Project Notebook
Rebomb

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January 7, 2025

Contents

Milestone 1: Formal Game Proposal

1 Game Description

We are planning to create a multiplayer turn-based game that contains time travel features, procedurally generated maps, and explosions via particle simulations. We draw inspiration from popular titles such as *Bomberman* for showing blast in maze, *Quantom League* or *Life is Strange* for their time travel features and *Candy Crush Saga* for the cascaded effects. *Rebomb* demonstrates the theme "Chain Reaction" in its mechanics by explosions of bombs. An active bomb affects nearby passive bombs, causing them to trigger and explode. Additionally, flammable objects such as oil buckets, haystacks, wooden fences and trees will be available on the map and players can use these items to their advantage. The game will be designed on several levels. In each round the player has resources that will be carried in the next rounds. The player gains progressively more resources for the chain reactions. Later rounds players can unlock powerful and more costly bombs with their survival bonus.

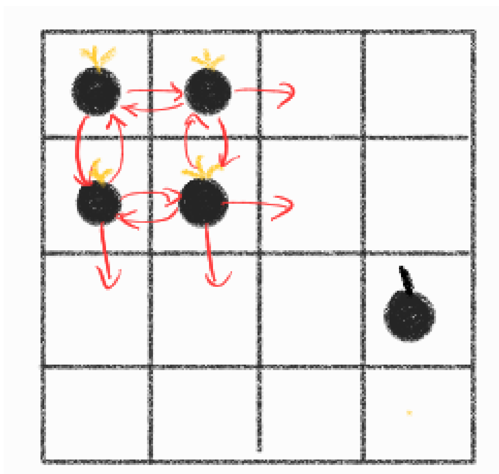


Figure 1: Chain Reaction.

1.1 Gameplay

Rebomb is a turn-based, maze-based multiplayer game that can be played with 2 or 4 players. The players can only move horizontally or vertically in a 2.5D map containing obstacles and collectibles. To win the game, players must eliminate all opponents and remain the last one standing. Players can get killed once they get caught up in a bomb's explosion, including their own. The bombs have to be strategically placed to destroy obstacles or kill other players. They explode in horizontal and vertical directions after some time causing a cascaded effect. Different types of bombs vary in their impact radius, with each type affecting the explosion distance to a greater or lesser extent.

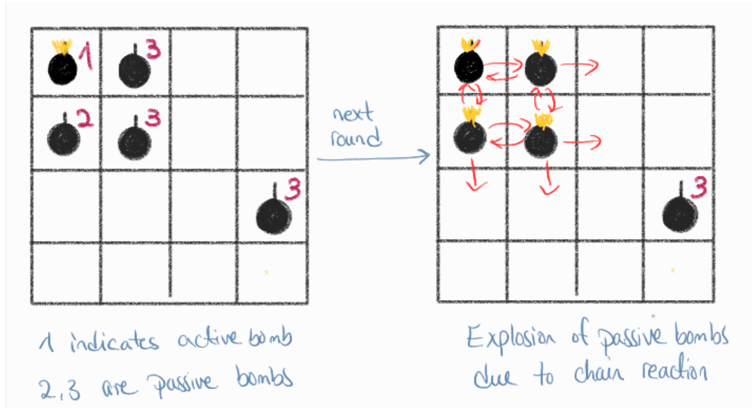


Figure 2: Passive and Active Bomb differentiation.

1.2 Game Mechanics

The player starts the game with fixed and limited resources. Resources can be measured by the number of coins a player holds. Placing the bombs costs coins. Various bombs have different costs. In each round, the player can move only n tiles in horizontal or vertical directions and place their bombs. Resources can be gathered by items on the map, by killing other players, or by designing an in-game interest system, so that the player gains more resources in the upcoming rounds, once they survive the round. The map consists of collectibles, such as hourglasses for time traveling, power-ups for stronger bombs, or extra coins. Once an hourglass is collected the player may choose to time travel back k rounds. In the context of this game, time travel means rewinding to a previous state of the map, where the position of the players, the resources, and all bombs, except for the last placed bombs by each player, will be reverted for all the players. This way the player with time-traveling ability has a chance to strategically change the course of the game in their own favour. Figure 3 demonstrates how time travel can be in a 1 versus 1 gameplay. Note that the same mechanic can also be applied when 4 players are in the game. In this example one bomb costs two coins and the players can move up to 3 tiles in each round.

