Routemark-Based Navigation
of a Wheelchair

Thomas Röfer

DFG Priority Programme "Spatial Cognition"
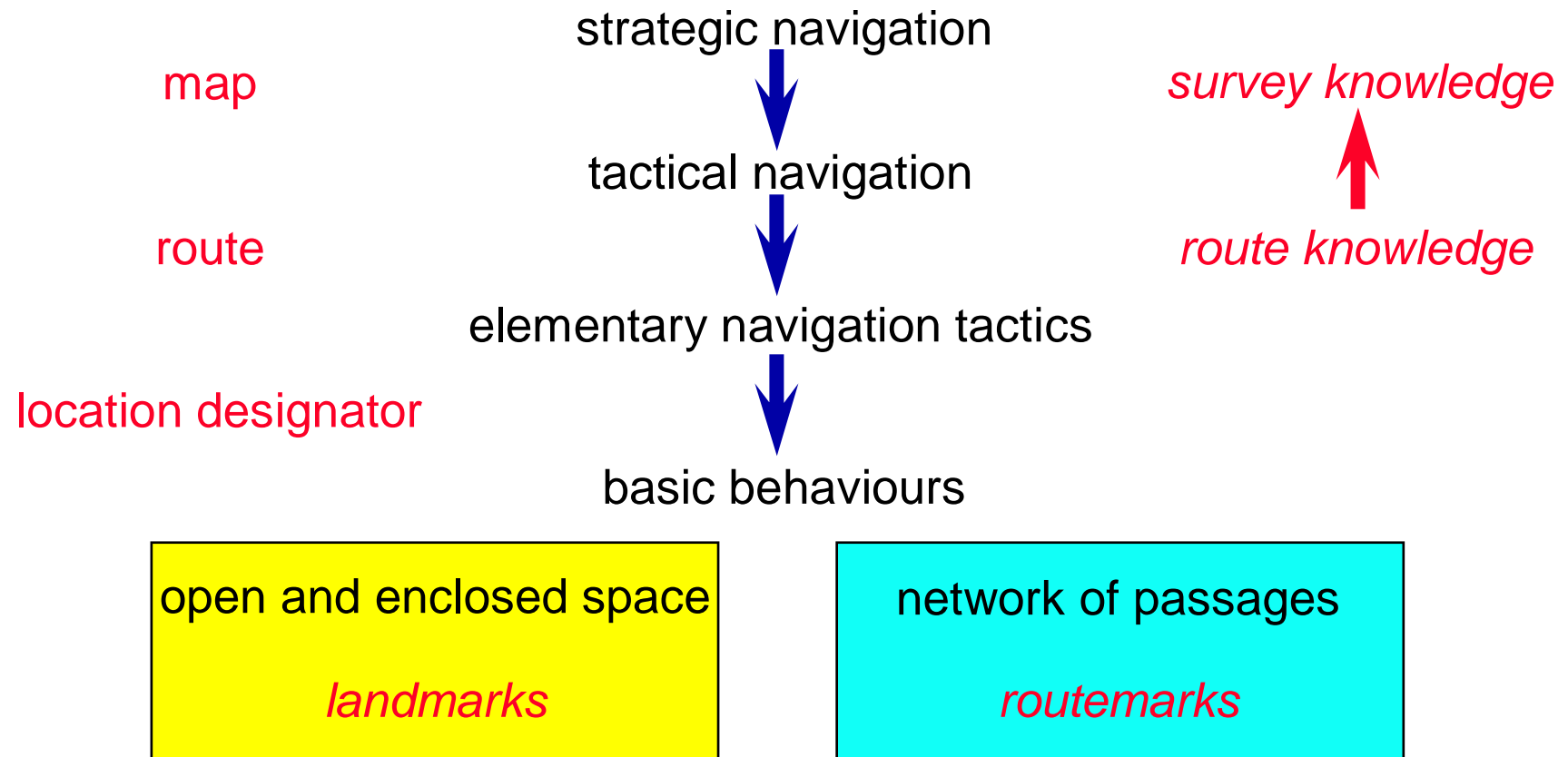
Prof. B. Krieg-Brückner
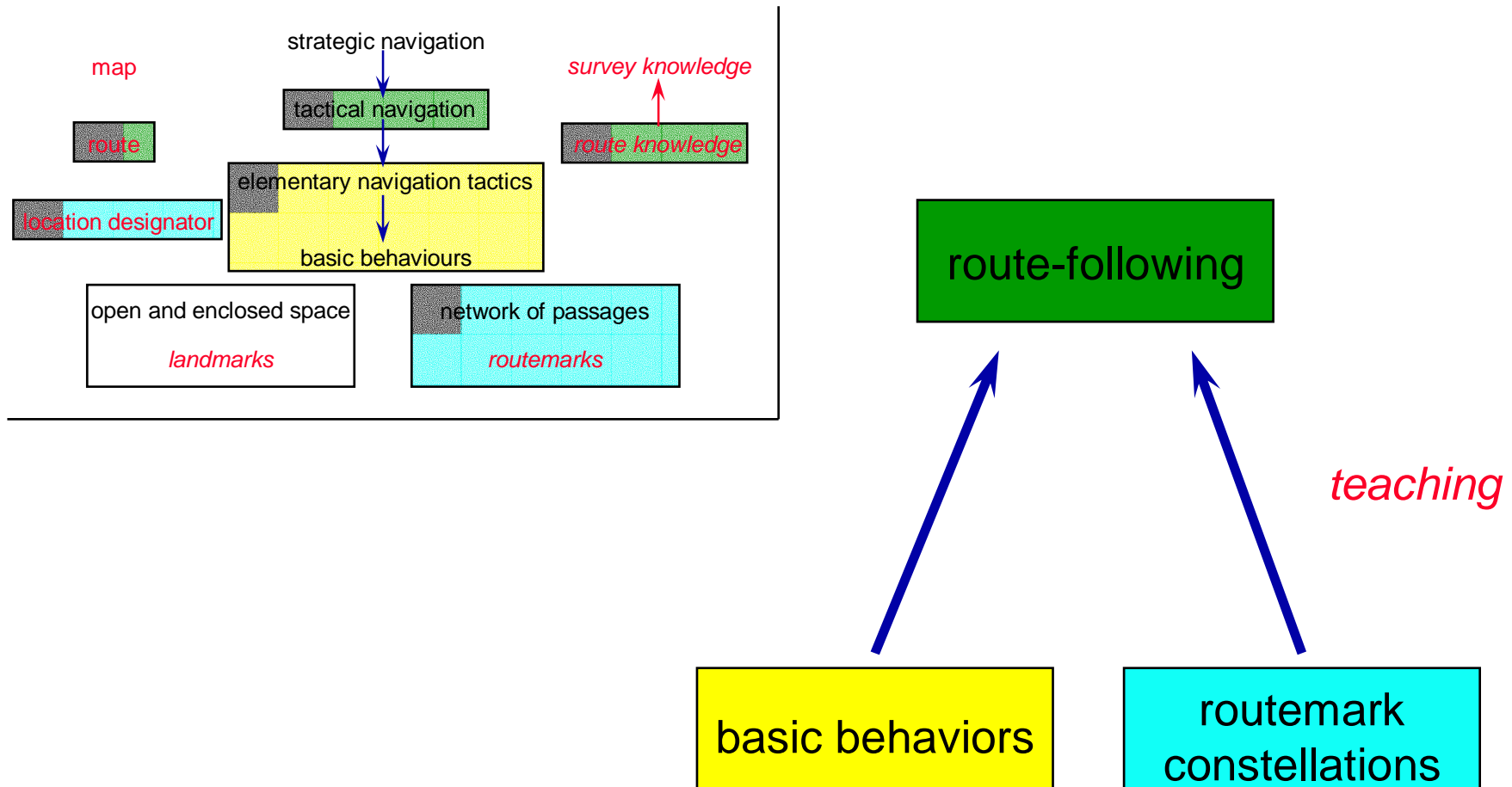**Bremen Institute for Safe and Secure Systems**
Center for Computing Technology

