HW2 – Tank Game

Game Overview:

The code represents a **tank battle game** with turn-based mechanics, shell collisions, and grid-based movement.

Map Structure (as given in example):

- #: **Wall** (2 HP, blocks movement/shots).
- @: **Mine** (instantly destroys tanks that step on them).
- 1/2: Starting positions for **Player 1** and **Player 2**.
- *: Shell moving on board (in bonus basic visual of game steps 'gameSteps_output
- _inputFileName.txt')

Turn Sequence

Shell Movement Phase:

1. All shells move 2 cells per turn
2. Collision detection happens after each movement step

Tank Action Phase

1. Each tank decides action based on its algorithm
2. Actions validated and executed sequentially

After each turn, Destroyed objects removed from board and the round is logged.

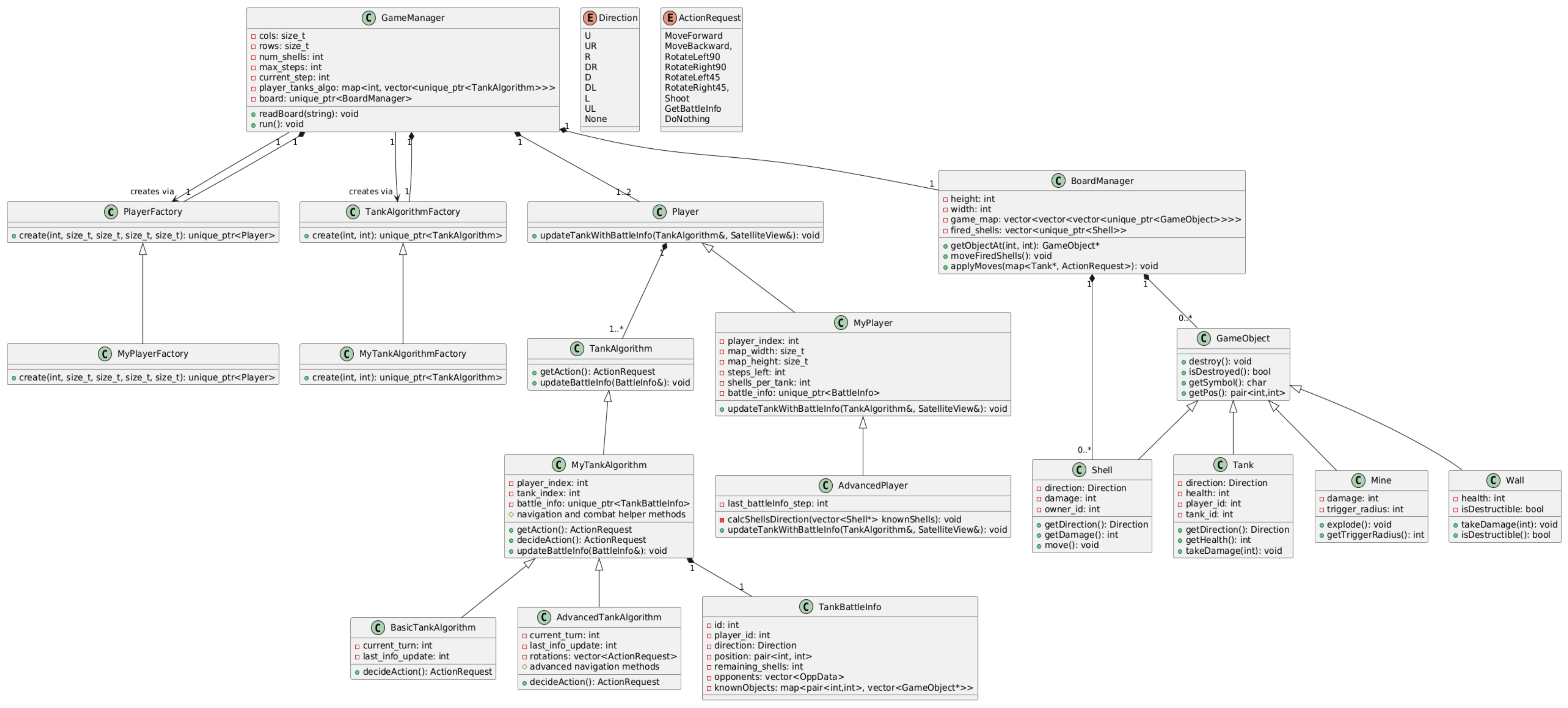
GameManager processes the rounds, updates its info about the tanks, and logs all changes, while the movement validation and application of all objects on the map and their collisions are done in BoardManager.

