Faculty of Environmental Sciences Institute for Cartography

Master Thesis

Design of Mobile Maps with Open Source Mapping Platforms

in fulfillment of the requirements for the degree of

Master of Science

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TECHNISCHE UNIVERSITÄT DRESDEN

Faculty of Environmental Sciences Institute for Cartography

Task of Master Thesis

Course of Studies: Cartography

Name of the Graduand: Chiyuan Gu

Topic: Design of mobile maps with open source mapping platforms

Goals of this Study:

The increasing use of mobile devices comes along with an emergence of more mobile map applications which however appear mostly in standardised styles. The aim of the work is to create an interactive map with a customized design for the use on mobile devices showing georeferenced newspaper articles. A literature review should focus on mobile maps in general, mobile map design and possible interactions with mobile maps. In the conceptual part of the thesis, a comparison of the 'default' Google Maps API and open source mapping platforms like Leaflet for different criteria regarding their properties and particularities shall be accomplished. Based on this comparison, a workflow for creating an interactive and customized mobile map with the help of open source mapping platforms shall be described. The developed workflow will serve as a basis for the lecture and exercise 'Mobile Cartography'.

The practical work aims at developing a prototype of the earlier mentioned mobile map for the Android operating system focussing on visualisation and map interaction.

The student should submit two printed versions of the master thesis together with the digital version on CD. The digital version should include the text description and all required data and software to run the prototype. It is encouraged to publish the thesis on the publication server Qucosa of SLUB. The major findings will also be presented in the form of an A2 colour poster.

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Declaration of authorship

Herewith I declare that I am the sole author of the thesis named “Design of Mobile Maps with Open Source Mapping Platforms” which has been submitted to the study commission of geosciences today. I have fully referenced the ideas and work of others, whether published or un-published. Literal or analogous citations are clearly marked as such.

Abstract

More and more mobile map applications are released on the App Store with specific functions. However, these mobile maps are always with a standardized style, especially for the default style of Google Maps. In fact, with the emergence of various open-source mapping platforms such as Leaflet Application Programming Interface (API), OpenStreetMap API, and Mapbox API, there are many possibilities of designing your own custom web map with various interactivities.

The objective of this thesis is to develop a prototype mobile map app about displaying geotagged news articles in Dresden based on the comparison of Google Maps API and other open-source mapping API like Leaflet API. A workflow of creating a customized mobile map can be described and it will serve as a basis for the course “Mobile Cartography”.

As a case study of developing mobile map, this thesis focuses not only on the basic functionality to display points of interest (POI) with related information, but also on the sophisticated methods for presenting geospatial data via some web mapping or mobile mapping techniques like jQuery mobile, MarkerCluster plugin, CARTO API, and Mapbox Studio. All in all, these existing tools can make the whole designing process convenient and inspire cartographers to represent geographic information in more efficient manner. As a result, this work explores more approaches for cartographers creating customized mobile map with open source mapping platforms.

Acknowledgements

I would like to express my sincere gratitude to my advisors Dr.-Ing. Eva Hauthal and Prof. Dirk Burghardt for their patient guidance. They always steer me in the right direction and make me clear of the aim of this thesis.

Furthermore, I would like to thank the web workshop from DUSPviz in MIT. The resource from their website inspires me, especially for some specific functionality.

What's more, I have to thank for those contributors of OpenStreetMap and developers for those ready-made plugins and JavaScript libraries. Without their share, I would not develop this mobile map smoothly.

Last but not least, thanks for my friends who accompany me during this period.

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Abbreviations

POI Points of Interest

LBS Location Based Services

VGI Volunteered Geographic Information

OGC Open Geospatial Consortium.

OSM OpenStreetMap

API Application Programming Interface

KML Keyhole Markup Language

HTML HyperText Markup Language

XML Extensible Markup Language

CSS Cascading Style Sheets

PHP Hyptertext Preprocessor

DOM Document Object Model

DLM Digital Landscape Model

DCM Digital Cartographic Model

LOD Level of Detail

1 Introduction

1.1 Background and Motivation

In the book of “The History of Cartography,” the map was described as “graphic representations that facilitate a spatial understanding of things, concepts, conditions, processes, or events in the human world”(Harley, Woodward, Lewis, & Monmonier, 1987). With the rise of Internet, the focus of mapmaking has been shifted to the web mapping which makes maps much more present to the public. And the potential of the Internet offers totally different approaches to visualize and communicate geospatial information(Pucher, 2015). In the beginning, web mapping was the domain of only large companies like Google, ESRI, and Yahoo. However, with the emergence of open-source mapping projects under the banner of FOSS4G (free open-source software for geo-applications) and the support from Open-source Geospatial Foundation (OSGeo), anyone can have access to create web maps by a computer connected to the Internet(Lovelace, 2014).

In recent years, the rapid adoption of smartphones leads a new revolution in the cartography. More and more mobile map applications are released to meet the increasing demands of users. These mobile maps are not only interactive but also as tangible as paper maps. Therefore, mobile mapping is the new trend in modern cartography.

Furthermore, as a combination of art and technology, cartography is often applied in

other fields. A well-designed map can express the information more vividly and clearly. These features of the map inspire the author a new thought so that this thesis work is going to make a combination of journalism and geographic information based on the location-based service (LBS).

1.2 Research questions

The goal of this thesis is to start the process of developing a mobile map application for Android to present the Geotagged news stories. Before practical work for this thesis, the following research questions are listed which can make us clear about the objectives of this thesis work.

How to design a better-customized background base map with existed tool?

How to develop a mobile map app in Android with open-source platform API?

How to present Geotagged news data in a proper way?

1.3 Outline

As an introduction to the topic, it provides an overview of current web mapping and mobile mapping and states the motivation for this case study. Furthermore, it presents clear objectives by answering three significant research questions. In next chapter, a well-organized literature review outlines the state-of-the-art technologies in web mapping and mobile mapping. And the history of map design will guide us in next implementation. The research about geotagged news data indicates that we should contribute much more to this field which will make our lives better. In chapter 3, the focus is set on illustrating some comprised technologies and concepts for the design of a prototype of mobile news map. Subsequently, it comes to the core of this thesis. It is about how to realize this mobile news map app step by step. It demonstrates the functions of specific codes. In the end, the author concludes the whole study and draws some experience that can be applied for mobile mapping in the future.

2 State of the Art

2.1 Web Mapping

In recent two decades, web mapping played a dominant role in cartography. It made cartography go through a tremendous change and made a major paradigm shift in cartography. There is no doubt that web mapping can be seen as a starting point for modern cartography. After the advent of web mapping, related innovations came up with the support of newly released technologies(Harrower, 2008).

Before looking into web mapping contemporary technologies, it is necessary to be clear about the goal of web map communication, which will guide us to design better web map. Muehlenhaus (2013) concluded some basic principles: appeal to the audience, but not necessarily everyone; limit what the map tries to convey; add interactive elements not by default but only if they facilitate communication goals.

“Web mapping technologies” is a popular term in modern cartography. It is gradually used to describe the compilation of APIs, libraries, services, etc., which force cartographers to keep the pace of new technologies. Among these techniques, as a modern cartographer or GIS expert, it is essential to be equipped with the skill sets of HTML, CSS, SVG, and XML web standards and Python, the JavaScript programming language(Roth, Donohue, Sack, Wallace, & Buckingham, 2015).

Among the most common kinds of web maps, “Slippy Maps” is widely used. It is with feature layers that can pan and zoom. In addition, it has the ability to convert data to map layers. What’s more, it is easy to extend with plugins.

What does “web mapping service” refer to? To answer this question, the Open Geospatial Consortium defined it. According to its official definition, web mapping service comprises of two functions(Peterson, 2012):

(1) GetCapablites defines the capabilities of the server like the available map layers, the supported file formats, and the method of display.

(2) GetMap tells the database what is needed. Besides, The OGC standard proposes the definition of a variety of services, including:

Web Map Service (WMS) – georeferenced map images that can not only in the form of raster tiles (PNG, GIF, or JPG) but also in a vector format. And a standard web URL is used to make requests.

Web Coverage Service (WCS) – a geographical area that can be overlaid on a map but cannot be edited or analyzed. WCS is used to transfer coverages that consist of objects such as vector point data.

Web Feature Service (WFS) – allows the request for geographical features. WFS web service allows features to be updated, created, queried, or deleted by the client. The data are usually provided in an XML format like GML.

