Lecture 4

Announcements

Wiz 1 Feedback

- Multi-directional movement
  - Probably using an if-or block for each key input
  - Use one if-or for vertical, one if-or for horizontal
- Different animations with different directions looks nicer too
- Movement should happen onTick rather than onKeyPressed/Typed
  - Set the keys that are down when they're pressed
  - onTick, look at the booleans and see which are true
- Viewport centering jank when you run into a wall?
  - Have the CenterComponent center on lateTick() instead of tick()

Get Ready for Wiz 2!

- We’re adding smart enemies!
- Actually challenging to play
- Even more fun than Wiz 1!

Announcements

QUESTIONS?

Think Pair Share

- How does a game developer use your engines level generator / level loader?

- How are frames of an animation loaded and displayed.

Lecture 4

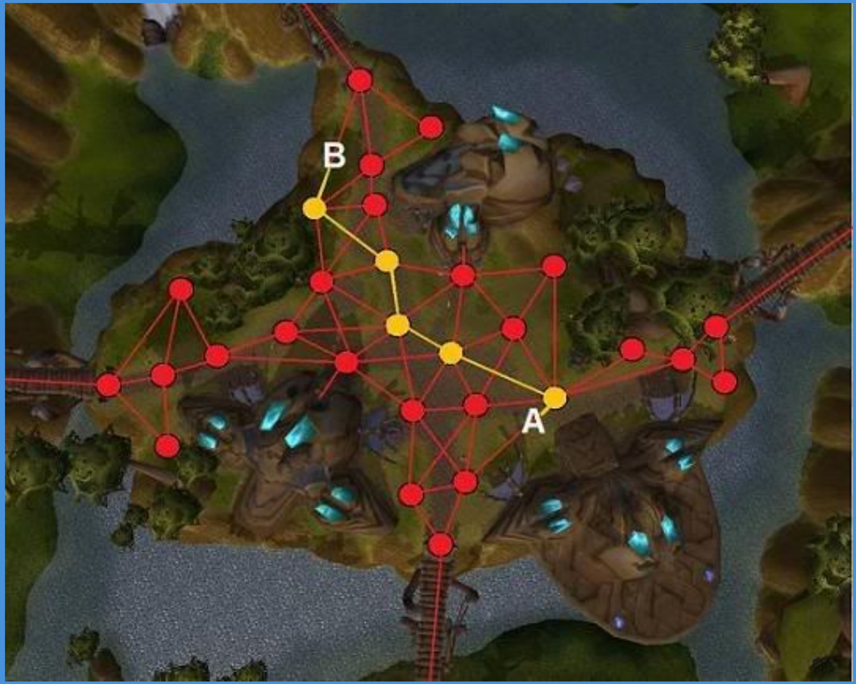
Pathfinding

Pathfinding

MOTIVATION

Why is pathfinding important?

- NPCs need to navigate an environment that has obstructions
- Goal: find minimum cost path from A to B
    - Cost includes factors such as distance, terrain, position of enemies.
- Typically uses a graph to represent navigable states.



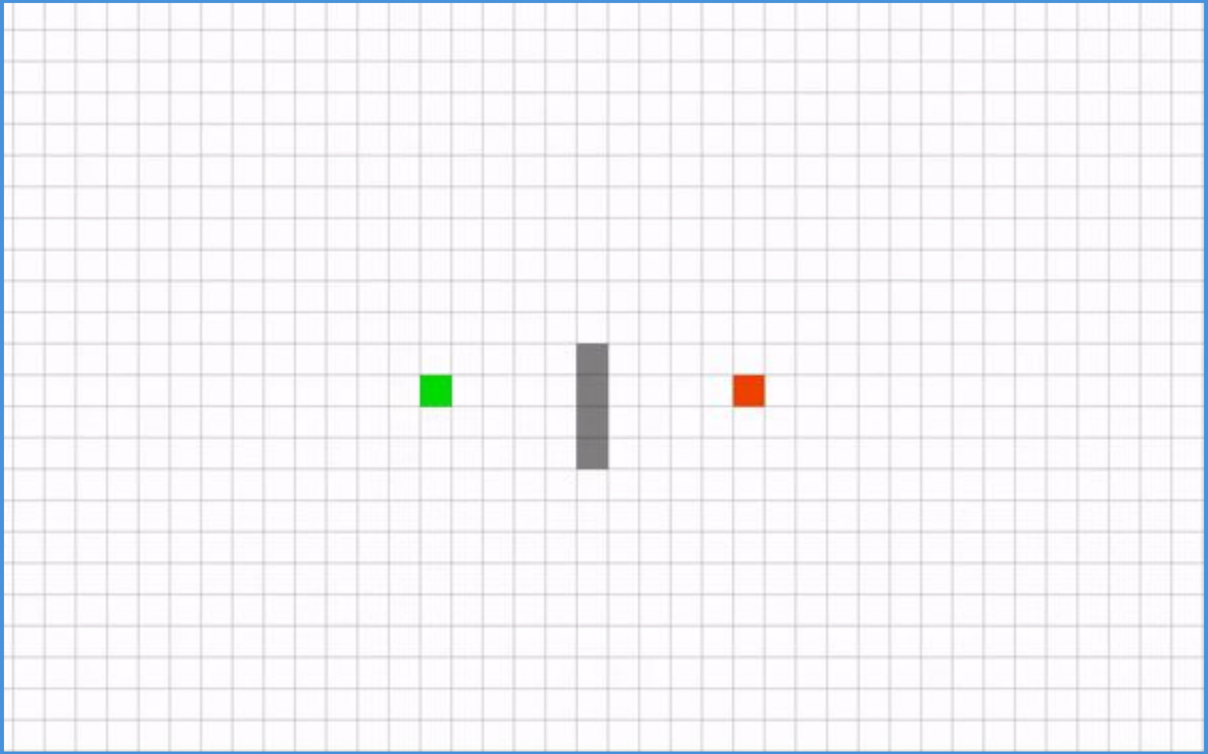
Pathfinding

DIJKSTRA'S ALGORITHM

Dijkstra’s

- Process nodes in order of shortest distance from start
- To process a node, update cost to each of its neighbor and add them to a `PriorityQueue`, then never process this node again
- Each node in `PriorityQueue` keeps track of shortest distance to it and pointer to previous node
- When you process the end node, you’re done!

Why Dijkstra's can be gross



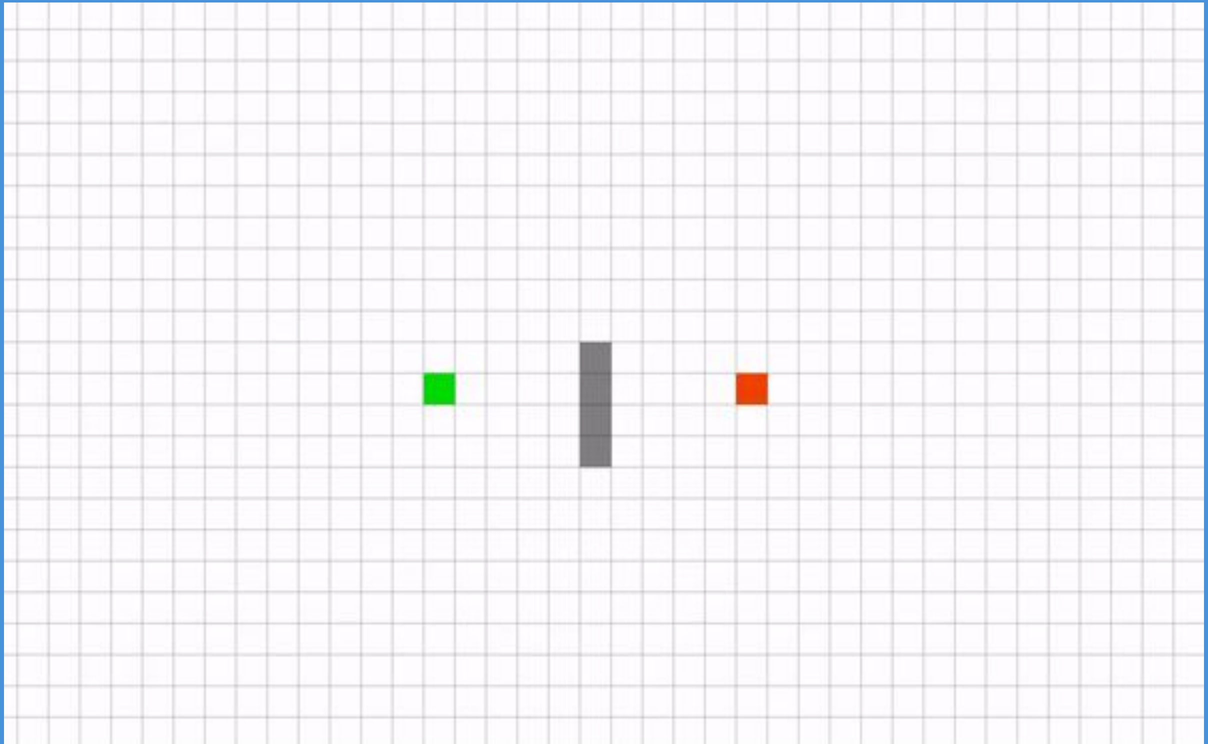
Pathfinding

A*

General idea

- Greedy Dijkstra’s
- Dijkstra’s assumes it’s impossible to predict cost
    - This is overly pessimistic
- In pathfinding, we at least know the general direction we want to go
- A* is a graph traversal algorithm that takes advantage of this

Why A* is better

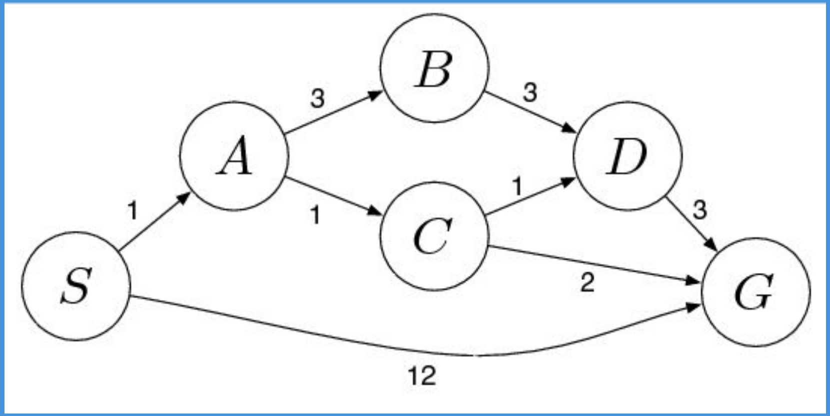


How does it work?

- Uses a “heuristic” to guess the cost from any given node to the destination node
    - Heuristic passed by the caller
- In addition to tracking distance from start, track heuristic value for each node
    - Prioritize in PriorityQueue based on `f(node) = distance_to(node) + heuristic(node)`
- Heuristic can be as simple as the Euclidean distance between the given and destination node, but also try to take other factors
    - Get creative – better heuristics help A* run faster!

Things to keep in mind

- You could have a bad heuristic that points you in the wrong direction.
- Experiment!
- You may use A* several times-- make it generalizable!!!



A* Pseudocode

- https://medium.com/@nicholas.w.swift/easy-a-star-pathfinding-7e6689c7f7b2
- https://en.wikipedia.org/wiki/A*_search_algorithm
- Come into hours if you need help understanding the algorithm
- Please come to hours… we are so lonely…

Pathfinding

PATHFINDING IN WIZ

What do you need?

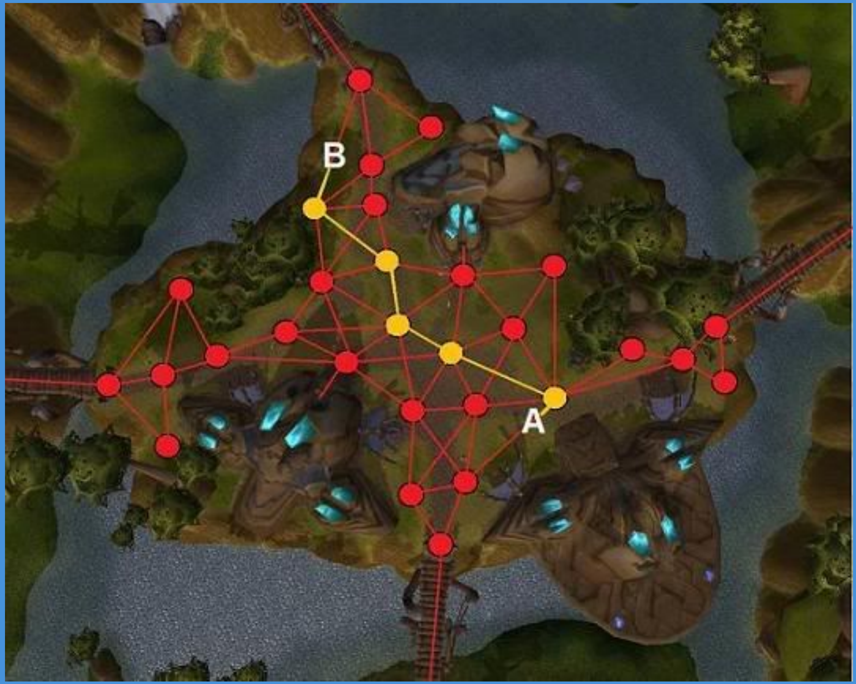
- Graph of accessible space
- A* implementation
- That’s pretty much it

The Graph

- Can’t include every point in the world
  - There are infinitely many
- Need discrete “waypoints” that units can move between

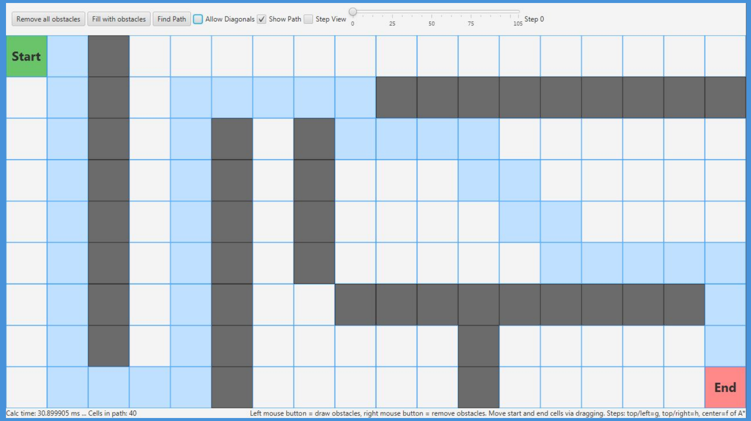
The Graph

- **One option:**
- Build a graph of accessible waypoints, each with a position
- Pathfind between waypoints by running A* on the graph



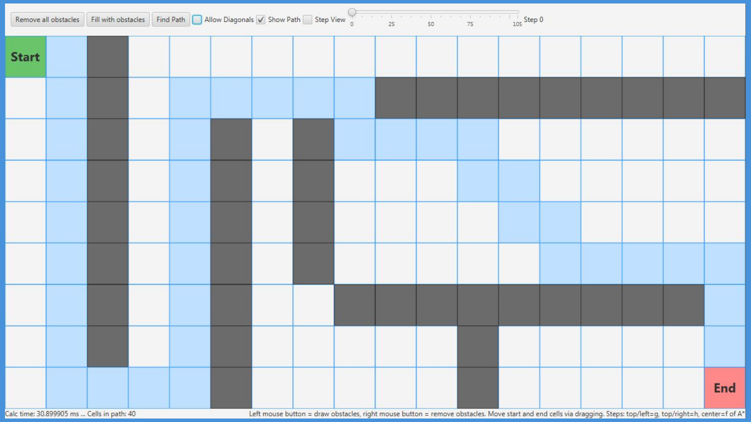
The Grid

- **Another option (recommended):**
- Represent the graph as a 2D array
  - Each entry represents a position in the world
  - Each entry specifies whether or not that position is accessible
  - getNeighbors(Vec2i pos) function that returns accessible neighbors of a grid position
  - Literally just a graph with Cartesian edges
- Can run A* in the same way
  - Yay for graph generalization!



