students of watan!

Final Design Document

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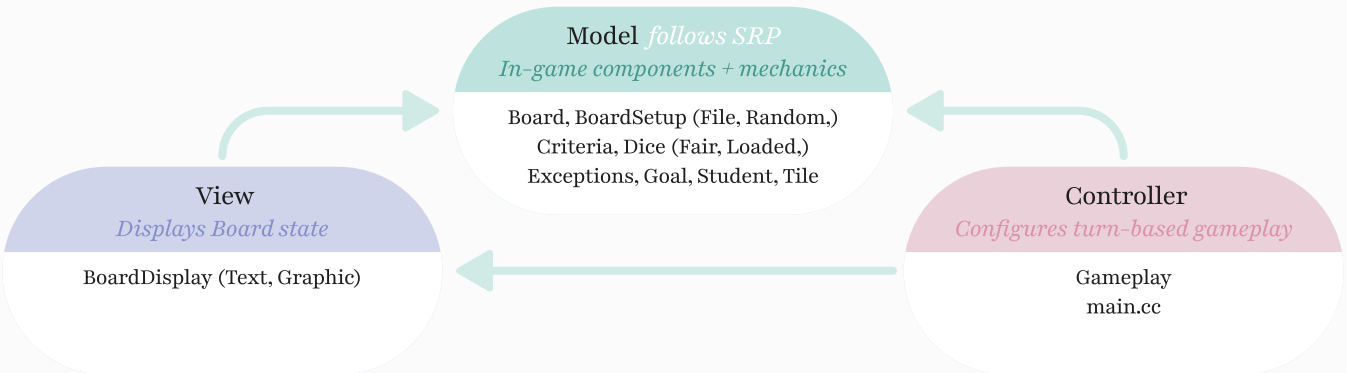
introduction.

We, as in the mutual decision-making of Yujin Bae, Angela Jin, and Halle Chan, present our adaptation of *Students of Watan* as implemented through an object-oriented C++11 structure, for the purpose of CS246's final assignment. *Students of Watan* is an adaptation of board game *Settlers of Catan*, in which users race for ten victory points in a turn-based claiming and upgrading of criterion and goals.

To aid with the explanations in this design document, we have added visualiser formats for some concepts.

overview.

To bring *Students of Watan* to life, we organized a object-oriented design structure that follows an **MVC architecture**:



Model

Board files: board.h/cc

The `Board` class serves as the central Model component in the MVC architecture for *Students of Watan.* It manages the key game elements in the context of the game—vectors of `Tile`, `Goal`, and `Criteria`, and an index `geesePosition`.

It provides functionality for core game actions that alter the attributes it possesses:

1. handling dice rolls to distribute resources (`tileRolled`);
2. enabling players to purchase goals or criteria (`buyGoal`, `buyCriteria`);
3. improving criteria upgrades (`improveCriteria`);
4. trading resources (`trade`);
5. setting the geese index (`moveGeese`).

`Board` interacts with other game elements to hold up adherence to adjacency rules and updates only to the game state it manages—we consider that in real life, a board directly owns its tiles, goals, and criteria. While one can argue that a tile owns its goals and criteria, we actually realize it does not—goals and criteria may be 'on' a tile, but multiple tiles share them as edges and vertices respectively, so we determined that `Board` as a whole owns them instead.

It utilizes an **Observer desigin pattern** to notify attached observers (`BoardDisplay`) of state changes, which upholds that the View remains synchronized with the game's current state.

BoardSetup files: boardSetup.h/cc, fileSetup.h/cc, randomSetup.h/cc

The abstract base class `BoardSetup` class is responsible for initializing the state of `Board`, with two board setup types. It defines the core steps required to configure the game board: (1) assigning resources and values to `tiles`, `goals`, `criterion`, and (2) ensuring the board adheres to the specified game rules.

