

Initial Document: A Multifunctional Fitness Application & Vertical Jump Height Calculator

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Chapter 1

Introduction

This document will outline the plan for development of a functional codebase for a fitness application. This process, herein referred to as “the project” is different to the application(s) produced as a result. The main difference is that the project is not concerned with the deployment, maintenance and future updates of the fitness application and no additional academic benefit is gained from creating the infrastructure or platform-specific functionality. This is to say that the creation of **both** a mobile and a web application is not needed for the project but makes up a core offering of the product for end users following deployment.

A **mobile** application will be produced during the project, which will have 2 main use cases:

1. A user will be able to pay (via monthly installments or upfront) for a fitness plan; where they can monitor, make notes and track their progress and routine via a calendar.
2. A user can create their own fitness plan by producing their own routine using available exercises on the app - the additional functions such as the calendar remain the same.

1.1 Motivations

The motivation for the project began following an initial consultation with a Californian NBA-level basketball athletic trainer who was looking for a bespoke application to reduce his business expenses. Initially, 4 days of planning and a 40-minute discussion took place before the business decided that the costs associated with building this platform are not a priority for the time being.

In the process of considering the development of said fitness platform, I spoke to developers working with smaller high-level sports trainers regarding the technology used and their clients future plans. At this time fitness influencers Krissy Cela and Jack Bullimore had proven the concept a year earlier with the rollout of “Tone and Sculpt” - grossing over GBP 1 million in the 8 months following its January 2019 release [1]. My initial desire to pursue a project in this space grew more after hearing the story and approach taken by “Tone and Sculpt” on the Diary of a CEO podcast [2].

In the world of athletic sports there is currently no viable, consistent and widely used means of measuring vertical leap besides the Vertec. Prices on these devices can be as high as £500 and cheaper alternatives commonly found at a youth/amateur level - that involve markings on walls - don’t allow for an approach jump (without the risk of hitting the wall). This is being mentioned because a large motivation for the jump calculator functionality is to allow an easy and accessible means of measuring a users vertical leap progress. Naturally, the use of a smartphone for measurement is not completely accurate but will provide sufficient consistency (given the user’s setup) and this can be used to monitor improvement.

From a trainers’ perspective, using PDFs to release fitness plans is cumbersome and involves finding a suitable workflow and rollout. Further to the fact that they’re easily copied and distributed. Existing white-label¹ mobile app solutions to these issues don’t offer much customization beyond simple re-branding; many don’t support video. Following discussion with fitness trainers in various countries (including the USA, UAE and UK) I concluded that this is something that needs to be addressed. Many robo-fitness apps exist for end users, but few include real trainers and even less give freedom to the administrator.

¹A white-label product is a product or service produced by one company that other companies rebrand to make it appear as if they had made it.

1. Introduction

In summary, the motivation for the project is to give a customizable fitness planning solution to those interested in monitoring their training. This solution should be usable by administrators (trainers/teams), average “gym go-ers” and highly trained athletes alike. The global fitness app market size was valued at USD 4.4 billion in 2020 and is expected to expand at a compound annual growth rate (CAGR) of 21.6% from 2021 to 2028 [3]. We can see that the total addressable market is huge and set to grow quickly, if this is any indicator of the volume of potential users looking for a fitness solution then the proposed project should prove tremendously useful at solving the aforementioned problems.

1.2 Overview & Aims

The projects aims include the following - some of these aims will be broken down into succinct functional and non-functional requirements in Section 3.2:

- The ability for a user to plan their workouts on a calendar.
- The ability for a user to track the progress of a workout.
- The ability for a user to measure their vertical leap using their phone.
- Allow users to keep track of their progress in relevant areas such as weight, strength measurements etc. more efficiently than traditional methods.
- Allow trainers to comfortably deliver fitness plans to clients without a steep technical learning curve.

The core overview of the project is that we're looking to develop a mobile application that allows a user to register an account before having the ability to follow/create a fitness plan and provide relevant tools for consistency and the successful reach of a users goals (irrespective of their background). The project aims to focus on the end user² however considerations will be made for the complete implementation of an administrator role (time permitting).

The project is concerned with the ability to solve both parties problems through the development of the application, but the primary focus is on the development of the core functionality and the vertical jump calculator. From a business perspective we can consider the jump calculator the unique selling point of *the product* and a complex component of *the project*.

²The user training using the app

Chapter 2

Project Research

We've previously seen that "Tone & Sculpt" is an existing similar application on the market. Below we'll consider other background research on existing systems and their functionality.

The bulk of fitness mobile applications fall into 2 categories:

1. Applications which allow fitness enthusiasts to monitor their training and nutrition - the market leaders in this space (by monthly active users) are "Fitbit" and "My Fitness Pal" (as of March 2018) [4].
2. Applications which allow trainers to facilitate the delivery of programmes either by partnering with the development company or white-labelling software. These are apps focused on trainers more than end users - the most notable player in this emerging market would be "TrueCoach", who raised USD 2.6 million in seed round funding before being acquired by TSG (Transaction Services Group) in April 2020 [5]. Estimated revenue over USD 1.2 million (from 20k users) for 2021 [6].

We can see the main difference in these groups are that the focus of the former is B2C (business-to-consumer) services whereas the latter focus on B2B (business-to-business; often acting as SaaS companies). This is an important distinction as *the project* is looking to combine elements of both and so the following research will reflect this.

We'll also look at vertical jump calculators and the mathematics involved in developing something of that nature.

2.1 Existing fitness application systems

We'll look at 4 systems, 2 from each of the aforementioned application groups. Here it is worth mentioning that some apps are on the borderline such as "Centr by Chris Hemsworth". The app follows a B2C approach but is marketed and part-owned by Chris Hemsworth, with his trainers being the facilitators of programmes and nutrition plans. A similar approach to the aforementioned "female-focused Tone & Sculpt". Because cases like these are not relevant to the application being built for the project, we will not look in any depth at these.

For each of these systems we'll be looking at:

- A typical user story for the given application.
- A high-level breakdown of the system(s) functionality.
- A look at the technology in use (where possible).

We'll then compare the applications (in pairs) to see any unique features and to understand which functions are seemingly core to a positive user experience in the fitness application space.

2.1.1 MyFitnessPal

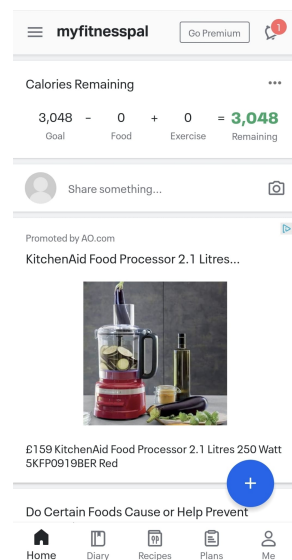


Figure 2.1: Homepage feed

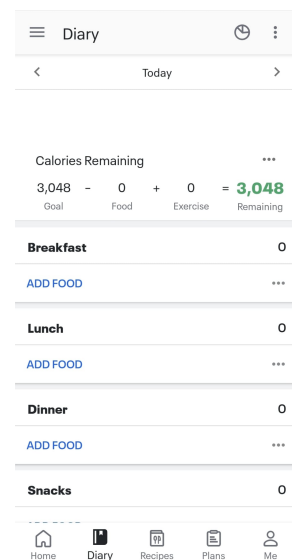


Figure 2.2: Food diary & calorie counter

User Story

“As a fitness enthusiast, I sign up to the app via email. I wake up every day and log my breakfast by scanning barcodes for my food. This is accounted for in my daily food tracking (Fig. 2.2). After breakfast I create a new workout based on advice from my community or homepage, I search for the exercises involved and log my workout later on in the day (Fig. 2.3).”

