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Puzzle Generator System Requirements Document

Team Prometheus

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Contents

1 Introduction

1.1 Product Name

Prometheus Puzzles

1.2 Purpose of the Software System:

The Puzzles Generator website aims to efficiently provide an interface for users to generate puzzles through the use of AI or create them manually. The AI based system will make use of a genetic algorithm.

1.3 Scope:

This system will aim to allow the user to create a puzzle based on a pattern/style of choice as well as with a different number of pieces per puzzle.

The system aims to allow users to share creations on the website and rate creations made by other users. A user should finally be able to use the system to generate a printable 3D model of a puzzle.

1.4 Business need:

The business need of this system is to automate the process of creating puzzles. The website design must be user friendly and appealing in order to attract users to interact with the system. Added to this, the steps taken to create the puzzle must be easy to follow and the process efficient.

1.5 Overview:

Puzzles have been a hobby of many people over the centuries, coming in various forms which have various ways of solving. Puzzles have played a role in people's problem solving skills. Puzzle generators have allowed for more puzzles to be created, using various techniques to create interesting and challenging puzzles.

The system involves the creation of 3-Dimensional puzzles (manually and from the use of AI), testing of puzzles, sharing and rating of puzzles by other users, as well as the ability of downloading 3D printable files.

2 User Characteristics

The general user of the website is someone proficient enough in the English language so that they can easily navigate the website and perform tasks as instructed. The user also needs to have an understanding of how to use technology, even though we aim to make our application very user friendly.
As such, we classified our users according to the following categories:

- Puzzle Enthusiasts - these can be users of any age, be it children, teenagers or adults who like playing with puzzles.
- Parents - some parents may want to make puzzles for their children to play with.
- Educational Users - these can be teachers who want to teach children with challenges such as autism or limited motor skills.

3 Functional Requirements

3.1 Use Cases

- UC1: Register
- UC2: Login
- UC3: Logout
- UC4: View Own Puzzles
- UC5: View Rated Puzzles
- UC6: Update Name
- UC7: Update Username
- UC8: Reset Password
- UC9: View Puzzles
- UC10: Rate Puzzles
- UC11: Update Puzzle Ratings
- UC12: Share Created Puzzles
- UC13: Search for a Puzzle
- UC14: Export Printable 3D File
- UC15: Manually Create Puzzle
- UC16: Manhattan Puzzle Creation

- UC17: Euclidean Puzzle Creation
- UC18: Generate Puzzle Using AI
- UC19: Select Puzzle
- UC20: Test Puzzle
- UC21: Delete Rating
- UC22: Delete Puzzle
- UC23: Sort Puzzles
- UC24: Admin: Delete User, Puzzle or Rating

3.2 User Stories

1 As a User I want to create an account so that I can create my own puzzles.

2 As a User I want to have a manual generation option so that I can create my own puzzle designs.

3 As a User I want to have an AI generation option so that I can tell the system to create a puzzle based on certain options.

