Design Overview

Final Project

You
Design Overview

Help Session
Design Overview

The Map → Directions & Enums → Ghost Behavior → BFS

Collisions
The Map

- Use our support map to generate your own **object-oriented** map

- What does this mean?
  - Instead of modeling each square of the map as a simple enum, design an object to keep track of the state of the square and encapsulate other helpful functions.

- What data structure will you use to organize these map square objects?
The Map: Squares

- Each map square should know if it is a wall and what elements are inside of it at any moment (ghosts, pellets, energizers, etc.)
  - Have a “smart square” class, and have it contain an `ArrayList`!
    - What type will this ArrayList hold?
    - **Beware:** If you try to remove or add something to an ArrayList while iterating through it, you will get a ConcurrentModificationException! There is a way to design your program so that you never run into this problem.

- Should this list contain Pacman?
  - Let’s think about how we would handle collisions both ways. Maybe that will help us answer this question.
Question: Should we store PacMan in a Square’s ArrayList?

- Benefits: We treat Pacman like we do other maze objects
- Downsides: Pacman isn’t always like other maze objects
  - We want our Pacman to collide with everything in the square, but we don’t want Pacman to collide with Pacself. To check, we might have to write isPacman() methods that return false in the pellets, which isn’t exactly logical...

Solution: Pacman is not directly stored in Squares’ ArrayList.

- When Pacman enters a square, iterate over that square’s ArrayList and tell each element to perform its collision action
- We can even delegate the collision actions to the other elements of the game—a little counter-intuitive, but super elegant!

Remember: Collisions occur when Pacman and an object are in the same square.
Collisions

● So, if collisions occur only when Pacman and a maze object are in the same cell...

● There’s an edgecase! If Pacman and a Ghost are moving towards each other with the right timing, it’s possible for them to switch cells without colliding.

How can we fix this?
Collisions

- Move Pacman
- Check for collisions
- Move ghosts
- Check for collisions

Note: This is NOT the only solution -- feel free to come up with your own!
In this project, you’ll be dealing with many, many points on the board, particularly during your BFS.

Should we use a `javafx.geometry.Point2D` to represent all of these points?

The `Point2D` constructor takes in two doubles, meaning:
- you could pass in negative numbers (we want only 0, 22)
- you could pass in decimal numbers (we only need integers)

What if you get an `ArrayIndexOutOfBoundsException`?
You might know what `line` of code caused it, but will you know when you created that point?

How can we fix this?
You’ll notice that this class throws exceptions when it receives bad coordinates (then prints a descriptive error message).
- Prevent bugs from appearing in your algorithm by catching them here!
- Ensures that you can’t make a BoardCoordinate instance that would exist outside of the board
- Be consistent with row, column indexing in your board!

**BUT** the BoardCoordinate constructor will NOT call `checkValidity` if the constructor boolean `isTarget` is true, so the exception will not be thrown
- This allows you to create chase targets based on offsets to Pacman while still using this class. You should only set `isTarget` to true if you are actually making a target square!
Directions & Enums

- How can you easily represent the directions that Pacman and the ghosts can move in?
- **enums**! A data type whose fields consist of a fixed set of constants

- Keep in mind that there are other ways to store directions, but enums are a very clean way to do so:
  - You might have used static constants in a similar way during Tetris, but this will be much more complicated in Pacman
  - It’s totally **unacceptable** (though maybe functional) solution is to use integers or strings that are never defined as constants. This is extremely buggy
  - (Use enums)
Directions & Enums

• Here is an example using `enum` to represent the directions left and right:

```java
/* Has its own .java file just like an
* interface or class */
public enum Direction {
    //The types of directions, MUST come first
    LEFT, RIGHT;

    //enums can have methods just like classes do
    public Direction getOpposite() {
        //enums are comparable just like ints
        switch (this){
            case LEFT:
                return RIGHT;
            case RIGHT:
                return LEFT;
        }
    }
}
```
Directions & Enums

- To get a specific value, use:
  ```java
  Direction.LEFT or Direction.RIGHT
  ```

- You cannot `new` enums
  - So, in code this would look like:
    ```java
    Direction dir = Direction.LEFT;
    ```

- All `enums` have a `static` method to return their values as an array:
  ```java
  Direction[] allDirections = Direction.values();
  ```
Here is an example of a method that uses the `Direction` enum:

```java
// method to check before crossing street
public boolean isSafeToCrossStreet() {
    Direction[] directions = Direction.values();
    for (int i = 0; i < directions.length; i++) {
        // check if a car is coming from that direction
        if (this.isCarDrivingFrom(directions[i])){
            return false;
        }
    }
    return true;
}
```
Ghost Behavior