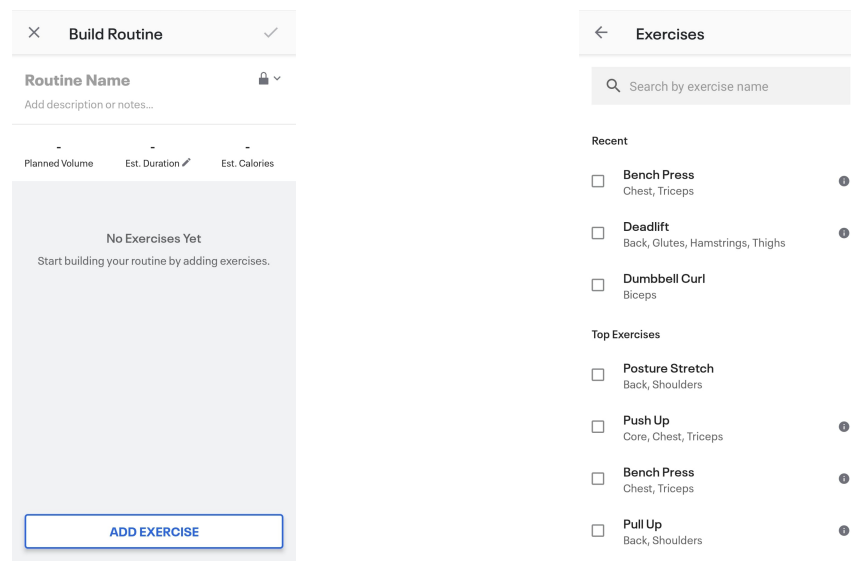


Figure 2.3: The custom workout routines in MFP

Features/Functionality

MyFitnessPal includes all of the following features:

- Estimate calories burned given a set of exercises/a routine.
- Track food intake via barcode scan or recipe input.
- Track water.
- Workout plans provided by MFP.
- Track weight.
- Create custom workout plans from existing exercises.
 - Exercises don't include video/images and no ability to add custom exercises.
 - These can be shared publically to dashboard.
- Count steps (using compatible devices).

2. Project Research

- Add friends and send/receive messages.
- Community tab (requires separate signup).
- Export progress as CSV.
- Meal and weight tracking reminders (via push notifications).
- Set workout/week, minutes/workout and “calories burned” goals.
- Discover recipes/meal plans via community and MFP suggestions.

Technology Stack

MyFitnessPal uses the following technologies according to Stackshare [7]:

- React (a JavaScript framework for creating cross-platform applications)
- Cloudflare (for web infrastructure)
- NginX (for server side use)
- Vanilla JavaScript and CSS + libraries (jQuery, Bootstrap)

Various other technologies are being used on the server-side but for *the project* we are primarily concerned with the technology used for the application as opposed to the backend infrastructure.

2.1.2 Fitbit

Fitbit is the app that accompanies many of the Fitbit brands’ hardware products, their first movers advantage was likely a large contributor towards their large market share (in 2018)¹ in the application space. The functionality of their hardware products (which had been the standard for fitness tracking wearables) is enhanced through use of the app. The research will consider the application alone and disregard any wearable-specific functionality.

¹Q3 2020 wearables market share = 2.6%[8]

2. Project Research

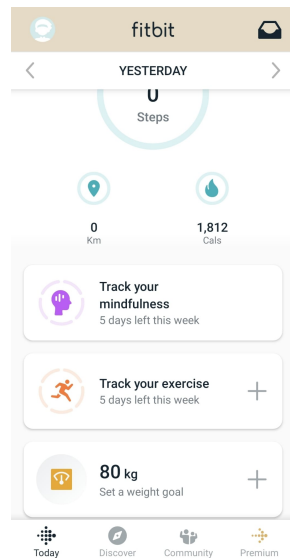


Figure 2.4: Dashboard

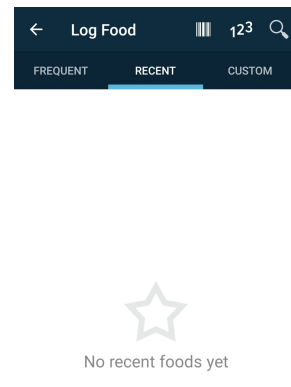


Figure 2.5: Food log screen & features

User Story

“As a professional athlete I wake up, go through guided meditation on my Fitbit calendar before weighing myself (Fig. 2.4). I then log my breakfast and eat (Fig. 2.5), followed by my commute to practice and logging my sport and duration (Fig. 2.6).”

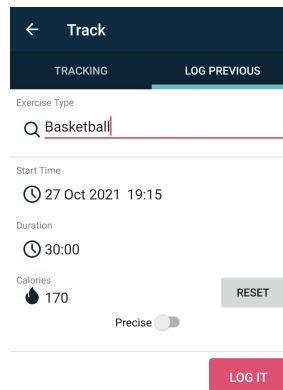


Figure 2.6: Using exercise search & log

Features/Functionality

Fitbit includes all of the following features:

- Guided meditation (w/ simple week-calendar scheduling).
- Guided video workout plans (w/ simple week-calendar scheduling).
- Guided programmes (for meeting targets in health, not just fitness).
- Challenges (1-10 people, gamifying targets).
- Water tracking.
- Food tracking.
- Track exercise (only by sport/activity, no custom option and no individual exercises/routines).
- Step counter.
- Community feed and groups.
- Add friends and send/receive messages.

Technology Stack

Fitbit uses the following technologies according to Stackshare [9]:

- JavaScript(and Ember.js) for the front end.
- Fastly (for cloud content delivery)
- Redis (for middle layer and database caching)
- Node.js (for producing backend APIs)
- Java (and Spring) for the non-mobile applications
- MySQL (for the backend database(s))

Fitbit is cross-platform and multifunctional, thus there will be some technologies not in use by the mobile app we are researching. It's unlikely Spring is in use, but the use of JavaScript (w/ Node.js) for the front and backend is common in current world of software. It's highly likely the whole system is using a microservice architecture where components maybe used in several places.

2.1.3 Comparing MyFitnessPal and Fitbit

Firstly, we'll note that both applications make use of JavaScript for their front-end technologies. It's difficult to pinpoint what is being used without decompiling both applications (both of which have a huge codebase). It is apparent that MFP is using React². Both apps are also using some form of CDN to speed up content delivery, which is needed given the abundance of data involved in the tracking of food and exercise. MFP offers developers access to their data set via their own API [?].