The game ends when only tanks of one player are still on the board, after 40 turns where all tanks have no shells left or after MaxSteps given is reached.

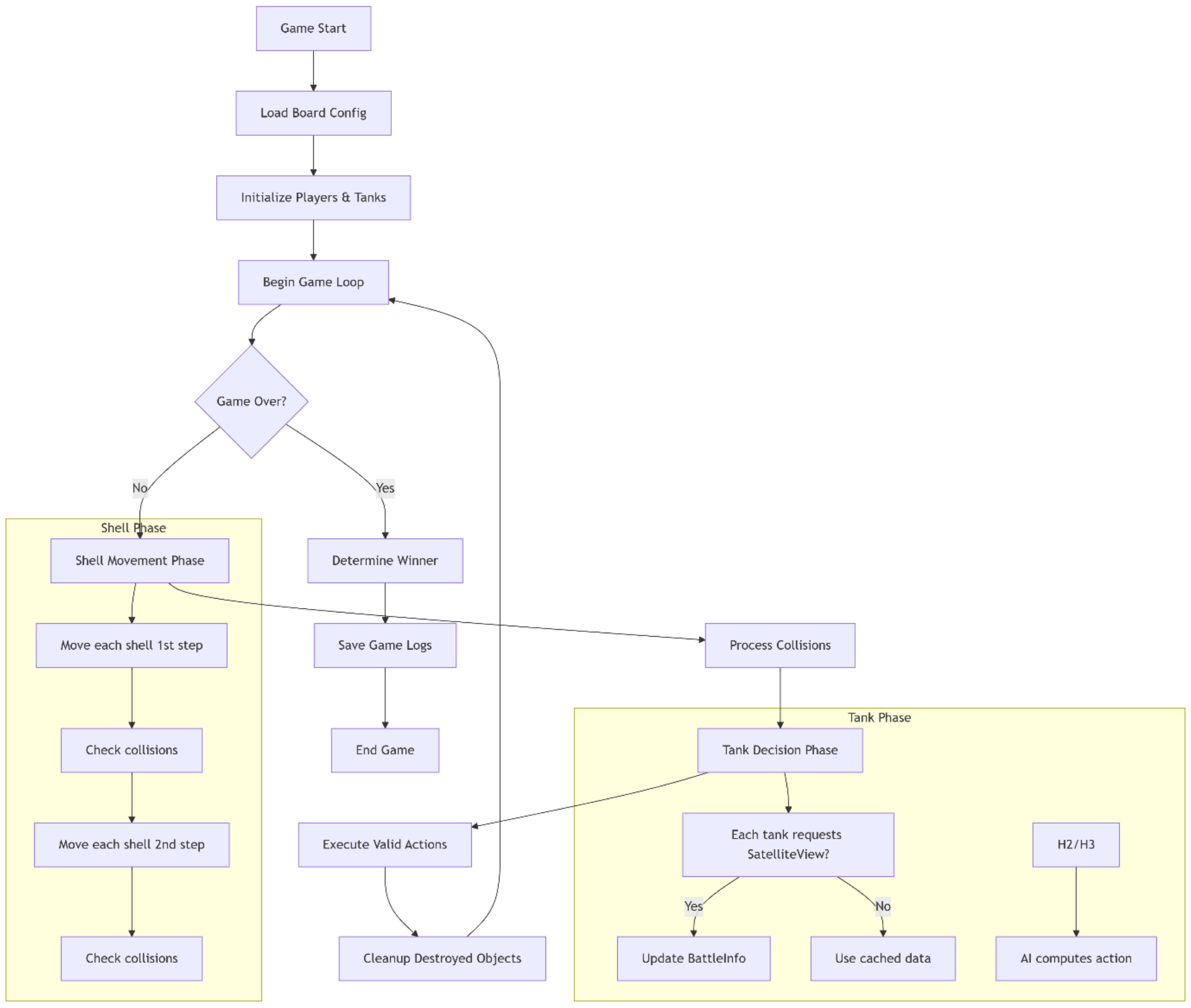
Important Remarks:

- **Move Decision -** all tanks decide their next move and only after both have decided, it happens. The actions decided are depending on the algo's gathered information so far.
- **Shell Collision** - If multiple shells land in the same cell, **all** are destroyed and if there's a wall\tank in that cell, they're destroyed as well.