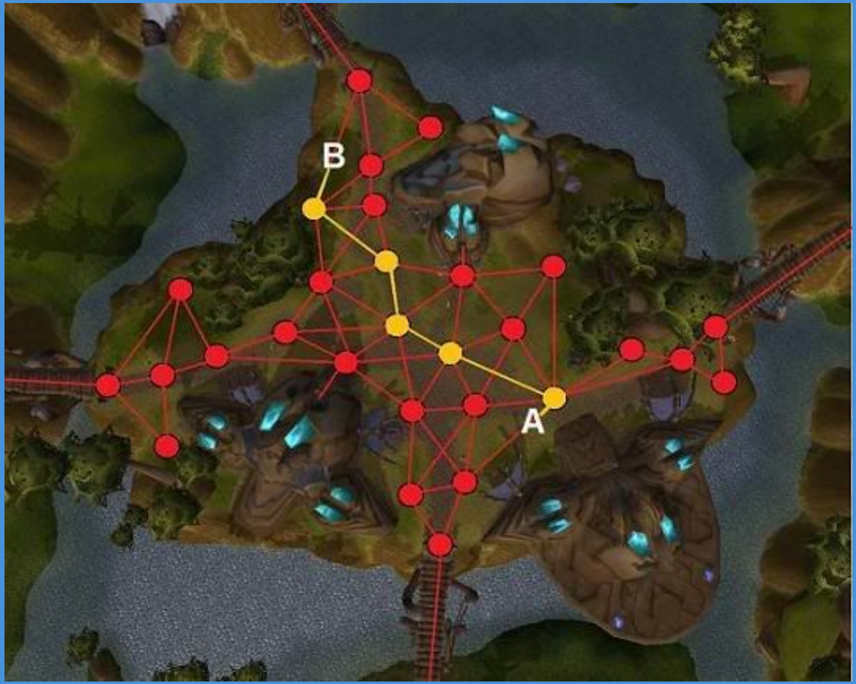
The Grid

- Don’t have to manually specify all accessible positions, just inaccessible ones
- Also, easier to update from a game design perspective than waypoint graph



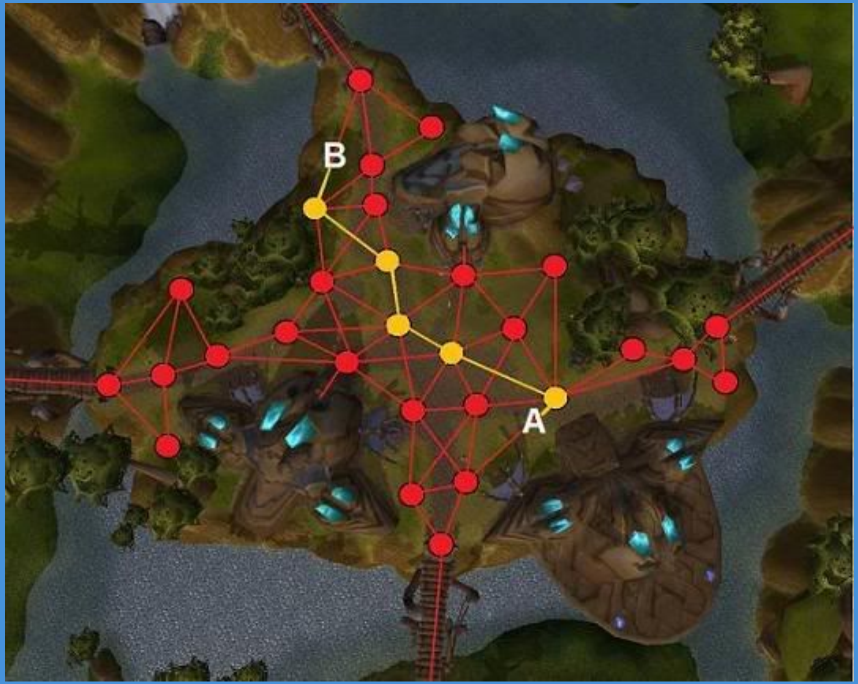
PathfindingComponent

- Hold onto a waypoint graph / grid of some sort
  - The graph / grid should be able to provide a path from point A to point B
- Hold onto a path
- Update position based on next location in path and current location



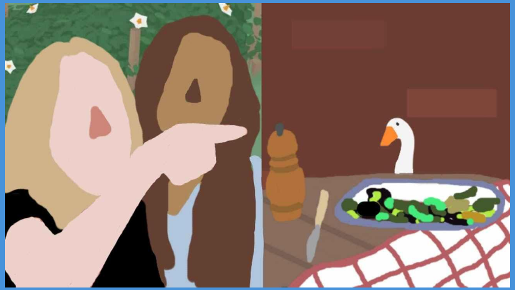
PathfindingSystem

- If you want a dynamic graph
  - Have a `PathfindingSystem` that updates the graph each tick based on game object positions and bounding boxes



Pathfinding

QUESTIONS?



Lecture 4

Decision Making

Decision Making

MOTIVATION

Game A.I.

- Usually used to make computer controlled units behave reasonably
- Can also be used to support the human player
- Essential for a good gameplay experience
- What are some examples of good AI that you have seen? Any bad examples?

Decision Making

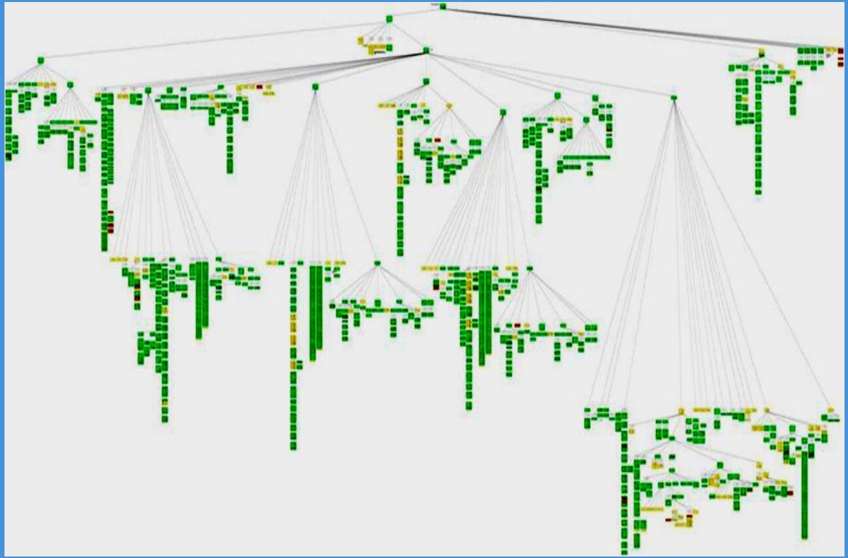
- NPCs should do something, but what?
- Could hardcode the logic
  - Game-specific
  - Likely involves copied code
- We want a structured way for NPC's to make decisions
  - Based on game state, unit state, random values, etc…

Lecture 4

Behavior Trees

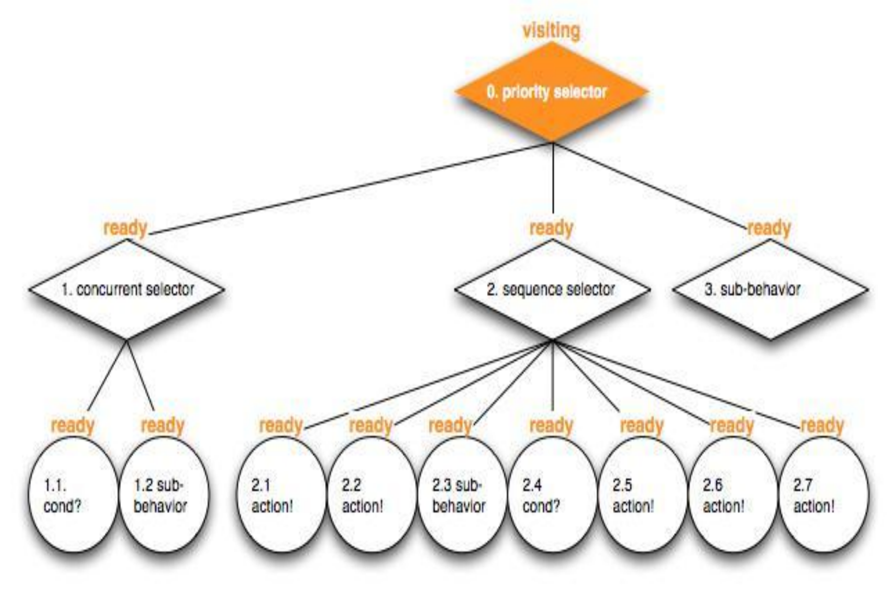
Behavior Trees

- “Recently” popularized by Halo 2
- Core functionality is engine-general!
  - Big plus!



Structure

- It's a tree!
- Every tick, the root node is updated
- Each node returns a status when it's updated
    - SUCCESS, FAIL, RUNNING
- Nodes will update their children and return a status based on responses



The Leaves

- Leaf nodes of the tree are `Action`s or `Condition`s
- `Action`s do things
  - e.g. make a unit move or attack
  - Return SUCCESS or FAIL based on result of Action
  - Return RUNNING if Action is still if progress
- `Condition`s check some game state
  - Returns SUCCESS if the condition is true, or FAIL if the condition is false

Eat
Action

Sleep
Action

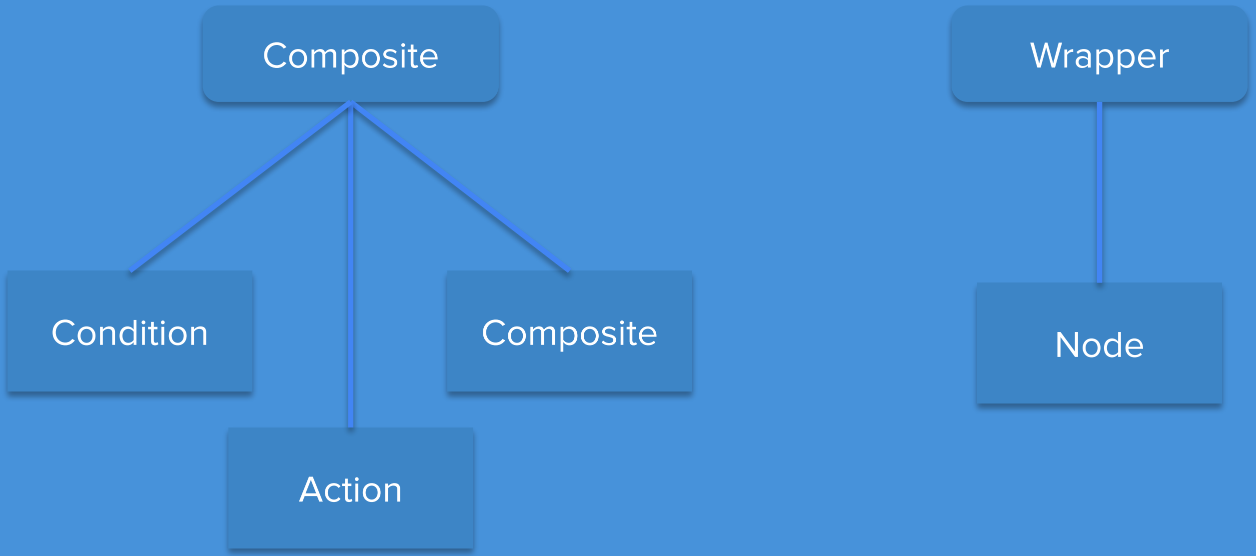
Party!
Action

Enemy near?
Condition

Is it daytime?
Condition

The Internal Nodes

- Internal nodes are `Composite`s or `Wrapper`s
  - `Composite`s have multiple children nodes, and dictate traversal during an update
  - `Wrapper`s wrap a single child node; more on this later

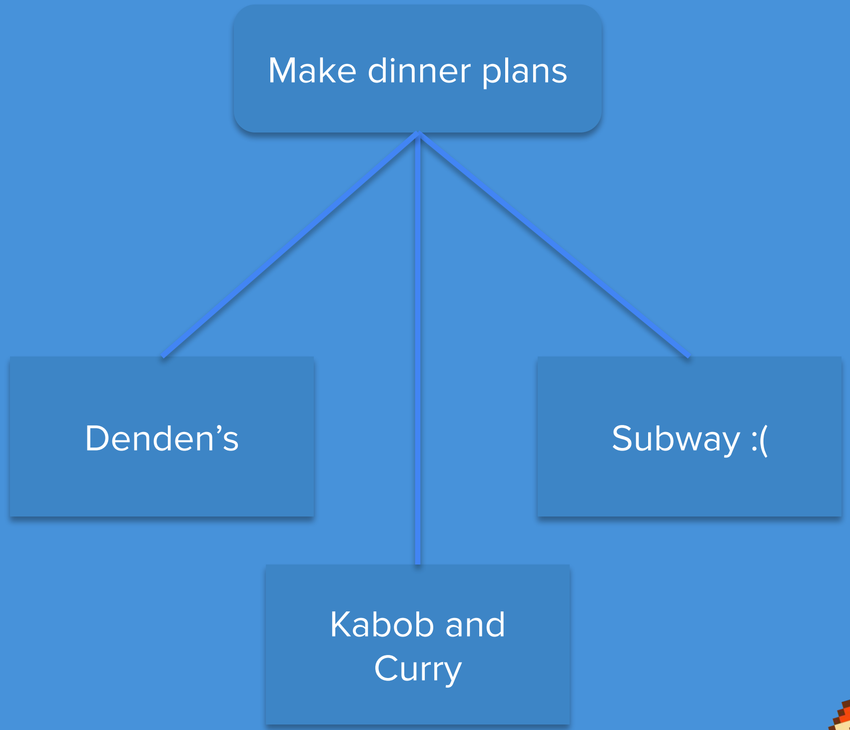


The `Composite`s

- Maintain a list of children nodes
- Update by updating the children nodes (usually in a particular order)
- Return RUNNING if a child returns RUNNING
- Return SUCCESS/FAIL under other circumstances depending on the type of composite

