Wheelchair Navigation System - Simple Explanation

Overview

The autonomous wheelchair navigates from its starting position to an elevator, travels between floors, and exits. The system guides the wheelchair through rooms, doorways, and the elevator automatically.

Quick Navigation

This document includes detailed flowcharts for:

- **[Door Crossing Phases](#door-crossing-flowchart)** - 4 phases with visual diagram
- **[Elevator Entry Phases](#elevator-entry-flowchart)** - 6 phases with visual diagram
- **[Complete System Flowchart](#flowchart)** - Overall navigation process

Navigation Process

1. System Startup

Map Loading

- Wheelchair reads a pre-made map of the building
- Map shows walls, rooms, doors, and elevator location
- Building layout includes multiple rooms connected by doorways

Route Planning

- System calculates best path from current location to elevator

- Breaks journey into segments: Room A → Door → Room B → Door → Room C → Elevator
- Plans specific points (waypoints) to follow in each room

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2. Main Navigation Cycle

The wheelchair repeats this cycle continuously until reaching the destination:

Step 1: Read Sensors

- Laser scanner detects surrounding obstacles and walls
- Position tracker determines current location on map
- Camera identifies nearby objects

Step 2: Understand Environment

- Identifies objects (people, furniture, walls)
- Measures distance to obstacles
- Confirms current position on map

Step 3: Decide Action

System determines what to do based on current situation:
- **Following Path:** Continue moving along planned route
- **Entering Door:** Navigate through doorway to next room
- **Entering Elevator:** Special sequence to enter and exit elevator

Step 4: Calculate Movement

- Determines safe direction to move
- Avoids obstacles detected by sensors
- Adjusts speed based on proximity to objects
- Maintains alignment with planned path

Step 5: Execute Movement

- Sends movement commands to wheelchair motors

- Moves forward at calculated speed

- Turns to follow path or avoid obstacles

Step 6: Check Progress

- Verifies if current segment completed

- Advances to next navigation segment when ready

- Updates display showing current status

Navigation Segments

Segment Type 1: Following Path in a Room

What happens:

- Wheelchair follows a series of guide points through the room

- Continuously checks sensors to avoid obstacles

- Adjusts path if objects block the way

- Moves toward the room exit (doorway)

Progress tracking:

- Marks each guide point as "reached" when wheelchair passes it

- Moves to next guide point automatically

- Completes when all guide points in room are reached

Duration: 10-60 seconds per room

Segment Type 2: Passing Through a Doorway

Phase 1: Approach Door

- Wheelchair positions itself 1 meter in front of doorway

- Aligns to face the door straight-on

- Stops to prepare for door crossing

Phase 2: Face Exit Direction

- Rotates to point toward the next room's path

- Ensures proper orientation before crossing

- Aligns with where it needs to go after passing through

Phase 3: Check Door is Open

- Laser scanner looks for obstacles in doorway

- **Door Open:** Few or no obstacles detected → proceed

- **Door Closed:** Solid surface detected → trigger automatic door

- Performs small back-and-forth movements - Activates motion sensor on automatic door - Waits for door to open

- Confirms door is passable before moving

Phase 4: Cross Threshold

- Moves straight through doorway at steady speed

- Travels 2 meters forward to clear the door completely

- Uses distance measurement, not position (more reliable during crossing)

Phase 5: Continue in Next Room

- Loads guide points for the new room

- Begins following path through next room

Duration: 5-15 seconds per door

Door Crossing Flowchart

```mermaid flowchart TB StartDoor([Wheelchair Arrives at Door]) --> Phase1[Phase 1: Approach Door
Stop 1 meter in front
Face door straight]

Phase1 --> Phase2[Phase 2: Turn to Face Exit
Rotate toward next room
Align with destination]

Phase2 --> Phase3{Phase 3: Check Door}

Phase3 -->|Door Open| Wait[Wait 2 Seconds
for Door to Fully Open] Phase3 -->|Door Closed| Trigger[Trigger Automatic Door

Move back and forth
Activate motion sensor]

Trigger --> CheckAgain{Is Door
Open Now?} CheckAgain -->|No| Trigger CheckAgain -->|Yes| Wait

Wait --> Phase4[Phase 4: Cross Doorway
Move forward 2 meters
at steady speed]

Phase4 --> Monitor{Traveled
2 meters?} Monitor -->|No| Phase4 Monitor -->|Yes| Complete([Door Crossing Complete
Load Next Room Path])

style StartDoor fill:#90EE90 style Complete fill:#90EE90 style Phase1 fill:#87CEEB style
Phase2 fill:#87CEEB style Phase3 fill:#DDA0DD style Phase4 fill:#87CEEB style Trigger
fill:#FFE4B5 style Wait fill:#FFE4B5 ```

**Visual Representation:**

