

SANCTA MARIA COLLEGE

DIGITAL TECHNOLOGIES

SCHOLARSHIP

Online Event Management Software Development Project

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Contents

1 Preface	3
2 Introduction	4
2.1 Initial Consultation	4
2.2 Specifications/Requirements	5
2.3 Key Stakeholders	5
2.3.1 Communication with Stakeholders	5
2.3.2 Usability Testing with Stakeholders	5
2.3.3 Other Stakeholders	5
2.4 Concept Statement	6
2.5 Existing Solutions	6
2.5.1 Eventbrite	6
3 Technical Component Research & Evaluation	9
3.1 Language	9
3.1.1 Javascript	10
3.1.2 PHP	10
3.1.3 Python	10
3.1.4 C#	10
3.1.5 Conclusion	11
3.2 Web Framework	11
3.2.1 Django	11
3.2.2 Flask	11
3.2.3 Conclusion	12
3.3 Relational Database Engine	12
3.3.1 SQLite	12
3.3.2 MySQL	12
3.3.3 PostgreSQL	12
3.3.4 Conclusion	12
3.4 Non-Relational Database Engine (Key-Value)	13
3.4.1 Memcached	13
3.4.2 Redis	13
3.5 Object Relational Mapper	13
3.5.1 PeeWee	14
3.5.2 SQLAlchemy	14
3.5.3 Conclusion	14
3.6 Task Queue	14

3.6.1	Celery	14
3.6.2	Redis Queue (RQ2)	14
3.6.3	Conclusion	15
3.7	Security Considerations	15
3.7.1	Safe Password Storage	15
3.7.2	SQL Injection	15
3.7.3	Cross Site Scripting (XSS)	16
3.7.4	Login Management	16
3.7.5	SSL	16
4	Development and Implementation	17
4.1	Back-End	17
4.1.1	Site Map	17
4.1.2	Database Tables	17
4.1.3	Application Diagram	17
4.1.4	User Primary Key	17
4.1.5	Storing Messages	18
4.1.6	Determining Unread Messages	18
4.1.7	Push Notifications	19
4.1.8	Concealing Object IDs	20
4.1.9	GET Idempotency	20
4.1.10	Password Entropy	20
4.1.11	Login Lockout	20
4.1.12	Rich Messages	21
4.1.13	Image Messages	21
4.1.14	Geo Search & Mapping	22
4.1.15	Server to Client Communication	22
4.1.16	Image Processing	23
4.1.17	Generating Random Events	24
4.1.18	SQLAlchemy Queue Pool Overflow	24
4.2	Front-End	25
4.2.1	Index Page	26
4.2.2	Dashboard	26
4.2.3	Discover	27
4.2.4	Event View	29
4.2.5	Create Event	30
5	Hosting & Deployment	31
6	Conclusion	32
6.1	Future	32

1. Preface

This Event Management Software Development project is my submission for the **New Zealand Technology Scholarship**¹.

It is entirely open source as part of my ethos and commitment to privacy & transparency. The source code is available on GitHub². I have also deployed the application, which is available at <https://jchad-event-app.herokuapp.com>. This online version will only be available October - December due to hosting costs.

This document was written in L^AT_EX and is also freely available on the public repository.

This document describes the journey of gathering requirements, making design/platform /technology decisions, development challenges and considerations, through to releasing and livening the product.

This document itself is a representation of the project journey, as this document has been evolving from the start.

It should be noted, that the requirements/objectives of this project have been completed.

¹<https://nzqa.govt.nz/qualifications-standards/awards/new-zealand-scholarship/scholarship-subjects/scholarship-technology/>

²<https://github.com/j-chad/event-app>

2. Introduction

I was approached by my clients, who recently had problems organising a school ball. Their main problem was communication between the large volume of attendees and the organisers. In particular, there were difficulties in efficiently notifying and updating all attendees of upcoming events and changes.

One of the main concerns for notifying attendees was that not all attendees used just one platform such as Facebook. This fact meant that some of the attendees were not always receiving relevant information.

My clients were mostly school students that had many other obligations and had volunteered to organise the ball. They found it difficult to keep everyone updated while still studying and performing other responsibilities.

2.1 Initial Consultation

I met with my clients, the Ball Committee, to discuss how they previously organised the ball, problems they encountered and to discuss their ideas for improvements.

The previous ball was organised mainly through Facebook. The Ball Committee members were all administrators of the page and published updates to attendees on this platform. Students attending the ball were advised to subscribe to the facebook page. The Committee found that not all students were on Facebook. This caused a need for the information to be relayed through other mediums such as email or SMS, inducing an effect not dissimilar to Chinese whispers as information would not be relayed as intended. In effect, this created more work for the Ball Committee and meant there wasn't a single source of information.

I asked the Committee if they could instead relay all their information by email rather than Facebook. They said most students do not regularly check their school email address, and it is harder to reply to a large volume of questions using this format. I then asked if the school newsletter would be a possible solution. However not all Teachers read out the information, and students don't tend to seek it out on their own.

To better understand the issue, I surveyed students who were not on Facebook. I found that a large proportion of respondents were worried about the privacy implications following the recent Facebook data scandal. I then asked this group what their preferred social media platform was, of which I got a broad range of different apps.

2.2 Specifications/Requirements

After the initial consultation and some research, the main specifications of this project are:

- Organisers can send out rich content updates to which **all** users can subscribe.
- Users shall be able to find events that matter to them efficiently.
- Notifications and updates shall be presented in real time.
- It must be aesthetically pleasing and appealing to the target audience.
- Users will be able to ask questions about the event.
- The app must be accessible by everyone.

On top of these requirements, the service should also be secure, private and easy to use.

2.3 Key Stakeholders

My key stakeholders are the Ball Committee and those attending the school ball.

2.3.1 Communication with Stakeholders

To ensure effective communication between these two parties I wanted to gather their needs and feedback throughout the development process. I have met with various Ball Committee members during development stages to discuss progress and future features being considered. I met with members individually as well as collectively to gather a better range of ideas.

2.3.2 Usability Testing with Stakeholders

Regarding usability, I will also consult with a number of fellow students about design and features to ensure that it is easy for them to use. Utilising usability testing principles from Jakob Nielson I worked with a small number of students and found that sufficient to make usability improvements.

2.3.3 Other Stakeholders

While the Ball Committee and attendees are my key stakeholders, I am also aware that this project has the potential to cater to a much broader demographic. During the design and development of this event management project, I also considered how the application could be used in other events, such as community events and concerts.

2.4 Concept Statement

The School Ball Committee that had recently organised a school ball, voiced concerns about the difficulties experienced in organising events with a high number of attendees. It was determined that a website event management system would help to ease the burden of effective communication to large groups of attendees. While this would be developed with the stakeholders in mind, it would also be beneficial for other significant events.

The main problem to solve was to find a unified way to communicate between organisers and a large number of attendees - ensuring that **all** attendees receive up to date reliable information in a timely and consistent manner.

