User-Oriented Campus Routing

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Outline

1. Introduction
2. Related work
3. Methodology
4. Case study
5. Evaluation results
6. Discussion
7. Research findings and future work
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1. **Introduction**

- Background and motivation
- Research goal and objectives
- Research questions
Background and motivation

Introduction

- Significant **time** spent in indoor environments (home, work, and other indoor spaces)

- **Structural complexity** of indoor environments

- **High fluctuation** of user groups

- Only a few **design** guidelines for indoor navigation maps
Research goal and objectives

Introduction

• **Goal:**
  - Design and develop a campus routing application that facilitates orientation and navigation of various user groups (students, staff members, and visitors) on the TUM main campus.

• **Objectives:**
  - Adopt the appropriate visualization method for indoor spaces
  - Adopt the appropriate methods to evaluate map design and visualization as well as the usability and utility
  - Make use of evaluation results to identify research findings and propose future work recommendations
Research questions

Introduction

• What map design principles and visualization techniques are appropriate for a campus routing system?

• What map elements, navigation network elements, and user interactions are needed for an effective and efficient campus routing system?
2. Related work

- Theoretical background
- Campus routing systems
Theoretical background

Related work

- Elements of indoor navigation systems:
  - Positioning/Orientation
  - Route planning
  - Route communication
- Structural indoor features as landmarks
- Map perspective and landmark representation make up to 30% of user satisfaction with map design for indoor spaces (Source [2])
- 3D maps have a considerable advantage compared to 2D maps when it comes to indoor navigations (Source [2])
Campus routing systems

Related work

- Interactivity levels of campus maps based on their implementation:

  - **Static maps**
    - No interactivity
    - No navigation
    - Printable

  - **Semi-interactive maps**
    - Clickable and/or zoomable
    - Limited to building and immediate surroundings
    - Isolated solution

  - **Full interactive maps**
    - Zoomable
    - Clickable
    - Navigation
    - Room-finding
    - Embedded in context (no isolation)

Categories of campus maps and their characteristics (Source [3])
Campus routing systems

Related work

TUM “Roomfinder”, room 1767 (Source [4])

TUW indoor spaces (Source [5])

TUD Campus Navigator (Source [6])

University of Applied Sciences Würzburg-Schweinfurt (FHWS) campus information system and route representation (Source [7])
3. Methodology

- Workflow
- Data pre-processing
- Data processing
- Campus routing evaluation
Workflow

Methodology

- Building floorplans (i.e., CAD data)
- Data pre-processing
- Data processing
- Campus Routing evaluation
- Web application
- User studies
- JavaScript API

GIS Software

Campus Routing System
Data pre-processing

Methodology

- Select
- Simplify
- Exaggerate
- Remove

- Walls
- Doors
- Stairs
- Stair handlers
- Etc.

Categorization of floorplan lines

Categorization of interior spaces

Projection

- PCS
- VCS

Generalization

Building floor plans (i.e., CAD data)

Pre-processed CAD files

Projection
Data processing

Methodology

- CAD to GIS
  - Building attributes
  - Elevation information

- Map design and visualization
  - Campus basemap
  - Floorplan lines
  - Building interiors
  - Building footprint

- Indoor network
  - Point-to-point indoor routing
  - Floor transitions

- Configure the Web App
  - JavaScript API
  - HTML
  - CSS
Campus routing evaluation

Methodology

• Map design and visualization evaluation
  • Expert-based method
  • Background in Geosciences
  • Evaluate the applied design principles and visualization techniques

• Usability and utility evaluation
  • User-based method
  • Evaluate effectiveness, efficiency, and users’ satisfaction
4. **Case study**

- Workflow
- The TUM Campus Routing System
- Map design and visualization evaluation
- Usability and utility evaluation
Workflow

Case study

CAD data

ArcMap (ArcGIS Desktop)

Data pre-processing

ArcGIS Indoors (ArcGIS Pro)

Data processing

The TUM Campus Routing System

Campus Routing evaluation

User studies (Survey123 for ArcGIS)

Web application

ArcGIS API for JavaScript 4.4, HTML, CSS

User-Oriented Campus Routing
The TUM Campus Routing System

Case study
The TUM Campus Routing System

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The TUM Campus Routing System

Case study
Map design and visualization evaluation
Case study

- Purpose: evaluate whether the design principles and visualization techniques applied for the TUM indoor spaces are appropriate and cartographically appealing.

- Quantitative method → survey:
  o General Information
  o Campus routing map design
  o Campus routing map use

- Expert-based method
  - Online distribution
  - 41 participants
  - Geosciences background
Usability and utility evaluation
Case study

• Purpose: evaluate the usability and utility of the TUM CRS by measuring its effectiveness and efficiency of the TUM CRS based on users' interaction and experience with the model

• Mixed method of quantitative and qualitative data

1. Experiment:
   o The TUM main building
   o Define your position and search for the provided destination
   o Generate the route and navigate to destination
   o Think aloud
   o Participants observation

2. Survey:
   o General information
   o Interface design
   o Map and route design

• User-based method
  • First time visitors
  • 5 participants
5. Evaluation results

- Map design and visualization
- Usability and utility
Map design and visualization

Evaluation results

• It is preferable to represent the doors with a level of transparency

• Walls and doors should be extruded to a certain height

• A transparent visualization of exterior walls should be used when users will generate a route between indoor spaces

• Different colours should be used when the route follows the stairs or elevators.