Bremen University, Germany

Overview

strategic navigation

map

$\downarrow$

survey knowledge

$\uparrow$

tactical navigation

route

route knowledge

$\downarrow$

elementary navigation tactics

location designator

$\downarrow$

basic behaviours

open and enclosed space

landmarks

network of passages

routemarks

State of Our Work

strategic navigation

map

tactical navigation

survey knowledge

route

route knowledge

location designator

elementary navigation tactics

basic behaviours

open and enclosed space

landmarks

network of passages

routemarks

route-following

teaching

basic behaviors

routemark constellations

The Bremen Autonomous Wheelchair

Vehicle

- 134 cm x 72 cm
- front driving axle
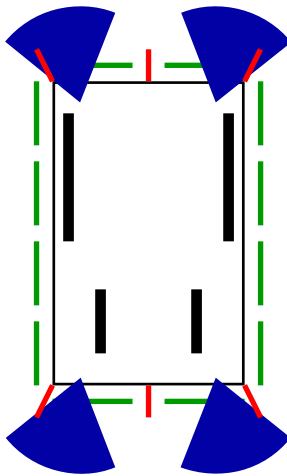- back steering axle
- on-board PC + 5 microcontrollers

Sensors

- 12 tactile sensors
- 6 infrared sensors
- 8 wide-angle ultrasonic sensors (80°)
- 8 narrow-angle ultrasonic sensors (7°)
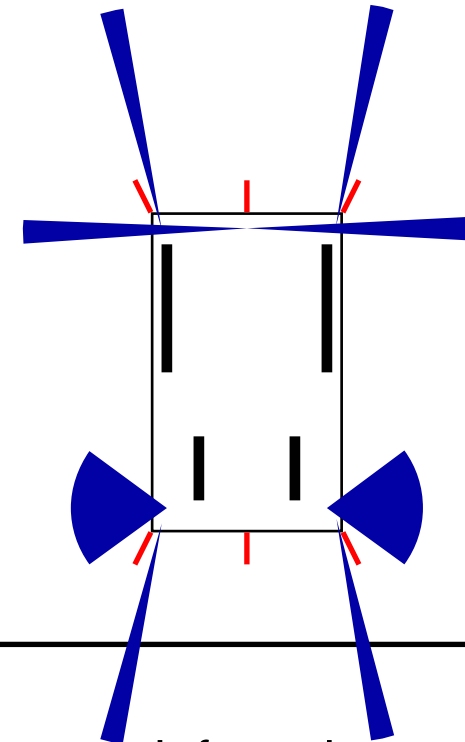- 1 camera on a pan-tilt-head
- odometry