2.5 Existing Solutions

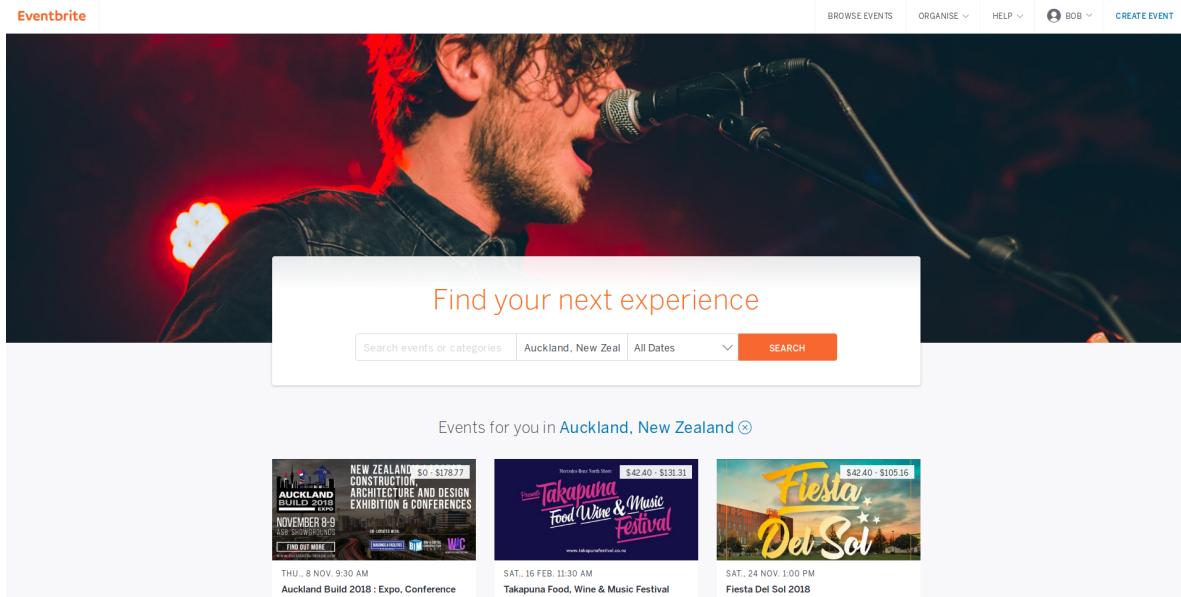
Event management is a fairly common task, and there are many out there. A number of event management solutions were quickly appraised to determine fit including Arlo, Grenadine, Facebook Events, Floktu and Eventbrite.

Each of the various solutions had advantages and disadvantages. As I wanted this scholarship application to be based on development capability rather than customisation and implementation, I elected to review one solution in depth before designing a custom developed solution. The existing event management solution I looked at in detail was Eventbrite.

2.5.1 Eventbrite

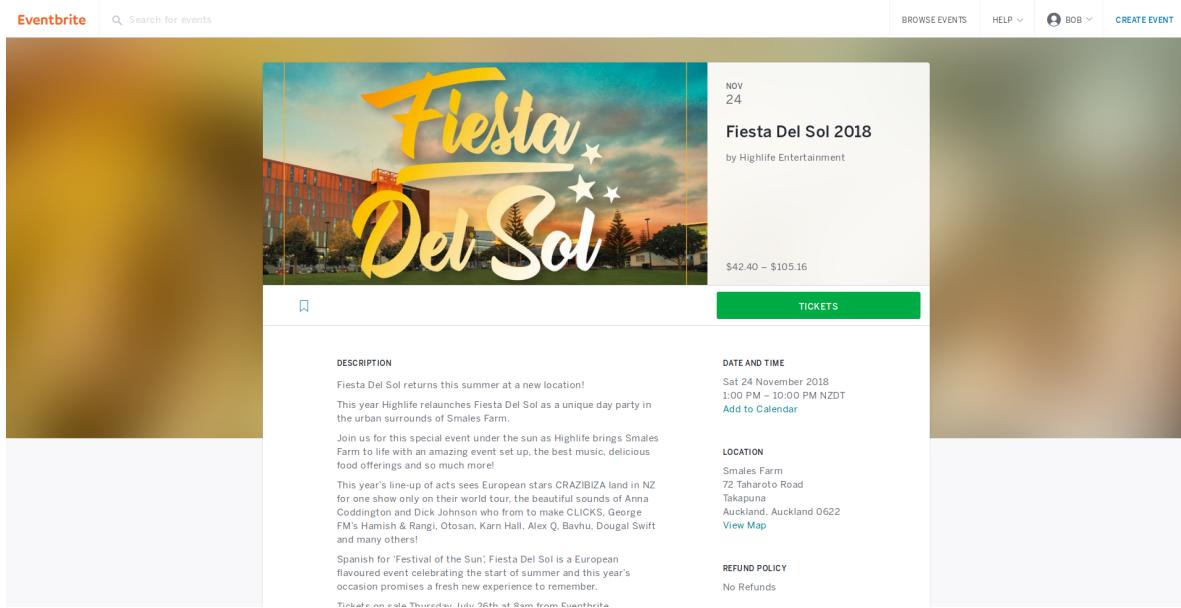
Eventbrite is another very popular event management system, that lets users view nearby events. It supports buying tickets, as well as settings to make the event private or public. The UI is a modern and clean design, and I found it very easy to navigate and create an event.

Figure 2.1: Eventbrite Homepage



The event pages give a high amount of detail, without cluttering the screen, including a map, and the time of the event. This information will be valuable in my application, as the user needs to be able to see the information quickly.

Figure 2.2: Eventbrite Event Page



A big problem with this site is that it doesn't allow for messages to the attendees, or for the attendees to ask questions about the event, which were both part of my specifications. Additionally, the site is also full of ads and trackers, which poses a privacy concern.

Conclusion

The user interface of Eventbrite is well designed, with clean colours and well-presented information. The fact that it supports tickets is good, but ticket provision is not a requirement of my application, and it has the potential to raise costs and security issues significantly. I will, however, consider their design and flow between pages when developing my application.

3. Technical Component Research & Evaluation

To build a custom online Event Management solution from scratch in a timely manner, a number of technical components can be selected so that they can be worked together to build a working product that achieves the expectations and requirements I have identified.

Aside from some security considerations and other interoperability, the primary solution elements considered are:

- Development Language
- Web Framework
- Relational Database Engine
- Non-Relational Database Engine (Key-Value)
- Object Relational Mapper
- Task Queue

Described below is a background to the research and design considerations for the technical components selected for use in the custom event management solution developed.

3.1 Language

Each programming language has its strengths and weaknesses. Since the programming language used for the back-end drives the whole application, it is essential to choose a language that suits a web application. For a language to suit this online event management project it must have a few features:

- It must be able to be concurrent and able to respond to requests simultaneously due to the large volume of users expected to use this site.
- It must be quick to develop in given the time constraint.
- It must efficiently interface with popular relational databases

I have decided to evaluate the following languages, which I have experience in: JavaScript, PHP, Python and C#.

3.1.1 Javascript

JavaScript is a dynamic, duck-typed language. It has been the de facto language for front-end programming since the inception of the web. Recently it has also become a popular back-end language with the advent of nodejs. This gives developers the significant advantage of only having to learn and write programs in one language both client-side and server-side.

JavaScript is a relatively new language for programming the back-end, it has historically been used to write code on the front-end. In recent years it has taken off and become popular due to website designers only needing to learn one language in order to build an application. The maturity of this language as a back-end is concerning, as it may not be as heavily vetted as alternatives. There are also other quirks of the language that put me off, such as strange type coercion (`1 == "1"`) and implicit global variables. I have a lot of experience using this language on the front-end but very little on the back-end.

3.1.2 PHP

PHP is the most widely used language for web development in the world, with over 80% of websites using it. This language does not have the problem of maturity, having been around for 24 years. The problem with PHP is it's unpredictable and inconsistent. In PHP: `NULL < -1` yet `NULL == 0`. This irregular behaviour is not a one-off case. The whole language is riddled with strange design decisions and many ways to do a single thing, each with different naming schemes. On top of all this, the language encourages bad website design and makes you go out of your way to create secure apps.

3.1.3 Python

Python is an object-oriented language that has been around for almost 28 years. It is a general-purpose programming language and has many frameworks that enable web development. The syntax and language are very concise and expressive, making development very quick and easy to debug. Python avoids both the pitfalls of PHP and JavaScript and is very flexible. Since python is an interpreted language, it is marginally slower than similar compiled languages. The fact that it is not specific to web development means that I can use a wide range of tools to accomplish my tasks.