2.2 Mobile Mapping

The mobile map is the newest presenting way to display geospatial information. Before mobile map appeared, a major disadvantage of traditional web-based maps is the lack of mobility compared to paper maps(Peterson, 2003). The development of mobile devices makes the larger screen and improves positioning technologies which are the basic foundation of realizing the mobile map. The most notable feature of the mobile map is that it provides user’s current position which represents a typical type of location-based

services (LBS). Interaction paradigms and usability issues of presenting geospatial are most discussed. Liqiu (2008) proposed some research questions related to the generation of mobile map such as “Which kinds of tasks involve mobile maps?”, “Which generalization methods are useful to the mobile map?” and “How to direct the attention of the user to the key content of mobile map?”

According to mobile map studies, today’s mobile map application can be categorized as mobility support, information acquisition and information communication(Liqiu, 2008). Besides, current mobile maps allow two types of adaptation. One of these two adaptations can be described as “with the help of sensors”. The mobile device receives the current location and moving direction by a GPS receiver. And the map view is automatically refreshed that makes a unique presentation to each different user. Another adaption depends on user’s inputs – the presentation of mobile map is based on what users input(Sarjakoski & Nivala, 2005). As a user, the interaction between users and the mobile map is the most concerning part. The primary operations are below:

Panning – the user can move the map in any directions.

Zooming – the user can change the display areas.

Switching – the user can select the particular presentation style.

Query – the user can search for any objects by inputting keywords.

Last but not least, a usability test has to be carried out before the mobile map app is released out on the market. It is a means to ensure the high quality of map production. Burghardt and Wirth (2011) compared several methods for examining the usability of the mobile map in a natural environment. Additionally, the usability of a mobile map can be measured in efficiency, user satisfaction and effectiveness(Sarjakoski & Nivala, 2005).

2.3 Cartographic Design for Web Mapping

A good map should be simple with objective and precise geospatial information. Besides, it should be well presented that can attract reader's attention to the significant information(Zealand, 2014). In order to meet the above stated requirements of a good map, cartographers have to keep certain goals of design in mind when planning a map. These goals of deign are order, clarity, contrast, balance, unity and harmony(Tyner, 2010).

Map design principles are a generalization of the wisdom of predecessors. In 1999, the British Cartographic Society's Design Group proposed five principles below:

Concept before Compilation – grasp the concept before design map that can ensure the unrelated content is not included. It will also save much time.

Hierarchy with Harmony – make users clear about what things are the most important.

Simplicity from Sacrifice – the less is better. A great map means that each element of it is indispensable.

Maximum Information at Minimum Cost – It is better to gain more and more information from this map.

Engage the Emotion to Engage the Mind – what cartographers chase is the attention from the users.

Buckley (2014) concluded five of main design principles which are visual contrast, legibility, balance, hierarchical organization, and figure-ground organization. Visual contrast and legibility have an impact on reading the content of map. Balance, hierarchical organization, and Figure-ground organization lead the map readers to focus on the most important content of map.

Visual Contrast – increasing illumination is a good way to help you distinguish map features from the background. Furthermore, the features should be large enough to see.

Legibility – this kind of ability depends on what symbols selected. A map with legibility makes readers have a better understanding of content.

Figure-ground Organization – it is about to outstand target figure from amorphous background. The common operations here include feathering and a drop shadow.
Hierarchical Organization – the structure of map including layout is fundamental to help people read the map.
Balance – it involves the organization of all map elements. The visual weight of each element has to be distributed evenly. A good balanced map will give people an aesthetic feeling.

These rules and principles I stated above are used for general map design. As for the web mapping, we have to adhere to the following principles(Zealand, 2014):
Perceivable – the components of the map have to be perceivable to users, which is the basis of the web map. This means that all of the information should be visible to users.
Operable – this means that users can get access to interact between the user interface and web map.
Understandable – this means that both contents of web map and operation of the user interface cannot go beyond their understanding.
Robust – this means that the web map has to be stable for using and operating. At the same time, it can be involved in extending some new functions.

2.4 User-generated Cartographic Information

2.4.1 User-generated Content and Volunteered Geographic Information (VGI)

In recent years, there is a new trend in data collecting. Collective intelligence is widely used in collecting and distributing various data. Content on the Internet is created and distributed in the form of “user-generated content” for other users to consume. This kind of data can be images, videos or some social network information which are derived from YouTube, Flicker, Facebook and Twitter. Users create this kind of content out of personal interest without professional duties(Stephens, 2013).

Meanwhile, Geographic Information System (GIS) is slowly evolving with the development of related technologies. And data collecting is always regarded as the bottleneck of developing GIS. The advent of user-generated content inspires the GIS researchers. Elwood, Goodchild, and Sui (2012) research growing practices of user-generated content and propose a conception of volunteered geographic information (VGI), representing a paradigm in how to create and share geographic information. At the same time, VGI answers the question that geographic information is created and shared by whom.

2.4.2 Geotagged News Story Data

Recently, some scholars of journalism are seeking a multidisciplinary approach to breaking through bottlenecks in journalism. There is no doubt that the geography of news stories is a valuable starting point for these scholars who wish to get a better understanding of what local news gets reported, why and how it gets reported, and the potential consequences of such news coverage(Lindgren & Wong, 2012). News articles contain implicit geographic content that if exposed to readers improves understanding of today's news. However, most articles are not explicitly tagged with their geographic content(Teitler et al., 2008). If these news stories could be tied to the geographic location by news publishers, so many amazing things would happen. For instance, people can search news stories by a specific point of interest (POI) like “Grosser Garten in Dresden,” or a general region like “within 30 miles of Dresden Hauptbahnhof”. And people would be more familiar with news about their living block. In addition, people can also receive any news stories happened within a specific mile of the user’s current location. However, before 2008, there is no such standard existing about applying geographic data to news stories(Tweney, 2008). Then some people made an effort to a project aiming to create an open-source standard for geotagging news stories so that any users can be seen as both publishers and readers who can upload, retrieve and comment on news based on geographic areas they are interested in. A few years later, a geoloca-

tion platform for news publishers came up. It is called “Bloom”[1] which can assist news organizations to decide not just what to write about, but where to write about. As their readers, people can read their news stories block-by-block reporting. So far, more than 2000 geotagged news articles have been collected. After that, with the development of mobile devices, a novel app “Blockfeed – the NYC news”[2] was released in September 2015. BlockFeed is taking a data-driven approach to local news by geotagging news stories and presenting them based on where users are(Bilton, 2015). It is an innovative approach to using location data to present local news. Users can judge what is important by themselves. The personalizing news stories will be told based on the location of users.

1 https://www.bloom.li/

2 http://www.blockfeed.com/

3 Concepts

3.1 Technologies

3.1.1 Coding Language

HTML

Hypertext markup language (HTML) is the core of the web which is the standard markup language for creating web pages. The browser deals with the content of HTML. HTML is easy to use because of its simple syntax. HTML can organize and deliver content via the use of tags. In general web applications, HTML is only used for content part. JavaScript and Cascading Style Sheets (CSS) are responsible for interactivity and styling.

Cascading Style Sheets (CSS)

As HTML is used to organize content and deliver content to the web browser, CSS styles this content by describing the presentation of it. It is a style sheet language which designed for separating document content from document presentation, including fonts, colors, and layout. It can be implemented and interpreted by different web browsers. If the users want to make web maps attractive, they have to be familiar with CSS. Because all of looking styles are designed by CSS such as colors, fills, and shapes. Fortunately, CSS is a quite easy and friendly programming language to comprehend and write. A general CSS looks like some rules about listing a set of characteristics of objects.

Frankly speaking, CSS is likely the easiest language among JavaScript and HTML.

JavaScript

Interactivity is left to JavaScript. It is an interpreted language used to control and manipulate the behavior of web pages by interacting with different elements on the web. One advantage of JavaScript is that it can be supported by modern web browsers without the need for plugins, which makes it convenient to use. Furthermore, JavaScript has an excellent performance on responding user's interactivity because of the self-processing of user's input. In a web page file, JavaScript is tagged in <script></script>. It is robust that people can create variables and functions. Furthermore, the huge open-source mapping scripts resource support users to start creating marvelous interactivity with their maps.

What's more, as the key of Web mapping, most of APIs are also written in JavaScript. In the case of Web mapping, APIs are used to help browsers to communicate with an online mapping service. For instance, in this map app, Leaflet.js, a JavaScript library, is selected as our API to realize the calling of online mapping service. Animation can be seen as another thing that makes the users start learning JavaScript. Various animation effects make web pages more attractive. All in all, JavaScript is the core technology of web mapping, and it is the most time-consuming part of this work's web mapping study. In this case study, JavaScript is used to tackle these two significant questions below:

How to add and store related geospatial data for this web map?