4 As a User I want to share my puzzles creations so that other users can solve and rate them.

5 As a User I want to stop sharing my puzzles creations so that other users will not be able to print my creations.

6 As a User I want to rate created puzzles so that other users can be encouraged to work on creating more puzzles.

7 As a User I want to update the rating on puzzles so that other users can see how I feel about their puzzles.

8 As a User I want to view all shared puzzles so that I can see what other users are sharing.

9 As a User I want my own profile page so that I can update my personal information.

10 As a User I want a tutorial so I know how to generate puzzles on the creation pages

11 As a User I want to have a delete puzzles option so that I can delete my puzzle creations that I do not like anymore

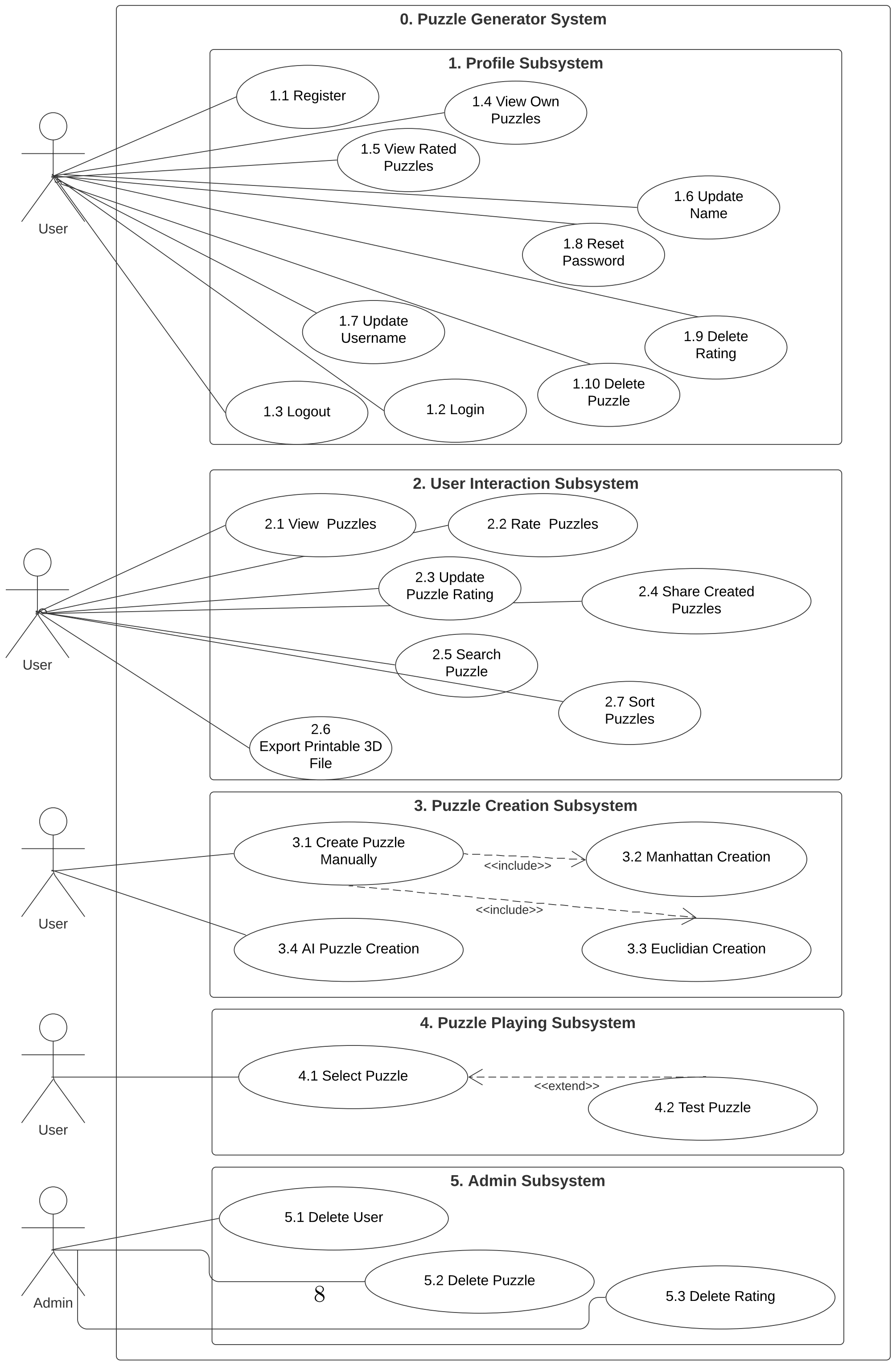
12 As a User I want to have a delete ratings option so that I can delete my puzzle ratings at will

13 As a User I want to have a search functionality so that I can find puzzles easily

14 As a User I want to have sorting functionality so that I can sort puzzles using different criteria

15 As an Admin I want to have all the functionalities of a normal user but also be able to delete a user, puzzle or rating if necessary.

Figure 1: Use Case Diagram



3.2.1 Use Case Diagram Description

Profile Subsystem
A user can use the register use case to create a new account, login as a registered user, and logout of his/her account. Once the user has a profile, the user can view a list of the puzzles that s/he has created and rated.

User Interaction Subsystem
This subsystem aims to highlight how the user interacts with created puzzles on the website. The user can view created puzzles, rate these puzzles, share their own puzzle creations and export puzzles to printable 3D files.

Puzzle Creation Subsystem
The user can uses this subsystem during puzzle creation. The user selects a desired shape from which they can decide to create the puzzle manually or use the AI to generate the puzzle. If a user decides on manual puzzle creation, they may upload an image for the puzzle

Puzzle Playing Subsystem
The user interacts with this subsystem when playing a puzzle. The user selects a desired puzzle and tests it (plays it).
Admin Subsystem
A special user (admin) logs into the system and is able to delete any users, puzzles or ratings if need be.

