

Metropolist

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Metropolist

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We recommend acceptance of this manuscript in partial fulfillment of this candidate's requirements for the degree of Master of Software Engineering in Computer Science. The candidate has completed the oral examination requirement of the capstone project for the degree.

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Abstract

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This manuscript describes the development of a web-based map generator, which allows the user to create randomly generated fantasy maps of cities and additionally allows the user to annotate and edit city elements at a fine granularity.

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Glossary

LaTeX

LaTeX is a document markup language and document preparation systems for the TeX typesetting program.

1. Introduction

1.1. Background

Generating content for computer games, CGI effects, feature films, print media, or Role-playing games is a significant bottleneck in terms of effort and resources. A typical game contains many thousands of audio files, images, textures, and 3D models. Procedurally generated content provides a cost-effective alternative to the manual creation of models, textures, images, and sound assets and can expand playability beyond what is otherwise possible. The video game “No Man’s Sky,” for example, was released in 2016 and relied on procedural asset generation to create over 18 quintillion planets each of which has a unique ecosystem composed of flora and fauna. Such a scale is, of course, beyond the reach of any manually created system. Figure 1 is a screenshot of a planetary terrain region of “No Man’s Sky.”

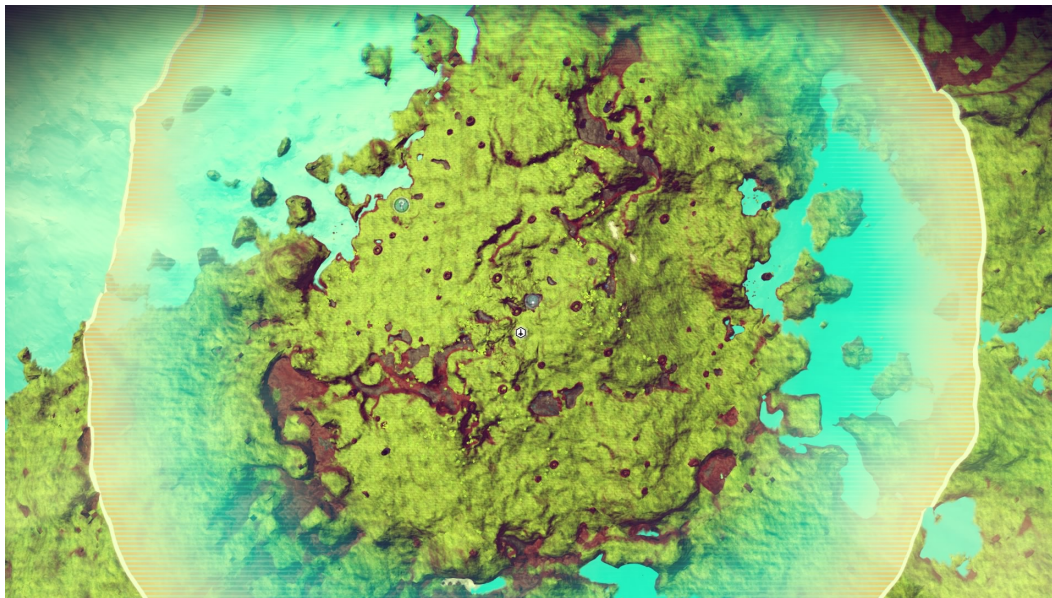


Figure 1. A screenshot of a planetary terrain region of “No Man’s Sky”

1.2. Similar Systems

1.2.1. Minecraft

“Minecraft” is a computer game that can produce massive worlds that are chock-full of little details, like elaborate cliff faces and waterfalls. Moreover, it relies on procedural generation, which automatically creates environments and objects that are at once random but guided by rules that maintain a consistent logic. Mountains are always rocky and sprinkled with snow, for example, while the low lands are typically full of grass and trees. Figure 2 is a screenshot of “Minecraft.”

