# Multiplayer Grid Based Dexterity Training Game

NEA: Georgiy Tnimov

# Contents

## 0.1. Abstract

This project develops a multiplayer grid-based dexterity training game called DoubleTapp, designed to simultaneously test and improve the dexterity of both hands. Building on the existing single-cursor game Tapp, this implementation introduces dual-cursor gameplay requiring coordinated control using different keys for each hand. The system features both singleplayer and multiplayer modes with competitive elements, leaderboards, and server-side anti-cheat mechanisms.

The technical implementation uses Rust for the backend with the Axum framework for websocket connections and PostgreSQL for data persistence. The frontend is built with SvelteKit and Tailwind CSS, featuring customizable controls including Delayed Auto Shift (DAS) functionality. A custom implementation of the Xoshiro256+ PRNG algorithm ensures fairness across game instances.

## 0.2. Problem Definition

I plan to develop a game, which tests the dexterity of both hands, simultaneously. I believe its important that people can maintain their dexterity of both hands, and this game will help them do that. I also believe the game will be fun, and will be a good way to pass time. adding a competitive and multiplayer aspect to the game will also help with this.

I plan to develop this game using Rust and Svelte, as well as a websocket server, which will be used to communicate between the client and server.

## 0.3. Client

### 0.3.1. Client Synopsys (conclusion)

The Client is Alexander Tahiri, a software developer at Studio Squared and the developer of Tapp, a game based on a 4x4 grid, which consists of 12 inactive tiles, and 4 active tiles. Players use the mouse cursor to click on an active tile, which then deactivates that tile and actives a new, currently non-active tile.the objective of Tapp is to achieve as high a score as possible, without making any mistakes. The Client requires a derivative of this game, which tests simultaneous dexterity of both hands, additionally The Client wants to incorporate a competitive aspect to the game, which consists of a leaderboard section, allowing players to see their position whithin the rankings and a Tetris-99-esque game mechanic, where players compete to either achieve the highest score, or last the longest in a mass multiplayer format. The Client has specifically asked for the Catppuccin colour scheme to be used, The Client has sufficient computing power to host both the client,server and database, which will be provided free of charge.

### 0.3.2. Interview Notes

(all notes are paraphrased)

**Q:** What features are most important to you for DoubleTapp?

**A:** My main requirement is that the new game tests both hands simultaneously, and has replayability. Features such as users and leaderboards, along with a competitive aspect would be awesome.

**Q:** How many users do you expect to scale to?

**A:** I am estimating up to 50 concurrent users, and aim for small latencies.

**Q:** Any specific UI/GUI choices, and what platform should DoubleTapp support?

**A:** DoubleTapp should be a website, like the original Tapp, and it should use the Catppuccin color scheme.

**Q:** Any specific technologies you would like implemented?

**A:** I am a fan of Svelte, and would like to use Rust as the backend due to its fast speeds and growing technology base. Tapp doesn’t have a database but SQL would be acceptable.

**Q:** DoubleTapp might have a cheating problem, would you like an anticheat?

**A:** An anticheat would be desirable. Due to Svelte being unobfuscated, a server-side anticheat might be best.

**Q:** What are your thoughts on monetization for DoubleTapp?

**A:** I’d prefer to keep it free to play. The focus should be on building a community rather than generating revenue at this stage.

**Q:** How important is cross-device compatibility?

**A:** The primary focus should be desktop browsers, but having it work reasonably well on tablets would be a nice bonus. I don’t expect mobile phone support due to the dual-input nature.

**Q:** Any accessibility considerations you’d like to see implemented?

**A:** Customizable keybindings would be essential since this is a dexterity game. Also, ensuring the color scheme has sufficient contrast for visibility would be good.

## 0.4. Success Criteria

- game is completely functional
- server can handle 50 concurrent users
- average user rating is 4/5 or higher
- aesthetically pleasing UI
- useful UX
- easy to understand and customize settings

## 0.5. Research

### 0.5.1. Similar Solutions

There are a few similar products on the market that test dexterity in various ways. Understanding these existing solutions helps position DoubleTapp in the competitive landscape and justify its development.

#### 0.5.1.1. Tetris

Tetris is one of the most recognized dexterity-based puzzle games worldwide. While it effectively tests hand-eye coordination and spatial reasoning, it differs from DoubleTapp in several key ways:

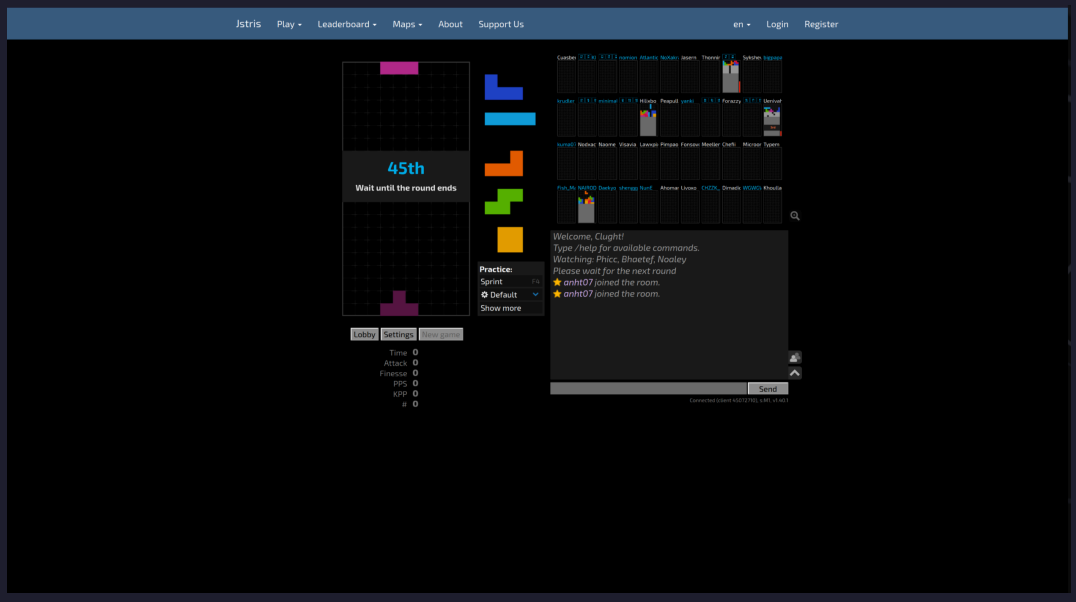



Figure 1: Tetris UI

- Tetris focuses primarily on single-hand dexterity, with players typically using one hand for directional controls and the other for occasional rotation/drop buttons
- It has a significant learning curve with complex strategies around piece placement and line clearing, i.e T-spins, Wall Kicks
- Players focus more on strategic planning of where to place pieces rather than pure dexterity training
- The modern competitive versions of Tetris (like Tetris 99) do incorporate multiplayer aspects, but interaction between players is indirect through “garbage lines”

Tetris has multiple useful features which I will be taking inspiration from, particularly Delayed Auto Shift (DAS)[1], which allows for precise control of pieces,

this allows for people to have more accurate control over their piece placement and allows for timing optimization

#### 0.5.1.2. Tapp

Tapp, developed by Alexander Tahiri at Studio Squared, is the direct predecessor to DoubleTapp and shares the most similarities:

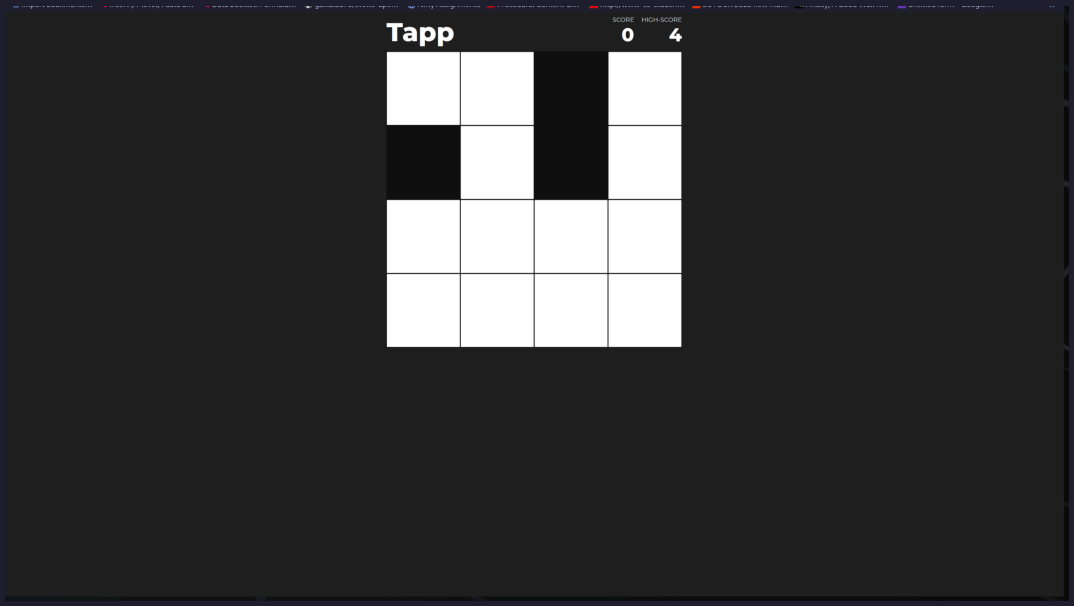



Figure 2: Tapp UI

- Uses a grid-based interface (4x4) with active and inactive tiles
- Tests dexterity through rapid target acquisition
- Focuses on score maximization without mistakes
- Simple, accessible gameplay with minimal learning curve

However, Tapp is limited to single-hand dexterity training, using only mouse input. It lacks the simultaneous dual-hand coordination that DoubleTapp aims to develop. Additionally, Tapp has no built-in multiplayer functionality or competitive leaderboard system.

#### 0.5.1.3. Other Dexterity Training Applications

Various other applications exist for dexterity training, including:

- Typing games that test two-handed coordination but in a highly structured, predictable pattern (monkeytype, nitrotype)
- Rhythm games (like Dance Dance Revolution or osu!) that test reaction time and coordination but typically focus on timing rather than spatial navigation
- Aim trainers (for FPS games) that focus exclusively on mouse precision, although sometimes incorporate simultaneous dexterity, i.e counterstrafing, bhopping, edgebugging

### 0.5.2. Multiplayer

for implementing multiplayer, there are multiple solutions that work, i.e unidirectional HTTP requests, custom UDP handling, and websockets

| Method | Pros | Cons |
|---|---|---|

| | | |
|---|---|---|
| HTTP [2] | • Simple implementation<br>• Reasonably performant<br>• Easily Debuggable<br>• widely supported | • Slow with many simultaneous users<br>• Requires entire connection sequence for each request<br>• relatively high latency<br>• not designed for bidirectional communication |
| UDP [3] | • Very performant<br>• allows for low level optimisations<br>• minimal overhead | • susceptible to packet loss, and is not guaranteed to have data parity (important for doubletapp)<br>• complex to implement, and difficult to interconnect with existing libraries without significant performance declines<br>• often blocked by firewalls<br>• no ordering guarantees |
| Websockets [4] | • allows for fast and safe data transmission<br>• relatively complex to implement, as need to handle assignment of websockets to individual games<br>• compatible with existing web server libraries<br>• fully duplex, no need to reestablish connection sequence each request | • websockets don't recover when connections are terminated<br>• some networks block the websocket protocol, limiting accessibility<br>• high memory usage per connection compared to UDP/ HTTP |

I have decided to use websockets, as they are a reasonable balance of complexity, performance, and ease of implementation, while still providing a high degree of reliability and safety.

#### 0.5.3. PRNG's (Pseudorandom Number Generators)

after considering many PRNG's (pseudorandomnumber generators), for example ARC4 , seedrandom, ChaCha20, and discounting them due to performance issues / hardware dependent randomization, I decided on using the Xoshiro/Xoroshiro family of algorithms, which are based on the Linear Congruential Generators, which are a (now-obsolete) family of PRNG's, which use a linear multiplication combined with modulus operations, to create quite large non-repeating sequences, although quite slow and needing very large state. xoshiro generators use a much smaller state (between 128-512) bits, while still maintaining a large periodicity,

| PRNG Algorithm | Pros | Cons |
|---|---|---|

| | | |
|---|---|---|
| ARC4 (Alleged RC4) | • Simple implementation<br>• Fast for small applications<br>• Variable key size | • Cryptographically broken<br>• Biased output in early stream<br>• Vulnerable to related-key attacks |
| Seedrandom.js | • Browser-friendly<br>• Multiple algorithm options<br>• Good for web applications | • JavaScript performance limitations<br>• Depends on implementation quality<br>• Not cryptographically secure by default |
| ChaCha20 | • Cryptographically secure<br>• Excellent statistical properties<br>• Fast in software (no large tables)<br>• Parallelizable | • Complex implementation<br>• Overkill for non-security applications<br>• Higher computational cost |
| Xorshift | • Extremely fast<br>• Simple implementation<br>• Good statistical quality | • Not cryptographically secure<br>• Simpler variants have known weaknesses<br>• Some states can lead to poor quality |
| Linear Congruential Generator (LCG) | • Simplest implementation<br>• Very fast<br>• Small state | • Poor statistical quality<br>• Short period for 32-bit implementations<br>• Predictable patterns |
| Mersenne Twister | • Very long period<br>• Good statistical properties<br>• Industry standard in many fields | • Large state (2.5KB)<br>• Not cryptographically secure<br>• Slow initialization |
| Xoshiro256+/++ | • Excellent speed<br>• Great statistical properties<br>• Small state (256 bits)<br>• Fast initialization | • Not cryptographically secure<br>• Newer algorithm (less scrutiny)<br>• Some variants have issues with specific bits |

| | | |
|---|---|---|
| PCG (Permuted Congruential Generator) | • Excellent statistical properties<br>• Small state<br>• Good performance<br>• Multiple variants available | • More complex than basic PRNGs<br>• Not cryptographically secure<br>• Relatively new |

| PRNG Algorithm | Estimated Time | Cycle Length | State Size | Performance |
|---|---|---|---|---|
| ARC4 | Medium | $10^{\{100\}}$ | 256 bits | Moderate |
| seedrandom.js | Medium | (multiple selectable algorithms) | Varies by algorithm | Moderate (JS limited) |
| ChaCha20 | High | $2^{256}$ | 384 bits | High for crypto |
| Xorshift | Very Low | $2^{128}-1$ | 128-256 bits | Very High |
| Linear Congruential Generator (LCG) | Extremely Low | Up to $2^{32}$ | 32-64 bits | Extremely High |
| Mersenne Twister | Medium | $2^{19937}-1$ | 2.5 KB (19937 bits) | Moderate |
| Xoshiro256+/++ | Very Low | $2^{256}-1$ | 256 bits | Very High |
| PCG (Permuted Congruential Generator) | Low | $2^{128}$ or more | 64-128 bits | High |

after testing, xoshiro256+ has provided the best results, in terms of speed and simplicity of implementation, while still providing a high degree of randomness, and a large cycle length, which is important for a game such as DoubleTapp, where we want to ensure that the game is fair and that the same seed will not be repeated for a long time. additionally the math behind Xoshiro is layered in complexity, and really interesting, which has led me to want to implement it

#### 0.5.4. Statistics(anti-cheat)

for the anticheat,I will be comparing the consistency of player movement timings, and the optimality of their paths, to approximately determine if they are using any forms of cheating, be it a bot, or a human using external software.

##### 0.5.4.1. Player timings

for player timings, I will be using the standard deviation of the player's move timings, and comparing it to a sampled standard deviation based on my own move timings, a high standard deviation indicates that the player is more human, as different grid positions require different amounts of thought to move optimally

##### 0.5.4.2. Path optimality

for calculating optimal paths, there are a few different algorithms that can be used, each having different time and space complexities, it is important that the algorithm calculates the optimal path, not a close approximation, as this will be used to detect potential cheaters. performance is inherently critical for this part, as it will be run on every "submission" of a move, and will need to be done concurrently.

| Algorithm | Time Complexity | Space Complexity |
|---|---|---|
| A-Star | $O(b^d)$ | $O(b^d)$ |
| Djikstra's | $O(V+E)$ | $O(V)$ |
| Manhattan Distance | O(1) | O(1) |

overall, manhattan distance is the best option for this project, as at max the grid would be 6x6, in which using A-star would be overkill, and manhattan distance is the fastest, while djikstra's is the slowest, and would be too slow for the game.

### 0.6. Prototyping

A rudimentary prototype has been made, which tested out multiple different input methods for simultaneous inputs, which has finalized in a "cursor"-based system, where you have two cursors controlled by Wasd-like movement, with each set of controls representing their respective cursor, additionally it has been decided that both cursors need to be on individual Tiles, to prevent copying movements on each hand. this prototype also implemented server-side move verification, making it more difficult to cheat. Finally, the UI design of the prototype will be used in later iterations of the project. the prototype has no game verification, but contains the core gameplay mechanics, and the UI design.

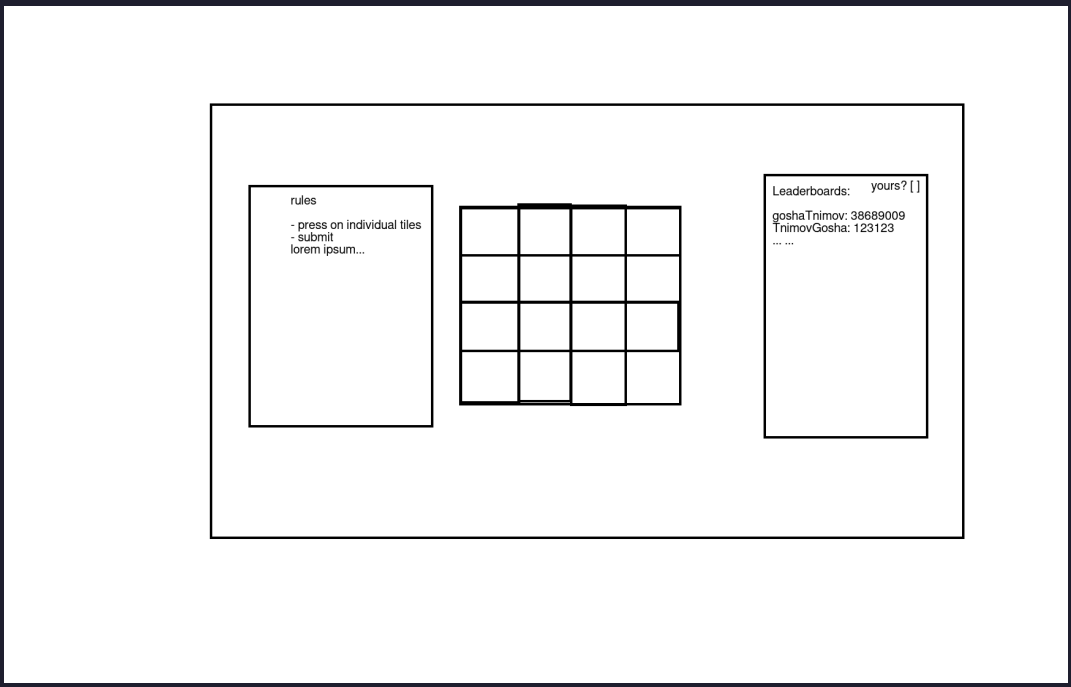



Figure 3: Initial Doubletapp WireFrame UI

this was the initial UI design sketch,which shows the general layout of the game

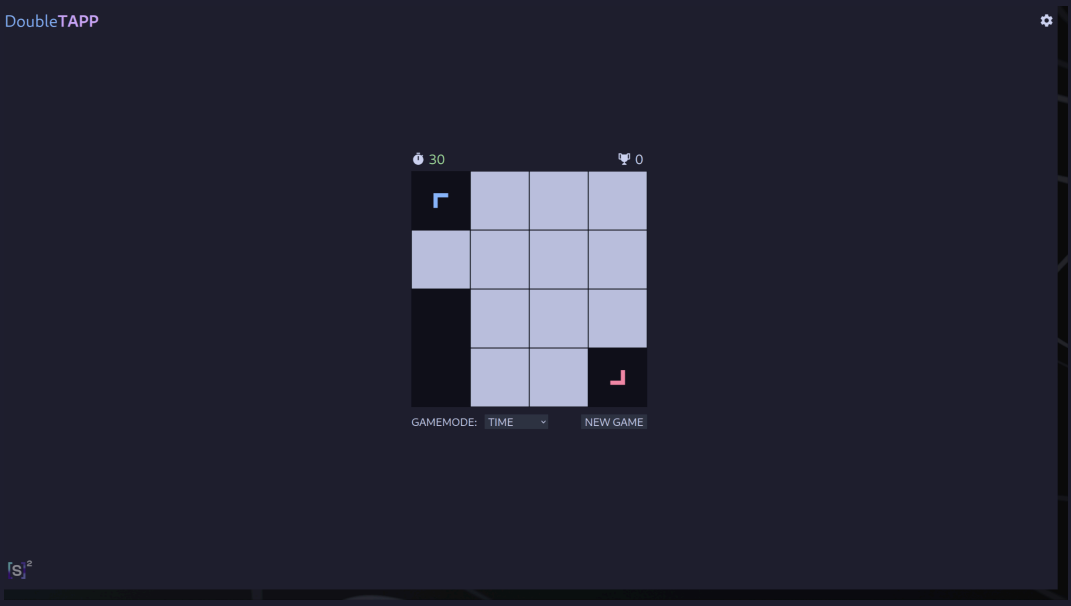



Figure 4: Initial Doubletapp WireFrame UI

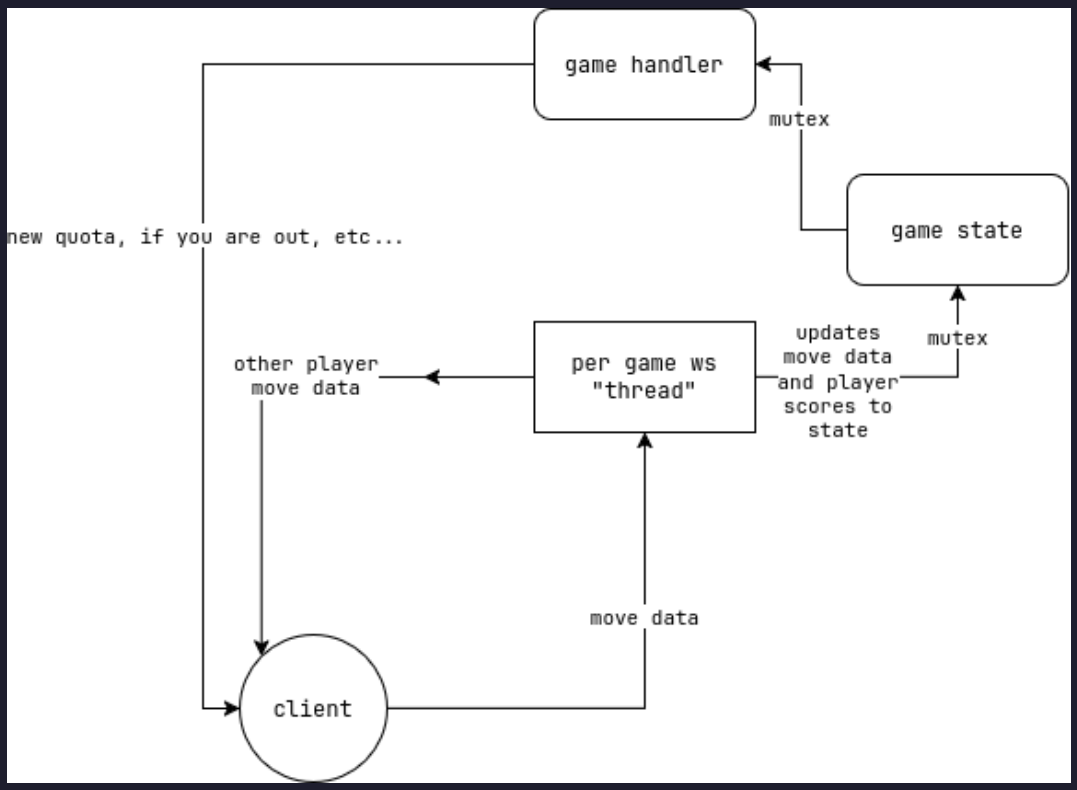



Figure 5: Game Handler Prototype Flowchart - Early design of the game processing pipeline