Sensor Control Subsystems

Collision Detection

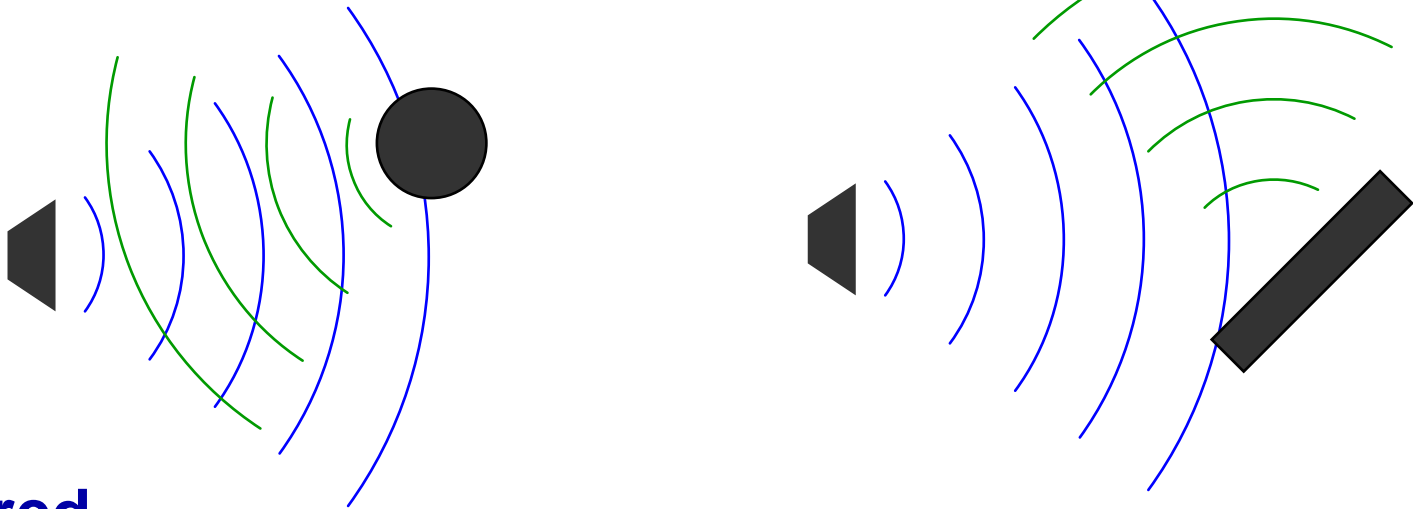**Steering Restriction**
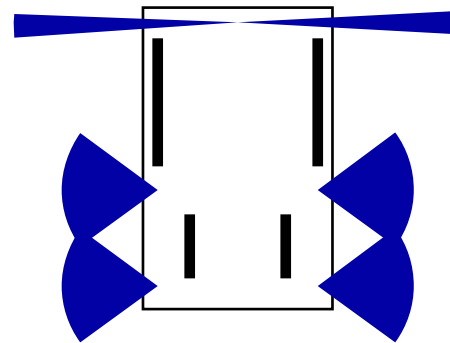
Navigation

| tactile sensors

▶ ultrasonic sensors

| infrared sensors

Sensor Weaknesses

Ultrasonic

- reflections: diagonal, smooth surfaces
- absorption: soft surfaces

Infrared

- perceived too late: dark, unreflective surfaces
- perceived too early: mirroring surfaces
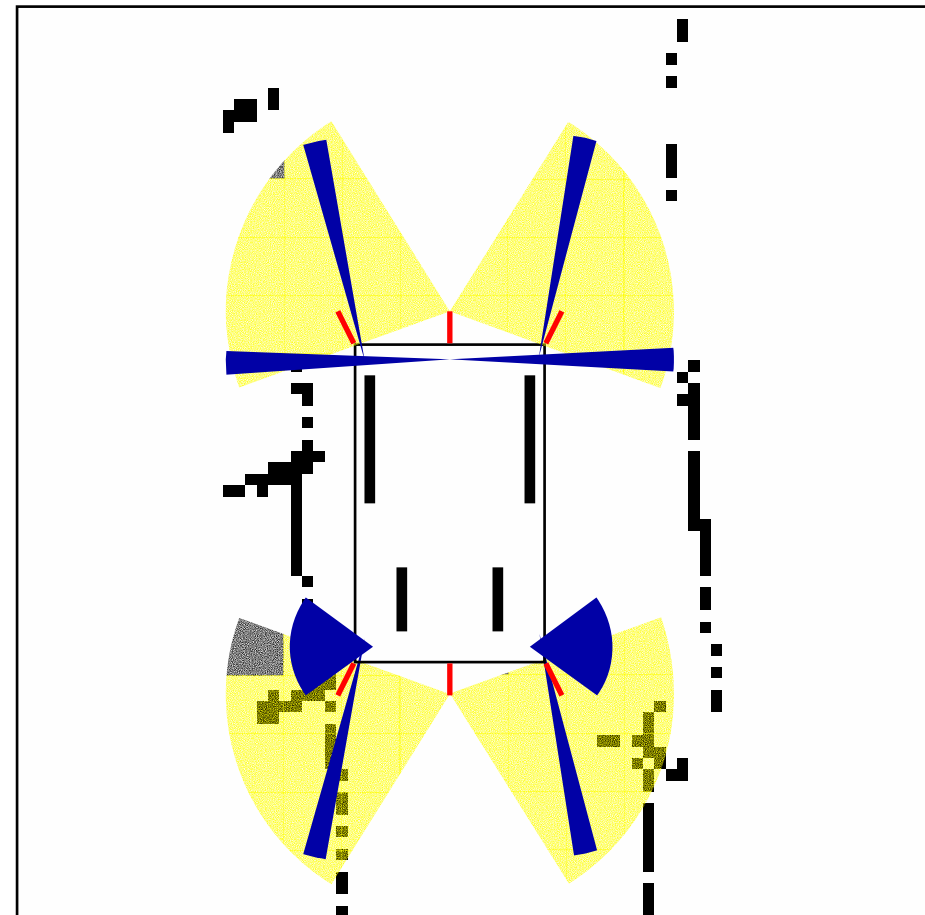
Local Obstacle Map

Properties

- "short term memory"
- stores local surroundings of the wheelchair
- size 4 x 4 m²
- entries are forgotten after 30 seconds