`RandomSetup` and `FileSetup` implement the `BoardSetup` interface using the **Template Method pattern** (allowing specific steps to vary.) `RandomSetup` generates the tile resources and values randomly; `FileSetup` reads these configurations from a file stream to create specific gameplay scenarios. We encapsulate the board init. logic to ensure that the setup process is reusable + extendable to future features.

Criteria files: criteria.h/cc

The `Criteria` class represents a vertex on a hexagon `Tile` on `Board`, where players achieve milestones through completions and upgrades. It tracks integer `index` on the board, enum `completionLevel`, adjacent goals, and a pointer to `Student owner`. In, `Criteria`, we enforces game rules specific to how `Criteria` can change (i.e. adjacency, improvement conditions, and ownership constraints). Non-constant methods comprise of attaching a new owner to a `Criteria` instance and improving it, to the tune of these conditions. Constant methods allow basic accessors, checking for conditions of attributes, and looking for the existence and ownership of adjacent `Criteria/Goal`.

Note that in this context, 'adjacent' means that on the display of the board, a `Criteria` is connected by one edge.

Dice files: dice.h/cc, fairDice.h/cc, loadedDice.h/cc

The `Dice` class represents the dice-rolling mechanism in the game, with two concrete implementations: `LoadedDice` and `FairDice`. Using the **Factory design pattern**, the game instantiates either `LoadedDice` for player-specified rolls or `FairDice` for random rolls. Both implement `roll` w. the intention of consistent interaction for clients.

Exceptions files: exceptions.h/cc

`Exceptions` in the code handle invalid game actions, such as insufficient resources, invalid inputs, or I/O errors, which provide clear error messages so we can be aware of exactly what undefined behaviour happens.

Goal files: goal.h/cc

`Goal` represents an edge on a hexagon `Tile` on the `Board`, where players achieve milestones by claiming connections between vertices. It tracks an integer `index` on the board, a pointer to the `Student` owner, and adjacent `Criteria`. In Goal, we enforce game rules specific to how goals can be claimed. Non-constant methods handle claiming ownership of a `Goal` (`playGoal`) and attaching adjacent `Criteria`. Constant methods provide basic accessors + validate conditions of adjacency, & the ownership of a goal or its associated criteria.

Student files: student.h/cc

`Student` is a placeholder 'inventory' for a player. It tracks attributes such as `Colour` for identification, collections of owned `Criteria` and `Goal` objects, and an `unordered_map` for managing resource counts by enum `ResourceType`. Methods `addResource`, `removeResource`, and `playCriteria` interact w. game elements (but adhering to resource requirements and adjacency constraints.) The designs associates `Student` objects with their achievements and resources, and includes `Student`-specific features like calculating victory points (calculatePoints) and exporting the object state (`save`). This structure enforces clear separation of player-specific logic.

Tile files: tile.h/cc

`Tile` is a hexagon on `Board` with integer `index`, resource type, value, and associated vertices (`criterion`). It tracks whether it is occupied by the goose, impacting resource distribution. We associate `Criteria` and `Goal` pointers with each `Tile` to enforce adjacency relationships. The class provides basic accessors (getResourceType, getIndex, getValue), but does not have modifying behaviour because `Tile` itself does not change states throughout the game.

Controller

Gameplay files: gameplay.h/cc

`Gameplay` acts as the mediator between the View and Model by managing game state and coordinating player actions with `Board` updates. It processes input to determines game progression + adherence to rules, which allows `Board` and `Student` models to reflect the current state (and thus the state of `Criteria/Goals`.)

main.cc function files: main.cc

`main.cc` initializes the models and board loading, before it begins Gameplay (which drives the game loop.) This is where the controller can take the driver's seat.

View

BoardDisplay files: boardDisplay.h textDisplay.h/cc, graphicsDisplay.h/cc

Abstract `BoardDisplay` (with `TextDisplay` and `GraphicDisplay` subclasses) serves the game board's state to players as a visualiser. Using the **Observer design pattern**, BoardDisplay attaches to the Board (Subject) to receive updates when the board changes. Plus, The **Factory design pattern** provides the dynamic creation of either a textual (TextDisplay) or graphical (GraphicDisplay) interface, so we can now vary the type of display for users.

design.