Whilst both apps calculate calories burned (an arguably useless metric for *our project*) during exercise. The scope and functionality of exercise is vastly different. Fitbit includes general sports and activities but no specific exercises (for example - "weights" is considered 1 exercise type and the calories burned are dependent on duration) and there is no ability to produce your own routine. On the other hand, MFP allows for the creation (and sharing) of your own routines using their database of exercises. There are no videos to follow for this component of the app. Both apps do however offer workout routines (and short-term programmes) via short videos published by the respective companies.

Both apps allow for the tracking of food and water intake, as well as the ability to scan product barcodes to log nutritional information. In regard to overall wellness, Fitbit seems to be covering more "bases" by providing guided meditation videos and challenges which can be taken alone or as a group. These challenges are a way to gamify the achievement of personal goals (such as using your phone less).

Finally, both apps include community features - very similar to traditional social media platforms. These and other nutrition focused features are beyond the desired scope of *our project* thus we won't be comparing and considering these.

Internal link to requirements

Overall, the fitness aspect of MFP seems more useful, but there are elements of the app which are not yet on par with Fitbit - such as the goal setting and mindfulness measurements. That said, the UX/UI of MFP is more usable and the app has fewer features locked behind hardware devices (yet you can still pair compatible devices to MFP). Neither app has any major feature involving the camera besides the barcode scanning components. A combination of elements from both apps will be paramount to a successful project.

²an open-source UI software framework created by Meta, Inc (formerly Facebook)

2. *Project Research*

reference prelim
work

The project is planned to have a side panel menu and similar minimal aesthetic to that of MFP. It's not planned that it will include the calories burned estimates; however other metrics will be included in similar vain, such as total time trained and cumulative weight lifted/cumulative distance travelled. Calorie estimates will be an enhancement (additional feature) where time permits. The abilities to create custom routines and follow preset routines that are featured in MFP and Fitbit respectively, are expected to be important features in *the project*. Albeit, the long term plan for things includes the ability for trainers to set these programmes as opposed to presets alone.

In summary, the design and layout of these apps is what's useful for us - inspiration and additional features can also be drawn from these existing systems. With that said, *our product* is not a nutrition tracker and focusing on elements in this space would shift the scope of the *project* substantially. An extensive breakdown of the feature set can be found in Chapter 3.

reference feature
set

2. Project Research

2.1.4 TrueCoach

TrueCoach provide a cross-platform system that includes a web application. We'll be considering the mobile app provided for end users and making reference to the functions available to administrators in the process. They provide a mobile app for each of these use cases - "TrueCoach for Clients" and "TrueCoach Connect" for trainers.

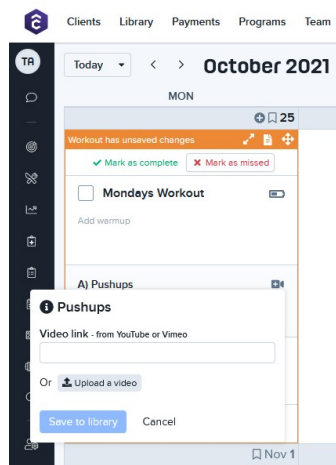


Figure 2.7: Trainer using web app to set clients workout(s).

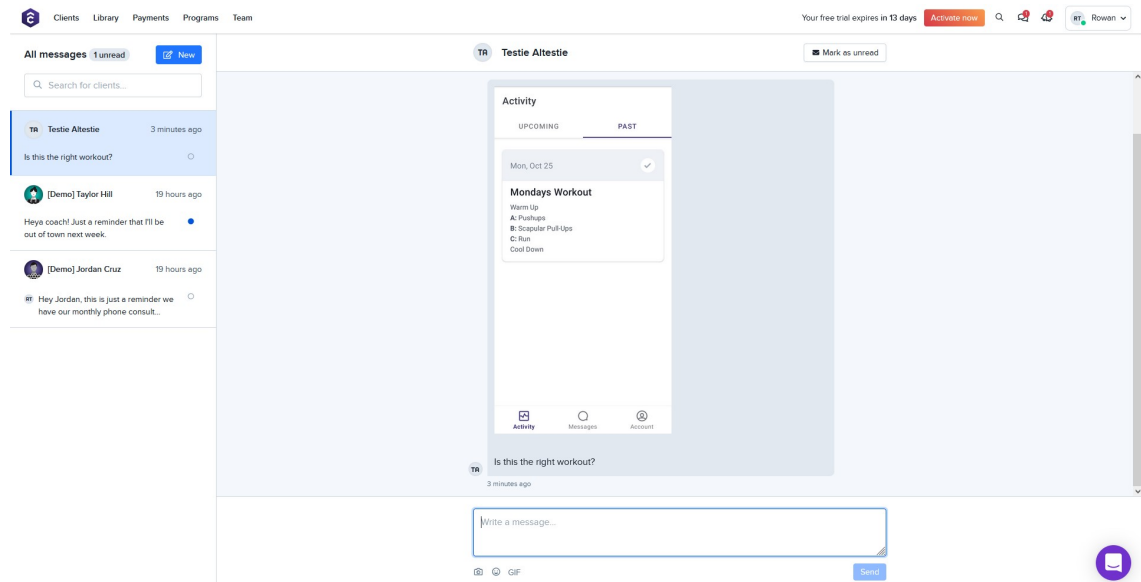


Figure 2.8: Trainer using web chat to manage clients.

User Story

“As a new gym go-er, I work remotely with my trainer (Figs. 2.8 and 2.10) to refine my training technique(s). I view my upcoming workouts (Fig. 2.9) and follow instructional videos before marking my workouts as complete and monitoring my progress via goals & challenges (Fig. 2.11). For advice I can view documents and progress photos in my settings page (Fig. 2.12).”

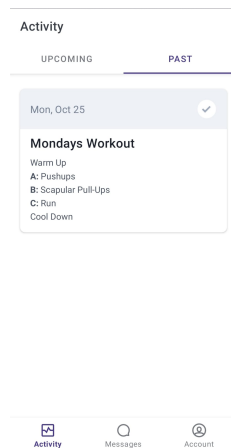


Figure 2.9: Viewing workouts (upcoming/past).

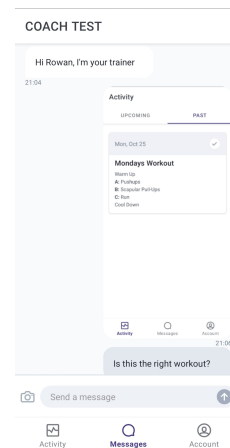


Figure 2.10: Instant messaging with a trainer.

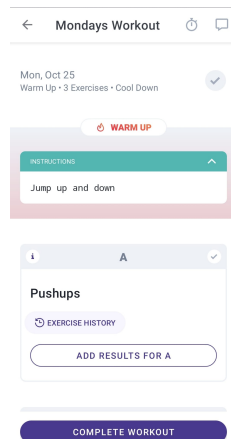


Figure 2.11: Logging a workout.

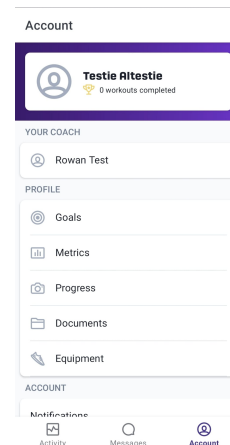


Figure 2.12: Viewing settings.