3.3 Requirements

- R1: The System must allow the user to register, and login to, a user profile.
- R2: The system must allow the user to rate puzzles.
- R3: The system must allow the user to view or play puzzles.
- R4: The system must allow the user to create a puzzle.
- R5: The system must be able to generate a puzzle through the use of Artificial Intelligence.
- R6: The system must be able to share puzzles.
- R7: The system must be able to export a puzzle to a 3-dimensional printable file.
- R8:The system must be able to store puzzles that have been created.
- R9: The system must be able to store user profiles.
- R10: The system must be able to search the puzzles.

- R11: The system must be able to reset the user password.
- R12: The system must be able to update the username and the name of the user.
- R13: The system must be able to use Euclidean distance or Manhattan distance to make the puzzle.
- R14: The system must update the username, name of the user.
- R15: The system must be able to delete puzzles and ratings as well.
- R16: The system must be able to sort puzzles.
- R17: The system must allow an admin to delete a user, puzzle or rating.

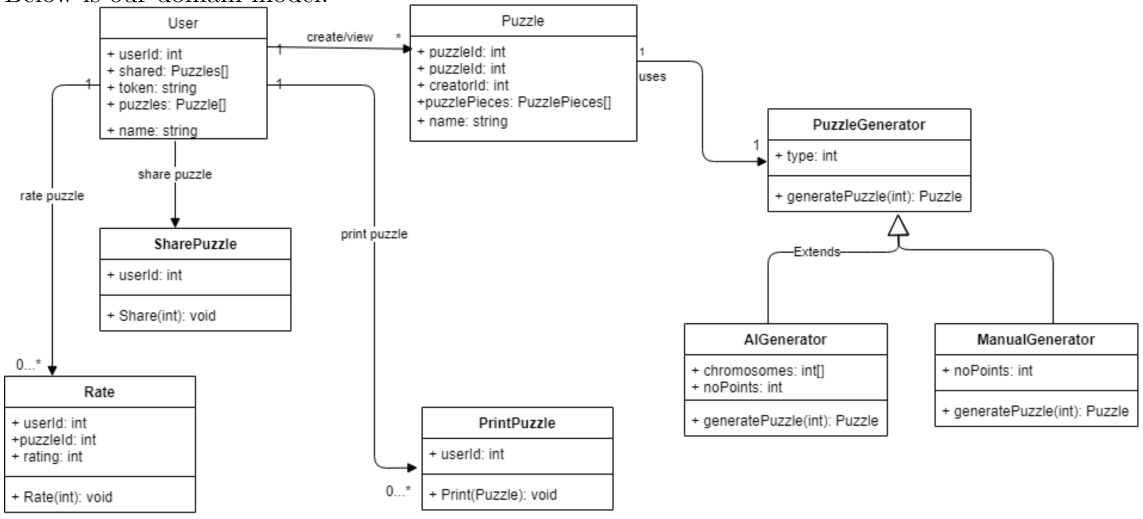
3.4 Subsystems

3.5 Trace-ability Matrix

Requirement	Priority	UC1	UC2	UC3	UC4	UC5	UC6	UC7	UC8	UC9	UC10	UC11	UC12	UC13	UC14	UC15	UC16	UC17	UC18	UC19	UC20	UC21	UC22	UC23	UC24
1	4	X	X	X																					
2	2										X	X													
3	1				X	X				X											X				
4	1															X	X	X	X						
5	1																		X						
6	3												X												
7	2														X										
8	5									X										X					
9	5															X	X	X							
10	2															X			X						
11	3						X	X	X																
12	4													X											
13	2																X	X							
14	3						X	X																	
15	2																					X	X		
16	1																							X	
17	1																								X
	UC Priority	1	1	1	1	1	2	2	1	2	1	1	1	1	1	3	3	3	3	1	1	1	1	1	

4 Domain Model

Below is our domain model.



4.1 Description of classes

4.1.1 User

The User class will be used for user management. Each user can create as many puzzles as they want and view shared puzzles. Each user can also rate, share and print as many puzzles as they want hence the link between the User class and SharingPuzzle, Rate and PrintPuzzle classes. The user also has an array of all their created and shared puzzles.