Input

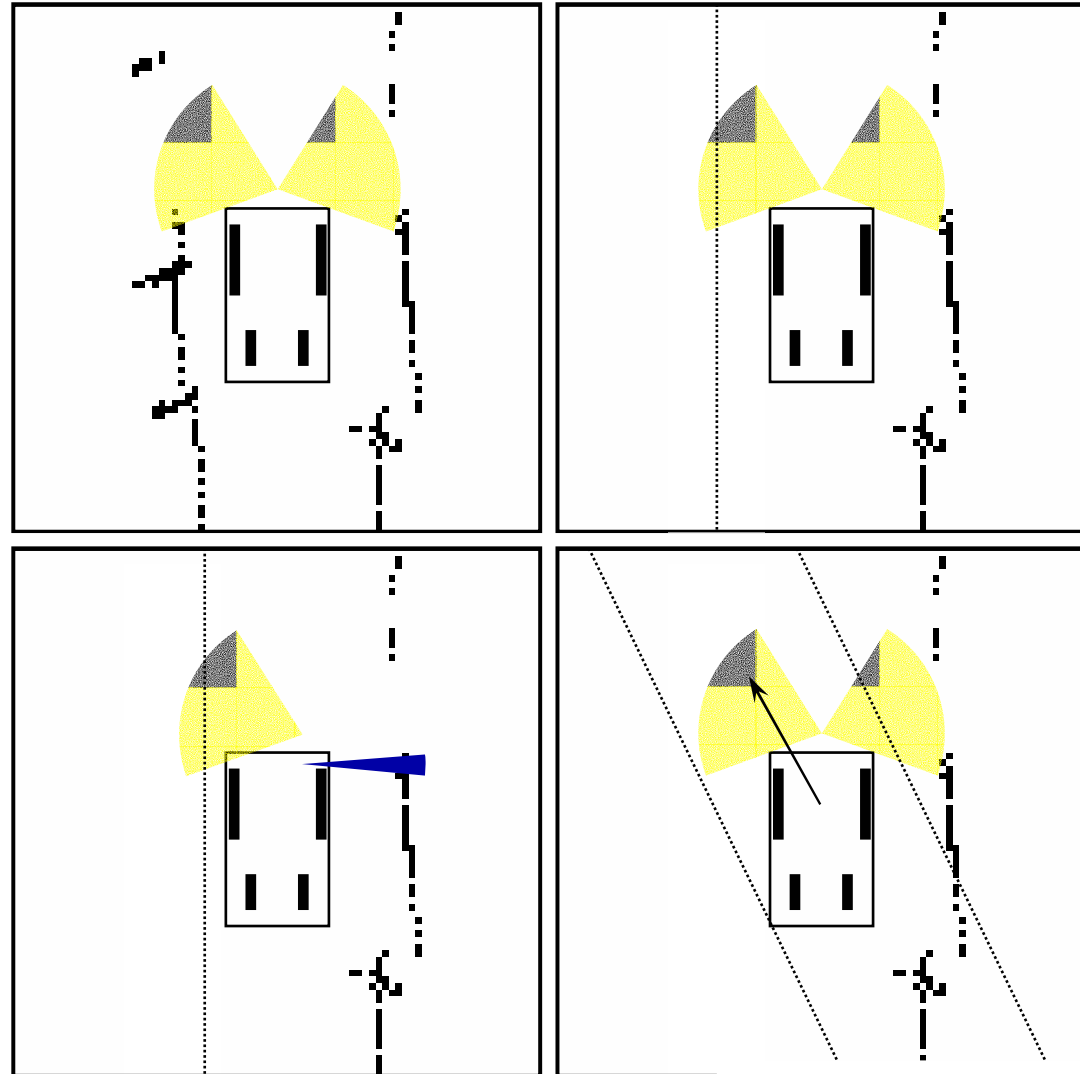- 6 narrow-angle and 2 wide-angle ultrasonic sensors
- 6 infrared sensors

Output

- 4 "virtual sensors"

Basic Behaviors

Behaviors

- wall-centering
- wall-following left/right
- turning into left/right door
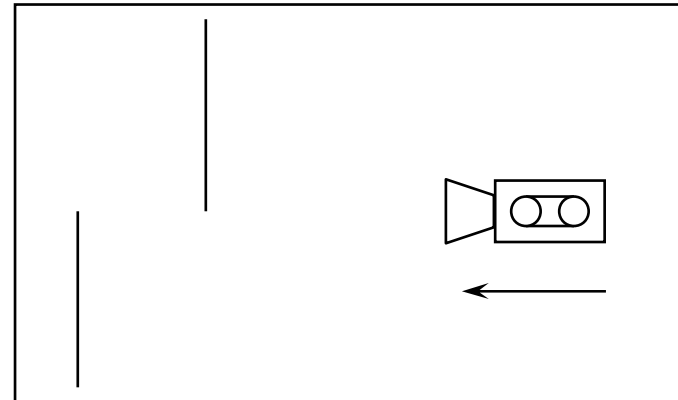- direction-following forward/backward
- stop