Above, “Testie Altestie” represents an end user and “Rowan Test” is the trainer. We can see the functions available to the user are dependent on the workouts uploaded/scheduled by the trainer using their interface (web application in this case).

Features/Functionality

“TrueCoach for Clients” includes all of the following features:

- Track coach’s release of phased training (upcoming/past workouts).
- Log workouts (w/ notes).
- Timer & stopwatch function for tracking timed exercises.
- Video breakdowns of exercises (w/ rich text instructions).
- Instant messaging w/ trainer (including multimedia uploads).
- Tracking of progress via trainer-set goals & metrics.
- Progress and additional documents (outbound link to web app).
- Create account via invite link from trainer.
- View notifications.
- Edit settings (outbound link to web app).

TrueCoach covers a lot of needs for a user, and we can see in Fig. 2.8 the relevant tools for the trainer to facilitate these workouts. They are administrators of their clients and they’re the means by which a user gets login credentials. Trainers can upload relevant videos (Fig. 2.7) and documents, as well as provide metrics to measure users progress.

Technology Stack

Stackshare (as used for the previous apps) is not useful in this case, so the following conclusions have been drawn following the decompilation of the TrueCoach APK [10]:

- Kotlin & Java (for Android development)
- Firebase (for push notifications and messaging)
- AWS Amplify (for backend deployment)
- Numerous open-source development packages such as glide.

After decompiling and opening the class files using dex2jar and JD-GUI, I found that the application is not using a cross-platform JavaScript framework as is standard in modern times. The app is using the recommended native language of Kotlin³ and Java for all data objects and frontend display.

³Learn more: android development documentation

2. Project Research

2.1.5 Exercise.com

Exercise.com are the company providing the white-labelled solution behind PJFPerformance. We'll be using the **PJFPerformance** app to analyse their application.

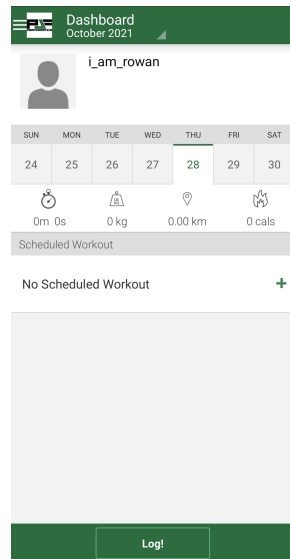


Figure 2.13: Home dashboard

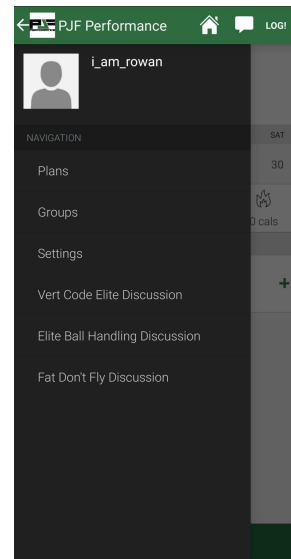


Figure 2.14: Sidebar menu options

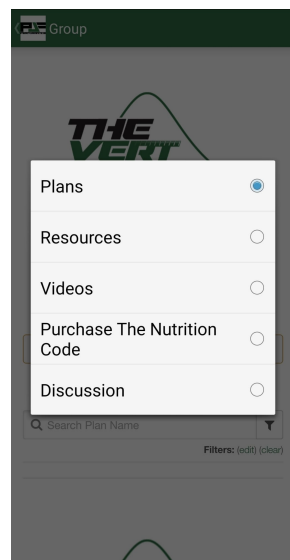


Figure 2.15: Viewing additional resources.

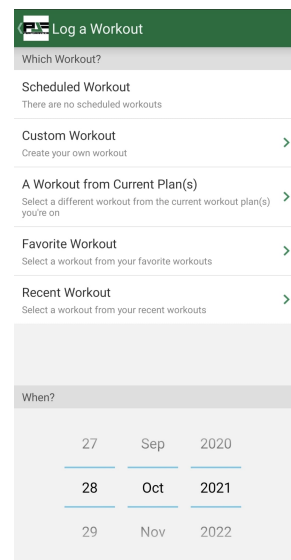


Figure 2.16: Scheduling/logging a workout.

User Story

“As a basketball player, I enroll to Paul Fabritz’ workout plan using the web application before receiving credentials for the mobile app. Here I schedule the programme to begin at the start of the month and I allocate days of the week for my workouts (Fig. 2.13). I create my profile containing my weight and other metrics, so I can ask relevant questions to Paul and others on the same programme as me via a discussion room (Fig. 2.14). For guidance on training during the season and managing load, there is a resources section (Fig. 2.15) (outbound links). I log all my workouts and make notes for my own use. I sometimes create workouts for myself (Fig. 2.16) using some exercises available through the app. Whenever I train, I can see exercises explained via videos embedded from YouTube.”

Features/Functionality

The PJFPerformance app includes all of the following features:

- Schedule workouts.
- Create custom workouts (using existing exercises).
- Log workouts (w/ notes).
- Enroll on phased programmes (made up of multiple workouts split over a given number of weeks & days).
- Edit profile.
- View settings.
- View notifications.
- Rest timer for timed sets in workouts.
- Videos (YouTube hosted) for exercises.
- Group discussions for programmes.
- View additional resources (hosted externally).

Exercise.com work on a 1-to-1 basis with trainers and white-label their solutions, this means any administrator view can only be presumed via the decompilation of the APK app file.

Technology Stack

Similarly to TrueCoach, finding the technology used by Exercise.com for the mobile application is only possible via decompilation using existing tools [10]. Based on my look into the source code, we can safely conclude that the app uses:

- Kotlin & Java (for Android development)
- Firebase (for push notifications and messaging)

- Amazon S3 (for data storage)
 - They expose data from the S3 instance via their web application API. This is where the mobile application is pulling data from.
 - The S3 instance is using some form of SQL database (we know this based on SQL migration scripts in the source code).
- Numerous open-source development packages such as FastJson.

Similarly to TrueCoach this app is written using Kotlin and not a cross-platform JavaScript framework. The MaterialDesign⁴ influence is noticeable in this app and so it is less surprising. Performance to the User feels somewhere between average and slow for this type of app.

2.1.6 Comparing TrueCoach and PJFPerformance (Exercise.com)

TrueCoach has a larger focus on the client-trainer relationship and is more suited to the public (anybody can become an administrator and begin using their platform for their business). On the other hand, PJF provides a greater reliance on the community of people following the same programme as the User. Our project aims to blend both of these concepts; the core functionality will be developed first (focusing on the end user) before producing administrator views and allowing a many-to-many relationship between clients and trainers.

From a technical standpoint the implementation of the applications are similar (both using Kotlin and Java, with some use of open-source packages for specific needs - such as confetti in TrueCoach when completing a challenge). Both apps also make use of Firebase messaging for push notifications. This is easily implemented and simplifies the implementation of push notifications across platforms (Android/iOS). This is noteworthy for the development of our project and will prove useful if Firebase is used instead of or alongside the technologies outlined in Chapter 3. Our application frontend will be built using Flutter. The reasoning for this will be outlined further in the document, but performance is not expected to be adversely affected. Whilst the technology will be different the functionality and user experience aims to be similar to that of both apps.

