Development of an interactive digital campus map with navigation functionality for mobile devices

by

Patrick Christoph Zdanowski

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Supervised by:
Prof. Dr. Axel Küpper

Assistant supervisor:
Dr. Dr. Chuck Norris

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Berlin, October 30, 2023 Patrick Christoph Zdanowski

Abstract

In this thesis, we show that lorem ipsum dolor sit amet.

Zusammenfassung

Hier kommt das deutsche Abstract hin. Wie das geht, kann man wie immer auf Wikipedia nachlesen `http://de.wikipedia.org/wiki/Abstract`...

Contents

1 Introduction

1.1 Context and background

With over 60 different buildings, more than 35000 students and an area of over 600,000 square meters, TU Berlin's campus in Charlottenburg is one of the biggest continuous campuses in Europe. While studying is the main reason for most people to be on campus, learning and visiting courses are not the only tasks that take place on it. Campus Charlottenburg gives people the opportunity to learn and research, but also to connect to other like-minded people, eat meals in one of the cafeterias or bakeries, as well as to participate in one of the many social events that take place on it. Campus Charlottenburg is also the working place of over 7000 persons, including professors, students and researchers.

With its enormous amount of important facilities for students, families and other members of the university, campus Charlottenburg plays a central role in the lives of many people.

1.2 Motivation

TU Berlin's enormous size and complexity come with several difficulties for people working and studying on campus Charlottenburg, including an overwhelming amount of information about and around the campus as well as problems with navigation across it. New members of TU Berlin have problems localizing certain buildings and are overwhelmed by the amount of information the campus provides.

A working, manageable and modern digital information culture is one of the most significant key factors for overcoming those difficulties and for successful study, work and life on campus Charlottenburg. Such a system should offer an easy and intuitive way of accessing and managing information about the university to all of TU Berlin's members.

Some online resources and systems attempt to enhance the digital information culture including websites provided by TU Berlin and Studierendenwerk Berlin as well as a campus map and digital navigation systems for mobile devices. Nevertheless, there are several problems with the current landscape of web resources and platforms provided by TU Berlin and Studierendenwerk Berlin:

One of them is the fact that there is currently no fitting digital solution for navigation on the campus. Students currently have two options when choosing a tool to navigate across it: On the one hand, TU Berlin provides a downloadable image of campus Charlottenburg, which gives a basic aerial overview of the whole campus. Although this solution is straightforward and understandable, it only provides the possibility to navigate manually over the campus. It also does not take full advantage of the digital tools mobile devices and personal computers offer us.

On the other hand, there are several external digital navigation system providers such as Google or Apple Maps. Those systems take advantage of the digital tooling we have and provide a modern and mobile way of navigation. The main problem with these systems is the fact that they do not contain a detailed mapping of campus Charlottenburg. Searching for several buildings is difficult/impossible and since these systems are not profound for most of the paths on campus, proposed routes are often based on public routes around the campus rather than the faster ones inside of it.

Another problem is the fact that the amount and size of provided platforms is, in itself, overwhelming and complicated. The information about campus Charlottenburg is spread across the internet, instead of bundled. There is no central entity, that contains all information. The fact that most of the information is provided in the form of websites has another consequence for members of TU Berlin: Looking up information fast and intuitive on mobile devices, one of the most used digital tools in the present time, is often slow, unintuitive and unnecessarily complicated.

1.3 Proposed solution

This bachelor's thesis tries to investigate the current digital information culture at TU Berlin and wants to solve information retrieval and navigation difficulties by providing an implementation of a digital information and navigation system for mobile devices.

Both of these features use an underlying offline map of campus Charlottenburg, which provides a base layer for the main screen of the app. All other features and interface elements are therefore stacked in separate layers on top of it.

1.3.1 Campus map

A custom map of campus Charlottenburg represents the main element of the app. It comes completely bundled with the application for offline usage and displays the most relevant information about the structure of campus Charlottenburg, e.g., buildings, cafeterias, green areas and pathways across the campus.

1.3.2 Navigation system

A fast, reliable and offline-usable navigation system overlays the campus map and helps users find their way across the campus. It contains all the geodata and points of interest (POI) of the campus and can reliably calculate the fastest route between them. It also integrates the GPS functionality of the mobile device, to consider the current user location while navigating.

1.3.3 Information layer

The second layer on the map displays information about the campus. It fetches and parses them automatically from publicly available web resources and maps the information onto their respective POI.

2 Related Work

2.1 GPS

The global positioning system (GPS) as described in [1] and [2] is the modern standard for determining the position of a user on Earth. It is widely used across several different domains including navigation, tracking functionalities, military usage and other location-based applications. At least since the rise of mobile devices equipped with GPS capabilities the majority of people regularly uses GPS within several mobile apps and services.

The basis of GPS technology consists of a synchronized satellite network, which constantly broadcasts status information about the respective position, orbit and time of its members. GPS devices calculate their latitude, longitude and altitude by receiving data from at least four satellites. After data is transmitted, the signal propagation time is used for lateration, from which the position of the device can be determined. Since a correct measurement of signal runtime is essential (errors of 1 ms result in uncertainties of around 300 km [2]) and consumer-friendly GPS devices usually only contain a simple quartz-based clock, error estimation and correction systems are needed to estimate the exact time.

Depending on the environment and scenario in which GPS is used, several optimizations and improvements can be made. Since this thesis implements a navigation system for mobile devices, smartphone-focused implementation and usage techniques are particularly interesting.

One important example of such an improvement is the Google fused location provider API. This API is specifically designed for usage on mobile devices and improves the efficiency and accuracy of location retrieval by combining several internal smartphone sensors such as GPS and WiFi [3].

