Karlsruhe Institute of Technology

Mind the Gap: Virtual Shorelines for Blind and Partially Sighted People

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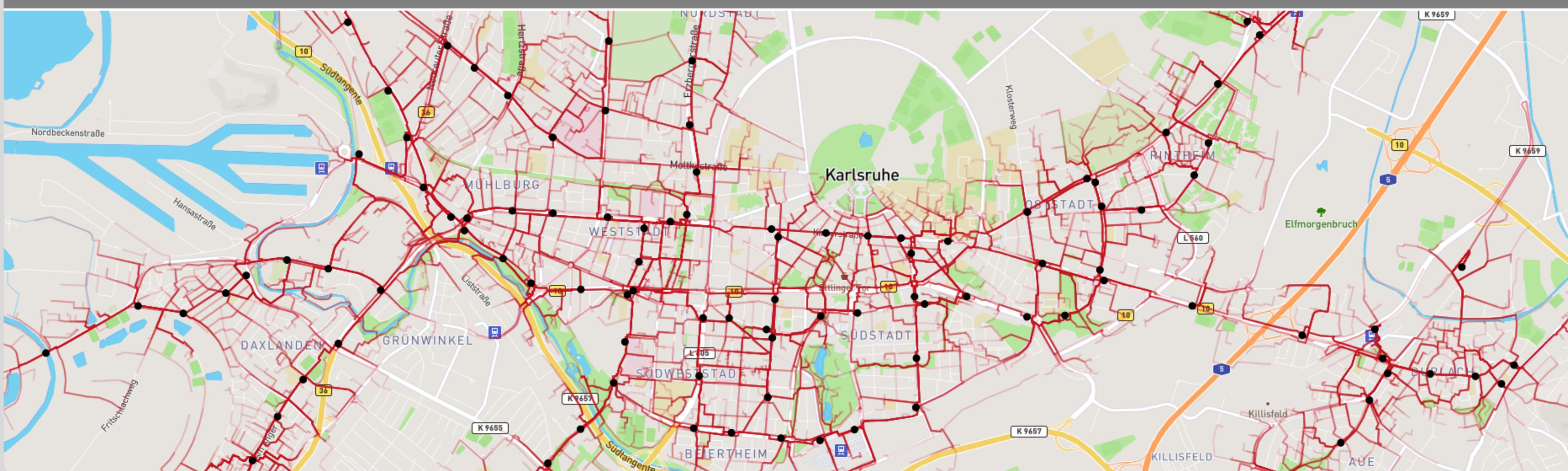
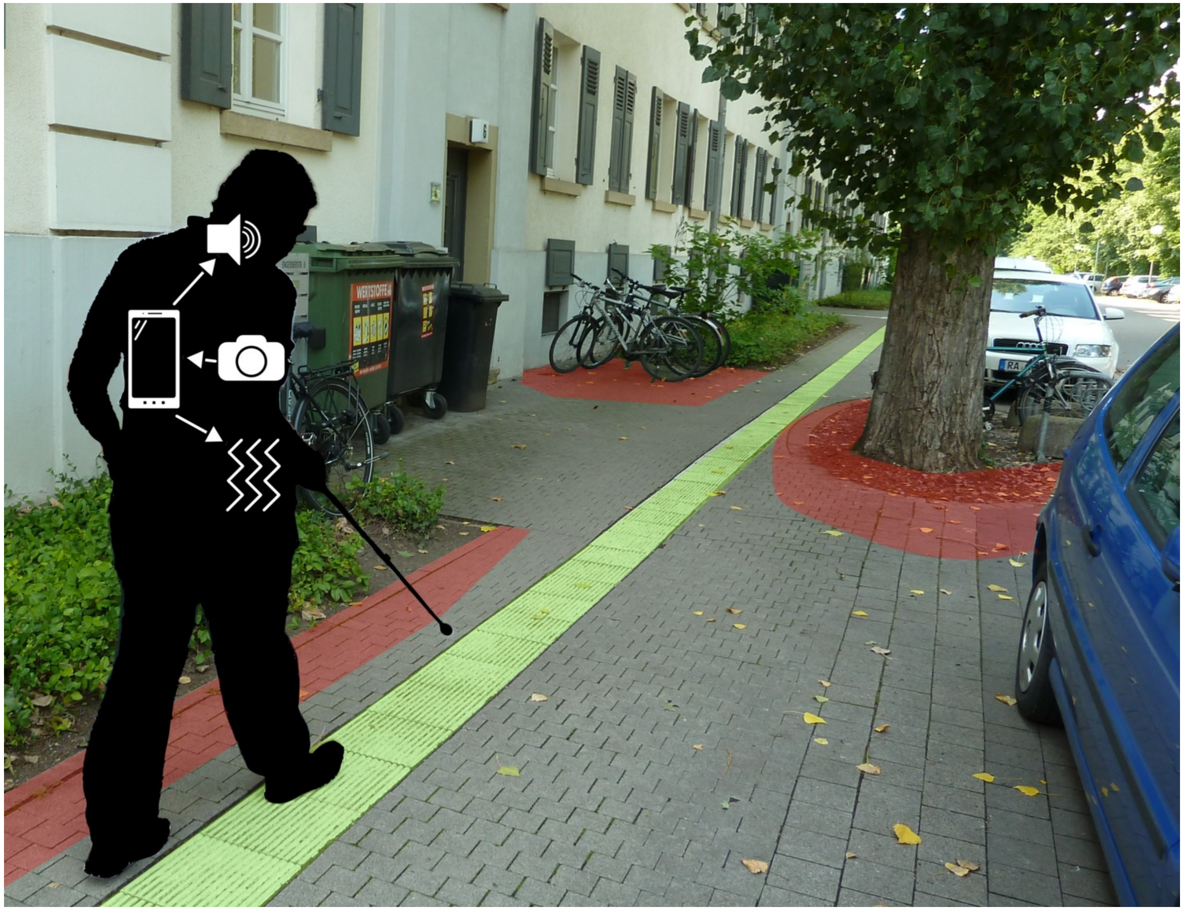
INSTITUTE FOR ANTHROPOMATICS AND ROBOTICS — COMPUTER VISION FOR HUMAN COMPUTER INTERACTION