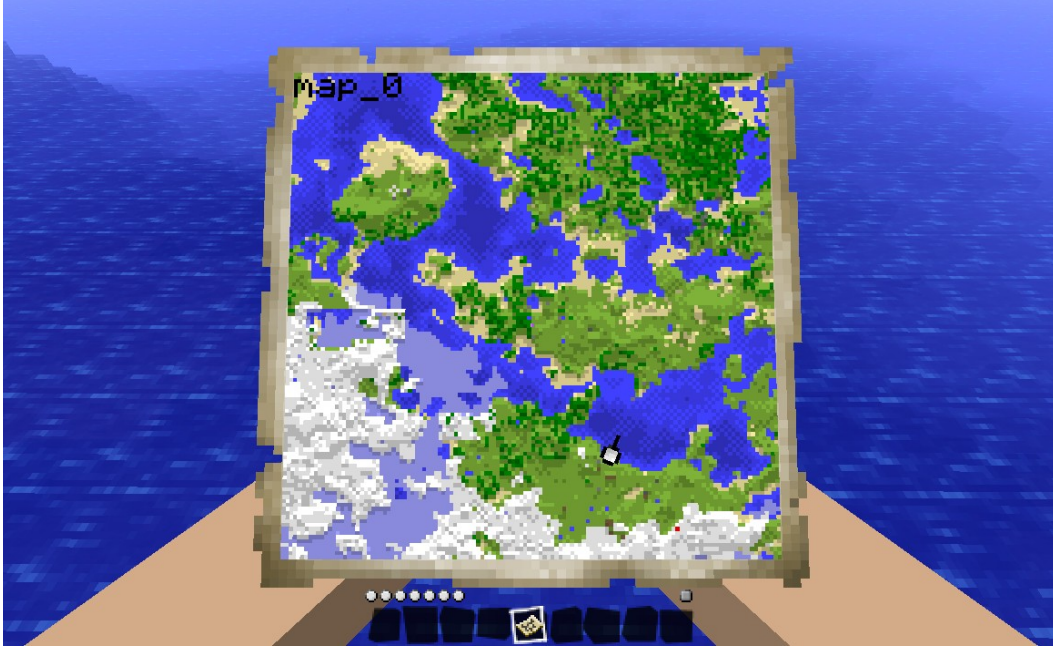


Figure 2. A screenshot of “Minecraft”

1.2.2. Medieval Fantasy City Generator(MFCG)

The “Medieval Fantasy City Generator(MFCG)” is a web application. This application generates a random medieval city layout of a requested size: small, medium or large, which is made up of different types of regions, and the generation method is rather arbitrary. Furthermore, many elements are provided for the user to add to the city, such as farm fields, citadel, plaza, temple, river, coast and so on. Because of the premise of medieval fantasy, the map always includes the walls and castle, but the user can decide whether to display them. It allows the user to edit the map to modify some unsatisfying places using the warp tool. The author also mentioned that the goal of the application is to produce a nice looking map, not an accurate model of a city. Finally, the user can save the map as an image in the “png” or “svg” format by using the export feature if he is satisfied with the map. Figure 3 is a screenshot of MFCG.

1.2.3. Azgaar’s Fantasy Map Generator(FMG)

The “Azgaar’s Fantasy Map Generator(FMG)” is another similar system, which is a large scale system. The size of the map made by FMG varies from western Europe to the world continent, not just an island, but a random fantasy map represents a pseudo-medieval world. Just like the real world, the map generated by FMG has the feature that the continent is always surrounded by the ocean and will never touch the border of the map. Although it is a random map, it is still based on real-world rules. While its most prominent feature is that the user can choose the type of map he likes, which provides the

