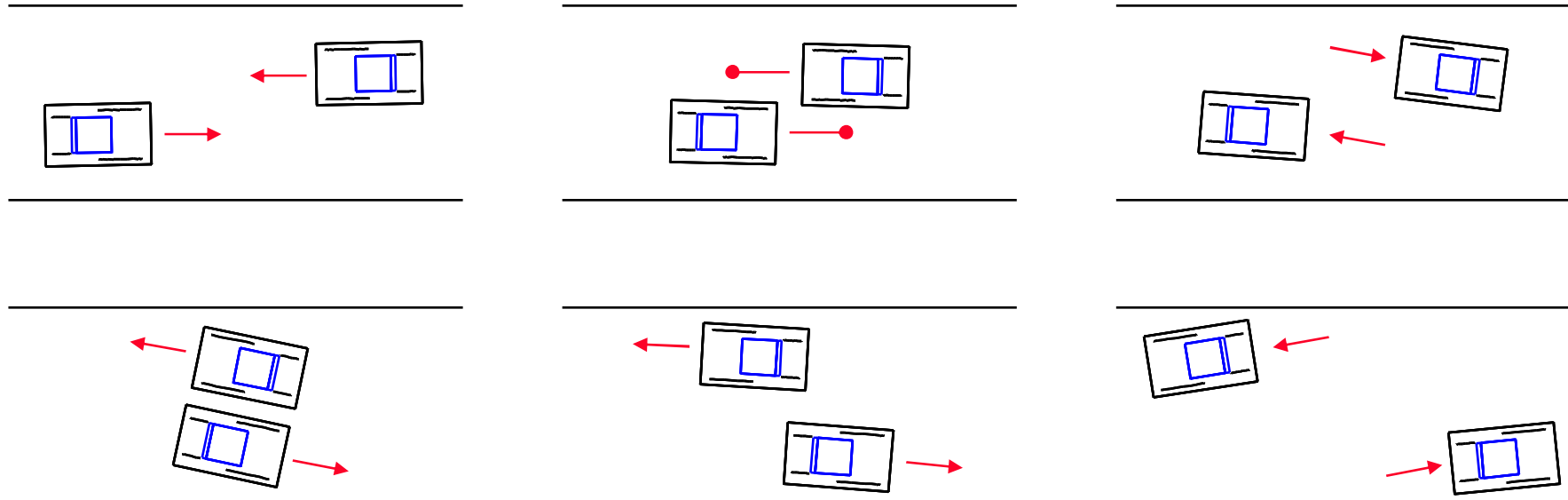
Tactic

- backtracking last segment, searching for routemarks
- repeating last segment
- backtracking last two segments
- repeating last two segments etc.

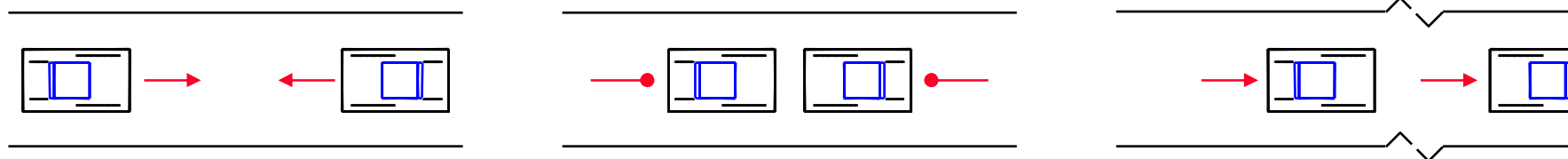


Cooperation of Two Wheelchairs

Wide Corridor (220 cm)



Narrow Corridor (150 cm)



Summary

The Bremen Autonomous Wheelchair

- sensor control subsystems

Basic Behaviors

- local obstacle map

Routemarks

- semi-local 3D-marks
- artificial routemarks
- local routemark map

Route Navigation

- teaching
- backtracking

Cooperation

- through behaviors