Motivation

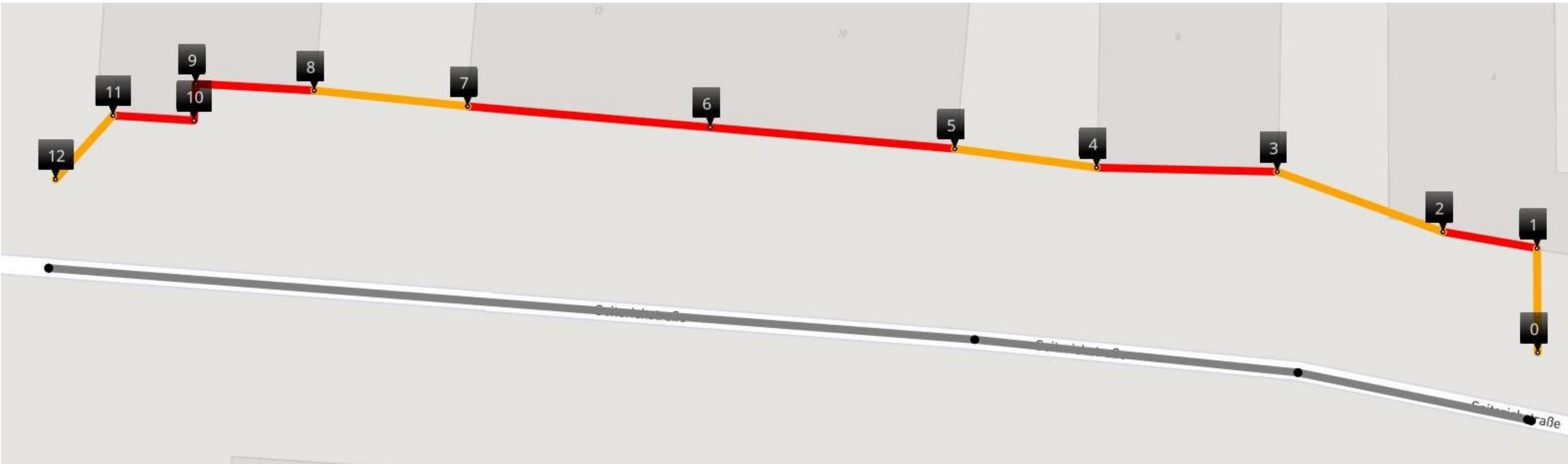


- “Please turn right in 200 meters!”
- “You have reached your destination!”