- **3 Modes** - Chase, Scatter, Frightened
- How will you handle switching between modes? How many Timelines do you need?
- How will you represent each ghost’s current mode? (Hint: *What did you just learn?*)
- **Frightened mode**
  - Starts when Pacman eats an energizer
    - lasts about 7 seconds
  - Ghosts will move **randomly**
  - How it works - At every intersection, choose a random direction to go
    - Note: ghosts should never do a 180 degree turn!
  - **Pacman can eat the ghosts**
Ghost Behavior

- **Chase** and **Scatter**
  - Ghosts switch between these two modes in normal game play
  - **Ghosts can eat Pacman**
  - How it works: ghosts use BFS to find the shortest path to a **target** location

- **The Breadth-First Search (BFS) needs a target**
  - We will explain BFS in a few slides, but right now we’ll explain targets
Ghost Target Locations

- **Scatter mode**
  - Each ghost should target a different corner of the board
  - Ghosts will run in circles during scatter mode (in the corners)
Ghost Target Locations (cont.)

- **Chase mode**
  - The targets should be *relative to Pacman’s current location*
    - Note: the target is constantly changing!
  - The ghosts should all be unique
    - This means they have different targeting schemes
  - The original game’s targeting is complicated
    - See extra credit if you're interested
  - Sample target locations:
    - Pacman’s location
    - 2 spaces to the right of Pacman’s location
    - 4 spaces above Pacman’s location
    - 3 spaces to the left and 1 space down from Pacman’s location
The Ghost's Search Algorithm

Depth-first search

Breadth-first search
Breadth-First Search

- Search algorithms are often used in Computer Science, and Breadth-First Search is one (of many) popular searches that are used. In Pacman, we will be adding functionality to a standard Breadth-First Search to implement Ghost smart turning.

- What is a Breadth-First Search?
  - Definition of “Breadth”: the distance or measurement from side to side of something; width.
  - A Breadth-First Search means: we will examine all neighbors of a given node before moving on to the next level.
Breadth-First Search

- Characteristics of a Breadth-First Search (BFS):
  - Using a BFS **guarantees** that we will find the shortest path between a starting node and a specified end node.
  - Here is a standard BFS:

```python
bfs(root):
    Q = new Queue()
    enqueue root
    while Q is not empty:
        current = Q.dequeue()
        enqueue current’s neighbors if they haven’t been visited
```
The Ghost’s Breadth-First Search

- **Goal:** When the Ghost must make a directional decision at a turn, use a BFS to determine the quickest direction towards Pacman.
  - We only want to determine the **DIRECTION** to turn, we *do not* want to find the path to take.
    - This is true because Pacman is always moving around and the Ghosts should move freely in an informed (BFS) way.
The Ghost’s Breadth-First Search

bfs(root):
  Q = new Queue()
  enqueue root
  while Q is not empty:
    current = Q.dequeue()
    enqueue neighbors

So, what needs to change to make a BFS work for the Ghosts?
  a. root needs to be the Ghost’s current BoardCoordinate
  b. Need a variable target, which would be the Ghost’s frightened location or some offset on Pacman’s location.
    - Because of offsets, the target may occasionally be a wall. In order to protect against this, we’ll search the entire board and just use the closest square to the target.
      * Therefore, we also need a closestSquare!
  c. Need to keep track of which direction to take!
**The Ghost’s Breadth-First Search**

- `bfs(root):`
  - `Q = new Queue()`
  - enqueue `root`
  - while `Q` is not empty:
    - `current = Q.dequeue()`
    - enqueue current’s neighbors if they haven’t been visited

- `ghostBFS(target):`
  - `Q = new Queue()`
  - initialize variables to track closest square and directions
  - enqueue initial turn options and document the directions
  - while `Q` is not empty:
    - `current = Q.dequeue()`
    - if current is the closest to target:
      - update relevant closest information
    - if current’s neighbors haven’t been visited
      - enqueue them
      - mark that you’re visiting them via the initial direction that lead you to dequeue current
  - return the direction to turn
The Ghost’s Breadth-First Search

The Direction Array!