## 0.7. Critical Path

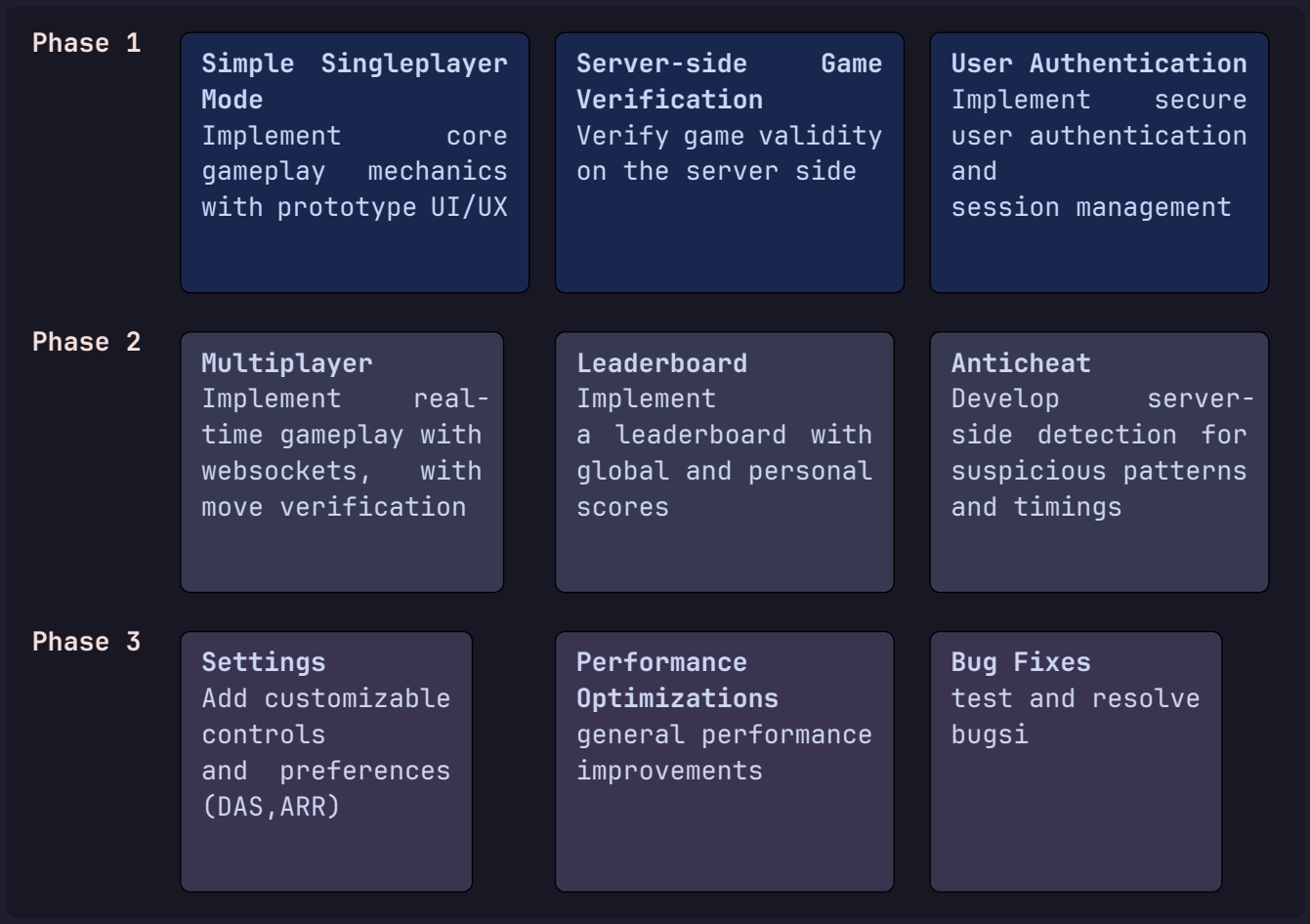



Figure 6: Intended Critical Path

## 0.8. Objectives

### 0.8.1. User Interface

1 user can interact with the grid
  1.1 user can move both cursors using keyboard on the grid
  1.2 user can “submit” moves using a keybind
  1.3 user can reset game (in single player) via a keybind
2 user can change gamemode (singleplayer,multiplayer) on the main page
  2.1 user can change grid size (4x4,5x5,6x6) in singleplayer
  2.2 in singleplayer, user can change time limit (30,45,60)
3 user can access settings
  3.1 user can modify keybinds for each action in the game
  3.2 user can change DAS
  3.3 user can change ARR
  3.4 user can log out of account
  3.5 user can reset all keybinds to a sane default
4 user can play the game
  4.1 on game start, user sees cursors are positioned on opposing sides of the board
  4.2 on game start, user sees the starting active tiles
  4.3 user can view current game score
  4.4 in singleplayer, user sees time remaining

4.5 in multiplayer, user can see time remaining for current quota, players remaining and current score
4.6 user is notified of their position in the multiplayer game
4.7 user can “submit” their move
4.7.1 user can interactively see if the move was valid via a colour interaction which flashes green or red depending on if the move was valid, a valid move is when the two cursors are on two active grid tiles within the grid boundary and they are distinct active tiles
4.7.2 on successfull submit, user sees two new tiles become active, which were previously inactive and are not on current cursor location
4.8 cursors are rendered via two different colours, with the two cursors being visually distinct but symmetrically consistent
5 user can see statistics post singleplayer game end
5.1 user views their score
5.2 user views if their score was validated by the server
5.3 user views their leaderboard position
5.4 user can copy their game statistics to the clipboard for sharing
5.5 if user is logged in and not marked as a cheater, user can view their game in the statistics page
5.6 user has the option to start a new game from the results menu
6 user can view leaderboard
6.1 user can view leaderboards, in a paginated format
7 user can play the multiplayer gamemode
7.1 user can see the other players movements on other grids in the game
7.2 user can see their remaining score quota for each 5 second interval period
7.3 after a user has been eliminated by not reaching the quota,the user can view their position in the game
8 user can log in to the application
8.1 user can login or signup depending on their requirements
8.2 user is shown error codes depending on if account already exists or their login details are incorrect

#### 0.8.2. Server Side

1 user authentication & management:
1.1 securely authenticate users with password hashing and username uniqueness checks.
1.2 implement robust session management using server-side sessions and cookies.
2 database schema:
2.1 contains a relational database schema encompassing:
2.1.1 `user` : stores user details (id, hashed password, username, admin/cheater flags).
2.1.2 `user_statistics` : tracks individual user stats (highest score, wins, games played, elo).
2.1.3 `game` : records authenticated game results (excluding individual moves for efficiency).
2.1.4 `statistics` : aggregates overall game statistics.
2.1.5 `anomalous_games` : stores games flagged as suspicious for review.
2.1.6 `session` : manages user sessions (session id, expiry, user id).
3 game verification:

3.1 validate all submitted moves for legality (correct cursor positions, active tiles).
3.2 anti-cheat measures:
3.2.1 analyze move timings for statistical anomalies (deviation from expected human reaction times).
3.2.2 assess path optimality to detect potential bot usage.
3.3 verify game submissions within allowed time limits (including a grace period).
4 multiplayer implementation:
4.1 establishes real-time, bidirectional communication between server and clients using websockets.
4.2 verifies each move server-side for integrity and cheat prevention.
4.3 minimizes latency in server-client communication for a responsive experience.
4.4 distinguishes and appropriately handles different types of client messages.
4.5 manages game state and player connections efficiently.
5 scalability and performance:
5.1 design database queries and data structures for optimal performance.
5.2 handle concurrent game instances and user connections efficiently.
5.3 implement robust error handling and logging.

## 0.9. Documented Design

### 0.9.1. Libraries Used

#### 0.9.1.1. Frontend Libraries

| Name | Version | Reason | Link |
|---|---|---|---|
| Svelte | 4.2.7 | Reactive UI framework with minimal boilerplate, used for the frontend to provide a performant, easily maintainable UI/UX | svelte.dev |
| SvelteKit | 2.0.0+ | Full-stack framework built on Svelte, allowing for simplification of operations between the frontend and the backend | kit.svelte.dev |
| Tailwind CSS | 3.4.4 | css library, which allows you to define your css classes embedded in the html, allowing for a more readable and quickly iterable codebase | tailwindcss.com |
| Tailwind Catppuccin | 0.1.6 | Client-requested color scheme | GitHub |
| Svelte Material Icons | 3.0.5 | Icon library for Svelte, MIT licensed | npm |

| | | | |
|---|---|---|---|
| UUID | 11.0.4 | frontend library for generating UUID's, used for game management | npm |
| Xoshiro WASM | Local | Custom WASM implementation of Xoshiro256+ | in code |
| TypeScript | 5.0.0+ | Typed JavaScript for better development | typescriptlang.org |
| Vite | 5.0.3 | Modern frontend build tool, used in frontend to allow for fast development and optimized production builds | vitejs.dev |
| Vite Plugin WASM | 3.4.1 | Vite plugin for WebAssembly integration | npm |

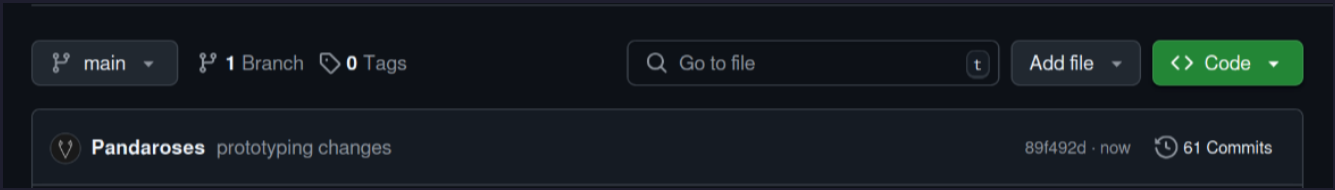
#### 0.9.1.2. Backend Libraries

| Name | Version | Reason | Link |
|---|---|---|---|
| Axum | 0.7.5 | Modern Rust web framework with WebSocket support, one of the fastest web frameworks currently available, asynchronous and type-safe | GitHub |
| Axum-Extra | 0.9.4 | Extension crate for Axum with additional features like cookie handling and typed headers | GitHub |
| Tokio | 1.39.2 | Asynchronous runtime for Rust, required by axum and used for thread handling in websockets | tokio.rs |
| SQLx | 0.8.0 | Async SQL toolkit with compile-time checked queries, used for database operations, inherently supports pooling and multithreading. | GitHub |
| Serde | 1.0.205 | Serialization framework for structured data, allows for parsing JSON and other data formats into Rust objects, speeding up development time and reducing the amount of code needed to be written | serde.rs |
| Serde_json | 1.0.128 | JSON implementation for Serde, used for parsing and generating JSON data in WebSocket communication | GitHub |

| | | | |
|---|---|---|---|
| Bcrypt | 0.17.0 | Password hashing library, used before storing passwords in the database, salted and performant, although slightly outdated | crates.io |
| Tower-HTTP | 0.5.2 | HTTP middleware stack, baseline from axum, used for low level websocket handling | GitHub |
| UUID | 1.7.0 | Library for generating UUIDs, used for game management | crates.io |
| ULID | 1.1.3 | Sortable identifier generation, used for game management | crates.io |
| Validator | 0.20.0 | Data validation library, used for validating user input | crates.io |
| Chrono | 0.4.37 | Date and time library with timezone support, used for handling timestamps and durations to verify games | crates.io |
| SCC | 2.1.11 | Concurrent collections for server applications, performant asynchronous hashmaps | crates.io |
| Silly-RNG | 0.1.0 | Custom RNG implementation, used for the game, based on xoshiro-wasm | Local package |
| Cookie | 0.18.1 | HTTP cookie parsing and cookie jar management, used for session handling | crates.io |
| Dotenvy | 0.15.7 | Loads environment variables from .env files, used for configuration management | crates.io |
| Futures | 0.3.31 | Async programming primitives, used for handling asynchronous websocket operations | crates.io |
| Rand | 0.8.5 | Random number generation utilities, used for game seeding | crates.io |
| Thiserror | 2.0.11 | Error handling library that simplifies custom error types, used for robust error management | crates.io |
| Tracing-subscriber | 0.3.18 | Utilities for implementing and composing `tracing` subscribers, used for logging and diagnostics | crates.io |

### 0.9.2. Iterative Design

i have been using git to manage the project, including reverting to commits when i made mistakes, and using branches to experiment with different features, and then merging them into the main branch.




additionally git has statistics, which allows me to see the changes i have made to the code, and the impact of the changes, which allows me to make more informed decisions about the code.


### 0.9.3. Algorithms

#### 0.9.3.1. Xoshiro256+

xoshiro256+ is my chosen RNG, as it is performant and has a relatively low state size, allowing for many concurrent games to be played on a single machine, it is also very simple to implement, and has a relatively high cycle length, allowing for a more consistent game experience, it is also very fast, and has a low memory footprint, making it a perfect fit for the game. xoshiro256+ has a time complexity of O(1), and a space complexity of O(1), as it only requires a single pass through the seed array, and a single pass through the result array, which is constant time, and constant space, as the size of the seed and result arrays are constant.

```
        // output is generated before the "next" cycle
        let result = self.seed[0].wrapping_add(self.seed[3]);
        // shifting prevents guessing from linearity
        let t = self.seed[1] << 17;
        // these 4 xor operations simulate a matrix transformation
        self.seed[2] ^= self.seed[0];
        self.seed[3] ^= self.seed[1];
        self.seed[1] ^= self.seed[2];
        self.seed[0] ^= self.seed[3];
        // last xor is just a xor
        self.seed[2] ^= t;
        // the rotation ensures that all bits in the seed eventually interact, allowing
    for much higher periodicity (cycles before you get an identical number, which in the case
    of xoshiro256+ is 2^256 - 1)
        self.seed[3] = Xoshiro256plus::rol64(self.seed[3], 45);
        // gets the first 53 bits of the result, as only the first 53 bits are guaranteed
    to be unpredictable for xoshiro256+, for the other variations i.e ++,*,** they are
    optimized for all the bits to be randomized, but as xoshiro256+ is optimized for floating
    points, which we require
        (result >> 11) as f64 * (1.0 / (1u64 << 53) as f64)
```

#### 0.9.3.2. Sigmoid Function

the sigmoid function is a function, that maps any real input onto a S shaped curve, which is bound between values, in my case i am bounding the output of the Xoshiro256+ float to be between 0..11, which allows me to easily use it to generate the “next” state of the game, allowing for a more natural distribution of numbers, as well as a more consistent distribution of numbers, which allows for a more consistent game experience.

```
// simple function, but incredibly useful
function sigmoid(x):
    return 1.0 / (1.0 + exp(-x))
```

#### 0.9.3.3. Manhattan Distance

the manhattan distance is a distance metric, which is the sum of the absolute differences of their Cartesian coordinates, in my case i am using it to calculate the distance between the cursors, which allows for a more accurate calculation of the distance between the cursors, which allows for a more accurate game experience. the time complexity of the manhattan distance is O(1), as it only requires a single pass through the coordinates, and a single pass through the result, which is constant time, and constant space, as the size of the coordinates and result are constant.

```
fn manhattan_distance(x1: f64, y1: f64, x2: f64, y2: f64) -> f64 {
    (x1 - x2).abs() + (y1 - y2).abs()
}
```

#### 0.9.3.4. MergeSort

mergesort is a sorting algorithm, which works by the divide and conquer principle, where it breaks down the array into smaller and smaller arrays, till it gets to arrays of length 2, which it then subsequently sorts from the ground up, returning a sorted array in O(nlog(n)) time complexity & O(n) space complexity

```
function merge_sort(array):
    if length of array <= 1:
        return array

    mid = length of array / 2
    left = merge_sort(subarray from start to mid)
    right = merge_sort(subarray from mid to end)

    return merge(left, right)

function merge(left, right):
    result = empty list
    left_index = 0
    right_index = 0

    while left_index < length of left and right_index < length of right:
        if left[left_index] <= right[right_index]:
            append left[left_index] to result
            left_index = left_index + 1
        else:
            append right[right_index] to result
            right_index = right_index + 1

    append remaining elements from left starting at left_index to result
    append remaining elements from right starting at right_index to result

    return result
```

#### 0.9.3.5. Standard deviation

the algorithm for standard deviation is as follows:

$$\sigma = \sqrt{\frac{(\sum(x) - \mu)^2}{N}}$$

where $N$ is the number of elements in the array, $x_i$ is the $i$th element in the array, and $mu$ is the mean of the array.

which can be implemented quite neatly in rust, using iterators, and their respective methods.

```rust
fn std_dev(arr: &[T]) -> T {
    let sum = arr.iter().sum::<T>();
    let mean = sum / arr.len() as T;
    let variance = arr.iter().map(|x| (x - mean).powi(2)).sum::<T>() / arr.len() as T;
    return variance.sqrt()
}
```

#### 0.9.3.6. Delayed Auto Shift

Delayed auto shift (DAS for short) is a technique implemented in tetris, where you wait for a period of time before starting to move the pieces, while the key is being held down, bypassing the operating systems repeat rate. This is useful for optimizing movements in games similar to DoubleTapp, or tetris, people can customize their DAS and their ARR(auto repeat rate) to be optimal for their own reaction time, so if they need to move a piece they can move it to the corners very quickly, but only after X time has passed, instead of the OS default of  1 second for delay and  100ms per repeat, in my algorithm I used the provided javascript api's of setTimeout and setInterval, wrapped inside an asynchronous function to allow for multiple consecutive inputs, I separately handle keyDown and keyUp events, where on key down the interval is added to an array of intervals (thanks to javascripts type safety), in which the interval is cleared when an OS keyUP is detected, this comes with caveats as there are operating systems which send these events at different times, which can introduce some uncertainty. But due to the timings being customizeable, this isn't much of a problem.

```
// Example for one direction, repeated for others
case $state.keycodes.wU:
    if (dasIntervals[0] == false) {
        dasIntervals[0] = setTimeout(() => {
            dasIntervals[0] = setInterval(() => {
                wcursorY = Math.max(wcursorY - 1, 0);
                if ($state.gameMode === 'multiplayer') {
                    ws.send(JSON.stringify({
                        type: 'Move',
                        data: { player_id: `${temp_id}`, action: 'CursorBlueUp' }
                    }));
                }
                moves.push(['CursorBlueUp', Date.now() - lastActionTime]);
                lastActionTime = Date.now();
            }, $state.das);
        }, $state.dasDelay);
    }
```

#### 0.9.3.7. Game Verification

```
ub async fn verify_moves(moves: Vec<Move>, size: u8, seed: u32) -> Result<u32, String> {
    //this is assuming we start at 0,0 and size,size (should be a client side force, now
enforced)
    let mut rng = sillyrng::Xoshiro256plus::new(Some(seed as u64));
    let mut grid: Vec<bool> = vec![false; (size * size) as usize];
    let mut blue_coords: (u8, u8) = (0, 0);
    let mut red_coords: (u8, u8) = (size - 1, size - 1);
    let mut score = 0;
    let mut distance = 0;
    let mut anomalous_distances = 0;
    let mut optimal_distance = 0;
    let mut count = 0;
    // grid initialisation
    while count < size {
        let x: u8 = (rng.next() * size as f64).floor() as u8;
        let y: u8 = (rng.next() * size as f64).floor() as u8;
        if grid[(x * size + y) as usize] == false {
            grid[(x * size + y) as usize] = true;
            count += 1;
        }
    }
    for i in moves.iter() {
        match i {
            Move::CursorRedUp => {
                red_coords.1 = (red_coords.1 as i8 - 1).max(0) as u8;
                distance += 1;
            }
            // all other moves are handled in the same way, albeit with different
coordinates
            Move::Submit => {
                // simple anomaly check
                if distance <= optimal_distance {
                    anomalous_distances += 1;
                }
                distance = 0;
                // verifies that the cursors are not on the same cell, and that both
cursors are on active tiles
                if grid[(red_coords.0 * size + red_coords.1) as usize]
                    && grid[(blue_coords.0 * size + blue_coords.1) as usize]
                    && !(blue_coords == red_coords)
                {
                    score += 1;
                    let mut count = 0;
                    let r = red_coords.0 * size + red_coords.1;
                    let b = blue_coords.0 * size + blue_coords.1;
                    // regenerates two new tiles, using the same rng as the client side
                    while count < 2 {
                        let x: u8 = (rng.next() * size as f64).floor() as u8;
                        let y: u8 = (rng.next() * size as f64).floor() as u8;
                        if !grid[(x * size + y) as usize]
                            && (x * size + y != r || x * size + y != b)
                        {
                            grid[(x * size + y) as usize] = true;
                            count += 1;
                        }
                    }
                    // resets selected tiles to inactive
                    grid[r as usize] = false;
                    grid[b as usize] = false;
```

### 0.9.4. API routes

although API routes are simple, the actual functions linked are quite complex, and require a lot of error handling, which is why I have included them here.

| Method | Route | Handler Function | Description |
|---|---|---|---|
| POST | /get-seed | create_seed | Creates a new game seed and returns it along with a game ID. |
| POST | /submit-game | submit_game | Submits a completed game for verification and scoring. |
| ANY | /game | ws_upgrade_handler | Handles WebSocket upgrades for real-time game communication. |
| POST | /get_scores | get_scores | Retrieves game scores, supporting pagination and filtering by user. |
| POST | /user/signup | register | Registers a new user. |
| POST | /user/login | login | Logs in an existing user. |
| Middleware | (All authenticated routes) | auth_middleware | Middleware applied to all routes, checking for a valid session cookie to authenticate the user. |