3.1.4 C#

C# is a strongly typed, compiled language from the C family. Microsoft created C# as an interface for .NET, a common core between multiple languages. Included in .NET is the ASP.NET library, the server-side web framework. The compiled nature of this language allows substantial optimisations to be made at compile time, leading to speedups in the application. I have experience in using this language as it is used in my job for a large-scale international web application. While it works well with larger applications that require constant maintenance and have a company driving development, it is often

overkill for smaller scale applications. ASP.NET development is much slower (albeit more thorough) than dynamic languages such as the above.

3.1.5 Conclusion

I have opted to use Python as the primary development language for my application. This decision is due to the dynamic nature of the language which allows a fast development pace. As well as the large community and environment that comes with it. Using PyPI (a.k.a the Cheese Shop), I have access to over 113,000 packages created by the python community that can help me to develop certain features.

3.2 Web Framework

To efficiently and securely write a web app, a web framework which handles all low-level details such as HTTP and routing logic is required. This follows the philosophy of not reinventing the wheel. A web framework sits between the browser and the language and handles common logic that is general to all websites. This allows me as the developer to ignore implementation details and focus on higher level application logic. I will need to use one of the many web frameworks made for python. The two most common frameworks in python are **flask** and **Django**. There is a divide in the community about which is better, but the consensus is that they are both suited for different use cases.

3.2.1 Django

Django is a web framework that takes a "battery included approach". It includes many features out of the box, meaning programmers can spend more time writing code without worrying about implementation details. Although this framework has many useful features, it would impose an infrastructure that is far too heavy for this project's purposes. It is 180 MB which is very heavy compared to flask (6.3 MB). This is because of the "include everything" approach Django takes, whether or not those features actually get used.

3.2.2 Flask

Flask is a "micro-framework" and is the opposite of Django in the fact that it makes fewer decisions for the programmer. It is very lightweight and leaves almost all of the higher level implementation and infrastructure details to the programmer. This is perfect for this project's needs as features can be picked and chosen as needed. Flask has a wide array of extensions made by the flask community. These range from login-management to asset bundling.

3.2.3 Conclusion

I chose to use Flask because of its scalability and extensibility.

3.3 Relational Database Engine

The relational database has a critical role as being the primary data store for my application. Therefore it must be efficient and reliable so as to keep my application running smoothly. I appraised three SQL databases (as described below): SQLite, MySQL and PostgreSQL.

3.3.1 SQLite

SQLite is a lightweight database engine that operates using database files. This means it is fast, efficient and straightforward to set up. However, this means it doesn't provide proper access controls. Another downside is that it only supports one write operation at any given time. The slow write operations will be a major drawback when the web app is scaled up and has many users.

3.3.2 MySQL

MySQL is a much more full-featured relational database. It is one of the faster available database engines available and is also one of the most popular engines. MySQL has a large open source community fixing bugs and providing support, which is always a welcome addition. MySQL is a database server (not embedded) and is designed for larger applications. MySQL is well known for being very secure and performant; both features would add value to my application. MySQL also offers a much more full-featured language with support for more constructs.

3.3.3 PostgreSQL

PostgreSQL is also a very popular relational database. It has very similar features to MySQL but is closer to the ANSI SQL standard, i.e. more feature complete.

3.3.4 Conclusion

Following consideration of the above three databases, MySQL and PostgreSQL are both capable databases that would be suitable for use. It came down to preference due to the similarity. I had previously used MySQL, so I was more familiar with its use and selected it for my event management solution.

3.4 Non-Relational Database Engine (Key-Value)

A non-relational database is used to handle tasks and data which are not related to other data or a request context, but still must be stored. Such data includes caching, tasks, rate-limiting and verification. I used a key-value model for the non-relational data. Two non-relational database engines were appraised - Memcached and Redis.

Note: of the two engines appraised, Redis was the engine selected and used in the event management project.

3.4.1 Memcached

Memcached is an older key-value store which is extremely efficient and fast. However, its operations are not atomic, meaning race conditions can be created. Race conditions are a massive problem in my application, as it could have many hundred requests per second which need to be handled simultaneously. Since the operations are not atomic, the data is not reliable with high traffic.

3.4.2 Redis

Redis is another excellent non-relational database. Unlike Memcached, every operation is atomic meaning that when the application is scaled up and there may be a few hundred changes to the database every second, there shouldn't be any data race issues. This is very important in a highly concurrent application. Redis is every bit as fast as Memcached and supports more features, which is always nice.

3.5 Object Relational Mapper

An Object Relational Mapper (ORM) handles an abstraction level between the programming language and the database. Using an ORM is desirable as it allows focus to remain on the logic of the application without worrying about implementation detail or intricacies of database management.

Using an ORM means that python code can be written so that the ORM will: generate SQL, execute the SQL, and transform any non-pythonic objects into python data types. Utilising an ORM allows safe and straightforward development and enabled me to use SQLite in a testing/development environment and MySQL in production with minimal changes in code.

I evaluated two ORMS: PeeWee and SQLAlchemy.

3.5.1 PeeWee

Peewee is a lightweight ORM with a simple syntax. It is quick and suitable for smaller apps, but it lacks more complicated features. Another important consideration is the community size. PeeWee only has one major contributor, meaning patches and features will be released slowly. It also has very few resources online.

3.5.2 SQLAlchemy

SQLAlchemy is a very stable ORM that integrates very nicely into flask using an extension. It is a very widely used ORM and I have the most experience with it. SQLAlchemy is much larger than PeeWee but offers a lot more features while maintaining simple and expressive syntax. There are 9 major contributors and it has a large online following. SQLAlchemy also offers the ability to drop down to raw SQL if needed, although this can open the application up to SQL injection vulnerabilities.

3.5.3 Conclusion

I chose to use SQLAlchemy due to its extensive documentation and simple extensible declarative model. Also factoring into this decision is my previous experience with smaller scale applications.

3.6 Task Queue

A task queue will become important in the later stages of development when I need asynchronous code is needed to prevent blocking the current request. Having a task queue in place will let tasks be run independent from the standard request context when the computer has resources to spare. This will decrease the time it takes for the web app to respond and allow asynchronous events to be scheduled.

3.6.1 Celery

Celery is a very large and full featured task queue. Due to the large community support, I started off with this task queue. However I quickly found it was much too complex and didn't have strong support for the flask web framework. It required a structure that interfered with the rest of my code and it needed many workarounds to get it to do basic things, such as send an email.

3.6.2 Redis Queue (RQ2)

I then tried a much more basic task queue which was designed to work with flask. This task queue was much more suited to my needs. I didn't have to worry about passing any

app contexts around or use any hacky workarounds. As in the name, this task queue uses Redis as a message broker to store and retrieve tasks from.

3.6.3 Conclusion

Of the two task queues I considered, I implemented Redis Queue. Even though celery is much more advanced, Redis Queue had all of the features I required and was much simpler to implement.

3.7 Security Considerations

As a developer, it is my belief that any website should do their absolute best to provide a secure and private service. There are many aspects to consider when ensuring an app is secure, and it is nearly impossible to cover everything. However I will minimise risks and threats by considering the below four security areas:

- Secure Password Storage
- SQL Injection
- Cross Site Scripting (XSS)
- Login Management
- SSL

3.7.1 Safe Password Storage

An important consideration in any application that manages passwords, is the hashing mechanism. I will use Bcrypt to hash the passwords with a random salt (per user) which is generated with the OS CSPRNG. Bcrypt performs in constant time which will mitigate timing attacks. The salt ensures that an attacker must bruteforce each password individually. They cannot find one hash and then test it against the whole database as each person's hash will be different, even if they have the same password. Storing passwords in such a way ensures that nobody, not even someone with access to the database, can access the passwords.