4.1.2 Puzzle

The Puzzle class is used to maintain the different puzzles. When the AI is used, i.e. the puzzle is not generated manually; the puzzle class makes use of the puzzle generator class which in turn uses a genetic algorithm to create the different puzzle pieces. The puzzle class is linked to the user class as the user interacts with the puzzle and each puzzle is owned by a user. The Puzzle class is also linked to the SharingPuzzle, Rate and PrintPuzzle classes as each of these services is linked to a certain puzzle.

4.1.3 SharingPuzzle

The SharingPuzzle class is responsible for sharing puzzles. The SharingPuzzle class is linked to the user and puzzle classes as this is needed when using the service. Sharing a puzzle enables other users on the website to view and test the puzzle.

4.1.4 Rate

The Rate class is responsible for rating puzzles. The Rate class is linked to the user and puzzle classes as this is needed when using the service.

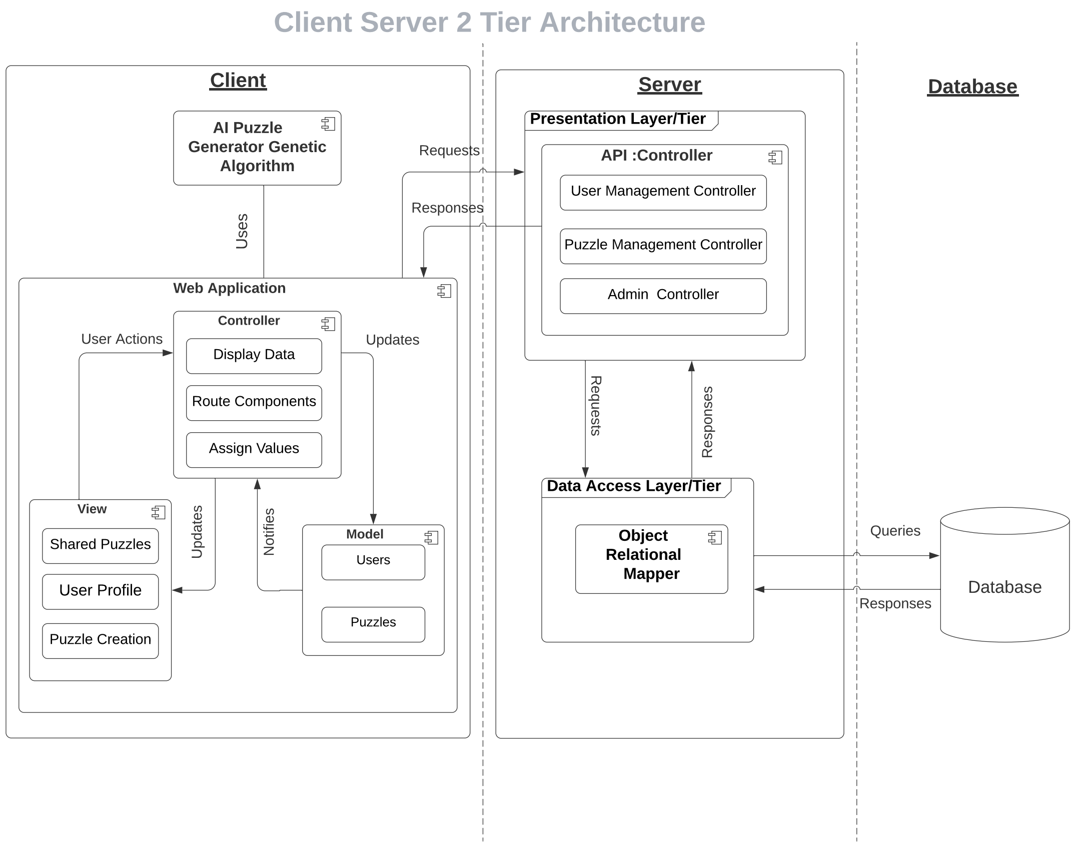
4.1.5 PrintPuzzle

The PrintPuzzle class is responsible for printing puzzles. The PrintPuzzle class is linked to the user and puzzle classes as this is needed when using the service.

4.1.6 AI Generator and Manual Generator

These two classes are subclasses of the Puzzle Generator class. These classes follow the prototype design pattern as the subclasses each contain a separate implementation of the generatePuzzle() function.