### 0.9.5. Database Design and Queries

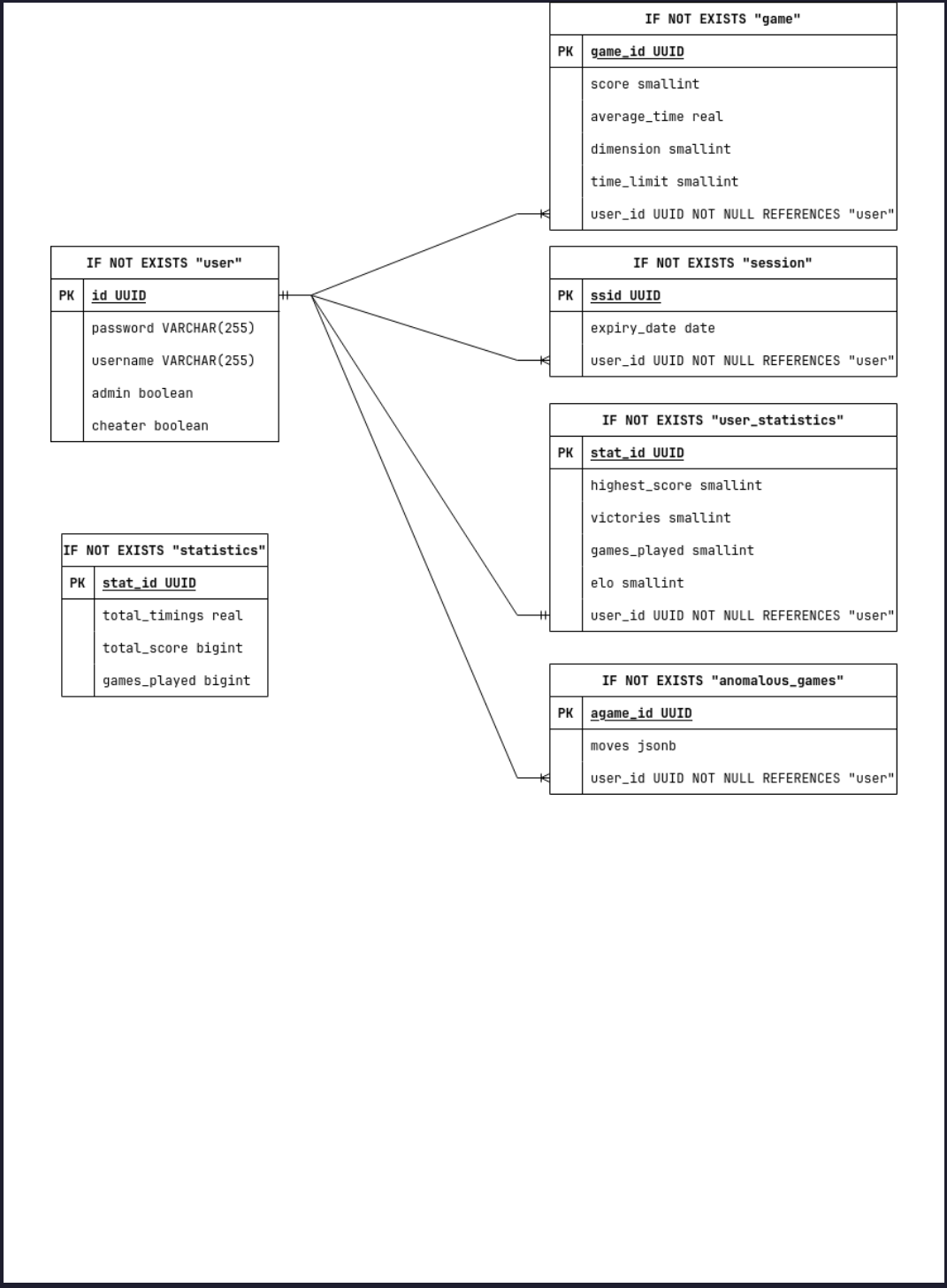



Figure 7: Entity Relationship Model - Database schema showing relationships between game entities

ERM

#### 0.9.5.1. User Authentication Queries

```
SELECT id, password FROM "user" WHERE username = $1
```

this query is quite simple, it just selects the id and password from the user table, where the username is the same as the one provided, as the password is hashed before being stored, this method is secure. additionally it is run on the server side, preventing any XSS attacks, or SQL injections.

#### 0.9.5.2. User Registration Query

```
INSERT INTO "user" (id, username, password) VALUES ($1, $2, $3)
```

another simple query, it just inserts the id, username and password into the user table, again, the password is hashed before being stored, this method is secure.

#### 0.9.5.3. Session Management

```
INSERT INTO session (ssid, user_id, expiry_date)
VALUES ($1, $2, NOW() + INTERVAL '7 DAYS')
```

another simple query, although it adds expiry date to the session, preventing ugly rust code

```
SELECT u.id, u.username, u.admin, u.cheater
FROM "user" u
INNER JOIN session s ON u.id = s.user_id
WHERE s.ssid = $1 AND s.expiry_date > NOW()
```

this query is quite pretty, it looks for all sessions that fit the ssid, and then checks if the expiry date is greater than the current date, if it is, then the user is authenticated, and the user id, username, and admin status is returned.

#### 0.9.5.4. Leaderboard Queries

```
-- Get global leaderboard
SELECT "game".score, "user".username
FROM "game"
JOIN "user" ON "game".user_id = "user".id
WHERE dimension = $1
AND time_limit = $2
ORDER BY score
OFFSET ($3 - 1) 100
FETCH NEXT 100 ROWS ONLY
-- Get user's personal scores
SELECT "game".score, "user".username
FROM "game"
JOIN "user" ON "game".user_id = "user".id
WHERE dimension = $1
AND time_limit = $2
AND "user".id = $4
ORDER BY score
OFFSET ($3 - 1) 100
FETCH NEXT 100 ROWS ONLY
```

these queries use postgresSQL's pagination function, which allows the leaderboards to be paginated, instead of loading all the data into memory, which would be very slow and inefficient. additionally the queries are very readable, I selected 100 rows as it is a good balance and takes up about a page of space.

#### 0.9.5.5. Game Submission

```
INSERT INTO "game" (game_id, score, average_time, dimension, time_limit, user_id)
VALUES ($1, $2, $3, $4, $5, $6)
```

self explanatory.

#### 0.9.5.6. Statistics Trigger

```
CREATE OR REPLACE FUNCTION update_statistics_on_game_insert()
RETURNS TRIGGER AS $$
BEGIN
UPDATE user_statistics
SET
games_played = games_played + 1,
highest_score = GREATEST(highest_score, NEW.score)
WHERE user_id = NEW.user_id;
UPDATE statistics
SET
total_timings = total_timings + NEW.average_time,
total_score = total_score + NEW.score,
games_played = games_played + 1;
RETURN NEW;
END;
$$ LANGUAGE plpgsql;
CREATE TRIGGER game_insert_trigger
AFTER INSERT ON game
FOR EACH ROW EXECUTE FUNCTION update_statistics_on_game_insert();
```

this trigger is used to update both user statistics, and global statistics, when a game is submitted, it is inserted into the game table, and then the trigger is called to update the statistics. a game is only submitted when it is verified and guaranteed to be a valid game, so the statistics do not include cheaters. additionally you do have to be logged in to submit a game, so the statistics are only updated for logged in users.

### 0.9.6. Data Structures

#### 0.9.6.1. Circular Queue

A queue is a data structure following the FIFO (first in first out) principle, where you use a sized array, along with variables to store the capacity, front & back of the array, when a file is queued, the file is put onto the index of the back of the array, and then the back index is added to % capacity unless the back becomes equal to the front, in which the queue returns an error instead, this allows for a non resizable array, which allows a set amount of elements to be queued, but not more than the size of the array, allowing for efficient memory management

#### 0.9.6.2. HashMap

A hash table (colloquially called a hashmap) is an array that is abstracted over by a “hashing” function, which outputs an index based on an output, usually the hash function aims to be as diverse as possible, but you can also write special hash functions that are more efficient for your given data types.

#### 0.9.6.3. Option/Result Types

an Optional type, is a simple data structure that allows for beautiful error handling, an Option type wraps the output data, allowing for the error to be handled before trying to manipulate data, i.e in a Some(data) or None, where None means that the data was nonexistent, or we can use a result type to handle errors down the stack, where

we can pass the error with Err(e) and Ok(d), so if one part of the function layer breaks we can know exactly where it errored and softly handle the error if needed

