Cartography M.Sc.

Cool Streets – Developing a Healthy Urban Route Planner

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Introduction

Challenges:

Over **50%** of the world population lives in cities; this value is predicted to reach **66%** by 2050 [1]

The growing city scale is accompanied by augmented air pollution and urban heat hazard [2]

Cities have been the hotspots of **pollution** and **diseases**

Motivation:

Developing a **health-oriented** routing application for urban pedestrians and cyclists

Optimizes human comfort and health by providing routes with less pollution and better thermal comfort

Introduction

Research objectives:

1. Develop a web application prototype helps find health-optimal paths in Munich
2. Investigate efficient means in health-related urban data visualization and interactive map design
3. Evaluate the usability, applicability, and user experience through a questionnaire-based user study

Hypothesis:

- This application prototype is helpful and applicable in practice regarding **learnability**, **effectiveness** and **contentment**
- Differences in users' performances in attention distribution can be observed in different cases

Methodology – Data and Routing Algorithm

Road Network:

Open-source road network shapefile of center Munich

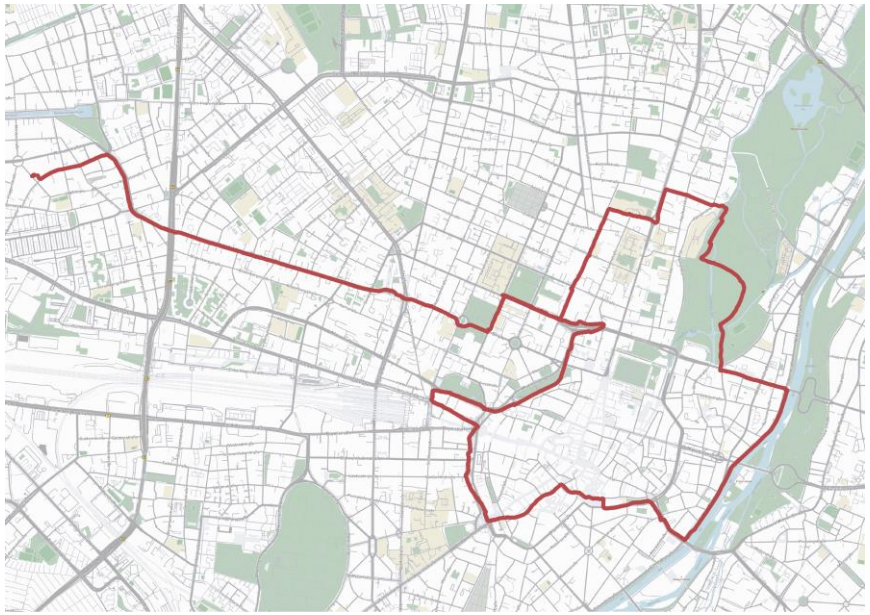
Sampled Temperature and Air Pollution:

Observed on ***22 April 2020 by Climateflux***

Contained ***4583 records***

Collected temperature, humidity, and concentrations of CO_2, PM10, PM25, and PM100

Study Area



Climateflux: https://www.climateflux.com/

Methodology – Data and Routing Algorithm

Five major pollutants of the US AQI system:

O_3, PM2.5, PM10, CO, and SO_2

The US AQI

Synthesis data:

- Obtained the concentration range for each air pollutant based on historical air pollution* measurement on *22 April 2020*.
- Calculated AQI range for each pollutant to get the range of overall AQI *(9.26-76.06)*
- Generated values of ***AQI*** and ***temperature*** for road network within the range

* Bayerisches Landesamt für Umwelt: https://www.lfu.bayern.de/index.htm

Methodology – Data and Routing Algorithm

Geospatial routing calculation:

- Imported road network with synthesis attributes into Geo-Database
- Used ***pgRouting*** to break road edges into segments and build network topology
- ***pgr_dijkstra*** for routes querying between the starting and ending nodes based on costing factor

GeoServer:

- Uploaded both edge and node dataset to GeoServer
- Created ***four SQL views*** to search nearest vertex and return desired routes

Web mapping:

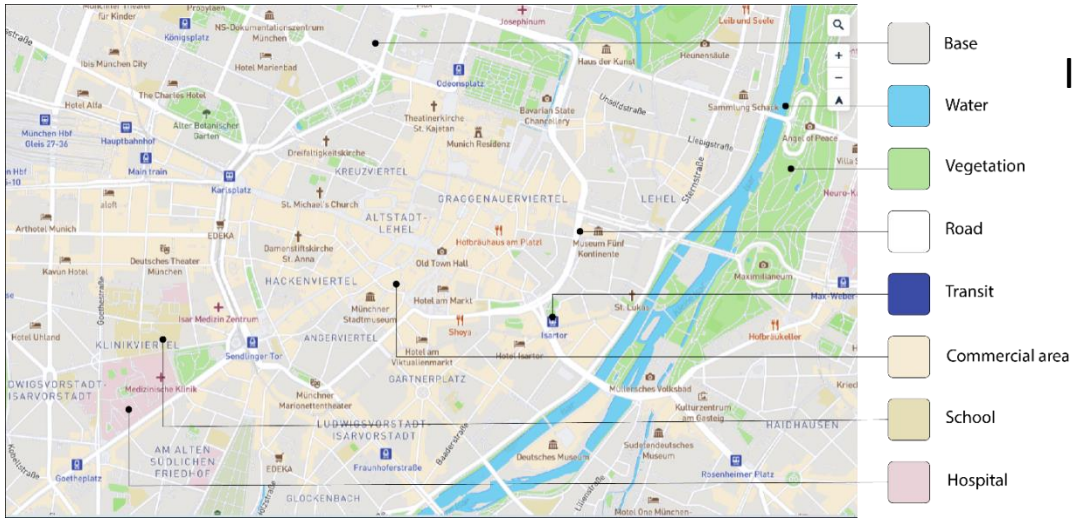
- Leaflet and its plugins were used
- Visualized requested paths from GeoServer in webpage

Methodology – Map Interface Design

Basemap:

Four basemaps were designed using Mapbox Studio

I



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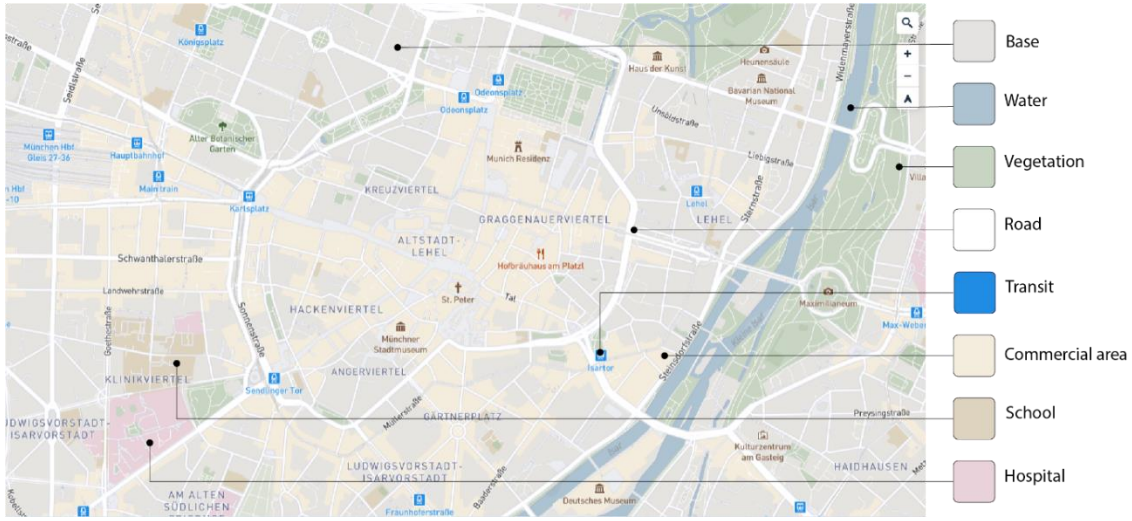


III

IV

Methodology – Map Interface Design

Map elements:

Search boxes, layer controller, legend, locating button

Route design:

- Colors designs of different routes based on color conventions and attention guiding techniques:

  cleanest route, coolest route, shortest route

- Thicker line designs for cleanest and coolest routes, thinner line design for shortest route
- Higher opacity (0.95) for cleanest and coolest routes, lower opacity (0.75) for shortest route
- When clicked and highlighted one route, the visual importance of it would be enhanced and the rests would be less important

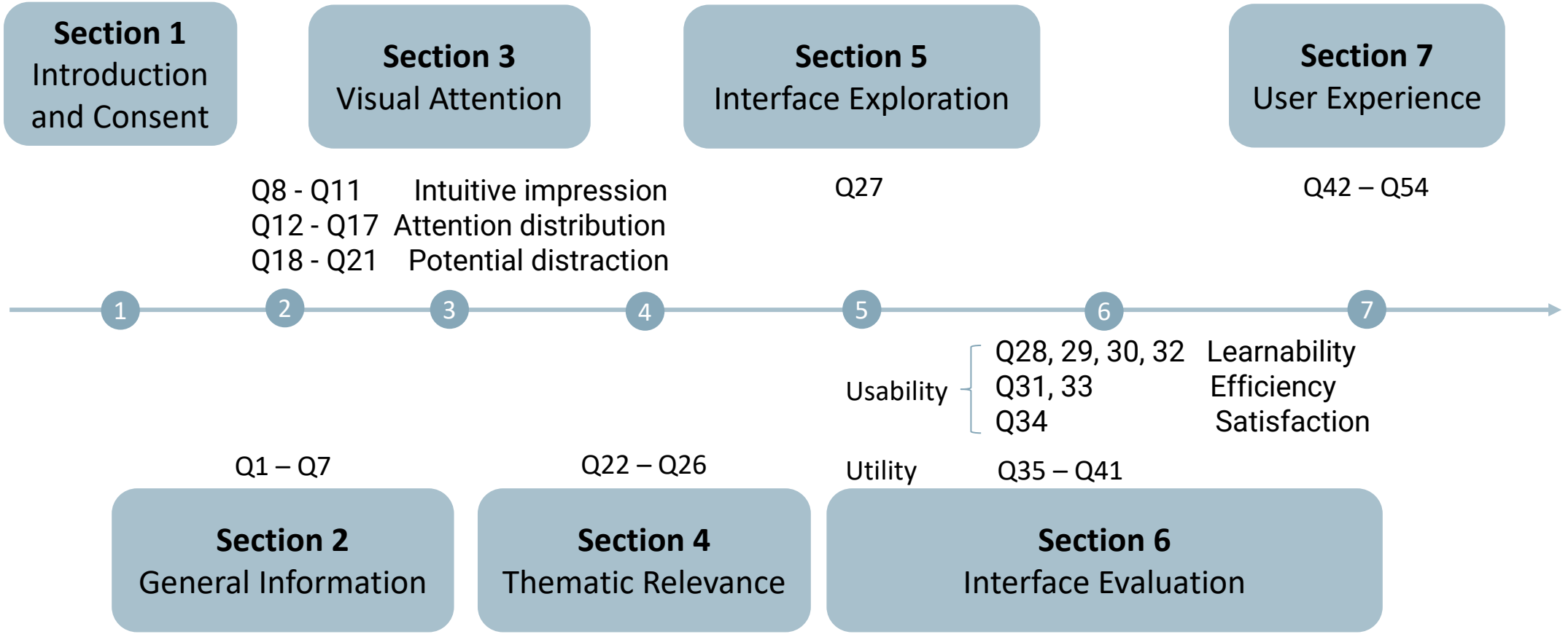
Methodology – User Study

Questionnaire Design:

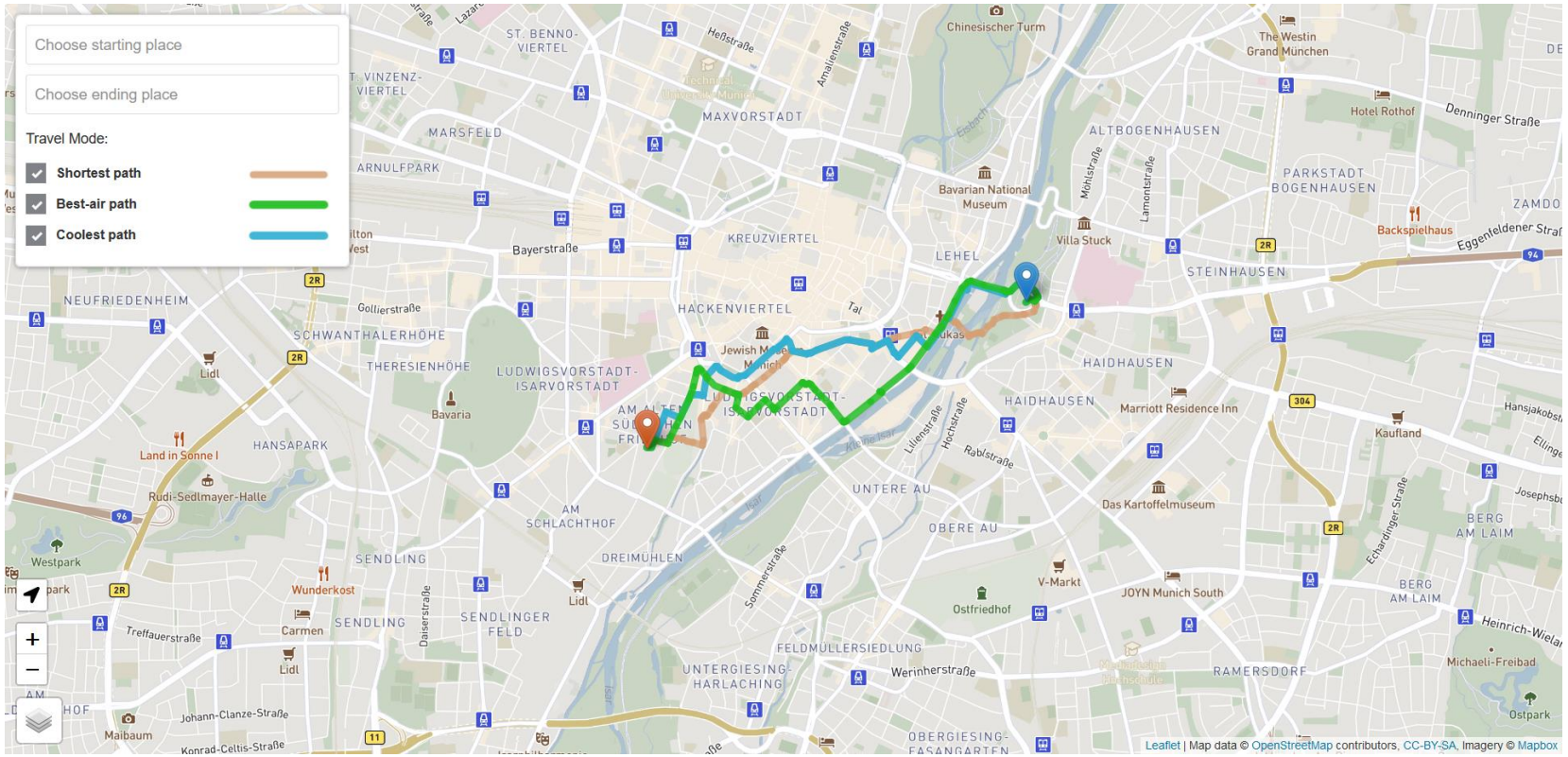
- Around ***30 participants*** were expected to take part in
- **Likert-type** (5 points) questions to measure attitude:
  the results were visualized in ***bar charts***
  chi-square was used to quantitatively verify whether the hypothesis holds
- **AttrakDiff** to measure the impression towards the prototype:
  the results were visualized in a ***line chart***
- Text-based questions to collect user's subjective opinions:
  qualitative ***thematic analysis*** was used to find patterns