5 Architectural structural design & requirements



We made use of a Client Server Architecture. The Client Side further uses the MVC pattern while the Server side uses a Two Tier Architecture. Detailed pattern usage descriptions are provided below:

5.1 Client Side

We made use of this architecture to model the web application component of our system. This is what the user interacts with in their browser. It is made up of two components:

5.1.1 Web Application (MVC Architecture)

Taking into consideration that our system is a game playing system, the MVC architectural pattern was the best choice for us. We decided to use the separation of concerns approach, into designing our system as follows:

- Model - this defines the structure/data contained in our puzzle, user and ratings objects. An example is the specifications of attributes that make up the puzzle object.

- View - this is the interface users interact with when using our web application on their devices to create puzzles, share and solve puzzles.
- Controller - responsible for communication between view and model in response to user actions. Results of these user actions/responses are visible through updates to the view, for example if a user requests to sort by date, the controller updates the view to match this as per user request.

5.1.2 AI Puzzle Generator Component

- This represents the Genetic Algorithm we use to for the AI puzzle generator
- The Web Application uses the AI Puzzle Generator for AI puzzle generation, hence the strong relationship between the two as one cannot function without the other on the Client.

5.2 Server Side (Two Tier Architecture)

This is used for data manipulation and communication of data between the Client Side and Database. We chose this architecture because its modular structure and flexibility, in that we could develop our server independent of the client side development. We could also update components in either Tier with ease at any time during system development without worrying about crippling the system as a whole because the modular structure made debugging easier.

5.2.1 Presentation Layer

When a request is made by the Web Application on the Client Side, the Presentation Layer will use one of its controllers for any data manipulation or retrieval required and return this to the Client's Web Application.

The Presentation Layer, depending on the request may communicate with the Data Access Layer in order to retrieve any data necessary for the successful execution of the request. The API controller holds the following controllers:

- User Management Controller - manages data pertaining to users such as user puzzle records and user authentication procedures.
- Puzzle Management Controller - manages data pertaining to puzzles such as puzzle saving/retrieval format procedures.
- Admin Controller - manages admin role access rights such as what data the admin role can retrieve and operations they can perform

5.2.2 Data Access Layer

We made use of an Object Relational Mapper to:

- facilitate querying of data to the database
- structuring of responses from the database to a format required by the controller in the Presentation layer

5.3 Database

- This represents the data store our application used for storing data specific to puzzles and users.
- Access is through the Server Side's Data Access Layer which sends queries and the databases responds which appropriate data or response code in the case of query failures.

6 Quality requirements

**For detailed descriptions and quantification of how we tested the quality requirements below, please refer to this document

6.1 Usability

This refers to how the system is easy to use, easy to learn and easy to remember how to use.

The MVC architectural pattern helps us achieve this due its modularization of components. As a result we are able to work on the view independent of other functionality of the website in order to provide the best user experience as follows:

- The website must be easy to learn and self explanatory for users within and outside of our target groups
- Since it is a game playing system, the website must be aesthetically pleasing. Special attention is paid to color and font usage and text readability.
- We provide tutorials on how to generate puzzles and correct user errors when filling in forms
- We will be able to measure usability through usability testing which aims to measure the amount of time taken on average by users to perform tasks, average number of errors encountered when navigating the site and general feedback given. We aim to have our website be at least 80% usable without the need for tutorials.

6.2 Performance

This refers to the system's ability to achieve its intended purpose efficiently and the speed the system takes to do tasks. Performance is essential for our system because:

- The system is largely reliant on puzzle data from the database so the database needs to be able to handle simultaneous requests instantaneously, this being at least 30 requests per second.
- Our system is a real time puzzle generator and solving system. A puzzle should be generated by the genetic algorithm AI system within 30-90 seconds so that the user does not have to wait long periods of time but rather has a good user experience.
- Using the Master Slave architecture for AI puzzle generation, the master instructs the slaves to generate puzzle objects as per user specifications and the slaves will all do the same task, with the best puzzle object generated chosen as the solution

6.3 Reliability

This refers to the endurance and consistent performance of the system in the real world during its lifetime.

- Since users can be expected to generate or solve puzzles at any time of the day, our website needs to be available at least 89% of the time on our server.
- The system needs to be able to load to the website view with correct and accurate information 99% of the time i.e. the correct puzzle images must be matched up to the correct creator, rating and other information.