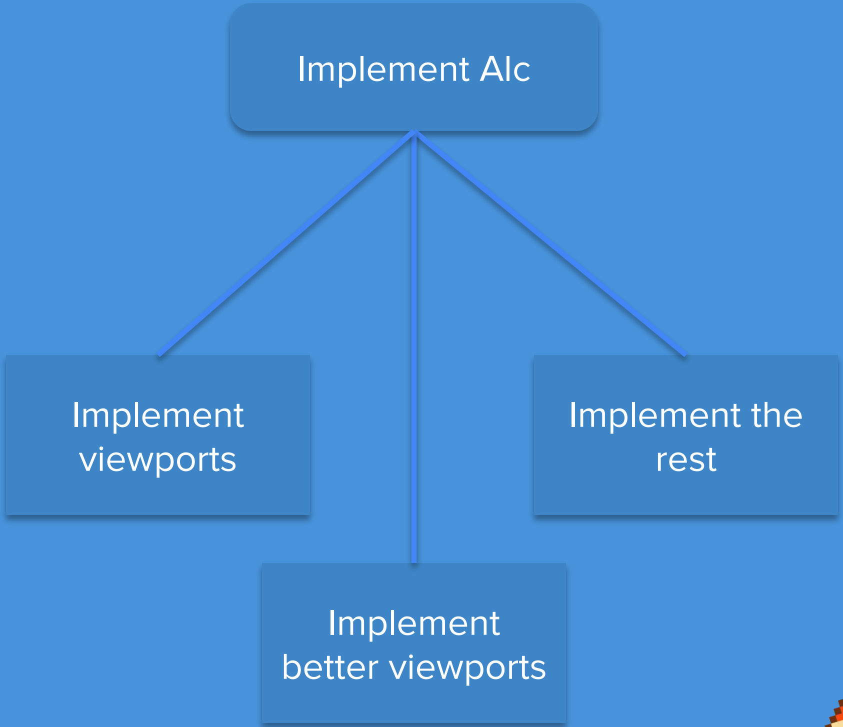
The `Selector`

- A concrete `Composite` node
  - On update, updates each of its children in order until one of them **<u>doesn't</u>** fail
  - Hence "select", as this child has been "selected"
- Returns FAIL only if **<u>all</u>** children fail
- Kind of like an if else statement or block of or's
  - If child 1 succeeds, else if child 2 succeeds, etc…



The Sequence

- Another concrete Composite
  - On update, updates each of its children in order until one **does** fail
  - If one behavior fails then the whole sequence fails, hence “sequence”
- Returns SUCCESS if the **entire** sequence completes, else FAIL
- Similar to a bunch of and’s



Other Nodes

- `Wrapper`s contain a single child and modify its behavior. Examples include:
  - Invert child
  - Repeatedly update child X times until FAIL or SUCCESS
- Randomize `Selector`s to update its children in random order
  - For unpredictable behavior
  - Harder to debug though
- Not required for Wiz, but feel free to play around!

BehaviorTree Nodes

- Just needs to be updated and reset
- Sample contract:

```
interface BehaviorTreeNode {
    Status update(float seconds);
    void reset();
}
```

Composites

- Needs a list of children
- Also should keep track of what child was running
- Sample contract:

```
class Composite implements BehaviorTreeNode {
     List<BTNode> children;
     BehaviorTreeNode lastRunning;
}
```

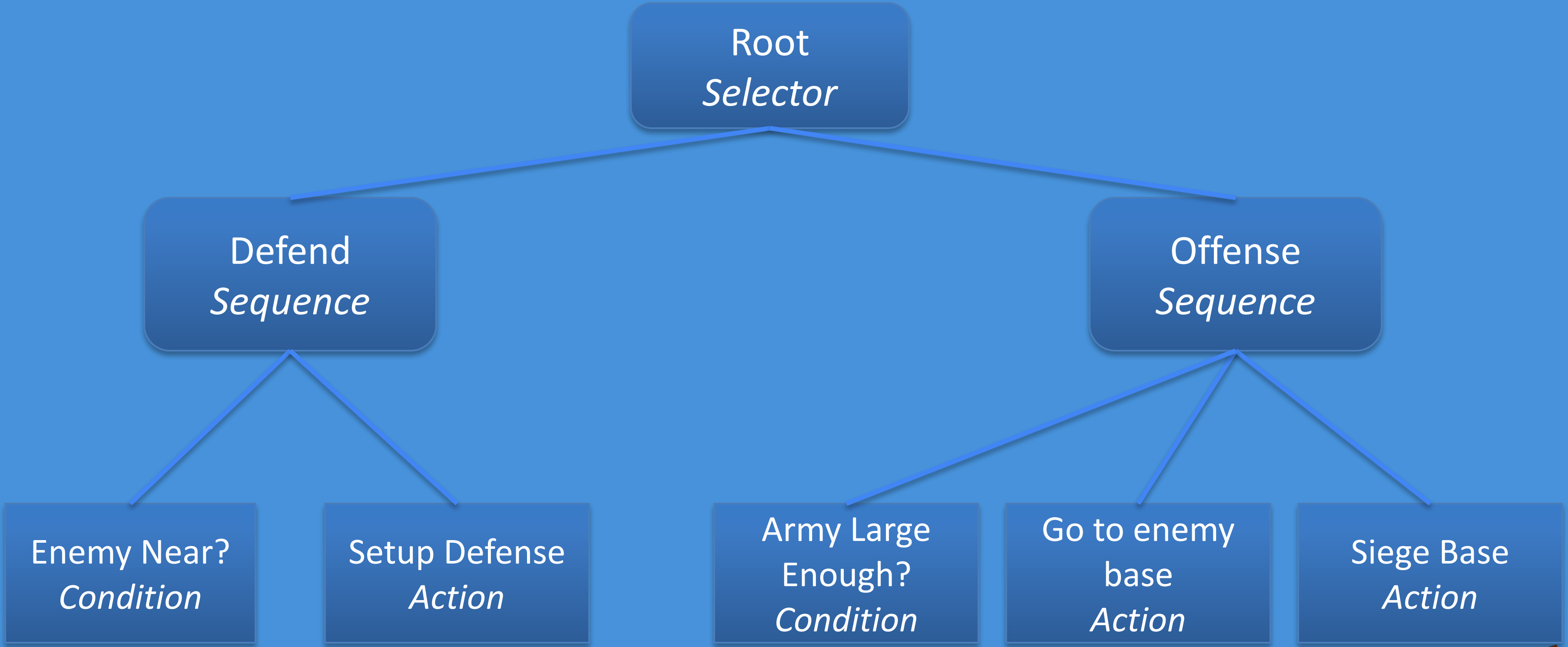
Note about Composites

- `Sequence`s start updating from the previously **<u>running</u>** child
  - Previously running child should be left intact after returning, unless the entire sequence was completed
  - Goal is to complete the entire sequence – “I was in the middle of something and should continue where I left off”
- `Selector`s should always update from the **<u>first</u>** child
  - Should reset the previously running child if a child before it starts RUNNING
  - Earlier children have priority – “I should always go back to defend my base, even if I’m in the middle of an offensive sequence”

Behavior Trees

QUESTIONS?