Methodology – User Study

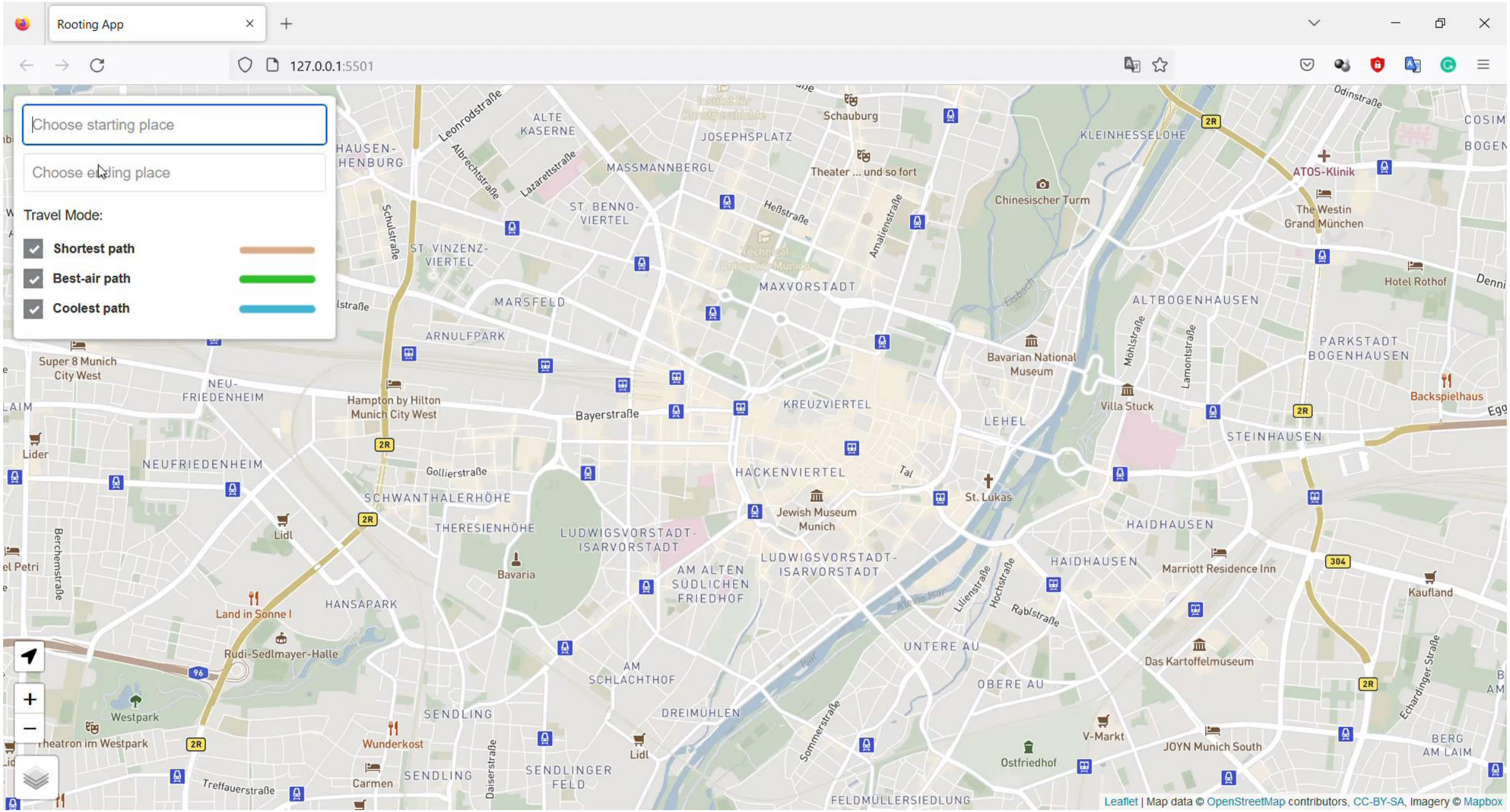
Procedures



Results – User Interface



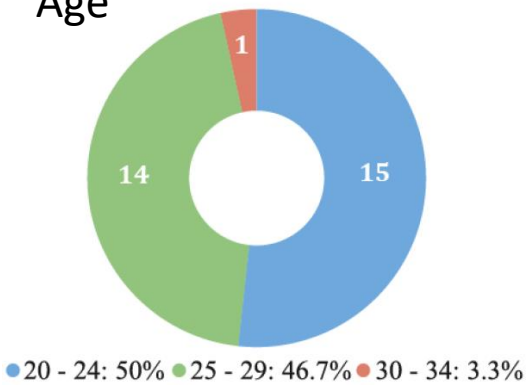
- Address search box
- Travel mode switcher
- Layer controller
- Locating button
- Draggable markers
- Clickable paths


Rooting App
127.0.0.1:5501
Choose starting place
Choose ending place
Travel Mode:
Shortest path
Best-air path
Coolest path
Leaflet | Map data © OpenStreetMap contributors, CC-BY-SA, Imagery © Mapbox

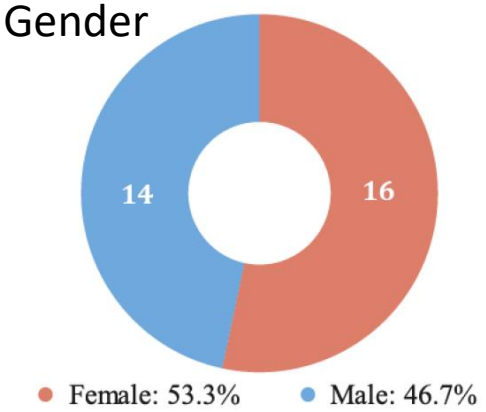
Results – User Study

Participants

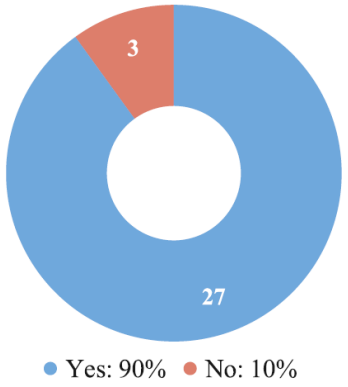
Age



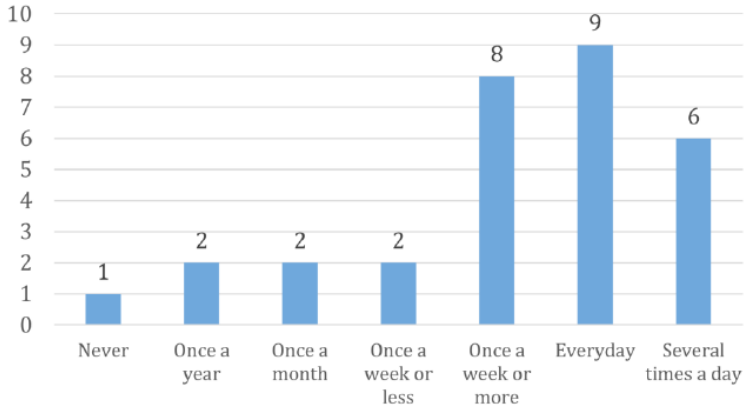
Gender



Munich residents



Frequency of using web navigation apps



The user study was carried out in Studentenwerk Giesing

30 participants took part in

Laptop screen with the size of 14 inches

Indoor lighting conditions during the daytime

- ages were mostly between **20 to 29**
- **16** female and **14** male participants
- **90%** once lived or currently living in Munich
- **> 50%** used web navigation apps quite often

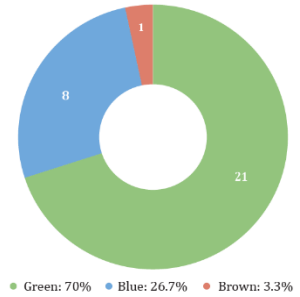
Results – User Study

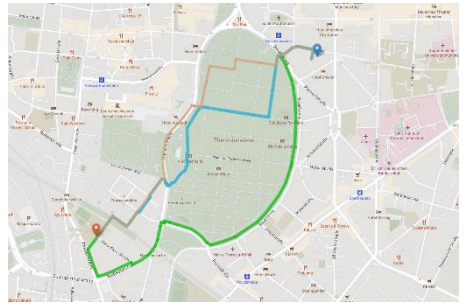
Visual Attention

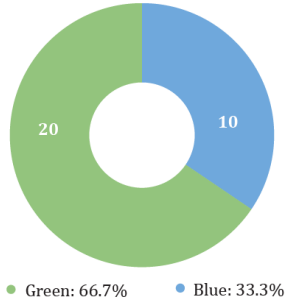
Q8 – Q11: Which path do you notice firstly?