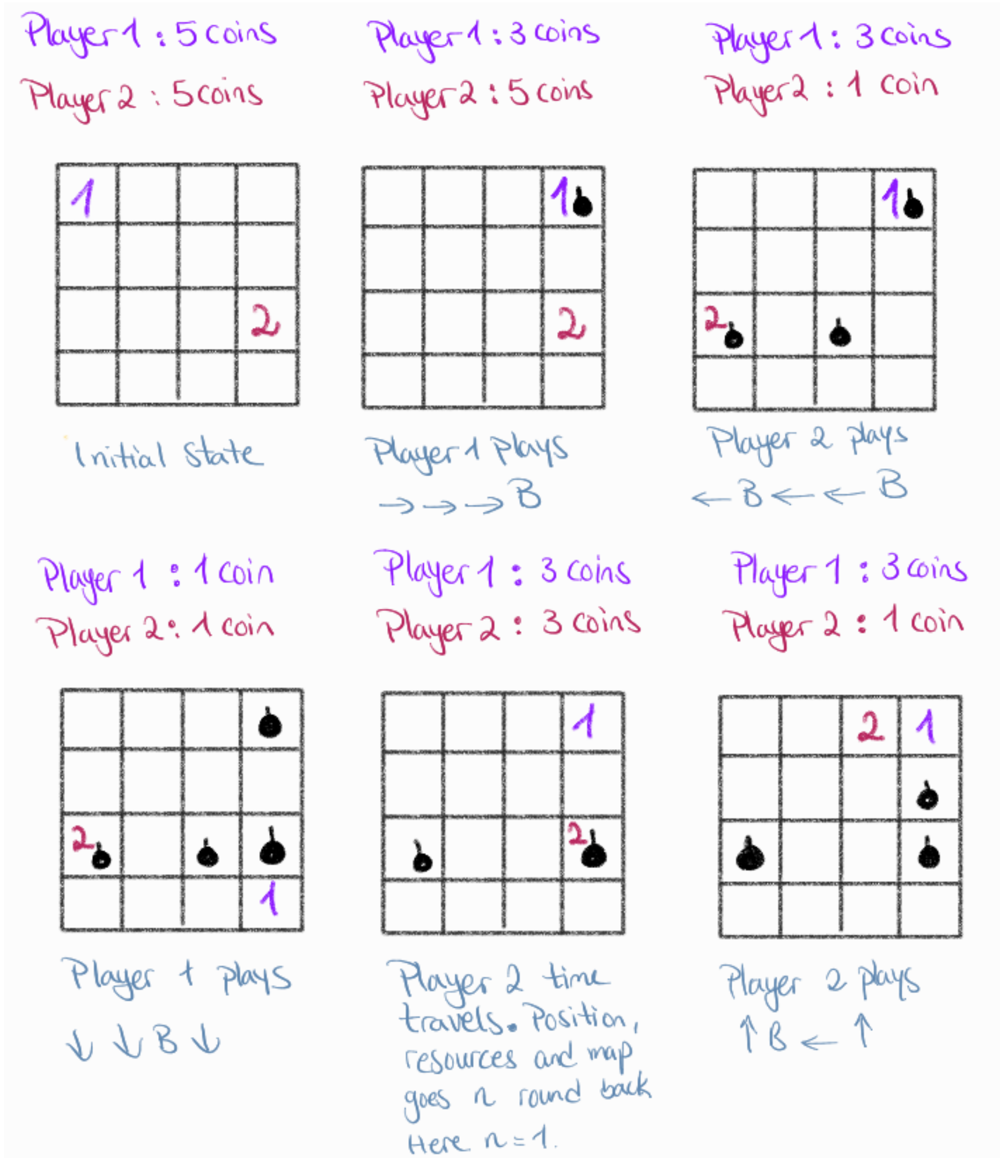


Figure 3: Time Travel Example.

2 Technical Achievement

2.1 Game Snapshots Recording

Our main technical achievement will be the implementation of a game state recording system to enable time travel mechanics. The system will save snapshots of key states including all necessary information to replay the game (movements, actions, objects, environment, etc). This will allow players to interact with previous game experiences, allowing them to explore alternative strategies and making time travel a functional and engaging game mechanic.

2.2 Multiplayer Functionality

Our game will support a multiplayer mode, allowing players to compete in the same scenario in real-time. This feature will require careful management of game states to ensure a minimal latency between devices so

Figure 4: Procedural generation in Minecraft.

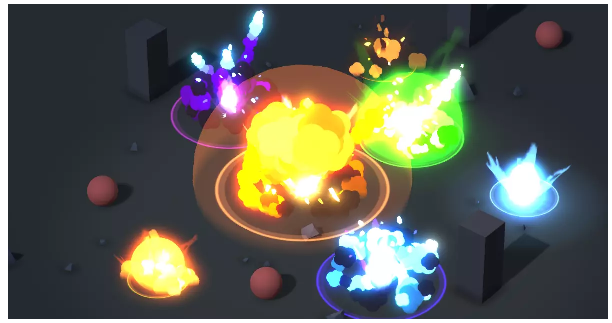


Figure 5: Different particle effects for explosions.

that game states are synchronized in every device. The multiplayer setup will also integrate seamlessly with the time travel mechanics to offer unique multiplayer interactions and experiences.

2.3 Procedural Generation

Using seed-based procedural generation, we will generate scenarios with unique configurations at each gameplay. This method provides players with new unseen environments each session while ensuring playability with a set of predesigned rules that control randomness. This simple algorithm also allows for the scalability of the map generation. The seed value will allow players to replay specific map setups that they consider interesting and share them with other players, encouraging game replayability.

2.4 Explosions via Particle Simulation

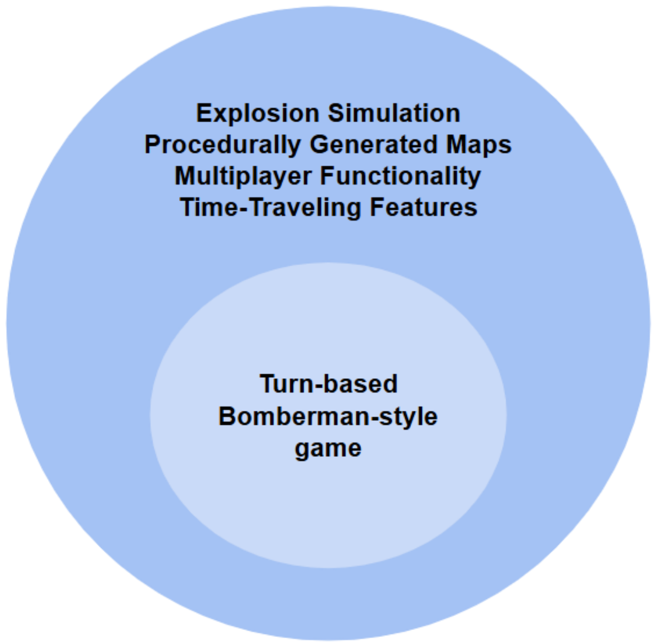
We will pay special attention to visual dynamic effects from explosions. Each explosion will be generated using particle effects and based on parameters such as brightness, color, shape, or velocity, allowing for distinct patterns and range effects. The particle properties will be tied to different types of explosives and objects, allowing the player to associate the effects with the objects used and better visualize the game state.

2.5 Environment Change

To visually enhance the passage of time within a game session, we will incorporate environmental changes, such as shifting sunlight, moving shadows, or changes in lighting as cues for time progression. This element will act as a way finder, helping players to orient themselves in the temporal dimension while also improving immersion to reflect player decisions. These changes will be achieved through dynamic lighting adjustments based on the game's internal clock and scene configurations.

Figure 6: Change on shadows due to different solar azimuth.

3 "Big Idea" Bullseye



4 Development Schedule

4.1 Layered development Description

4.1.1 Functional minimum

Our minimum goal is to deliver a playable turn-based Bomberman-style game with simple default maps and limited interactive elements. The initial focus will be on core mechanics to ensure a functional foundation.

- Player movement and item placement logic.
- Basic environment objects.
- A fundamental weapon system that includes active and passive bombs.
- A basic resource system for initial resources and survival bonus.
- Essential assets.

4.1.2 Low target

At this stage, we aim to enhance gameplay mechanics and introduce additional features to create a richer experience.

- Time travel mechanics.
- Weapon system: sequentially unlocks more powerful bombs and special items.
- A basic GUI with menus and gameplay options.
- Assets specifically for special items.

4.1.3 Desirable target

Building on previous stages, we aim to create a more dynamic and engaging game environment.

- Procedural map generation to increase replayability.
- Local multiplayer for competitive play.
- Enrich interactive elements in environments.
- Assets and GUI for a better user experience.