Mode of operation

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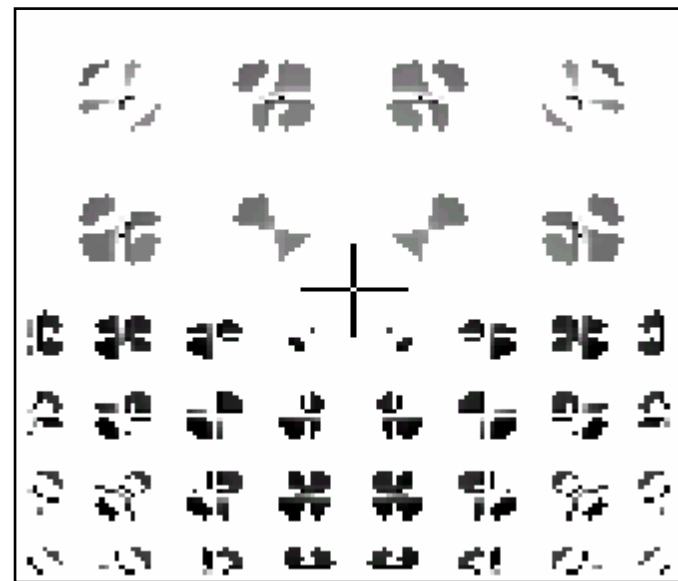- again forward

Semi-Local 3D-marks

Preliminary Work

image sequence

$\rightarrow$ small (semi-local) image regions

$\rightarrow$ normal flow field

$\rightarrow$ focus of expansion

Future

$\rightarrow$ depth

$\rightarrow$ semi-local 3D-structures

$\rightarrow$ 3D-marks

Advantages

- efficient (realtime)
- robust against noise

Artificial Routemarks
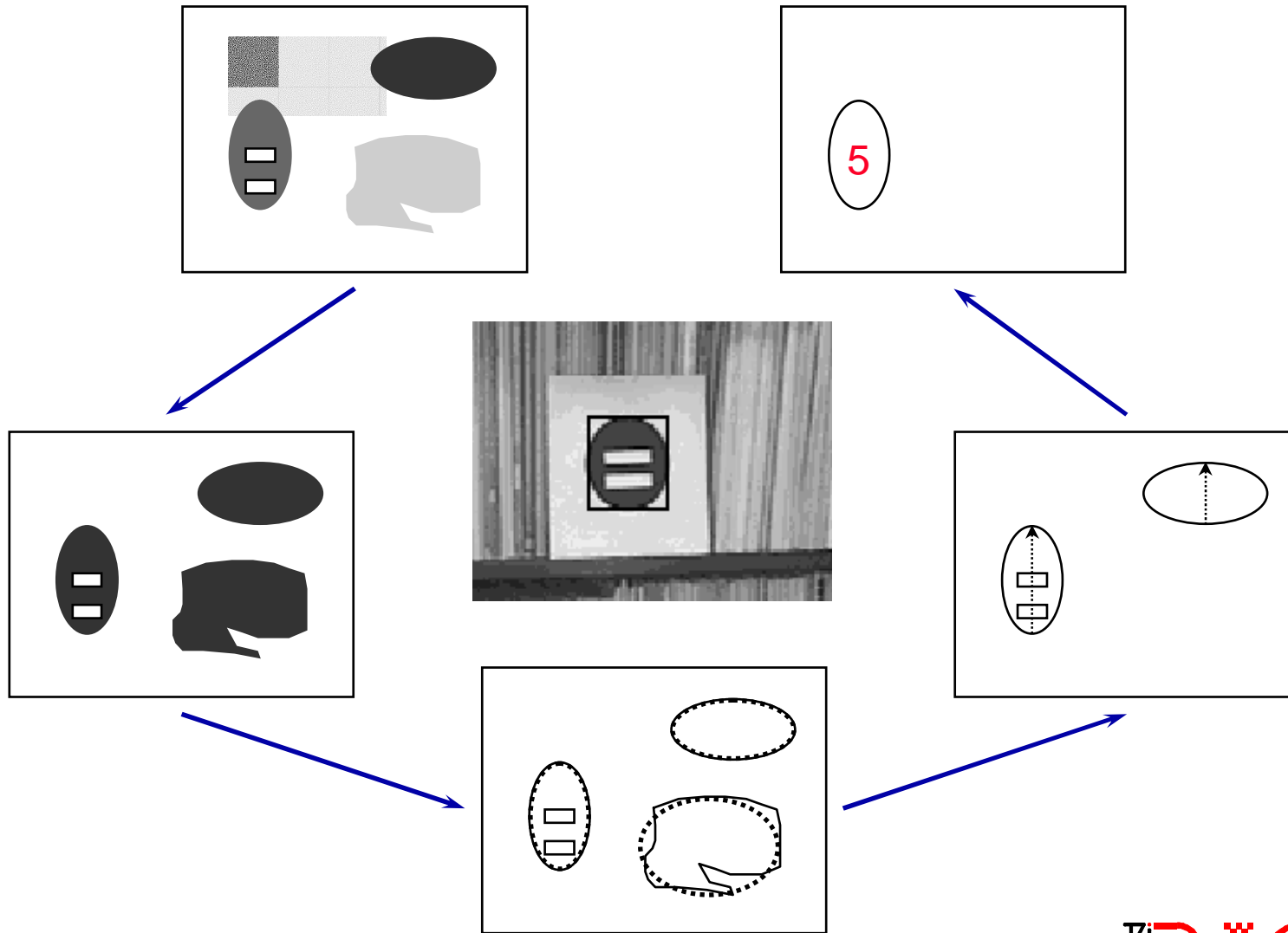
Local Routemark Map

Properties

- "short term memory"
- stores routemarks in the local surroundings of the wheelchair
- radius 5 m