Challenge: Who should have ownership of certain game elements—in particular, goals, criteria, and students, that seem to be useful in many places?

The challenge was determining ownership for goals and criterion, which are shared among multiple tiles on a board. We resolved this by assigning ownership to a class that manages all of these entities `Board` rather than individual `Tile` objects, as the board logically encompasses all game elements. This centralized ownership simplified adjacency validation and separated tile game logic, which doesn't necessarily 'own' goals and criteria, but uses it constantly.

Challenge: There are two different types of dice rolls, but we don't want to keep writing *if* statements to determine which method to use. How can we use a design pattern to facilitate different types of rolls that change at runtime?

To handle both fair and loaded dice, we used the **Factory design pattern** to instantiate the appropriate dice type, in which can be changed as the game progresses. This abstraction allowed the game to create either FairDice or LoadedDice based on player input. By providing a consistent roll interface, dice behaviour can now vary without affecting the rest of the gameplay logic.

Challenge: What categorization fits better as a Class, versus an Enum?

To decide what to model as classes versus enums called for balancing complexity (i.e. how much information something stores) and functionality (i.e. what we need it for.) As an example, `Tile` and `Criteria` were implemented as classes because they have state and behaviour—tracking ownership + determining resource production. Conversely, simple, unchanging attributes like resource/completion types (`CAFFEINE`, `EXAM`, etc.) and player colours were represented as enums to reduce overhead. We wanted to ensure that elements requiring dynamic interaction had sufficient structure without over-complicating static identifiers.

Challenge: How do we store and connect adjacent `Goals` and `Criteria`?

From the provided watan.pdf, we observed that each tile, goal, and criteria has an ordered index according to the board format display. We use this concept, giving each of them a unique 'identifier' saying, "I'm criteria/goal/tile number *x*," so that we could identify by integer. The hexagonal layout prompted us to use a constant map to define adjacency relationships, which connects tiles to their surrounding criteria + goals, and goals with criteria. This approach avoids recalculating adjacency dynamically for the requirements of our program (a fixed board structure.)

Challenge: Cool—now we have all these elements that have behaviour based on game mechanics. Where can we put together the sequence of play that allows the game to actually run, in a way that is encapsulated and does not interfere with mechanics?

Construing responsibilities of `Gameplay` needed careful delegation of tasks to avoid bloating the controller and over-forcing its involvement. We decided that defining exactly how much `Gameplay` is involved in managing things was key to separating concerns in game logic. Using a DAC204 - Game Design concept 'Formal Game Elements - Sequence of Play,' we could determine that direct game state changes should be away from the controller and only done in the model component. That is, `Gameplay` focuses on managing game progression and processing inputs, while state updates are handled by `Board`, `Student`, and related models. For example, when a player completes a goal, `Gameplay` validates the action but delegates ownership and adjacency updates to the `Goal` object, which adheres to principles of MVC architecture.

resilience to change.