The separation of concerns of the MVC architecture allows our system to achieve reliability:

- We can identify failure points at any point in time, if there are any.
- We are able to test the functionality of the Model, View and Controller independently through unit testing and as a whole through integration testing
- Should a component/module e.g. model or controllers encounter an issue, the view will still be available allowing the user to interact with the website to some extent

6.4 Scalability

This refers to the ability of our system to scale efficiently to be able to handle a growing number of users and operations. The Puzzle Generator system needs to be scalable because:

- We know a large number of puzzles will be generated by our users. Our database needs to be able to store up to a thousand records related to these puzzles, including shared statuses, ratings and the puzzle images themselves so that when users request to view this information, it can be readily available.
- As a result, we are making use of pagination to display puzzles on each page to cater for the large number of puzzles.
- We except to have at least over 100 users registered on our system as the popularity of our website grows. Therefore, our website needs to be able to handle a large number of requests at the same time (e.g. 20 users may be actively sharing puzzles while other 20 are making ratings). The website should be able to ensure these users get the best experience when doing so.
- Our filter queries happen in two ways: filtering on the View component of the MVC architecture, and filtering on the Model and Controller MVC components to cater for large scale searches.

6.5 Security

The puzzle creations made by users are their intellectual property. Therefore, users have the have the right to decide which of these puzzles to share and keep private. This along with user details need to be kept secure and only for the eyes of the user. As such:

- Our system makes use of a token system. A user is assigned a token on registration which will be used with every request made to the database, such as when deciding to share a creation.
- If a user has been inactive for at least one hour, they are automatically logged out of their account
- MVC also allows us to achieve security due to its modular structure: all sensitive data is handled by the controller and model.

6.6 Cost

The software and libraries used must be free/open source.

- The website runs on a free tier web server.
- The website uses open source architectural technologies such as Angular and Node Express.

7 Technology requirements and Reasons

7.1 Hosting

- Heroku's free tier is used to host the website through this link
- We used Heroku as per client's request and because the hosting service was freely available for our application deployment.

7.2 API Server

We made use of NodeJS using the Express framework to host our API on the server side. We also considered the C# as described below below.

7.2.1 C# ASP.NET framework

- We considered using the framework but it fell short because it is less flexible in its support for scalability which is one of our non functional requirements.
- ASP.NET can be used alone as MVC pattern showing its best used as a Client side technology than a server side technology. Our API exists on the Server Side of our Client-Server Architecture[4].

7.2.2 NodeJS

This is one of the most widely used server scripting technology is this day and age. It is highly scalable (addresses our scalability requirement), which will allow easier handling of requests as our website grows in popularity[11]. We could also incorporate an Object Relational Mapper into the technology as required by our data access layer. As such, we used NodeJS as follows:

- We made use of the REST framework in order to write our endpoints. This allows us to easily verify the functionality of our system as known status codes can be tested in our unit tests for the various endpoints defined.
- Since our API handles CRUD database operations, we made use of the Sequelize ORM framework instead of normal SQL queries. This largely helps make our code compact and readable
- The technology falls into the JavaScript technologies family and our system largely uses JavaScript technologies making integration between components almost seamless

7.3 Website

7.3.1 PHP

Initially, we built the website using PHP because of the following reasons:

- it is an easily accessible open source technology with a big online community we could freely consult as well as the website manual available [9]
- PHP is flexible for database connectivity [2] and as such would work well with our chosen PostgreSQL database.

However, after our Demo One consultation with our client, the client requested we stop using PHP but rather we looked into other technologies, namely React, Angular and Meteor for our frontend. The client advised we consider all these and chose the most suitable for our system.

7.3.2 React

- This was a great technology choice supporting the building of interactive websites and used a component based structure [10]
- However, React is not an MVC[5] pattern but rather MVP. As a result we did not use it as we needed an MVC pattern.

7.3.3 Meteor [6]

This was another amazing full stack application development technology but did not quite work well for us because:

- It does not have support for SQL but rather for MongoDB. Our system makes used of PostgreSQL
- it is not very scalable which meant it would fail to support our scalability non-functional requirement as defined in section 6.4

7.3.4 Angular[1]

Finally, we settled on the best technology we thought ideal for our Web Application - Angular. The technology itself alone uses the MVC architecture we had defined in our Architectural diagram in Section 5. It also provided the following advantages:

- Angular allows for a single page website with various components attached to it, each performing its own set of functions. This was the major selling point of this technology to us as it allows us to separate our website functionality into - sharing components, rating components, creation components, etc which all work together at the end of the day to ensure the smooth running of of website.
- Angular's separation of concerns further allows us to define separate service files which we used for communicating with our API
- The technology's modular structure allows us to identify errors easily as only the affected component will stop working should an error exists.