Symbols

- routemark X
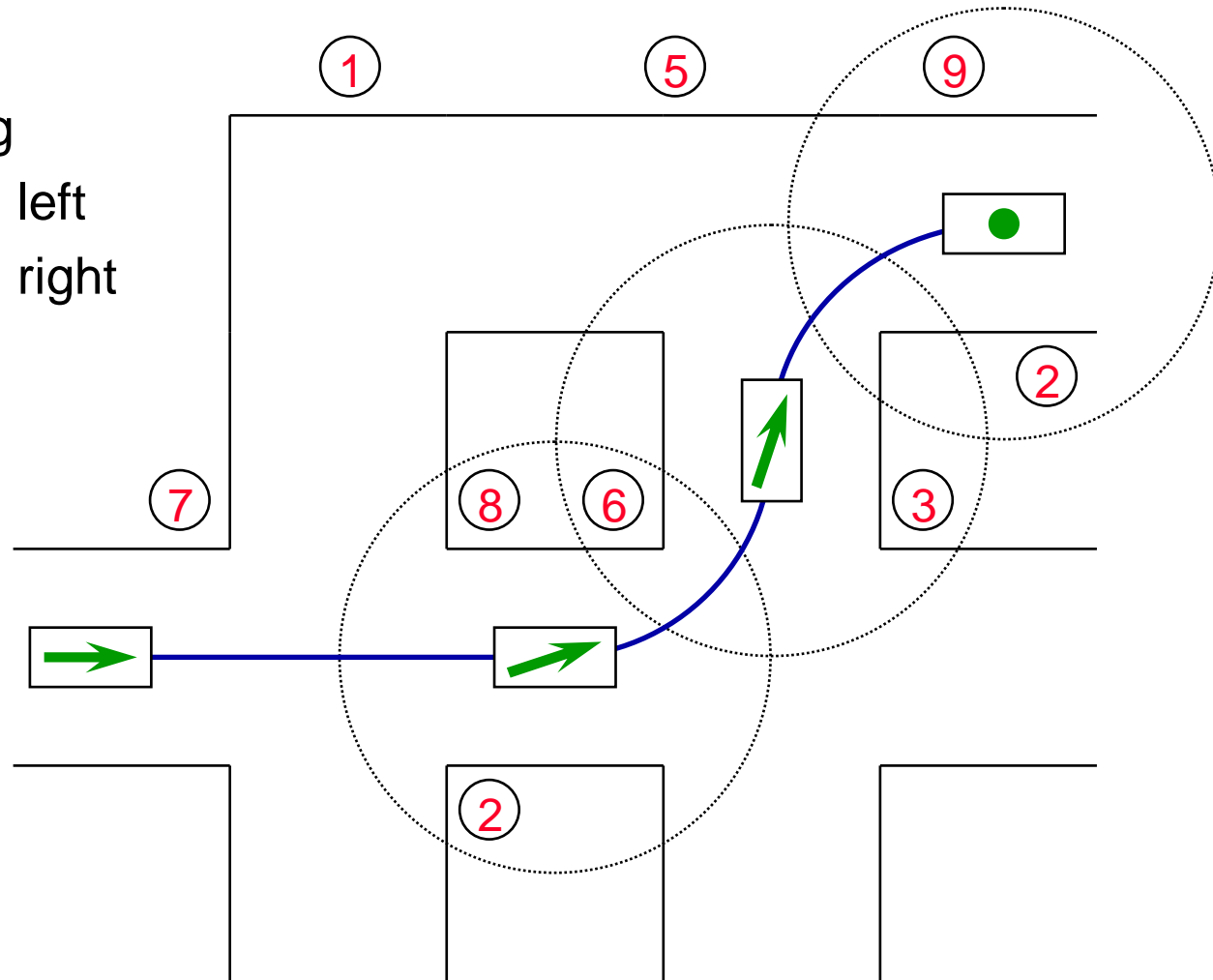- camera on turning pan-tilt-head