- We use a 2D array of Directions to keep track of the initial direction the Ghost would need to take in order to get to the current square
  - Remember: a Direction is an enum!
- Goal: determine direction the Ghost should turn to reach Pacman soonest
  - How do we find this given a Direction[][][]?
    - The Direction marked on the “closest cell” indicates the best initial turn!
The Ghost’s Breadth-First Search

- We will use a few different data structures to perform the BFS.
  - BoardCoordinates to represent squares on the board.
  - A 2D Array of Directions to mark the initial direction taken that leads to a given cell.
    - Cells indexed into by BoardCoordinate location
    - The BoardCoordinate that represents the closest square will allow us to index into the 2D Array to find the best initial direction.
  - Queue of BoardCoordinates to make sure we visit all squares
    - Add cells by their BoardCoordinate location
    - We add the “neighbors” at each iteration
    - Assures we look at the closest cells first
The Ghost's Breadth-First Search

Step 0: Initial Population of Queue

- Enqueue the initial neighbors of the cell containing the ghost
  - Cannot be a wall nor a cell in the direction opposite to the direction of the ghost’s movement
- Mark each cell with their initial direction
  - This direction is the direction the ghost must go in order to reach the cell
- Do we need to do anything for the cell in which the ghost currently lies?
The Ghost’s Breadth-First Search

Step 1: Check the Current Cell

- While the queue of \texttt{BoardCoordinates} is not empty, dequeue to get current cell
  - When the queue is empty, we have visited all possible cells and have found the optimal direction!
- Calculate the distance between the current cell and the target cell
  - This can just be the Euclidean Distance between the \texttt{BoardCoordinates}
- If the current cell is closest to the target cell:
  - Update the closest reference cell
  - Update the smallest distance to the target
The Ghost’s Breadth-First Search

Step 2: Mark Neighbors of Current Cell

- Determine which neighbors are valid:
  - Cannot be a wall
  - Must be unvisited
    - How do we check if something has been visited?
    - Whether or not a direction has been assigned to a cell
- We need to be store the directions of the cells we have marked in some data structure...
  - Remember the 2D array of Directions?
- Enqueue the valid neighbors so that they can be checked later
The Ghost’s Breadth-First Search

Step 3: **Repeat**

- When we finish with the current cell, move on to the next cell
  - The unvisited cells are stored in the queue!
  - We dequeue the next unvisited cell as the current cell
- When do we stop?
  - When we have no more cells to check (the queue is empty)
  - ...So we need to repeat *while the queue is not empty!*
The Ghost’s Breadth-First Search

Hand Simulation of Ghost’s Breadth First Search

- Let’s consider a simple case:
  - The Ghost can make two choices
  - Look at a small gameboard

- **Step 0: Initial Population**
  - Create an empty queue of BoardCoordinates
  - Add the neighbors of the Ghost’s starting location with their corresponding directions

- **Step 1: Check the Current Cell**
  - Dequeue to get the current cell
  - Calculate the distance of the current cell from the target
  - Update closest cell and smallest distance references if necessary

- **Step 2: Mark the Neighbors**
  - Enqueue the valid neighbors of the current cell

- **Step 3: Rinse and Repeat!**
  - Repeat until the queue of BoardCoordinates is empty
Ghost Pen

- The ghost pen is the place the Ghosts start in, and where they are returned to when they are eaten by Pacman
- The first challenge is to know which Ghost should exit at a given point
  - For example, in the beginning of the game we want Pinky, then Inky, and then Clyde to exit the pen
Ghost Pen

- Also, when two ghosts get eaten, we want the first one eaten to be the first one to exit. **What does this sound like?**
- Great, so now we know which ghost should exit the pen, but when should it exit?
  - Hint: How can we track of a Duration of time?
- **Use a Timeline!** And specifically the pen should have its own Timeline to make your lives easier.
Coding Incrementally

- Get your board to show up with all of the Dots and Energizers.
- Get PacMan to move correctly - this means both time and key input.
- Get Collisions to work - PacMan should collide with Dots and Energizers and the score should increment properly.
  - Think about implementing a Collideable interface!
- Get a Ghost to BFS properly.
  - Consider testing in Scatter Mode, or Blinky in Chase Mode (as Blinky goes right to PacMan)
- Get Ghosts to appear and leave the Ghost Pen.
Good Luck!

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• Sign up for design discussion time by **Monday, 11/29 at 5 PM**
  ○ Signups will go out next week
• Mini-Assignment will be due **Wednesday, 11/30 at 2 PM**
• Design Discussions will be **Wednesday, 11/30 - Friday 12/2**
• Handin Deadlines:
  ○ Ontime: **Sunday 12/18, 11:59 PM**
  ○ Late: **Tuesday 12/20, 5 PM**
  ■ Note: You **cannot** use a late pass for the final project
Reminder!

No class on Tuesday, 11/22

Happy Thanksgiving!