Example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Action

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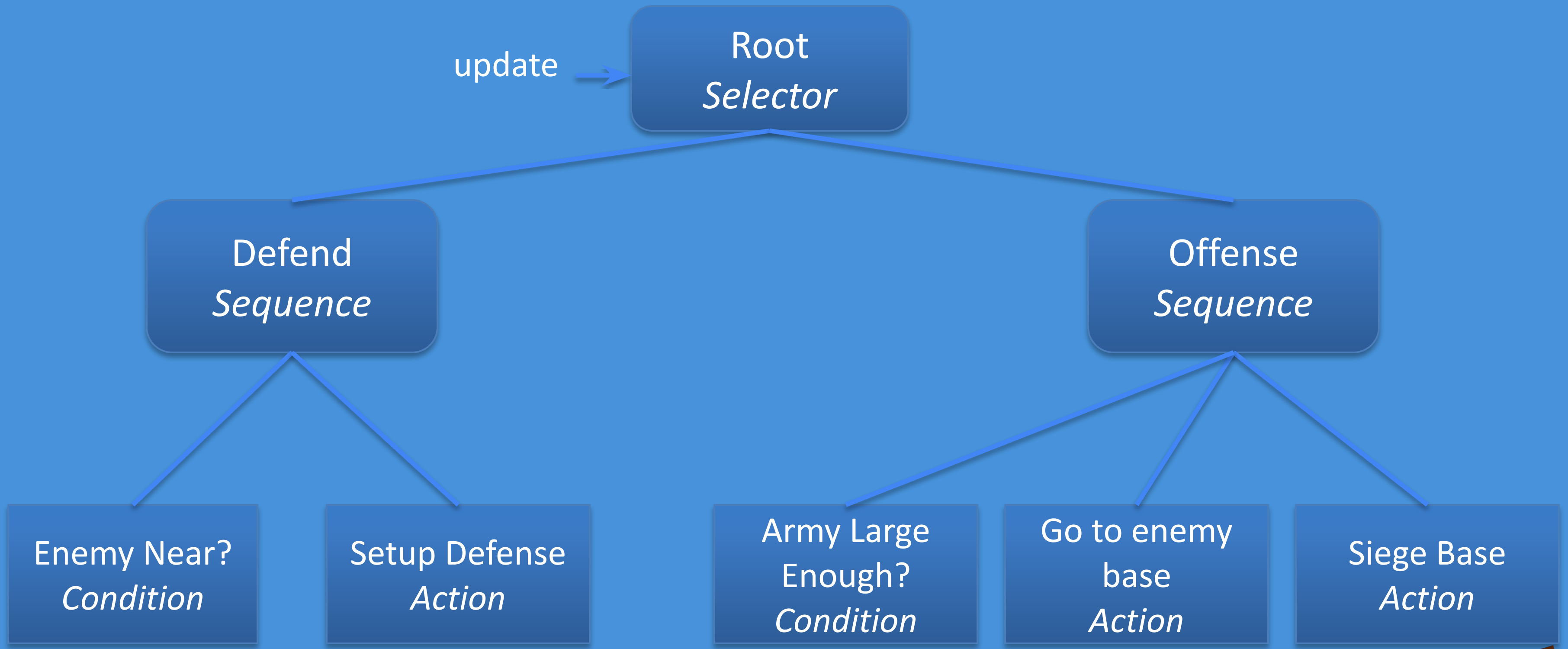
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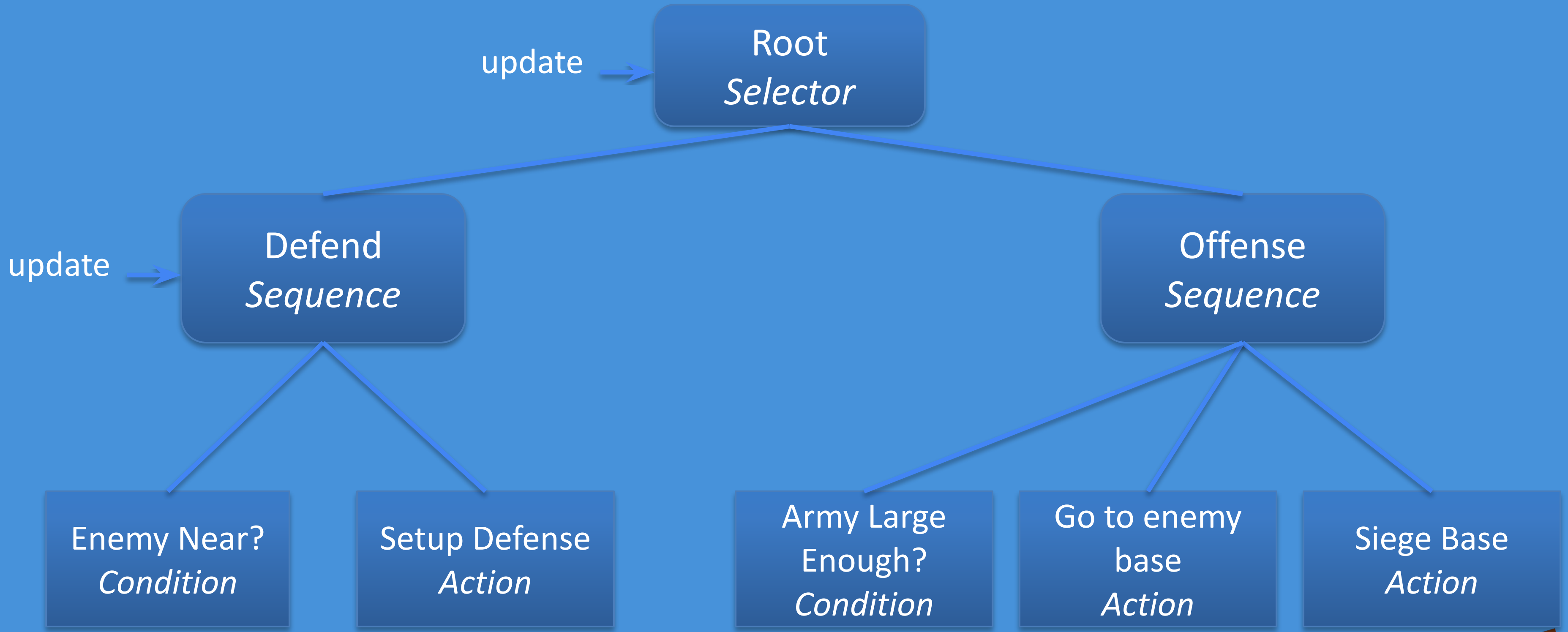
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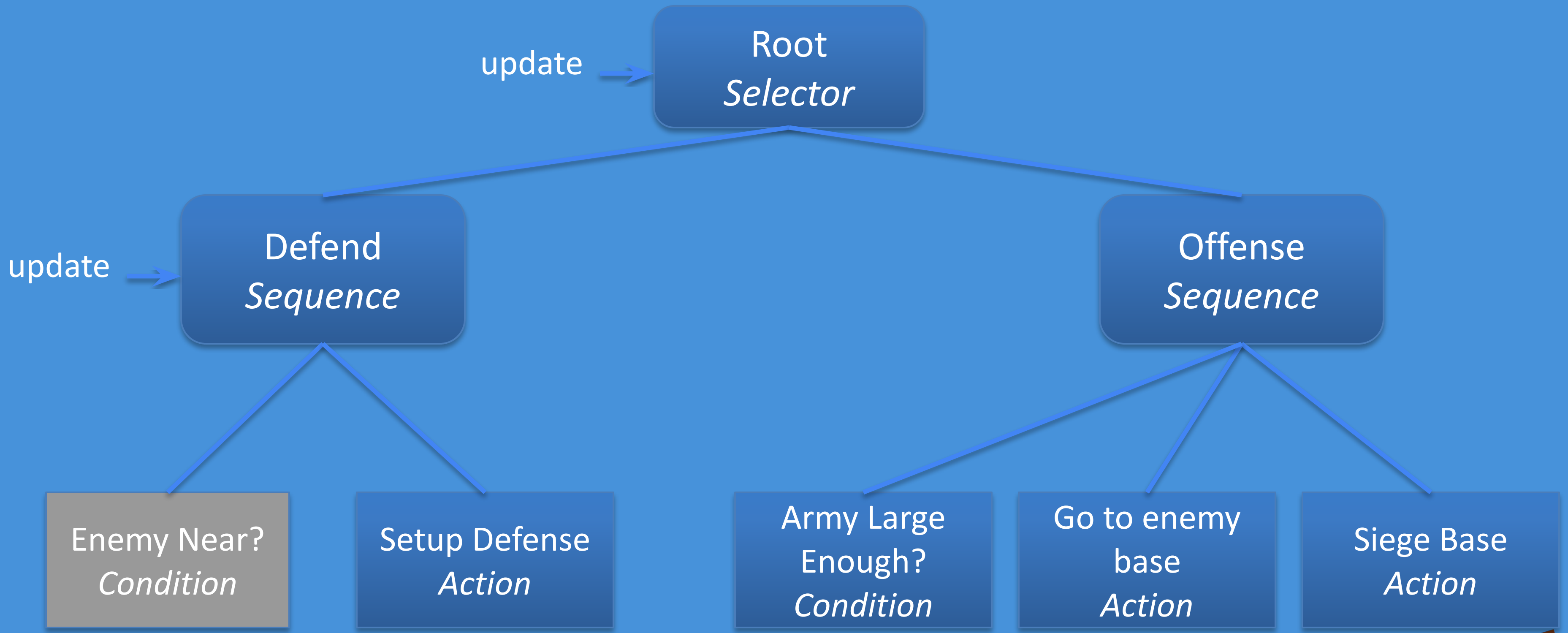
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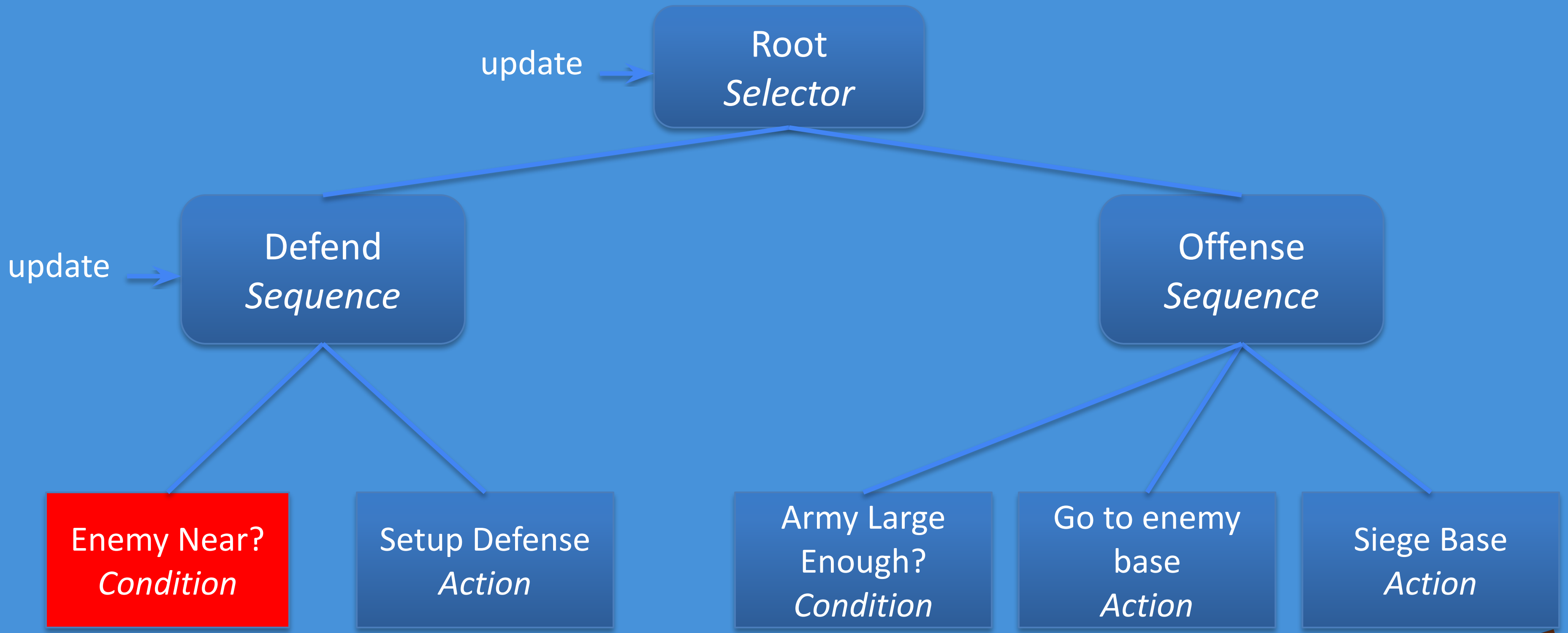
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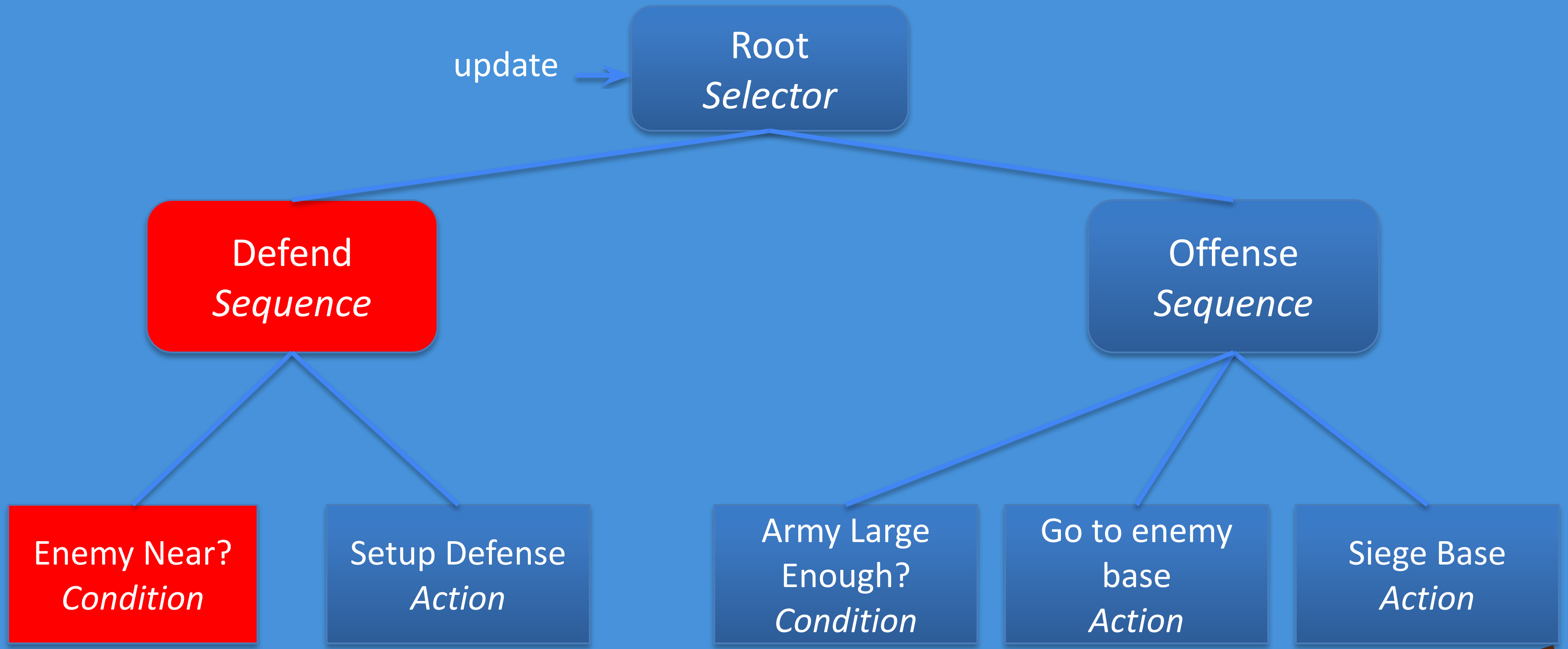