State of the Art

State of the Art: Reality

Routing: Directions



0) “*Please turn north until you reach a façade.*”

1) “*Follow the façade to the left for 8m.*”

2) “*Continue for 18m at 1 o’clock to cross a driveway.*”

…

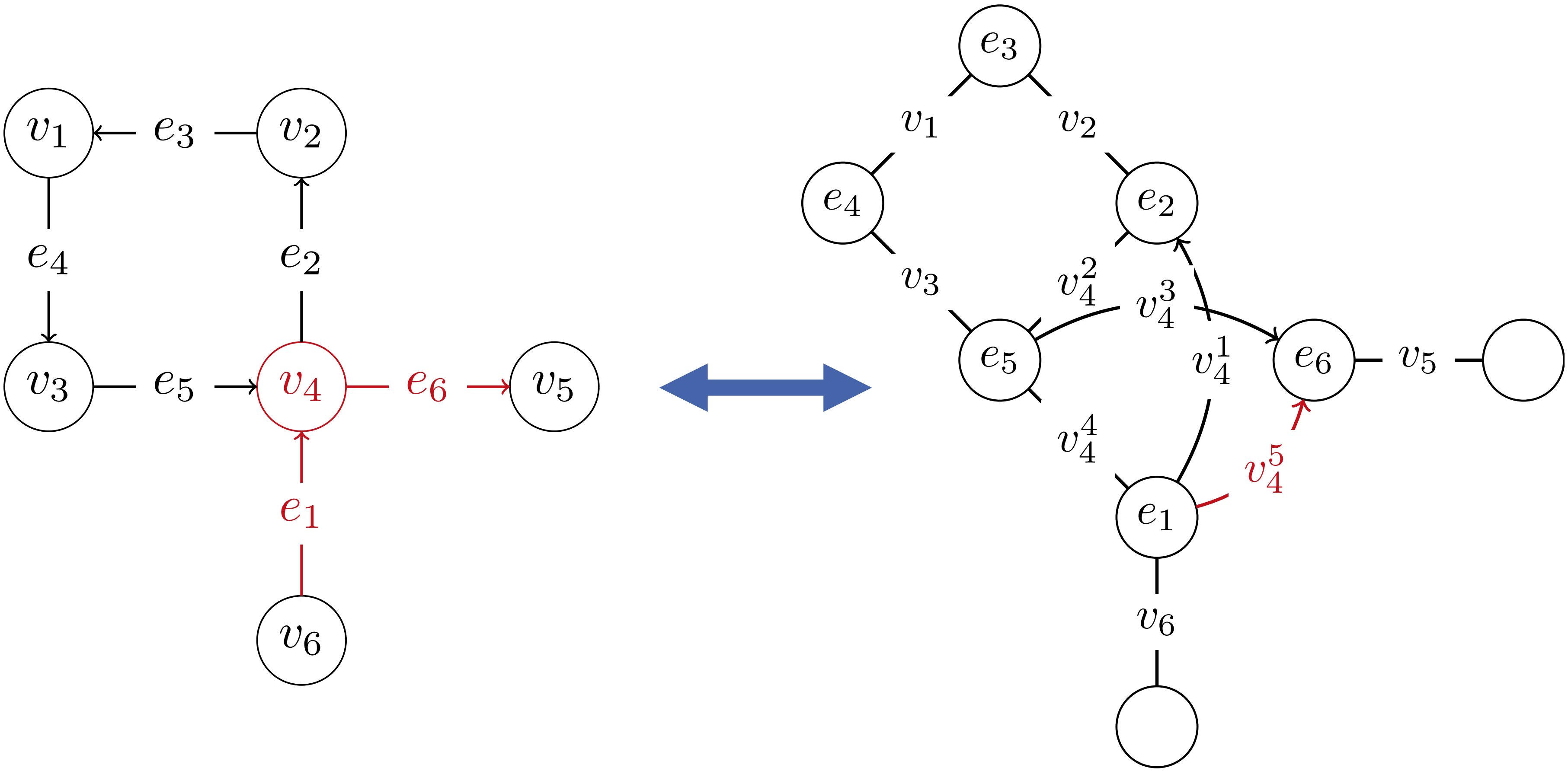
10) “Turn right and follow the façade for 6m.”

11) “Continue for 6m at 10 o’clock across the sidewalk.”

12) “You have reached your destination.”