3.7.2 SQL Injection

SQL Injection occurs when a SQL query takes malicious user input and executes it. It is a fairly easy threat to deal with, but it still one of the most common. Since I am using an ORM, SQL Injection will be managed for me, with all input data being cleaned before a query is performed. Theoretically this should completely mitigate SQL injections as an attack vector. However, SQLAlchemy also allows using raw SQL for some operations. Raw SQL code will not be automatically cleaned by SQLAlchemy and is therefore unsafe

unless it doesn't rely on user input. A simple and rather elegant solution to this is to simply **NEVER** use raw SQL, as everything that can be written in SQL can also be written in SQLAlchemy's declarative API.

3.7.3 Cross Site Scripting (XSS)

XSS is very similar to SQL injection in the fact that it involves executing malicious input. XSS means a user can write malicious code that will be delivered to other users of the site. The template engine installed with flask (jinja2) is by default configured to escape any special symbols into the html equivalent, rendering any malicious inputs useless. However this setting escapes everything which adds unnecessary overhead and slows down the application, because of this speed loss, I decided to manually mark input as unsafe/safe. This is a bit riskier but is safe if handled correctly. I also opted to escape user input before it was entered into the database for items such as message text, rather than escaping it before rendering. This minimises future risk of the malicious data being presented to users, and saves the resource cost of cleaning the input every time it needs to be rendered.

3.7.4 Login Management

I initially began this project with the intention of creating my own login management system, however the complex and time consuming nature of this application meant I switched to a prebuilt solution using flask-login and flask-paranoid. Flask login integrates with SQLAlchemy and provides essential session management, where the session is stored as a cookie and verified each request. Flask-paranoid is used as a second layer of security which verifies that the users session doesn't suddenly switch to another computer, which could indicate the users session has been stolen by a malicious user.

As an extra layer, I also added a verification email, which is sent to the users email. This helps to protect against spam and verifies that the user owns the email. Until a users email is verified, no notifications will be sent to their inbox.

3.7.5 SSL

A SSL certificate has been installed on the host web-server to ensure encrypted communication between users and the host site. This is also important for push notifications, as most browsers will not accept push notifications from an unencrypted connection.

In development I used a self signed certificate, whereas when I pushed to a production server, I used LetsEncrypt.

4. Development and Implementation

4.1 Back-End

This section of the document outlines the journey and technical detail of building the backend to achieve the stated project requirements.

4.1.1 Site Map

One of the first decisions I needed to make, is a map of how the site would function and flow. The site map was revised a few times and below is the end result.

4.1.2 Database Tables

4.1.3 Application Diagram

Below is a simplified diagram of how all the different components of the app interact with each other.

4.1.4 User Primary Key

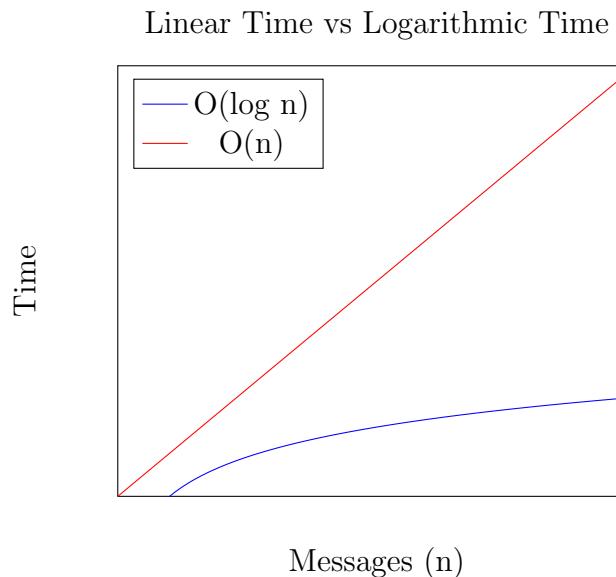
The user table is a key table in the database, almost every table relies on it either directly or indirectly. Initially (and for most of its development) I used the users email as the primary key. Having users all have separate emails seems like a natural way to identify users, however if a user needs to change their email, we need to change the primary key. This leads to essentially creating a new user, losing and invalidating all references to other tables. To solve this issue I simply changed the primary key and all related foreign keys to use a simple integer. I then used a unique constraint on email to ensure it is still unique.

4.1.5 Storing Messages

The application needed a way to store and retrieve messages. Multiple types of messages are supported, each with different data (e.g. text, location, file). This became a problem as I can't store different types of data for each type of message. I solved this by specifying the type using a ENUM and containing the data within a json field. This way, I can easily create new types of messages by adding to the enum and specifying fields expected in the JSON. This approach keeps the solution flexible and allows for future expansion.

4.1.6 Determining Unread Messages

An important piece of data needed for the dashboard screen, is what messages the user hasn't read. A simple solution to this problem was to include a boolean on each message that indicates whether it has been displayed to the user. However, I found querying by this way slow and inefficient. I found a better solution was to instead store a timestamp of when the user last loaded a specific event, or the page was updated in any way. This way any messages broadcast after this timestamp could be queried. Message timestamps can be indexed as a binary tree. With binary tree indexes an average lookup speed of $O(\log n)$ can be achieved, which is a significant improvement on the previous speed of $O(n)$ (as shown in the below graph).



I initially stored the “last viewed” timestamp in the redis datastore, but after some testing decided to move it to the Subscription table. This move was due to two reasons:

- The timestamp is fairly critical, we don't want the user to suddenly be notified about every single message ever sent. All critical data should be kept in the relational database.
- The timestamp is actually reliant on a subscription, e.g. when a user creates or deletes a subscription, the timestamp must be modified or deleted manually. This adds unnecessary code into the application and is unintuitive.

4.1.7 Push Notifications

Push notifications were one of the trickier features to implement.

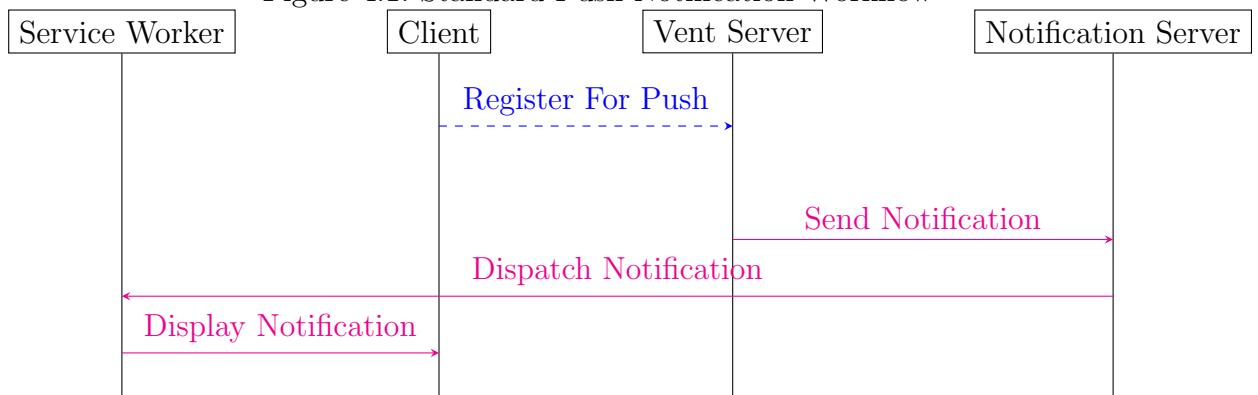
1. Push starts off with a service worker, which must be registered in the global scope. (I simply set a url “/service-worker” to return the file, but in production this will be served by the web server). The user is then prompted to allow notifications.
2. Once the event management app has been given permission, it gets handed some cryptographic keys and an endpoint.
3. The cryptographic keys and endpoint are then registered in my database through an asynchronous call.

I initially set the user as the primary key, however, this quickly caused errors as each endpoint is specific to a device. This meant that users would only be able to have one device receiving push notifications.

I then changed the primary key to a new id column, however that lead to new problems where an endpoint would be registered twice if a user subscribed, unsubscribed, and subscribed again, resulting in users receiving multiple push notifications for each event.