Compared to KML (Keyhole Markup Language) with larger file size, the smaller GeoJSON is more suitable for geospatial data. Besides, it is easier to read and edit than XML (Extensible Markup Language). In summary, that is why GeoJSON format is selected to store related data, and it can be easily controlled and manipulated by JavaScript. Fig.3.1 shows the basic format of a GeoJSON file.

```
{
    "type": "Feature",
    "geometry": {
    "type": "Point",
    "coordinates": [125.6, 10.1]
    },
    "properties": {
    "name": "Dinagat Islands"
    }
}
```

Fig.3. 1 The basic format of GeoJSON

How to realize functionality and interactivity for web map?

The answer is jQuery which is a small and fast JavaScript library. It helps me to traverse and manipulate HTML documents. The way of writing JavaScript has been changed by jQuery's extensibility and versatility. The following Fig.3.2 demonstrates how to manipulate DOM (Document Object Model) and how to handle an event.

```
//DOM Traversal and Manipulation
//Get the <button> element with the class 'continue' and change its HTML to 'Next Step...'
$( "button.continue" ).html( "Next Step..." )
//Event Handling
//Show the #banner-message element that is hidden with  display:none in its CSS when any button in #button-container is clicked.
var hiddenBox = $( "#banner-message" );
$( "#button-container button" ).on( "click", function( event ) {
  hiddenBox.show();
});
```

Fig.3. 2 Manipulate DOM and handle an event

What's more, another jQuery foundation project called jQuery Mobile is a popular JavaScript library for touch-optimized web framework. A cross-platform responsive application or web site can be designed for different demands of each unique operating system.

PHP

PHP is a server-side scripting language which is interpreted on the server. It means these PHP codes never go to your browser. In this thesis work, PHP is used to communicate with database like CARTO. Users' generated data are stored and pushed into the CARTO by it, which makes the data safe to be used.

JAVA

Android is an open-source operating system for mobile devices like smartphones, tablets, and smart watch. It is written in Java which is an object-oriented programming language. Java is one of the most popular programming languages in use, particularly for client-server web applications. This is because that Java codes can run without the need for recompilation.

3.1.2 Tools for Designing and Developing Customized Mobile Maps

Mapbox

Mapbox[3] is getting more popular in recent years. It is a very flexible mapping platform that can helps users visualize millions of personal data. Many background maps are styled by Mapbox. The content and the style of the map can be selected by users according to their taste.

CARTO (used name: CartoDB)

CARTO[4] is an open, wonderful, powerful platform for discovering insights according to location data in the real world. Here all attributes data are stored in CARTO database, and then in this work's map these data can be fetched by its API.

Android Studio

Android Studio[5] is the official integrated development environment (IDE) for Android application development. It is a good alternative to Eclipse IDE. It is the trend to develop Android app in Android Studio. On its website, it offers a wealthy of tutorials to guide the user.

3 https://www.mapbox.com/studio/

4 https://carto.com/

5 https://developer.android.com/studio/index.html

3.2 Concepts of Customized Map for Mobile Use

3.2.1 Digital Landscape Model (DLM)

DLM is proposed in order to meet demands of visual purposes. Understanding and Simulating some invisible aspects of the landscape require some more operations like simplification and abstraction(Ervin, 2001). In general, water, terrain, and vegetation can be regarded as three basic landscape elements. Besides, structures (including architecture and infrastructure), animals, and atmosphere are combined as well in common DLM. Each of elements faces its own challenges. In this case, the focus is on how to present and style landform, water, and structures. According to demands of this mobile map, water, buildings, bridges, and roads have to be presented on the map.

3.2.2 Digital Cartographic Model (DCM)

DCM provides a way for integrating map layers and analyzing spatial data. In this case, DCM has the ability to outstand the theme of this mobile map by setting the attributes of different map elements. The specific required elements are listed below in Tab.3.1.

Tab.3. 1 The display of map in each zoom level

Layer group	Layer	Zoom level range
Building		15-18
Parks		10-18
Water		10-18
Road	Road-primary	10-18
	Road-secondary-tertiary	12-18
	Road-street	15-18
Bridges	Bridge-primary	10-18
	Bridge-secondary-tertiary	10-18
Road Label	Road-label-large	12-18
	Road-label-medium	15-18
	Road-label-small	15-18

3.2.3 Map composition and layout

Map composition is related to visual hierarchy. It is about to decide which map elements within map area to focus on. A good map composition will improve the communication with users. Compared with map composition, map layout deals with how to display different elements. Both of them involve aesthetic theory.

Borden Dent (Dent, 1999) proposed his visual hierarchy for map design. In his theory, all map elements and objects are arranged in a logical order by their relative importance depending on the communicative purpose of the map (see in Tab.3.2). His visual hierarchy is not only useful for the traditional map but also for the web map. As a map designer, it is significant to know how to make certain map elements stand out. There is no doubt that designing each map element is the best way to highlight it in the visual hierarchy. Some common techniques include manipulating color value, hue, and intensity to

establish contrast and styling objects to make them look different. In this map, establishing contrast and styling are based on thematic web map visual hierarchy (see in Tab.3.3).

Tab.3. 2 Dent's Visual Levels for Thematic Maps

Dent's Visual Levels for Thematic Maps	
Level 1a	Thematic Symbols
Level 1b	Title Legend Map Symbols Labels
Level 2	Base Map: Land Areas, Political Boundaries
Level 2-3	Explanatory Materials: Map Sources, Credits
Level 3	Base Map: Water features
Level 4	Other Base Map Elements: Grids, Scales

Tab.3. 3 Visual Hierarchy for Dresden News Map

Visual Hierarchy for Dresden News Map	
Level 1	Title/Splash Screen Thematic visualization
Level 2	Base Map Info Windows
Level 3	Base Map Labels Map Interactivity: pan/zoom/menus
Level 4	Supplemental Information: attribution and copyright

The aim of map layout is to arrange these map elements in a balanced manner to communicate information with map users. There are two typical web map layouts. One is called fluid map layout. In the fluid layout, all elements are placed on the top of the map area. For achieving the balancing effect, elements are allocated in the blank area. It is an excellent choice for mobile mapping. On the other hand, compartmentalized map layout separates map elements into the small part. Each one has its own particular place. For instance, map tile is set above the map area and scale bar shows underneath the map area instead of overlaying the map. It works well on big screens, especially for some for-

mal presentation. Both of these two layouts have their own advantages and disadvantages. It is better to draw their benefits to design this work's map. Finally, the navigation bar including the menu is above the mapview. And a scale bar is in the bottom left corner of the screen, and the zoom bar is preserved on the top left of the screen. On the top right, there is a layers control to switch the base map style. Besides, the attribution and copyright of the map tile are shown in the bottom right corner. As a result, all of four corners of the screen have some map elements in a balanced manner.

3.2.4 Color

Color plays a major role in cartography. The importance of color exceeds the understanding of many mapmakers. A good color scheme should be attractive and match the nature of the data(Harrower & Brewer, 2013). Thus, selecting an effective color scheme for mapping tends to be much difficult. Fortunately, the advent of ColorBrewer[6] makes a choice easy. ColorBrewer is an online tool that helps people to make a decision on the choice of color schemes for thematic cartography. According to the specific mapping needs, many aspects of color are considered based on the basic properties of color including value, hue, and saturation.

3.3 Comparison of Different Online Maps APIs

In 2005, an Application Programming Interface (API) was released by Google Maps which brings a tremendous change to the web mapping. It realized panning and zooming in a tile-based mapping system based on AJAX and it gave programmers access to add much more data on the top of Google Maps. With more and more APIs came up, web maps got more means to acquire, analyze and display geographic information from various sources. These APIs can be seen as function libraries which are the core of Mashups which combine multiple resources and technologies.

6 http://colorbrewer2.org/

Google Maps API

Google Maps API[7] can be regarded as the pioneer of API, and it is the most common used API for mapping. The API consists of a serious of functions that allow developers adding their trusted data and controlling the display of the map content. Developers can make a custom map for their sites by various style, 3D architecture model, and indoor plan. Its advantages include its street view, a wide range of static and dynamic visualizations and good integration of with Google Earth which is other open-source APIs struggle with. As for personal users, the use of it is essentially free except a site loads map more than 25000 times a day for 90 consecutive days. Fig.3.3 demonstrates a simple map demo by Google Maps API.