Routing: Graph Transformation

- Transform **Directed Graph** to **Edge Expanded Graph:**



Disallow right turn from e_1 to e_6 at intersection v_4!

Routing: Algorithm Overview

$d := \{0, \infty, \ldots, \infty\}$
prev $:= \{0, -1, \ldots, -1\}$
$q := \{(p_{r=0}, 0)\}$
while $q \neq \emptyset$ **do**
    $p_u := q.\text{pop}()$
    for all $l_i \in (\mathcal{S}'_{\mathcal{R}} \cup \mathcal{R})$ **do**
        $p_v := f_{near}(p_u, l_i)$
        if $d[u] + \delta_{p_u p_v l_I} < d[v]$ **then**
            $d[v] := d[u] + \delta_{p_u p_v l_I}$
            $\text{prev}[v] := u$
            $q.\text{push}(p_v, d[v])$
        end if
    end for
end while

Routing: Cost Function

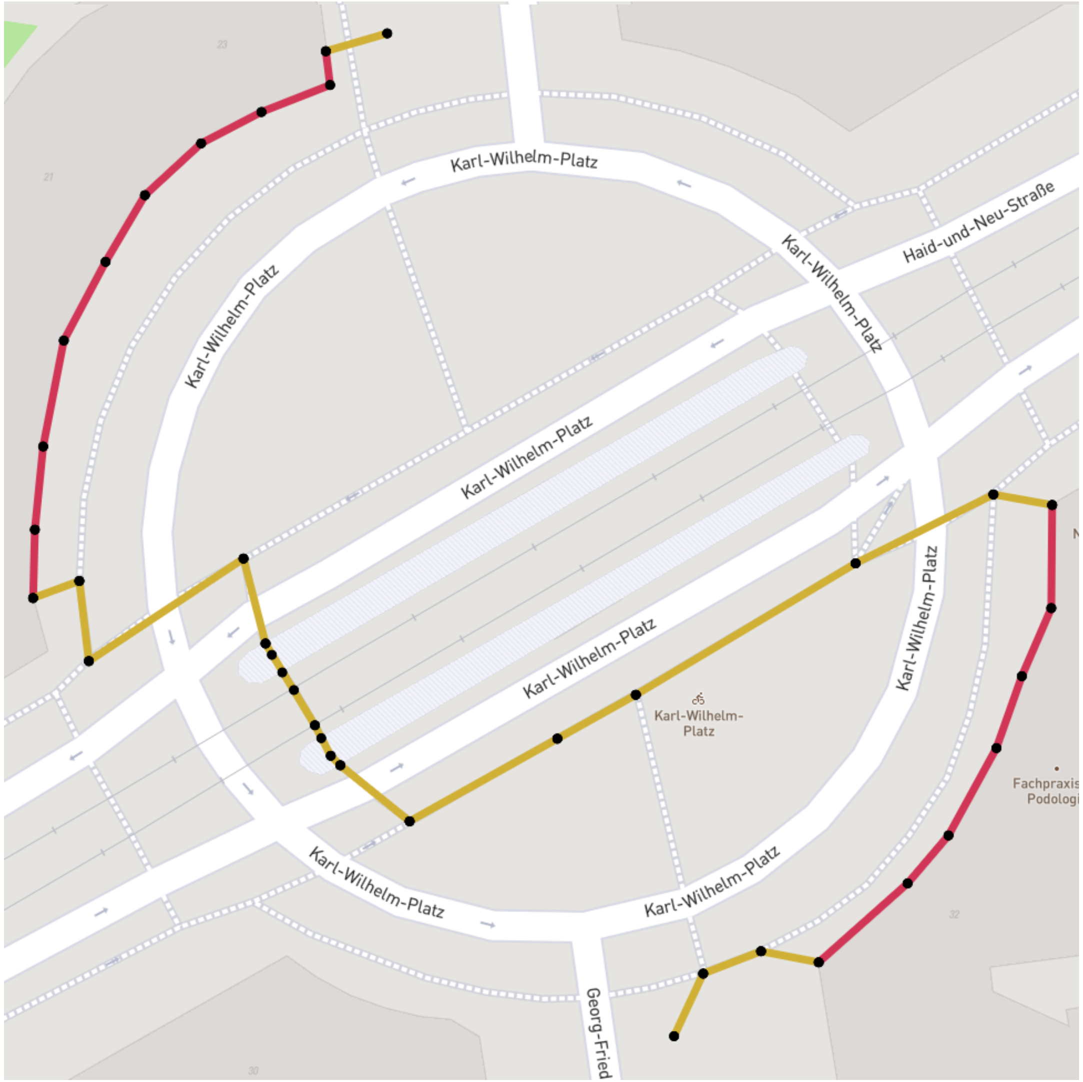
$$\delta_{p_u p_v l_I} := \begin{cases} \mathcal{W}_S \cdot \|p_u - p_v\|_2\,, & (\delta_{p_u l_I} = 0) \wedge (l_i \in \mathcal{S}) \\ \mathcal{W}_R(l_i) \cdot \|p_u - p_v\|_2\,, & (\delta_{p_u l_I} = 0) \wedge (l_i \in \mathcal{R}) \\ \delta_{p_u l_I}\,, & otherwise \end{cases}$$