2.2 OSM mapping service

OpenStreetMap (OSM) is a community-driven open-source mapping service that provides annotated digital maps for most of the countries in the world. It was initiated in 2004 and consists of a web application [4] that hosts a static map as well as the Overpass Turbo API [5] for data retrieval.

One problem arising from the fact that OSM is community-based is the fact that it lacks quality assurance [6]. OSM quality varies depending on the country and region [6]: While rural areas often lack information, urban locations are often precisely represented and contain information comparable to data provided by the respective government of the selected area or commercial companies.

[6], with its implementation of the web app ‘Is OSM up-to-date?´ provides a systematic approach for measuring the OSM quality of an area. It presents how recently certain areas have been edited by the community and infers from that the need for revision on the map. In the case of TU Berlin’s campus in Charlottenburg, the available data is well-maintained [7] and can be used as a starting point for this thesis.

2.3 Techniques used in navigation systems for mobile devices

Navigation systems for mobile devices are nowadays a crucial part of the landscape of available navigation solutions. Popular mobile apps, such as Google [8] or Apple Maps [9], often provide users the ability to navigate, locate and explore the world around them. The core features of those systems and important aspects for this thesis are:

2.3.1 Routing

Routing through a network of streets and places is an important key functionality of every digital navigation system. The most popular techniques for routing all use an underlying graph representation of the street network [10]. With this technique, streets are represented as weighted nodes, which model the underlying cost of moving between different locations.

One of the most popular algorithms to determine the fastest way between two nodes is Dijkstra’s Algorithm. It greedily computes the shortest paths in the whole network to solve the routing problem. Despite its popularity and efficiency, the algorithm’s runtime scales poorly for huge graphs, e.g., the underlying data of Google Maps [10]. This is the reason why most of the algorithms used for routing in a navigation environment use different heuristics to speed up calculation. One example of them is the A* algorithm: It works similarly to Dijkstra’s algorithm but applies a heuristic to every node in the graph. By prioritizing the promising paths in the graph, A* usually finds the optimal routing solution faster than the basic Dijkstra implementation [10].

2.3.2 Location detection

The main system used for outdoor localization in Google Maps and other similar services is GPS [10]. During usage of the navigation app, the user gets the opportunity to activate it and give permission for its usage. While Google’s fused location API is the default location provider for Android devices [3], IOS devices use Apple’s Core Location framework [11].

Although GPS is the standard system for localization, several other techniques are often used to improve pedestrian location detection on mobile devices. [12] describes an approach for merging data of the smartphone’s built-in sensors with GPS functionality using a Kalman filter. The work states that such a technique can improve localization accuracy as well as energy-saving in a pedestrian position detection scenario.

2.3.3 Estimated time of arrival (ETA)

Providing an estimation of the time it takes to overcome the distance from start to destination is an important task for modern navigation systems. Google Maps calculates the estimated time of arrival (ETA) based on several different factors [10], including:

- Distance from start point to destination
- Average speed of the user and its selected form of transportation
- Current traffic situation on the chosen route
- Official and recommended speed limits
- Road types
- Historical average speed data
- Collected data from users who traveled similar routes

By collecting and merging this information, Google Maps manages it to provide its users with a precise ETA [10].

2.3.4 Visual design

The next step after retrieving the user's location and calculating the best route as well as its ETA is the presentation of that information within the app. [13] provides an overview of different solutions for information presentation within a mobile navigation system. It compares auditory instructions with route presentation of a map, simple route presentation on a map, display of current location and direction as well as a list of textual descriptions.

After evaluating all four different methods, [13] suggests the following aspects for a successful presentation of navigation data:

- A map oriented in the current walking direction should show the user's current location as well as the taken route and information about the map (landmarks, street names)
- The map should provide a zoom function
- Textual instructions are the most inefficient way of communicating navigation information
- Audio instruction can improve the map functionality, although GPS accuracy has to be taken into account when providing information about distance

2.4 Location-based services and geofencing

Location-based services are mobile applications/services, which utilize the ability to localize the user to provide customized information [14]. By offering users information about nearby restaurants, supermarkets, shops, hotels and other POI, mobile navigation systems such as Google [8] or Apple Maps [9] also fall into the category of such services. Other popular apps using location-based systems are emergency services, tour guides, delivery tracking systems, social-media platforms with location-sharing functionalities, weather apps and mobility or taxi apps [15] [16].

Location-based mobile apps nowadays usually use the in-build GPS capabilities of mobile devices to provide their services in outdoor environments. Other techniques used for indoor environments are WiFI, RFID, ZigBee and Bluetooth [16].

One important topic related to location-based services is the concept of geofencing. Geofencing describes a class of techniques used to automatically send notifications based on entering or leaving a specified geographic location [17]. These geographic areas are usually specified geometrically, by placing circles, polygons or polylines into specific locations, or symbolically by specifying a symbolic location such as a state, a country or an address [17].

One key enabler for geofencing is an extensive background tracking functionality [15]. In the case of modern mobile devices, smartphone apps with a geofencing functionality need the ability to constantly query the user's location, even if the app is in the background. Such systems can be combined with push notification techniques to deliver geofencing notifications when a certain area is entered or left.

Since the core functionality of the software developed in this thesis is comparable to mobile navigation systems such as Google or Apple Maps, the goal of this thesis itself can be described as a location-based service.

3 Concept and Design

3.1 General concept and key features

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4 Implementation

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Appendices

Appendix 1

```
for($i=1; $i<123; $i++)
{
    echo "work harder! ;)";
}
```