### 0.9.7. Diagrams

### 0.9.8. Frontend

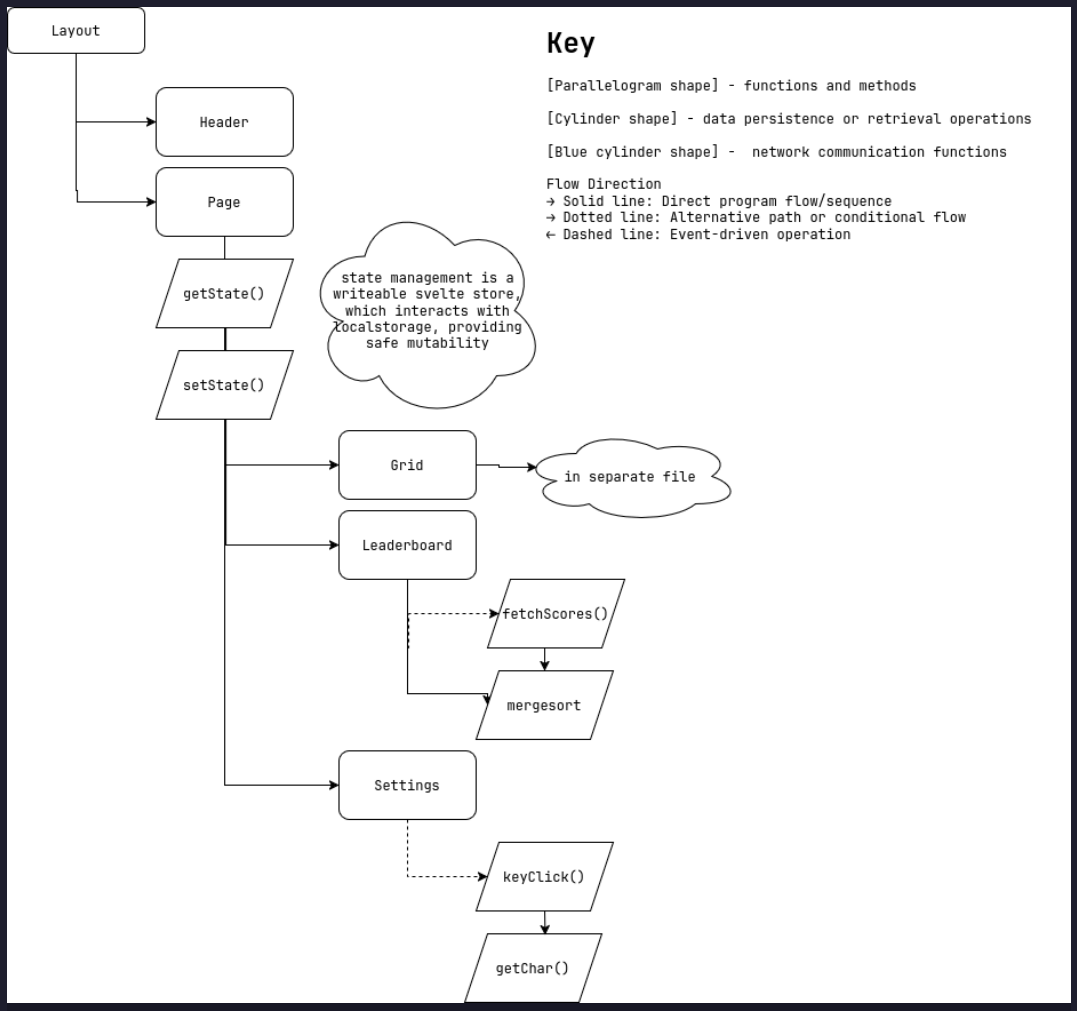



Figure 8: Client Component and Flow diagram

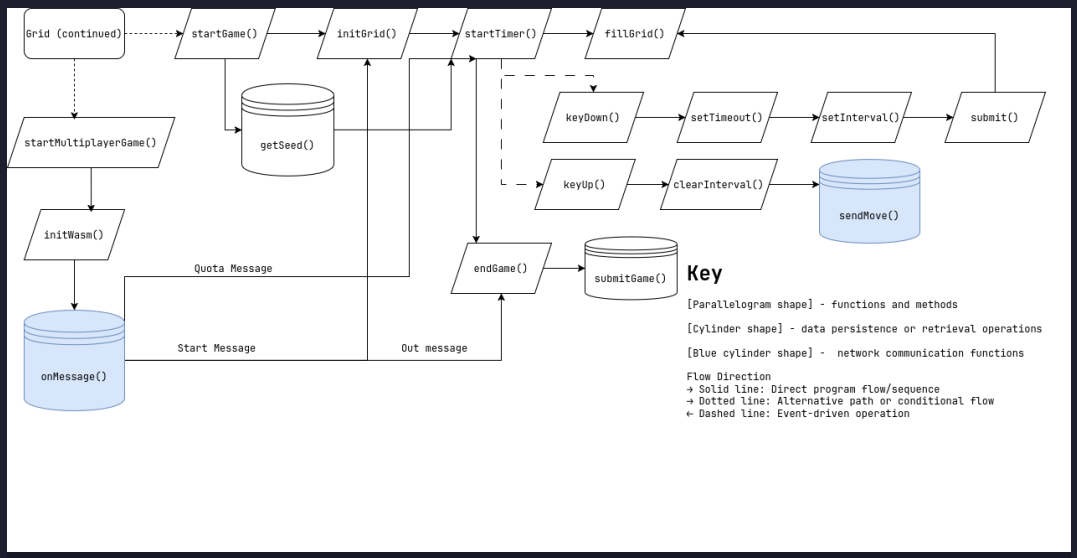



Figure 9: Grid Component

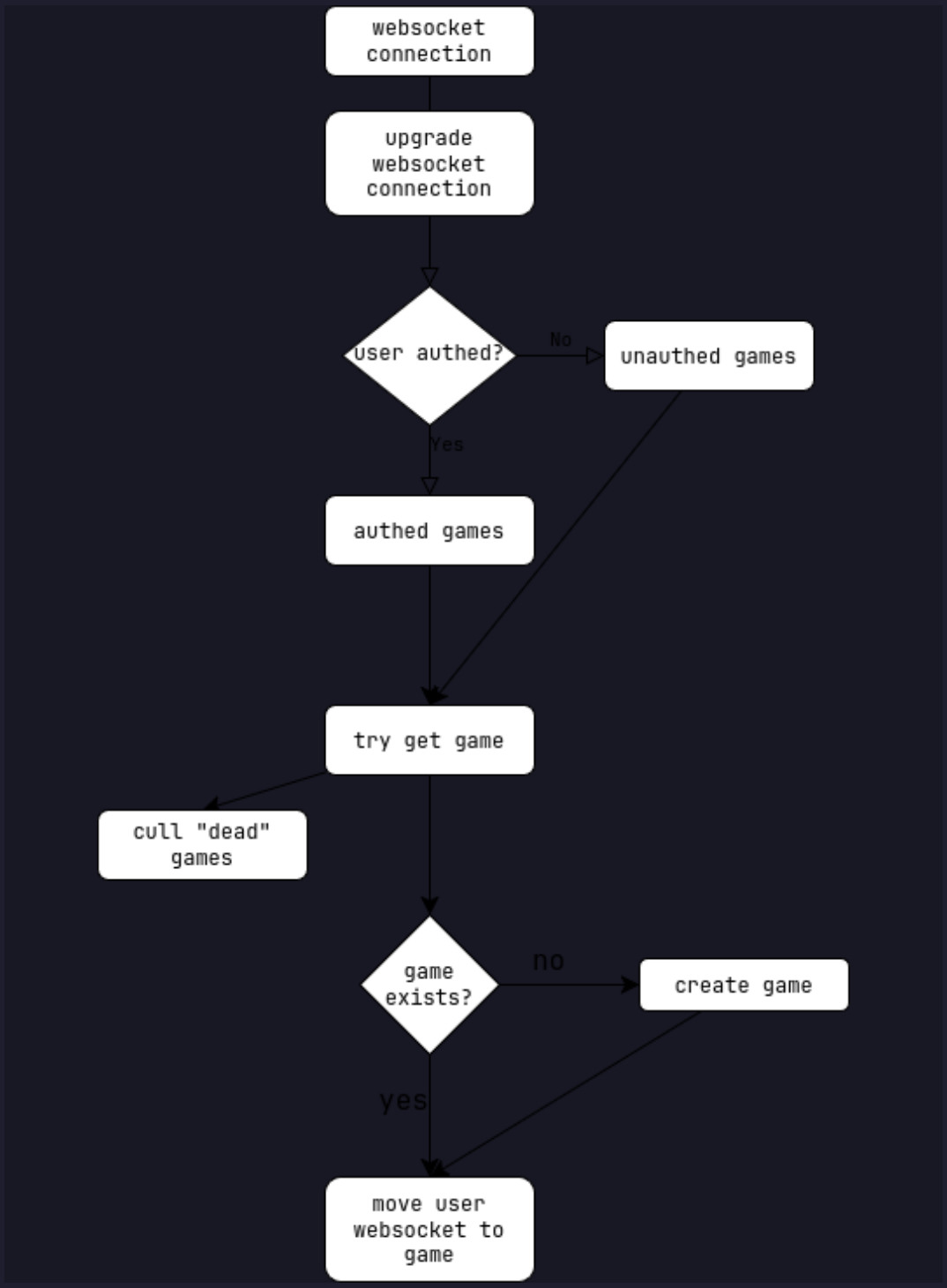



Figure 10: Game Handler Flowchart

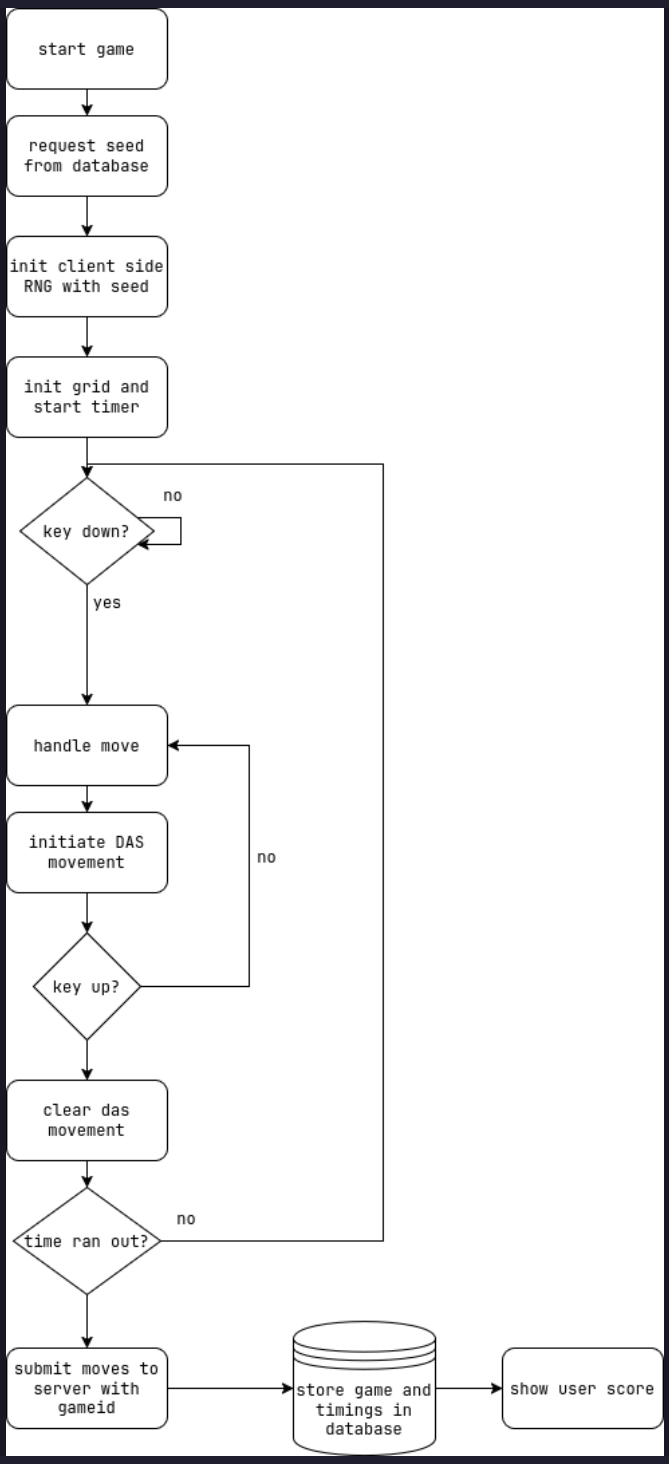



Figure 11: Singleplayer Game Flowchart

### 0.9.9. Backend

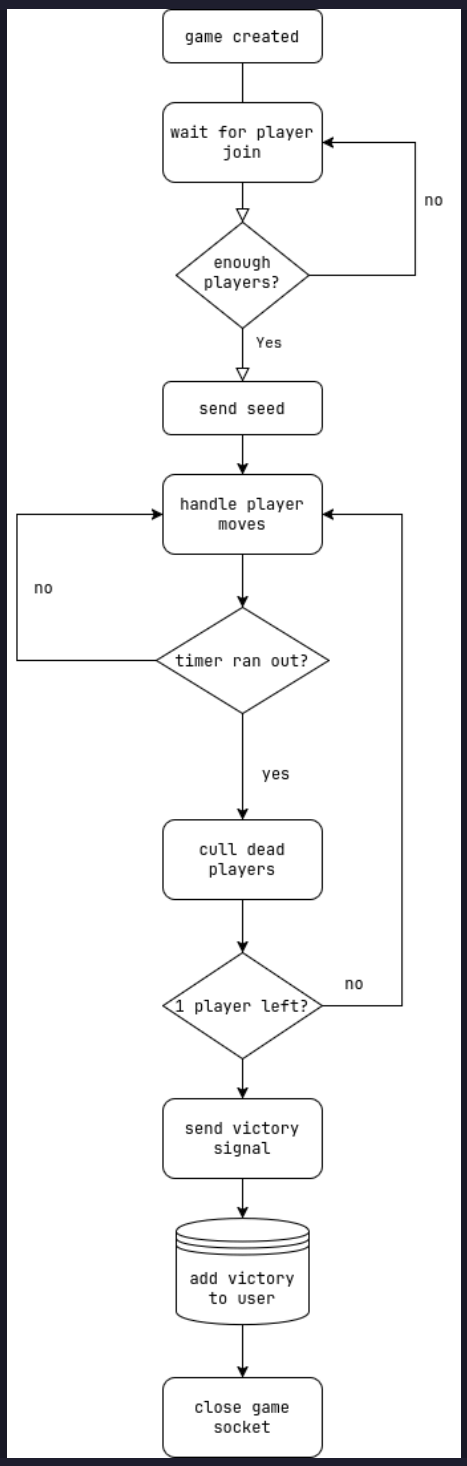



Figure 12: Multiplayer Game Flowchart

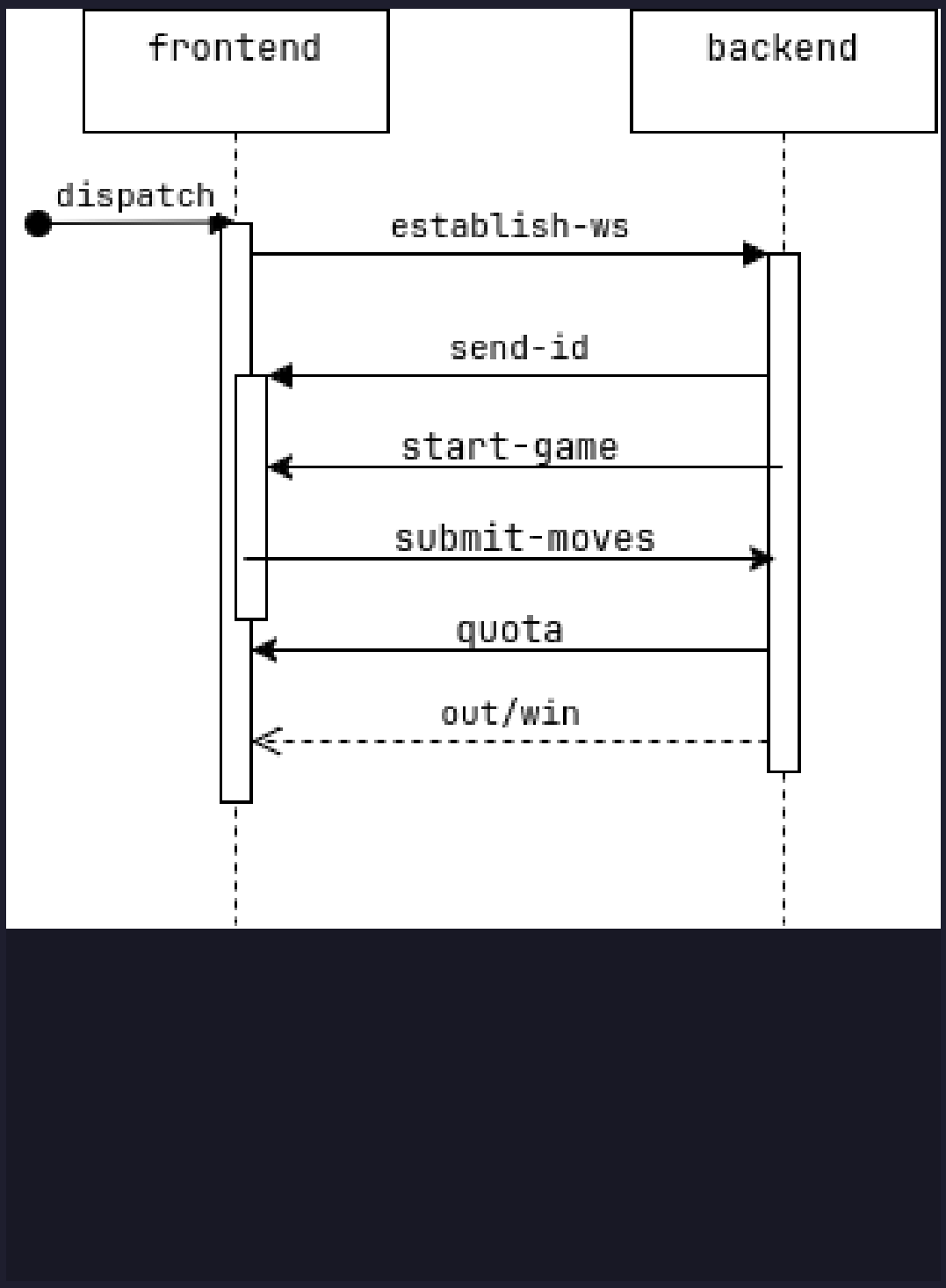



Figure 13: WebSocket message diagram

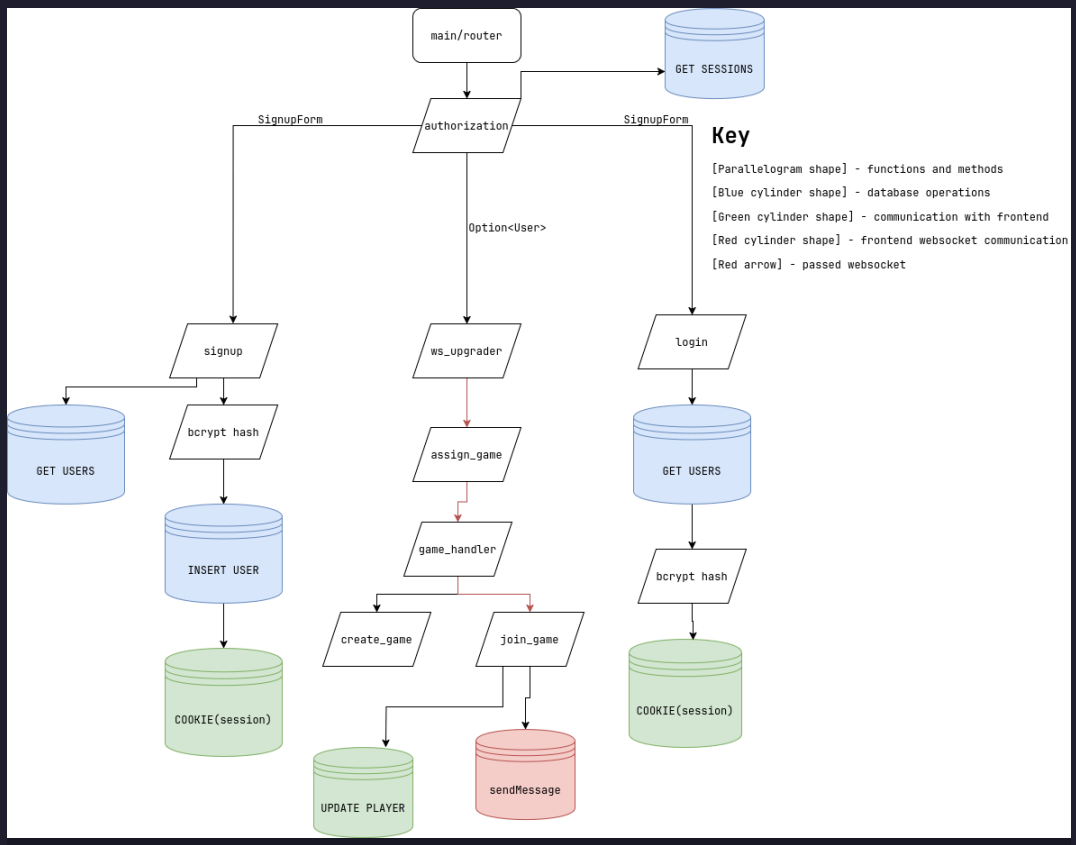



Figure 14: Backend Multiplayer Flowchart

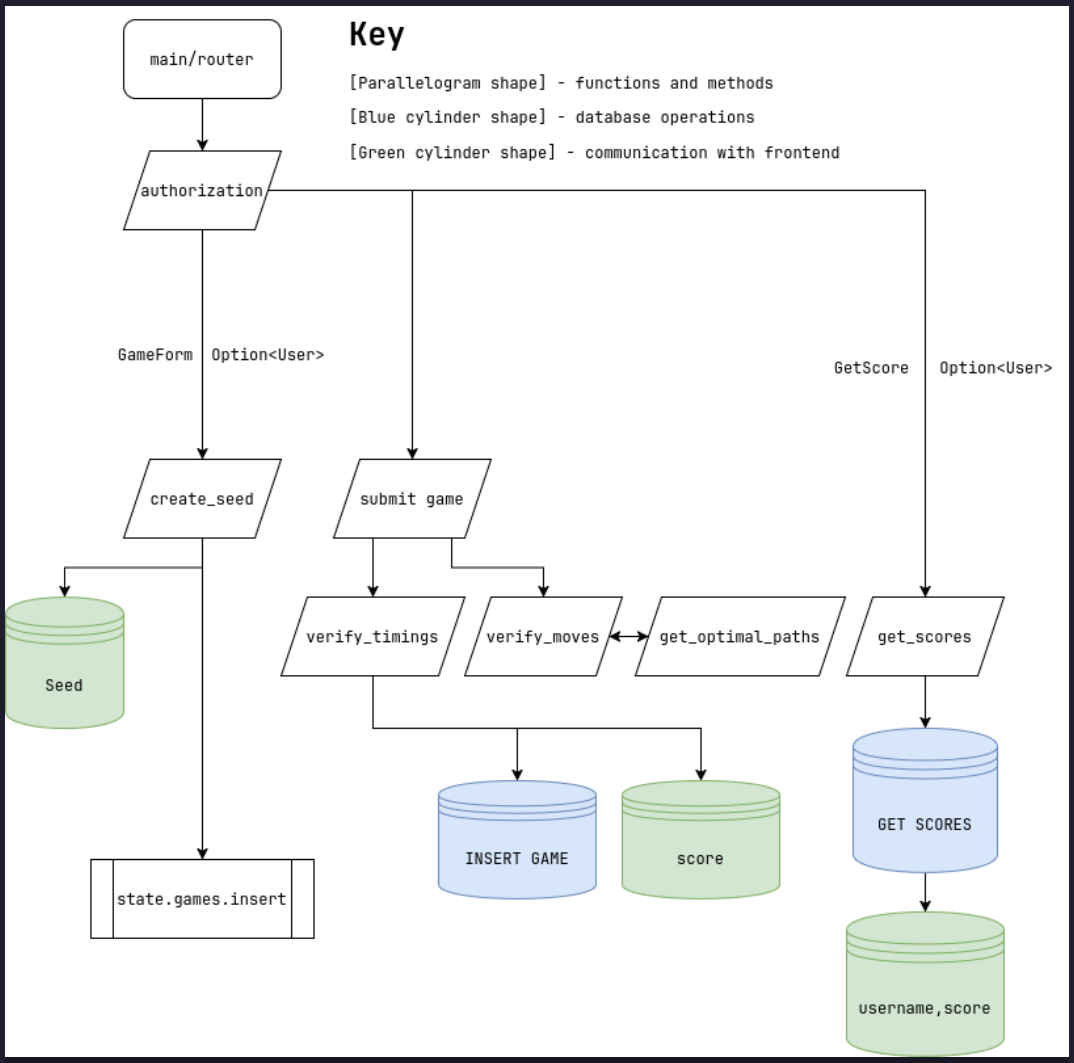



Figure 15: Backend Flowchart

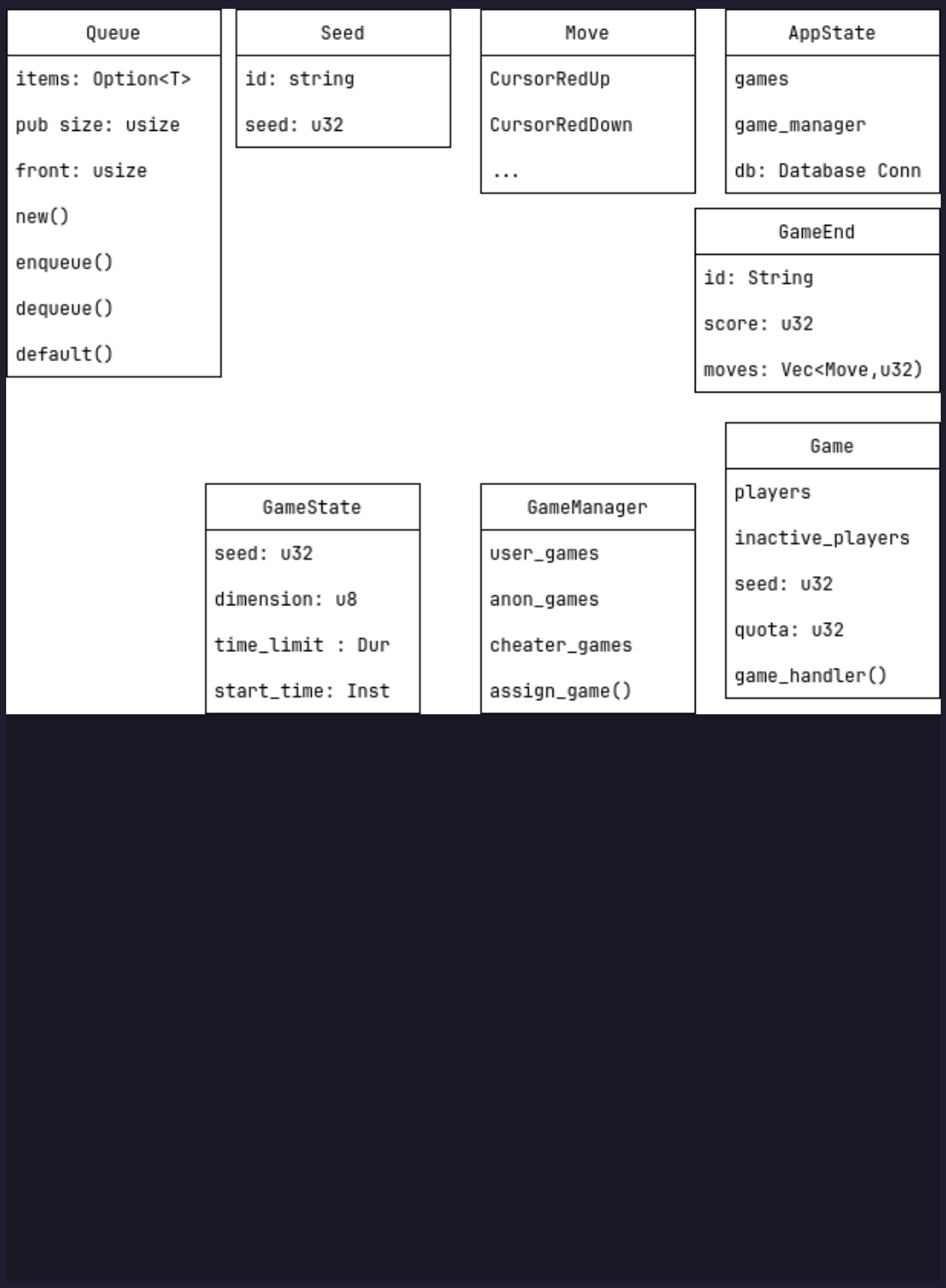



Figure 16: Class Diagram

## 0.10. Technical Solution

### 0.10.1. Code Contents

| Component | Description | Path/Location |
|---|---|---|

| | | |
|---|---|---|
| Grid | Core game grid display and interaction component, handles cursor movement, tile activation, and game state | /src/lib/Grid.svelte |
| Authentication | User registration, login, and session management | src/routes/signup/+page.svelte, backend/src/misc.rs |
| Leaderboard | Leaderboard component, displays the leaderboard | src/routes/leaderboard/+page.svelte |
| Settings | Settings component, displays the settings | src/routes/settings/+page.svelte |
| Singleplayer Game Management | Singleplayer game management component, handles the singleplayer game | backend/src/main.rs |
| Multiplayer Game Management | Multiplayer game management component, handles the multiplayer game | backend/src/game.rs |
| Database Models | Database models, defines the database schema | backend/src/models.rs |
| Server Routing | Server routing, defines the server routes | backend/src/main.rs |
| Backend Error Handling | Backend error handling, handles errors in the backend | backend/src/error.rs |
| WASM | WASM implementation, used for the PRNG | xoshiro-wasm/src/lib.rs, pkg/* |
| Queue | Queue implementation, used to manage game states | backend/src/misc.rs |

### 0.10.2. Skill table

| Group | Skill | Description | Link/(s) |
|---|---|---|---|
| A | Complex Data Models | Interlinked tables in database, along with complex queries | Database Models, Authentication, Leaderboard |
| A | Hash Tables | Hashmaps used to map ULID's to games and user websockets | Multiplayer Game Management, Singleplayer Game Management |
| A | Queue | Circular queue used to manage game states | Queue |
| A | Hashing | Hash function used to hash passwords | Authentication |
| A | Complex Mathematical Model | Implementation of a PRNG | WASM |
| A | Complex Mathematical Model | MergeSort implementation for leaderboard | Leaderboard |
| A | Complex Control Model | Websocket Future Pattern Matching, (scheduling/pattern matching) | Multiplayer Game Management |
| A | Complex OOP model | game handler class, grid class, user class, etc. uses inheritance, composition, abstraction | Game Handler, Grid, Multiplayer Game Management, Database Models |
| A | Complex client-server model | complex HTTP request handling, including deserializing and parsing JSON objects | Server Routing, Backend Error Handling, Authentication, Singleplayer Game Management |
| A | Complex client-server model | Websocket handling, including sending and receiving messages, and transfer of websockets between threads | Multiplayer Game Management |

| | | | |
|---|---|---|---|
| A | Complex client-server model | Authentication Middleware | Authentication |
| B | Simple Mathematical Model | Game Timing and Score Calculation | Game Handler |

#### 0.10.3. Completeness of Solution

everything apart from cheater game verification is complete

#### 0.10.4. Code Quality

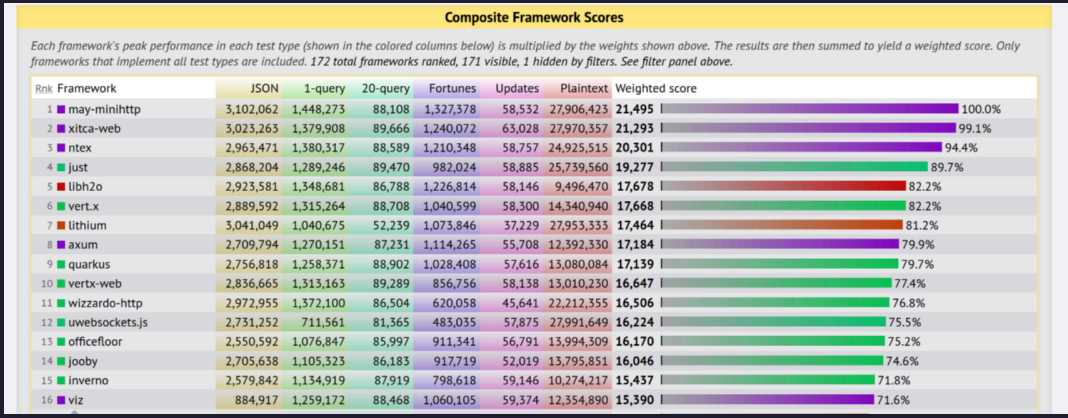
my coding style follows rust's programming principles, i.e error handling through result and option types, and a focus on readability and maintainability, i.e i use descriptive variable names, and i try to comment my code to explain why behind the code, i also try to use meaningful variable names, and i try to keep functions small and focused, i.e single responsibility.

for error handling i use result and option types, i try to handle errors in the frontend and backend, and i try to use meaningful error messages, and i try to keep the code clean and readable, allowing for easier debugging and maintenance, i use the thiserror crate to define custom a custom error type, `AppError`, which is used to handle all errors in the backend, i also use the axum crate to handle errors in the backend, additionally AppError implements `IntoResponse`, which allows for handling of errors with constructing HTTP and websocket responses.

one particular example of performance optimizations is in the Multiplayer Game Management section, I use the `tokio::select` macro to handle the websocket messages and game states, this allows for the websocket messages and game states to be handled concurrently, and the `tokio::sync::mpsc` crate to send the websocket to the game handler thread, this allows for the websocket to be sent to the game handler thread without blocking the main thread, the `tokio::select` macro brings great improvements to performance, as it is non-blocking and only runs when there is an available event.

additionally I have used rust, which is a systems programming language with performance on-par with c++ and alternatives, and used libraries known for high performance. particularly `axum`, which is currently the 8 fastest web framework, per the [techempower framework](https://www.techempower.com/benchmarks/#hw=ph&test=composite&section=data-r23) benchmark, and `tokio`, which is a high-performance asynchronous runtime for Rust. svelte is also known for performance, and is one of the fastest frontend framework for building user interfaces.

additionally i use scc Hashmaps, instead of rust's standard library hashmaps, which perform better in concurrent environments, and are more memory efficient.