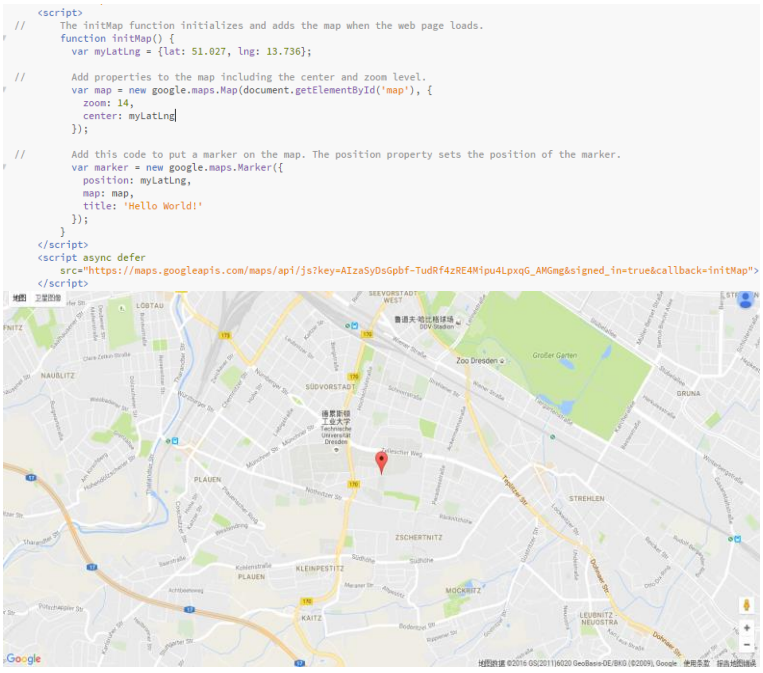

Fig.3. 3 A single marker with the Google Maps API

OpenStreetMap API

OpenStreetMap[8] is the typical representative for volunteered geographic information (VGI). It is also an open-source web mapping platform. Thousands of contributors make it possible to meet the requirement of any web mapping task. The ability of underlying

7 https://developers.google.com/maps/

8 https://www.openstreetmap.org/#map=5/51.500/-0.100

vector data is OpenStreetMap API's major advantage. Although its API has a few more functionality than others, its code is a bit longer and more complicated than other mapping APIs.

```
<script src="http://openlayers.org/api/OpenLayers.js"></script>
<script>
    var lat            = 51.027;
    var lon            = 13.736;
    var zoom           = 14;

    var fromProjection = new OpenLayers.Projection("EPSG:4326");   // Transform from WGS 1984
    var toProjection   = new OpenLayers.Projection("EPSG:900913"); // to Spherical Mercator Projection
    var position       = new OpenLayers.LonLat(lon, lat).transform( fromProjection, toProjection);

    map = new OpenLayers.Map("map");
    var mapnik         = new OpenLayers.Layer.OSM();
    map.addLayer(mapnik);

    var markers = new OpenLayers.Layer.Markers( "Markers" );
    map.addLayer(markers);
    markers.addMarker(new OpenLayers.Marker(position));

    map.setCenter(position, zoom);
</script>
```

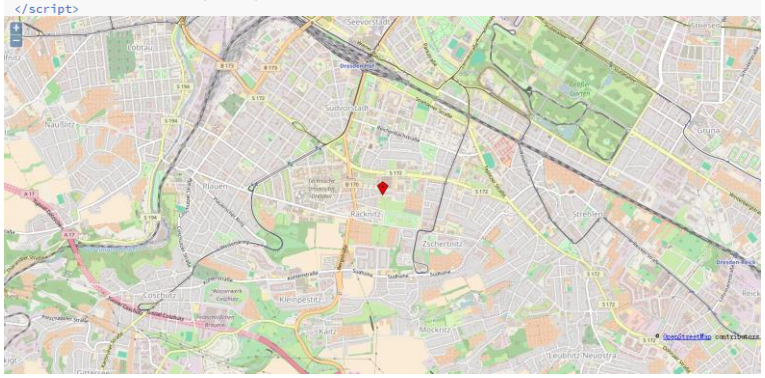

Fig.3. 4 A single marker with the OSM API

Mapbox API

Mapbox is the mapping platform for developers. Its open-source libraries support the functionality of interactivity and control. Besides, Mapbox also provides the tool to design the custom map style. With the friendly user interface, it is easy and enjoyable to deal with the whole process of making the map from tile designing to map publishing. What's more, Mapbox supports other mapping APIs like Leaflet.

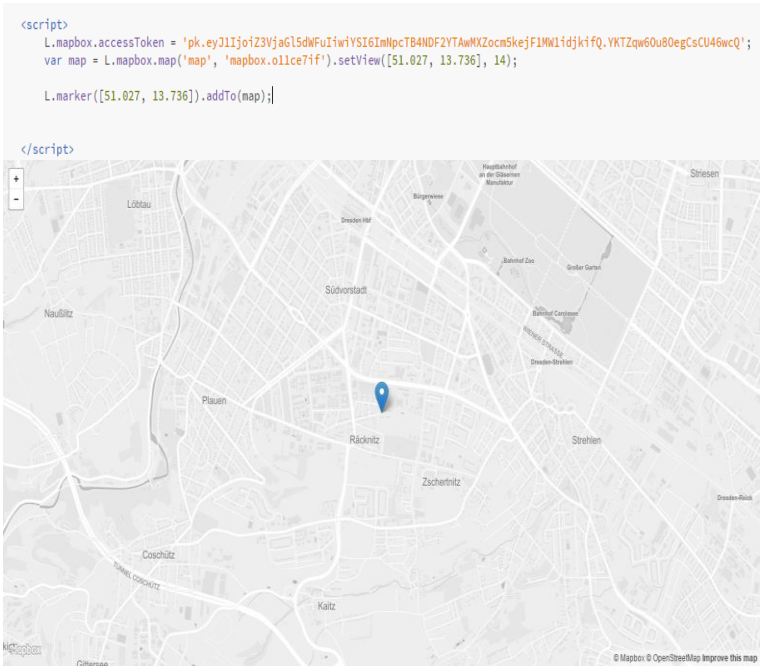

Fig.3. 5 A single marker with Mapbox API

Leaflet API

Leaflet [9] is probably the most popular open-source JavaScript library for mobile-friendly interactive maps. It is just about 33 KB of JS with all the mapping features most developers ever need. Leaflet is designed with the conception of simplicity and lightweight so that it has an incredible performance across almost all desktop and mobile platforms. In addition, with its readable API documentation reference, more and more developers have contributed some useful plugins which makes other users more convenient to enjoy the process of communicating with the web mapping.

9 http://leafletjs.com/

```
<script>
    //Add properties to the map including the center and zoom level.
    var mymap = L.map('map').setView([51.027, 13.736], 14);

    //Set the tilelayer of the map
    L.tileLayer('https://api.tiles.mapbox.com/v4/{id}/{z}/{x}/{y}.png?
    access_token=pk.eyJ1IjoibWFwYm94IiwiYSI6ImNpandmbXliNDBjZWd2M2x6bDk3c2ZtOTkifQ._QA7i5Mpkd_m30IGElHziw', {
        maxZoom: 18,
        attribution: 'Map data &copy; <a href="http://openstreetmap.org">OpenStreetMap</a> contributors, ' +
            '<a href="http://creativecommons.org/licenses/by-sa/2.0/">CC-BY-SA</a>, ' +
            'Imagery © <a href="http://mapbox.com">Mapbox</a>',
        id: 'mapbox.streets'
    }).addTo(mymap);

    //Add marker to the map
    L.marker([51.027, 13.736]).addTo(mymap);
</script>
```

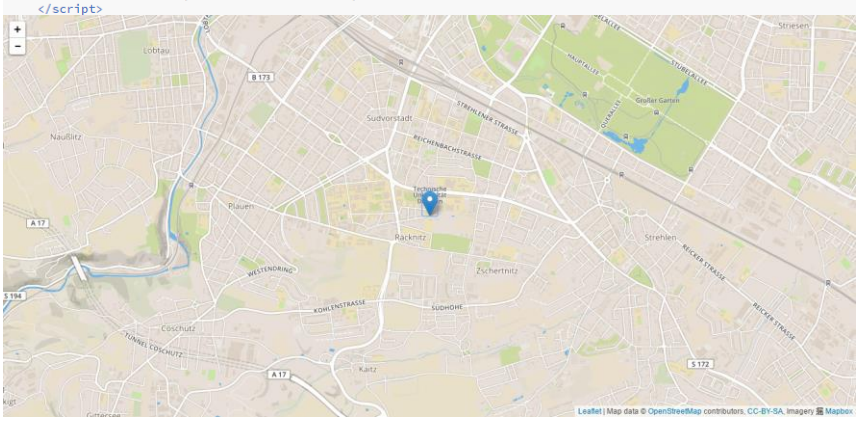

Fig.3. 6 A single marker with Leaflet API

Evaluation of mapping APIs

APIs as a popular issue have been evaluated in many different ways (Farooq and Zirkler 2010; Gerken et al. 2011). These studies provide some basic guidelines for evaluating APIs. The following aspects are related to mapping APIs which have a few special features compared with common APIs.

The complexity of codes

Even though the way to realize functionality is similar in these mapping APIs, the length of the code is a bit different. Much more codes written indicate that this API is properly not well written in some degree that needs more codes to support the necessary operations.