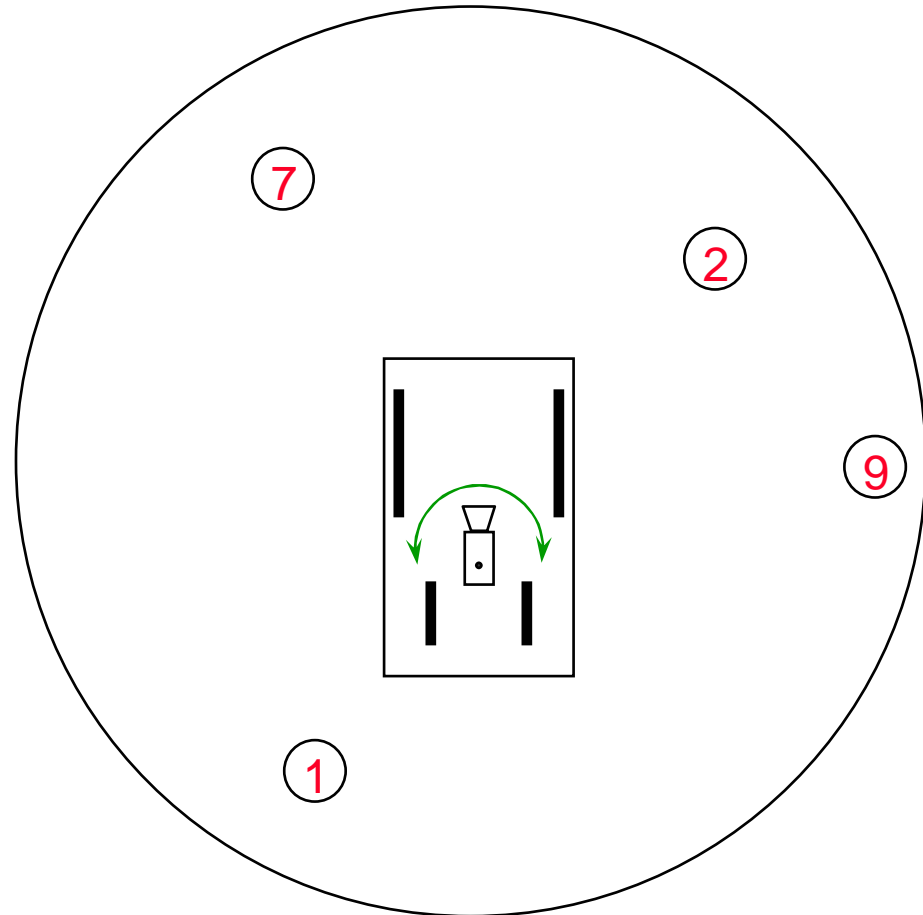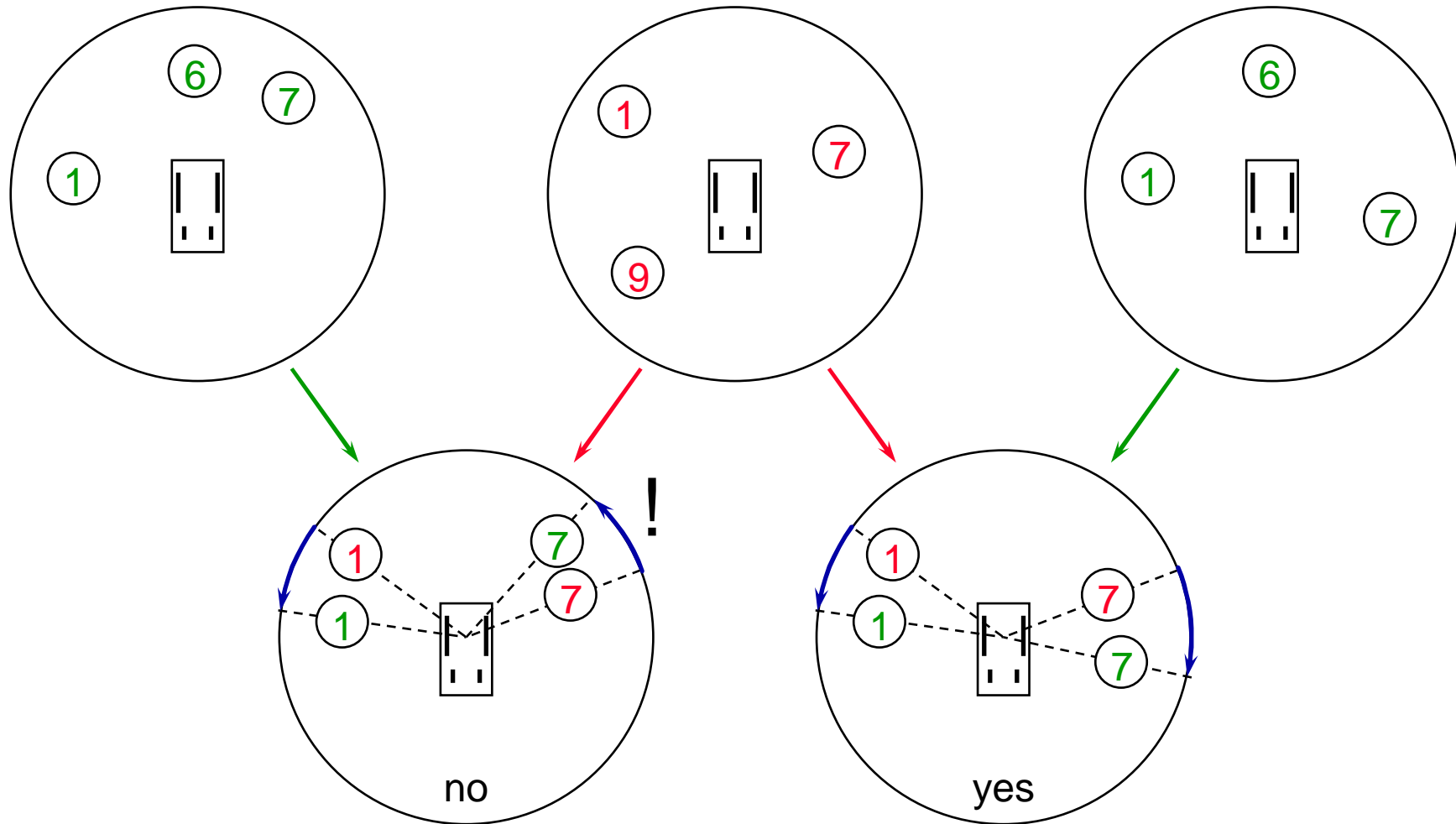
Teaching