**Composite Framework Scores**

*Each framework's peak performance in each test type (shown in the colored columns below) is multiplied by the weights shown above. The results are then summed to yield a weighted score. Only frameworks that implement all test types are included. 172 total frameworks ranked, 171 visible, 1 hidden by filters. See filter panel above.*

| Rnk | Framework | JSON | 1-query | 20-query | Fortunes | Updates | Plaintext | Weighted score |
|---|---|---|---|---|---|---|---|---|
| 1 | may-minihttp | 3,102,062 | 1,448,273 | 88,108 | 1,327,378 | 58,532 | 27,906,423 | 21,495 (100.0%) |
| 2 | xitca-web | 3,023,263 | 1,379,908 | 89,666 | 1,240,072 | 63,028 | 27,970,357 | 21,293 (99.1%) |
| 3 | ntex | 2,963,471 | 1,380,317 | 88,589 | 1,210,348 | 58,757 | 24,925,515 | 20,301 (94.4%) |
| 4 | just | 2,868,204 | 1,289,246 | 89,470 | 982,024 | 58,885 | 25,739,560 | 19,277 (89.7%) |
| 5 | libh2o | 2,923,581 | 1,348,681 | 86,788 | 1,226,814 | 58,146 | 9,496,470 | 17,678 (82.2%) |
| 6 | vert.x | 2,889,592 | 1,315,264 | 88,708 | 1,040,599 | 58,300 | 14,340,940 | 17,668 (82.2%) |
| 7 | lithium | 3,041,049 | 1,040,675 | 52,239 | 1,073,846 | 37,229 | 27,953,333 | 17,464 (81.2%) |
| 8 | axum | 2,709,794 | 1,270,151 | 87,231 | 1,114,265 | 55,708 | 12,392,330 | 17,184 (79.9%) |
| 9 | quarkus | 2,756,818 | 1,258,371 | 88,902 | 1,028,408 | 57,616 | 13,080,084 | 17,139 (79.7%) |
| 10 | vertx-web | 2,836,665 | 1,313,163 | 89,289 | 856,756 | 58,138 | 13,010,230 | 16,647 (77.4%) |
| 11 | wizzardo-http | 2,972,955 | 1,372,100 | 86,504 | 620,058 | 45,641 | 22,212,355 | 16,506 (76.8%) |
| 12 | uwebsockets.js | 2,731,252 | 711,561 | 81,365 | 483,035 | 57,875 | 27,991,649 | 16,224 (75.5%) |
| 13 | officefloor | 2,550,592 | 1,076,847 | 85,997 | 911,341 | 56,791 | 13,994,309 | 16,170 (75.2%) |
| 14 | jooby | 2,705,638 | 1,105,323 | 86,183 | 917,719 | 52,019 | 13,795,851 | 16,046 (74.6%) |
| 15 | inverno | 2,579,842 | 1,134,919 | 87,919 | 798,618 | 59,146 | 10,274,217 | 15,437 (71.8%) |
| 16 | viz | 884,917 | 1,259,172 | 88,468 | 1,060,105 | 59,374 | 12,354,890 | 15,390 (71.6%) |

Figure 17: TechEmpower Framework Benchmark

### 0.10.5. Source Code

#### 0.10.5.1. Grid Component

rust

```rust
<script lang="ts">
  import Clock from 'svelte-material-icons/Timer.svelte';
  import Trophy from 'svelte-material-icons/Trophy.svelte';
  import Dice from 'svelte-material-icons/Dice5.svelte';
  import Meow from 'svelte-material-icons/ViewGrid.svelte';
  import Party from 'svelte-material-icons/PartyPopper.svelte';
  import { browser } from '$app/environment';
  import { getContext, onMount } from 'svelte';
  import { json } from '@sveltejs/kit';
  import { v4 as uuidv4 } from 'uuid';
  import { Xoshiro256plus } from 'xoshiro';

  async function initWasm() {
    rng = new Xoshiro256plus(BigInt(69));
  }

  let rng: Xoshiro256plus;
  if (browser) {
    initWasm().catch(console.error);
  }
  export let showModal;
  let state: any = getContext('state');
  let scoreboard: any = 0;
  let end = true;
  let interval: any;
  let dasIntervals = Array(8).fill(0);
  let gameStarted = false;
  let gameId = 0;
  let time = $state.timeLimit;
  let score = 0;
  let quota = 0;
  let playersLeft = 0;
  let moves: any = [];
  let grid = Array(Math.pow($state.size, 2)).fill(false);
  let cGrid = Array(Math.pow($state.size, 2)).fill('neutral');
  let wcursorX = 0;
  let wcursorY = 0;
  let acursorX = $state.size - 1;
```

```
39  let acursorY = $state.size - 1;
40  let lastActionTime = 0;
41  let temp_id: String = '';
42  let ws: WebSocket;
43  const initGrid = () => {
44    gameStarted = false;
45    wcursorX = 0;
46    wcursorY = 0;
47    acursorX = $state.size - 1;
48    acursorY = $state.size - 1;
49
50    grid = Array(Math.pow($state.size, 2)).fill(false);
51  };
52  const endGame = () => {
53    score = 0;
54    time = $state.timeLimit;
55    wcursorX = 0;
56    wcursorY = 0;
57    acursorX = $state.size - 1;
58    acursorY = $state.size - 1;
59    moves = [];
60    clearInterval(interval);
61
62    // Close WebSocket if in multiplayer mode
63    if ($state.gameMode === 'multiplayer' && ws) {
64      ws.close();
65      temp_id = '';
66    }
67
68    initGrid();
69  };
70  const startGame = () => {
71    switch ($state.gameMode) {
72      case 'timer':
73        gameStarted = true;
74        startTimer();
75        break;
76      case 'multiplayer':
77        startMultiplayerGame();
78      // case 'pulse':
79      // case 'endless':
80    }
81  };
82  const startMultiplayerGame = () => {
83    if (ws) {
84      ws.close();
85    }
86    ws = new WebSocket('/ws/game');
87    ws.onopen = (e) => {
88      console.log('WebSocket opened');
89    };
90    ws.onmessage = (e) => {
91      const data = e.data;
92
93      try {
94        const message = JSON.parse(data);
95        switch (message.type) {
96          case 'Start':
```

```
            console.log('Game starting with seed:', message.data);
            gameStarted = true;
            rng = new Xoshiro256plus(BigInt(message.data));
            time = 5;
            wcursorX = 0;
            wcursorY = 0;
            acursorX = $state.size - 1;
            acursorY = $state.size - 1;
            interval = setInterval(() => {
              time -= 1;
              if (time <= 0) {
                clearInterval(interval);
              }
            }, 1000);
            fillGrid($state.size);
            break;
          case 'Quota':
            console.log(
              'Quota update:',
              message.data.quota,
              'players left:',
              message.data.players_left
            );
            quota = message.data.quota;
            playersLeft = message.data.players_left;
            time = 5;
            score = 0;
            clearInterval(interval);
            interval = setInterval(() => {
              time -= 1;
              if (time <= 0) {
                clearInterval(interval);
              }
            }, 1000);
            break;
          case 'Move':
            console.log('Received move:', message.data);
            break;
          case 'Out':
            console.log('player out placed', message.data);
            end = false;
            scoreboard = message.data;
            ws.close();
            break;
          case 'Win':
            console.log("you won!!!!", message.data);
            end = false;
            scoreboard = 1;
            ws.close();
            break;
          case 'ID':
            console.log('Received ID:', message.data);
            temp_id = message.data;
            break;
          case 'Ping':
            console.log('Received ping');
            break;
          default:
```

```
            console.log('Unknown message type:', message);
        }
      } catch (err) {
        console.error('Failed to parse message:', err);
      }
    };
    ws.addEventListener('close', (e) => {
      ws.close();
      temp_id = '';
    });
  };
  const startTimer = async () => {
    let data = { dimension: $state.size, time_limit: $state.timeLimit };
    await fetch('/api/get-seed', {
      method: 'POST',
      headers: {
        'Content-Type': 'application/json'
      },
      body: JSON.stringify(data)
    })
      .then((res) => {
        return res.json();
      })
      .then((data) => {
        rng = new Xoshiro256plus(BigInt(data.seed));
        gameId = data.id;
      });

    wcursorX = 0;
    wcursorY = 0;
    acursorX = $state.size - 1;
    acursorY = $state.size - 1;

    fillGrid($state.size);
    time = $state.timeLimit;
    interval = setInterval(async () => {
      time -= 1;
      if (time == 0) {
        end = false;
        await fetch('/api/submit-game', {
          method: 'POST',
          headers: {
            'Content-Type': 'application/json'
          },
          body: JSON.stringify({ id: gameId, moves: moves, score: score })
        })
          .then((res) => {
            return res.json();
          })
          .then((data) => {
            scoreboard = data;
          })
          .catch((err) => console.error('wahrt'));
        moves = [];
        clearInterval(interval);
      }
    }, 1000);
  };
```

```
  const submit = (time: any) => {
    if (!gameStarted && $state.gameMode === 'timer') {
      lastActionTime = Date.now();
      startGame();
      return;
    }
    if ($state.gameMode === 'timer') {
      moves.push(['Submit', time]);
    } else if ($state.gameMode === 'multiplayer') {
      ws.send(
        JSON.stringify({ type: 'Move', data: { player_id: `${temp_id}`, action: 'Submit' } })
      );
    }
    if (end) {
      let wIndex = wcursorX * $state.size + wcursorY;
      let aIndex = acursorX * $state.size + acursorY;
      let wStatus = grid[wIndex];
      let aStatus = grid[aIndex];
      if (wStatus && aStatus && (wcursorX !== acursorX || wcursorY !== acursorY)) {
        cGrid[wIndex] = 'correct';
        cGrid[aIndex] = 'correct';
        let count = 0;
        while (count < 2) {
          let x = Math.floor(rng.next() * $state.size);
          let y = Math.floor(rng.next() * $state.size);
          if (
            !grid[x * $state.size + y] &&
            (wIndex !== x * $state.size + y || aIndex !== x * $state.size + y)
          ) {
            grid[x * $state.size + y] = true;
            count += 1;
          }
        }
        grid[wIndex] = false;
        grid[aIndex] = false;
        score += 1;
      } else {
        if (wStatus && aStatus) {
          cGrid[wIndex] = 'incorrect';
        } else if (wStatus) {
          cGrid[aIndex] = 'incorrect';
          cGrid[wIndex] = 'correct';
        } else if (aStatus) {
          cGrid[wIndex] = 'incorrect';
          cGrid[aIndex] = 'correct';
        } else {
          cGrid[wIndex] = 'incorrect';
          cGrid[aIndex] = 'incorrect';
        }
        score = 0;
      }
      setTimeout(() => {
        cGrid[wIndex] = 'neutral';
        cGrid[aIndex] = 'neutral';
      }, 150);
    }
  };
  const onKeyUp = (e: any) => {
```

```
    let i = 0;
    switch (e.key) {
      case $state.keycodes.wU:
        i = 0;
        break;
      case $state.keycodes.wD:
        i = 1;
        break;
      case $state.keycodes.wL:
        i = 2;
        break;
      case $state.keycodes.wR:
        i = 3;
        break;
      case $state.keycodes.aU:
        i = 4;
        break;
      case $state.keycodes.aD:
        i = 5;
        break;
      case $state.keycodes.aL:
        i = 6;
        break;
      case $state.keycodes.aR:
        i = 7;
        break;
    }
    clearInterval(dasIntervals[i]);
    dasIntervals[i] = false;
  };
  const onKeyDown = (e: any) => {
    if (!gameStarted && $state.gameMode === 'multiplayer') {
      return;
    }
    const timeDiff = Date.now() - lastActionTime;
    switch (e.key) {
      case $state.keycodes.wU:
        if (dasIntervals[0] == false) {
          dasIntervals[0] = setTimeout(() => {
            dasIntervals[0] = setInterval(() => {
              wcursorY = Math.max(wcursorY - 1, 0);
              if ($state.gameMode === 'multiplayer') {
                ws.send(
                  JSON.stringify({
                    type: 'Move',
                    data: { player_id: `${temp_id}`, action: 'CursorBlueUp' }
                  })
                );
              }
              moves.push(['CursorBlueUp', Date.now() - lastActionTime]);
              lastActionTime = Date.now();
            }, $state.das);
          }, $state.dasDelay);
        }
        wcursorY = Math.max(wcursorY - 1, 0);
        if ($state.gameMode === 'multiplayer') {
          ws.send(
            JSON.stringify({
```

```
329               type: 'Move',
330               data: { player_id: `${temp_id}`, action: 'CursorBlueUp' }
331             })
332           );
333         }
334         moves.push(['CursorBlueUp', timeDiff]);
335         lastActionTime = Date.now();
336         break;
337       case $state.keycodes.wD:
338         if (dasIntervals[1] == false) {
339           dasIntervals[1] = setTimeout(() => {
340             dasIntervals[1] = setInterval(() => {
341               wcursorY = Math.min(wcursorY + 1, $state.size - 1);
342               if ($state.gameMode === 'multiplayer') {
343                 ws.send(
344                   JSON.stringify({
345                     type: 'Move',
346                     data: { player_id: `${temp_id}`, action: 'CursorBlueDown' }
347                   })
348                 );
349               }
350               moves.push(['CursorBlueDown', Date.now() - lastActionTime]);
351               lastActionTime = Date.now();
352             }, $state.das);
353           }, $state.dasDelay);
354         }
355         wcursorY = Math.min(wcursorY + 1, $state.size - 1);
356         if ($state.gameMode === 'multiplayer') {
357           ws.send(
358             JSON.stringify({
359               type: 'Move',
360               data: { player_id: `${temp_id}`, action: 'CursorBlueDown' }
361             })
362           );
363         }
364         moves.push(['CursorBlueDown', timeDiff]);
365         lastActionTime = Date.now();
366         break;
367       case $state.keycodes.wL:
368         if (dasIntervals[2] == false) {
369           dasIntervals[2] = setTimeout(() => {
370             dasIntervals[2] = setInterval(() => {
371               wcursorX = Math.max(wcursorX - 1, 0);
372               if ($state.gameMode === 'multiplayer') {
373                 ws.send(
374                   JSON.stringify({
375                     type: 'Move',
376                     data: { player_id: `${temp_id}`, action: 'CursorBlueLeft' }
377                   })
378                 );
379               }
380               moves.push(['CursorBlueLeft', Date.now() - lastActionTime]);
381               lastActionTime = Date.now();
382             }, $state.das);
383           }, $state.dasDelay);
384         }
385         wcursorX = Math.max(wcursorX - 1, 0);
386         if ($state.gameMode === 'multiplayer') {
```

```
          ws.send(
            JSON.stringify({
              type: 'Move',
              data: { player_id: `${temp_id}`, action: 'CursorBlueLeft' }
            })
          );
        }
        moves.push(['CursorBlueLeft', timeDiff]);
        lastActionTime = Date.now();
        break;
      case $state.keycodes.wR:
        if (dasIntervals[3] == false) {
          dasIntervals[3] = setTimeout(() => {
            dasIntervals[3] = setInterval(() => {
              wcursorX = Math.min(wcursorX + 1, $state.size - 1);
              if ($state.gameMode === 'multiplayer') {
                ws.send(
                  JSON.stringify({
                    type: 'Move',
                    data: { player_id: `${temp_id}`, action: 'CursorBlueRight' }
                  })
                );
              }
              moves.push(['CursorBlueRight', Date.now() - lastActionTime]);
              lastActionTime = Date.now();
            }, $state.das);
          }, $state.dasDelay);
        }
        wcursorX = Math.min(wcursorX + 1, $state.size - 1);
        if ($state.gameMode === 'multiplayer') {
          ws.send(
            JSON.stringify({
              type: 'Move',
              data: { player_id: `${temp_id}`, action: 'CursorBlueRight' }
            })
          );
        }
        moves.push(['CursorBlueRight', timeDiff]);
        lastActionTime = Date.now();
        break;
      case $state.keycodes.aU:
        if (dasIntervals[4] == false) {
          dasIntervals[4] = setTimeout(() => {
            dasIntervals[4] = setInterval(() => {
              acursorY = Math.max(acursorY - 1, 0);
              if ($state.gameMode === 'multiplayer') {
                ws.send(
                  JSON.stringify({
                    type: 'Move',
                    data: { player_id: `${temp_id}`, action: 'CursorRedUp' }
                  })
                );
              }
              moves.push(['CursorRedUp', Date.now() - lastActionTime]);
              lastActionTime = Date.now();
            }, $state.das);
          }, $state.dasDelay);
        }
```

```
        acursorY = Math.max(acursorY - 1, 0);
        if ($state.gameMode === 'multiplayer') {
          ws.send(
            JSON.stringify({
              type: 'Move',
              data: { player_id: `${temp_id}`, action: 'CursorRedUp' }
            })
          );
        }
        moves.push(['CursorRedUp', timeDiff]);
        lastActionTime = Date.now();
        break;
      case $state.keycodes.aD:
        if (dasIntervals[5] == false) {
          dasIntervals[5] = setTimeout(() => {
            dasIntervals[5] = setInterval(() => {
              acursorY = Math.min(acursorY + 1, $state.size - 1);
              if ($state.gameMode === 'multiplayer') {
                ws.send(
                  JSON.stringify({
                    type: 'Move',
                    data: { player_id: `${temp_id}`, action: 'CursorRedDown' }
                  })
                );
              }
              moves.push(['CursorRedDown', Date.now() - lastActionTime]);
              lastActionTime = Date.now();
            }, $state.das);
          }, $state.dasDelay);
        }
        acursorY = Math.min(acursorY + 1, $state.size - 1);
        if ($state.gameMode === 'multiplayer') {
          ws.send(
            JSON.stringify({
              type: 'Move',
              data: { player_id: `${temp_id}`, action: 'CursorRedDown' }
            })
          );
        }
        moves.push(['CursorRedDown', timeDiff]);
        lastActionTime = Date.now();
        break;
      case $state.keycodes.aL:
        if (dasIntervals[6] == false) {
          dasIntervals[6] = setTimeout(() => {
            dasIntervals[6] = setInterval(() => {
              acursorX = Math.max(acursorX - 1, 0);
              if ($state.gameMode === 'multiplayer') {
                ws.send(
                  JSON.stringify({
                    type: 'Move',
                    data: { player_id: `${temp_id}`, action: 'CursorRedLeft' }
                  })
                );
              }
              moves.push(['CursorRedLeft', Date.now() - lastActionTime]);
              lastActionTime = Date.now();
            }, $state.das);
```

```
          }, $state.dasDelay);
        }
        acursorX = Math.max(acursorX - 1, 0);
        if ($state.gameMode === 'multiplayer') {
          ws.send(
            JSON.stringify({
              type: 'Move',
              data: { player_id: `${temp_id}`, action: 'CursorRedLeft' }
            })
          );
        }
        moves.push(['CursorRedLeft', timeDiff]);
        lastActionTime = Date.now();
        break;
      case $state.keycodes.aR:
        if (dasIntervals[7] == false) {
          dasIntervals[7] = setTimeout(() => {
            dasIntervals[7] = setInterval(() => {
              acursorX = Math.min(acursorX + 1, $state.size - 1);
              if ($state.gameMode === 'multiplayer') {
                ws.send(
                  JSON.stringify({
                    type: 'Move',
                    data: { player_id: `${temp_id}`, action: 'CursorRedRight' }
                  })
                );
              }
              moves.push(['CursorRedRight', Date.now() - lastActionTime]);
              lastActionTime = Date.now();
            }, $state.das);
          }, $state.dasDelay);
        }
        acursorX = Math.min(acursorX + 1, $state.size - 1);
        if ($state.gameMode === 'multiplayer') {
          ws.send(
            JSON.stringify({
              type: 'Move',
              data: { player_id: `${temp_id}`, action: 'CursorRedRight' }
            })
          );
        }
        moves.push(['CursorRedRight', timeDiff]);
        lastActionTime = Date.now();
        break;
      case $state.keycodes.submit:
        submit(timeDiff);
        lastActionTime = Date.now();
        break;
      case $state.keycodes.reset:
        end == false ? (end = true) : '';
        endGame();
        break;
    }
  };
  const fillGrid = (count: number) => {
    let placed = 0;
    while (placed < count) {
      let x = Math.floor(rng.next() * $state.size);
```

```
      let y = Math.floor(rng.next() * $state.size);
      if (grid[x * $state.size + y] == false) {
        grid[x * $state.size + y] = true;
        placed += 1;
      }
    }
  };
  initGrid();
</script>

<div class="">
  {#if end}
    <div class="flex flex-row text-3xl text-text justify-between py-2">
      <div class="flex flex-row items-center">
        <Clock />
        <div class="px-2 {time < 3 ? (time < 2 ? 'text-red' : 'text-peach') : 'text-green'}">
          {time}
        </div>
      </div>
      <div class="flex flex-row items-center">
        <Trophy />
        <div class="px-2">
          {$state.gameMode === 'multiplayer' ? `${score}/${quota} (${playersLeft})` : score}
        </div>
      </div>
    </div>
    <div class="flex flex-col items-center">
      <div class="relative w-fit h-fit">
        {#if $state.gameMode === 'multiplayer' && (!temp_id || !gameStarted)}
          <div
            class="absolute top-0 left-0 right-0 bottom-[4.5rem] flex items-center justify-center
z-10 bg-base/80"
          >
            {#if !temp_id}
              <button
                class="px-4 py-2 rounded-lg transition-colors duration-300 bg-lavender text-mantle
hover:bg-rosewater"
                on:click={startMultiplayerGame}
              >
                Join Game
              </button>
            {:else}
              <div class="text-text text-3xl flex flex-col items-center gap-4">
                <div class="flex items-center gap-2">Waiting for players...</div>
              </div>
            {/if}
          </div>
        {/if}
        <!-- svelte-ignore a11y-autofocus -->
          <div class="w-fit h-fit flex flex-col" autofocus>
            {#each Array($state.size) as _, col}
              <div class="w-fit h-fit flex flex-row">
                {#each Array($state.size) as _, row}
                  <div
                    id={grid[row * $state.size + col]}
                    class="{cGrid[row * $state.size + col] === 'correct'
                      ? 'bg-green'
                      : cGrid[row * $state.size + col] === 'incorrect'
```

```
                        ? 'bg-red'
                        : grid[row * $state.size + col]
                          ? 'bg-crust'
                          : 'bg-text'}

                w-32 h-32 border-crust border flex items-center justify-center transition-colors duration-100"
                  >
                    <div
                      class="h-8 w-8 {row == wcursorX && col == wcursorY
                        ? 'border-t-blue border-l-blue border-t-8 border-l-8'
                        : ''}  {row == acursorX && col == acursorY
                        ? 'border-b-red border-r-red border-b-8 border-r-8'
                        : ''}"
                    />
                  </div>
                {/each}
              </div>
            {/each}
            <div class="text-text flex flex-row text-2xl py-4 justify-between">
              <div class="flex flex-row">
                <select
                  id="gamemodes"
                  name="modes"
                  class="bg-surface0 px-2"
                  bind:value={$state.gameMode}
                >
                  <label for="gamemodes" class="pr-4"> GAMEMODE: </label>
                  <option value="timer"> TIME </option>
                  <option value="multiplayer"> MULTIPLAYER </option>
                  <option value="endless"> ZEN </option>
                </select>
              </div>
              <select
                id="size"
                name="sizes"
                class="bg-surface0 px-2"
                bind:value={$state.size}
                on:change={() => {
                  endGame();
                }}
              >
                <option value={4}> 4x4 </option>
                <option value={5}> 5x5 </option>
                <option value={6}> 6x6 </option>
              </select>
              <select
                id="time"
                name="times"
                class="bg-surface0 px-2 {$state.gameMode == 'timer'
                  ? 'bg-surface0'
                  : 'bg-surface0/0 text-crust/0'}"
                bind:value={$state.timeLimit}
                on:change={() => {
                  time = $state.timeLimit;
                  endGame();
                }}
              >
```

```
674                <option value={30}> 30s </option>
675                <option value={45}> 45s </option>
676                <option value={60}> 60s </option>
677              </select>
678              <button class="bg-surface0 px-2" on:click={endGame}> RESET </button>
679            </div>
680          </div>
681      </div>
682    </div>
683  {:else}
684    <div class="text-text flex align-right flex-col w-96">
685      <div class="text-5xl py-2 font-bold flex items-center border-b-4 border-b-subtext0">
686        <Party class="mr-4" />game ended
687      </div>
688      <div class="text-4xl py-2 flex items-center justify-between">
689        score: {score}
690        <div class="text-overlay1">
691          {#if $state.gameMode === 'multiplayer' && scoreboard > 0}
692            Position: #{scoreboard}
693          {:else}
694            #{scoreboard}
695          {/if}
696        </div>
697      </div>
698      <div class="flex-col items-center text-3xl justify-between pb-2">
699        <div class="flex items-center my-1">
700          <Dice /> gamemode:
701          <div class="ml-1 text-overlay1">{$state.gameMode}</div>
702        </div>
703        <div class="flex items-center my-1">
704          <Meow /> size:
705          <div class="ml-1 text-overlay1">{$state.size}x{$state.size}</div>
706        </div>
707        <div class="flex items-center my-1">
708          {#if $state.gameMode == 'timer'}
709            <Clock /> time:
710            <div class="ml-1 text-overlay1">{$state.timeLimit}s</div>
711          {/if}
712        </div>
713      </div>
714      <button
715        class="text-2xl h-12 my-2 bg-blue/80 hover:bg-blue border-rosewater transition-colors
    duration-150 font-bold"
716        on:click={() => {
717          end = true;
718          endGame();
719        }}
720      >
721        submit score?
722      </button>
723      <button
724        class="text-2xl h-12 my-2 bg-mauve/80 hover:bg-mauve border-rosewater transition-colors
    duration-150 font-bold"
725        on:click={() => {
726          end = true;
727          endGame();
728        }}
729      >
```

```
730         play again?
731       </button>
732     </div>
733   {/if}
734 </div>
735
736 <svelte:window on:keydown={onKeyDown} on:keyup={onKeyUp} />
737
738
739
740
741
```