4.1.4 High target

- Character personalization and animation.
- Multiplayer functionality across multiple machines.
- Additional game mode (e.g. round-based).
- Fine-tune numerical settings to balance gameplay and improve mechanics.

4.1.5 Extras

- Explore more interesting time travel feature possibilities and realtime gameplay.
- Online multiplayer gameplay.

4.2 Timeline

According to our layered development description and milestones in this semester, a initial time schedule is illustrated in Figure 11 and Figure 8.

Date	Milestone	Week	Layer	Task	Expect Hours	Actual Hours
Nov 06-12	**Prototype**	1	Prototype	physical Prototype	4 * 5	
			Minimum	simple assets	5	
				simple map & static object	5	
				player move & item place	5	
				simple GUI	5	
Nov 13-19		2		active & negative bomb	6	
				resourse system	6	
				interactive map & object	6	
				turn-based gameplay	6	
				version integration	4 * 4	
Nov 20-26		3	Low	specifical assets	8	
				time travel mechanism 1/2	8	
				weapon & interactive obje	8	
				full GUI	8	
				version integration	4 * 2	
Nov 27-Dec 03	**Interim demo**	4		time travel mechanism 2/2	8	
				cascaded explosion refine	8	
			Desirable	map generation 1/3	8	
				local multiplayer 1/3	8	
				version integration	4 * 2	

Figure 7: Time schedule [1/2].

Dec 04-10		5	Desirable	map generation 2/3	8	
				local multiplayer 2/3	8	
				explosion effects 1/2	8	
				more weapon and objects	8	
				version integration	4 * 2	
Dec 11-17		6		map generation 3/3	6	
				local multiplayer 3/3	6	
				explosion effects 2/2	6	
				numerical refine	6	
				version integration	4 * 4	
Dec 18-24		7		remaining tasks & test	4 * 10	
Dec 25-31		8	holiday(Dec 24-Jan 06)		0	
Jan 01-07	**Alpha release**	9			0	
Jan 08-14		10	High	remote multiplayer	2 * 8	
				assesment & bugfix	2 * 8	
				version integration	4 * 4	
Jan 15-21	**Playtesting**	11		remote multiplayer	2 * 8	
				improve mechanics	8	
				refine animation/character:	8	
				version integration	4 * 4	
Jan 22-28		12		remaining tasks & test	4 * 10	
Jan 29-Feb 04	**Final release**	13	Extra	extra tasks & test	4 * 10	

Figure 8: Time schedule [2/2].

5 Assessment

The game will combine strategic decision-making with explosive chain reactions, creating a dynamic and suspenseful experience. The time travel feature will add a unique twist, allowing players to strategically undo their moves, heightening both strategic depth and unpredictability.
The game is designed for players who enjoy competitive strategy games, especially fans of Bomberman, turn-based tactics, and games with elements of mind games or puzzle-solving. Players seeking multiplayer experiences with strategic depth and unique gameplay mechanics are expected to be particularly drawn to this game.
In this game:

- Players place bombs with an option to activate their fuses. Activated bombs explode after a delay of a few turns, while unlit bombs remain dormant and can be triggered by chain reactions from other explosions.
- The time travel feature allows players to revert all players and the environment to their state from some turns ago. However, the last bomb each player placed before turning back time will remain and explode according to its original timing.

This gameplay will introduce both offensive and defensive layers, encouraging strategic bomb placement and reactionary tactics.

1. **Engagement and Replayability**: Players should feel compelled to play multiple rounds and experiment with new strategies, especially utilizing the time travel mechanic.

2. **Balanced Mechanics**: A successful design should make the time travel and bomb chain reactions feel fair, with strategy prioritized over luck.

3. **Strategic Depth**: Players should have opportunities to improve with experience, discovering advanced tactics and evolving their strategies.

4. **Player Retention**: The game's success can be measured by a strong player base with high retention, indicating enjoyment and multiplayer appeal.

Milestone 2: Game Prototype

6 Description

We create a physical prototype in a 2D board that fully reflects the gameplay functionality of our game. Initially we propose the following rules for playing the game:

1. The board is set arbitrarily to a 8x8 grid of tiles. The tiles will contain an unbreakable walls, breakable walls or be empty.
2. Every tile can be occupied by a single element at the same time.
3. The game is played via sequential turns as in chess. First a player decides and plays his actions, then the next player plays his turn until every player has completed their actions.
4. In his turn, a player can move up to 3 tiles horizontally and vertically in any possible trajectory. A player cannot move into a tile occupied by any other element or player. Additionally, in his turn, a player can place a single bomb in any of the tiles it has visited. Every bomb is either active or passive and this is decided by the player at the moment he places on the board.
5. Active bombs have attached a counter that begins at 3 when placed. At the beginning of the player who originally placed the bomb, the counter is decreased by 1. When the counter reaches 0 the bomb explodes. The explosion reaches all the horizontal and vertical tiles that are at a distance of 1 tile from the bomb and the tile the bomb is at. All other bombs that are in tiles affected by the explosion also explode causing a chain reaction that get resolved at that same moment. The breakable walls that are affected become empty tiles. The players in affected tiles are eliminated and lose the game.
6. Passive bombs do not have a counter but when affected by an explosion explode as an active bomb.
7. One breakable wall will have hidden an hourglass item. When the tile is affected by an explosion, the hidden item will appear on that tile. The first player that moves over the item will acquire it and the item will disappear the board. At the beginning of his turn, a player can use the item, which is consumed, to perform a time travel of 3 turns in the past to the beginning of that turn. When this happens the board is reset to the exact state it was 3 turns before with the exception of the bomb both players might have played in the turn before performing the time travel, which are also carried in the state they are to the new board.
8. The game ends when a single player is alive and all the other players have been eliminated.