Behaviors

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

Routemarks

- X • routemark X
- • routemark constellation

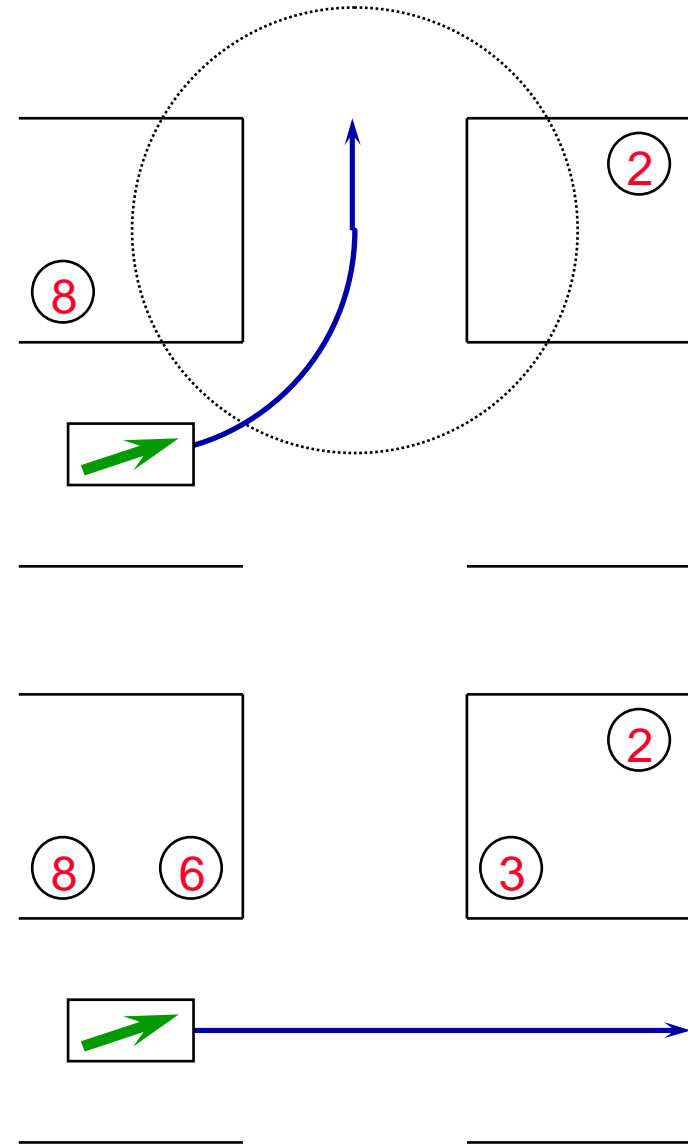# Autonomous Switching of Behaviors
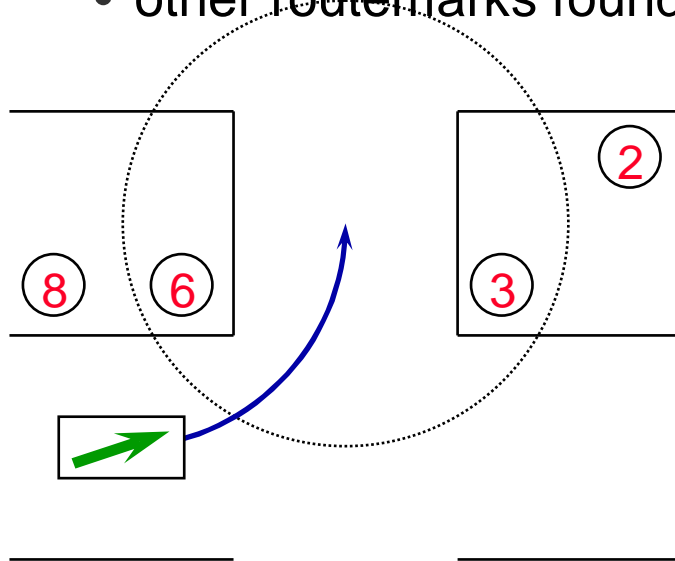

no

yes

13

Errors

Possible Errors

- all routemarks missing
- behavior performed erroneously

Finshing Erroneous Behaviors

- timeout
- other routemarks found

Backtracking

Method

- no inverse behaviors
- instead: recording odometry positions during behavior
- canceling behavior by backtracking recorded positions
- with "direction-following backward" behavior

Strategy

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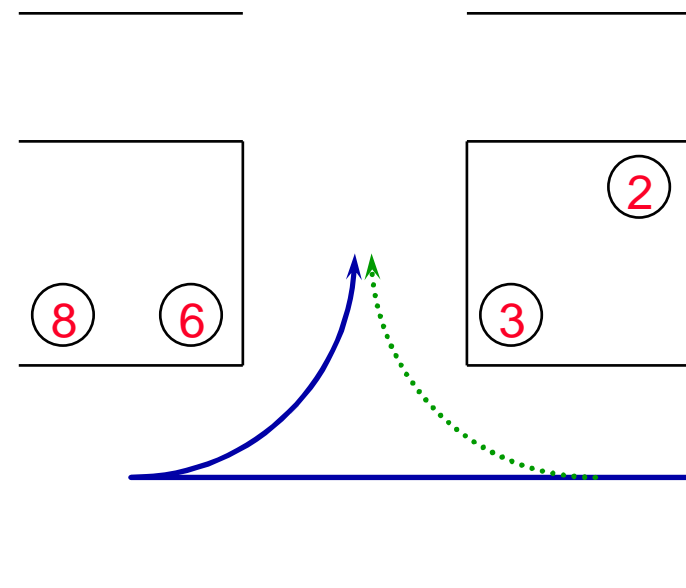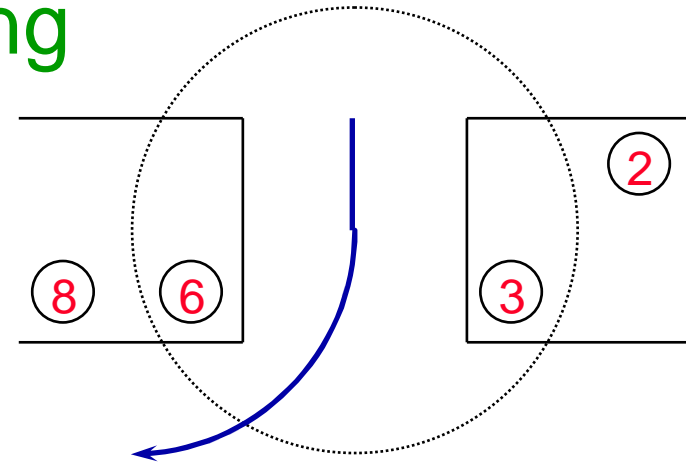
Summary

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
- autonomous switching of behaviors
- errors
- backtracking