Class UML -


GameManager
cols: size_t
rows: size_t
num_shells: int
max_steps: int
current_step: int
player_tanks_algo: map<int, vector<unique_ptr<TankAlgorithm>>>
board: unique_ptr<BoardManager>
readBoard(string): void
run(): void
Direction
U
UR
R
DR
D
DL
L
UL
None
ActionRequest
MoveForward
MoveBackward,
RotateLeft90
RotateRight90
RotateLeft45
RotateRight45,
Shoot
GetBattleInfo
DoNothing
creates via
1
PlayerFactory
create(int, size_t, size_t, size_t, size_t): unique_ptr<Player>
TankAlgorithmFactory
create(int, int): unique_ptr<TankAlgorithm>
1..2
Player
updateTankWithBattleInfo(TankAlgorithm&, SatelliteView&): void
BoardManager
height: int
width: int
game_map: vector<vector<vector<unique_ptr<GameObject>>>>
fired_shells: vector<unique_ptr<Shell>>
getObjectAt(int, int): GameObject*
moveFiredShells(): void
applyMoves(map<Tank*, ActionRequest>): void
MyPlayerFactory
create(int, size_t, size_t, size_t, size_t): unique_ptr<Player>
MyTankAlgorithmFactory
create(int, int): unique_ptr<TankAlgorithm>
1..*
TankAlgorithm
getAction(): ActionRequest
updateBattleInfo(BattleInfo&): void
MyPlayer
player_index: int
map_width: size_t
map_height: size_t
steps_left: int
shells_per_tank: int
battle_info: unique_ptr<BattleInfo>
updateTankWithBattleInfo(TankAlgorithm&, SatelliteView&): void
0..*
GameObject
destroy(): void
isDestroyed(): bool
getSymbol(): char
getPos(): pair<int,int>
MyTankAlgorithm
player_index: int
tank_index: int
battle_info: unique_ptr<TankBattleInfo>
navigation and combat helper methods
getAction(): ActionRequest
decideAction(): ActionRequest
updateBattleInfo(BattleInfo&): void
AdvancedPlayer
last_battleInfo_step: int
calcShellsDirection(vector<Shell*> knownShells): void
updateTankWithBattleInfo(TankAlgorithm&, SatelliteView&): void
Shell
direction: Direction
damage: int
owner_id: int
getDirection(): Direction
getDamage(): int
move(): void
Tank
direction: Direction
health: int
player_id: int
tank_id: int
getDirection(): Direction
getHealth(): int
takeDamage(int): void
Mine
damage: int
trigger_radius: int
explode(): void
getTriggerRadius(): int
Wall
health: int
isDestructible: bool
takeDamage(int): void
isDestructible(): bool
BasicTankAlgorithm
current_turn: int
last_info_update: int
decideAction(): ActionRequest
AdvancedTankAlgorithm
current_turn: int
last_info_update: int
rotations: vector<ActionRequest>
advanced navigation methods
decideAction(): ActionRequest
TankBattleInfo
id: int
player_id: int
direction: Direction
position: pair<int, int>
remaining_shells: int
opponents: vector<OppData>
knownObjects: map<pair<int,int>, vector<GameObject*>>

Game flow Chart –



Design Considerations & Alternatives

Here are our key design choices and potential alternatives:

1. Architecture:

Current Design –

- GameManager` acts as the orchestrator, responsible for:
  - Reading the board.
  - Running the main game loop.
  - Logging and result reporting.
  - It owns all major components: (BoardManager, Players, TankAlgorithms,…).
- **Game Map Structure:**
  - game_map is a 3D `vector<vector<vector<unique_ptr<GameObject>>>>`.
  - Each `Cell` contains a list of objects (Mine/Wall\Empty + Tank\Shell).