To solve this a composite primary key of the endpoint and user id was used. This did not cause problems but on later review of the code I removed the primary key on the user id. The primary key on the user was unnecessary as each user is assigned a unique endpoint by their browser.

Figure 4.1: Standard Push Notification Workflow



When a notification needs to be sent, a call is made to each endpoint with relevant data. I used pywebpush to achieve this. If a 410 *gone* or 404 *not found* are returned, I assume that the endpoint is expired or invalid and delete it from my database.

Following a number of complexities, trial and troubleshooting, push notifications were successfully integrated into the application.

4.1.8 Concealing Object IDs

While developing the application, I realised that some of my urls weren't as secret as they should be. The primary key for events is an integer type and is set to auto increment. This means that (most) event's primary keys will simply be the previous event's primary key + 1. The way that I exposed the events to users was `myapp.com/event/<id>`. This gives any malicious users a straightforward way to iterate over every listed event. To fix this I used a module named hashid, which provides a reversible obfuscated base64 id. Hashids also take a salt which means its not just a straight reversal. Hashids are in no way secure, but they provide a useful url obfuscation technique.

I implemented this behaviour using encapsulation, which means the behaviour can be changed with minimal code. This allows me to later scale up the security by providing a cryptographically secure hash as the ID.

4.1.9 GET Idempotency

Another issue I discovered during my development, is the method I use to access endpoints. When I added email verification to my app, I also added the ability to resend an email in case it doesn't reach the inbox. However this method (and the logout method) was accessed using a GET request. The issue with a GET request is that it is defined as a safe and idempotent method in the HTTP specifications. This means that it shouldn't modify any system state, only retrieve information. Browsers will often cache and refetch endpoints retrieved with GET causing the code to run unintentionally. This could cause the user to retrieve multiple emails or be logged out without pressing anything. To fix this, I added a hidden form that is submitted when the user clicks on the logout button.

4.1.10 Password Entropy

When the user made a password, I wanted to ensure that it would be sufficiently secure. I began with basic password rules such as minimum length, lowercase, uppercase and digits. However I felt that this was too strict and imposing. This was also a server side validation and at the time didn't have any client side validation. I decided to instead remove the server side validation and use a entropy + common password checker on the client side. Although it is a simple matter to bypass client side validation, there is no motivation to make a less secure password for themselves.

4.1.11 Login Lockout

While designing my security features, I added logic to lockout users who keep entering the wrong password in an attempt to stop brute force and dictionary attacks. I use the same identification function as my rate limiter. I also use another identification method provided by the helpful flask extension: paranoid, but paranoid tests if it is a different client, while a rate limiter checks if it is the same client. It would be extremely easy to trick paranoid's detection to think you are a different user. I store the amount of

times that a user has got an incorrect password in redis using the identifier. I also set an expiry time which gets reset when they get a password wrong. This allows the data to be erased after a while ensuring lockdowns are only temporary. If the number of attempts is too high, I deny any POST requests and return a helpful link to reset their password using their verified email.

4.1.12 Rich Messages

I wanted a simple way to enable users to write text using rich formatting. I decided on using markdown, which is a lightweight markup language, which is human readable and easy to convert to html. Converting user input into html will bring with it a risk of XSS. To circumvent this, I sanitize with **Bleach** - a library by mozilla, for sanitizing html.

Originally, I attempted to use all messages as markdown. This lead to problems in my database. This is due to the database having max lengths for answers and questions. This can be exploited by the user by writing markdown which expands. For this reason, I decided to only use markdown for event messages.

For example, the markdown: * * * * * A expands to 131 characters when converted to html. By using this technique, a 299 character long string can be expanded to > 3000 characters.

Another problem of markdown is when it generates the HTML, it does so without context of the page it will be presented in. This means that it can (and will) generate a `<h1>` tag in the middle of the page. This causes issues with displaying content. Luckily the markdown processor I use supports extensions, and it was a trivial matter to find an extension which increases the header depth.

I also expanded markdown into event descriptions, to allow more control over the information presented to potential participants. This required me to change the description column from `VARCHAR(500)` to `TEXT`, to avoid the problem listed above.

4.1.13 Image Messages

I ran into a problem when implementing sending images as messages. Traditionally images and files cannot be uploaded asynchronously, due to security risks with javascript reading local files. However, in 2008 a proposal was created for *XMLHttpRequest Level 2*. This specification is an improvement on the initial *XMLHttpRequest*, and allows (among many things) asynchronous file uploading. There is enough support for this standard to use it without worrying about polyfills.

Figure 4.2: Support for XMLHttpRequest Level 2



4.1.14 Geo Search & Mapping

For users to be able to see nearby events, we first need to know the location of events. An important consideration in storing the coordinates (latitude & longitude) is how accurate they need to be. I found that 5 decimal points gives precision of 1m which is more than enough precision. I wrote the algorithm to calculate the distance as a hybrid method in my ORM, which means it will work in the database and on the server with no changes to the code.

Given the variables x_{search} and x_{event} are the latitude in radians, and y_{search} and y_{event} are the longitude in radians, we can define the distance between an *event* and given *search* coordinates in km as:

$$\cos^{-1} \left(\begin{array}{c} \cos(x_{event}) \\ \times \cos(x_{search}) \\ \times \cos(y_{event} - y_{search}) \\ + \sin(x_{event}) \\ \times \sin(x_{search}) \end{array} \right) \times 6371$$

This equation gives us the great circle distance between the two coordinates. This is the shortest distance measured along the curve of a sphere. Although the earth is not completely spherical (it is elongated slightly at the equator), this equation is accurate enough for the purpose of this application. We can then use this equation to find nearby events.

4.1.15 Server to Client Communication

While users of my application will get real-time emails and push notifications, any updates to the data will not be presented to them until the page is refreshed. Automatic updates without user input is an important feature for my application to have, before the data is truly real-time.

HTTP is traditionally a half-duplex protocol, where a client sends a request and receives a response. To show real time data, I need to be able to send data to the client from

the server whenever there is new data.

There have been numerous methods used to overcome these client-side refresh limitations. One of the most common methods, is simply asking the server constantly for the new data. A variation is to ask for the data but let the server wait until it receives new data before responding.

While some of these techniques work well, they have a large amount of overhead, constantly sending or receiving unnecessary data. There are two relatively new specifications that allow communication between the server and client.

- The first method I tried was Server Sent Events (SSE). SSE is built upon http and is fairly straightforward: The client connects to an event source, and then the server pushes data to that event source, giving the client the data. This is still technically half-duplex but the server initiates the request, rather than the client.
- The other specification is Websockets. Websockets are a separate protocol from http and are achieved by using an upgrade header in http. Websockets are fully duplex and very efficient.
- I used SSE as Websockets were much more difficult to implement safely and I did not require client → server communication.

When implementing SSE I needed an identifier for each channel a user would subscribe to. A quick solution was to use the base64url encoded version of the users email, however this can leak the users email, even if served over https. I switched this to a sha256 hash, to better secure the information.

In practice, I found that the hosting service provider (heroku) issued a timeout if no data was provided from the server within 55 seconds. To get around the issue of time-out by the hosting

4.1.16 Image Processing

When a user uploads an image, the image is compressed to save space and bandwidth. A simple and effective first step is to limit the maximum size of the image. However if the maximum image size is set too low, then the user might not be able to upload their images, and if it is set too high then it won't be effective. To compress the image, I used JPEG compression set at 75% quality and set the optimise flag, which does an extra pass through the image. This provided a much smaller file size with little decrease in visual fidelity.