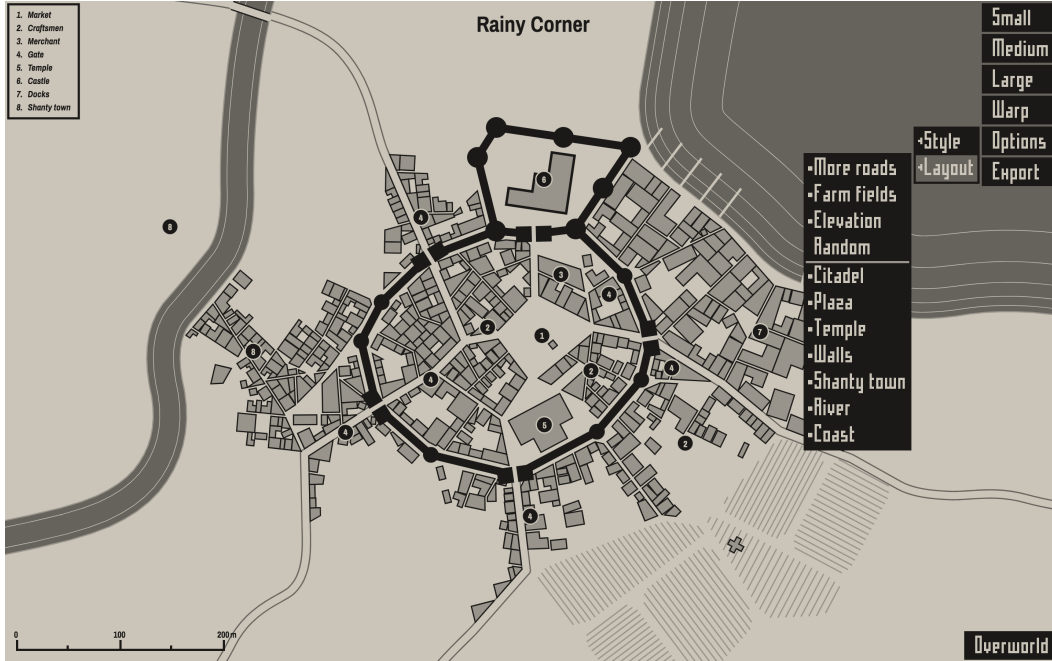


Figure 3. A screenshot of the Medieval Fantasy City Generator

following 5 map types: political, cultural, height, biomes and pure landmass. It also supports user-defined map type, and the user can add additional layers on existing map layers: rivers, temperature, and population. Also, it allows the user to annotate and edit the map using various such editors: layout, style, template, scale, countries, or cultural. It also supports exporting the map in the “png” or “svg” format, but unlike the previous application, if the user wants to come back to edit the map in the future, he can save it in the “map” format. Figure 4 is a screenshot of FMG.

1.3. Project Goal

The goal of this project is to automatically generate city maps for use in Role-playing games or Worldbuilding narratives. While the ultimate goal of this project is to procedurally replicate maps of a quality similar to the best cartographic hand-created maps by expert artists, we expect to obtain a modest approximation to the desired level of quality. Our system will have the essential features, such as: allowing the user to annotate or edit, supporting the user to export the map as an image in the “png” or “svg” format, allowing the user to save it to the database and restore it from the server. To achieve these goals, we provide the following operations and obey these rules:

- The user should use the given tool to draw the map
- The user manually creates water, lands, and walls

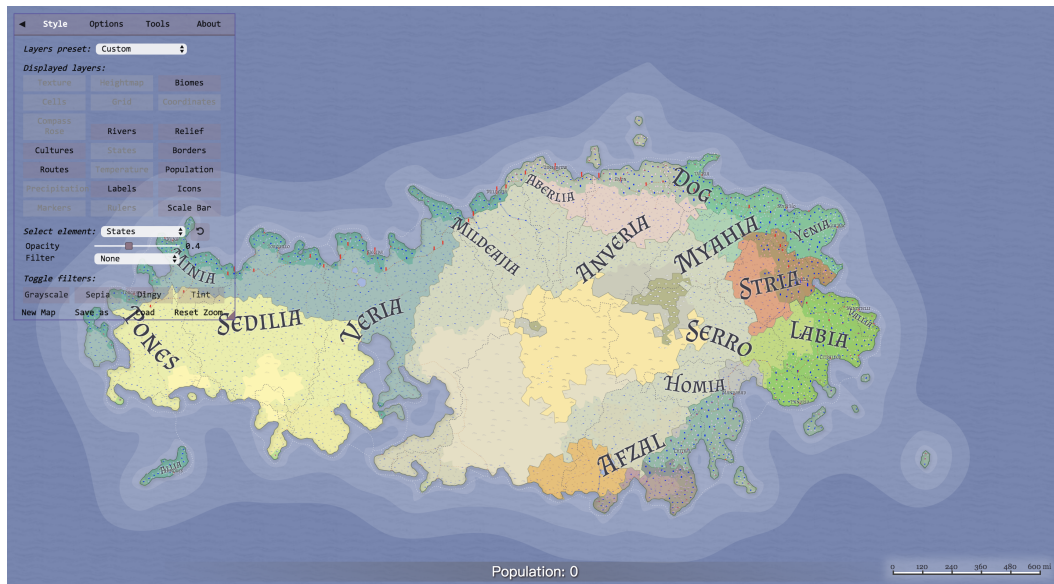


Figure 4. A screenshot of the Azgaar's Fantasy Map Generator

- The map procedurally generates districts, buildings, streets, and street names

2. Requirements

2.1. Functional Requirements

Initially, almost all the requirements were given by Dr. Kenny Hunt, in an introductory meeting. There were daily meetings after that, in which Dr. Kenny Hunt would add additional requirements each time. He would also tune up any previous requirements that were given. The functional requirements focus on developing a web application. There are two roles for this system: admins and users. As a result, the following functional requirements were established for the project:

- Both admins and users can:
 - Log In: with unique email and password
 - Log Out: end the session
 - Edit Personal Profile: delete the account or change email, first name, last name, and password
- The admin is able to:
 - View All Users: on the “dashboard” page
 - Enable or Disable Users: allow the user to log in or not
 - Search for Users: use any combination of email, first name, and last name; on the “dashboard” page
- The user is able to:
 - Sign Up: with unique email, first name, last name, long password, and confirmed password
 - View All Own Maps: on the “dashboard” page
 - View All Visible Maps: on the “community” page
 - Search for Maps: use any combination of the map name, created date, edited date, the owner’s email, the owner’s first name, and the owner’s last name; on the “community” page
 - Download Maps: of either your own or other visible maps; in “png” or “svg” format
 - Make Maps Public or Private: allow the map displaying on the “community” page or not
 - Create Maps: with a name; on the “dashboard” page
 - Delete Maps: on the “dashboard” page
 - Edit Maps:

- * When the user opens the map editor page, it shows an empty map with random map seeds by default, and then the user can make maps by accessing the menu on the right
- * In the menu, the user can input the number of map seeds to create a new empty map
- * The user can select different types of layers for the map: elevation, affluence, desirability, district, and building, which can superimpose on each other
- * The user can choose to display street names or not
- * The user can manipulate the “increase/decrease toggle,” “increment sliding,” and “waterline sliding” to edit the map: increasing or decreasing the value of elevation and affluence; building or removing the wall; making map cell as water or city
- * If the waterline is changed, the continent will be changed accordingly
- * The user can choose to display contour lines or not
- * After selecting one or more than one layers under “edit” mode, the user can change the size of the “soft brush” by using the mouse wheel, which determines the area where the map will be edited
- * The user edits the map by clicking and dragging the “soft brush.”
- * The districts and buildings are procedurally generated
- * The user is allowed to change the type of the current district by right-clicking and selecting a new type from the context menu
- * The map provides 13 different types of districts: rich, medium, poor, empty, plaza, park, farm, water, harbor, university, religious, castle, and military
- * The user can zoom in and zoom out the map by pressing on the alt key and using the mouse wheel
- * The user can use a specialized button to resize the map on the right top
- * The user can save the map or download it by clicking the button on the right bottom

Figure 5 is the use case diagram that describes the functionalities to be implemented by this web application.

2.2. Non-Functional Requirements

There are too many non-functional requirements of a system: response time, availability, usability, security (authentication, authorization, integrity, privacy, etc.), and so on. Preventing writing a wish list, we decided to focus on the following requirements:

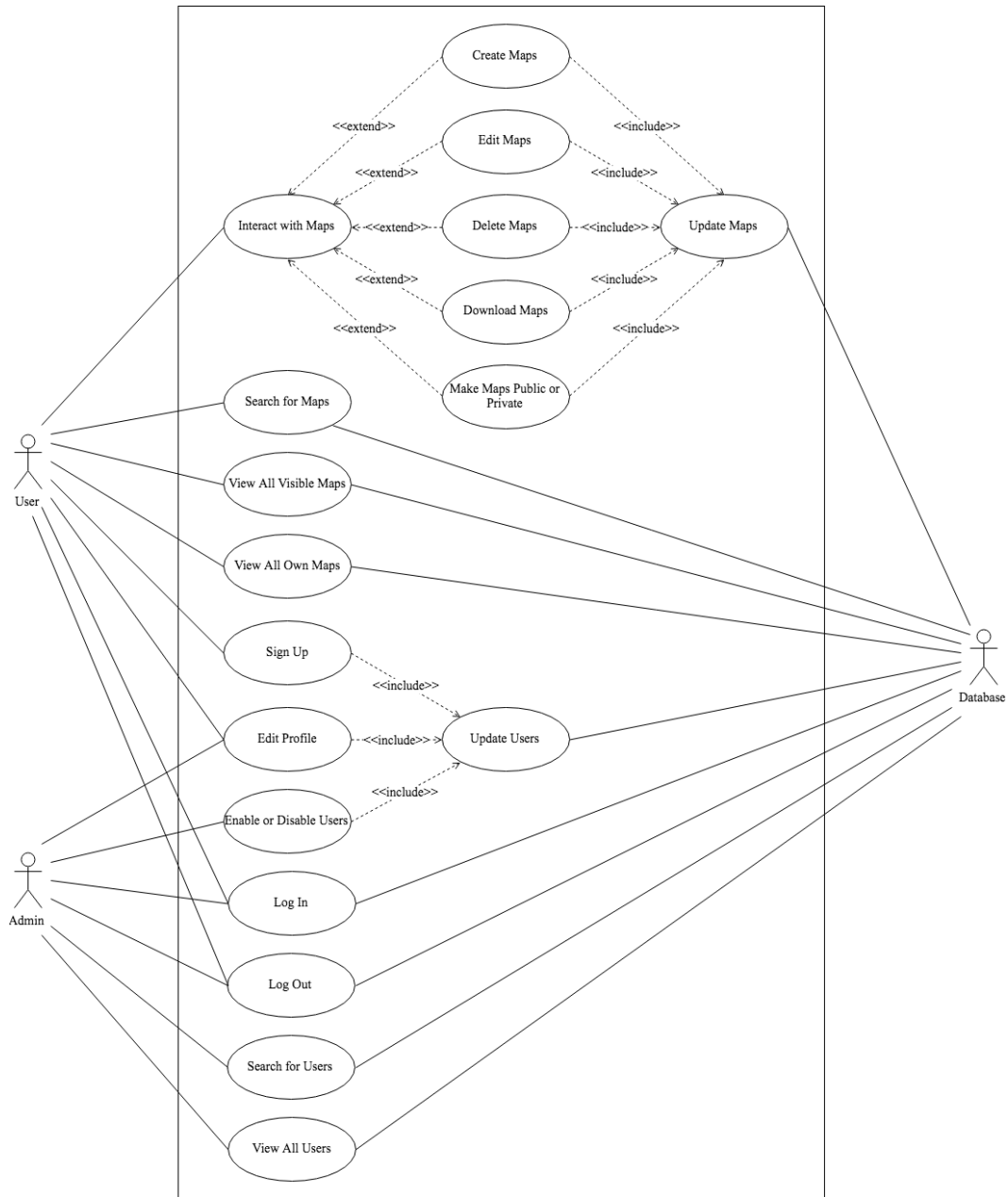


Figure 5. Use Case Diagram

- Security:
 - Input Validation:
 - * Add validations at both client and server sides
 - * All methods should always validate all parameters in the server-side
 - Password Encryption:
 - * Shall always be encrypted
 - * Not even the system administrators shall see clear text passwords
 - * Applying a hashing algorithm to passwords
 - Prohibiting Cross Site Scripting (XSS):
 - * Never insert data anywhere in a “script” element
 - * Never insert data in an HTML comment
 - * Never insert data anywhere in CSS
 - * Never insert data in an attribute name
 - * Never insert data in an attribute value
 - * Never insert data in a tag name
 - Secure Session Cookie:
 - * Set the “Secure” cookie attribute and instruct web browsers to send the cookie only over encrypted, e.g., HTTPS, links.
 - * Set the “HttpOnly” attribute true and prohibiting the JavaScript code from reading the cookie via the DOM “document.cookie” JavaScript object.
 - * Always change the session id after login
- Performance:
 - High performance of rendering map:
 - * Compare and select the most appropriate and the fastest way to render maps, e.g., canvas, SVG

2.3. Selection of Software Development Life Cycle Model

We analyzed and summarized the following possible risks:

- Lack of experience of making a map generator
- Uncertainty of choosing a third-party library as the map rendering tool
- There is a potential misunderstanding between the advisor and the developer

To reduce or avoid these risks, two life cycle models were considered in the beginning: waterfall and agile. Because of the daily meeting between the advisor and the author, and there will be new requirements almost every time. The waterfall model is beyond our consideration. Unlike the waterfall model, we only need initial planning to start this project, and every time the new requirements are almost based on the previous one. Finally, the agile model was chosen, which is shown in Figure 6.