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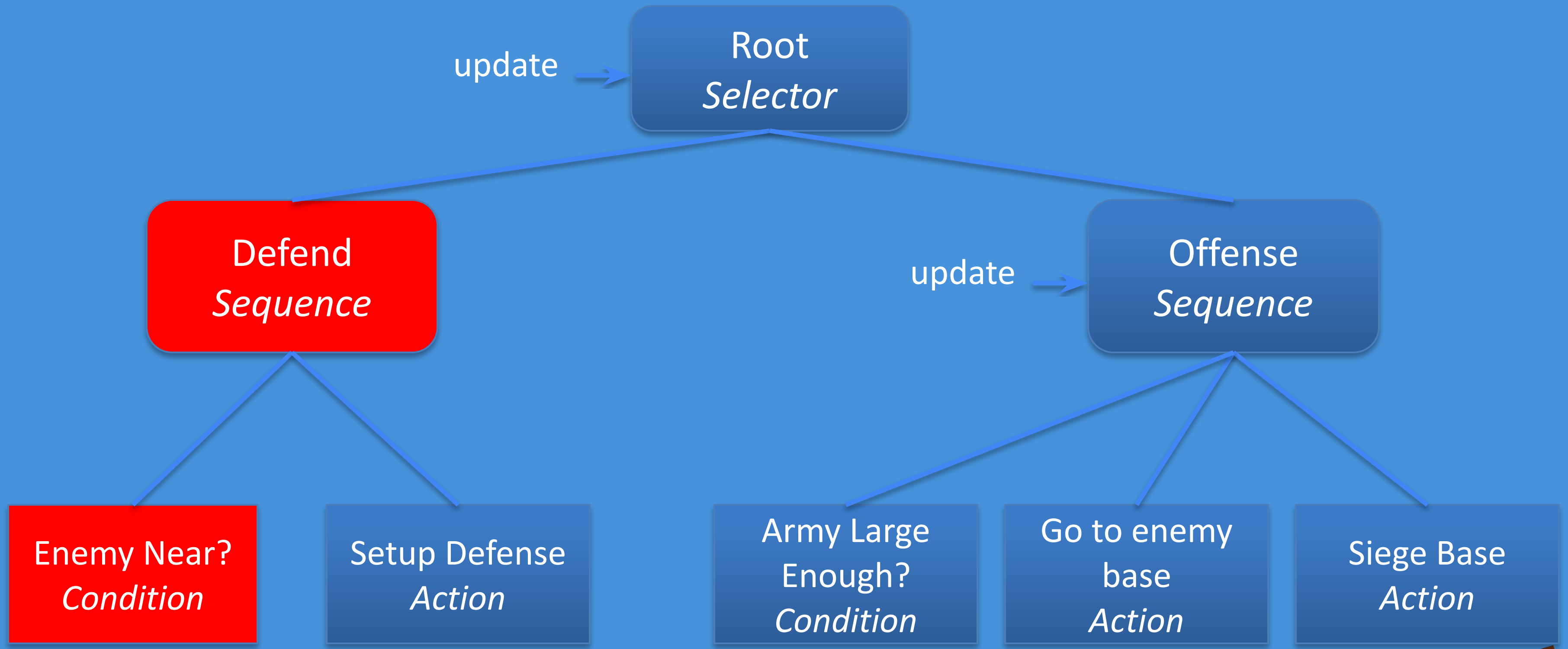
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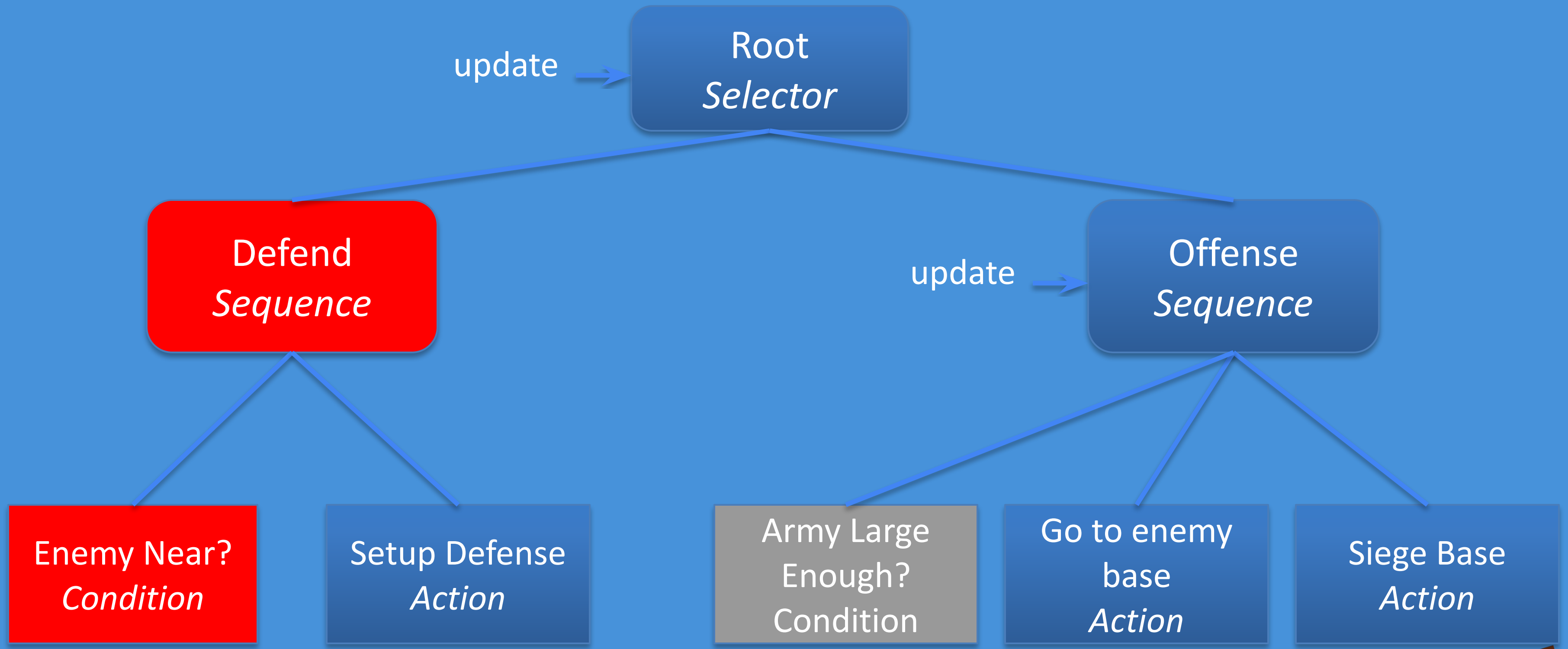
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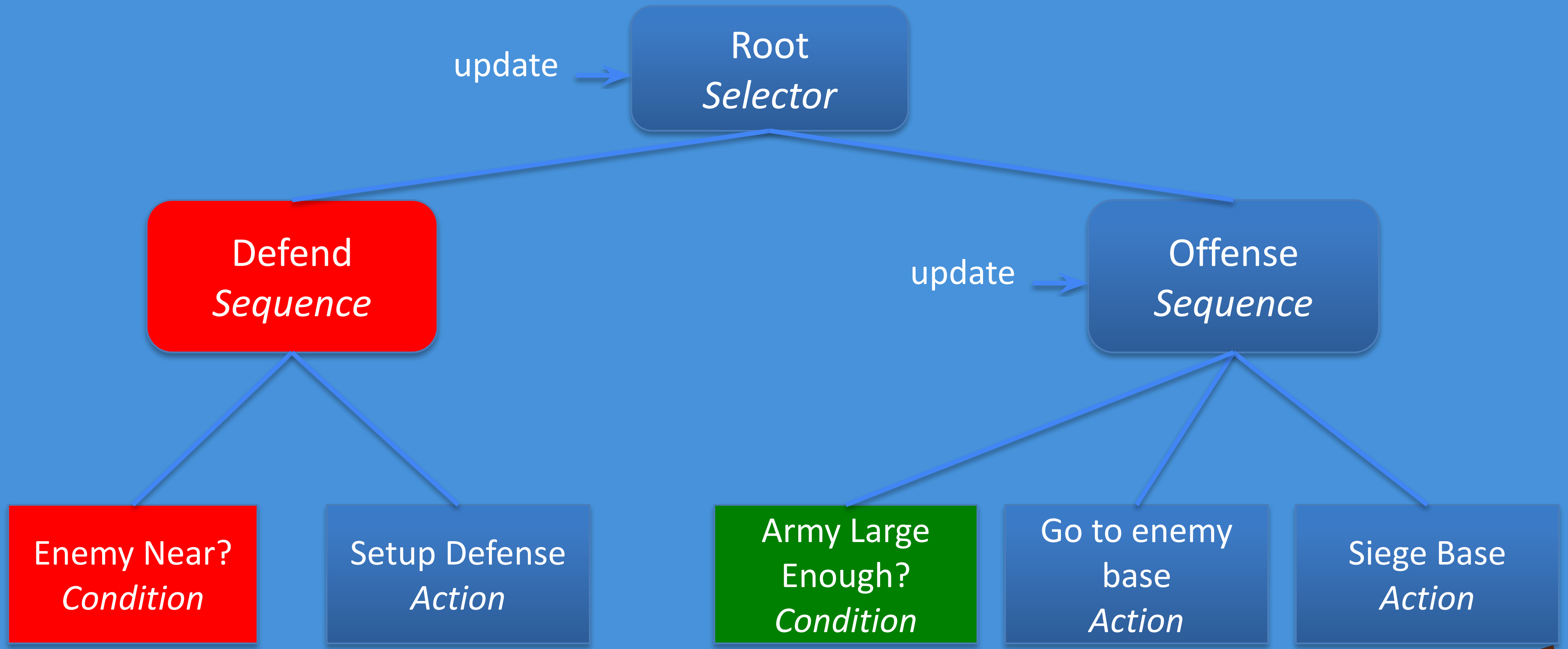
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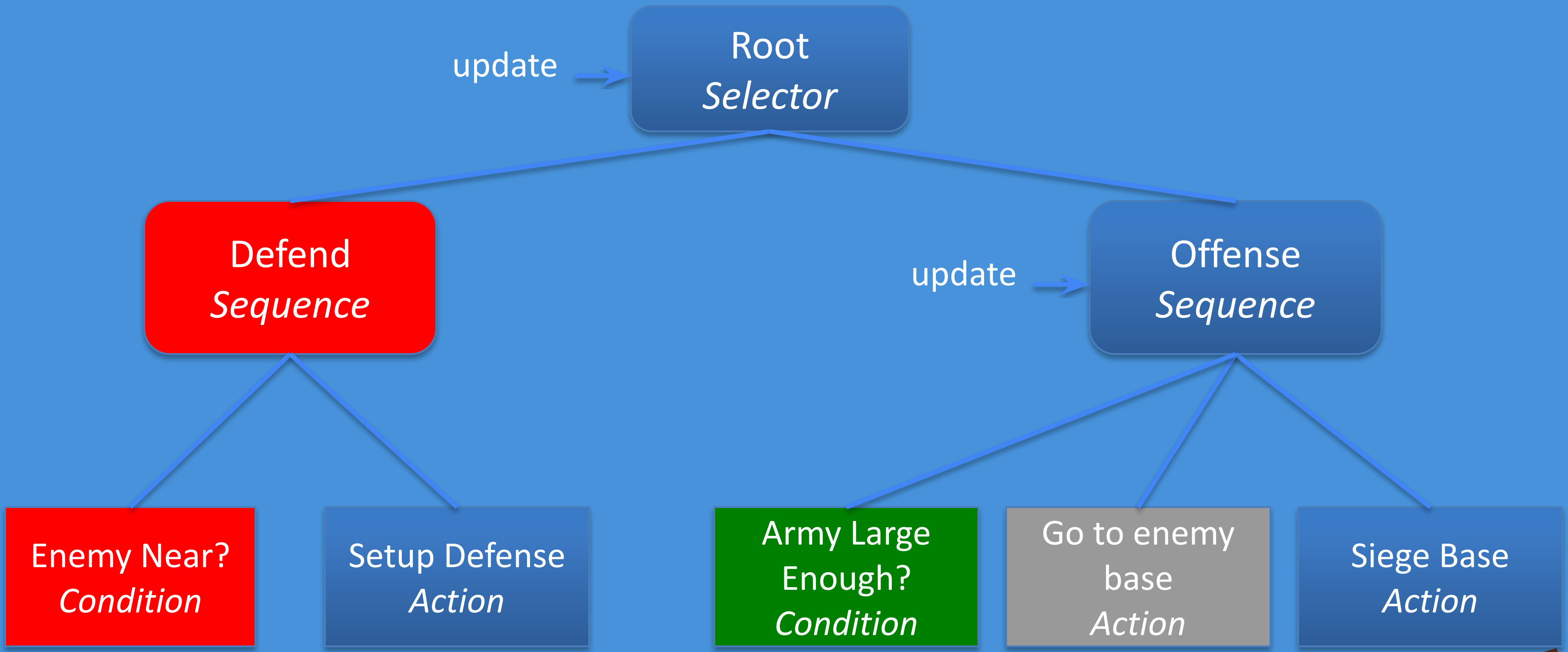
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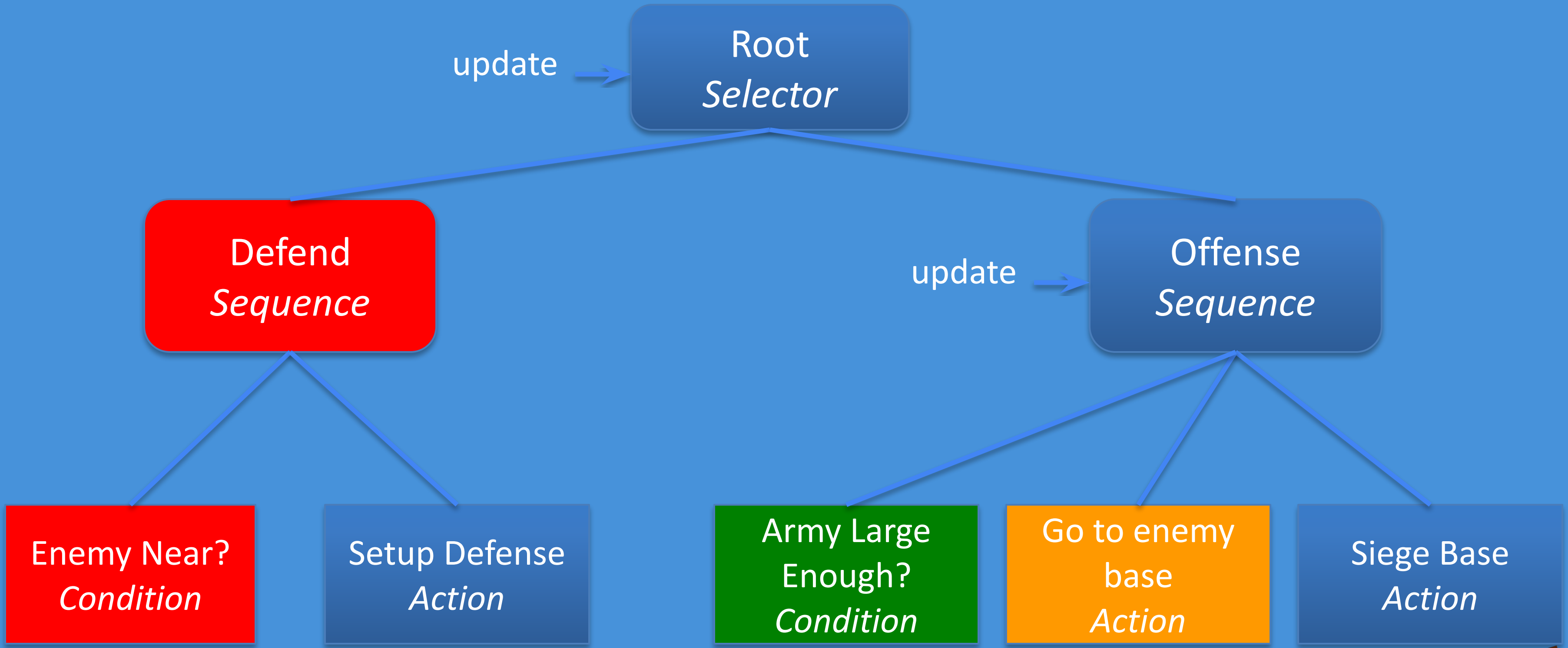
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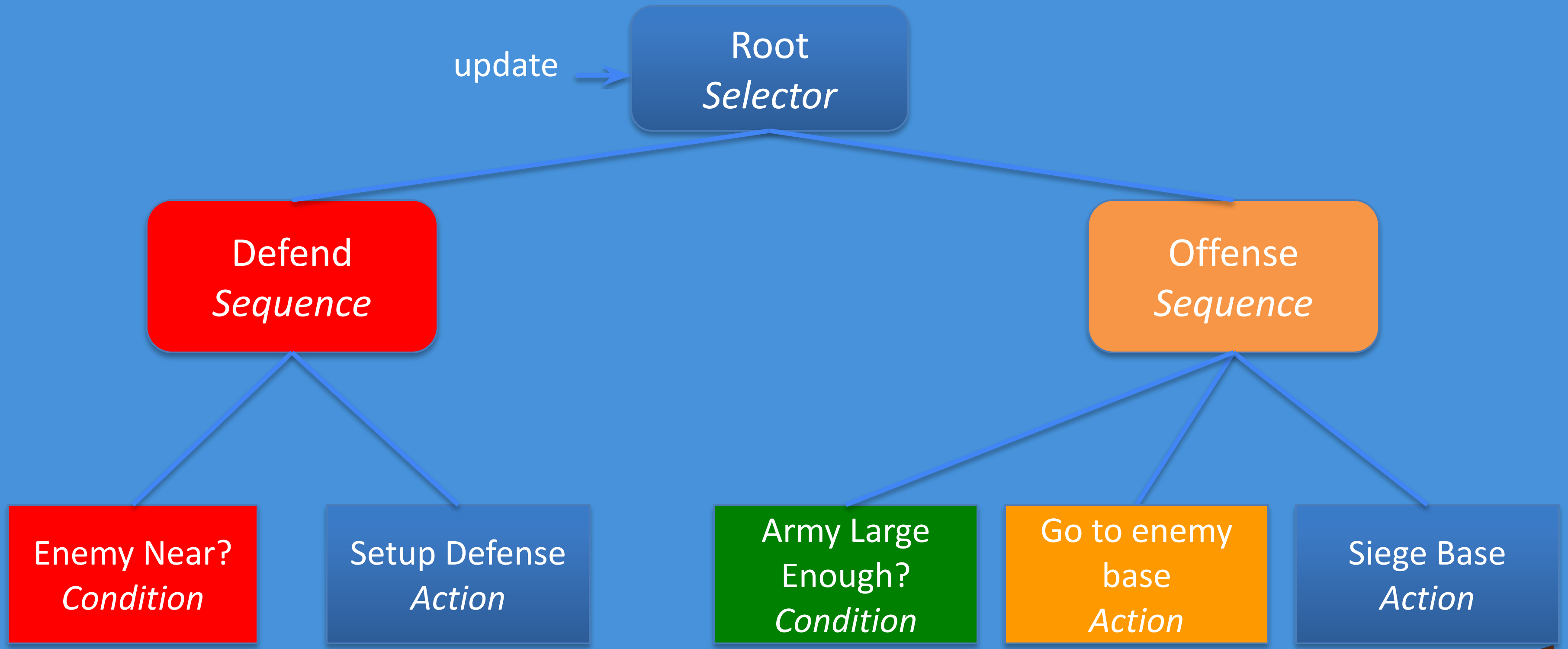
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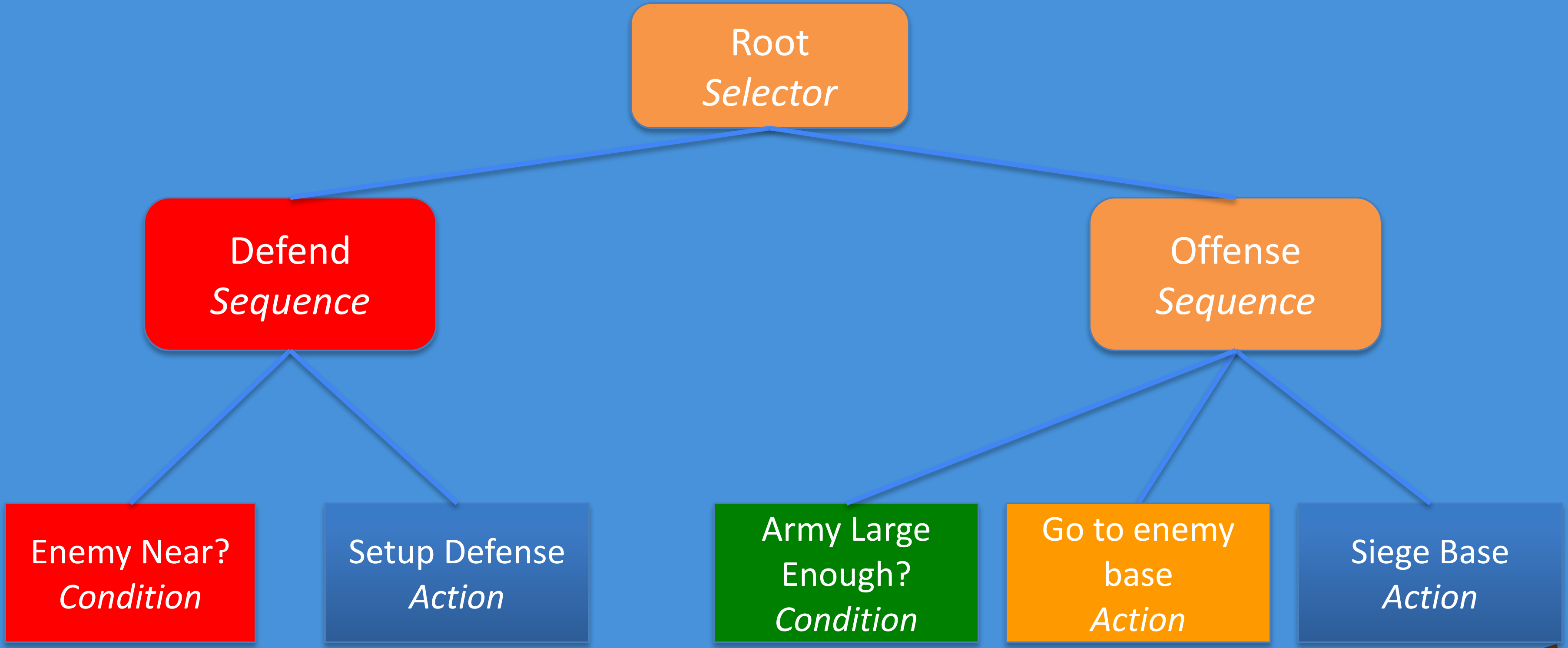
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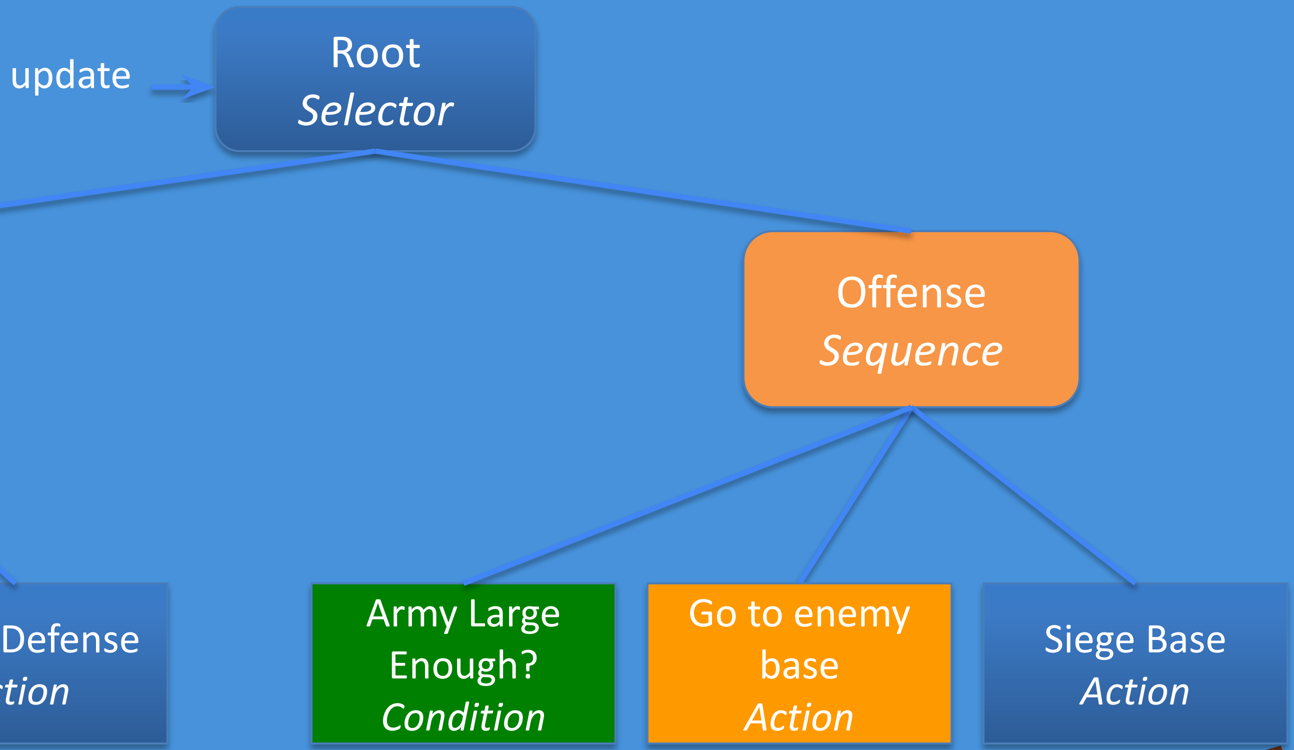