<table>
<thead>
<tr>
<th>Statements</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transparent doors represent better visualization option than opaque doors</td>
<td>12,20%  60,98%  12,20%  14,63%</td>
</tr>
<tr>
<td>Walls and doors extruded to 1m represent better visualization option than extruded to the ceiling</td>
<td>48,78%  36,59%  7,32%  7,32%</td>
</tr>
<tr>
<td>The 3D visualization of floor transition elements (stairs and stair handlers) represent a better option than a 2D visualization</td>
<td>51,22%  41,46%  7,32%  7,32%</td>
</tr>
<tr>
<td>To visualize the whole route from the start point to destination, a fully transparent visualization of the exterior walls represents a better option than a textured model of the building</td>
<td>41,46%  46,34%  7,32%  7,32%</td>
</tr>
<tr>
<td>Using different colours to differentiate the route that follows stairs and/or elevators will increase the users’ understanding of the route and will improve the navigation</td>
<td>31,71%  48,78%  9,76%  9,76%</td>
</tr>
</tbody>
</table>
“Based on what you have seen within this survey, how would you evaluate the developed campus routing model of TUM?”
Usability and utility

Evaluation results

- **Effectiveness**: The TUM CRS helps users for a more effective indoor wayfinding process as they did not manifest any problems during the task and reached the destination easily.

- **Efficiency**: The TUM CRS represent an easy and simple to use indoor navigation system and requires a minimum number of steps to generate an indoor route.

- **Users' satisfaction**: The TUM CRS represent a pleasant indoor navigation app with a user-friendly interface.
Usability and utility

Evaluation results

- **Hypotheses 1**: Users can **navigate** in indoor campus environments with only a few or no **landmarks**, as long as the map design is intuitive and the route planning as well as the route representation avoid confusions among the users.

<table>
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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Floor transition elements (stairs, stair handlers) were clearly marked on the map</td>
<td>80,00% Strongly agree 20,00% Agree</td>
</tr>
<tr>
<td>Doors and hallways were clearly marked on the map</td>
<td>50,00% Strongly agree 40,00% Agree</td>
</tr>
<tr>
<td>The presence of landmarks was in the right amount</td>
<td>100,00% Strongly agree</td>
</tr>
</tbody>
</table>

**Legend**
- Green: Strongly agree
- Light Green: Agree
- Yellow: Neither
- Orange: Disagree
- Red: Strongly Disagree
Hypotheses 2: It is possible for the users to reach their destination in indoor campus navigation systems without the aid of indoor positioning and orientation techniques

<table>
<thead>
<tr>
<th>Statements</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>I could visualize the whole route from the starting point to the destination</td>
<td>100.00%</td>
</tr>
<tr>
<td>The map was easy to understand and I knew right away which way I had to go</td>
<td>100.00%</td>
</tr>
<tr>
<td>I was always sure if I had to turn left or right</td>
<td>80.00%</td>
</tr>
<tr>
<td>I was always sure if I had to walk up or down</td>
<td>100.00%</td>
</tr>
<tr>
<td>I was always sure on which floor I currently was</td>
<td>80.00%</td>
</tr>
</tbody>
</table>
6. Discussion
Discussion

- The literature review on developing and designing a CRS is meagre due to missing literature and only little research.

- The number of exciting CRS taken into consideration to perform an interactivity evaluation could be expanded.

- More literature review is needed to identify how and what visual variables should be applied to visualize indoor spaces.

- Provide expert users with access to the interactive 3D model of the TUM CRS.

- Apply other methods for the user studies to compare the results and reach more participants.
7. **Research findings and future work**

- Research findings
- Future work recommendations
Research findings
Research findings and future work

• Literature review identifies interactive 3D applications as the medium to visualize and convey indoor navigation systems

• The methodology adopted to develop the TUM CRS can be applied to other campuses and complex indoor spaces

• Expert-based method and user-based method are identified as the most appropriate methods to evaluate the TUM CRS

• The TUM CRS is an indoor navigation application, which makes use of structural features to plan and convey the route to various users in an effective and efficient way.

• High user satisfaction resulting from the user studies
Future work

Research findings and future work

- Future research on the correlation between visual variables and space use
- Apply various evaluation methods with a higher number of participants
- A better observation of users' behaviour while using the model to navigate
- Connecting all buildings and campuses of the TUM in a single outdoor/indoor navigation system
- Deploy the TUM CRS as an interactive mobile application
- Enable indoor positioning and orientation by using APIs offered as additional services
8. Sources
Sources


Thank you for your attention!