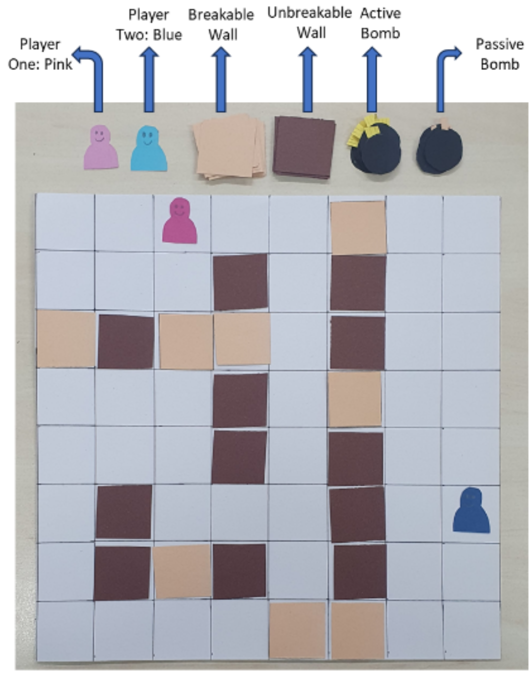
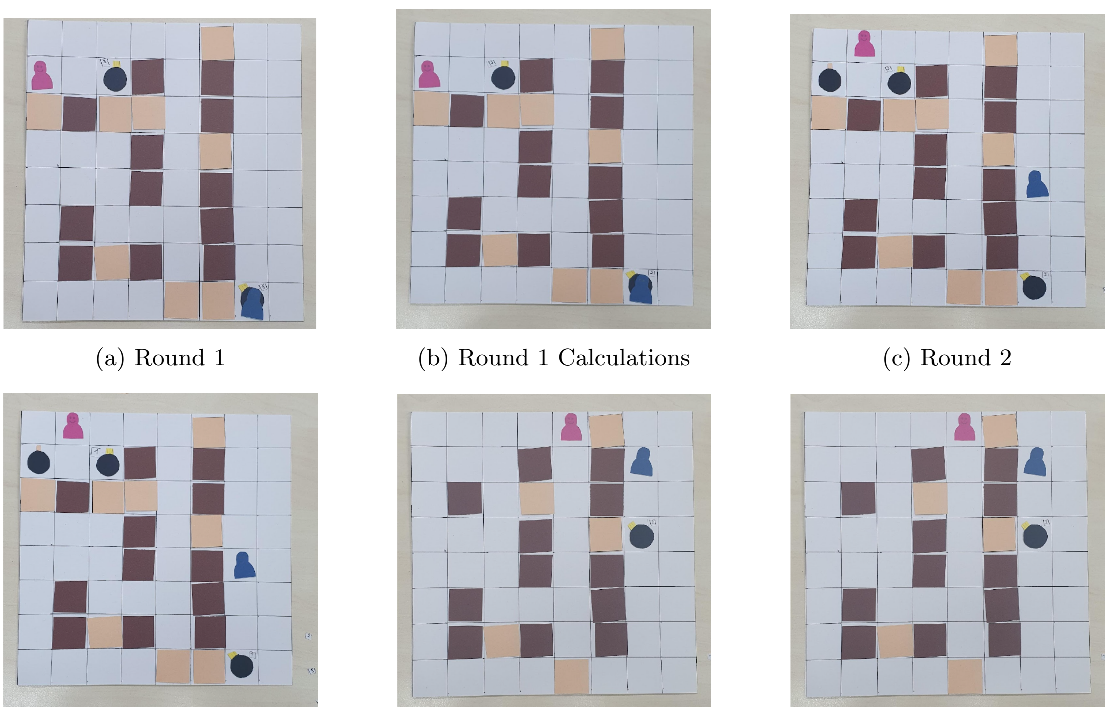


Figure 9: Paper Prototype - Round 0



(a) Round 1 (b) Round 1 Calculations (c) Round 2

(d) Round 2 Calculations (e) Round 3 (f) Round 3 Calculations

Figure 10: Gameplay demonstration of prototype

7 Experience

7.1 Strategy and Interaction

Throughout our play sessions, we observed that players are motivated to explore and develop various strategies based on our interaction and mechanics. These mechanics distinguished our game from the traditional action game Bomberman, leaning more towards a strategy-driven experience. Rather than relying on quick reflexes, players are encouraged to plan, anticipate, and outmaneuver each other.

- **Timing with Bomb Detonations**: the combination of explosion range, movement step size, and bomb countdown encourages players to carefully time their moves. Planning ahead becomes essential, as players must anticipate both their own and their opponents' actions to avoid explosions and capitalize on positioning.
- **Early Bomb Triggering**: players tend to place bombs early in the game to remove breakable walls and expand the battlefield. This strategy creates a dynamic environment where players have more options and tactical opportunities.
- **Trap Setting**: an integral aspect of gameplay is players attempting to trap each other by strategically placing bombs. By predicting and limiting opponents' movement options, players can increase the likelihood of an opponent getting caught in an explosion, making for tense, engaging moments.
- **Chain Reactions**: to maximize impact and maintain safe positions, players frequently set up bomb chains that trigger successive explosions. This strategy allows them to target opponents from a distance, adding a rewarding level of risk management.

7.2 Weapons and Items

The integration of our core items—the active and passive bombs, as well as the hourglass for time travel—adds both depth and breadth to the strategic possibilities. Each item introduces new layers of decision-making.

- **Impact of Bomb Collision**: when bombs are placed with collision volumes, they can act as barriers, restricting movement options and enhancing the trapping mechanics. Players are motivated to use bombs as obstacles to manipulate opponent movement.
- **Hourglass to Travel Back**: the hourglass item brings a unique twist to gameplay. When used, it rewinds recent turns while keeping the player's last bomb in place. This mechanism allows for surprise strategies, such as reversing a near-loss situation or enhancing a bomb trap.

8 Revisions to Game Idea

By creating the prototype, we are able to play the game, spot the advantages and disadvantages of our proposed design, and make modifications to our design.
The basic winning strategy of classical Bomberman is trapping the enemies in the bombs' explosion region. Our game should also take it as the key to winning, in ways of placing the bombs as obstacles, creating chained explosions, and using time travels or other potential items.

- **Map Design**: the map design appears to be harder than expected. During our test plays on the prototype, we found adding the number of breakable walls can help increase the suspense of the possession of the time travel feature but at the same time increase the length of the game. The unbreakable walls should be of a larger number but not continuous in a large size, to provide enough possibility of trapping enemies and encourage the use of chain reactions simultaneously.
- **Numerical Design**: as expected, the numerical design is crucial to tuning the desired player behavior. For example, a small explosion range encourages more blocking opponents using bombs which is not what we want from a chain-reaction-centered game, while a large one also kills the value of cascaded

explosions because single explosions are already powerful enough. On a current 8x8 prototype map with max. 3 tiles movement and max. place 1 bomb per player each round, we tested and found the sweet point explosion range of 2 that can hopefully highlight the potential of chain reactions.