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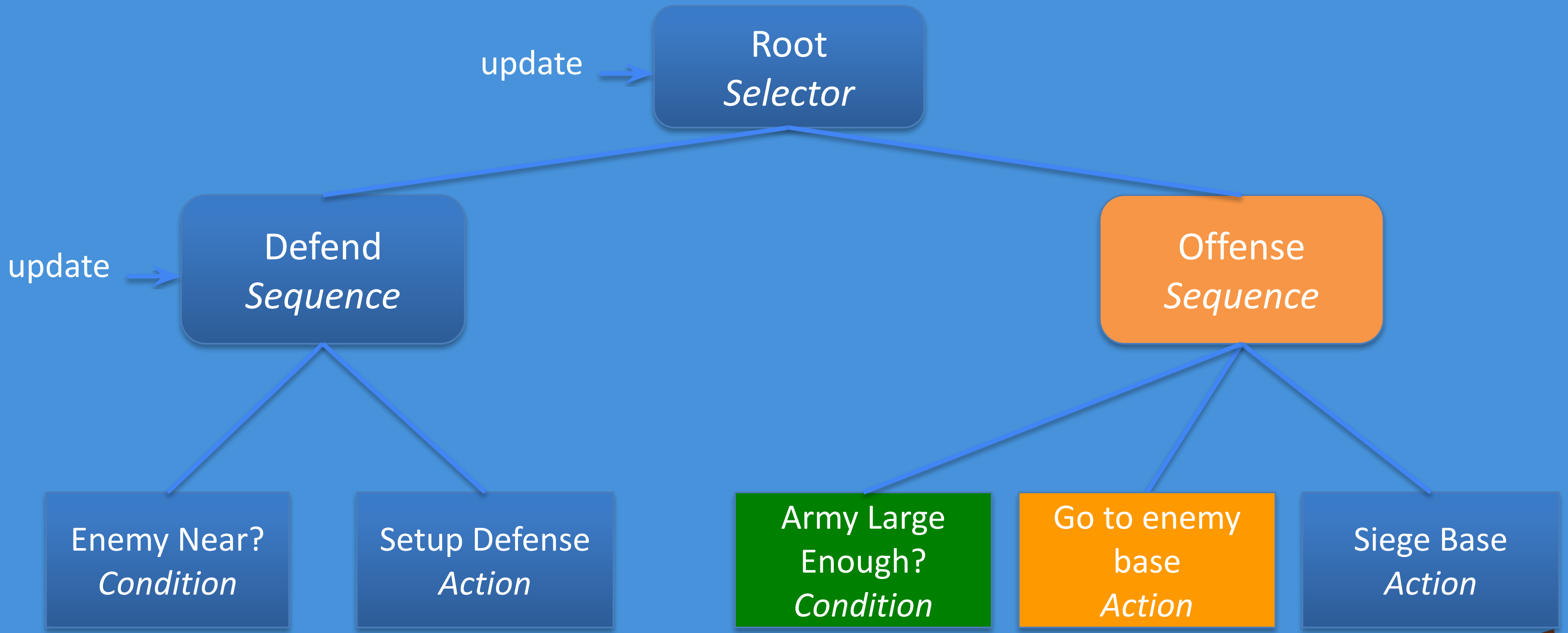
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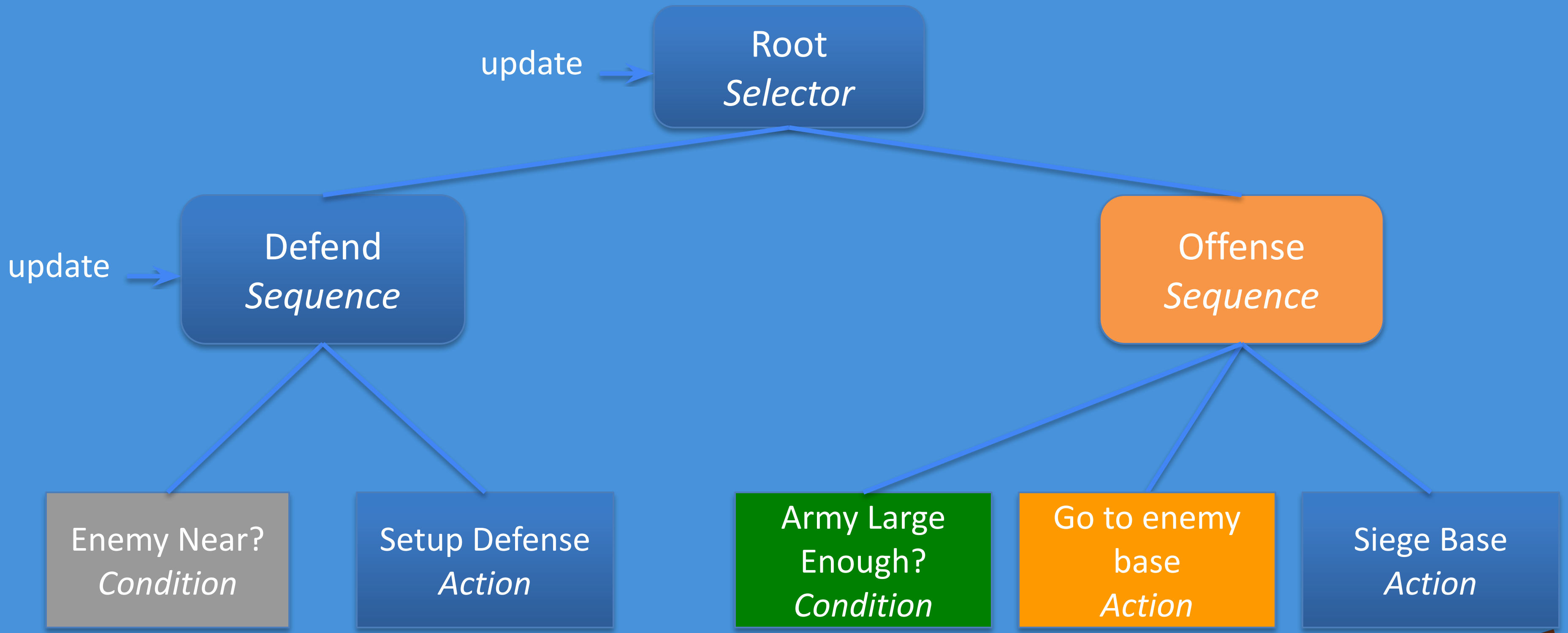
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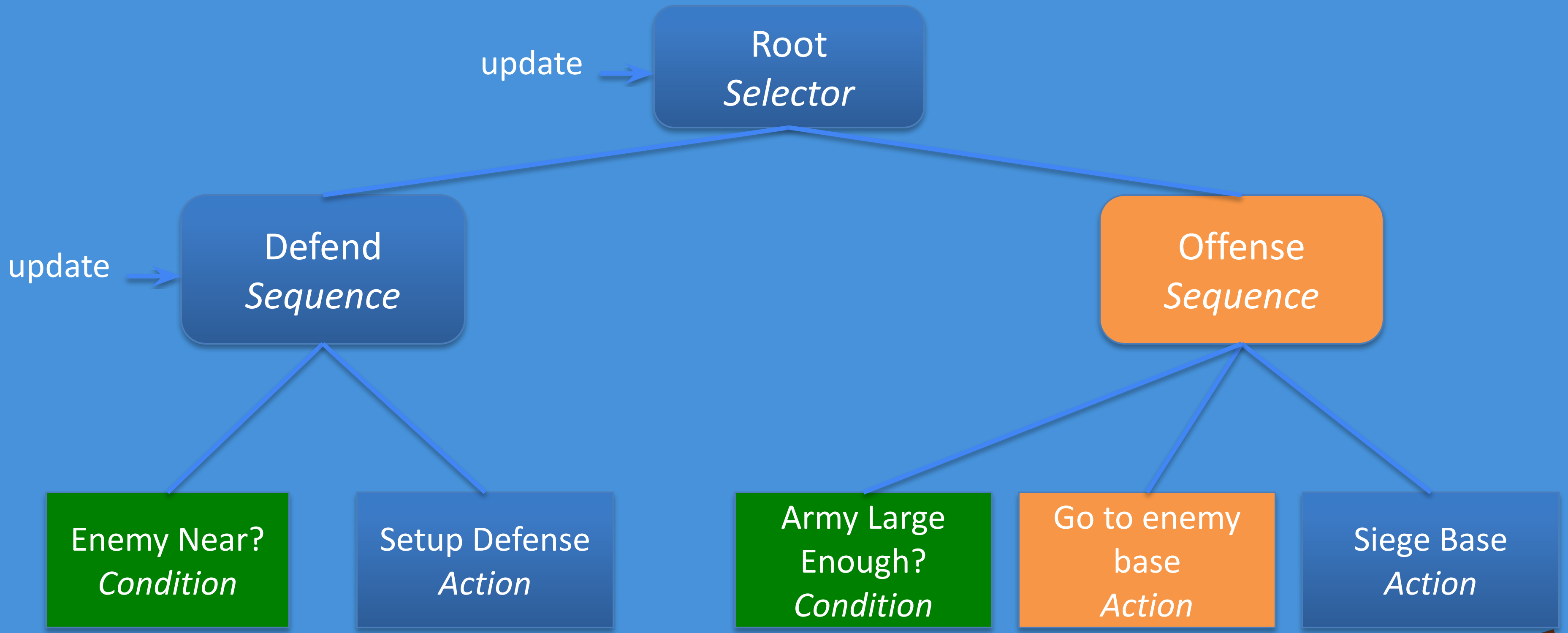
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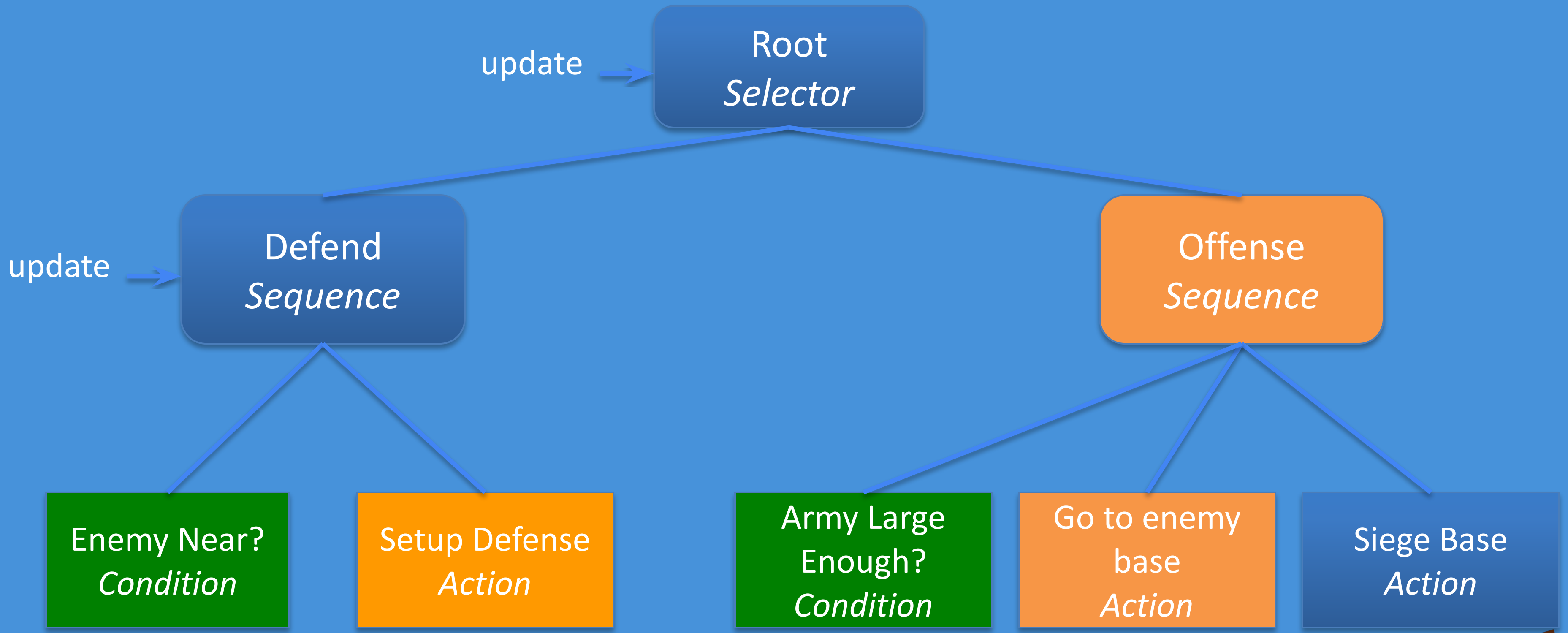
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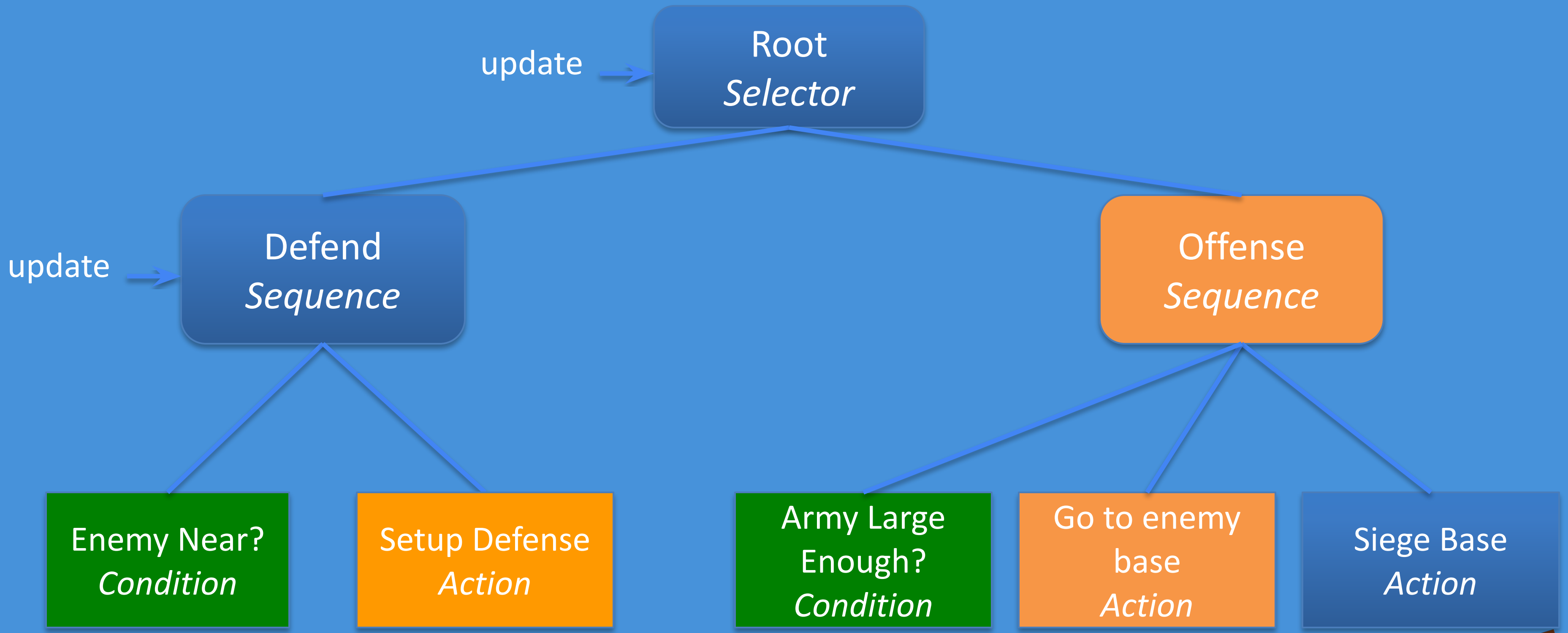
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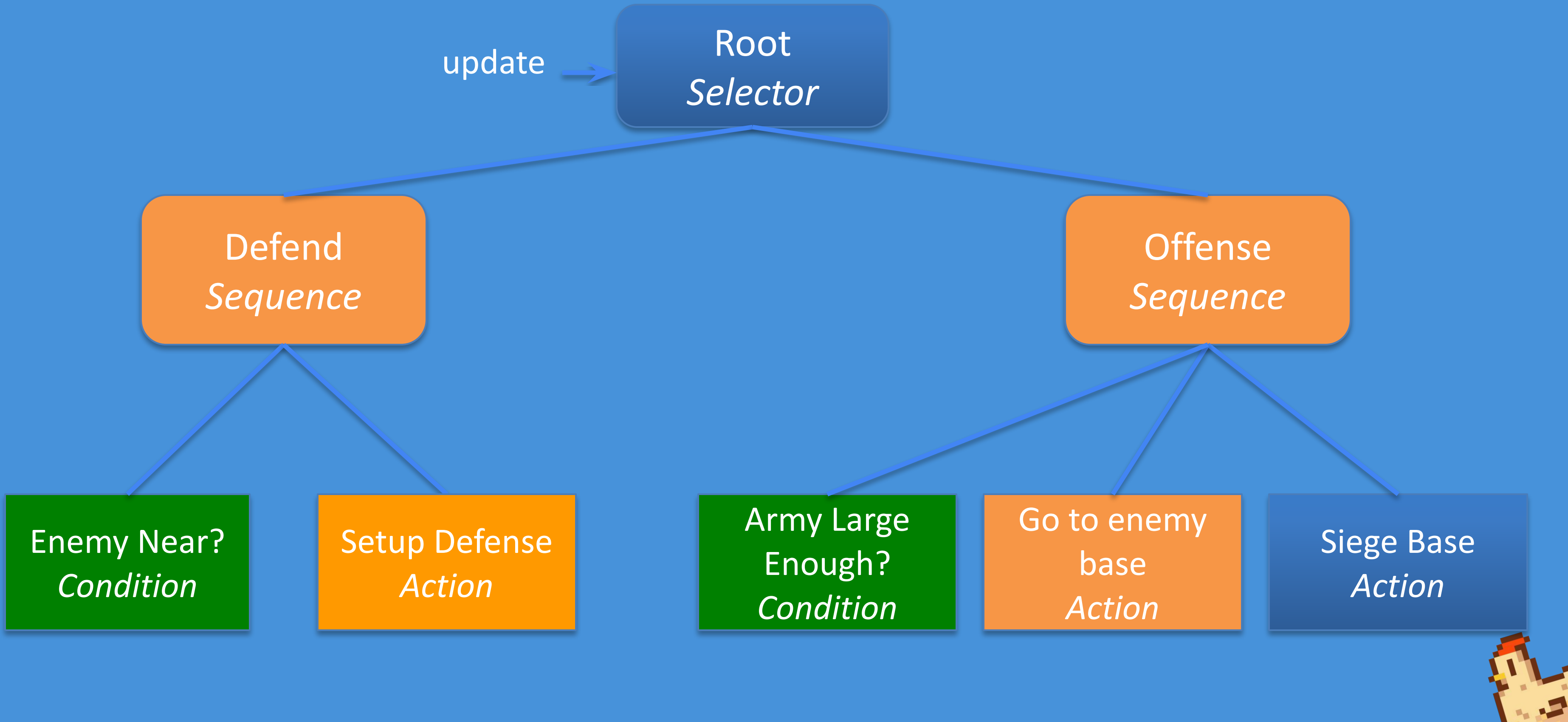
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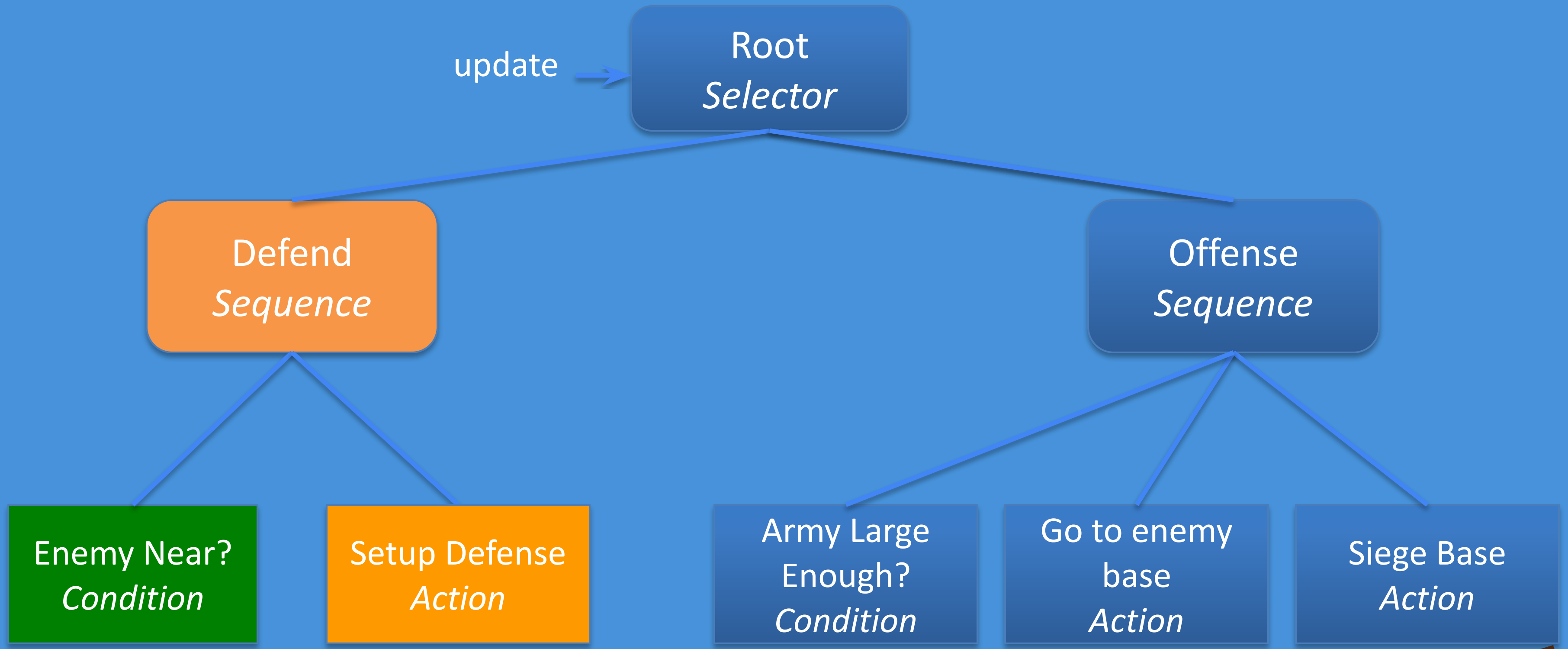