7.4 Database

We are making use of the PostgreSQL database to store our data for the following reasons:

- Our system makes use of simple relational data which can be easily stored using a relational model database
- Heroku free tier provides support for the database
- The database was a hard requirement provided by the client

7.5 Puzzle Generation

Before settling on JavaScript to use for the implementation of our Genetic Algorithm, we considered the following options:

7.5.1 Python

- According to our architectural diagram, our Genetic Algorithm falls into the Client Side and has a strong association with the Web Application, however, even though Python is good for AI programming, it is best suited for backend use when combined with Angular for optimum application performance [8]. As such, our GA would have to be on the Server Side which would considerably slow down the loading time of our create puzzle views than running the GA from the client side
- Python uses DJango which best supports the MVT pattern of which we are making use of the MVC design pattern[12].

7.5.2 Java [3]

Despite having support for canvas element use, which we needed for our puzzle creation and solving, the language was not ideal because:

- Our application is a web application so a scripting language would be the best option of which Java is compiled and interpreted programming language.
- Java also requires it be run in an environment with the Java Virtual Machine environment installed. This was unnecessary for our web application.

7.5.3 JavaScript

- Both AI and manual puzzle generation algorithms were written in JavaScript
- Our Genetic Algorithm uses the Konva library which was best integrated into the JavaScript.

- This was ideal as our system in largely comprised of Javascript variations namely NodeJS and TypeScript so integrating that into the Angular website was an easy task

7.6 Unit Testing

We took the Jasmine unit testing framework into account when deciding of a framework before settling on Chai.

7.6.1 Jasmine [7]

- Jasmine was not ideal as it is a user mimicker that allows you to perform test cases similar to user behavior on a website and better suited for testing frontend visibility.
- Our units tests focus largely on our backend so Jasmine was dismissed as a choice.

7.6.2 Chai

We are making use of Chai for unit testing because:

- This tester integrates well with NodeJS hence it was the ideal technology to use to test our API endpoints as our API server is written in NodeJS

7.7 Integration Testing

We are making use of Selenium Webdriver to test the integration of our system. However, we also considered using Protractor

7.7.1 Protractor

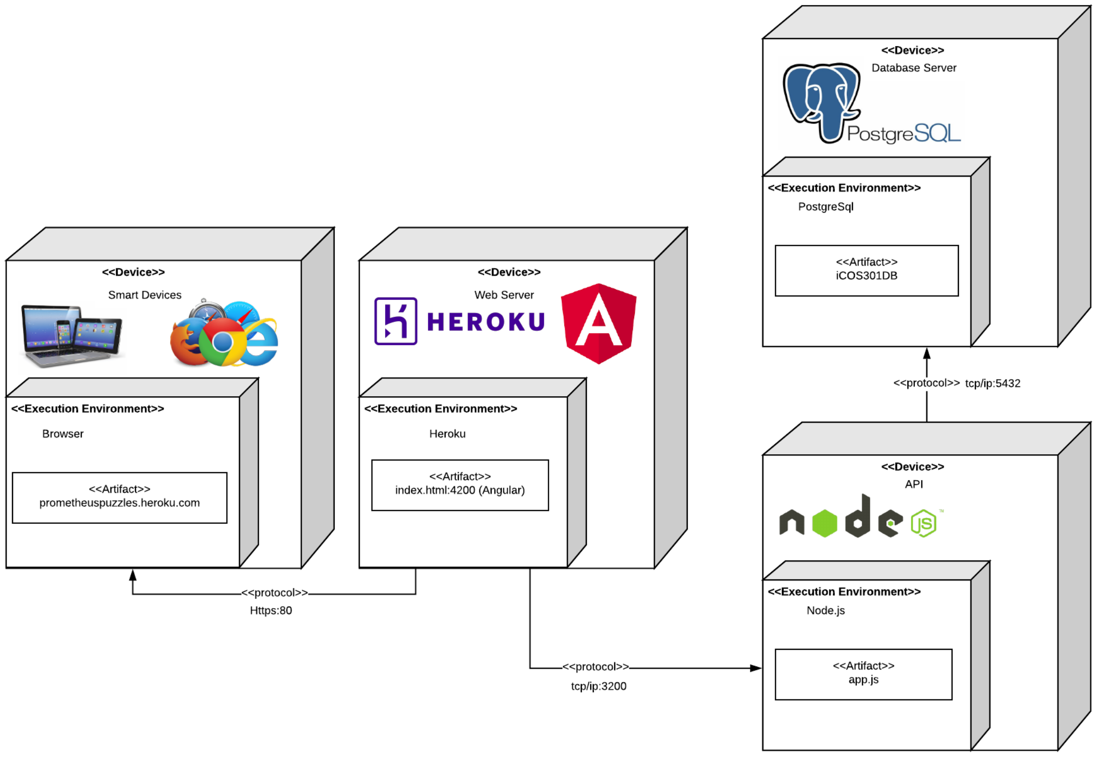
- Protractor was a great choice as it is the only automation tool which has inbuilt support for Angular element identification strategies.
- However, the framework failed to make the cut because is implemented as a wrapper to the WebdriverJs meaning there is one more layer added in between Selenium server and the Protractor. If there is an issue with WebdriverJs the Protractor team should wait for the WebDriverJs team to fix that issue[13].