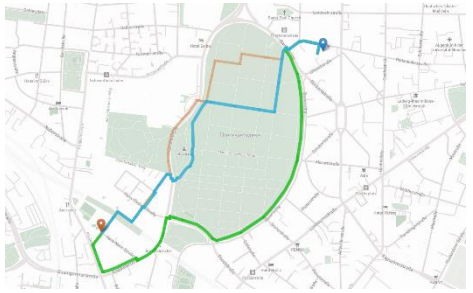
- When the background was understated: users tended to faster notice the objects that occupy more spatial extents, i.e., green path.
- When the background was more salient, users tended to notice the path with the biggest contrast to the background, i.e., blue path

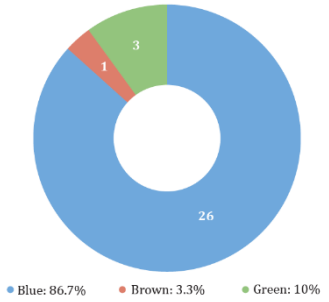
Basemap played a role in guiding user's visual attention and influencing user's choices

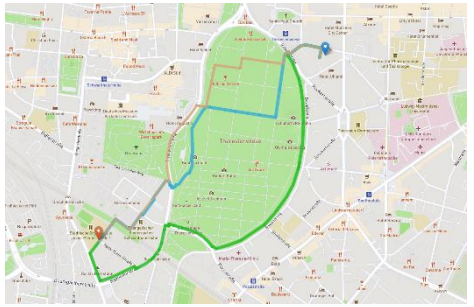


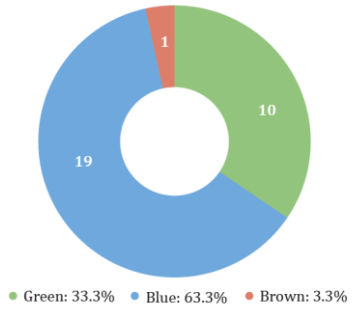


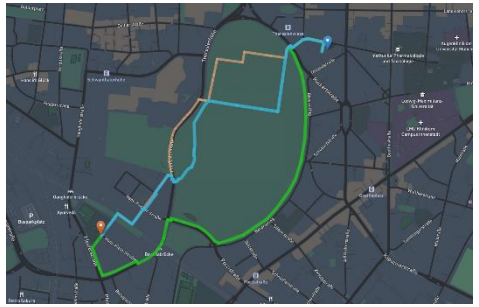










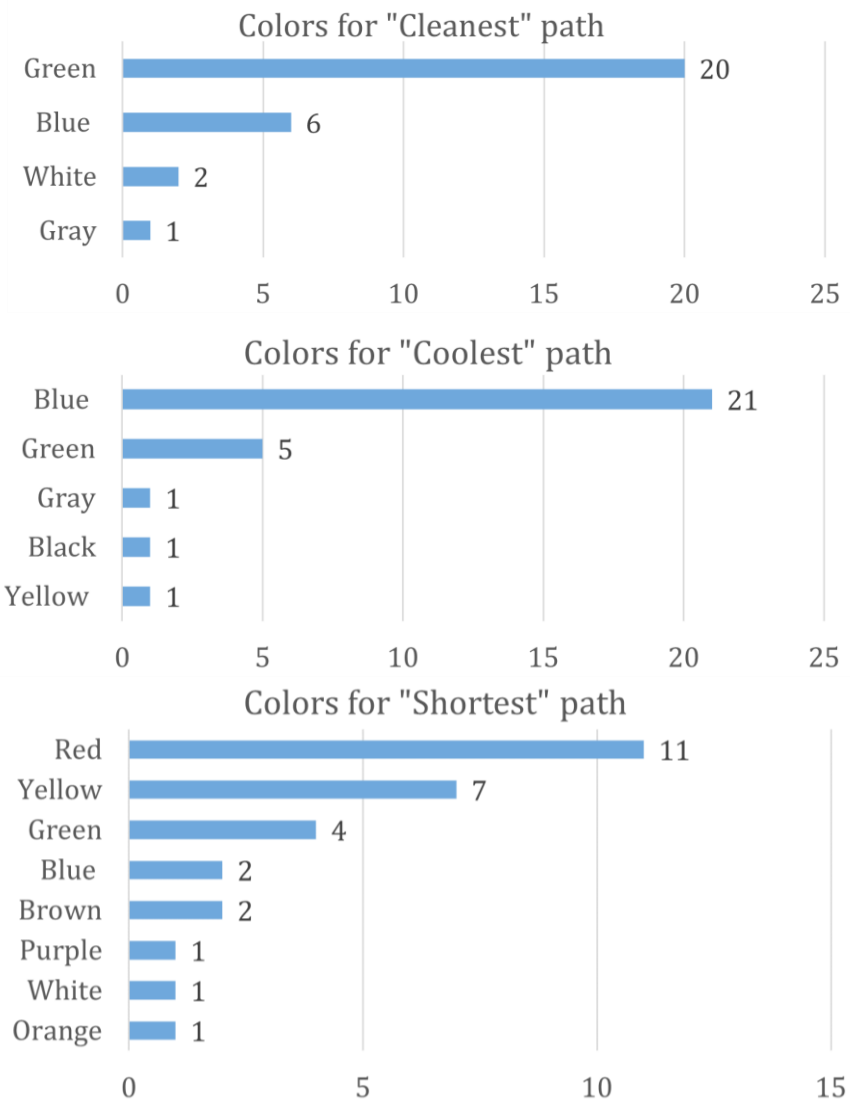


Results – User Study

Thematic Relevance I

- **Green** and **Blue** were the most popular two colors associated with the themes of cleanness and cooling
- **66.7%** of users chose **GREEN** for the route with the best air quality, **70%** of the users chose **BLUE** for the coolest route **63.3%** of the users chose warm (red, yellow, orange) colors for the shortest route
- Majority (**73.3%**) of the users employed different colors to represent different paths
- Some participants chose the same hue but different saturations or opacity to represent different paths.

Q22. Which color is the best to represent “cleanest”, “coolest”, and “shortest” path respectively?