$$\mathcal{W}_R(l_i) := \begin{cases} \mathcal{W}_C\,, & informalCrossing(l_i) \\ \mathcal{W}_{PS} \cdot \mathcal{W}_R, & PedestrianSignal(l_i) \\ \mathcal{W}_{APS} \cdot \mathcal{W}_R, & APS(l_i) \\ \mathcal{W}_{APS_p} \cdot \mathcal{W}_R, & PilotTone(l_i) \\ \mathcal{W}_R, & otherwise \end{cases}$$

$$\delta_{p_u l_I} := (1 + |\mathcal{C}_{p_u p_v}| \cdot \mathcal{W}_R) \cdot d(p_u, l_i)$$

$$\mathcal{W}_C > \mathcal{W}_{PS} > \mathcal{W}_{APS} > \mathcal{W}_{APS_p} > \mathcal{W}_R > \mathcal{W}_S > 1$$

Routing: Example Intersection



Evaluation: Random Routes

distance ($\bar{d}$), % pedestrian walkway ($\bar{r}_w$), # pedestrian signal ($\overline{ps}$), % real/virtual shorelines ($\bar{s}_r/\bar{s}_v$) and # informal crossings ($\bar{c}$)

	$\bar{d}$	$\bar{r}_w$	$\bar{ps}$	$\bar{c}$
R_{OSRM}	**458**	12.8	.157	.064
$R_{Walkway}$	466	**16.4**	.669	.128
R_{APS}	464	**16.4**	**.792**	**.063**

	$\bar{d}$	$\bar{r}_w$	$\bar{s}_r$	$\bar{s}_v$	$\bar{c}$
$R_{Shorelines}$	**139**	00.0	**24.5**	12.3	0.056
R_{Final}	162	**17.6**	20.9	**11.0**	**0.043**