7.7.2 Webdriver

- Our tester aims to emulate user operations such as logging into the website, sharing a puzzle and more. This verifies communication is indeed happening between the website view, API server (by making the request) and database server (returning requested data).

- We used the technology because our system is website based and the best way to verify that all components are working as intended was to emulate user actions on the website

8 Deployment Model



The image above is our deployment model showing the various components of our system and technologies used to bring our system together.

The user will use a browser on any smart device to access our website at prometheuspuzzles.herokuapp.com.

The website is hosted on our web server. The web server we are using is Heroku and we used Angular as our programming language. The web server use the http protocol to serve our website on port 80. Angular runs on port 4200 on our web server.

We communicate with our database via our API. The API is written in nodejs. The web server uses port 3200 to communicate with our API. and our API uses port 5432 to communicate with our database. These communications are done with TCP/IP protocols.

Our Database Server is PostgreSQL. We used pgAdmin locally to interact with the database.

9 Coding standards document

9.1 Server component

NodeJs Express applications has its own folder structure. The folder structure of the server is as follows:

- Front-end files are listed under a directory called **/src**. The structure of the directory is as follows:
  - /app
    - /app/models
    - /app/navbar
    - /app/pages
    - /app/rate-dialog
    - /app/services
  - app.module.ts
  - app.component.ts
  - app.component.spec.ts
  - app.component.html
  - app.component.css
- Back-end related JavaScript files are listed under the directory **Router**, after which the routing of the API call are in separate files:
  - api.js
  - users.js
  - puzzles.js

Unit testing of back-end the API is tested through Mocha/Chai frameworks. The testing file is listed as test.js in the root folder of the application base.

9.2 Angular component

Angular by design has its own folder structure which we maintained during the creation of our front-end.

- Every website page is a component (e.g. landing page, login page etc) are stored within the pages. folder. Please follow the link to see the structure on our Github page.

- The shared navbar is in the root app folder for easy access to components needing it.
- API calls are defined in a service stored under the services folder.
- Models are defined and stored under the models folder.
- All images can be found in the assets folder.
- All components have a .css, .ts and .html file. Component specific code is defined in the relevant files while global styles are defined in the app css, ts and html files.

9.3 Node API component

We made use of NodeJS to write our API. Calls to the database are made using the Sequelize ORM. Our file structure is as follows:

- Please follow this link to visit our Github page to see the structure
- /config directory - it contains the database configurations .
- /routes directory - it contains files which define the routes for particular endpoints. A typical endpoint route is ”api/users/createUser”, and the folder therefore contains a users.js file contain routes concerned with the user which in case would be. createUser.
- /models directory - this folder allows the definition of models as defined in the database as per Sequelize standards. An example would be the User class defining the fields which are found in the users database table. A model is referenced when doing database operations.

10 Technical Installation manual

The Technical Installation manual can be found at the following link:
https://www.overleaf.com/read/zhgbzhfdwmbt

11 User manual

The User manual can be found at the following link:
https://www.overleaf.com/read/hkvxmjmcfhcq

12 User manual

The Testing Policy Document can be found at the following link:
https://www.overleaf.com/read/hrqbxjwtnnnn

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