⁴a design language invented by Google (Android parent company) in 2014.

TrueCoach has a simple 3 screens - logging and monitoring workouts (Fig. 2.11) has a much better UX/UI. The ability for a trainer to add new exercises and accompanying video (both via embeds or uploading raw video) is unique (Fig. 2.7). These are features that are greatly beneficial to our project and reducing the number of app screens and keeping the interface minimal will both provide a much better final product and ease the time stress of development and testing. Only in the PJJ app can a user create their own workout and log this (Fig. 2.16). This ability is core to our app. On the other hand, the TrueCoach app is entirely dependent on a trainer/administrator supporting you throughout your programme. Furthermore, TrueCoach allows for the measurement of set metrics (by the trainer) and goals to surpass. The PJJ app lacks these features but does allow for further planning in the form of a calendar view and a “traffic-light system” for workouts on a daily basis. A red circle appears under missed workouts on the calendar, amber for pending workouts for the day and green workouts for completed workouts. TrueCoach has personal goals but no extensive calendar view and there is a simple “mark as completed” feature for scheduled workouts. Both of these elements are planned to be included on our project; looking at the preliminary prototype and feature set should provide more clarity on how this will be achieved.

reference
prototype

reference feature
set

The final difference I consider notable between the apps is the use of timers. TrueCoach makes use of both a stopwatch and a timer for users to utilise during exercises. Alternatively, PJJ includes a rest timer which Paul suggests to use for other functions but no stopwatch if needed (for example, when training for speed). We plan on following TrueCoach’s example here and allowing users the option of both. Implementation is relatively easy and should enhance user experience.

Many of the differences outlined above come down to the business objectives of the relative applications. TrueCoach is building a SaaS company whereas Exercise.com is building a fitness application product that they can white-label to notable trainers in the fitness industry. This core difference means there are certain design decisions that differ between the apps. A common and core feature with both is the ability for users to view videos of exercises during workouts and to log their progress as they exercise. This is important to the success of *the product* and the approach we are looking at following involves a dashboard upon registration where a trainer can include their branding and thereby personalise the end user experience - similar to Stripe (Fig. 2.17).

2. Project Research

This functionality falls beyond the scope of the outlined *project* but will help you form a long-term understanding of the proposed system.

There are many small differences both in the technologies used (such as AWS Amplify vs S3 storage and a self-hosted API) and in the feature sets. Ultimately, elements of both applications should be used in *the project* in order to produce a market-suitable *product*.

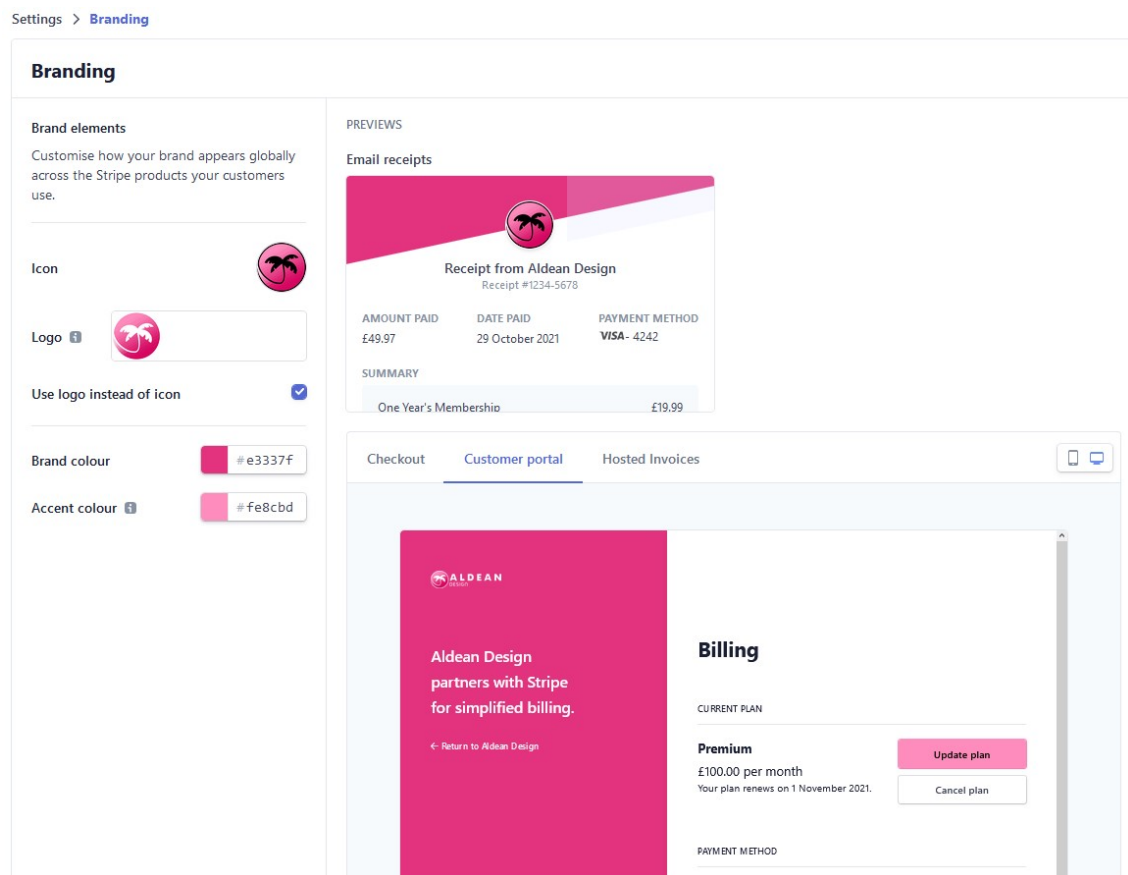


Figure 2.17: Customizing Stripe products using personal branding.

2.2 Existing vertical jump calculators

There are few *modern* jump calculators on the market right now. None are combined with existing fitness platforms - our research shows all of them being standalone mobile or web applications (2.2.2 to 2.2.4).

There are multiple methods of measuring jump height, often this is important to athletes where success is caused/correlated with jump ability i.e. Sprinting [11], American football, Basketball, Volleyball. We also know vertical jump is an important test to assess the explosive strength of the leg musculature of athletes [12, 13]. We'll be using the time-in-air (TIA) to estimate jump height. Whilst this is inevitably not perfectly accurate, when using a force plate ⁵ it is no worse than other methods (in terms of consistency) [14]. Thereby still proving useful to the target demographic.

To summarise, the vertical jump calculator created for the project is intended for use as a measurement of progress and not a concrete result. There will be some deviation from other measurements (such as using a Vertec).

⁵A measuring instrument that measures the ground reaction forces generated by somebody.

2.2.1 Maths behind calculating vertical jump using video

Below we'll be considering the physics [15] involved in finding vertical jump height using **only smartphone video footage**.