#### 0.10.5.2. Authentication

##### 0.10.5.2.1. Frontend

svlt

```svlt
1  <script lang="ts">
2      import { goto, invalidateAll } from "$app/navigation";
3      let isSignup = true;
4      let error = "";
5
6      async function handleSubmit(e: SubmitEvent) {
7        e.preventDefault();
8        let data = new URLSearchParams(new FormData(e.target as HTMLFormElement));
9        let path = isSignup ? "/api/user/signup" : "/api/user/login";
10       const res = await fetch(path, {
11         method: "POST",
12         headers: {
13           "Content-Type": "application/x-www-form-urlencoded",
14         },
15         body: data,
16       });
17       if (res?.ok) {
18         await invalidateAll();
19         goto("/");
20       } else {
21         switch (res?.status) {
22           case 409:
23             error = "Username or email already exists";
24             break;
25           case 401:
26             error = "Invalid credentials";
27             break;
28           case 404:
29             error = "not found";
30             break;
31           default:
32             error = "An unknown error occurred";
33             break;
34         }
35       }
36     }
37   </script>
38
39   <div class="min-h-screen w-screen flex items-center justify-center bg-base">
40     <div class="w-full max-w-md mx-4 bg-mantle rounded-xl shadow-xl p-8">
```

```
41      {#if isSignup}
42        <div class="flex flex-col gap-8">
43          <div class="text-center">
44            <h1 class="text-3xl font-medium text-lavender mb-2">Create Account</h1>
45          </div>
46          <form on:submit={handleSubmit} class="flex flex-col gap-6">
47            <div class="flex flex-col gap-4">
48              <input
49                type="text"
50                name="username"
51                placeholder="Username"
52                class="w-full px-4 py-3 rounded-lg bg-base text-text border border-surface0
   focus:border-lavender transition-colors"
53              />
54              <input
55                type="password"
56                name="password"
57                placeholder="Password"
58                class="w-full px-4 py-3 rounded-lg bg-base text-text border border-surface0
   focus:border-lavender transition-colors"
59              />
60            </div>
61            {#if error}
62              <div class="bg-red/10 border border-red/20 text-red px-4 py-3 rounded-lg text-sm">
63                {error}
64              </div>
65            {/if}
66            <button
67              type="submit"
68              class="w-full px-4 py-3 rounded-lg font-medium bg-lavender text-mantle hover:bg-
   rosewater transition-colors"
69            >
70              Sign Up
71            </button>
72          </form>
73          <button
74            on:click={() => (isSignup = false)}
75            class="text-subtext0 hover:text-text transition-colors pt-2"
76          >
77            Already have an account? Login here
78          </button>
79        </div>
80      {:else}
81        <div class="flex flex-col gap-8">
82          <div class="text-center">
83            <h1 class="text-3xl font-medium text-lavender mb-2">Welcome Back!</h1>
84          </div>
85          <form on:submit={handleSubmit} class="flex flex-col gap-6">
86            <div class="flex flex-col gap-4">
87              <input
88                type="username"
89                name="username"
90                placeholder="Username"
91                class="w-full px-4 py-3 rounded-lg bg-base text-text border border-surface0
   focus:border-lavender transition-colors"
92              />
93              <input
94                type="password"
```

```
                name="password"
                placeholder="Password"
                class="w-full px-4 py-3 rounded-lg bg-base text-text border border-surface0
focus:border-lavender transition-colors"
              />
            </div>
            {#if error}
              <div class="bg-red/10 border border-red/20 text-red px-4 py-3 rounded-lg text-sm">
                {error}
              </div>
            {/if}
            <button
              type="submit"
              class="w-full px-4 py-3 rounded-lg font-medium bg-lavender text-mantle hover:bg-
rosewater transition-colors"
            >
              Login
            </button>
          </form>
          <button
            on:click={() => (isSignup = true)}
            class="text-subtext0 hover:text-text transition-colors pt-2"
          >
            Don't have an account? Sign up here
          </button>
        </div>
      {/if}
    </div>
  </div>
```

#### 0.10.5.2.2. Backend

rust

```rust
pub struct SignForm {
    pub(crate) username: String,
    #[validate(length(min = 8))]
    pub(crate) password: String,
}

#[axum::debug_handler]
pub async fn signup(
    State(state): State<Arc<AppState>>,
    headers: HeaderMap,
    Form(details): Form<SignForm>,
) -> Result<CookieJar, AppError> {
    let mut conn = state.db.acquire().await?;
    let jar = CookieJar::from_headers(&headers);
    let exists: Option<(i64,)> = sqlx::query_as("SELECT 1 FROM \"user\" WHERE username = $1")
        .bind(&details.username)
        .fetch_optional(&mut *conn)
        .await?;

    if exists.is_some() {
        return Err(AppError::Status(StatusCode::CONFLICT));
    }

    let hashed = bcrypt::hash(details.password, bcrypt::DEFAULT_COST)?;
    let user_id = uuid::Uuid::new_v4();
```

```
26
27      sqlx::query!(
28          "INSERT INTO \"user\" (id, username, password) VALUES ($1, $2, $3)",
29          user_id,
30          details.username,
31          hashed
32      )
33      .execute(&mut *conn)
34      .await?;
35
36      let session_id = uuid::Uuid::new_v4();
37      sqlx::query!(
38          "INSERT INTO session (ssid, user_id, expiry_date) VALUES ($1, $2, NOW() + INTERVAL '7
    DAYS')",
39          session_id,
40          user_id
41      )
42      .execute(&mut *conn)
43      .await?;
44
45      Ok(jar.add(
46          Cookie::build(("session", session_id.to_string()))
47              .path("/")
48              .build(),
49      ))
50  }
51
52  pub async fn login(
53      State(state): State<Arc<AppState>>,
54      jar: CookieJar,
55      Form(details): Form<SignForm>,
56  ) -> Result<CookieJar, AppError> {
57      let mut conn = state.db.acquire().await?;
58
59      let user: Option<(uuid::Uuid, String)> =
60          sqlx::query_as("SELECT id, password FROM \"user\" WHERE username = $1")
61              .bind(&details.username)
62              .fetch_optional(&mut *conn)
63              .await?;
64
65      let (user_id, hashed) = user.ok_or(AppError::Status(StatusCode::UNAUTHORIZED))?;
66
67      if !bcrypt::verify(details.password, &hashed)? {
68          return Err(AppError::Status(StatusCode::UNAUTHORIZED));
69      }
70
71      let session_id = uuid::Uuid::new_v4();
72      sqlx::query!(
73          "INSERT INTO session (ssid, user_id, expiry_date) VALUES ($1, $2, NOW() + INTERVAL '7
    DAYS')",
74          session_id,
75          user_id
76      )
77      .execute(&mut *conn)
78      .await?;
79
80      Ok(jar.add(
81          Cookie::build(("session", session_id.to_string()))
```

```rust
            .path("/")
            .build(),
    ))
}

#[axum::debug_middleware]
pub async fn authorization(
    State(state): State<Arc<AppState>>,
    headers: HeaderMap,
    mut request: Request,
    next: Next,
) -> Result<Response, AppError> {
    let jar = CookieJar::from_headers(&headers);
    let user = if let Some(cookie) = jar.get("session") {
        if let Ok(session_id) = uuid::Uuid::parse_str(cookie.value()) {
            let mut conn = state.db.acquire().await?;
            sqlx::query_as!(
                crate::models::UserExt,
                r#"
                SELECT u.id, u.username, u.admin, u.cheater
                FROM "user" u
                INNER JOIN session s ON u.id = s.user_id
                WHERE s.ssid = $1 AND s.expiry_date > NOW()
                "#,
                session_id
            )
            .fetch_optional(&mut *conn)
            .await?
        } else {
            None
        }
    } else {
        None
    };

    request.extensions_mut().insert(user);
    let response = next.run(request).await;
    Ok(response)
}
```

#### 0.10.5.3. Queue

```rust
#[derive(Debug)]
pub struct Queue<T> {
    items: [Option<T>; 64],
    pub size: usize,
    front: usize,
}

impl<T> Queue<T> {
    pub fn new() -> Self {
        Self {
            items: std::array::from_fn(|_| None),
            size: 0,
            front: 0,
        }
    }
```

```

    pub fn enqueue(&mut self, item: T) -> bool {
        if self.size == self.items.len() {
            return false;
        }
        let rear = (self.front + self.size) % self.items.len();
        self.items[rear] = Some(item);
        self.size += 1;
        true
    }

    pub fn dequeue(&mut self) -> Option<T> {
        if self.size == 0 {
            return None;
        }
        let item = self.items[self.front].take();
        self.front = (self.front + 1) % self.items.len();
        self.size -= 1;
        item
    }
}

impl<T> Default for Queue<T> {
    fn default() -> Self {
        Self::new()
    }
}
```

### 0.10.5.4. Leaderboard

svlt

```
<script lang="ts">
  import { onMount } from 'svelte';

  let dimension = 4;
  let timeLimit = 30;
  let leaderboard: Array<[string, number]> = [];
  let currentPage = 1;
  let userOwned = false;
  onMount(() => {
    fetchScores();
  });

  async function fetchScores() {
    const res = await fetch(`/api/get_scores`, {
      method: 'POST',
      headers: { 'Content-Type': 'application/json' },
      body: JSON.stringify({ page: currentPage, dimension, time_limit: timeLimit, user_scores:
userOwned }),
    });
    const data = await res.json();
    leaderboard = mergesort(data);
  }

```

```
23   function mergesort(arr: Array<[string, number]>): Array<[string, number]> {
24     if (arr.length < 2) return arr;
25     const mid = Math.floor(arr.length / 2);
26     const left = mergesort(arr.slice(0, mid));
27     const right = mergesort(arr.slice(mid));
28     return merge(left, right);
29   }
30
31   function merge(left: Array<[string, number]>, right: Array<[string, number]>): Array<[string,
   number]> {
32     let result = [];
33     while (left.length && right.length) {
34       if (left[0][1] > right[0][1]) {
35         result.push(left.shift());
36       } else {
37         result.push(right.shift());
38       }
39     }
40     return [...result, ...left, ...right];
41   }
42   //TODO make the dimension and timelimit a select
43 </script>
44
45 <div class="min-h-screen bg-mantle text-text p-8">
46   <div class="text-3xl font-bold mb-6">Leaderboards</div>
47   <div class="flex gap-4 items-center mb-6">
48     <div class="font-semibold">Dimension:</div>
49     <select id="size" name="dimension" class="bg-surface0 px-2" bind:value={dimension}>
50       <option value={4}> 4x4 </option>
51       <option value={5}> 5x5 </option>
52       <option value={6}> 6x6 </option>
53     </select>
54     <div class="font-semibold">Time Limit:</div>
55     <select id="size" name="dimension" class="bg-surface0 px-2" bind:value={timeLimit}>
56       <option value={30}> 30s </option>
57       <option value={45}> 45s </option>
58       <option value={60}> 60s </option>
59     </select>
60     <div class="font-semibold">Personal Bests:</div>
61     <input type="checkbox" bind:checked={userOwned} class="bg-surface0 px-2">
62     <button on:click={fetchScores} class="px-4 py-1 rounded bg-green text-text font-semibold
   hover:bg-sky">Refresh</button>
63   </div>
64   <table class="min-w-full border-collapse">
65     <thead class="bg-[#1e2030]">
66       <tr>
67         <th class="px-4 py-2 border border-text">Username</th>
68         <th class="px-4 py-2 border border-text">Score</th>
69       </tr>
70     </thead>
71     <tbody>
72       {#each leaderboard as [user, score]}
73         <tr class="hover:bg-text">
74           <td class="px-4 py-2 border border-text">{user}</td>
75           <td class="px-4 py-2 border border-text">{score}</td>
76         </tr>
77       {/each}
78     </tbody>
```

```
  </table>
  <div>
    <button on:click={() => {currentPage -= 1; fetchScores()}} disabled={currentPage === 1} > back </button>
    {currentPage}
    <button on:click={() => {currentPage += 1; fetchScores()}}  > next </button>
  </div>
</div>
```

rust

```rust

#[derive(Serialize, Deserialize, sqlx::FromRow)]
pub struct Score {
    username: String,
    score: Option<i16>,
}

#[derive(Serialize, Deserialize)]
pub struct GetScore {
    page: u32,
    dimension: u8,
    time_limit: u8,
    user_scores: bool,
}

#[axum::debug_handler]
pub async fn get_scores(
    State(state): State<Arc<AppState>>,
    Extension(user): Extension<Option<UserExt>>,
    Json(data): Json<GetScore>,
) -> Result<Json<Vec<(String, usize)>>, AppError> {
    let query_string = if data.user_scores && user.is_some() {
        r#"
        SELECT "game".score, "user".username
        FROM "game"
        JOIN "user" ON "game".user_id = "user".id
        WHERE dimension = $1
        AND time_limit = $2
        AND "user".id = $4
        ORDER BY score
        OFFSET ($3 - 1) * 100
        FETCH NEXT 100 ROWS ONLY
        "#
    } else {
        r#"
        SELECT "game".score, "user".username
        FROM "game"
        JOIN "user" ON "game".user_id = "user".id
        WHERE dimension = $1
        AND time_limit = $2
        ORDER BY score
        OFFSET ($3 - 1) * 100
        FETCH NEXT 100 ROWS ONLY
        "#
    };
    let user_id = match user.is_some() {
        true => user.unwrap().id,
        false => uuid::Uuid::new_v4(),
```

```
    };
    let res: Vec<(String, usize)> = sqlx::query_as::<_, Score>(query_string)
        .bind(data.dimension as i32)
        .bind(data.time_limit as i32)
        .bind(data.page as i32)
        .bind(user_id)
        .fetch_all(&mut *state.db.acquire().await?)
        .await?
        .iter()
        .map(|x| (x.username.clone(), x.score.unwrap() as usize))
        .collect();
    Ok(Json(res))
}
```

### 0.10.5.5. Server Routing

rust

```rust
[tokio::main]
async fn main() {
    // basic initialization
    dotenvy::dotenv().ok();

    let database_url = std::env::var("DATABASE_URL").expect("DB_URL must be set");

    let pool = PgPool::connect(&database_url).await.unwrap();

    tracing_subscriber::fmt::init();

    let state = Arc::new(AppState {
        games: Mutex::new(HashMap::new()),
        game_manager: GameManager {
            user_games: Arc::new(Mutex::new(Queue::<(
                ulid::Ulid,
                tokio::sync::mpsc::Sender<WebSocket>,
            )>::new())),
            cheater_games: Arc::new(Mutex::new(Queue::<(
                ulid::Ulid,
                tokio::sync::mpsc::Sender<WebSocket>,
            )>::new())),
            anon_games: Arc::new(Mutex::new(Queue::<(
                ulid::Ulid,
                tokio::sync::mpsc::Sender<WebSocket>,
            )>::new())),
        },
        db: pool,
    });
    let app = Router::new()
        .route("/get-seed", post(create_seed))
        .route("/submit-game", post(submit_game))
        .route("/game", any(ws_upgrader))
        .route("/get_scores", post(misc::get_scores))
        .route("/user/signup", post(misc::signup))
        .route("/user/login", post(misc::login))
        .layer(middleware::from_fn_with_state(
            state.clone(),
            misc::authorization,
        ))
        .with_state(state)
```

```
42         .layer(CorsLayer::permissive())
43         .layer(TraceLayer::new_for_http());
44 
45     let listener = tokio::net::TcpListener::bind("0.0.0.0:3000").await.unwrap();
46     axum::serve(listener, app).await.unwrap();
47 }
```

### 0.10.5.6. Singleplayer Game Management

rust

```rust
/// enum representing all possible moves done by the client
#[repr(u8)]
#[derive(Serialize, Deserialize, Debug, PartialEq, Eq, Clone, Copy)]
pub enum Move {
    CursorRedUp,
    CursorRedDown,
    CursorRedLeft,
    CursorRedRight,
    CursorBlueUp,
    CursorBlueDown,
    CursorBlueLeft,
    CursorBlueRight,
    Submit,
}
#[derive(Serialize, Deserialize)]
pub struct GameForm {
    dimension: u8,
    time_limit: u8,
}

#[derive(Debug, Copy, Clone)]
pub struct GameState {
    seed: u32,
    dimension: u8,
    time_limit: Duration,
    start_time: Instant,
}

#[derive(Serialize)]
pub struct Seed {
    id: String,
    seed: u32,
}
#[derive(Serialize, Deserialize, Debug)]
pub struct GameEnd {
    id: String,
    score: u32,
    //u32 is time difference in ms
    moves: Vec<(Move, u32)>,

}

/// creates a new seed using the implemented splitmix and xoshiro256+ algorithms from sillyrng
#[axum::debug_handler]
pub async fn create_seed(
    State(state): State<Arc<AppState>>,
    Json(form): Json<GameForm>,
) -> (StatusCode, Json<Seed>) {
```

```rust
    let game_id = ulid::Ulid::new();
    let seed = rand::random::<u32>();
    let game_state = GameState {
        seed,
        dimension: form.dimension,
        time_limit: Duration::from_secs(form.time_limit.into()),
        start_time: Instant::now(),
    };

    println!(
        "Creating game {} with dimension {} and time limit {}s",
        game_id, form.dimension, form.time_limit
    );

    state.games.lock().await.insert(game_id, game_state);

    let res = Json(Seed {
        id: game_id.to_string(),
        seed,
    });

    (StatusCode::OK, res)
}

#[axum::debug_handler]
pub async fn submit_game(
    State(state): State<Arc<AppState>>,
    Extension(user): Extension<Option<UserExt>>,
    Json(game): Json<GameEnd>,
) -> Result<(StatusCode, Json<u32>), AppError> {
    println!(
        "Received submission for game {} with {} moves",
        game.id,
        game.moves.len()
    );

    let id = ulid::Ulid::from_string(&game.id).unwrap();
    let lock = state.games.lock().await;
    let mut conn = state.db.acquire().await?;
    let details = lock.get(&id).unwrap();


    let elapsed = Instant::now().duration_since(details.start_time);
    if elapsed > details.time_limit + Duration::from_secs(3) {
        println!("Game {} exceeded time limit ({}s + 3s)", game.id, details.time_limit.as_secs());
        return Ok((StatusCode::NOT_ACCEPTABLE, Json(0)));
    }

    let time = verify_timings(game.moves.iter().map(|(_, m)| *m).collect(), state.clone()).await;

    if !time.0 {
        println!("Rejected game {} due to suspicious timings", game.id);
        return Ok((StatusCode::NOT_ACCEPTABLE, Json(0)));
    }
    let score = match verify_moves(
        game.moves.iter().map(|(m, _)| *m).collect(),
        details.dimension,
        details.seed,
```

```
    )
    .await
    {
        Ok(s) => s,
        Err(e) => {
            println!("{:?}", e);
            // TODO anomalous game pushing
            return Ok((StatusCode::NOT_ACCEPTABLE, Json(0)));
        }
    };
    if score == game.score {
        if let Some(u) = user {
            println!(
                "Game {} submitted with score {}, user exists : {}",
                game.id,
                score,
                u.clone().username
            );
            sqlx::query!("INSERT INTO
    \"game\" (game_id,score,average_time,dimension,time_limit,user_id) VALUES ($1,$2,$3,$4,$5,
    $6)",uuid::Uuid::new_v4(),score as i32,time.1, details.dimension as i32,30,u.id).execute(&mut
    *conn).await?;
        }
        Ok((StatusCode::OK, Json(score)))
    } else {
        Ok((StatusCode::NOT_ACCEPTABLE, Json(0)))
    }
}

pub async fn verify_moves(moves: Vec<Move>, size: u8, seed: u32) -> Result<u32, String> {
    //this is assuming we start at 0,0 and size,size (should be a client side force, now enforced)
    let mut rng = sillyrng::Xoshiro256plus::new(Some(seed as u64));
    let mut grid: Vec<bool> = vec![false; (size * size) as usize];
    let mut blue_coords: (u8, u8) = (0, 0);
    let mut red_coords: (u8, u8) = (size - 1, size - 1);
    let mut score = 0;
    let mut distance = 0;
    let mut anomalous_distances = 0;
    let mut optimal_distance = 0;
    let mut count = 0;
    while count < size {
        let x: u8 = (rng.next() * size as f64).floor() as u8;
        let y: u8 = (rng.next() * size as f64).floor() as u8;
        if grid[(x * size + y) as usize] == false {
            grid[(x * size + y) as usize] = true;
            count += 1;
        }
    }
    for i in moves.iter() {
        match i {
            Move::CursorRedUp => {
                red_coords.1 = (red_coords.1 as i8 - 1).max(0) as u8;
                distance += 1;
            }
            Move::CursorRedDown => {
                red_coords.1 = (red_coords.1 + 1).min(size - 1);
                distance += 1;
            }
```

```
            Move::CursorRedLeft => {
                red_coords.0 = (red_coords.0 as i8 - 1).max(0) as u8;
                distance += 1;
            }
            Move::CursorRedRight => {
                red_coords.0 = (red_coords.0 + 1).min(size - 1);
                distance += 1;
            }
            Move::CursorBlueUp => {
                blue_coords.1 = (blue_coords.1 as i8 - 1).max(0) as u8;
                distance += 1;
            }
            Move::CursorBlueDown => {
                blue_coords.1 = (blue_coords.1 + 1).min(size - 1);
                distance += 1;
            }
            Move::CursorBlueLeft => {
                blue_coords.0 = (blue_coords.0 as i8 - 1).max(0) as u8;
                distance += 1;
            }
            Move::CursorBlueRight => {
                blue_coords.0 = (blue_coords.0 + 1).min(size - 1);
                distance += 1;
            }
            Move::Submit => {
                if distance <= optimal_distance {
                    anomalous_distances += 1;
                }
                distance = 0;

                if grid[(red_coords.0 * size + red_coords.1) as usize]
                    && grid[(blue_coords.0 * size + blue_coords.1) as usize]
                    && !(blue_coords == red_coords)
                {
                    score += 1;
                    let mut count = 0;
                    let r = red_coords.0 * size + red_coords.1;
                    let b = blue_coords.0 * size + blue_coords.1;
                    while count < 2 {
                        let x: u8 = (rng.next() * size as f64).floor() as u8;
                        let y: u8 = (rng.next() * size as f64).floor() as u8;
                        if !grid[(x * size + y) as usize]
                            && (x * size + y != r || x * size + y != b)
                        {
                            grid[(x * size + y) as usize] = true;
                            count += 1;
                        }
                    }
                    grid[r as usize] = false;
                    grid[b as usize] = false;
                    optimal_distance =
                        get_optimal_paths(grid.clone(), red_coords, blue_coords, size)
                            .await
                            .iter()
                            .min()
                            .unwrap_or(&0)
                            .to_owned();
                } else {
```

```
                    score = 0
                }
            }
        }
    }
    println!(
        "Game completed with score {} (anomaly ratio: {:.2})",
        score,
        anomalous_distances as f64 / score as f64
    );
    Ok(score)
}


pub async fn get_optimal_paths(grid: Vec<bool>, r: (u8, u8), b: (u8, u8), size: u8) -> Vec<u32> {
    let mut paths = Vec::new();
    for i in 0..grid.len() {
        for j in 0..grid.len() {
            if grid[i] && grid[j] && i != j {
                let r_cell = ((i / size as usize) as u8, (i % size as usize) as u8);
                let b_cell = ((j / size as usize) as u8, (j % size as usize) as u8);
                let r_dist = (r.0.abs_diff(r_cell.0) + r.1.abs_diff(r_cell.1)) as u32;
                let b_dist = (b.0.abs_diff(b_cell.0) + b.1.abs_diff(b_cell.1)) as u32;
                paths.push(r_dist + b_dist);
            }
        }
    }
    paths
}