Design aspect	How we structured it	Changes we can process
Setting board up with resources + values	The **Template Method design pattern** allows new setup types to extend `BoardSetup` and override specific steps of configuring `Board` resources, without affecting others.	Ways to configure setup. Current specification processes random + file, but what if we want a 'plentiful' set up (mostly non-`NETFLIX`) or a 'scarce' set up (mostly `NETFLIX`?) These custom configurations are possible.
Types of dice rolls	The **Factory design pattern** alters the behaviour of `LoadedDice` and `FairDice` subclasses—both of which take from virtual class Dice.	Introducing new dice types (such as weighted dice, different # of sides, or advantage/disadvantage dice—when the dice roll happens twice and takes the highest/lowest value respectively.)
Storing data on criterion + goals	Created class `Board` where all instances of `Criteria` and `Goal` are stored in a vector and identified by its integer index. Used constant mapping for adjacency.	Changing adjacency rules (say being able to claim neighbours of neighbours), adding new relationships between criterion and goals. With the assistance of other maps, creating more/less tiles or differently shaped tiles.
Types of ways to view the board of the game	The **Observer design pattern** allows additional displays to attach to the Board without modifying existing code.	Adding new display types (for instance, 3D graphics, web-based UI, accessibility-focused interfaces (like colourblind), audio-based display).
Managing the turns in the turn-based sequence of play	A custom **Iterator** is used to rotate through the player vector (and automatically return to the start after reaching the end,) which allows looping through turns.	Ever-changing turn orders or looping turn management (accommodating new player actions or skipping turns).
Enforcing game rules and game logic in mechanics	Encapsulating rules in classes like `Criteria`, `Goal`, and `Student` which examines specific conditions and permissions for each mechanic.	Modifying rules or adding/subtracting conditions, such as adjacency checks (e.g. neighbours of neighbours can be bought) or resource trade constraints (e.g. instead of x amount of resource, make it $x + 2$ amount of resource.)
Encapsulating tiles as separate from criterion + goals, but still part of board	Encapsulation in the `Tile` class allows behaviour-specific methods to be added without affecting the broader game structure.	Adding special effects to tiles, such as resource multipliers, penalties (similar to the geese mechanic,) or condition-based generation ('owning' all criterion/goals of a tile gives bonuses, for instance.)
Managing the inventory of each player	`Student` uses an `unordered_map` for resource tracking, allowing easy addition of new resource types. Methods like `addResource`, `removeResource`, and `playCriteria` define the behaviour of players' actions.	Attaching new resource types (say we wanted to add `EXTRACURRICULAR` or `INTERVIEW`) or expanding the range of player actions (like introducing unique abilities or special trades, such as force-trading or bartering.)

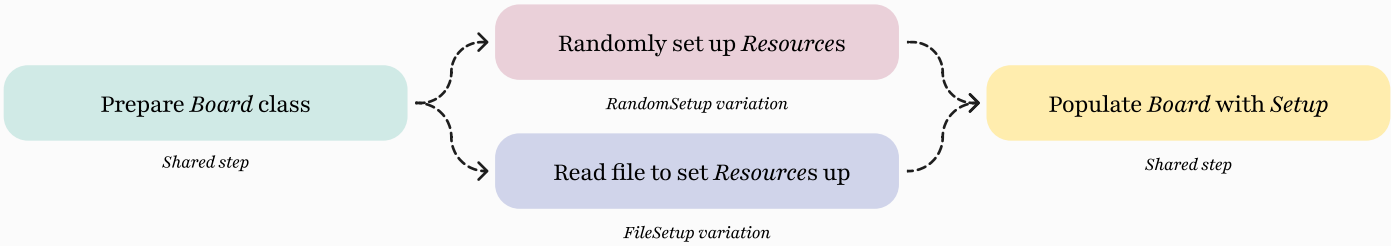
answers to questions.

1: You have to implement the ability to choose between randomly setting up the resources of the board and reading the resources used from a file at runtime. What design pattern could you use to implement this feature? Did you use this design pattern? Why or why not?