Alternatives –

- **Event-Driven Architecture:**
  1.event queues and listeners.
  2.Actions like `TankFired`, `TankMoved`, `TankDestroyed` trigger subscribers.
  Pros: More modular, suitable for extensibility.
  Cons: Overhead and unnecessary complexity for current scale.
- **Micro-Service Style Modules:**
  Separate modules for ShellManager, TankLogic, CollisionHandler.
  Pros: Independent testing, scalability.
  Cons: Far too heavy for this project.
- **Flat Object Registry + Spatial Hashing:**
  Maintain a global object list + map from coordinates to indices.
  Pros: Better for large maps and performance tuning.
  Cons: Adds complexity without functional gain at small scale.
- **2D Grid with Type Masks:**
  Use enums or bitmasks to represent presence of different object types.
  Pros: Lightweight and cache-friendly.
  Cons: Loses polymorphism and behavior encapsulation.

2. Object Management

Current Design –

- Uses `unique_ptr<GameObject>` in `BoardManager::game_map` for ownership.
- Movement via moveFireShells, applyMoves, extractObjectFromMap() and updateMap functions in BoardManager.

Alternatives –

- **Shared Ownership:**
  Use shared_ptr<GameObject> to allow access across multiple modules.
  Pros: Flexible object lifetime.
  Cons: Risks of dangling references, harder to trace lifetime.
- **Object Pooling for Shells:**
  Reuse `Shell` objects instead of frequent allocations.
  Pros: Improved performance in shell-heavy rounds.
  Cons: Harder to track state resets and ownership.

<u>3. Movement and Collision Handling</u>

Current Design –

- **Movement steps are grid-based:**
  - `moveFiredShells()` handles double-step shell movement with collision detection.
  - `applyMoves()` handles tanks movements per round with collision detection.
  - `processCollision()` handles compound interactions in one cell.
- **Delayed Actions (Backward Movement, Shooting Cooldowns):**
  - Backward move: 2-step cooldown implemented via `waitingForBackward`, `backwardCooldown`, `movedBackwardLast`.
  - Shooting cooldowns: `isWaitingToShoot` flag and cooldown counter.

Alternatives –

- **Continuous Coordinate**:
  Use floating-point positions for smoother movement.
  Pros: More realistic physics.
  Cons: Complex collision detection.
- **Task Scheduler for delayed actions:**
  - Each tank has a queue of scheduled delayed actions.
  Pros: Clean handling of complex delays.
  Cons: Adds more complexity, less intuitive for fixed delays.

<u>4. Tank Decision-Making:</u>

Current Design –

- **Strategy Pattern:**
  - `TankAlgorithm` is abstract, `MyTankAlgorithm`, `AdvancedTankAlgorithm`, and `BasicTankAlgorithm` implement it.
  - Tank behavior depends on the algorithm pointer (`MyTankAlgorithmFactory` assigns Basic algo to tanks of Player 2 and Advanced algo to player 1).

Alternatives –

- **Behavior Trees or State Machines:**
  Represent tank logic as transitions between states (like Dodge, Attack, Reload).
  Pros: Visual, modular, expandable.
  Cons: Requires more boilerplate, logic less centralized.

- **Neural Network or Reinforcement Learning:**
  Use past rounds to learn optimal moves.
  Pros: High adaptability.
  Cons: Overkill for turn-based grid game.

5. Logging and Output

Current Design –

- GameManager logs all events and generates per-turn summaries.
- BoardManager::printBoard() captures board state snapshots and by the end of the game, we get a simple visual of the game.

Alternatives –

- **Observer Pattern:**
  if there is a need of a more informational logging, have a `Logger` subscribe to events like `TankDestroyed` or `ShellFired` or something else we'd like to log.
  Pros: Separation of concerns.
  Cons: Too many callbacks, not beneficial unless logging logic grows.
- **Structured JSON Logging:**
  Log moves and collisions in JSON for replay or analysis.
  Pros: Great for visualization tools.
  Cons: More parsing effort, not needed for simple logs.

6. Memory Safety

Current Design –

- unique_ptr used extensively (in tanks, shells, etc.).
- No raw pointer ownership (except temporary in maps)

Alternatives –

- **Smart Pointer Everywhere:**
  Use shared_ptr for shell tracking, for `Tank*` in maps.
  Pros: Uniform memory management.
  Cons: Possible cyclic references or overhead.