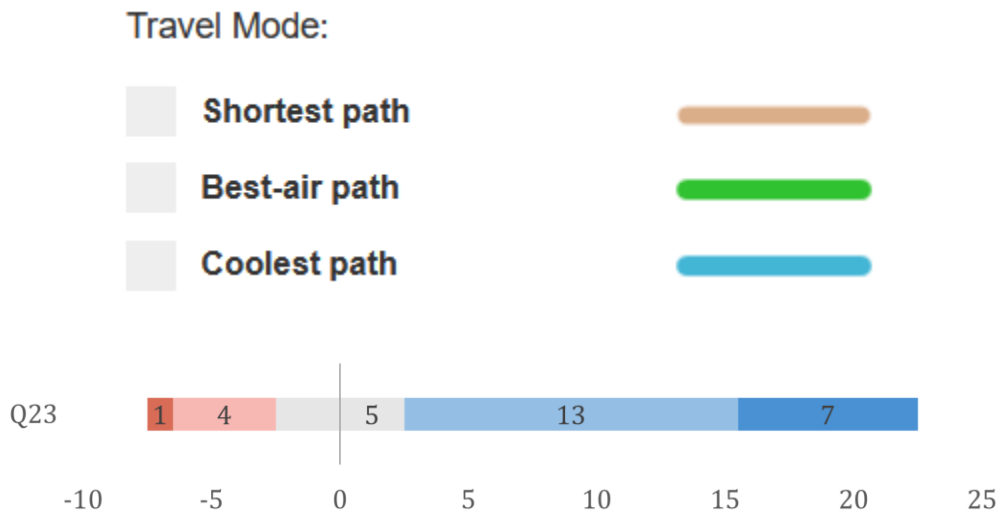
Results – User Study

Thematic Relevance II

- 20 (66.7%) users expressed positive attitudes towards the color design.
- p-value (0.0027) of the chi-square test **significantly less** than 0.05.

Null hypothesis rejected

Q23. How do you agree with the color design of routes ?



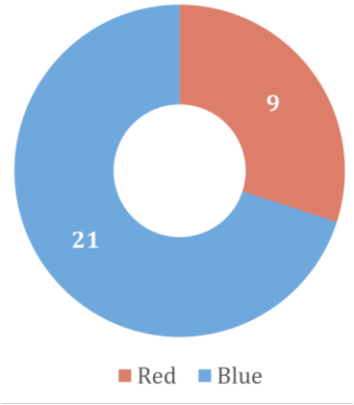
Results – User Study

Thematic Relevance III

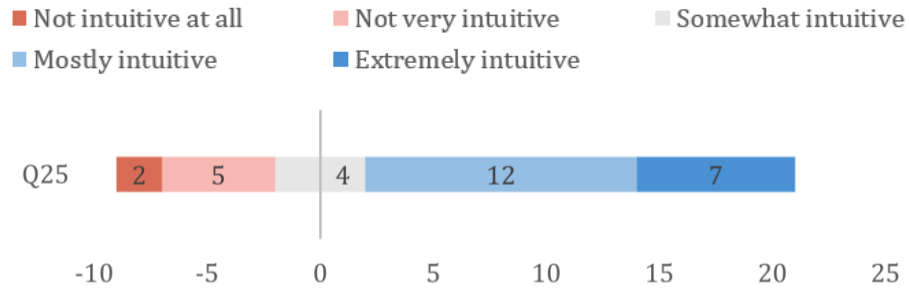
- **70%** of the users thought the blue marker represented the starting point
- **63.3%** of the participants stated the marker color matched their expectations and intuitiveness
- p-value of the user's intuitiveness is **0.0186** (< 0.05)

Null hypothesis rejected

Q24. Which marker do you think represents the origin?



Q25. How intuitive are the marker colors for origin and destination?
(blue is origin, red is destination)

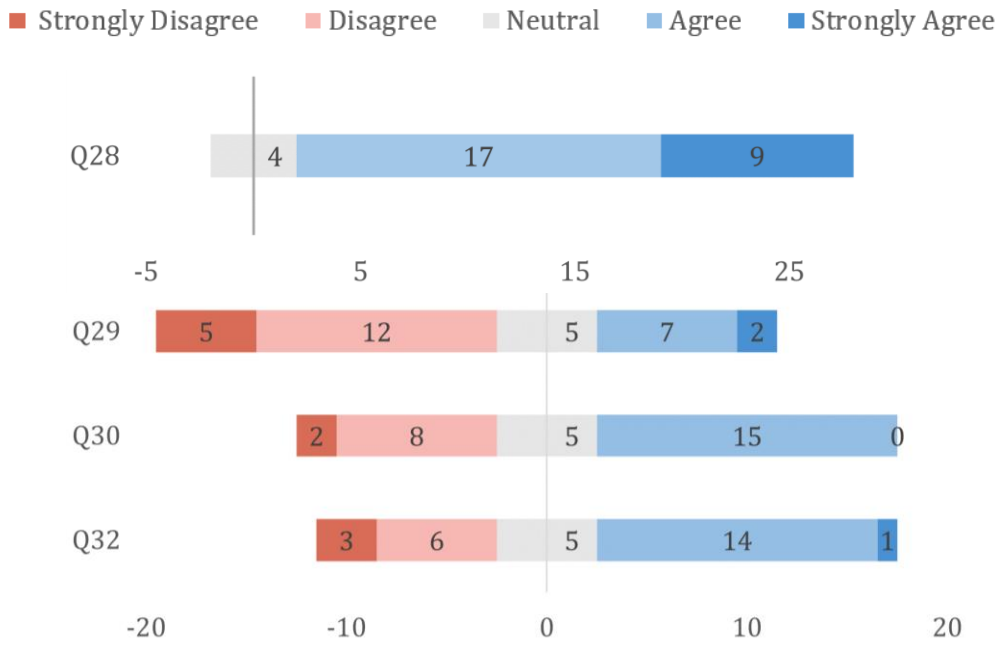


Results – Interface Evaluations

Usability Evaluation I – Learnability

- **NO** participant disagreed with the statement in Q28. The p-value **significantly less** than 0.05 ($p < 0.00001$)
- For Q30, **half** of the users agreed to have introduction or explanation for a better understanding of the use of the prototype
- Prior experience and knowledge about interactive map interface were considered necessary

Q28: It is very easy to understand and use to find healthier paths.
Q29: A support of a technical person is needed to be able to use the map.
Q30: Some detailed help or tutorial is required to be able to use the map.
Q32: Some background knowledge of using interactive maps is necessary to be able to use the map.