By observing above simple demos in these four mapping APIs, leaflet API has the most concise code. In contrast, the OpenStreetMap API has the longest code. However, it does not mean that Leaflet API is absolutely better than OpenStreetMap API. Perhaps OpenStreetMap API offers more functionalities and can be easily extended when users

need to realize some complex functions.

The speed of map display

Generally speaking, the execution speed of showing map can be used to measure the efficiency of a mapping API. The speed will be high if the code is well written with a powerful computing ability. However, it is difficult to judge which one is better by only comparing execution time. Because APIs are based on JavaScript, a programming language that is compiled and processed by the browser itself so that different browsers will lead much more significant difference in execution time than that caused by the quality of APIs. Frankly speaking, this slight difference has no impact on non-institutional users.

The amount of cartographic functionality

All mapping APIs include the functions like adding points, lines or polygons, setting the zoom level and some basic interactive events. Some of Google Maps API, Leaflet API, and Mapbox API allow users to customize the markers and they all can process vector data. In addition, Leaflet API and Google Maps API both have access to make some cartographic animation which makes the web map more interactive. This is what go beyond the traditional paper map.

In summary, Leaflet.js is selected to apply for this thesis's mobile map. Because Leaflet.js is the most lightweight among those mapping APIs that can meet the requirement of this mobile map. It means that Leaflet.js will not increase the burden of mobile devices. Furthermore, the helpful tutorial is also a reason for this selection. However, Leaflet does not provide any data for the user. It is only a framework for displaying the data. Thus, before use the Leaflet, related data have to be well prepared.

4 Implementation - Design

When designing the map, map composition and layout, elements, color, and typography should be considered. According to the theory of map composition and layout, implementations are taken to design this mobile map. Dresden news map can be regarded as a thematic web map. Firstly, a list of all elements is given to show the visual hierarchy for this news map. Then this visual hierarchy will guide us to design the map from one level to the next step by step. These background maps can be seen as the base map of "Slippy Maps" which let you pan around and zoom. And then the "Slippy Maps" will be integrated into a web page by Leaflet.js.

4.1 Methodology

4.1.1 Content of Map

Firstly, the content of the map has to be decided. Level of details (LOD) is a concept applied to geometry detail, especial in GIS and 3D city modeling. In this 2D map, although LOD is not that important, the core concept of LOD will guide us to determine what to display in each zoom level (see in Tab.3.1).

4.1.2 Create the Feature Layer of Dresden Region – GeoJSON

The theme of this mobile map is limited to the region of Dresden. As a result, it is necessary to highlight the area of Dresden by a feature layer. Regardless of what technolo-

gies are used, the problem of how to create and store the data in a suitable format has to be addressed. Compared with some geodata formats, as a text-based format, GeoJSON has the advantages including being edited with a normal text editor and being easily processed in programs. Besides, GeoJSON is smaller than KML (Keyhole Markup Language), and it is more intuitive than XML (Extensible Markup Language) for reading and editing. As for the support from many APIs, it is widely used in web mapping. That is why the Dresden region in Shapefile format is converted to GeoJSON. There are various related online tools about converting from Shapefile to GeoJSON. Here the 2GeoJSON.com[10] is used to create GeoJSON file. Just upload the original Shapefile file and then it will be converted to GeoJSON automatically (see in Fig.4.1). GeoJSON file provides a "vocabulary" to describe features of the region of Dresden.

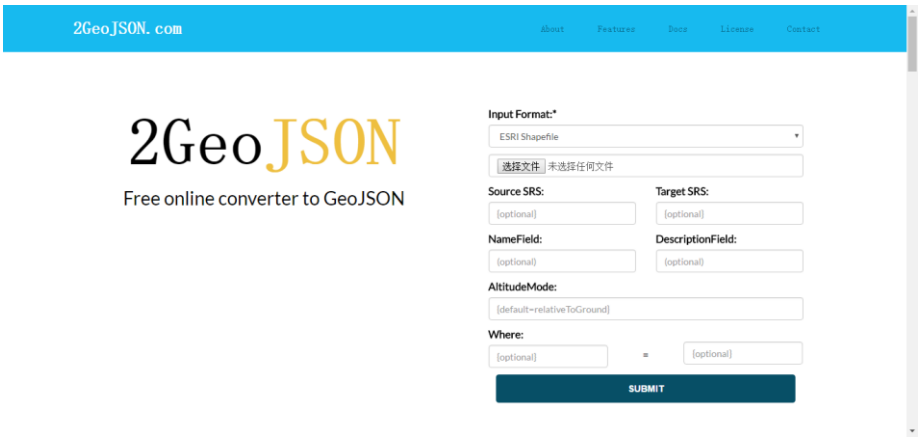

Fig.4. 1 The interface of 2GeoJSON

4.1.3 Design the News Symbol of Point Marker

As we know, a good customized marker will attract user's attention. Unfortunately, when web map is mentioned, upside-down teardrops, thumbtacks, or pushpins will come up. After the advent of Google Maps, these default symbols play the prominent role in web mapping. As web map designers, the importance of web map symbol in

10 http://2geojson.com/

communication cannot be ignored, and custom symbols have to be designed to represent the geographic information in an intuitive manner. In order to meet the demand of showing news articles in the mobile map, the news story symbol is designed by the author in Adobe Illustrator[11] which is a vector graphics editor. The customized news icon consists of simple lines and polygon which indicates the feature of news article clearly. What's more, three different percentage of transparency of the marker are set to present the temporal difference. Fig.4.2 shows the custom icons with different transparency in 100%, 80%, and 50%.

Fig.4. 2 The custom icons for point markers

4.1.4 Style the Background Layer of Custom Base Map

Style a background layer is the last step for designing the base map. As it is shown, the full extent of the map canvas is covered by background layers. Multiple background layers are created to create textures for map styles. Mapbox offers style options for background layers including Fill color, Pattern, and Opacity (see in Fig.4.3). A custom SVG image can be uploaded to create a pattern effect.

11 http://www.adobe.com/de/products/illustrator.html

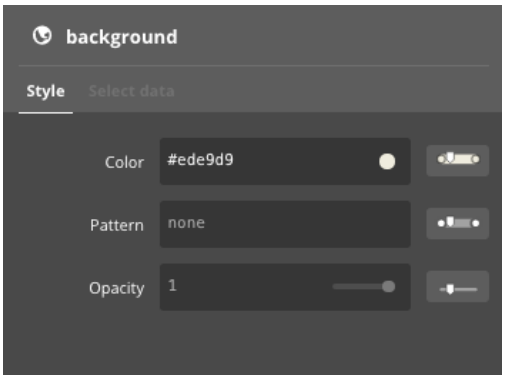

Fig.4. 3 The options of background layer (© 2016 Mapbox)

As for this step, the most significant option is the color. Selecting an effective color scheme is the base of a successful map. A color scheme is picked up with the help from ColorBrewer. However, it does not mean that this choice is best. It just suits author's taste. As a result, two kinds of the base map are designed, which can meet more users' preference. One of them is dark style. Another one is light style. Both of them use green, red and blue to present parks, bridges, and water respectively. However, the values of these hues are different based on what style they belong to. In the light style, the color of the background is white and the more important roads with the darker color. However, in the dark style, the tone of color between background and constructions is swapped. The background looks dark but constructions are in light color. Detailed properties for light style can be seen in Tab.4.1.

Tab.4. 1 Properties of each layer of custom map (light style)

Layer group	Layer	Zoom level range	Style
Building		15-18	Color: Level 15: hsl(55, 5%, 91%) Level 18: hsl(0, 0%, 76%)
Parks		10-18	Color: hsl(150, 66%, 82%) Opacity: 0.75
Water		10-18	Color: hsl(185, 9%, 81%)
Road	Road-primary	10-18	Color: hsl(0, 0%, 0%)
	Road-secondary-tertiary	12-18	Color: hsl(0, 1%, 58%)
	Road-street	15-18	Color: hsl(0, 0%, 84%)
Bridges	Bridge-primary	10-18	Color: hsl(0, 80%, 85%)
	Bridge-secondary-tertiary	10-18	Color: hsl(0, 80%, 85%)
Road Label	Road-label-large	12-18	Color: hsl(0,0%,100) Font: DIN Offc Pro Bold Halo color: hsla(0, 0%, 0%, 0.75) Halo width: 1px
	Road-label-medium	15-18	Color: hsl(0, 0%, 0%) Font: DIN Offc Pro Regular Halo color: #ffffff Halo width: 1px
	Road-label-small	15-18	Color: hsl(0, 0%, 0%) Font: DIN Offc Pro Regular Halo color: #ffffff Halo width: 1.25px
Background			Color: hsl(0, 0%, 100%) Opacity: 1

4.2 Map Design Workflow

First step is to determine the content of this map. And then prepare the related data that will be added to the map. In the end, style the background layer of the base map. Fig.4.4 illustrates the whole workflow of designing the customized background map.