- **Game Mode**: we proposed the game as a turn-based one available for local multiplayer, which means one player has to wait for the others' turns to finish the round. In our tests on the prototype, we found it possible to allow simultaneous actions for all players within a round. To solve edge conditions, the bombs placed in one round take effect (block players and being triggered by other bombs) only after the next explosion calculation (i.e. the start of the next round). At the same time, local multiplayer will not be possible because the players should act at the same time and should not know the other player's action in the round.
- **Time Travel Feature**: the travel back feature has been proven to successfully deepen strategy depth and to be a powerful resource to compete for. It can be used as a redo to save the user's life when trapped, or as an aggressive item by taking advantage of the remained last bomb. However, players feel the consequence of using time travel on our paper-based prototype is unclear, which affects user experience. In our game development, we should provide previews of travel-back to the players.
- **Game Concept**: we are happy to find that all 4 members of our team feel it's fun to play with the prototype. Since we are different types of gamers, we are more confident in having the game attract a large range of players.

Milestone 3: Interim Demo

9 Task Progression

We have successfully completed all tasks within our minimum and low target objectives. We have focused mainly on the game logic and its functionality until now. For features in our desired target, we have made significant progress. The local multiplayer functionality is now fully implemented, allowing two players to share one keyboard (each using either the left or right half). Our game is now fully playable locally in a two-player mode on a single level, featuring active and passive bomb explosions, chained reaction mechanics, and time travel functionality.

Date	Milestone	Week	Layer	Task	Time		Owner	State
					Expect	Actual		
Nov 06-12	**Prototype**	1	Prototype	physical Prototype	4 * 5	4 * 5	All	DONE
			Minimum	simple assets	5	5	All	DONE
				simple map & static object	5	3	Jialin	DONE
				player move & item place	5	1	Jialin	DONE
				simple GUI	5	2	Mahdis	DONE
Nov 13-19		2		active & passive bomb	6	7	Miguel	DONE
				resourse system	6	1	Yaxuan	DONE
				interactive map & object	6	6	All	DONE
				turn-based gameplay	6	10	Yaxuan	DONE
				version integration	4 * 4	4 * 2	All	DONE
Nov 20-26		3	Low	specifical assets	8	2	Miguel	TODO
				time travel mechanism 1/2	8	6	Jialin	DONE
				weapon & interactive object	8	8	Mahdis	DONE
				full GUI	8	8	Yaxuan	DONE
				version integration	4 * 2	4 * 2	All	DONE
Nov 27-Dec 03	**Interim demo**	4		time travel mechanism 2/2	8	10	Jialin	DONE
				cascaded explosion refine	8	2	Miguel	TODO
			Desirable	map generation 1/3	8			
				local multiplayer 1/3	8	10	Yaxuan	DONE
				version integration	4 * 2	4 * 2	All	TODO
Dec 04-10		5	Desirable	map generation 2/3	8			
				local multiplayer 2/3	8		Yaxuan	DONE
				explosion effects 1/2	8			
				more weapon and objects	8			
				version integration	4 * 2		All	
				map generation 3/3	6			
				local multiplayer 3/3	6		Yaxuan	DONE

Figure 11: Time schedule

10 Challenges

10.1 Input System: Keyboard Splitting

Implementing local multiplayer using Unity's modern input manager presented unexpected challenges. While the system is designed to simplify input handling, configuring two players to share a single keyboard proved non-trivial. The default player-joining behavior assigns players to separate devices, which conflicted with our keyboard-splitting setup.
To resolve this issue, we:

- Switched the player join behavior from automatic to manual, and manually join the players in GameManager.
- Assigned the same keyboard device to both players.
- Configured distinct key schemas for each player, ensuring that the shared keyboard functionality operates as intended.

10.2 Time Travel Feature: Snapshots and Current States

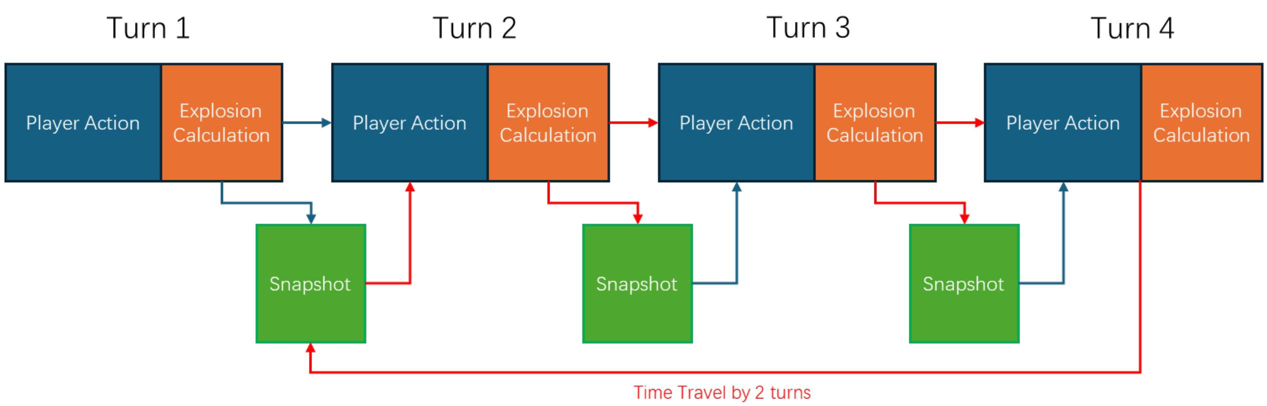


Figure 12: Overview of Time Travel Feature. The red arrows denote the pipeline of Time Travel.

The time travel feature requires taking snapshots of each round and properly rewinding to the related previous snapshots. So the main task of the time travel feature is separated into three subtasks:

- Definition of the data structure of snapshots.
- Taking the snapshots to save the current state.
- Loading snapshots to rewind to a previous state.

10.2.1 Data Structure Definition

Because the Player, Bomb, and Resource are Monobehavior classes, we need to define information classes as a record to take a copy of their current states, otherwise the information in snapshots will be changed due to reference. So we created PlayerData, BombData, and ResourceData classes to store their core data in the snapshots. The wall data is stored as a list of position, and the map items are in a list of GameObjects for convenient placing and enabling/disabling. To allow remaining the last bomb placed by each player, we recorded the last placed bomb in Player class and stored it in PlayerInfo class.

10.2.2 Taking Snapshots

At the end of every turn, a snapshot of the whole game state will be taken, by storing data to the defined data structure.