``` Room A Door Room B

[Wheelchair] → Phase 1: Stop 1m before door [🚗] |

Phase 2: Turn to face Room B [🚗→] |

Phase 3: Check door is open | ← Laser checks here

If closed: Phase 3: Trigger door [🚗←→] | ← Small movements

Phase 4: Move through | [🚗→→→]

[🚗] Room B entered! ```

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# Segment Type 3: Entering Elevator

This is the most complex segment with multiple sub-stages:

## Stage 1: Approach and Align (Phases 1-2)

- Positions 1 meter in front of elevator door
- Rotates to face elevator entrance straight-on
- Aligns perfectly for smooth entry

## Stage 2: Door Opening (Phase 3)

- Laser scanner checks if elevator door is open
- **Door Closed:** Detects solid surface

- Performs small movements to trigger motion sensor - Waits for automatic door to open

- **Door Open:** Detects clear path inside

- Waits 2 seconds for door to fully open - Proceeds to entry

## Stage 3: Enter Elevator (Phase 3)

- Moves straight into elevator cabin
- Travels 2 meters to reach center of elevator
- Stops inside elevator

## Stage 4: Wait Inside (Phase 4)

**Sub-stage A: Door Closes**

- Elevator door closes automatically
- Wheelchair remains stationary inside

**Sub-stage B: Floor Selection**

- System registers desired floor number
- (In real system: interfaces with elevator panel)

**Sub-stage C: Travel to Floor**

- Elevator travels up or down to destination floor
- Wheelchair waits motionless during travel

**Sub-stage D: Door Opens**

- Elevator arrives at destination floor
- Door opens automatically
- Laser scanner detects when door is fully open

## Stage 5: Exit Elevator (Phase 5)

- Wheelchair reverses backward out of elevator
- Travels same distance as entry (2 meters)

- Uses distance measurement to track progress

- Exits smoothly without turning around

**Why reverse?**

- Elevator cabin too small to turn around

- Reversing maintains stability

- Simpler than complex turning maneuvers

## Stage 6: Complete (Phase 6)

- Wheelchair fully outside elevator on new floor

- Ready to continue navigation on new floor

**Duration:** 20-60 seconds total

## Elevator Entry Flowchart

```mermaid
flowchart TB StartElev([Wheelchair Arrives at Elevator]) --> Phase1[Phase 1-2:
Approach and Align
Stop 1 meter in front
Face elevator straight]

Phase1 --> CheckDoor{Phase 3: Is Elevator
Door Open?}

CheckDoor -->|Door Closed| TriggerElev[Trigger Elevator Door
Move back and forth
Activate motion sensor] TriggerElev --> CheckDoor

CheckDoor -->|Door Open| WaitOpen[Wait 2 Seconds
Ensure Door Fully Open]

WaitOpen --> Enter[Phase 3: Enter Elevator
Move forward 2 meters
Stop inside cabin]

Enter --> InsideCheck{Inside
Elevator?} InsideCheck -->|No| Enter InsideCheck -->|Yes| DoorClose[Phase 4A: Door
Closes
Wheelchair stays still]

DoorClose --> SelectFloor[Phase 4B: Floor Selection
System registers target floor]
```

SelectFloor --> Travel[Phase 4C: Travel to Floor
Elevator moves up/down
Wheelchair remains motionless]

Travel --> ArriveFloor[Phase 4D: Arrive at Floor
Elevator stops
Door opens automatically]

ArriveFloor --> DetectOpen{Detect Door
Fully Open?} DetectOpen -->|No| ArriveFloor DetectOpen -->|Yes| Reverse[Phase 5:
Reverse Out
Move backward 2 meters
Exit elevator]

Reverse --> ExitCheck{Exited
Elevator?} ExitCheck -->|No| Reverse ExitCheck -->|Yes| Complete([Elevator Exit Complete
Now on New Floor])

style StartElev fill:#90EE90 style Complete fill:#90EE90 style Phase1 fill:#FFB6B6 style
CheckDoor fill:#DDA0DD style Enter fill:#FFB6B6 style DoorClose fill:#FFE4B5 style
SelectFloor fill:#FFE4B5 style Travel fill:#FFE4B5 style ArriveFloor fill:#FFE4B5 style
Reverse fill:#FFB6B6 style TriggerElev fill:#FFE4B5 ```