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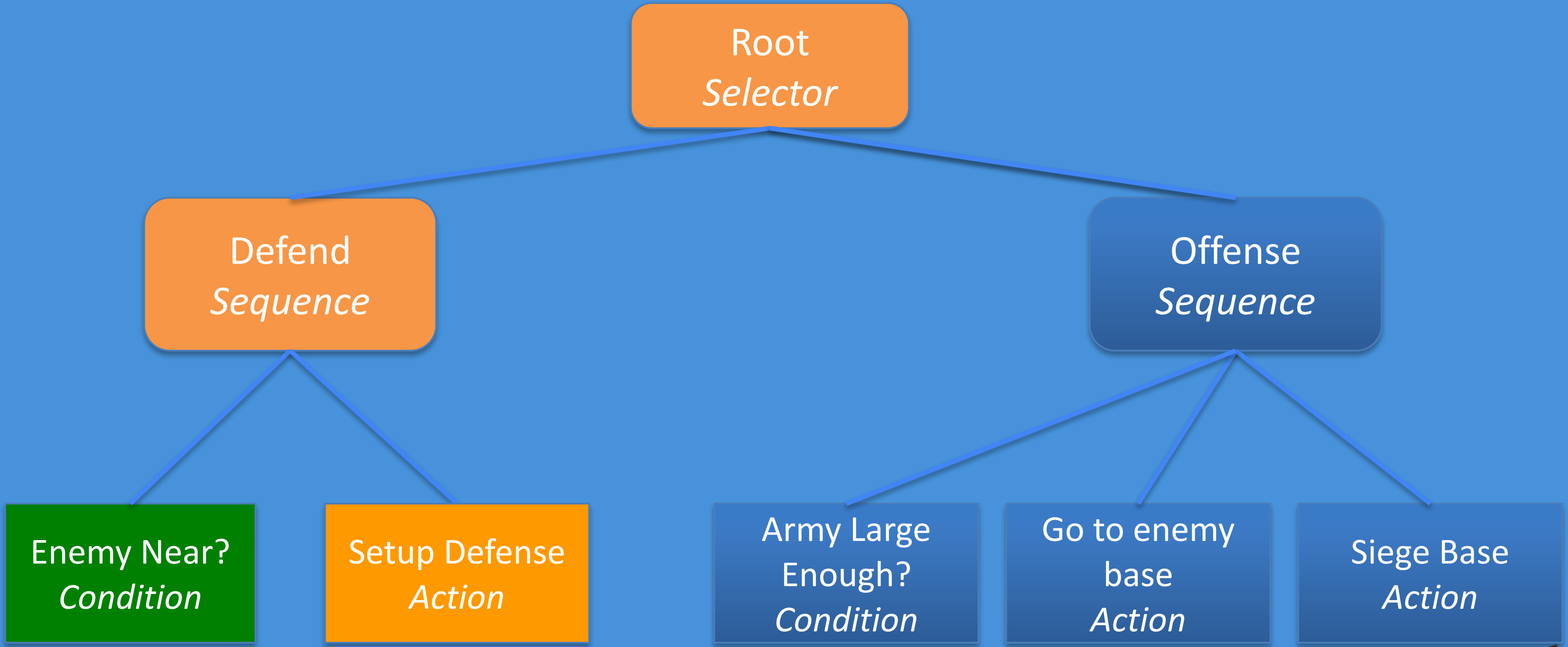
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Data Persistence