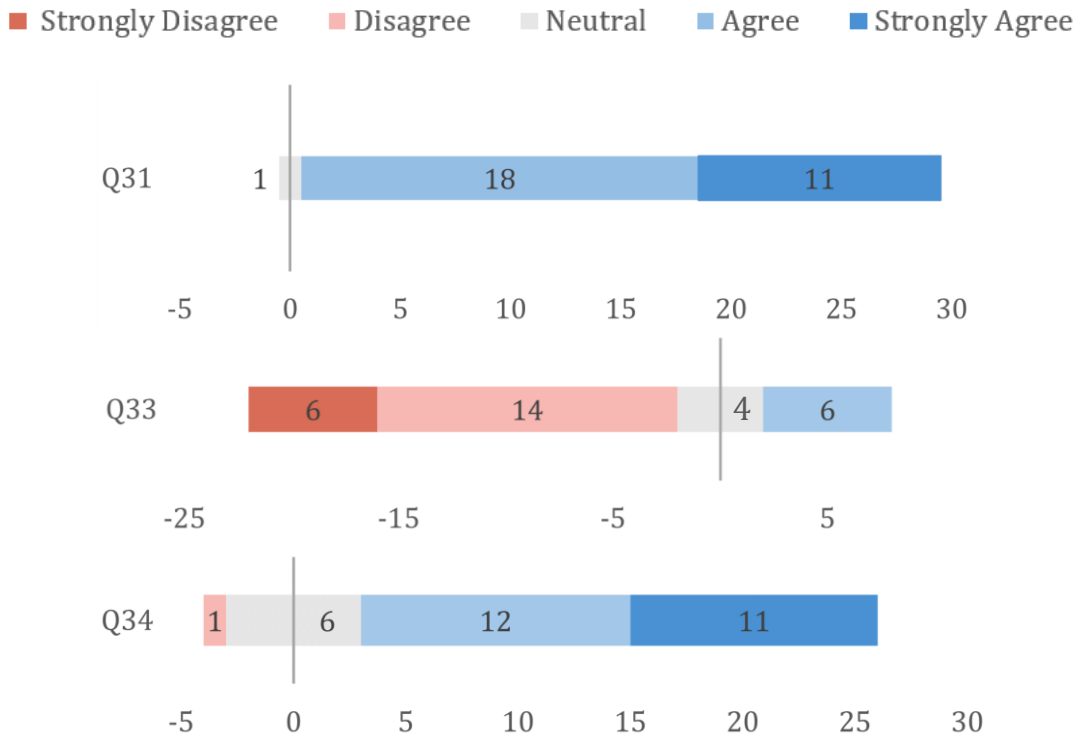


Results – Interface Evaluations

Usability Evaluation II – Efficiency and Satisfaction

- **29 out of 30** participants agreed that route finding tasks can be implemented fast
- **66.7%** of the users did not encounter big challenges when using the route planner
- **76.7%** of the users gave positive feedback towards the interface appearance
- P-values of Q31, Q33, Q34 were all significantly less than 0.05

Q31: Many people will be able to conduct the route-finding task quickly.
Q33: I was often confused about where to click or where to look when using the map.
Q34: The visual design of the application is well done.



Results – Interface Evaluations

Utility Evaluation

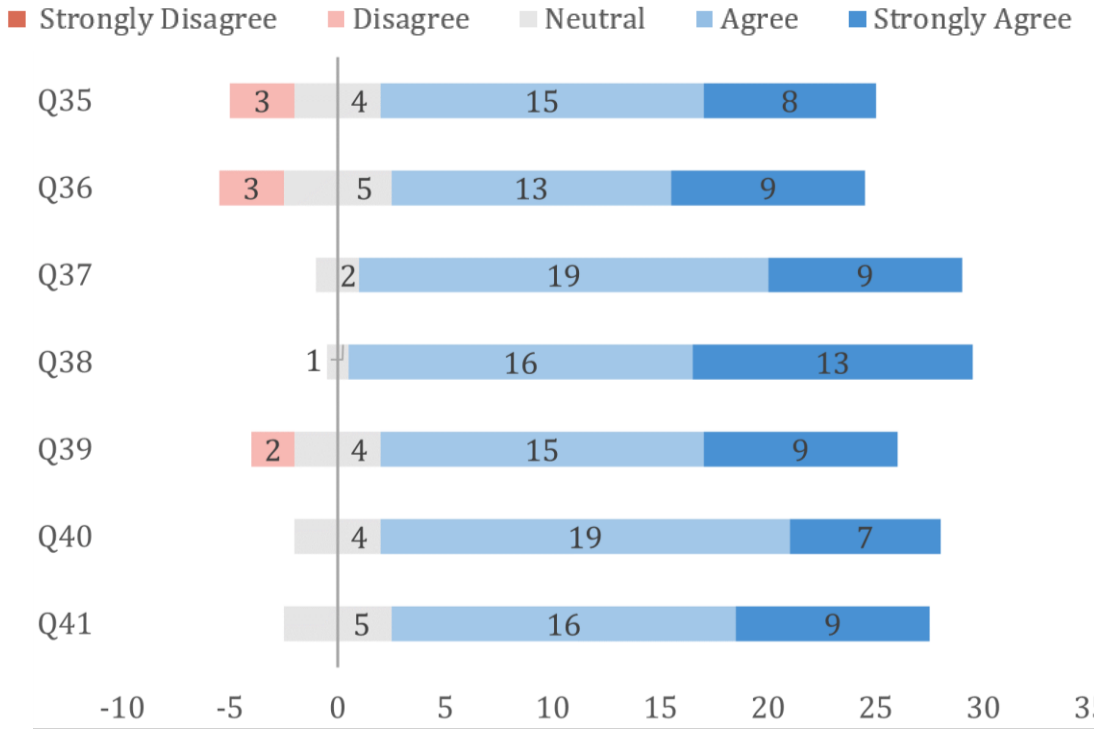
- Most of the answers fell on the positive side

→ Generally, users were satisfied with its utility

- p-value of the set of questions is 1.91 x 10-35

→ The alternative hypothesis that the prototype is useful and applicable were verified.