Visual Representation:

``` Floor 4 Hallway Elevator Floor 1 Hallway

[Wheelchair] → Phase 1-2: Stop and align [🚗] |

Phase 3: Check door | ← Laser checks

If closed: Phase 3: Trigger door [🚗 ← →] | ← Small movements

Phase 3: Enter elevator | [🚗 → → →] | | [🚗] ← Inside! | Phase 4A: Door closes ‖🚗‖

Phase 4B-C: Travel ‖🚗‖ ← Moving between floors ‖↓↓‖ ‖🚗‖

Phase 4D: Door opens | [🚗] | Phase 5: Reverse out | [← ← ←🚗]

[🚗] Arrived on Floor 1! ```

**Elevator Phases Summary:**

| Phase | What Happens | Wheelchair Movement | Duration |
|-------|-------------|---------------------|----------|
| **1-2** | Approach and align | Stop in front | 5 sec |
| **3** | Check door, trigger if closed, enter | Forward 2 meters | 5-10 sec |
| **4A** | Door closes | Stay still | 5 sec |
| **4B** | Floor selection | Stay still | 2 sec |
| **4C** | Travel between floors | Stay still | 15-20 sec |
| **4D** | Arrive, |

door opens | Stay still | 3 sec | | **5** | Reverse out of elevator | Backward 2 meters | 7 sec | | **6** | Complete | Stop | - |

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# Complete Journey Example

**Starting Location:** Room A (Floor 4) **Destination:** Elevator → Floor 1

## Journey Breakdown:

1. **Room A Navigation** (30 sec) - Follow 15 guide points through Room A - Avoid furniture and walls - Reach door to Room B

2. **Door A→B Crossing** (8 sec) - Approach door - Align to face Room B - Check door open - Cross into Room B

3. **Room B Navigation** (25 sec) - Follow 12 guide points through Room B - Navigate around obstacles - Reach door to Room C

4. **Door B→C Crossing** (10 sec) - Approach door - Wait for automatic door to open - Cross into Room C

5. **Room C Navigation** (20 sec) - Follow 8 guide points through Room C - Approach elevator entrance

6. **Elevator Entry** (45 sec) - Align in front of elevator (5 sec) - Wait for elevator door to open (5 sec) - Enter elevator cabin (5 sec) - Door closes (5 sec) - Travel from Floor 4 to Floor 1 (20 sec) - Door opens (3 sec) - Reverse out of elevator (7 sec)

**Total Time:** ~2 minutes 18 seconds

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# Safety Features

## Obstacle Avoidance

- Continuously scans 360° around wheelchair
- Calculates safe paths around detected objects
- Slows down or stops if obstacles too close

- Replans route if original path blocked

## Door Safety

- Never attempts to cross closed door
- Actively opens automatic doors using motion trigger
- Waits for confirmation door is passable
- Stops immediately if door closes unexpectedly

## Elevator Safety

- Confirms door fully open before entering
- Remains stationary during floor travel
- Detects door opening before exiting
- Uses slow, controlled movements inside cabin

## Position Tracking

- Constantly monitors current location
- Verifies progress along planned path
- Uses multiple methods to confirm position
- Falls back to distance measurement if position uncertain

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# User Interaction

**During Normal Operation:**

- System runs completely autonomously
- User can monitor progress on display
- Shows current room, action, and progress percentage

**Optional User Commands:**

- Can request wheelchair to replan route from current position
- Can activate special testing modes
- Can stop navigation at any time

# System Display

**Real-time Status Information:**

**Section 1: Position**

- Current X, Y coordinates on map
- Current facing direction
- Time elapsed

**Section 2: Navigation Progress**

- Current guide point: 8/15
- Distance to final destination
- Detected obstacles nearby

**Section 3: Current Action**

- "Following path in Room B"
- "Entering doorway to Room C"
- "Entering elevator - waiting for door"

**Section 4: Overall Progress**

- Action 3 of 6 (50% complete)
- Current segment: "Path following in Room B"

# Flowchart

```mermaid flowchart TB Start([Wheelchair Turned On]) --> LoadMap[Load Building Map and Plan Route]

LoadMap --> StartNav[Begin Navigation from Starting Position]

StartNav --> MainLoop[Main Cycle Starts]