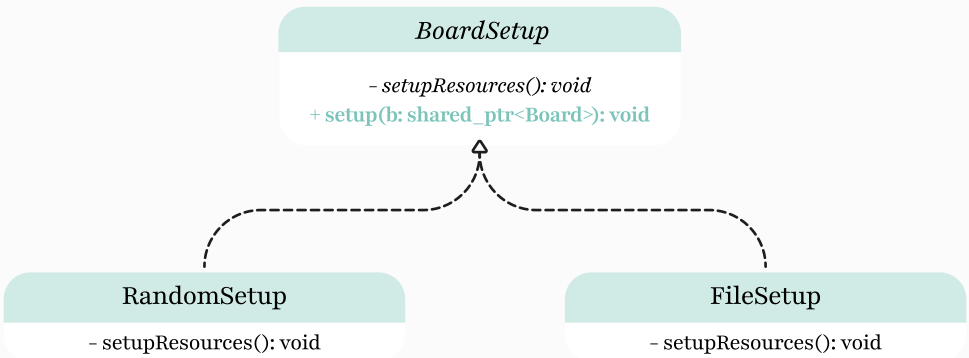
After implementing the code, we reaffirmed that the **Template design pattern** was the ideal choice for supporting both random and file-based board setups. Our reasoning remained consistent—the process of setting up the board possesses shared steps (e.g., populating the board) and steps that vary based on a random or file-based setup method.

1: The Template design pattern is ideal for altering steps of a process/algorithm, which is what we're doing here—we are promoting variations in the step it takes to set the board up, but ultimately, we end up with a *Board* instance that does not ultimately vary in how it handles behaviour.

2: That is, whether we set up randomly or with reading, we can actually end up with the same *Board* (in theory.) We don't require differentiating behaviour based on which "method" of set up is chosen, so we only must implement a change in one of the steps in algorithm, as shown below.



What *did* differ from our initial plan was the plan to implement the diagram above as three different methods (and the second one as the virtual, overridden method.) Instead, we created one public method, `setup(shared_ptr<Board> b)`, that wrapped `virtual void setupResources()` and added the shared steps together. The idea behind this approach was to avoid complexity in implementing the setup, since setup serves a sufficiently singular purpose. This is shared in the fixed diagram below:



extra credit features.

final questions.

1: What lessons did this project teach you about developing software in teams? If you worked alone, what lessons did you learn about writing large programs?

This project was sort of akin to running a *superhero* headquarters. Each of us—Angela, Yujin, and Halle—brought our own powers—whether it was design, implementation, or game mechanics expertise (shoutout DAC204)—and we learned the importance of playing to those strengths. We also had differing levels of team experience from the work done in previous co-op positions, personal projects, and hackathons—but this was *helpful* rather than a hinderance.

Delegation was our foremost handy tool. Halle took charge of `Board` mechanics, Yujin tackled `BoardSetup` and `Student`, and Angela worked on some key related elements like `Tile`, `Criteria`, and `Goal`. We brought this together with Gameplay, our view components, and writing this document collaboratively. Through Git and GitHub version control—in which was Angela's first time using it—we pushed/pulled on *main* branch regularly.

Discord served as our command centre for quick check-ins, calls, and long discussions, like deciphering the semantics of game rules, as demonstrated on the right. We also had in-person meetups.

When disagreements arose, we hashed out solutions until they clicked—for instance, we had different interpretations of how the Geese move mechanic worked. Lots of screenshots later, we worked through its semantics.

Ultimately, this project proved that teamwork doesn't solely rely on task division (as we students do in elementary-level work) but harmonizing strengths, collaborating ideas in-person, and staying united when the going gets tough.

2: What would you have done differently if you had the chance to start over?

If given a fresh start, we'd put a stronger emphasis on scalability and resilience to change. Namely, the following:

1: While representing resource/completion types as *enums* worked for this iteration, future expansions (maybe unique resource behaviours, like `CAFFEINE` slowly depleting if not used quickly) would benefit from modelling them as classes.

2: Configuring `Student` as the entity driving actions—rather than delegating solely to `Gameplay`—would leave the door open for custom computer-controlled players.

3: While constant maps were efficient for this scope, relying on them for adjacency felt like using a hammer where a compass would suffice—geometric calculations would have offered more resilience to changes or alternate layouts, like the square layout brought up in program specification questions.

4: We noticed the potential for smarter cohesion choices with respect to handling updates; encapsulating changes in a dedicated `GameState` handler could simplify propagation of actions across components.

Though these tweaks might have slowed us in the short term scope, we would've built a sturdier foundation for *Watan*'s evolution.