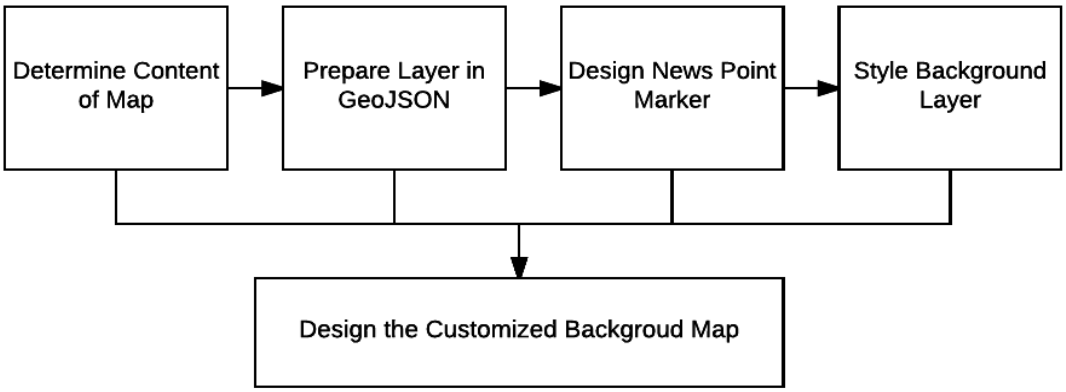

Fig.4. 4 A workflow for background map design

4.3 Prepared Data and Background Map

The GeoJSON file can be opened in a text editor (see in Fig.4.5).


```
var district={"type":"FeatureCollection","features":[{"type":"Feature","properties":
{"OBJECTID":1,"Ortsamt_Or":"Altfranken","Shape_Leng":0.059453,"Shape_Area":0.000164},"geometry":{"type":"Polygon","coordinates":
[[[13.636981199822571,51.03860739971179],[13.639248600242752,51.03894840014863],[13.639140200459906,51.039241800368887],
[13.64467310038333,51.04005359949406],[13.646937595590615,51.04005250052256],[13.646941801223193,51.03997765894184],
[13.647007126177982,51.03988472480029],[13.647283700082767,51.039511800229434],[13.647544100579807,51.03918819987558],
[13.647818599748632,51.03883480048569],[13.648160500406846,51.03836670066278],[13.648475699294124,51.03792970029548],
[13.648787499643447,51.03752469960523],[13.648969799416761,51.0375386004261],[13.649298900024291,51.037591900545806],
[13.6493820000793,51.037618599618725],[13.649674400253446,51.037703699765984],[13.649930699841946,51.03777599986256],
[13.650120700509945,51.037803299682594],[13.650462700093556,51.037820299567215],[13.650609400203678,51.03781609973328],
```


Fig.4. 5 Content of GeoJSON file

The three custom markers have different transparency (see in Fig.4.2). They will be used to realize temporal representation.

The final styled base maps (see in Fig.4.6)

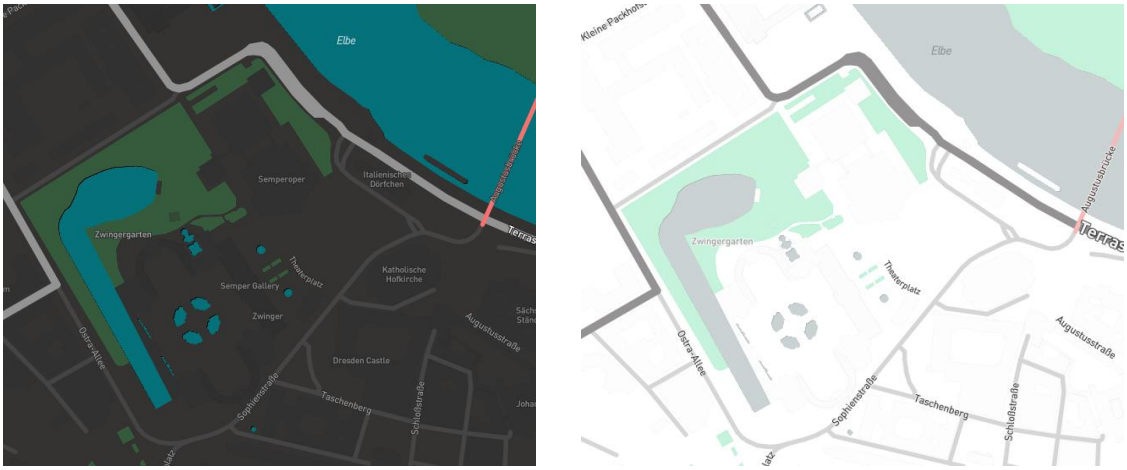

Fig.4. 6 Dark style and light style of the background map

5 Implementation - Develop

After designing, we get custom background map by Mapbox. These base maps can be seen as the “Slippy Maps” which let you pan around and zoom. Moreover, then the “Slippy Maps” will be integrated into the webpage by Leaflet.js. At the same time, some interactivities will be combined with some existing plugins and APIs. In the end, this web map will be integrated into a mobile application by Android Studio.

5.1 Methodology

5.1.1 Create a Dataset in CARTO

A dataset (see in Fig.5.1) is set up in CARTO. It has a total of 9 fields in the table. Two of them (cartodb_id and the_geom) are generated automatically. Then another seven fields are set:

Category – string, the type of each piece of news.

Date – string, the exact time of news happening.

Title – string, the title of the news.

Description – string, the simple description of the news.

Detailed – string, the URL of the website introducing the news with more details.

Image – string, the URL of the related news picture.

Name – string, the name of the news contributor.

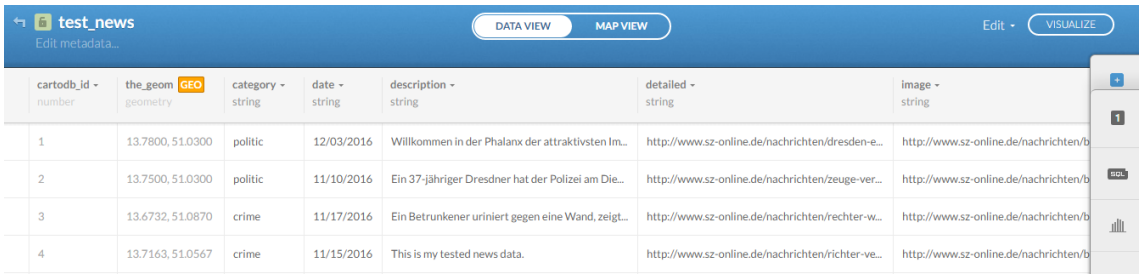

Fig.5. 1 A news data dataset is created in CARTO

5.1.2 Use of Leaflet.js to Create Map and Display Data

a. Initialize a simple map

In the beginning, link the web page with Leaflet API by an HTML element as below:

```
<script src="https://unpkg.com/leaflet@1.0.2/dist/leaflet.js"></script>
```

This element is used to link an external JavaScript library served by leaflet, and it is commonly added in the head section of the webpage. Next step is to initialize a map object to load the custom map. A div container is used to hold the map.

```
<div id="map"></div>
//create a map object and set its view center and zoom level.
var map = L.map('map').setView ([51.05, 13.73], 10);
```

Then L.tileLayer can be used to add custom tiles by their URL into the map.

b. Add Dresden region layer in GeoJSON

In Leaflet API, it provides a special factory like `L.geoJSON(<Object> geojson?, <GeoJSON options> options?)`

c. Pan and zoom

As this map is the “Slippy Map”, it has the ability of panning and zooming. In this mobile map, it has the touch-and-drag panning capability which is the most intuitive method of panning. It is also the default manner of many online web map services like Google maps and OSM. The ability to zoom in is the basic functionality in the “Slippy

Map". However, it does not mean that zoom functionality should be added in all map application. It depends on the aim of the map. Therefore, limiting the amount of zoom is a good solution so that users have the choice to zoom but also cannot ignore the change of message in the map. In this mobile map, the zoom bar is preserved on the top-left of the map. And it is also possible to pinch to zoom by two fingers. Furthermore, in order to keep the mapped areas staying in the center of map, the minimum zoom level is set in 10.

d. Add custom marker into web base map

The properties of News icon can be set in following codes (see in Fig.5.2).

```
var NewsIcon = L.Icon.extend({
                options: {
                                iconSize:     [32, 32],
                                popupAnchor:  [0, -16]
                }
                });
var newsIcon_today = new NewsIcon({iconUrl:'images/newsicon_today.png'});
L.marker(latlng, {icon: newsIcon_today});
```

Fig.5. 2 Define the icon and set its properties

As for how to fetch data from dataset in CARTO, cartodb.js provides a method to get these data in the format of JSON (see in Fig.5.3). Then these points of news are marked with above custom icon.

```
$.getJSON("https://"+cartoDBUserName+".carto.com/api/v2/sql?format=GeoJSON&q="+sqlQuery, function(data) {});
```

Fig.5. 3 Method to fetch data from CARTO

e. Customize information window

After clicking the marker, a pop-up window will show up. This information window provides some information on the related news story. In general, it contains the title and the description of the news. What's more, it contains an image with a hyperlink to the

related web page. In addition, when users click one of the markers, the center of the map will be panned to the position of the target marker.