MainLoop --> ReadSensors[Read Sensors
- Laser scanner
```

- Position tracker
- Camera]

ReadSensors --> Understand[Understand Environment
- Detect obstacles
- Confirm location]

Understand --> DecideAction{What Action
is Needed?}

DecideAction -->|Following Path| PathAction[Following Path Through Room] DecideAction --
>|At Door| DoorAction[Passing Through Doorway] DecideAction -->|At Elevator|
ElevatorAction[Entering Elevator] DecideAction -->|Mission Done| MissionComplete[Arrived
at Destination]

PathAction --> PathCalc[Calculate Movement
- Avoid obstacles
- Stay on path
- Adjust speed] PathCalc --> PathMove[Move Wheelchair
Forward/Turn] PathMove --> PathCheck{Reached
End of Room?} PathCheck -->|No| MainLoop PathCheck -->|Yes| AdvanceAction[Move to
Next Segment]

DoorAction --> DoorPhase1[Phase 1:
Position in Front of Door] DoorPhase1 --> DoorPhase2[Phase 2:
Face Correct Direction] DoorPhase2 --> DoorPhase3{Phase 3:
Is Door Open?} DoorPhase3 -->|No| OpenDoor[Trigger Automatic Door
with Small Movements] OpenDoor --> DoorPhase3 DoorPhase3 -->|Yes| DoorPhase4[Phase
4:
Move Through Doorway
Travel 2 meters] DoorPhase4 --> DoorComplete{Crossed
Doorway?} DoorComplete -->|No| DoorPhase4 DoorComplete -->|Yes| AdvanceAction

ElevatorAction --> ElevP1[Phase 1-2:
Approach and Align
in Front of Elevator] ElevP1 --> ElevP3{Phase 3:
Is Elevator
Door Open?} ElevP3 -->|No| ElevOpenDoor[Trigger Door
with Small Movements] ElevOpenDoor --> ElevP3 ElevP3 -->|Yes| ElevEnter[Phase 3:
Enter Elevator Cabin
Move 2 meters Forward] ElevEnter --> ElevP4[Phase 4:
Door Closes
Travel to Target Floor

Door Opens] ElevP4 --> ElevP5[Phase 5:
Reverse Out of Elevator
Move 2 meters Backward] ElevP5 --> ElevComplete{Exited
Elevator?} ElevComplete -->|No| ElevP5 ElevComplete -->|Yes| AdvanceAction

AdvanceAction --> CheckMission{Is Journey
Complete?} CheckMission -->|No| MainLoop CheckMission -->|Yes| MissionComplete

MissionComplete --> SaveData[Save Navigation Data] SaveData --> ShowResults[Display
Journey Map
and Statistics] ShowResults --> End([Navigation Finished])

style Start fill:#90EE90 style End fill:#FFB6C1 style LoadMap fill:#FFE4B5 style
DecideAction fill:#DDA0DD style PathAction fill:#F0E68C style DoorAction fill:#87CEEB style
ElevatorAction fill:#FFB6B6 style MissionComplete fill:#98FB98 style AdvanceAction
fill:#98FB98 ```

Color Legend

Main Navigation Flowchart:

- **Green:** Start and end points

- **Light Orange:** Initial setup and planning

- **Purple:** Decision points (what to do next)

- **Yellow:** Path following through rooms

- **Light Blue:** Door crossing sequences

- **Light Red:** Elevator entry and exit sequences

- **Light Green:** Progress advancement

Door Crossing Flowchart:

- **Green:** Start and completion

- **Light Blue:** Door phases (position, turn, cross)

- **Purple:** Door check decision

- **Light Orange:** Door triggering actions

Elevator Flowchart:

- **Green:** Start and completion

- **Light Red:** Elevator movement phases (approach, enter, reverse)

- **Light Orange:** Waiting phases (door close, travel, door open)
- **Purple:** Door check decision

Summary

The autonomous wheelchair:

1. **Plans** a route through multiple rooms to reach the elevator 2. **Follows** guide points through each room while avoiding obstacles 3. **Crosses** through doorways using a 4-phase sequence 4. **Enters** the elevator using a 6-phase sequence 5. **Travels** between floors inside the elevator 6. **Exits** by reversing backward onto the new floor 7. **Repeats** this cycle for each room and door until reaching the destination

The entire process is automatic, requiring no user intervention. The wheelchair continuously monitors its sensors, adjusts its path to avoid obstacles, and safely navigates through the building environment.