Q35: I would like to use the map often.
Q36: It is an application of my interest.
Q37: It would be applicable to the users who want to have health-oriented routes
Q38: The features or functions should be added to routing applications like Google Maps.
Q39: It has expected functions for health-oriented routing.
Q40: It has necessary visualizations to understand
Q41: Different paths are visualized in a proper way.



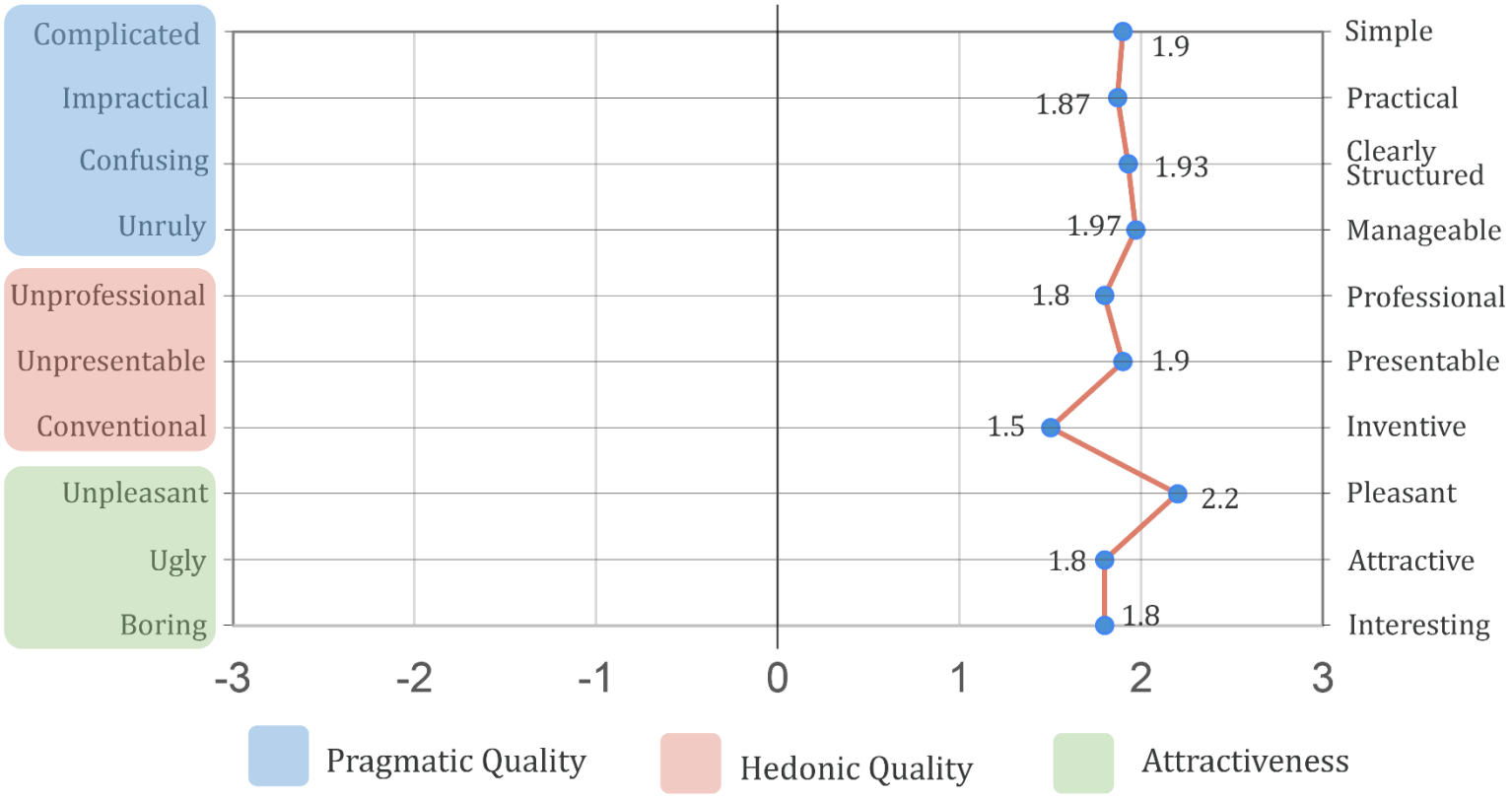
Results – User Experience

AttrakDiff Measurement

Users' average ratings on this prototype were **positive** from the aspects of pragmatic, hedonic, and attractive qualities

This prototype was regarded as a pleasant, inventive, and practical product that was liked by majority of the participants.

Q44-Q53. What is your impression on this prototype?



Results – User Experience

Thematic Analysis

Q54. How would you like to improve the prototype?

Theme	Example quotes	No. of people mentioned
Interface function	“ I would like to have autocorrection for address search”	13
Symbol design	“ Using the same marker symbol for origin and destination sometimes cause confusion”	6
Personal attitude	“ Dark mode is the most pleasing and interesting”	2
Desired feature	“ I would add expected time of arrival”	12
User instruction	“ Need to specify the intended user group”	5
Outlook	“ It’s better to collaborate with existing map apps”	4

Discussion – Overall Evaluation

Research Objectives were fulfilled by:

- Prototype development
- Interface design
- User study conduction

Hypothesis was validated through quantitative analysis of survey responses

Discussion – Limitations

Health Oriented Modeling

- Generated air quality/temperature attributes of road network failed to reflect actual spatial pattern

- Ignored the effect of travelling time on air pollution and heat exposure

User Study

- Lack of objective methods to measure users' attention and performance

- Participants were not randomly selected

Conclusion

- Developed a route planner as an output, which targets pedestrians and cyclists
- Promoted health-oriented paths by proper visualizations and attention-guiding techniques
- Usability, utility and user satisfaction were verified through a comprehensive user evaluation
- Extra features and functions can be added to enhance its performance for the future study

References

[1] UN, D. (2015). World urbanization prospects: The 2014 revision. *United Nations Department of Economics and Social Affairs, Population Division: New York, NY, USA*, *41*.

[2] Lu, J., Li, B., Li, H., & Al-Barakani, A. (2021). Expansion of city scale, traffic modes, traffic congestion, and air pollution. *Cities*, *108*, 102974.

Thank you for your attention!