5.1.3 Use of jQuery mobile to Create a Category Web Page

jQuery mobile makes the process of designing responsive web sites and apps on the mobile enjoyable. The sample codes about how to realize a click event as below.

In the category page, the user can get news articles by different categories (see in Fig.5.4).

```
$(document).on("click","#refresh",function(event){
    event.preventDefault();
});
```

Fig.5. 4 jQuery mobile provides a method to handle a click event

5.1.4 Develop the App by Android Studio

One of the best methods of conveying the topic is via the title. Thus, a splash screen is designed to grasp users' attention. Furthermore, the layout of each Activity contains two main elements. A navigation bar offers different functionalities in the menu. Moreover, a WebView is used to display web pages. The web maps will be loaded in the WebView. However, the navigation bar is set in Android client by Java so that we need a way to call the function in JavaScript. It is the key to realize the interaction with the map. The essential codes are shown below.

```
// enable JavaScript with setJavaScriptEnabled().
mapView.getSettings().setJavaScriptEnabled(true);
//load the HTML by the loadUrl().
mapView.loadUrl("file:///android_asset/demo.html");
//call functions from JavaScript with loadUrl().
mapView.loadUrl("javascript:stopEdits()");
```

```
mapView.loadUrl("javascript:showAll()");
```

5.2 Adaptation of the News Mobile Map

5.2.1 Visualization

Visualization of map attracts much of user's attention. Cartographic visualization is concerned with the representation of geospatial data and the spatial understanding of users(Jiang, 1996). In this thesis work, the focus is on two problems about information overflow and temporal representation.

In this case study, displaying a large number of news markers causes sluggish interaction and visual overload(Hu, 2012). Clustering is the common technique to deal with this situation. It aggregates markers that are close to each other by consolidating them on the map. There are a few clustering methods including Distance-based Clustering, Grid-based Clustering, Fusion Tables, and Viewport Marker Management(Mahe & Broadfoot, 2010). The use of any clustering will have a good effect on simplifying the data visualization. In this case study, a ready-made marker clustering plugin called Leaflet.markercluster[1] is used. It provides a nice animated marker clustering functionality for Leaflet. When using it, this plugin needs to be linked to the web page. Thus, the following codes need to be added in the head section.

```
<script
src="http://leaflet.github.io/Leaflet.markercluster/dist/leaflet.markercluster-src.js"></scr
ipt>
```

Then it is used by creating a new MarkerClusterGroup, and adding markers to it, then add the cluster group to the map. The related codes are following (see in Fig.5.5).

```
//define a markerclustergroup called markers
var markers = L.markerClusterGroup();
//add markers(newsLocations) to the markerclustergroup
markers.addLayer(newsLocations);
//add markerclustergroup to the map
map.addLayer(markers);
```

Fig.5. 5 Use the MarkerCluster Plugin to cluster markers

At the same time, temporal representation is an important task to be realized. Considering time is an important attribute of news data, the difference of news data with the different date will be presented in this mobile news map. The news articles are divided into 3 three groups (news in today, news in last week, and news in last 31 days) by calculating. Then custom icons are used to present the news data by their different transparency. The icon with high transparency stands for the news has occurred for a long time.

5.2.2 Interaction

Compared with the traditional static map, a well-designed web map or mobile map emphasizes on the interactions between map and users. As advanced users, more functionality and tools are required to perform complicated tasks such as route planning or analysis. Considering this mobile map app, the key mission is to balance simplicity with specific functionality.

In order to realize the basic interaction with the map, some standard web map controls are added such as map layer control, and Zoom control. In addition, the info window pops up with the tap of clickable markers.

After realizing basic map interactions, the particular functionality of this mobile map has to be considered. It seems a simple task to match news articles with related locations. However, it is a challenge to create a simple way to for anyone to complete above task online. In the end, I make it with the help from a web map workshop from

DUSPviz[12] in MIT. In this mobile news map, the user can browse the news stories in the whole region of Dresden by just tapping the news marker or browse them through the category page. Also, the user can also filter the news articles by their date. Furthermore, in this map, users can upload their own news stories by inputting required information. For this function, it is necessary to collect and write the new news data into the database by the interface of the map. Thus, a popular Leaflet plugin called Leaflet Draw[13] has to be used. This plugin offers access to add and draw data to the map. Firstly, add a draw control to the map. Moreover, then create a dialog to collect geotagged news data. After collecting news data, the task is to send collected data to CARTO through a PHP proxy. The process of this step is below (in Fig.5.6).

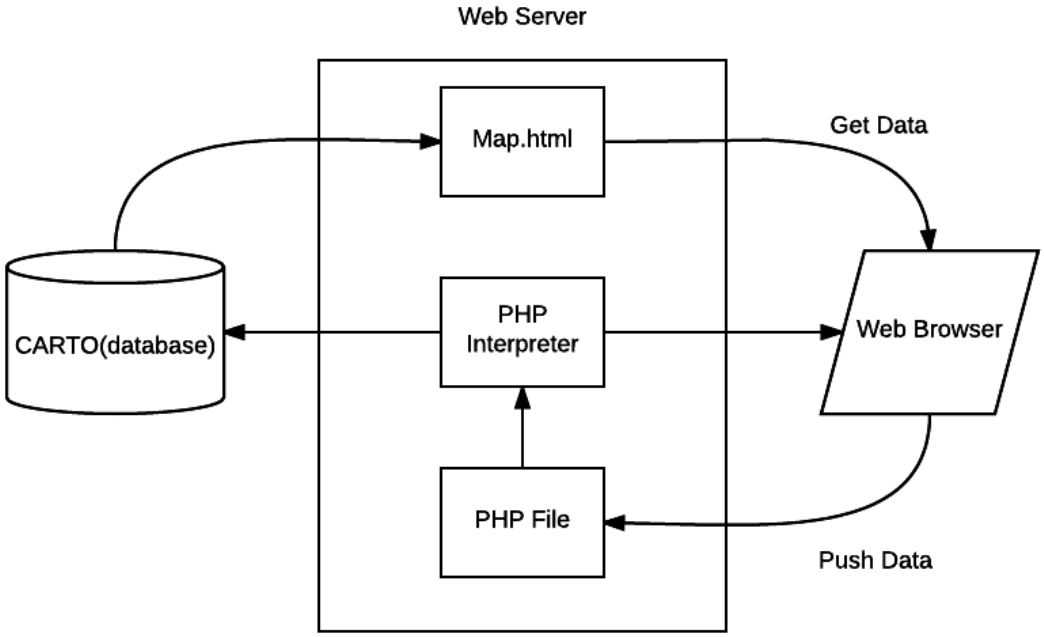

Fig.5. 6 The process of fetching data from database and pushing data into the database by PHP

Two PHP files are needed in this process.

callProxy.php

12 http://duspviz.mit.edu/web-map-workshop/

13 https://github.com/Leaflet/Leaflet.draw

```php
<?php
    include 'php\cartoDBProxy.php';
    //          ^THE PATH TO YOUR cartodbProxy.php
    $queryURL = $_POST['qurl'];
    $return = goProxy($queryURL);
    echo $return;
?>
```

Fig.5. 7 The content of callProxy.php

This file calls the proxy, and passes the query as a variable, then runs a function named goProxy using the query.

cartoDBProxy.php

```php
<?php
    session_cache_limiter('nocache');
    $cache_limiter = session_cache_limiter();
    function goProxy($dataURL)
    {
        $baseURL = 'http://guchiyuan.cartodb.com/api/v2/sql?';
        //                  ^THE 'CARTODB-USER-NAME' to your cartoDB url!
        $api = '&api_key=bd1efcedc3c067e38569f8f44d6ab00fe3cf0bb4';
        //             ^ENTER YOUR API KEY HERE!
        $url = $baseURL.'q='.urlencode($dataURL).$api;
        $result = file_get_contents ($url);
        return $result;
    }
?>
```

Fig.5. 8 The content of cartoDBProxy.php

This file sets the goProxy function and holds the credentials.