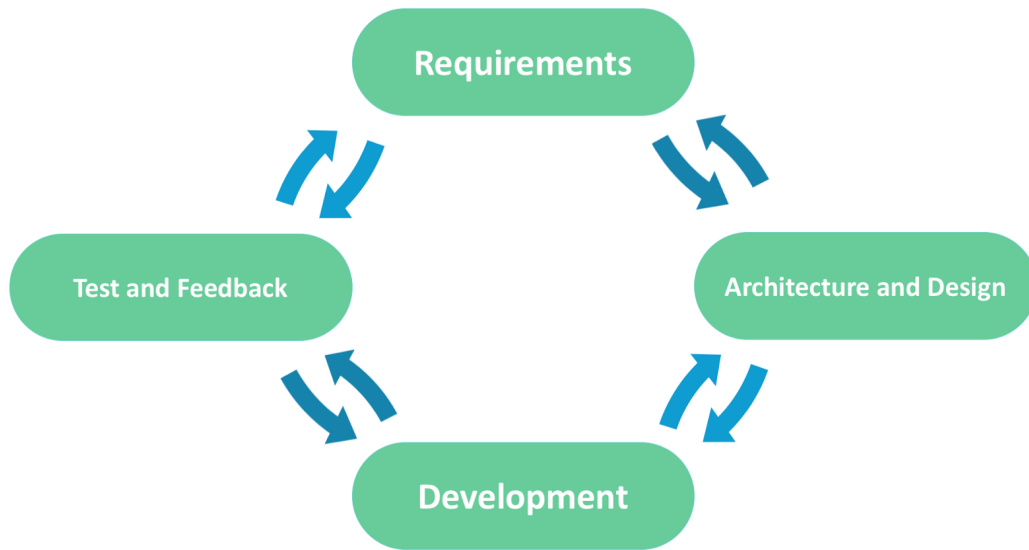


Figure 6. Agile Development Life Cycle Model

Agile methodology is a practice that helps continuous iterations of development and testing in the software development process. In this model, development and testing activities are concurrent. Unlike the waterfall model, this process allows more communications between the advisor and the developer. Furthermore, the agile model is a combination of iterative and incremental process models. Agile methods break the product into small incremental builds. These builds are provided in iterations. Each iteration typically lasts from about one to three weeks. The iterations that have occurred in this project are listed below:

- Iteration 1: Change third-party libraries to generate maps
- Iteration 2: Change entirely and procedurally generated maps to partially and manually generated
- Iteration 3: Migrate codes from demo to the main project
- Iteration 4: Improve the performance of rendering maps

At the end of the iteration, a working product demo is displayed to stakeholders. There are several known advantages and disadvantages of using the agile model in this project:

- Advantages:
 - Easy to manage
 - Little or no planning required
 - Gives flexibility to developers
 - Resource requirements are minimum
 - Suitable for fixed or changing requirements
- Disadvantages:
 - More risks of sustainability, maintainability, and extensibility
 - An overall plan, an agile leader (the advisor) is a must without which it will not work
 - There is a very high individual dependency since there is minimum documentation generated

3. Design

3.1. Architecture Design

Because we selected the web application model from the beginning, so the classic client-server architecture was quickly adopted, which is a distributed application structure that partitions tasks or workloads between the providers of a resource or service, called servers, and service requesters, called clients. In theory, any device connected to the Internet can try to access and obtain the resources or services of the server while the server is running normally. Figure 7 shows how it works.