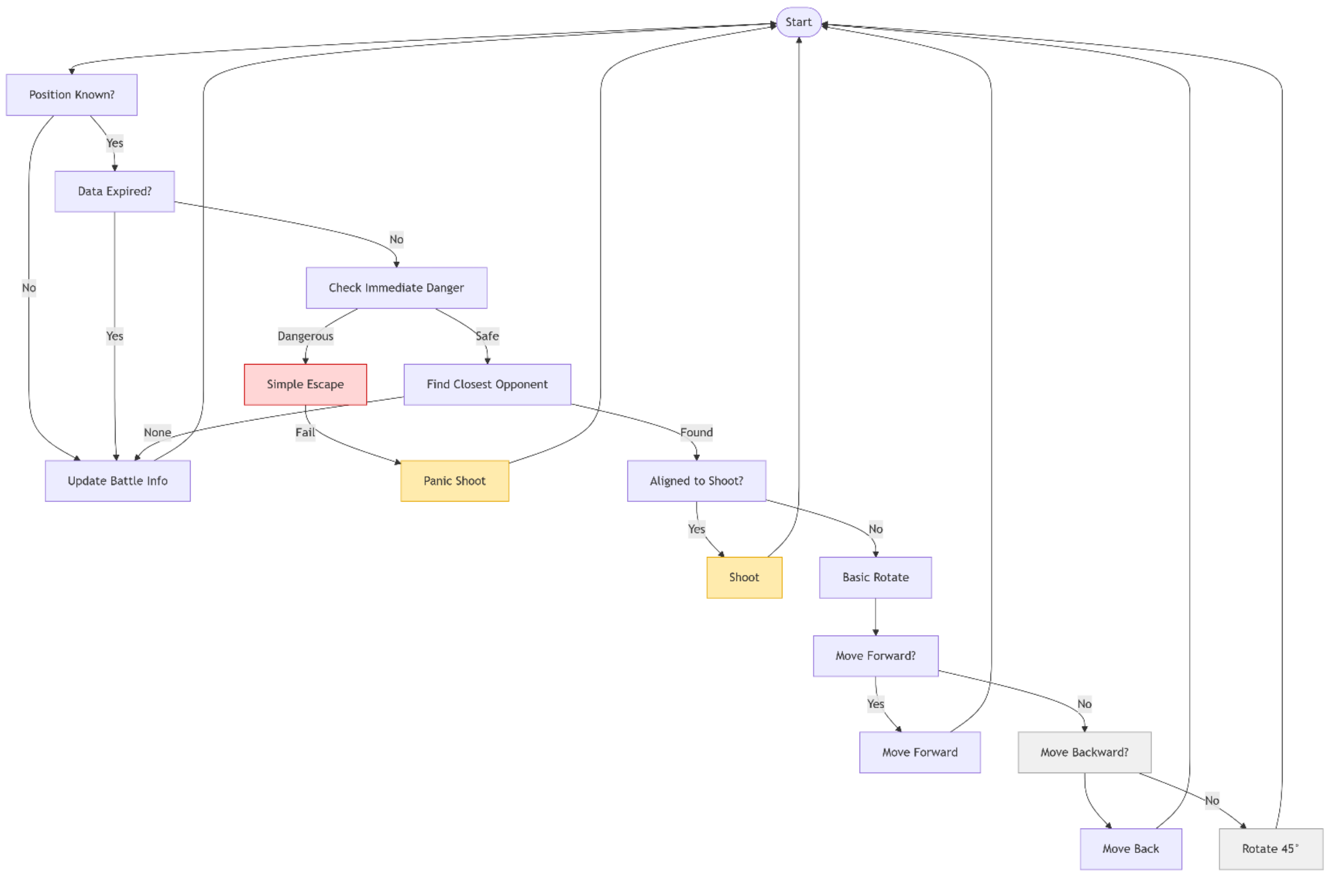
Algorithm explanation Basic vs Advanced

BasicTankAlgorithm –

This algorithm has a simple reactive behavior:

- Checks immediate danger (1 step ahead)
- Shoots when aligned with opponent
- Rotates toward opponent when not aligned
- Moves forward when path is clear
- Defaults to rotating right when stuck