To ensure that this doesn't cause a large delay in the request, I decided to measure the time it took to process the image. To measure this, I used the following code, with a large (1 MB) PNG image:

```
1 import time
2
3 def process(f_handle):
4     img = Image.open(f_handle)
5     img.thumbnail((800, img_handle.height), Image.ANTIALIAS)
6     img.save('test.jpg', optimize=True, quality=75)
```

```

7
8     start = time.clock()
9     with open('test.png') as f_handle:
10        process(f_handle)
11    print(time.clock() - start)
12

```

After running this code many times, I found that it takes around 50 ms to fully process the image. This is an acceptable timeframe, and will be perceived as instantaneous. As it doesn't take up much time or resources, I was able to process the image directly in the request context.

4.1.17 Generating Random Events

In order to test my website, I needed a number of events. For most of the developmental period I did this by hand, with 2 or 3 hardcoded events. This was fine but eventually I needed to scale up the amount of events so it was more reflective of its intended use. To do this I wrote a simple factory which creates events in the database using random data. I then refactored the *populate* command to create as many events as necessary. This worked well but gave me very random names that were just random words glued together. To create more meaningful names I decided to use a simple Markov chain.

A Markov chain is essentially a list of states with a probability of moving to another state. This gives a cheap way to mimic artificial intelligence. It is often used for the predictive text function in phone keyboards. In this use-case, it tells us if we have the letter **A** then the most probable next letter based on our data. We then randomly select a letter using the weights given by the chain. The process then repeats using the new letter. It can be made to work better by changing the number of letters used for the state.

To get the data needed to find probabilities, I used selenium to scrape over 1000 event names (almost 45000 characters). I then generated a markov chain (of order 1) and saved the state to a json file. The resultant names were (generally) suitably convincing.

4.1.18 SQLAlchemy Queue Pool Overflow

While the *SQLAlchemy Queue Pool* error isn't so much a problem in my design, It caused minor annoyances during the development stage. When I actually looked into this behaviour, It gave me some insight on how flask works behind the scenes.

One of the most common errors that was raised during the development of my app was:

sqlalchemy.exc.TimeoutError: QueuePool limit of size 10 overflow 10 reached

This error is due to the nature of both flask and SQLAlchemy. Behind the scenes, SQLAlchemy creates a pool of connections. This is because it is inefficient to create and maintain a new connection whenever a new user connects. With large web apps, this could easily lead to holding millions of database connections simultaneously. Instead, a

specific number of connections are created, these are reused by different users. If there are no connections ready in the pool, a new one will be created. If too many connections are held, and a new connection is requested, it will eventually timeout, giving this error.

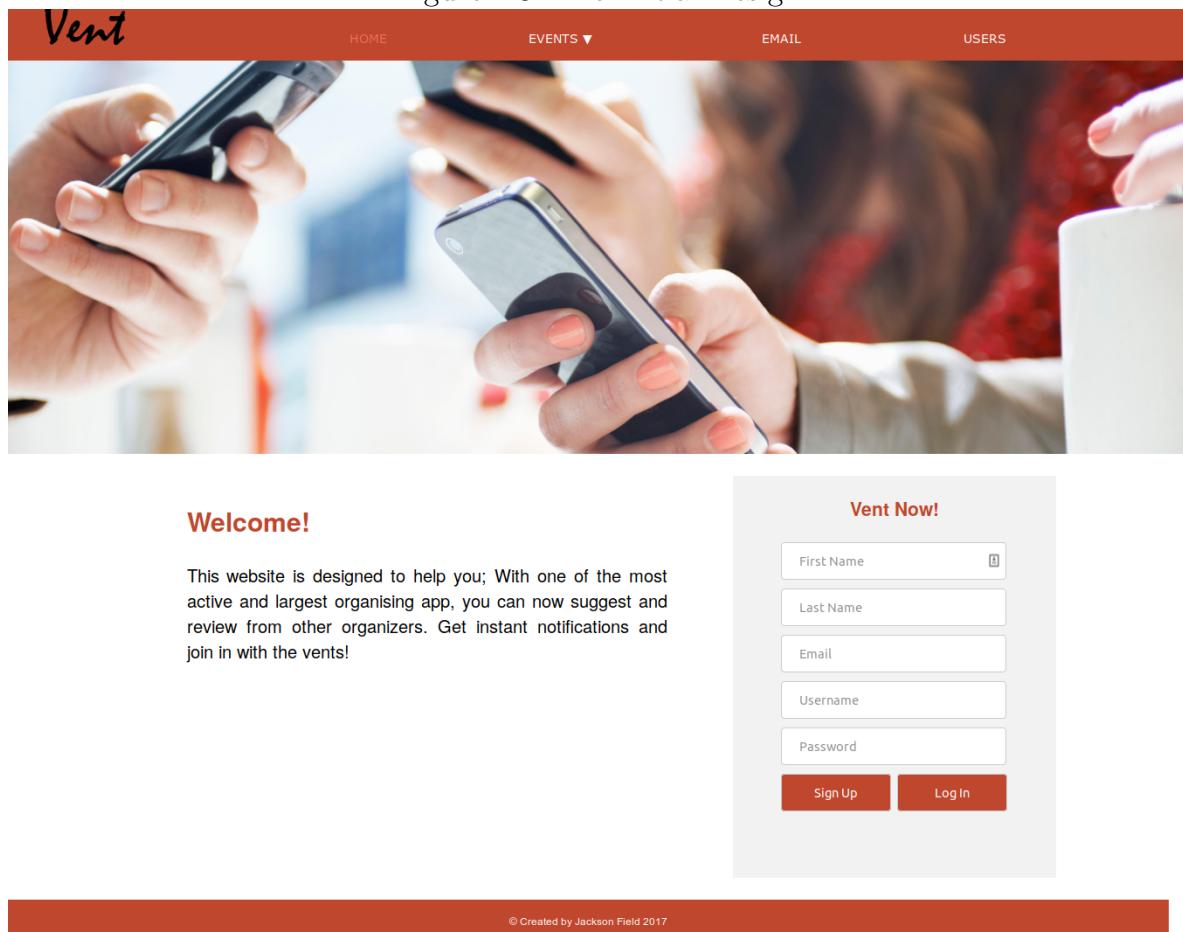
Attempting to replicate this behaviour when testing in a production environment was unsuccessful. As it turns out, this is because it is only an issue in a debugging environment. When flask is in debug mode, it keeps a live debugger open which keeps the connections busy. This means they cannot be recycled, and will be held open. This causes an overflow when the pool eventually tries to open more connections than allowed.

The solution to this, was to raise the connection limit in a development environment. This way it gives the debugger more breathing space to keep connections open.

4.2 Front-End

Designing the front end was more challenging to get right, as the user interface needed to feel friendly, simple and flexible. I started off with drawing up a mock of the home page with my client, so that I could get a feel for the theme.

Figure 4.3: The Initial Design



We decided on an orange theme, with large simple blocks of content. This made it easy

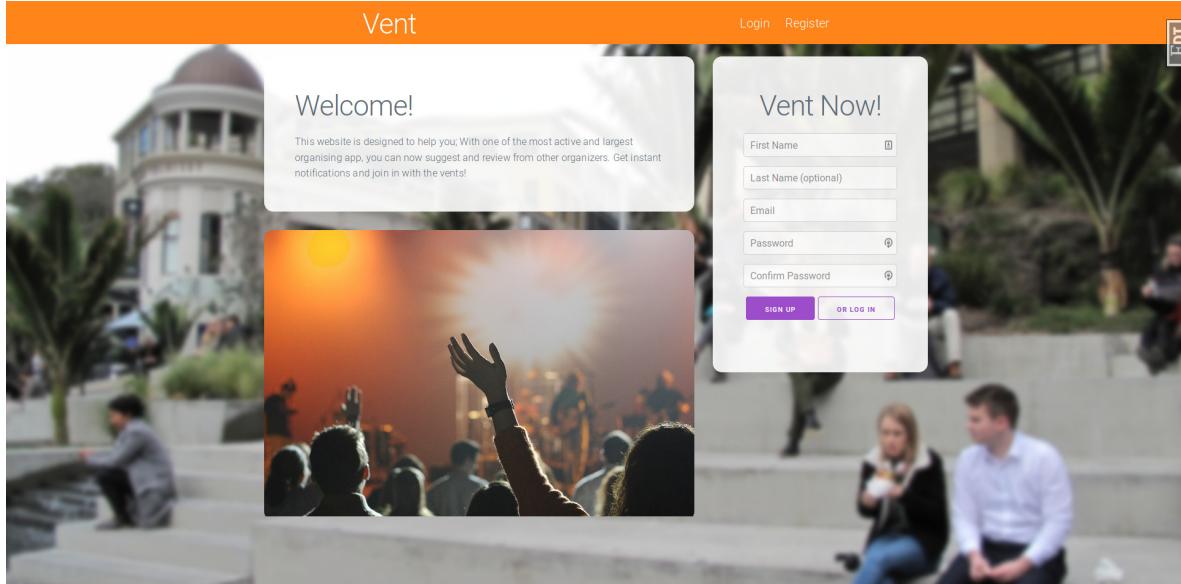
to understand the content quickly, and gave a modern and fresh feel. I decided to use milligram as a minimal css template, as it was small and didn't get in the way, while still noticeably improving the overall look and feel.