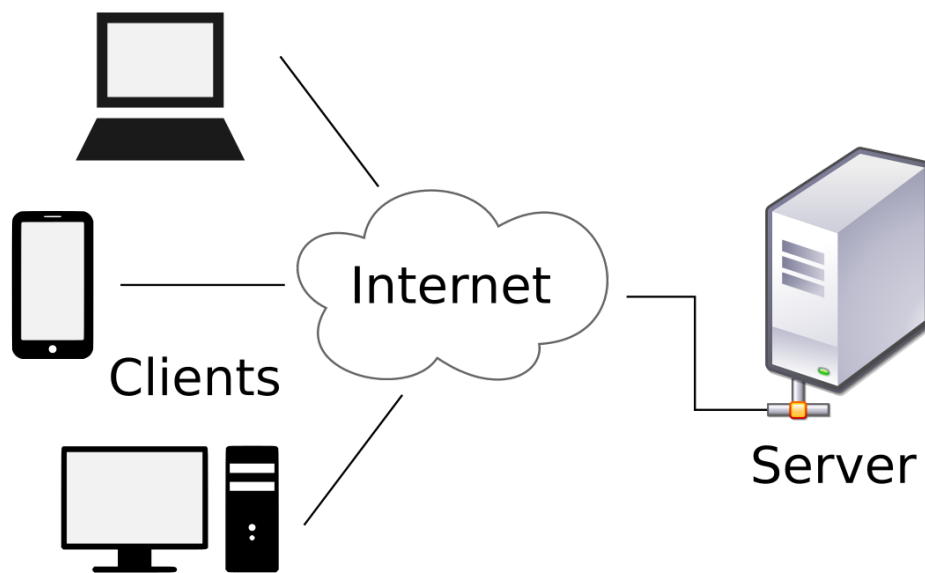


Figure 7. the Architecture of Client-Server Model

Based on the client-server structure, we have detailed its component structures below:

3.1.1. Web Browser or Client

The web browser or client is the interface rendition of a web app functionality, with which the user interacts with. This content delivered to the client can be developed using HTML, JavaScript, and CSS and doesn't require operating system related adaptations. In essence, the web browser or client manages how end users interact with the application.

There are three, well-known Web Application Architecture types available in the modern tech landscape: Single Page Applications (SPA), Microservices, and Serverless Architectures. Considered the needs of the project and the choice of the software development life cycle model, we chose the SPA architecture.

The SPA model interacts with the user in a more dynamic fashion by providing updated content within the current page, rather than loading entirely new pages from the server with each action from the user. It helps prevent interruptions in the user experience, transforming the behavior of the application such that it resembles a traditional desktop application.

3.1.2. Web Application Server

The web application server manages business logic and data persistence and can be built using PHP, Python, Java, Ruby, .NET, Node.js, among other languages. It's comprised of at least a centralized hub or control center to support multi-layer applications. The essential purpose of a web server architecture is to complete requests made by clients for a website. The clients are typically browsers and mobile apps that make requests using secure HTTPs protocol, either for page resources or a REST API.

Since the focus of this project is on the client side (frontend), which is the map generator (written in JavaScript), so we chose the Node.js Express framework. Moreover the Node.js is written using JavaScript and is the same technology as frontend components, which makes it easier for the developer to program backend services and frontend user interfaces. It also provides consistency, code sharing and reusability, simple knowledge-transfer, and a large number of free tools. These benefits bring flexibility and efficiency when building this project.

3.1.3. Database Server

The database server provides and stores relevant data for the application. Additionally, it may also supply the business logic and other information that is managed by the web application server.

Since the project involves a small number of entities and the relationships among entities are not complicated, so we chose MongoDB. MongoDB is dynamic, flexible and easy to get started, which provides high performance, high availability, and high scalability. What's more, our main purpose is to save maps and implement basic CRUD (create, retrieve, update, delete) operations of the database. As MongoDB is a schema-less database (written in C++), we can serialize the map data to JSON, send it to MongoDB and then save it.

3.2. Database Design

3.3. REST API Design

3.4. Map Generator Design

HTTP Verb	URI	Description
POST	/metro/auth/signup	Sign up for a new account
POST	/metro/auth/login	Log in to the system
POST	/metro/auth/logout	Log out of the system
GET	/metro/api/v1/users	Get a list of all users
GET	/metro/api/v1/users/{id}	Get the user with {id}
GET	/metro/api/v1/users/{uid}/maps	Get a list of all maps of the user with {uid}
PATCH	/metro/api/v1/users/{id}/password	Verify the password of the user with {id}
PUT	/metro/api/v1/users/{id}/password	Update the password of the user with {id}
PUT	/metro/api/v1/users/{id}/email	Update the email of the user with {id}
PUT	/metro/api/v1/users/{id}/name	Update the name of the user with {id}
PUT	/metro/api/v1/users/{id}/enabled	Update the enabled of the user with {id}
GET	/metro/api/v1/maps/{id}	Get the map with {id}
GET	/metro/api/v1/maps/?page={page}&limit={limit}	Get a list of {limit} maps on page {page}
POST	/metro/api/v1/maps	Add a new map to the database
PUT	/metro/api/v1/maps/{id}	Update the map with {id}
DELETE	/metro/api/v1/maps/{id}	Delete the map with {id}

Table 1. REST API Design Table

4. Bibliography

5. Appendices