To explain the forces demonstrated in a countermovement jump (CMJ)⁶ we'll be considering the 5 phases of action involved (Fig. 2.18).

Figure 2.18: Motion phase of countermovement jump (CMJ). 1: Rest. Before jump.
2: Countermovement. 3: Push to ground.
4: Jump. Fly. 1*: Rest. Land.
Vertical position of torso is y position [16].

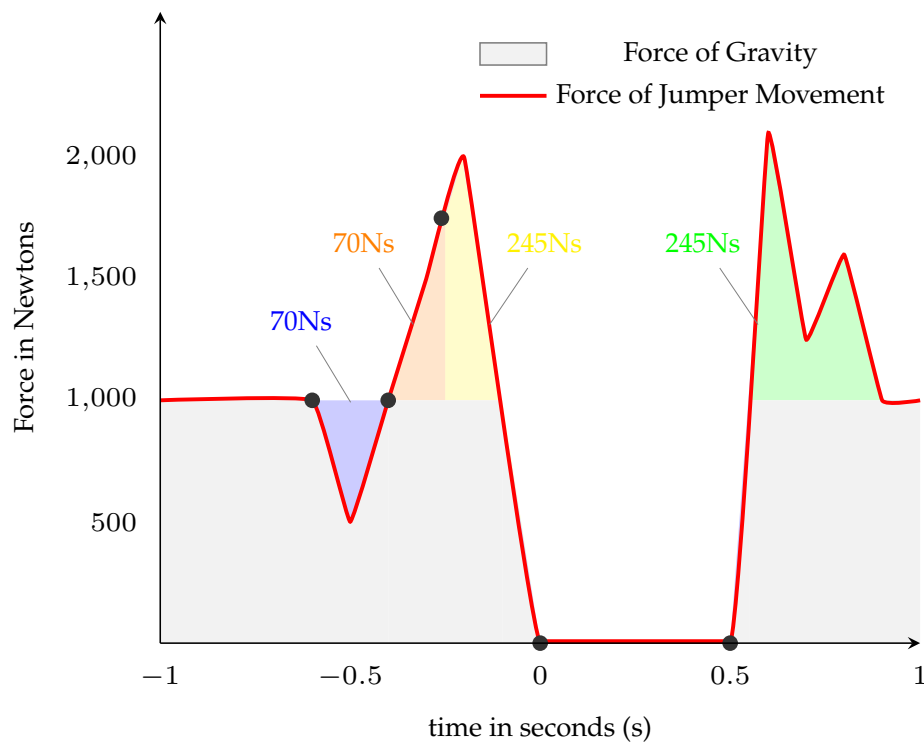
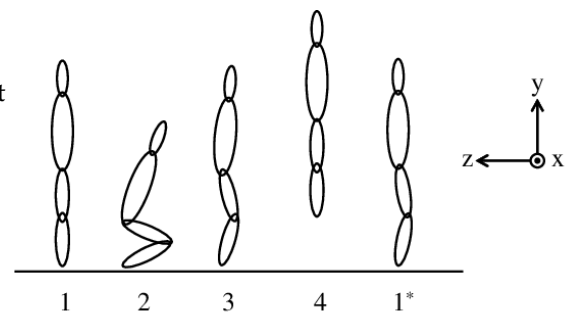


Figure 2.19: Ground reaction forces during vertical jump.

⁶A vertical jump test performed by having an athlete quickly squat to a self-selected depth and then jump as high as possible.

We'll be using the above, simplified force plate analysis (Fig. 2.19), to delve further into the phases of a jump and the mathematics. In reality the force curve wouldn't be so smooth but this should demonstrate the phases quite clearly.

Phase 1: Rest (Pre-jump)

Before jumping we can see a flat line at 981 Newton (Fig. 2.19). The athlete isn't jumping, but this is gravity doing its work. It's easily explained as $F = m * g$, where m is the mass of the athlete and g is the acceleration of earth's gravity. F is the force needed to counter the effects of gravity. We know that $g = 9.81m/s^2$ on earth, thus:

$$\begin{aligned} 981N &= m * 9.81m/s^2 \\ \Rightarrow m &= \frac{981N}{9.81m/s^2} = 100kg \end{aligned}$$

Here you can see that the force plate is basically acting as a weighing scale, showing the force gravity exerts on the athlete.

Phase 2: Countermovement

As seen in Fig. 2.18, the countermovement involves the bending of the knees and typically swinging of the arms to lower the center of gravity before the jump. The force plate (Fig. 2.19) is registering forces lower than 981N, which means the athlete is accelerating in a downward movement.

Recall Newton's 3rd Law of motion; which states whenever two objects interact, they exert equal and opposite forces on each other. Knowing the above, we can define Ground Reaction Force (GRF) as "the force exerted by the ground on a body in contact with it". We can describe the forces acting at this time as follows:

$$F_{Jumper} = F_{GRF} - F_{Gravity} \leq 0$$

We can also use the analysis (Fig. 2.19) to find the speed the athlete is moving at before the jump. We know that $F = ma$ (mass * acceleration), and force is happening over time. Thus, $Ft = mat$. We also know force isn't a constant, it's a function of time and that we can define velocity as $v = at$; so our formula is:

$$\int_{t_1}^{t_2} F_{Jumper}(t)dt = mv$$

where $F_{Jumper}(t)$ is the difference between the GRF and gravity. The integral can be

calculated from the force plate data. The downward impulse⁷ made by the athlete is shown in the graph (Fig. 2.19) as the blue area below the line representing gravity.

We've assumed the integral (impulse) is $-70Ns$ ⁸. With this, we can conclude that:

$$\begin{aligned}\int_{t_1}^{t_2} F(t)dt &= mv \\ \Rightarrow -70Ns &= 100kg * v \\ \Rightarrow v &= -70Ns/100kg = -0.7m/s\end{aligned}$$

Therefore, our athlete reaches a peak velocity of $-0.7m/s$ during the countermovement phase.

Phase 2.5: Deceleration

Now we've seen where GRFs are lower than expected due to gravity - we must look for the period where our athlete has to decelerate the downward movement (pause) before launching up (Fig. 2.18). This should be an equally big impulse to that found above but in the opposite direction. We can describe this as:

$$\int_{t_2}^{t_3} F_{Jumper}(t)dt = 70Ns$$

Because we know $F(t)$ and t_2 , the algorithm of the force plate analysis now looks for t_3 so the impulse equals $70Ns$.

On our graph (Fig. 2.19) we have pictured this - we are looking for the blue and orange areas to be the same size.

Phase 3: Push to ground

The athlete then generates force in preparation for takeoff before the GRFs register as 0 (when they are in flight). They reach some of the peak forces seen. To assess the velocity during takeoff we use the same technique as Phase 2:

$$\int_{t_3}^{t_4} F_{Jumper}(t)dt = mv$$

Pictured in our graph (Fig. 2.19) as the yellow area.

⁷Impulse is the integral of a force.

⁸Newton seconds are the units of impulse.