It is also important that all of the pages work well with mobile, as it is a requirement that the website works the same on all devices and screen sizes. To ensure this, I implemented responsive design techniques that allowed the content to fit within the screen.

4.2.1 Index Page

After the redesign of the index page, I mostly stuck with the initial design. I brightened the orange, changed the image, and made it feel a bit more modern.

Figure 4.4: Revamped Index Page

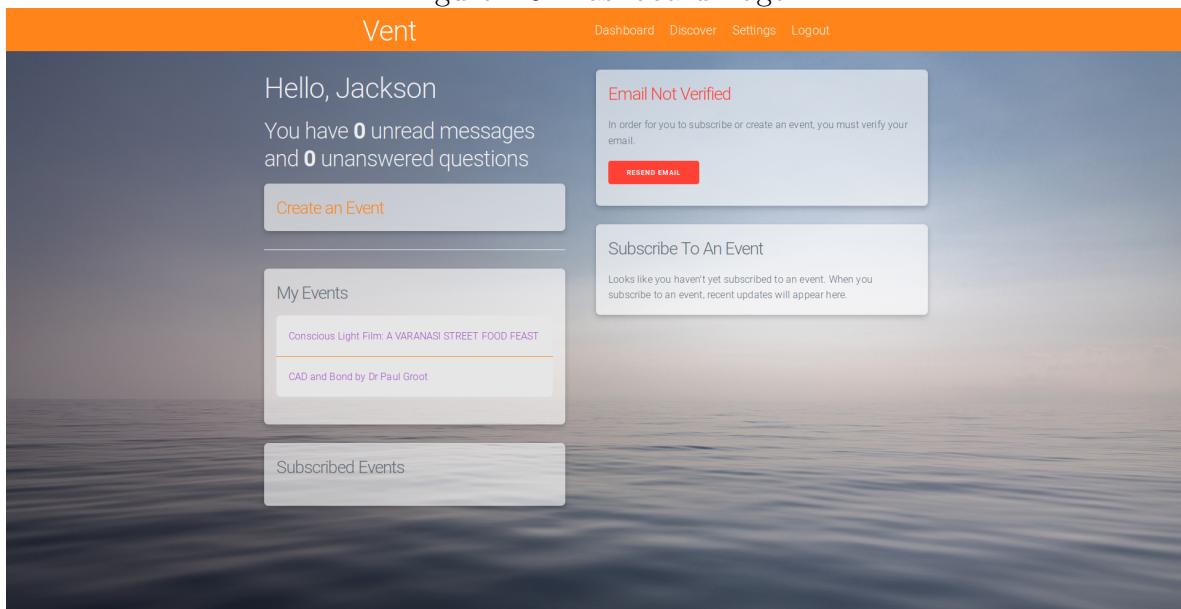


The resulting website is much more inviting with a functioning and responsive register form. In order to improve the user experience when they sign up, the register form first validates locally. If it is valid, the data will be submitted asynchronously to the server side. The data is then validated on the server to ensure the data is still valid. This provides a "fast-fail" experience when filling out the form, which ensures it will warn you if the data is not valid, saving a frustrating page refresh.

4.2.2 Dashboard

This page is the users main page, it gives an overview over all the events they own or follow. It is important that this page is clear and easy to navigate.

Figure 4.5: Dashboard Page



For the dashboard, I opted for a card based approach. The left hand side of the screen gives information about subscribed events and owned events, as well as containing helpful statistics and buttons. The right hand side contains *insights*, which are generated based on various contexts. For example, figure 4.5 shows 2 *warning* insights and 1 *tip* insight. Updates to events will also be shown here. This design is highly customisable for the user, as well as being very flexible.

4.2.3 Discover

I initially designed this page with a category based design, where there would be separate categories that would have a list of events. This was inspired by the google play store design.

Figure 4.6: Initial Discover Page Design

3 Nearby Events

- Private Event
super not fun
[View](#)
- Public Event
also super fun
[View](#)
- My Event
super fun
[View](#)

3 Coming Up

- My Event
super fun
[View](#)
- Public Event
also super fun
[View](#)
- Private Event
super not fun
[View](#)

Upon consulting my clients, I was told that it was hard to use and confusing. The design also didn't scale down to a smaller device well. It was also difficult for the user to look for an event that matches criteria, as they would have no control over the categories that appear. After a redesign, the feedback I received was much more positive.

Figure 4.7: Discover Page Redesigned

Date & Time	Event Name	Distance	Action
WED 24 OCT. 4:30 AM	Organisation Training - CPD Seminar	0.5 Kilometres	SUBSCRIBE VIEW
TUE 13 NOV. 4:22 AM	World Cafe - 30 September 2018	0.7 Kilometres	SUBSCRIBE VIEW
TUE 20 NOV. 10:04 AM	FIT COLLEGE - Wolf & Robotics - Auckland SEP 29	1.3 Kilometres	SUBSCRIBE VIEW
SAT 27 OCT. 2:55 AM	NZBEF Performance - 30 September 2018	1.8 Kilometres	SUBSCRIBE VIEW

Order By

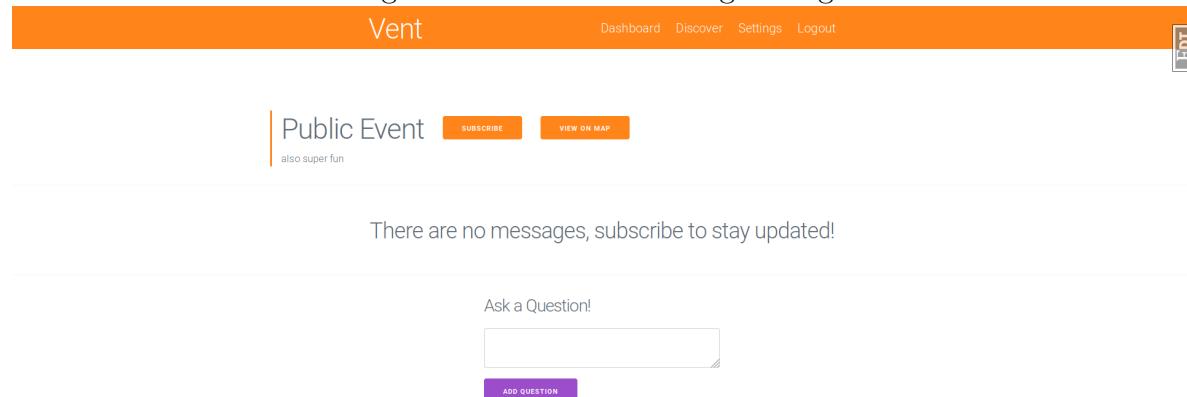
- TIME
- DISTANCE
- NAME
- Distance
 - NEARBY
 - MEDIUM
 - FAR
- ALL

This design was much more user friendly, in the sense that it gave users more refined choices as well as having better presentation of the data. The page uses flexboxes to scale appropriately on smaller screens, while keeping a consistent experience. It also gives users the ability to subscribe to an event without needing to first go to the event page.