```

### 0.10.5.7. Backend Error Handling

rust

```rust
use axum::http::{Response, StatusCode};
use axum::response::IntoResponse;
use bcrypt::BcryptError;
use thiserror::Error;
#[derive(Error, Debug)]
pub enum AppError {
    #[error("statuscode")]
    Status(StatusCode),
    #[error("bcrypt error")]
    Hash(#[from] BcryptError),
    #[error("Ulid Encode Error")]
    UEncode(#[from] ulid::EncodeError),
    #[error("Ulid Decode Error")]
    UDecode(#[from] ulid::DecodeError),
    #[error("failed to deserialize")]
    Json(#[from] serde_json::Error),
    #[error("pool failed to execute")]
    Pool(#[from] sqlx::Error),
}

impl IntoResponse for AppError {
    fn into_response(self) -> axum::response::Response {
        let (body, code) = match self {
            AppError::Status(e) => ("", e),
```

```
            _ => ("Unknown", StatusCode::INTERNAL_SERVER_ERROR),
        };
        Response::builder().status(code).body(body.into()).unwrap()
    }
}
```

### 0.10.5.8. Database Models

```rust
#[derive(serde::Serialize, serde::Deserialize, Clone)]
pub struct User {
    pub id: uuid::Uuid,
    pub password: String,
    pub username: String,
    pub admin: Option<bool>,
    pub cheater: Option<bool>,
}

#[derive(serde::Serialize, serde::Deserialize, Clone, Debug)]
pub struct UserExt {
    pub id: uuid::Uuid,
    pub username: String,
    pub admin: Option<bool>,
    pub cheater: Option<bool>,
}

#[derive(serde::Serialize, serde::Deserialize)]
pub struct UserStatistics {
    pub stat_id: uuid::Uuid,
    pub highest_score: Option<i16>,
    pub victories: Option<i16>,
    pub games_played: Option<i16>,
    pub elo: Option<i16>,
    pub user_id: uuid::Uuid,
}

#[derive(serde::Serialize, serde::Deserialize)]
pub struct Game {
    pub game_id: uuid::Uuid,
    pub score: Option<i16>,
    pub average_time: Option<f32>,
    pub dimension: Option<i16>,
    pub time_limit: Option<i16>,
    pub user_id: uuid::Uuid,
}

#[derive(serde::Serialize, serde::Deserialize)]
pub struct Statistics {
    pub stat_id: uuid::Uuid,
    pub total_timings: Option<f32>,
    pub total_score: Option<i64>,
    pub games_played: Option<i64>,
}

#[derive(serde::Serialize, serde::Deserialize)]
```

```rust
pub struct AnomalousGames {
    pub agame_id: uuid::Uuid,
    pub moves: serde_json::Value,
    pub user_id: uuid::Uuid,
}

#[derive(serde::Serialize, serde::Deserialize)]
pub struct Session {
    pub ssid: uuid::Uuid,
    pub expiry_date: chrono::NaiveDate,
    pub user_id: uuid::Uuid,
}
```

### 0.10.5.9. Multiplayer game management

```rust
pub async fn ws_upgrader(
    ws: WebSocketUpgrade,
    State(state): State<Arc<AppState>>,
    Extension(user): Extension<Option<UserExt>>,
) -> Response {
    // required due to state not implementing copy
    let cloned_state = state.clone();
    ws.on_upgrade(move |socket| ws_handler(socket, cloned_state, user))
}

pub async fn ws_handler(ws: WebSocket, state: Arc<AppState>, user: Option<UserExt>) {
    state.game_manager.clone().assign_game(ws, user).await
}

use axum::extract::ws::{Message, WebSocket};
use futures::stream::SplitSink;
use futures::{SinkExt, StreamExt, TryFutureExt};
use sillyrng::{Gen, Xoshiro256plus};
use std::{collections::HashMap, sync::Arc};
use tokio::select;
use tokio::sync::{mpsc, Mutex};
use tokio::time::{interval, Duration};
use ulid::Ulid;

use crate::misc::Queue;
use crate::models::UserExt;
use crate::Move;

#[derive(Clone)]
pub struct GameManager {
    pub user_games: Arc<Mutex<Queue<(ulid::Ulid, mpsc::Sender<WebSocket>)>>>,
    pub anon_games: Arc<Mutex<Queue<(ulid::Ulid, mpsc::Sender<WebSocket>)>>>,
    pub cheater_games: Arc<Mutex<Queue<(ulid::Ulid, mpsc::Sender<WebSocket>)>>>,
}

pub struct Game {
    players: HashMap<Ulid, Player>,
    inactive_players: HashMap<Ulid, Player>,
    seed: u32,
```

```rust
    quota: u32,
}

#[derive(Clone, Debug)]
pub struct Player {
    grid: [bool; 16],
    b_coords: (u8, u8),
    r_coords: (u8, u8),
    current_score: u8,
    rng: sillyrng::Xoshiro256plus,
}

#[derive(serde::Serialize, serde::Deserialize, Debug)]
pub struct MMove {
    player_id: Ulid,
    action: Move,
}

#[derive(serde::Serialize, serde::Deserialize)]
#[serde(tag = "type", content = "data")]
pub enum WsMessage {
    Move(MMove),
    Quota { quota: u32, players_left: u32 },
    ID(Ulid),
    Start(u32),
    Out(u32),
    Win,
    Ping,
}

impl GameManager {
    pub async fn assign_game(&self, ws: WebSocket, user: Option<UserExt>) {
        println!("Attempting to assign player to a game");
        let games = match user {
            Some(u) => {
                //innocent until proven guilty, very demure, very fashionable
                if u.cheater.unwrap_or(false) {
                    self.cheater_games.clone()
                } else {
                    self.user_games.clone()
                }
            }
            None => self.anon_games.clone(),
        };
        let mut attempts = games.lock().await.size;
        let mut ws = ws;
        while attempts > 0 {
            let mut lock = games.lock().await;
            if let Some(game) = lock.dequeue() {
                match game.1.send(ws).await {
                    Ok(()) => {
                        lock.enqueue(game.clone());
                        return;
                    }
                    Err(mpsc::error::SendError(rws)) => {
                        ws = rws;
                        attempts -= 1;
                    }
```

```
                }
            } else {
                break;
            }
        }

        let (tx, rx) = mpsc::channel(40);
        let game_id = Ulid::new();
        tokio::spawn(game_handler(game_id.clone(), rx));

        match tx.send(ws).await {
            Ok(_) => {
                println!("Created new game with ID: {}", game_id);
                games.lock().await.enqueue((game_id, tx));
            }
            Err(e) => {
                println!("failed to send to game error: {}", e);
            }
        };
    }
}


async fn game_handler(id: Ulid, mut rx: mpsc::Receiver<WebSocket>) {
    println!("Game {} initialized, waiting for players", id);
    let mut state = Game {
        players: HashMap::new(),
        inactive_players: HashMap::new(),
        seed: rand::random::<u32>(),
        quota: 0,
    };
    let mut senders: HashMap<Ulid, SplitSink<WebSocket, Message>> = HashMap::new();
    let mut receivers = vec![];
    while state.players.len() <= 5 {
        match rx.recv().await {
            Some(mut p) => {
                let meow_id = Ulid::new();
                println!("Player {} joined game {}", meow_id, id);
                p.send(axum::extract::ws::Message::Text(
                    serde_json::to_string(&WsMessage::ID(meow_id)).unwrap(),
                ))
                .await
                .unwrap();
                state.players.insert(
                    meow_id.clone(),
                    Player {
                        grid: [false; 16],
                        b_coords: (0, 0),
                        r_coords: (3, 3),
                        current_score: (0),
                        rng: Xoshiro256plus::new(Some(3)),
                    },
                );
                let (sender, receiver) = p.split();
                senders.insert(meow_id, sender);
                receivers.push(receiver);
            }
            None => {}
```

```
156         }
157     }
158
159     println!("Game {} starting with {} players", id, state.players.len());
160     for i in state.players.iter_mut() {
161         i.1.rng = Xoshiro256plus::new(Some(state.seed.clone() as u64));
162         let mut count = 0;
163         while count < 4 {
164             let x: u8 = (i.1.rng.next() * 4 as f64).floor() as u8;
165             let y: u8 = (i.1.rng.next() * 4 as f64).floor() as u8;
166             if i.1.grid[(x * 4 + y) as usize] == false {
167                 i.1.grid[(x * 4 + y) as usize] = true;
168                 count += 1;
169             }
170         }
171     }
172     for (_p, i) in senders.iter_mut() {
173         i.send(axum::extract::ws::Message::Text(
174             serde_json::to_string(&WsMessage::Start(state.seed)).unwrap(),
175         ))
176         .await
177         .unwrap();
178     }
179
180     println!("Game {} is now running", id);
181     let mut interval = interval(Duration::from_secs(5));
182
183     loop {
184         let websocket_futures = futures::future::select_all(
185             receivers
186                 .iter_mut()
187                 .enumerate()
188                 .map(|(i, ws)| Box::pin(async move { (i, ws.next().await) })),
189         );
190
191         select! {
192             (result, _, _) = websocket_futures => {
193                 let (idx, msg_result) = result;
194                 match msg_result {
195                     Some(Ok(axum::extract::ws::Message::Text(text))) => {
196                         match serde_json::from_str::<WsMessage>(&text) {
197                             Ok(WsMessage::Move(mrrp)) => {
198                                 println!("Received move from socket {}: {:?}", idx, mrrp);
199                                 let player = state.players.get_mut(&mrrp.player_id);
200                                 match player {
201                                     Some(p) => {
202                                         match mrrp.action {
203                                             Move::CursorRedUp => p.r_coords.1 = (p.r_coords.1 as
    i8 - 1).max(0) as u8,
204                                             // 3 should be constant, but multilpayer is only 4x4
205                                             Move::CursorRedDown => p.r_coords.1 = (p.r_coords.1 +
    1).min(3),
206                                             Move::CursorRedLeft => p.r_coords.0 = (p.r_coords.0 as
    i8 - 1).max(0) as u8,
207                                             Move::CursorRedRight => p.r_coords.0 = (p.r_coords.0 +
    1).min(3),
208                                             Move::CursorBlueUp => p.b_coords.1 = (p.b_coords.1 as
    i8 - 1).max(0) as u8,
```

```
209                                         Move::CursorBlueDown => p.b_coords.1 = (p.b_coords.1 +
    1).min(3),
210                                         Move::CursorBlueLeft => p.b_coords.0 = (p.b_coords.0
    as i8 - 1).max(0) as u8,
211                                         Move::CursorBlueRight => p.b_coords.0 = (p.b_coords.0
    + 1).min(3),
212                                         Move::Submit => {
213                                             dbg!(p.grid);
214                                             dbg!(p.r_coords,p.b_coords);
215                                             if p.grid[(p.r_coords.0 * 4 + p.r_coords.1) as
    usize] && p.grid[(p.b_coords.0 * 4 + p.b_coords.1) as usize] && !(p.b_coords == p.r_coords) {
216                                                 println!("successfull submission");
217                                                 p.current_score += 1;
218                                                 let mut count = 0;
219                                                 let r = p.r_coords.0 * 4 + p.r_coords.1;
220                                                 let b = p.b_coords.0 * 4 + p.b_coords.1;
221                                                 while count < 2 {
222                                                     let x: u8 = (p.rng.next() * 4 as
    f64).floor() as u8;
223                                                     let y: u8 = (p.rng.next() * 4 as
    f64).floor() as u8;
224                                                     if !p.grid[(x * 4 + y) as usize]
225                                                         && (x * 4 + y != r || x * 4 + y != b)
226                                                     {
227                                                         p.grid[(x * 4 + y) as usize] = true;
228                                                         count += 1;
229                                                     }
230                                                 }
231                                                 p.grid[r as usize] = false;
232                                                 p.grid[b as usize] = false;
233                                             } else {
234                                                 p.current_score = 0;
235                                             }
236                                         },
237                                     }
238                                     }
239                                     None => {
240                                         println!("Recieved message from invalid player");
241                                     }
242                                 }
243 
244                             }
245                             Ok(_) => {
246                                 println!("Received non-move message from socket {}", idx);
247                             }
248                             Err(e) => {
249                                 println!("Error parsing message from socket {}: {}", idx, e);
250                             }
251                         }
252                     }
253                     None => {
254                         println!("Socket {} closed for game {}", idx, id);
255                         let _ = receivers.remove(idx);
256                     }
257                     _ => continue,
258                 }
259             }
260             _ = interval.tick() => {
```

```
                println!("New quota for game {}", id);
                let mut culled_players = vec![];
                let  player_count = state.players.len();
                for (i, p) in state.players.iter_mut() {
                    dbg!(p.current_score);
                    if (p.current_score as u32) < state.quota {
                        let position = (player_count - culled_players.len()) as u32;

                        if let Err(e) = senders.get_mut(&i.clone()).unwrap()
                            .send(axum::extract::ws::Message::Text(
                                serde_json::to_string(&WsMessage::Out(position))
                                    .expect("Failed to serialize Out message")
                            )).await
                        {
                            println!("Failed to send message to player, removing {}: {}", i, e);

                            continue;
                        }
                        culled_players.push(i.clone());
                        state.inactive_players.insert(i.clone(), p.clone());
                        senders.remove(&i);
                    }
                    p.current_score = 0;
                }
                for i in culled_players {
                    state.players.remove(&i);
                }
                if state.players.len() <= 1 {
                    println!("Game {} ended - {} player(s) remaining", id, state.players.len());
                    for (i,_) in state.players.iter() {
                        // add to database when that gets done

    senders.get_mut(&i.clone()).unwrap().send(axum::extract::ws::Message::Text(serde_json::to_string(&W
                    }
                    break;
                }

                state.quota += 1;
                for (_i,sender) in &mut senders {
                    sender.send(axum::extract::ws::Message::Text(
                        serde_json::to_string(&WsMessage::Quota {
                            quota: state.quota,
                            players_left: state.players.len() as u32,
                        })
                        .unwrap(),
                    ))
                    .await
                    .unwrap();
                }
            }
        }
    }
    println!("Game {} has ended", id);
}
```

### 0.10.5.10. WASM

```rust
pub trait Gen {
    type NumberType;
    fn new(seed: Option<u64>) -> Self;
    fn next(&mut self) -> Self::NumberType;
    fn sigmoid(x: f64) -> f64 {
        1.0 / (1.0 + (-x).exp())
    }
}

pub struct SplitMix {
    seed: u64,
}

impl Gen for SplitMix {
    type NumberType = u64;
    fn new(seed: Option<u64>) -> Self {
        SplitMix {
            seed: seed.unwrap(),
        }
    }
    /// based on https://xoshiro.di.unimi.it/splitmix64.c and rand_xoshiro
    fn next(&mut self) -> u64 {
        self.seed = self.seed.wrapping_add(0x9e3779b97f4a7c15);
        let mut z: u64 = self.seed;
        z = (z ^ (z >> 30)).wrapping_mul(0xbf58476d1ce4e5b9);
        z = (z ^ (z >> 27)).wrapping_mul(0x94d049bb133111eb);
        z ^ (z >> 31)
    }
}

#[derive(Debug, Clone)]
pub struct Xoshiro256plus {
    seed: [u64; 4],
}

impl Gen for Xoshiro256plus {
    type NumberType = f64;

    fn new(seed: Option<u64>) -> Self {
        let mut rng = SplitMix::new(seed);
        Xoshiro256plus {
            seed: [rng.next(), rng.next(), rng.next(), rng.next()],
        }
    }
    fn next(&mut self) -> Self::NumberType {
        let result = self.seed[0].wrapping_add(self.seed[3]);
        let t = self.seed[1] << 17;

        self.seed[2] ^= self.seed[0];
        self.seed[3] ^= self.seed[1];
        self.seed[1] ^= self.seed[2];
        self.seed[0] ^= self.seed[3];

        self.seed[2] ^= t;
        self.seed[3] = Xoshiro256plus::rol64(self.seed[3], 45);

```

```
        (result >> 11) as f64 * (1.0 / (1u64 << 53) as f64)
    }
}

impl Xoshiro256plus {
    pub fn rol64(x: u64, k: i32) -> u64 {
        (x << k) | (x >> (64 - k))
    }
    pub fn get_seed(&self) -> String {
        format!("{:?}", self.seed)
    }
}
```

js

```
import * as wasm from "./xoshiro_wasm_bg.wasm";
export * from "./xoshiro_wasm_bg.js";
import { __wbg_set_wasm } from "./xoshiro_wasm_bg.js";
__wbg_set_wasm(wasm);
wasm.__wbindgen_start();

/* tslint:disable */
/* eslint-disable */
export const memory: WebAssembly.Memory;
export const sigmoid: (a: number) => number;
export const __wbg_splitmix_free: (a: number, b: number) => void;
export const splitmix_new: (a: number, b: bigint) => number;
export const splitmix_next: (a: number) => bigint;
export const __wbg_xoshiro256plus_free: (a: number, b: number) => void;
export const xoshiro256plus_new: (a: number, b: bigint) => number;
export const xoshiro256plus_next: (a: number) => number;
export const xoshiro256plus_get_seed: (a: number) => [number, number];
export const __wbindgen_export_0: WebAssembly.Table;
export const __wbindgen_free: (a: number, b: number, c: number) => void;
export const __wbindgen_start: () => void;

/* tslint:disable */
/* eslint-disable */
export function sigmoid(x: number): number;
export class SplitMix {
  free(): void;
  constructor(seed?: bigint);
  next(): bigint;
}
export class Xoshiro256plus {
  free(): void;
  constructor(seed?: bigint);
  next(): number;
  get_seed(): string;
}

```

### 0.10.5.11. Settings Component

svlt

```
<script lang="ts">
```

```
import { getContext } from 'svelte';
let meow = 0;
export let showModal: boolean;
export let closeModal: any;
let dialog: any;
let idx: any;
let state: any = getContext('state');
let keycodes: any;

$: keycodes = $state.keycodes;
const reset = () => {
  $state = JSON.parse(
    JSON.stringify({
      gameMode: 'timer',
      timeLimit: 30,
      keycodes: {
        wU: 'w',
        wD: 's',
        wL: 'a',
        wR: 'd',
        aU: 'ArrowUp',
        aD: 'ArrowDown',
        aL: 'ArrowLeft',
        aR: 'ArrowRight',
        submit: ' ',
        reset: 'r'
      },
      size: 4,
      das: 133,
      dasDelay: 150
    })
  );
  meow += 1;
};
const getChar = (i: any) => {
  let char: any;
  switch (i) {
    case '0':
      char = keycodes.wU;
      break;
    case '1':
      char = keycodes.aU;
      break;
    case '00':
      char = keycodes.wL;
      break;
    case '01':
      char = keycodes.wD;
      break;
    case '02':
      char = keycodes.wR;
      break;
    case '10':
      char = keycodes.aL;
      break;
    case '11':
      char = keycodes.aD;
      break;
```

```
      case '12':
        char = keycodes.aR;
        break;
      case '20':
        char = keycodes.submit;
        break;
      case '21':
        char = keycodes.reset;
        break;
    }
    switch (char) {
      case 'ArrowUp':
        char = '↑';
        break;
      case 'ArrowDown':
        char = '↓';
        break;
      case 'ArrowLeft':
        char = '←';
        break;
      case 'ArrowRight':
        char = '→';
        break;
    }
    return char;
  };

  const keyClick = (i: any) => {
    idx = i;
    setTimeout(() => {
      window.addEventListener('keydown', setChar, { once: true });
    }, 0);
  };
  const setChar = (e: any) => {
    switch (idx) {
      case '0':
        $state.keycodes.wU = e.key;
        break;
      case '1':
        $state.keycodes.aU = e.key;
        break;
      case '00':
        $state.keycodes.wL = e.key;
        break;
      case '01':
        $state.keycodes.wD = e.key;
        break;
      case '02':
        $state.keycodes.wR = e.key;
        break;
      case '10':
        $state.keycodes.aL = e.key;
        break;
      case '11':
        $state.keycodes.aD = e.key;
        break;
      case '12':
        $state.keycodes.aR = e.key;
```

```
        break;
      case '20':
        $state.keycodes.submit = e.key;
        break;
      case '21':
        $state.keycodes.reset = e.key;
        break;
    }
    let doc: any = document.getElementById(idx);
    let char = e.key;
    switch (char) {
      case 'ArrowUp':
        char = '↑';
        break;
      case 'ArrowDown':
        char = '↓';
        break;
      case 'ArrowLeft':
        char = '←';
        break;
      case 'ArrowRight':
        char = '→';
        break;
    }
    doc.textContent = char;
    idx = 69420;
  };

  $: if (dialog && showModal) dialog.showModal();
</script>

<dialog
  bind:this={dialog}
  on:close={closeModal}
  class="h-screen w-screen bg-crust/0 flex items-center justify-center {showModal ? '' :
'hidden'}"
>
  {#key meow}
    <div class="flex flex-col bg-surface0 w-fit h-fit rounded-md">
      <div class="text-text text-3xl m-4 mb-0">settings</div>
      <div class="text-xl text-text mb-0 m-4">movement:</div>
      <div class="flex flex-row m-4">
        {#each Array(2) as _, x}
          <div class="flex flex-col items-center mx-4">
            <!-- svelte-ignore a11y-click-events-have-key-events -->
            <!-- svelte-ignore a11y-no-static-element-interactions -->
            <div
              id={x.toString()}
              class=" rounded-md w-16 h-16 hover:scale-105 transition flex items-center justify-
center text-crust text-xl bold focus:bg-surface0 m-1 select-none cursor-pointer {idx ==
              x.toString()
                ? 'bg-green'
                : 'bg-text'}"
              on:click={() => keyClick(x.toString())}
            >
              {getChar(x.toString())}
            </div>
            <div class="flex flex-row">
```

```
174              {#each Array(3) as _, y}
175                <!-- svelte-ignore a11y-click-events-have-key-events -->
176                <!-- svelte-ignore a11y-no-static-element-interactions -->
177                <div
178                  id={x.toString() + y.toString()}
179                  class=" rounded-md w-16 h-16 hover:scale-105 transition flex items-center
    justify-center text-crust text-xl bold focus:bg-surface0 m-1 select-none cursor-pointer {idx ==
180                  x.toString() + y.toString()
181                    ? 'bg-green'
182                    : 'bg-text'}"
183                  on:click={() => keyClick(x.toString() + y.toString())}
184                >
185                  {getChar(x.toString() + y.toString())}
186                </div>
187              {/each}
188            </div>
189          </div>
190        {/each}
191      </div>
192      <div class="text-xl text-text mb-0 m-4">place:</div>
193      <!-- svelte-ignore a11y-click-events-have-key-events -->
194      <!-- svelte-ignore a11y-no-static-element-interactions -->
195      <div
196        id={'20'}
197        class=" rounded-md max-w-full h-16 hover:scale-105 transition flex items-center justify-
    center text-crust text-xl bold focus:bg-surface0 mx-8 my-4 select-none cursor-pointer {idx ==
198        '20'
199          ? 'bg-green'
200          : 'bg-text'}"
201        on:click={() => keyClick('20')}
202      >
203        {getChar('20')}
204      </div>
205      <div class="text-xl text-text mb-0 m-4">reset:</div>
206      <!-- svelte-ignore a11y-click-events-have-key-events -->
207      <!-- svelte-ignore a11y-no-static-element-interactions -->
208      <div
209        id={'21'}
210        class="rounded-md max-w-full h-16 hover:scale-105 transition flex items-center justify-
    center text-crust text-xl bold focus:bg-surface0 mx-8 my-4 select-none cursor-pointer {idx ==
211        '21'
212          ? 'bg-green'
213          : 'bg-text'}"
214        on:click={() => keyClick('21')}
215      >
216        {getChar('21')}
217      </div>
218      <div class="text-xl text-text mb-0 m-4">auto repeat rate:</div>
219      <div class="flex flex-row text-text text-xl mx-8">
220        <div class="w-8">
221          {$state.das}
222        </div>
223        <input class="mx-4 w-64" type="range" min="0" max="1000" step="1"
    bind:value={$state.das} />
224      </div>
225      <div class="text-xl text-text mb-0 m-4">delayed auto shift:</div>
226      <div class=" flex flex-row text-text text-xl mx-8">
227        <div class="w-8">
```

```
228           {$state.dasDelay}
229         </div>
230         <input
231           class="mx-4 w-64"
232           type="range"
233           min="0"
234           max="1000"
235           step="1"
236           bind:value={$state.dasDelay}
237         />
238       </div>
239       <div class="flex flex-row self-center m-4">
240         <button class="text-crust bg-red rounded-md w-16 h-8 mx-2 hover:scale-105"
    on:click={reset}
241           >reset</button
242         >
243         <button
244           class="text-crust bg-blue rounded-md w-16 h-8 mx-2 hover:scale-105"
245           on:click={() => dialog.close()}>exit</button
246         >
247       </div>
248     </div>
249   {/key}
250 </dialog>
251
```