2. Project Research

The force plate graph detects 245Ns, so we can determine initial velocity as follows:

$$\begin{aligned}245Ns &= 100kg * v \\ \Rightarrow v &= 245Ns/100kg = 2.45m/s\end{aligned}$$

Phase 4: Jump. Flight! Here the athlete can't control their velocity any longer; their jump height is determined by the speed built before and during takeoff. Only gravity is acting on them, bringing them back to the ground.

We've determined initial velocity was $v(0) = 2.45m/s$ and the gravity of earth has an acceleration of $a = 9.81m/s^2$. Plus, the peak of the jump must have a vertical velocity of zero: $v(t_{peak}) = 0$.

Using the initial velocity and earths gravity we can find velocity at any given time using:

$$v(t) = v(0) - a * t$$

Thus we can find the velocity at the peak of the jump using:

$$\begin{aligned}v(t_{peak}) &= v(0) - a * t_{peak} \\ \Rightarrow 0 &= v(0) - a * t_{peak} \\ \Rightarrow t_{peak} &= \frac{v(0)}{a} = \frac{2.45m/s}{9.81m/s^2} = 0.25s\end{aligned}$$

With the knowledge of $v(t)$ during every moment and knowing the peak of the jump was 0.25s, we can calculate the jump height as the integral of velocity over the time it takes to reach the peak of the jump:

$$\begin{aligned}h_{jump} &= \int_0^{\frac{v(0)}{a}} (v(0) - at) dt = \\ &= v(0)t - \frac{1}{2}at^2 \Big|_0^{\frac{v(0)}{a}} \\ &= v(0) \left(\frac{v(0)}{a} \right) - \frac{1}{2}a \left(\frac{v(0)}{a} \right)^2 \\ &= \frac{v(0)^2}{a} - \frac{1}{2} \frac{v(0)^2}{a} \\ \Rightarrow h_{jump} &= \frac{1}{2} \frac{v(0)^2}{a}\end{aligned}$$

This leaves us with a simple formula for finding jump height *when we know the initial velocity*. For our force plate analysis (Fig. 2.19) we get

$$h_{jump} = \frac{1}{2} \frac{(2.45m/s)^2}{9.81m/s^2} = 0.306m$$

2. Project Research

Because we only need the initial velocity of an athlete to satisfy our formula, we don't have to rely on a force plate and expensive equipment. We simply have to find the initial velocity for a jump that takes 0.5s.

If someone jumps 0.5m high, they must also fall 0.5m after they peak. We have established velocity is a linear function ($v = at$), thus we can demonstrate the athletes peak is at the exact middle of the jump. Formally:

$$t_{peak} = 0.5 * t_{hangtime}$$

Thus to find the jump height of someone who jumps for 0.5s, we can calculate the distance of free fall in 0.25s!

$$\begin{aligned} S &= \int_0^{\frac{1}{2}t_{hangtime}} v(t) dt \\ &= \int_0^{\frac{1}{2}t_{hangtime}} a * t dt \\ &= \frac{1}{2}at^2 \Big|_0^{\frac{1}{2}t_{hangtime}} \\ &= \frac{1}{2}a \left(\frac{1}{2}t_{hangtime} \right)^2 \\ &= \frac{1}{8}a t_{hangtime}^2 \end{aligned}$$

In the case of a 0.5s hangtime, this gives us (as before with the force plate data):

$$S = \frac{1}{8}a t_{hangtime}^2 = \frac{1}{8} * 9.81m/s^2 * 0.5^2 = 0.306m$$

This formula is the crucial component to developing this feature. We won't be looking at the physics of "the landing" in this document as it is not directly relevant. However it is worth noting that to counteract the forces created during impact, the athlete braces themselves and absorbs force - this is notable as the green area in the graph has a value of 245Ns exactly like the yellow area.

2.2.2 FitnessMeter - Test & Measure

FitnessMeter is an iOS (Apple) exclusive mobile app, used for “fitness testing and athletic performance evaluation” [17].

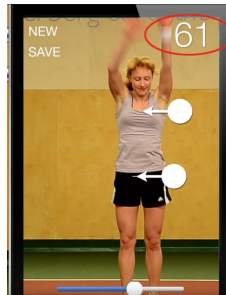


Figure 2.20: The FitnessMeter vertical jump calculator in use.

The app uses the change in position of the torso (Fig. 2.20) to determine jump height. Seemingly by comparing this to their position in the initial start. Our app aims to comfortably work even when only the feet are in frame. In traditional vertical jump tests the athlete maintains straight legs and so the issue of raising the legs/bending the knees to artificially increase hangtime is not a major concern. *Directions in our app will discourage this technique and establish how to best find accurate results.*

2.2.3 What's My Vertical?

Another iOS only application with poor UI. This application uses the same methods we plan on using; however, the app serves no purpose beyond the vertical jump measurement and “dunk calculator” math. It lacks further functionality and training support.

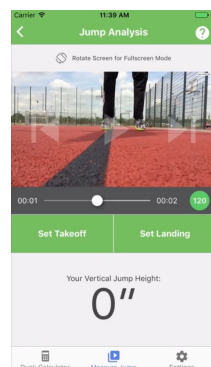


Figure 2.21: The jump calculator functionality in use.

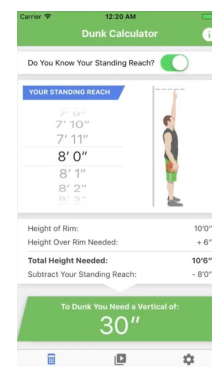


Figure 2.22: The dunk calculator math being used for estimation.

2. Project Research

As mentioned, we intend on using a very similar system to what's seen here (Fig. 2.21). We will consider having a dunk math calculator (Fig. 2.22) as an enhancement and extra feature however this doesn't seem very useful for our project as the fitness application is not sport specific. Whilst the app will be usable by basketball players, having basketball specific functionality may limit user growth and alienate average enthusiasts.

2.2.4 My Jump 2

Finally we have looked at "MyJump 2" - a cross-platform sports science validated calculator app. It's been proven to be "valid, reliable and useful" [18] and provides the most clarity and insight.

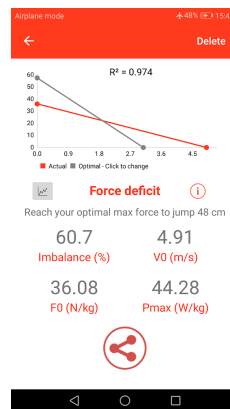


Figure 2.23: Analysis of a jump and data visualisation provided.

The level of precision and insights provided are beyond the scope of our project, as we are focused on providing consistency first and foremost - thereby allowing our users to track their progress. This app estimates and visualises forces produced (Fig. 2.23), which is useful in the field of sport science but may not provide sufficient benefit to users for us to dedicated time to development of a similar feature.

Chapter 3

Project Specification

3.1 Feature specification

The following is a summary of the core features we aim to provide; these will help in fulfilling the aims we set in Chapter 1.