Flow chart –

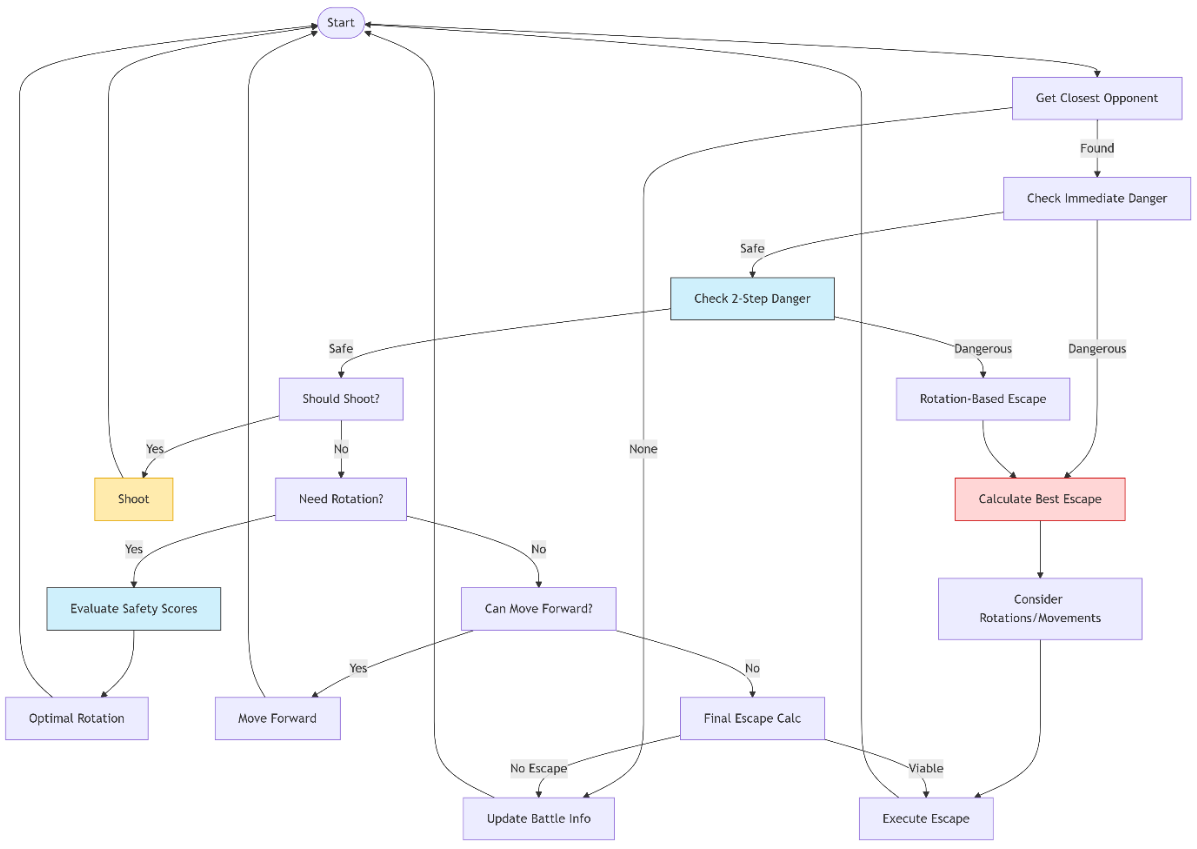


AdvancedTankAlgorithm –

This algorithm has a more sophisticated behavior:

- Multi-step danger assessment (1 and 2 steps ahead)
- Safety scoring system for rotations
- Active shell tracking and prediction
- Space-aware movement decisions (checkForEscape() func)
- Comprehensive battle info analysis

Flow chart –



<u>Players:</u>

<u>myPlayer and AdvancedPlayer –</u>

The primary purpose of both is to extracts battle information from the satellite view and updates the tank's position and direction, opponents, and shells.

<u>AdvancedPlayer</u>:

- Extends MyPlayer with enhanced decision-making capabilities.
- Implements logic to calculate potential directions of shells.

<u>Testing Approach</u>

We did a combination of unit tests, AI-generated scenarios(gameboards), and interactive debugging to validate the tank battle game logic.

- **Unit Testing (Core Logic)**
  Focus: Validate low-level mechanics in isolation.
  Test Cases: Movement & Collision, Wall Damage

- **Scenario Testing (AI-Generated)**
  Focus: Cover edge cases with multiple gameboard options (ChatGPT generated edge-case scenarios) and we tested them.
  We also manually verified those scenarios, debugged failed tests by replaying steps and fixed what we could spot.