### 0.10.5.12. Layout and Styling

svlt

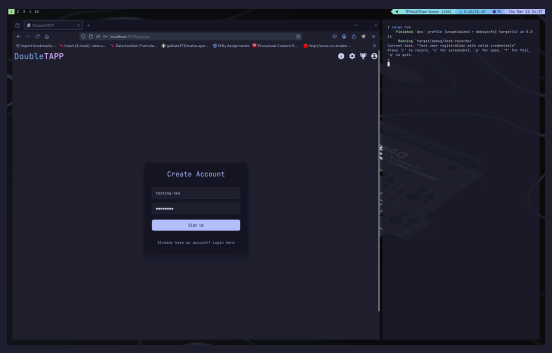
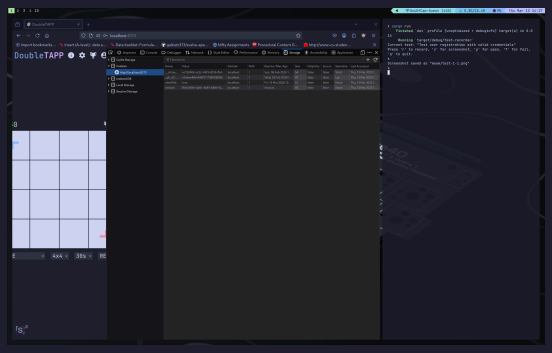
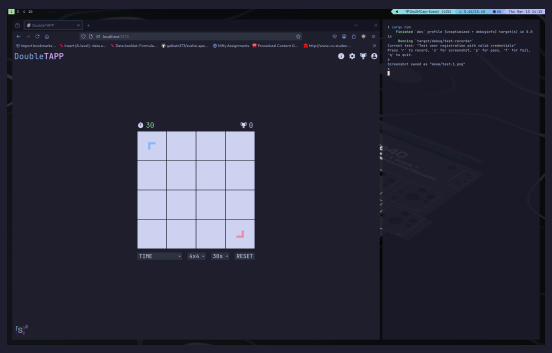
```
 1 <script lang="ts">
 2   import '../app.css';
 3   import studio from '$lib/assets/studio.png';
 4   import Modal from '$lib/settings.svelte';
 5   import Trophy from 'svelte-material-icons/Trophy.svelte';
 6   import AccountCircle from 'svelte-material-icons/AccountCircle.svelte';
 7   import Settings from 'svelte-material-icons/Cog.svelte';
 8   import { onMount, setContext } from 'svelte';
 9   import { browser } from '$app/environment';
10   import { writable } from 'svelte/store';
11   import Information from 'svelte-material-icons/Information.svelte';
12   import { redirect } from '@sveltejs/kit';
13   import { goto } from '$app/navigation';
14   const FLAVOUR = 'mocha';
15   let showModal = false;
16   let showWelcome = false;
17   let selectedElement: { focus: () => void; };
18   //TODO custom bg
19   type gameState = {
20     gameMode: string;
21     timeLimit: number;
22     keycodes: object;
23     size: number;
24   };
25   const defaults = JSON.stringify({
26     gameMode: 'timer',
27     timeLimit: 30,
28     keycodes: {
29       wU: 'w',
```

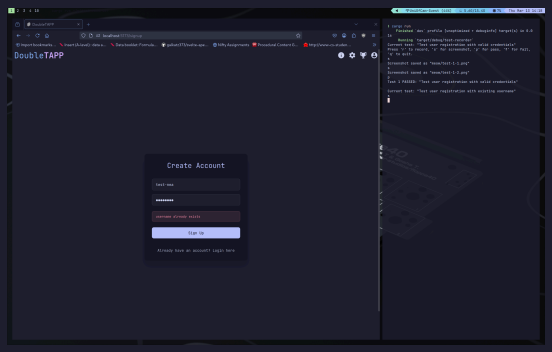
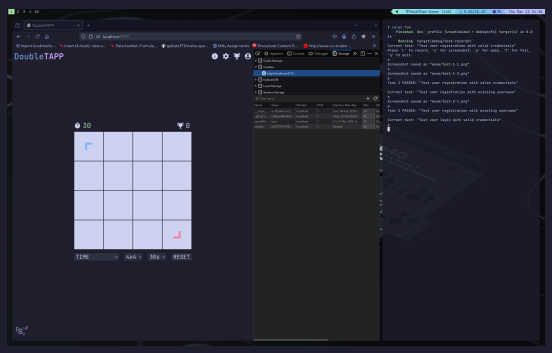
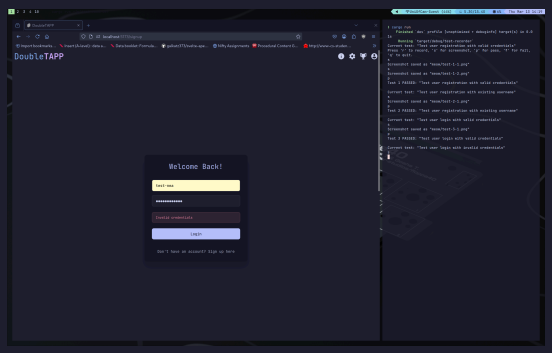
```
      wD: 's',
      wL: 'a',
      wR: 'd',
      aU: 'ArrowUp',
      aD: 'ArrowDown',
      aL: 'ArrowLeft',
      aR: 'ArrowRight',
      submit: ' ',
      reset: 'r'
    },
    size: 4,
    das: 133,
    dasDelay: 150
  });
  const getState = (): gameState => {
    if (browser) {
      return JSON.parse(localStorage.getItem('state') || defaults);
    } else {
      return JSON.parse(defaults);
    }
  };
  const state = writable<gameState>(getState());

  if (browser) {
    state.subscribe(($state) => {
      localStorage.setItem('state', JSON.stringify($state));
    });
  }

  setContext('state', state);

  onMount(() => {
    if (browser) {
      const hasSeenWelcome = document.cookie.includes('seenWelcome=true');
      if (!hasSeenWelcome) {
        showWelcome = true;
      }
    }
  });

  const closeWelcome = (permanent: boolean) =>{
    showWelcome = false;
    if (permanent) {
      document.cookie = 'seenWelcome=true; max-age=31536000; path=/';
    }
  }

  const openModal = (e: any) => {
    selectedElement = e.currentTarget;
    showModal = true;
  }

  const closeModal = () => {
    showModal = false;
    if (selectedElement) {
      selectedElement.focus();
    }
  }
```

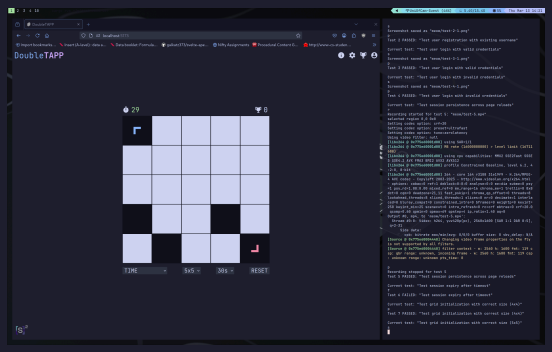
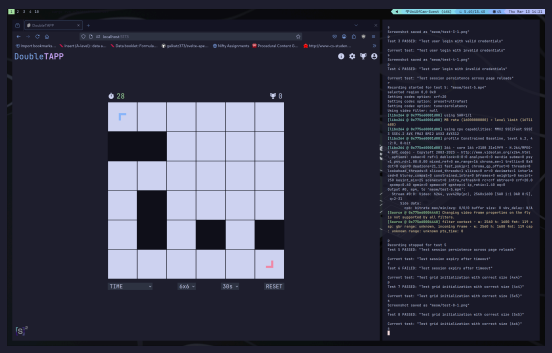
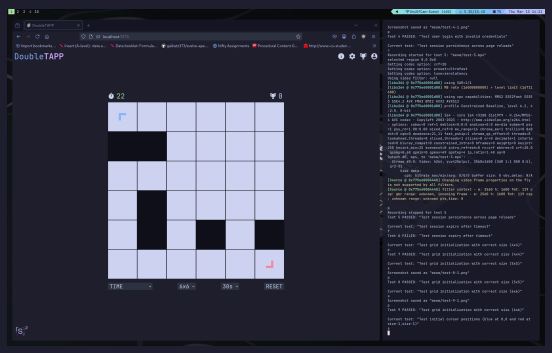
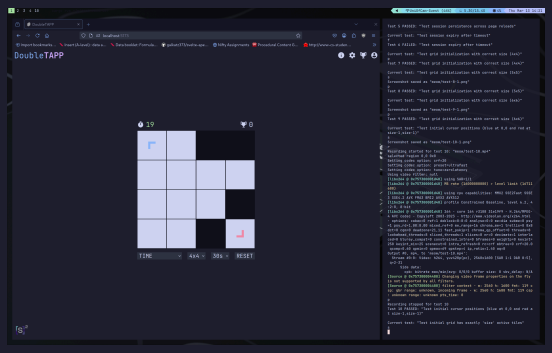
```
88
89
90 </script>
91
92
93 <main class={FLAVOUR}>
94   <div class="flex flex-col justify-between h-full max-h-screen min-w-screen font-mono">
95     <div class="flex flex-row bg-base justify-between h-fit w-full items-center">
96       <a class="flex flex-row text-4xl text-rosewater p-2" href="/">
97         <x class="text-blue">Double</x> <x class="text-mauve font-bold">TAPP</x>
98       </a>
99       <div class="flex flex-row">
100        <button on:click={() => showWelcome = true}>
101          <Information color="#cdd6f4" class="h-12 w-12 p-2" />
102        </button>
103        <button on:click={openModal}>
104          <Settings color="#cdd6f4" class="h-12 w-12 p-2" />
105        </button>
106        <button on:click={() => goto('/leaderboards')}>
107          <Trophy color="#cdd6f4" class="h-12 w-12 p-2" />
108        </button>
109        <button on:click={() => goto('/signup')}>
110          <AccountCircle color="#cdd6f4" class="h-12 w-12 p-2" />
111        </button>
112      </div>
113    </div>
114    <div class="bg-base h-screen">
115      <slot></slot>
116    </div>
117    <div class="flex flex-row bg-base justify-between h-24 w-full items-center">
118      <div class="flex flex-row items-center opacity-50">
119        <a href="https://studiosquared.co.uk">
120          <img class=" m-4 h-10" src={studio} alt="[S]^2" />
121        </a>
122      </div>
123    </div>
124  </div>
125
126  {#if showWelcome}
127    <div class="fixed inset-0 bg-black bg-opacity-50 flex items-center justify-center">
128      <div class="bg-base p-6 rounded-lg max-w-md">
129        <h2 class="text-2xl text-rosewater mb-4">Welcome to DoubleTAPP</h2>
130        <p class="text-text mb-4">
131          In DoubleTAPP, your aim is to move both your cursors onto different active tiles to
    score points. (WASD and arrow keys as default controls)
132        </p>
133        <p class="text-text mb-4">
134          You get a point for each correct move, and lose all your points if you place your
    cursors incorrectly, good luck!
135        </p>
136        <p class="text-text mb-4">
137          you can customize your controls and other settings in the settings menu.
138        </p>
139        <button
140          class="bg-blue text-base px-4 py-2 rounded"
141          on:click={() => closeWelcome(true)}
142        >
143          Got it!
```

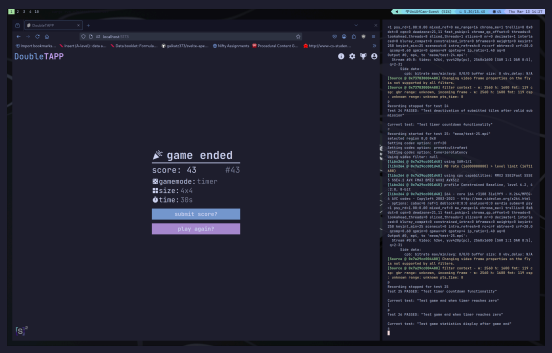
```
144         </button>
145       </div>
146     </div>
147   {/if}
148
149   <Modal bind:showModal />
150 </main>
151
152
```

## 0.11. Testing

| Test Description | Status | Proof |
| --- | --- | --- |
| Test user registration with valid credentials | Pass |    |

| | | |
|---|---|---|
| Test user registration with existing username | Pass |  |
| Test user login with valid credentials | Pass |  |
| Test user login with invalid credentials | Pass |  |
| Test session persistence across page reloads | Pass | test-5.mp4 |
| Test session expiry after timeout | Pass | 7 day expiry, functional |
| Test grid initialization with correct size (4x4) | Pass | shown in all other tests |

| | | |
|---|---|---|
| Test grid initialization with correct size (5x5) | Pass |  |
| Test grid initialization with correct size (6x6) | Pass |  |
| Test initial cursor positions (blue at 0,0 and red at size-1,size-1) | Pass |  , test-10.mp4 |
| Test initial grid has exactly 'size' active tiles | Pass |  |
| Test blue cursor movement in all directions with keyboard | Pass | test-12.mp4 |

| | | |
|---|---|---|
| Test red cursor movement in all directions with keyboard | Pass | test-13.mp4 |
| Test cursor movement boundary limits (cannot move outside grid) | Pass | test-14.mp4 |
| Test DAS (Delayed Auto Shift) functionality for cursor movement | Pass | test-15.mp4 |
| Test valid submission when both cursors are on active tiles | Pass | test-16.mp4 |
| Test invalid submission when cursors are on the same tile | Pass | test-17.mp4 |
| Test invalid submission when one cursor is not on an active tile | Pass | shown in other tests |
| Test score increment on valid submission | Pass | test-19.mp4 |
| Test score reset on invalid submission | Pass | test-20.mp4 |
| Test visual feedback (green) for correct submissions | Pass | test-21.mp4 |
| Test visual feedback (red) for incorrect submissions | Pass | test-22.mp4 |
| Test new active tiles appear after valid submission | Pass | test-23.mp4 |
| Test deactivation of submitted tiles after valid submission | Pass | test-25.mp4 |
| Test timer countdown functionality | Pass | shown in other tests |
| Test game end when timer reaches zero | Pass |  |

| | | |
|---|---|---|
| Test game statistics display after game end | Pass | test-28.mp4 |
| Test leaderboard display with correct pagination | Pass | test-29.mp4 |
| Test leaderboard filtering by grid size | Pass | test-30.mp4 |
| Test leaderboard filtering by time limit | Pass | test-31.mp4 |
| Test leaderboard filtering for personal bests | Pass | test-32.mp4 |
| Test multiplayer game joining functionality | Pass | test-33.mp4 |
| Test multiplayer game quota system | Pass | shown in other tests |
| Test multiplayer game player elimination | Pass | shown in test 33-35 .mp4 |
| Test multiplayer game final rankings | Pass | test-35.mp4 |
| Test WebSocket connection establishment | Pass | shown in other tests |
| Test WebSocket message handling for different action types | Pass | test-37.mp4 |
| Test server-side move verification with valid moves | Pass | shown in other tests |
| Test server-side move verification with invalid moves | Pass | shown in other tests |
| Test server-side timing verification for normal play | Pass | test-39.mp4 |
| Test server-side timing verification for suspicious patterns | Pass | test-40.mp4 |
| Test server-side path optimization detection | Pass | shown in test-40 |

| | | |
|---|---|---|
| Test PRNG (Xoshiro256+) deterministic output with same seed | Pass | test-42.mp4 |
| Test game state persistence in database | Pass | tested manually |
| Test user statistics update after game completion | Pass | tested manually |
| Test keybind customization persistence | Pass | test-48.mp4 |
| Test settings reset to defaults | Pass | test-49.mp4 |
| Test game performance with rapid inputs | Pass | test-50.mp4 |
| Test game performance with simultaneous inputs | Pass | test-51.mp4 |

## 0.12. Evaluation

### 0.12.1. Evaluation Against Objectives

| Objective | Evaluation | Evidence |
|---|---|---|
| User can interact with the grid | Implemented ✓ | Grid component manages cursor movements with keyboard controls and displays active tiles with visual feedback. |
| User can move both cursors using keyboard | Implemented ✓ | `onKeyDown` event handler implements movement for both cursors with configurable controls. |
| User can “submit” moves using keybind | Implemented ✓ | `submit` function processes move validation when the submit keybind is pressed. |
| User can reset game via keybind | Implemented ✓ | Reset functionality implemented via the `reset` keybind in `onKeyDown` handler. |
| User can change gamemode and settings | Implemented ✓ | UI includes dropdown selectors for gamemode, grid size, and time limit with reactivity. |
| User can modify keybinds, DAS and ARR | Implemented ✓ | Settings component allows full customization of keyboard controls and timing parameters. |

| | | |
|---|---|---|
| Cursors are visually distinct | Implemented ✓ | Blue cursor (top-left borders) and red cursor (bottom-right borders) are visually distinct. |
| User can view game statistics | Implemented ✓ | End-game screen displays score, position, and game parameters. |
| Leaderboard functionality | Implemented ✓ | Leaderboard component with pagination and filtering is fully implemented. |
| Login/authentication system | Implemented ✓ | Complete authentication flow with signup, login, and session management. |

| Objective | Evaluation | Evidence |
|---|---|---|
| User authentication & management | Implemented ✓ | Secure authentication with password hashing (bcrypt) and session management. |
| Database schema | Implemented ✓ | Comprehensive relational database schema with user, statistics, and game tables. |
| Game verification | Implemented ✓ | Server-side move validation with comprehensive checking for legitimate gameplay. |
| Anti-cheat measures | Partially Implemented ⚠ | Move timing analysis is implemented, but advanced anti-cheat verification is incomplete. |
| Multiplayer implementation | Implemented ✓ | WebSocket-based real-time multiplayer with quota system and elimination mechanics. |
| Performance optimizations | Implemented ✓ | Efficient data structures (HashMap, Queue) and high-performance libraries (Axum, Tokio). |

#### 0.12.2. User Feedback

##### 0.12.2.1. Client Feedback

• “the gameplay is surprisingly engaging

the leaderboard system is nice and offers a unique gameplay incentive the user experience was very well executed and intuitive“

**UI** : 5/5 **Functionality** : 4/5 **UX**: 4/5

#### 0.12.2.2. Test User Feedback

overall users have enjoyed the game, and found it to be quite challenging at first, but with practice they were able to improve. users have particularly enjoyed the multiplayer system, and the challenge of trying to beat their friends.

“I like the lay out and the colour scheme. initiative to use and edit the game format”
“The app was smooth and everything worked well. I found the usage of two hands to be a unique challenge, but the game was explained well and the UI was intuitive and easy to understand.”

### 0.12.3. Future Improvements

In the future, i plan to improve the game by adding mobile support, and having more in depth analytics on the users profile page. additionally i would like to implement more stringent verification, such as a obfuscated library that detects html injections and other methods for securing.

# 1. Bibliography


[1] Hard Drop - Tetris Wiki, “Delayed Auto Shift - Understanding Modern Tetris Controls.” Accessed: Dec. 17, 2023. [Online]. Available: https://harddrop.com/wiki/DAS

[2] MDN Web Docs, “HTTP - Overview of the Hypertext Transfer Protocol.” Accessed: Dec. 20, 2023. [Online]. Available: https://developer.mozilla.org/en-US/docs/Web/HTTP/Overview

[3] IETF - Network Working Group, “User Datagram Protocol (UDP) - Internet Protocol Suite.” Accessed: Dec. 20, 2023. [Online]. Available: https://www.ietf.org/rfc/rfc768.txt

[4] Mozilla Developer Network, “An Introduction to WebSockets.” Accessed: Dec. 10, 2023. [Online]. Available: https://developer.mozilla.org/en-US/docs/Web/API/WebSockets_API

[5] David Blackman and Sebastiano Vigna, “xoshiro / xoroshiro generators and the PRNG shootout.” Accessed: Dec. 15, 2023. [Online]. Available: https://prng.di.unimi.it/

[6] Svelte Team, “SvelteKit Documentation.” Accessed: Dec. 19, 2023. [Online]. Available: https://kit.svelte.dev/docs/introduction

[7] Rust Language Team, “Asynchronous Programming in Rust.” Accessed: Dec. 02, 2023. [Online]. Available: https://rust-lang.github.io/async-book/

[8] Tailwind Labs, “Tailwind CSS Documentation.” Accessed: Dec. 05, 2023. [Online]. Available: https://tailwindcss.com/docs

[9] Catppuccin Team, “Catppuccin Color Scheme.” Accessed: Dec. 08, 2023. [Online]. Available: https://github.com/catppuccin/catppuccin

[10] Towards Data Science, “Understanding the Sigmoid Function in Mathematics.” Accessed: Dec. 14, 2023. [Online]. Available: https://towardsdatascience.com/understanding-the-sigmoid-function-385f5c01ae3e

[11] Joshua Glazer and Sanjay Madhav, *Multiplayer Game Programming*. Accessed: Dec. 12, 2023. [Online]. Available: https://www.informit.com/store/multiplayer-game-programming-architecting-networked-9780134034300