5.3 Development Workflow

a. Create a welcome activity to realize the function of splash screen.

b. Create a category activity to display the list of categories. It contains a navigation bar which includes the menu of functions and a WebView display the designed webpage.

c. Create a main activity to display the news web map and provides some interactivities. The layout of this activity is similar to the category activity with a little bit different menu items.

d. Create a HTML to show the category of news. And it needs to set another JS file (mymapcode.js) to store some interaction functionalities based on jQuery mobile.

e. Create the web map in a HTML includes all interaction functionalities.

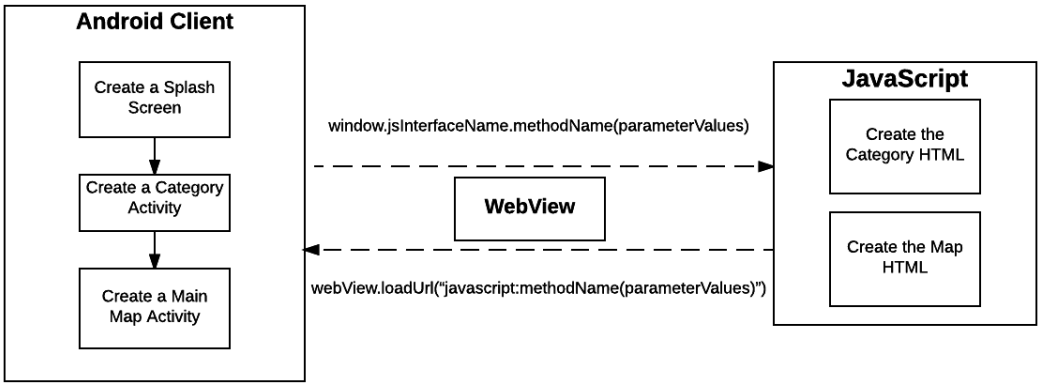

Fig.5. 9 The workflow of developing the mobile news map

5.4 Results

The use of WebView container in Android app provides an opportunity of creating a hybrid Android app, that accelerates the process of developing mobile map. Designed web maps can be integrated into the mobile app directly.

The figure 5.10 gives an outlook of this mobile map by showing different interfaces of the map app including a splash screen, the category content page, and the main map page. When running the app, the splash screen comes up and it links to the category activity automatically in a few seconds. In the category page, users can select the news that they are interested according to the category. After taping the map style icon in the top right, it goes to the main map activity. At the initial launch of the map, points of news stories are displayed on the web map which is within a WebView container. These point markers are presented as clusters to deal with the issue of information overflow.

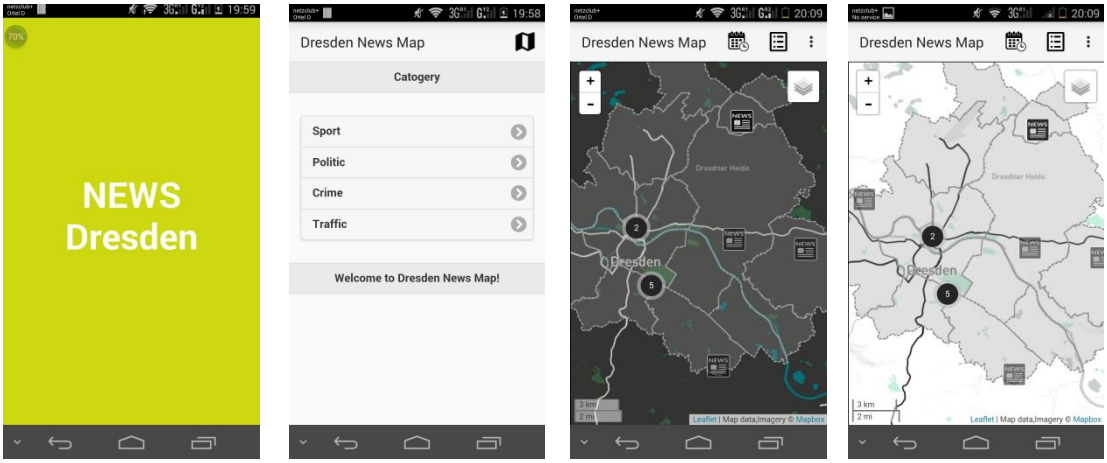

Fig.5. 10 The main interfaces of the mobile map

The figure 5.11 shows interfaces of three main interactivities – illustrating the brief news story in the info window, displaying geotagged news data with different time, and uploading the user-generated news data. The info window can show the brief information if users tap an icon on the map. Notice the icon on the action bar, when tapping the calendar icon, a dialog that provides three items of different time spans to select can show up. What's more, in the menu, users can find the item of adding news data. After selecting this function, a marker draw control shows up blow the zoom control. Then users can pick up any of location to upload their own news stories in the news information dialog.

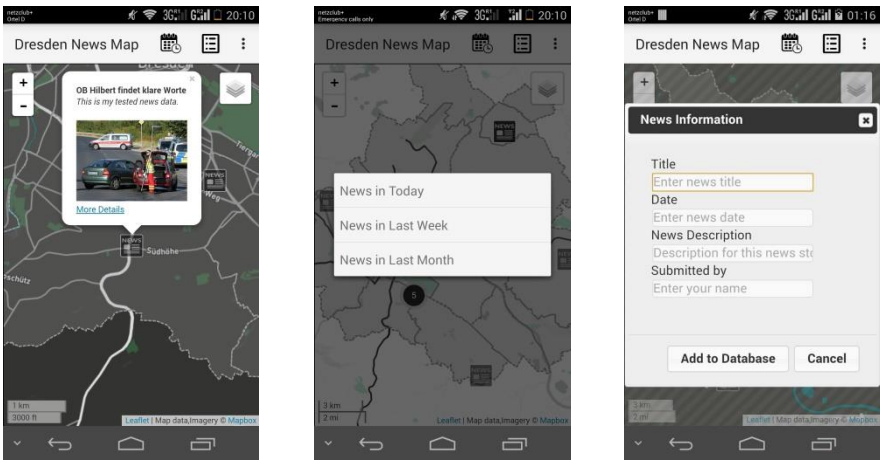

Fig.5. 11 The main interactivities of the mobile map

6 Conclusions and Discussion

This thesis demonstrates a way of creating an interactive mobile map for showing geotagged news articles based on open-source platform. As the result of this work, the modern trend of mobile mapping is grasped by referring to recent related studies. Besides, this thesis gives an outlook of the popular web mapping APIs. Through a rough comparison, a better understanding of using these APIs comes up. As for the implementation part, there are two aspects – design of customized map and development of this prototypical mobile map app. Mapbox is a useful online mapping tool that makes the design for web map convenient. The background map is designed by setting various related properties including content of map, color of layers, and the font of labels. All manipulation can be shown in a friendly user interface. On the other hand, Android provides a WebView container, which can display the content of web page, for developers. This container allows developing a hybrid Android app that gets more support from web techniques. This case study successfully uses the open-source methods especially for some JavaScript libraries including Leaflet API, MarkerCluster plugin, jQuery, and jQuery mobile. These open-source methods allow cartographers doing web mapping on their own, which results in so many interesting applications come up. In addition, mastering these related techniques can help us in visualizing and analyzing geospatial data. Through this case study, it is obvious that a good looking map can be easily designed by open source platforms. Many methods are offered to create a variety of maps with unique dazzling style. Besides, the gap between the web map and mobile map is getting smaller. In this case study, the core functions are realized by web mapping technique,

then the web map can be integrated into a native Android app easily.

Although this prototype has realized some basic function, it has much room for improvement as far as being used for the public. There are some obvious bugs in this map app. First of all, the function of uploading user-generated news data only can be done by a web server because PHP is a server-side scripting language. As a result, users can only run it unless the related files are uploaded to a host or users install PHP server (e.g., KSWEB[14]) on their mobile. Besides, another problem is that when it is going to show news articles on the map, the user has to activate the map view so that it can give a corresponding response on the map.

In the end, for the further development, there are some possible ideas. Firstly, the web map can use other artistic styles which can be created by custom textures rather than those default styles on Mapbox. In addition, the each district of Dresden can be presented in different color with different value based on the density of news articles. The map will look like a choropleth map which is a kind of typical thematic maps. What's more, the temporal representation can be improved by supporting the user to select relevant news articles occurred in some specific date instead of just three rough categories (today, last week, and last 30 days). Last but not least, there is no usability test during this thesis work. Thus, not only for the custom map style but also for the interactions with the mobile map, it is just personal taste, and it does not comply with the principles of user-centered design.

14 http://kslabs.ru/

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