10.2.3 Loading Snapshots

When a player calls time travel, the current turn will not be taken into account and will rewind back to a previous state by loading a snapshot.
The Loading of snapshots contains player position placement, player resource management, map wall placement, map item recovery, past bomb and last bomb placement, bomb state (e.g. turns until explosion) loading, game manager state loading.
There are some edge conditions here that can bring up unexpected conditions, such as:

- Calling a 3-turn time travel in the 2nd turn.
- Time Travel back to a turn when the hourglass hasn't been picked up.

To deal with the issues, we:

- Revert to initialized state when calling an early time travel.
- Make the hourglass an exception in recovery, i.e. the hourglass is a one-time item.

10.3 Item Interaction

Until now we display the picked-up items in the game world such as hourglass, coins and the weapons in a UI panel. For the coins we use yellow sphere and for the hourglass we use a blue sphere for now. We have defined an Item class to demonstrate different existing item types that appear as in-game world items. The user picks up the items by collision detection with the items. The resource management system that we have implemented facilitates the storage of them in our inventory and is easily scalable.
We differentiate between stackable and unstack-able items. Items such as coins and various types of weapons are considered stackable. However, hourglass item is a unique and unstackable item, which the user can hold a use one time. This way there is a fair chance for all players to be able to pick up at least one hourglass per game, once it appears.
Items for now are placed manually by us, for further improvement we plan to design a respawn system of the in-world items. The respawn system has to be randomized but also calibrated with the generated map per level. Additionally, one further improvement will be creating a visual inventory to display the items as icons and reduce the amount of text displayed. This will improve the game experience for the players.

10.4 Chain Reaction

We implement the logic for placing active and passive bombs on the current player position. Active bombs have a counter that is decreased at the end of each turn. Once the counter reaches 0 the bomb explodes and affects the tiles in all 4 directions (up, let, down, right). We check for collisions with any object tracing a ray from the bomb position and retrieve the first hit object (if any). If the object lies within the bomb radius, then it will be affected in the following way: breakable walls will be broken, players will be eliminated and other bombs will explode. We add a small explosion animation at every affected tile to keep visual coherence and help the development testing.
To prevent any undesired behaviour we place every object center at round number positions and assume their position as the tiles for our game with a tile step of 1. This allows us to perform all the distance checks using the objects' positions directly and avoids the additional logic for a matrix based tile manager.
In order to maintain the logic proposed in our prototype, we want to perform all explosions at the same time, and afterwards compute the result on the breakable walls. This prevents some edge cases where the order of the bomb explosion changes the final result, e.g. propagating an explosion through a breakable wall after it has been affected by another bomb that same turn. We consider this specially important for obtaining a deterministic output from the same initial situation in a strategy game.

11 Design Revision

11.1 Scalability Considerations

During the implementation we learnt that it is important to focus on the scalability of the code to facilitate the extension of mechanisms, if needed. We have not made any design revision compared to our presented prototype up until now. Instead, we focused on not only achieving the current targets but also ensuring scalability for future versions. Below we focus on some of them:

- **Turn Mechanism**: instead of managing turns solely within a single game, we implemented a hierarchical structure that organizes gameplay into games, rounds, and turns. This approach eliminates the need for major refactoring when introducing a multiple-round setting, enabling seamless winner calculation and turn management adjustments.
- **Resource Management**: all user resources (including steps, coins, and time-travel items) are managed cohesively. This structure simplifies the addition of new items and facilitates future numeric or categorical extensions.
- **Input Handling**: by adopting Unity's event-driven input system, we ensured that our local multiplayer requirements are met. This approach also lays a strong foundation for transitioning to remote multiplayer in the future.

12 Progress in Photos

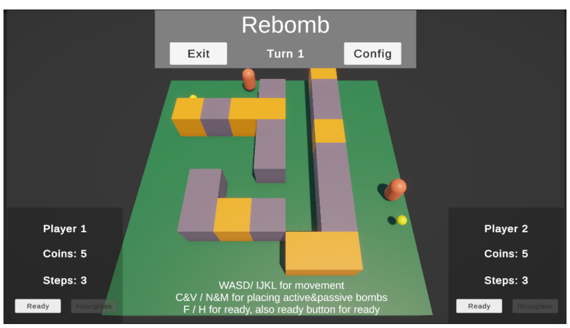


Figure 13: Initial state of the game

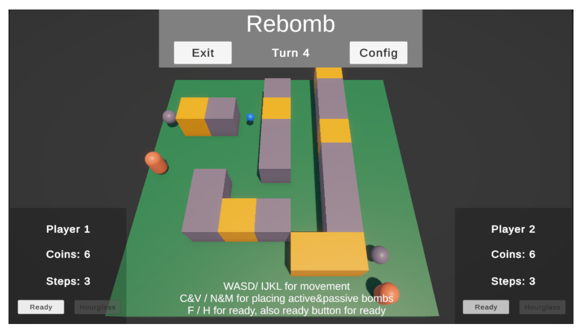


Figure 14: Hourglass spawns under breakable wall.

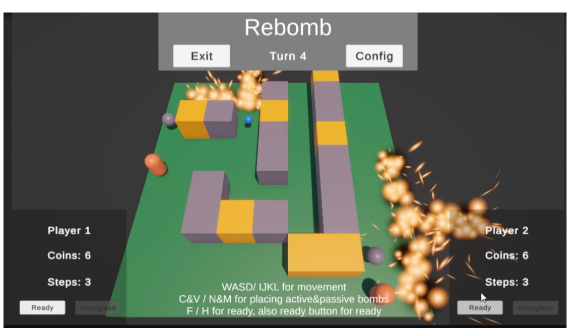


Figure 15: Active and Passive Bomb Explosion

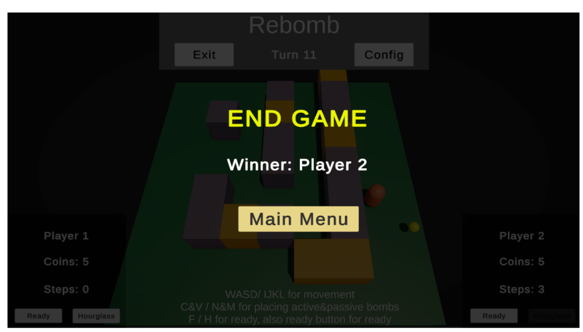
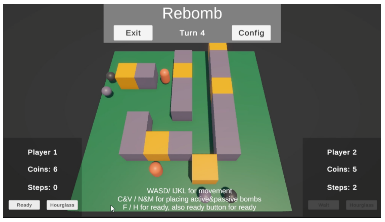
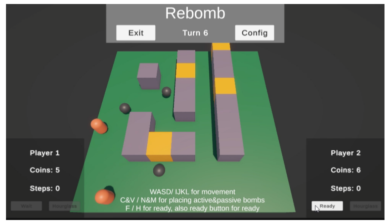


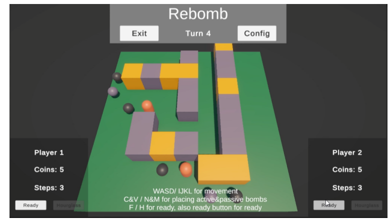
Figure 16: Endgame Result



Turn 4 Status



Before the Usage of Hourglass



After the Usage of Hourglass

Milestone 4: Alpha Release

13 Task Progression

Despite some pending numerical refinement decisions, we ensured all critical elements for the Alpha release were delivered, aligning well with the overall project timeline.
Tasks were not fully packed into the last two weeks before the Alpha release, showcasing how the period from 18th–24th December, reserved for bugfixes and delayed tasks, allowed the team to make up for missing assets and tackle several features beyond the original plan.