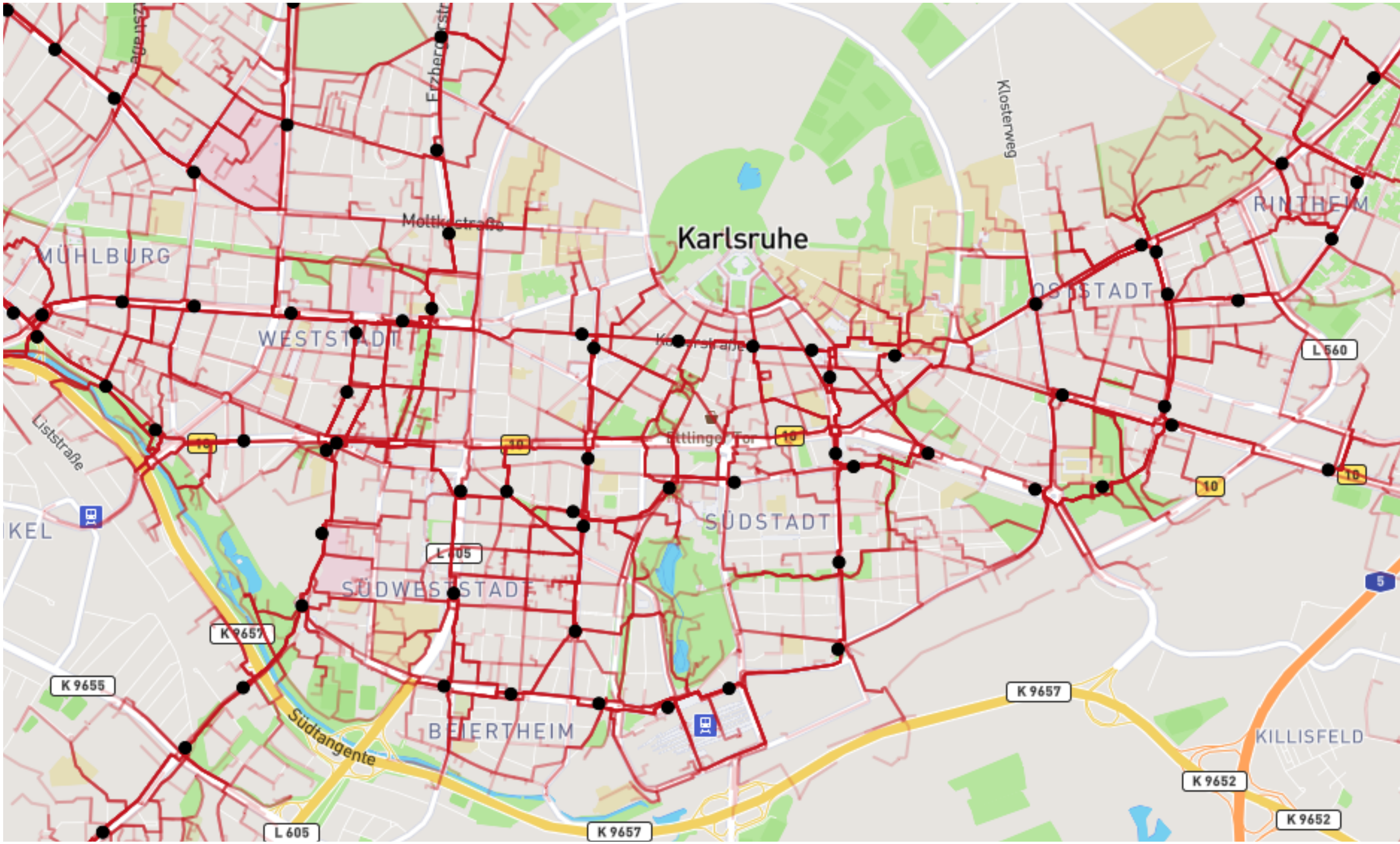
Evaluation: Public Transit Station Based

distance ($\bar{d}$), % pedestrian walkway ($\bar{r}_w$), # pedestrian signal ($\overline{ps}$), haptic/aural/pilot-tone *APS* ($\overline{ps}_a/\overline{ps}_p$), % real/virtual shorelines ($\bar{s}_r/\bar{s}_v$) and # informal crossings ($\bar{c}$)

	$\bar{d}$	$\bar{r}_w$	$\bar{ps}$	$\bar{ps}_a$	$\bar{ps}_p$	$\bar{c}$
R_{OSRM}	**621**	26,4	2.327	0.205	0.019	0.702
$R_{Walkway}$	654	**46,4**	**4.819**	**0.338**	0.070	1.501
R_{APS}	655	45,5	4.709	0.320	**0.814**	**0.615**

	$\bar{d}$	$\bar{r}_w$	$\bar{s}_r$	$\bar{s}_v$	$\bar{c}$
$R_{Shorelines}$	**178**	00.0	**31.4**	7.9	.056
R_{final}	198	**22.0**	26.0	**8.2**	**.035**

Evaluation: Public Transit Station Based



Evaluation: Wizard of Oz

- No access to GNSS receiver with sufficient position accuracy.
- Two 400m long routes in unknown locations.
- Closely following supervisor interactively reads generated directions.
- More a “sanity check” than a real evaluation!

- Results:
- much appreciated: next shoreline’s location and length
- helps in creation of a mental map
- long virtual shorelines: lighthouse mode / pilot-tone
- suggested: output should be highly configurable (verbosity level, direction announcement type, …)

Conclusion and Future Work

- We propose a **novel routing system** on a shoreline level of detail.
- We use openly available geolocation data.
- The system considers actual white-cane based movement.
- The algorithm creates **safer routes** according to pre-defined criteria: avoid informal crossings, prefer accessible pedestrian signals and integrate available shorelines wherever possible.
- Our system **improves users' understanding** of the upcoming route, the environment lying ahead and its impediments.

- Upcoming:
- Work on visual egocentric shoreline detection.
- Proper user study as part of the TERRAIN project (also provide shoreline level routing as a local/remote service).