- Your behavior tree nodes might need to communicate somehow
  - Finding a target and going to the target are separate nodes
- How to share data?
- `Blackboard`: shared object that holds information, that nodes can write and read from
  - Minimally, wrapper for a `Map<String, ???>`
- Groups of nodes can share different `Blackboard`s

In Summary

- Interfaces/abstract classes for:
  - BTNode
  - Composite
  - Condition/Action
- Full classes for:
  - Sequence
  - Selector
  - Other wrappers
- Game-specific classes extend Condition/Action

Behavior Trees

QUESTIONS?

Lecture 4

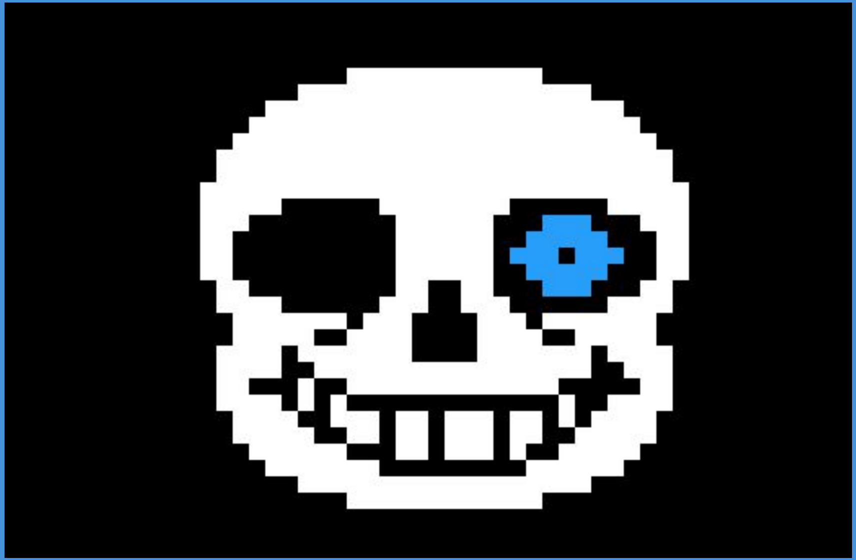
Goal Oriented Action Planning (GOAP)

Issues with BTs

- Behavior trees aren’t perfect
  - Lots of enemies
  - Too much work to code each
- Minor tweaks change a lot of code
- Procedurally generated enemies
  - Behavior trees usually aren’t expressive enough for complex behavior

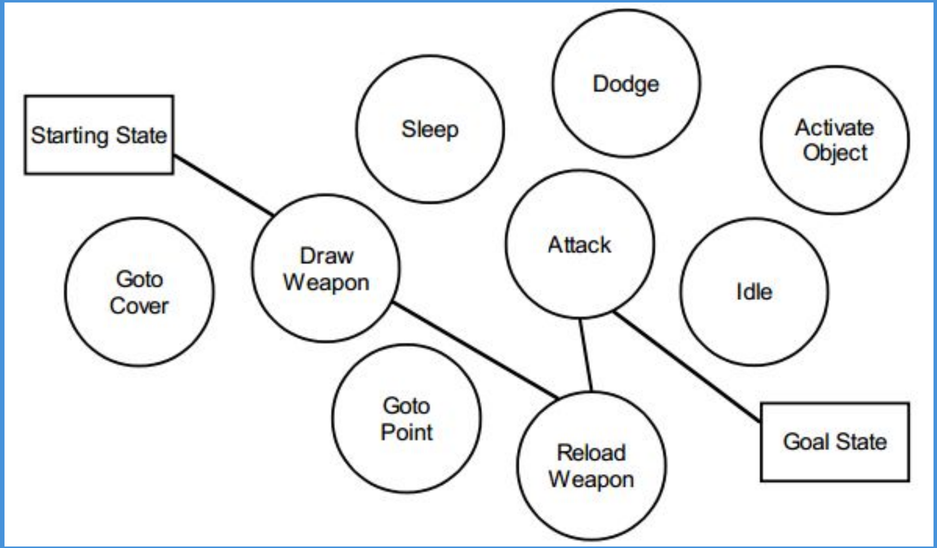
What is GOAP?

- Goal oriented action planning
- e.g. What’s the fastest way to kill the player?



What is GOAP?

- GOAP is a graph of game states
- We can search over it with A*



The Nodes

- Each node is a `GameState`
- `GameState`s are probably a map of string tags to booleans or integers
- The tags and their meaning are determined game-side

```
class GameState {
    Map<String, Integer> _props;
}
```

The Edges

- Each edge is an `Action` the AI can take
- Each `Action` has a cost and a `Condition`
- `Action`s also change the `GameState`

```
public abstract class Action {
    private List<Condition> _conditions;
    private double _cost;

    public abstract void changeState(GameState s);
}
```

Planning

- Goal
  - Generate a plan or “path” of actions
  - This plan should take you from start state to end state
- Just use A*!

Planning

- Start at a state
- Add neighboring states to priority queue
  - Go through all `Action`s (edges)
  - All `Action`s whose conditions are true from the current state are allowed
  - Generate a neighbor for each by applying the corresponding action to a copy of the `GameState`
- Pop lowest cost state from the priority queue
- Continue
- Return “path” or list of actions that took you from start to end state

Actions

- Just like behavior trees, GOAP has actions
- Actions are much simpler in GOAP
  - Change one or more of the tags in the game state

Conditions

- Just like behavior trees, GOAP has conditions
- Conditions are also much simpler
    - Return true or false
    - Determined entirely by GameState

```
public abstract class Condition {
    public abstract boolean isMet(GameState s);
}
```

GOAP

- The game defines a start state based on the current game world
- The game also defines a goal (`Condition`)
- Once the search is done, you need to map the list of actions to some real game effect
- Usually only the first action is executed before GOAP is run again
  - The action might not be completed before a new plan is generated
  - E.g., following the player

Problems

- Depending on the `Action`s available, GOAP can generate an infinite graph without any goal states
- This can be handled by any of the following:
  - Allow each `Action` to be used once/max # of times
  - Specify a maximum cost

Problems

- With lots of actions and a distant goal, GOAP can be really slow
- GOAP is best used to solve small problems

Problems

- GOAP optimizes over a single parameter (time, cost, etc.)
- GOAP is good for short, discrete problems:
  - Which combo should I use?
  - Which route should I take?
- GOAP is bad for long-term, strategic problems:
  - How do I optimize my economy?
  - Which item will maximize my options next level?

Mix and Match

- Behavior trees and GOAP don’t have to be mutually exclusive
- Behavior tree can determine the strategy (setting up which actions are available, how much each is weighted, what the goal is, etc.)
- GOAP can determine the plan to execute that strategy
- Behavior tree turns that plan into concrete actions
- e.g., sequence

Goal Oriented Action Planning

QUESTIONS?

Lecture 4

Tips for Wiz II

Floating Elements

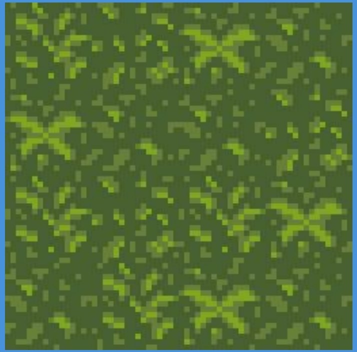
- “Floating” elements are common
- We recommend having your viewport support these!
  - Determine where on the screen a point in the game is
  - Draw element at screen scale
  - Consider a second `draw()` call responsible for floating elements

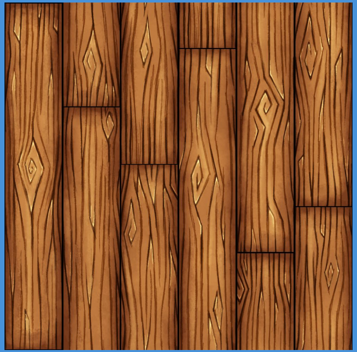
`lateTick`

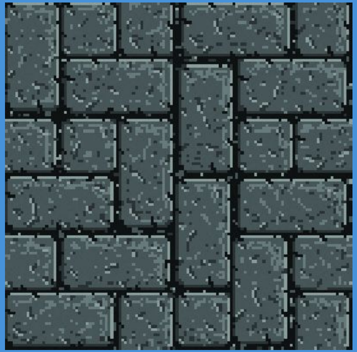
- Remember this method from Lecture 1?
    - Call on `System`s, `GameObject`s, or `Component`s!
- Used for actions that need to be executed once all `GameObject`s have been ticked and collided
- Example: updating the position of the viewport
    - Avoids viewport center lagging behind player

Good things to include...

- Easy mode/cheat settings
  - TAs need to be able to beat your game to grade it
  - Also, easier for you to debug…
- Diagonal movement is cool
- Wide doorways: make sure you can easily traverse your dungeon
- Use tiled sprites for your dungeon!







Tips for Wiz II

QUESTIONS?

Lecture 4

Final Project Overview

Overview

- Can be any 2D game
- You should work in groups!
    - But feel free to work alone.
- Each person is responsible for 10 “points” worth of new engine features
- More members in a group means more engine features
- More details in the final project handout

Timeline

- 4 main parts:
  - **Week 1**: Idea
  - **Week 2**: Form groups and get approved
  - **Week 3**: Design
  - **Weeks 4-7**: Code, demos, polish, present

Week 1: Idea (this week!)

- A few paragraphs submitted via Google Forms (link in Wiz II handout)
- Describe basic gameplay idea
  - How is your game fun?
  - Describe engine feature(s) you plan on implementing
  - **Give a 60-second “elevator pitch” of your game in class next week**
- Everyone should submit an idea!

Week 2: Groups

- Form a group (or decide to work alone)
- Finalize game and engine features
- Each group must meet with the TA’s to present their ideas

Week 3: Design

- Research new engine features
- Design the engine and game
- Decide exact breakdown of member responsibilities
- Choose someone’s engine to use
    - We don’t recommend merging engines, but you can try if you want
- We’ll set up GitHub repositories for you

Weeks 4-5

- Week 4:
  - Engine should be mostly done
- Week 5:
  - Engine should be done
  - Game is playable (barebones is fine)
  - 2 playtests per member from people not in CS1971
    - Let us know if this will be difficult for you

Weeks 6-7

- Week 6:
  - Game should be more done
  - 2 more playtests per member from outsiders
- Week 7:
  - Game should be done
  - Fix bugs, polish up gameplay
  - 3 playtests per member
  - Get ready to record a demo video!

Final Project Overview

QUESTIONS?

‘Til Next Week!

- Wiz II & Extras released today!
- See handout for FP proposals
- Remember to upload your demos