Date	Milestone	Week	Layer	Task	Time		Owner	State
					Expect	Actual		
Nov 27-Dec 03	**Interim demo**	4		time travel mechanism 2/2	8	10	Jialin	DONE
				cascaded explosion refine	8	5	Yaxuan	DONE
				specifical assets	8		Miguel	Later
			Desirable	map generation 1/3	8	8	Mahdis	DONE
				map manager refactoring **(new)**	3	1	Mahdis	DONE
				local multiplayer 1/3	8	10	Yaxuan	DONE
				version integration	4 * 2	4 * 2	All	DONE
Dec 04-10		5	Desirable	map generation 2/3	8	8	Mahdis	DONE
				audio effects **(new)**	8	8	Mahdis	DONE
				explosion visual effects 1/2	8	4	Yaxuan	DONE
				explosion refactoring **(new)**	3	4	Yaxuan	DONE
				preview time travel **(new)**	8	12	Jialin	DONE
				more weapon and objects	8	6	Jialin	DONE
				version integration	4 * 2	4 * 2	All	DONE
Dec 11-17		6		map generation 3/3	6	6	Mahdis	DONE
				explosion visual effects 2/2	6	6	Yaxuan	DONE
				numerical refine	6	0	All	Later
				version integration	4 * 4	4 * 4	All	DONE
Dec 18-24		7		specifical visual/audio assets	8	12	Mahdis	DONE
				turn&level logic **(refine)**	6	6	Yaxuan	DONE
				bugfix before integration	3 * 4	3 * 4	All	DONE
				version release			All	DONE
Dec 25-31		8		holiday(Dec 24-Jan 06)	0			
Jan 01-07	**Alpha release**	9			0			
Jan 08-14	**Playtesting**	10	High	remote multiplayer	2 * 8		Yaxuan	
				assesment & bugfix	2 * 8			
				version integration	4 * 4		All	
Jan 15-21		11		remote multiplayer	2 * 8		Yaxuan	
				improve mechanics	8			
				refine animation/characters	8			
				version integration	4 * 4		All	
Jan 22-28		12		remaining tasks & test	4 * 10		All	
Jan 29-Feb 04	**Final release**	13	Extra	extra tasks & test	4 * 10		All	

Figure 17: Time schedule.

14 Challenges

14.1 Map Generation

One important factor that makes our game re-playable and interesting in each level is its map. For the first level of the game, we are using the same map as our prototype. This level serves as a tutorial level for new players to get familiar with the in-game mechanics. For other levels we are generating maps by procedural content generation to make each level unique and special. For the map generation we are using the Random Walk Algorithm [1]. After thorough research it was concluded that this algorithm with some minor adjustments can fit best to our needs.

14.1.1 Random Walker Generator

Our map has accessible (tunnels) and inaccessible areas (walls) and the players can navigate through a connected route. Initially we generate a map with the given dimensions that contains only unbreakable walls. Then we place the 'Walker' in a random position on the map and replace the unbreakable wall with a floor and we 'dig' tunnels. We dig tunnels by choosing a random length from maximum allowed length and a random direction (up, down, right,left) and finally drawing a tunnel in that direction and length. The algorithm keeps digging tunnels, making random turns with random length, updating the walker's position until the desired number of tunnels are satisfied.
The generated map until now includes a route for the walker to navigate inside a maze of unbreakable walls. Therefore we have to adapt it to our needs. Firstly, we wanted to place the players in the corners for the start of the game. Since the generated map can also include unbreakable walls on the corners, we had to set a flag for the desired map that we would accepted. We keep generating the map and only accept the one that has corners free, meaning floors are places on each corner, so we can place players on the corners. Since this could end in a endless loop if the maximum tunnel is too low, we have also set the maximum attempts to try. By various trials and adjustments of the numerical values of maximum tunnel and maximum length we found out the best combinations that provides us a fast and well-suited generated map for our needs and not making the game crash.

14.1.2 Breakable Walls and Items

Since our game should consist of breakable and unbreakable walls, we had to add extra constraints to the generated map even further. For placing the breakable wall, we decided to replace the floors with breakable walls, since technically the players can also walk through the path of the breakable walls after they are broken. We start with a starting probability for the breakable wall and a random number. If the random number is more than the starting probability we increase its value. Otherwise we replace the floor with a breakable wall and reset the starting probability. For placing items (coins and boots) on the map, we also use the same logic. We don't differentiate between item types here yet. while instantiating the items we choose a random number generator to either instantiate a boot or a coin on the map. Therefore, it can happen that the number of generated coins and boots do not match, or items of one type only will be generated. While this outcome may not be optimal, the players learn to play strategically with the available resources on the map.
After placing breakable walls and items, we clear the corners so there is enough room for the first movement of the players, for placing bombs without being affected by it. Finally, we add border to our map for nicer visual appealing. For placing the borders we create another map with dimension + 2 full of borders, and copy our generated map into it.
The only missing item is now placing the hourglass under one breakable wall. For this we loop through our final generated map and create a list of breakable walls and we return the position of a randomly chosen breakable wall. We then instantiate the hourglass under the chosen breakable wall.

Figure 18: Examples of the generated map

The challenges we faced for the map generation was mostly in regard of making the map look as we desired with an existing algorithm. The random walk algorithm gave us a good basis and by adding some constraints we adapted the generated map until we finally met our desired goal.