- CRUD (Create, Read, Update, Delete) operations for a user account.
- A vertical jump calculator, operating via video upload (*not recording through the app*).
 - Core: Scrub through the video to set the takeoff/landing point.
 - Extra: Record video on the app (using the phone's camera).
- Create a workout.
 - Core: From existing exercises.
 - Extra: From custom uploaded exercises.
- Subscribe to a preset workout.
- A calendar for monitoring progress.
- A “traffic light system” for monitoring consistency.
- A means of communication with other users.
 - Potentially direct messaging or forum style messaging.
- Provide video playback of exercises
- Allow measurement via metric & imperial units (primarily for US users).
- Provide timer & stopwatch functionality.
- Provide push notification reminders for calendar scheduled workouts.
- Provide notes functions for each workout.
 - Extra: Notes per exercise (allowing specific notes).

3.2 Requirements

Using the above feature set (Section 3.1), we can place features into functional requirements. Other additional requirements will make up our non-functional requirements.

3.2.1 Functional requirements

- CRUD for a User account.
- Upload video from storage.
- Scrub through video and set takeoff/landing.
- Calculate vertical jump in given units (metric or imperial).
- Support video(s) at different frame rate(s).
- Track vertical jump progress.
- Add/remove a workout to or from a user's calendar.
- Mark workouts as complete (with some visual feedback).
- Make notes regarding a specific workout.
- Provide push notification reminders at set duration(s) before a workout.
- Video playback from a source (embedded or from our own data storage).
- Stopwatch & timer must work correctly.
- Simple chat/forum with other users.
- Calendar available on dashboard.
- Create a workout from existing exercises.

3.2.2 Non-functional requirements

- The app should be cross-platform (run on both iOS and Android).
- Have a consistent margin of error (under fixed conditions), when measuring vertical jump.
- Visualise workout consistency on user's dashboard.
- Operate smoothly and provide a close-to-native experience. Users must not feel delayed by the app if/when interviewed following usage.
- Aid users workout experience (aside from the vertical jump calculator).
- Be reliable (no unexpected data loss).

3.3 Technology Stack & Considerations

3.3.1 Frontend technologies

Given that the app will be cross-platform there are a few largely accepted technologies for achieving this with a single codebase. Namely, WebView frameworks (such as Apache Cordova, Ionic, and PhoneGap), “React Native” (created by Facebook) and “Flutter” (created by Google).

We’ll be using **Flutter for the frontend** development for multiple reasons. Commonly, developers opt to use React Native due to its large community support - however in 2021, Flutter has a very similar ecosystem in my opinion. Furthermore, whilst React Native is not noticeably slower than Flutter (in many cases) there is a fundamental difference in how these software frameworks operate (and product native platform code from your high-level codebase). React Native uses a JavaScript bridge to communicate between native code modules; on the other hand, Flutter has native component availability by default - in practice the difference in performance is under a second (milliseconds) but it’s a consideration that holds weight as complexity of a project grows.

Flutter is written using Dart (a rarely used language that is predominantly only used for Flutter development). This is a stark change from JavaScript (used for React Native and more) which I have had previous experience with. *The project* is an opportunity for me to expand my skill set and learn to work with Dart when using the Flutter framework - something which I have little experience with at present. Additionally, JavaScript will be used for *the product* during deployment.

The final reason worth mentioning is Flutter comes with out-of-the-box testing features as a framework - meaning there is less trouble finding a good workflow. All of this in addition to the plethora of default UI components and APIs¹ means that Flutter will be perfect for any form of iterative approach to software development.

¹Application programming interface(s)

3.3.2 Backend technologies

For the backend data storage, **we'll be using MongoDB** - the most popular NoSQL database currently in use. In large part, this is being used as an opportunity for me to utilise NoSQL databases as part of a large project as well as learning to design NoSQL databases from scratch. Ordinarily developers are typically assigned to projects that have been set-up by other engineers thus they aren't typically involved in the architectural stages of system design - including the considerations made when creating database schema.

Personal motivation aside, NoSQL databases are hugely beneficial in a variety of ways. Firstly, we have the ability to handle large amounts of data at high speeds. This is achieved using a "scale-out architecture" - this simply means that instead of relying on more computing power (as is the case in traditional "scale-up architecture") we can scale by adding nodes. Related to this is the removal of SQL; not only are we now avoiding potentially complex and inefficient queries but by remove the "SQL magic" developers can focus on elegant application solutions instead of spending precious development hours optimizing SQL queries for the database schema that is in use.

From a data perspective, NoSQL means we can store all kinds of data structures (formally "models") instead of the SQL default tables, rows, columns. MongoDB supports all forms of raw, semi-structured and structured data; this can be as simple as binary data, to creating "documents" that represent highly structured data such as "User accounts" with multiple references.

Overall MongoDB is being used primarily due to it being the most popular NoSQL database and the inherent community support that coincides with this will be greatly beneficial during development. It's important to note that poor implementation of NoSQL databases can mean operating at shockingly slow speeds. Due to the nature of the flexibility and scalability involved with these databases they are also more susceptible to duplicate data - it is much more difficult to remove this redundancy than traditional relational models where we can follow a normalization process. Often traditional normalization makes use of joins, which are not easily executed using MongoDB and can easily lead to inferior code.

To expose the backend data for the apps to consume we'll be using Express.js - a backend web application framework for **Node.js** used in building APIs. Routing is simple and a fully functional basic API can be written in under 100 lines of code. This level of detail is not essential at this stage but noting our use of Express will hopefully help in rationalizing the more high-level decisions outlined above.

Naturally, the technology stack used may include other middle layer technologies, but it's more than likely we focus our efforts on Flutter & MongoDB before further decisions. For example, we may introduce a cache layer using Redis to optimize queries and make our product more efficient. This iterative behavior is natural in software engineering and so there's an abundance of changes that can occur in our stack which will ease development. This doesn't mean radical changes to our simple Flutter-Express-Node stack but hopefully explains why it's difficult to document any packages and frameworks we intend to use without a thorough system design stage (often taking months).

3.3.3 Security and deployment considerations

The application backend will be hosted on the cloud using AWS (Amazon Web Services). This is easier to set up than self-hosting on dedicated servers and avoids the configuration needed to create a secure system. The costs are predictable based on the usage we see, and we can easily scale without having to invest in additional server hardware. AWS is more configurable than other major cloud providers but provides greater support versus IAC² tools like Terraform.

We also plan on using fastlane as the CD component of the CI/CD pipeline for deployment. GitHub Actions can also be used during growth stages before moving to a traditional CI/CD tool like Jenkins - which can also be integrated with many AWS services.

A note must be made that many of the above technology decisions are made with HR in mind. To explain this we must think further into the future; avoiding IAC means we're less likely to need to employ cloud infrastructure engineers (thus reducing costs) and using popular technologies means we won't struggle to find talent if needed. These decisions are largely dependent on what happens with the product and whether the concept is proven as commercially viable, but that doesn't dismiss the need to account for factors such as employee churn as early as possible.

²Infrastructure-as-code

Chapter 4

Preliminary Work

4.1 Software architecture

4.2 User interface design

4.3 Database design

Chapter 5

Project Plan

5.1 Time management

Gantt and refs to risk mgmt plan

5.2 Software development strategy

Feature Driven development

5.2.1 Choice of model

Agile

5.2.2 Testing lifecycle

Behaviour driven development

5.3 Risk management plan

5.3.1 Risk analysis

5.3.2 Risk mitigation

Chapter 6

Summary

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