4.2.4 Event View

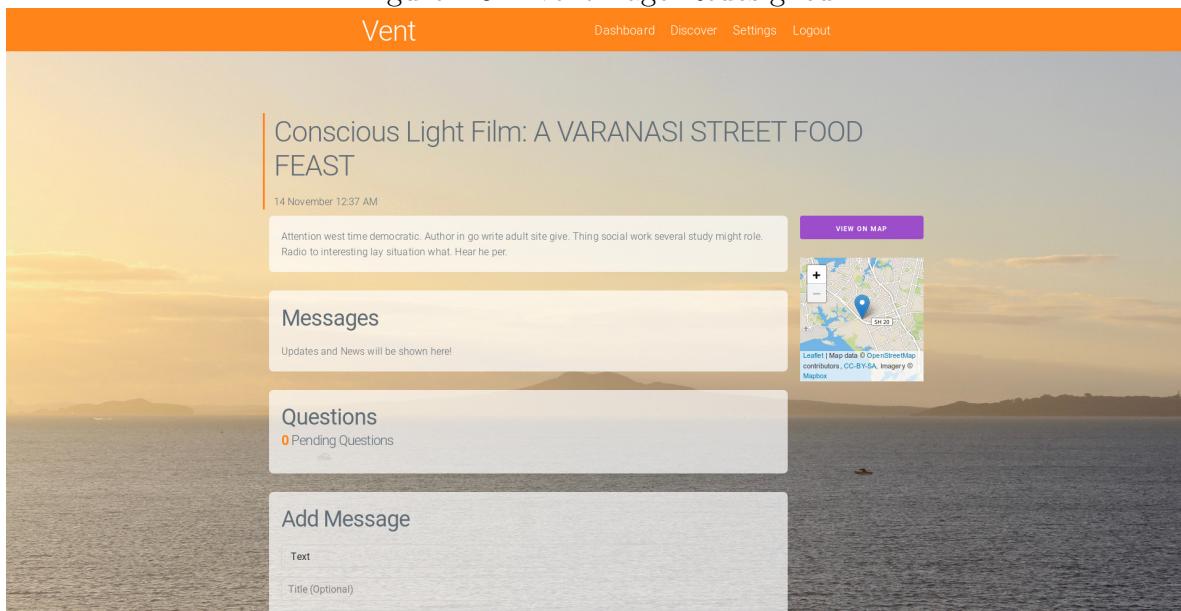
It is imperative that the event details page will give as much information as possible, while still remaining easy to consume. This page is central to the whole app, and thus must be simple to use. My initial design was simple, yet it was not suited to resize to smaller devices.

Figure 4.8: Initial Event Page Design



My redesigned page takes elements from the initial design (such as the header), and uses the card based design I have used throughout the rest of the application. I use the dashboard layout, where there are two columns which contain the information and controls respectively. This design also lent itself to the inclusion of asynchronous http requests, as the grouped cards allow new entries to be included instantly.

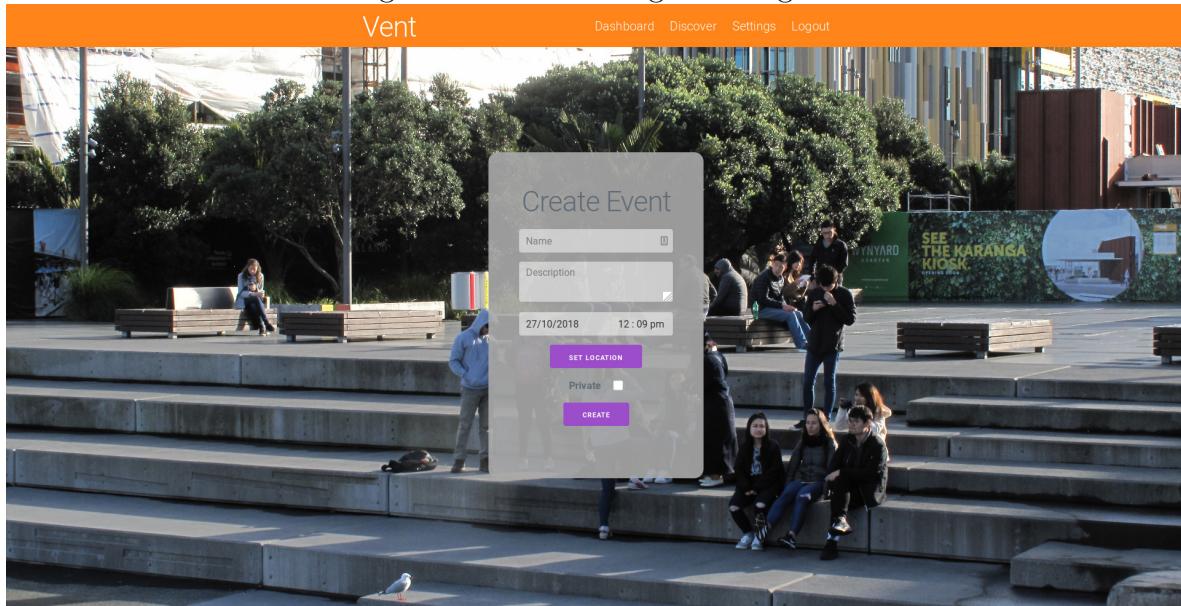
Figure 4.9: Event Page Redesigned



4.2.5 Create Event

For the create event page, I just used a simple form. I used custom datetime components to make it more user friendly entering data. The form follows the same philosophy as the register and login form, where it will verify client-side and fail without waiting for a network request if possible.

Figure 4.10: Event Page Redesigned



5. Hosting & Deployment

To host the application, I chose to use Heroku, from the recommendations of other developers in the flask community. In Heroku, I elected to get the hobby tier, which included automated SSL certificates from LetsEncrypt. Heroku also allowed me to spin up a free Redis and MySQL database.

When generating the tables in my database, the MySQL server kept returning syntax errors, stating that the *Specified key was too long*. After researching the error message, I discovered that on older MySQL servers (≤ 5.6) the maximum key length for a prefix index (e.g. VARCHAR) was 767 bytes. In later versions this was increased to 3072 bytes. To fix this, I simply changed the database to a newer version. Rebuilding the tables on the new database worked perfectly.

When testing in the hosted production environment, I noticed that the database would fail often, with the error: *too many connections*. I discovered that the free plan of the database I was using had a maximum of 10 connections. I attempted to fix this by lowering the connection pool, but this just delayed the errors. I fixed this by renting a virtual machine on digitalocean servers, and configuring it with my own MySQL server. This gave me a cheap, cost-effective server with no imposed limits. After this, it was purely a matter of allowing connections from the heroku IP and configuring the new database URI.

6. Conclusion

I designed this event management application with the intent of it being able to be used for a wide variety of events, not just school balls. The main advantage of this application is to provide event communication, both of the event itself and subsequent information.

The open source, secure nature of this application means that it can be used as a private stand-in replacement for commonly used event management solutions. This means users that avoided apps, such as Facebook, due to privacy issues will now be able to use this application as a secure advertisement free alternative. The online nature and simple user interface means a wider demographic will be able to utilise it.

By designing parts of the application in a modular way (e.g. Message types and notifications), I have made it easy for further features if required.

During the process, I learned a lot about the software development process, including requirements analysis, overcoming design challenges and more. I enjoyed seeing the project evolve from an initial concept to a fully functional application. I am pleased with how it looks and the feedback from users regarding how easy it is to use. I believe it has got the potential to be used widely in the Community.

I am looking forward to refining my software development skills through further projects and tertiary education.