14.2 Audio and Visual Elements

For the audio sounds and visual aspects of the game we used materials from the unity asset store, sketchfab, and pixabay websites. We had envisioned a world where the players are robots and fight between them takes place in space. With this vision, we tried to find assets that fits our needs. For UI icons we also used generated AI to create new icons was used for our inventory system for instance.
For the players we used Sci-Fi Ball Robot asset [2]. For the breakable walls we used Cartoon Crate Collection [3] and for unbreakable walls and floor we used Yughues Free Metal Materials [4]. The boot [5], coin [6] and border [7] 3D models were found in Sketchfab. The bombs and hourglass 3D models were used from Props 3D [8] and the skybox from Diverse Space Skybox asset [9] in unity assets store.
For the music we chose arcade-vibe style. This not only matches the original nostalgic vibe of the original Bomberman game, it also adds the originality flavor to the game. All sounds effects for bomb explosion [10], coin pickup [11], boot pickup [12], hourglass pickup [13], and background music for levels [14] [15], main menu [16], gameover menu [17] were found from pixabay website. We implemented an audio mixer so that the player can adjust the volume for effects and background music according to their preference. A full list of resources used assets and audio tracks can be found in the bibliography section.

14.3 Time Travel Preview

To provide the hourglass holder with an idea about the effect of using time travel in the current turn, we have introduced time travel preview in Alpha Release, as shown in 19.

Figure 19: Time Travel Preview.

The appearance of the preview panel is half-transparent for a better see-through between current states and potential time travel results. To avoid blocking, the viewing angle is perpendicular to the floor plane. The time travel preview allows easier decisions on the usage of time travel, and contributes to deepening decision depth.
To implement this feature, we first planned to create a duplicated scene of the whole game, perform time travel on the copied scene, and display the rewind scene in a small window as the preview. But the plan has been proved to be sub-optimal, due to:

- High performance cost. Duplication of all objects and rendering simultaneously takes significantly higher memory and computation power.
- Difficulties in development. Many scripts define Monobehavior, which requires manual deep copies to make sure the duplication doesn't affect the current state. This is not recommended in Unity development standards.
- Invisible bombs. If one last bomb is planted at a location where a breakable wall is restored after time travel, the bomb will be invisible to the player as it's hidden in the wall.

As a solution, we finally implemented time travel preview by combining snapshot images and last bomb rendering results. Every time a snapshot is saved, an extra screenshot of the state will be taken and saved as texture in the snapshot. When a time travel preview is requested (by hovering the pointer on the hourglass button), another screenshot containing only the current last bombs is taken. By combining the last bomb image and the screenshot in the target snapshot, we can get the preview image with past map states and current last bombs. This method is flexible to further changes to the the game features and minimizes the memory and computational costs, but brings up frame rate jitter when calling the review, due to the real-time rendering of last bombs.

14.4 Explosion Visual Effects

To enhance the explosion effects and enrich the game with new featured bombs, the explosion effects system was upgraded with various new visual and audio effects. The goal was to improve the player's experience and clearly differentiate bomb types. The following new features were introduced:

1. **Decay Management:** An `ExplosionManager` was introduced to handle all visual and audio effects with proper timing, synchronization, and scalability. Using `Coroutine`, we ensure asynchronous operations can manage multiple explosions simultaneously following the trigger delay.
2. **Visual Effect Refinement:** Each bomb's visual and audio effects are now managed independently within the explosion MonoBehaviour. Specific tuning of visual effects was achieved programmatically. For instance, the flame color of the `SafeBomb` was visually distinguished to reduce user confusion (indicating it only damages walls and not players). Additionally, a decay effect was implemented for flames, causing the visual intensity to diminish with distance from the explosion center, enhancing realism and user experience.

15 Design Revision

15.1 Cascaded Explosion Refinement

The explosion system faced significant issues when managing the cascaded effects, especially regarding bomb triggers and delays. The following key challenges were identified and addressed:

- The order of bomb triggers was not well-defined; adding delays caused deviations from expected behavior.
- Features like the `Chainbomb`, which powers up bombs it triggers, did not function as intended due to limitations in the trigger order.
- Adding new bomb features, such as the `SafeBomb`, was challenging due to the lack of proper layer management for cascaded triggers.

To address these challenges, we implemented the following refactorings:

1. **Decoupling Explosion from Bomb:** The trigger decision and cascaded effects on players and walls are now handled by the bomb. Explosion-specific details, such as delay, range, and visual effects, are managed independently by the explosion system.

2. **Refactoring Explosion Calculation:** The mechanism for handling triggers within the current turn and their cascaded effects was restructured from a Depth-First Search (DFS) to a Breadth-First Search (BFS) approach. A trigger queue was introduced, ensuring triggers are processed from early to late, and delays are handled in ascending order. This satisfies the functional requirements for features like `Chainbomb`.

3. **Implementing Triggering with Layers:** The cascaded triggering of surrounding objects with raycasting was configured using the layer system in Unity. Previously, players could occlude rays, preventing them from detecting walls behind. By configuring all entities (walls, players, bombs) with appropriate layers, calculations became manageable, and features like the `SafeBomb` (which damages walls but not players) were effectively integrated.

15.2 Other Refactorings

- **Bomb Mechanism Adjustment:** To simplify the gameplay and highlight decisions, the bombs placed in the current turn will take effect instantly, instead of earlier planned starting from the next turn.

- **Consistent Resource Management:** Items picked up by players are now managed as a total resource count, rather than by maintaining object references in the inventory list. This enhances compacity and reduces complexity especially for time travel.

- **Centralized Bomb Configuration:** Each bomb type now has a centralized `BombConfig` that handles its properties and appearance. This approach makes numerical adjustments easier, facilitates the addition of new bomb types, and ensures consistent handling of bomb features across the game.

- **Map Generation:** The initial version of the Random Walker Generator used numerical values in various functions to distinguish between floors, breakable walls, and unbreakable walls. For instance 0 for the floor, and 1 for unbreakable wall. While this approach was initially straightforward, it became difficult to follow as map generation constraints grew more complex. To address this, we refactored the code by defining constants for map generation. These constants are now used to represent floors, walls, borders, and items, making the code more readable and maintainable. Adding new elements is now as simple as defining a new constant.

- **Item Placement:** Our map contains two primary items: coins and boots. Additionally, we have a special item, the hourglass, which is placed randomly under a single breakable wall. Initially we were differentiating between primary item types, creating respective functions for placing coins and boots separately. To ensure scalability, we refactored the code so that adding a new primary item type is as simple as instantiating it. The refactoring process eliminated the need to differentiate between item types (e.g., coins and boots). We randomly choose from a pool of defined items and instantiate the item type in the designated item placement position. This approach allows any newly added item to be seamlessly integrated and randomly generated on the map.

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