

Design task: Pacman

Software engineering
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Outline

- CRC cards
- Requirements for Pacman
- CRC cards for Pacman
- Class diagram

CRC cards

What is an object?

- It is a service provider
- It should have a limited number of provided services (responsibilities)
- It has a hidden internal state
- The provided services should be closely related to each other and to the inner state
- It is collaborating with other objects by using their services

How to decompose the problem domain into objects?

- Find the nouns in the problem description (use cases, user stories, requirements)
- Identify the ones within the problem domain and the ones outside the system boundary
- The system boundary is usually at the user interaction and at the communication with external systems
- The nouns within the problem domain are the most important objects

How to decompose the problem domain into objects?

- Find the responsibilities of each identified object
- Find the collaborators of each object, that is, other objects whose services the object uses
- Decompose the objects into simpler objects until they are small enough, self-consistent and self-contained
- Follow the problem domain whenever possible
- Make up other objects and agents, if they simplify things
- Do not deal with internal state at this point

How to create classes from the objects?

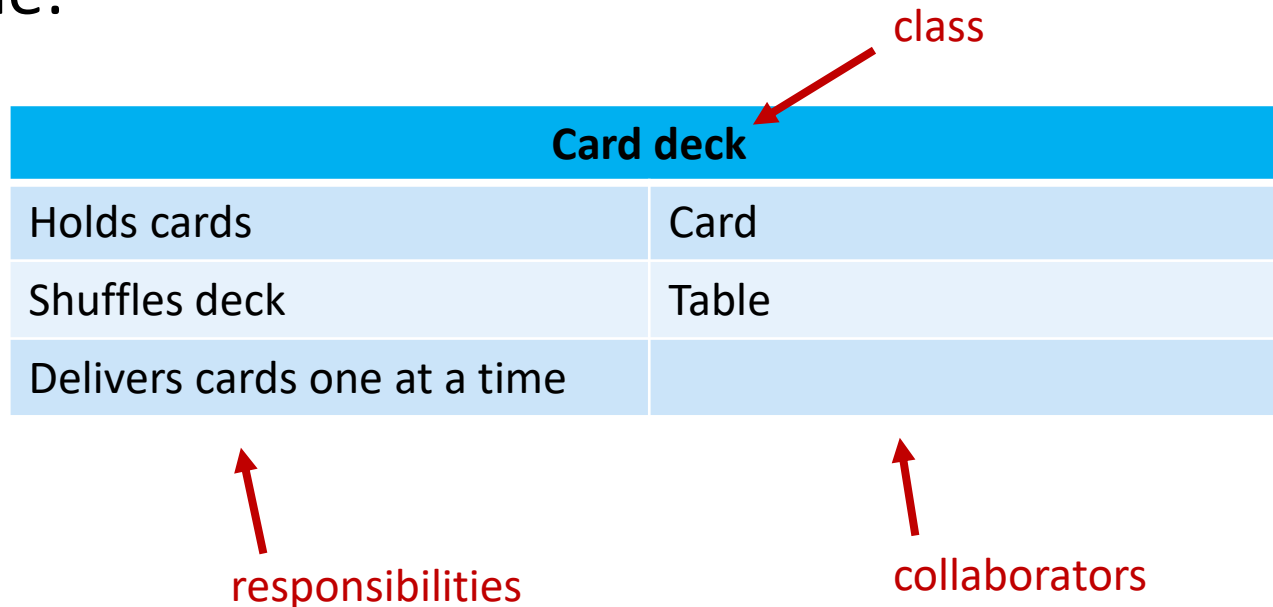
- The objects of the problem domain will become classes
- The provided services (responsibilities) will become methods
- The collaborators will appear in relationships (uses, association, containment, inheritance)

Consistent method for problem decomposition

- CRC cards:

- Class-Responsibilities-Collaborators
- physical paper cards (3x5 inches, 10x15 cm)
 - could be supported by a software tool
- informal language in the problem domain

- Example:



CRC cards

- Informal
 - uses the language of the problem domain
 - can be discussed with the customer
 - non-technical: no programming language constructs, no types, no methods
- Physical record of design decisions

Design process

- Create a card for each identified object in the problem domain
- Use the name of the object as the class name
- Store the cards in alphabetical order
- Start writing responsibilities if you already know some of them
- Go through the scenarios (use cases, user stories) and identify who is responsible for what

Design process: going through a scenario

- Find the initial object
- Write down its responsibility for the initiation of the scenario if it is not yet written
- Find the objects it has to interact with
- Iterate: write down their responsibilities and find their collaborators in the scenario, etc.
- You can physically put the next card on a table or put it back if it is no longer part of the scenario
- Add abstract objects and agents if necessary

From CRC cards to UML

- Create classes from the CRC cards
- Create methods from the responsibilities
- Create relationships (uses, association, containment, inheritance) with the collaborators
 - inheritance: is the object a kind of another?
should they have a common ancestor?
 - containment: is the object a part of another?
 - association: does the relationship survive method calls?
 - uses: does the relationship last for a single method call?
- Add attributes for the inner state
- Refine the model to follow the OO patterns, principles, guidelines and heuristics
- Draw sequence diagrams for the scenarios (use cases, user stories)

Requirements: Pacman

Informal requirements I.

- The player controls Pac-Man through a maze, eating pac-dots (also called pellets). Pac-Man gets 20 points for eating a pac-dot. When all pac-dots are eaten, Pac-Man is taken to the next stage. Four enemies (Blinky (red), Pinky (pink), Inky (blue) and Clyde (orange)) roam the maze, trying to catch Pac-Man. Pac-Man is faster than the monsters, but if an enemy touches Pac-Man, a life is lost and the Pac-Man dies. When all lives have been lost, the game ends.

Informal requirements II.

- Sometimes larger dots known as power pellets appear randomly in the maze for a limited time. The power pellets have many kinds and they give Pac-Man some abilities. The life pellet gives Pac-Man a new life, but the maximum number of lives is five. If the maximum number is reached and Pac-Man collects a life pellet, the pellet disappears without any effect. Pac-Man can also collect bomb pellets, at most five of them. If the maximum number is reached, Pac-Man cannot collect any more, and the pellets remain in the maze. Pac-Man can place the collected bombs in the maze. The bombs have a timer ticking backwards. If the time is expired, the bomb vanishes. If anyone (Pac-Man or a monster) touches the bomb before the time is expired, he dies. Collecting the bonus pellet gives 1000 points to Pac-Man.

Informal requirements III.

- Monsters cannot pick up pellets. However, they apply different strategies for catching Pac-Man. Blinky always follows Pac-Man through the path Pac-Man used. Pinky goes toward Pac-Man on the shortest path. Inky is stupid and only wanders randomly. Clyde is a bit cleverer. He also wanders randomly, but when Pac-Man is near (within five steps), he starts chasing him using the shortest path.

Formal requirements I.

Identifier	Requirement
R01	The player controls Pac-Man through a maze.
R02	Pac-Man eats pac-dots (also called pellets).
R03	Pac-Man gets 20 points for eating a pac-dot.
R04	When all pac-dots are eaten, Pac-Man is taken to the next stage.
R05	Four enemies (Blinky (red), Pinky (pink), Inky (blue) and Clyde (orange)) roam the maze.
R06	The enemies are trying to catch Pac-Man.
R07	Pac-Man is faster than the monsters.
R08	If an enemy touches Pac-Man, a life is lost and the Pac-Man dies.
R09	When all lives have been lost, the game ends.
R10	Sometimes larger dots known as power pellets appear randomly in the maze for a limited time.
R11	The power pellets have many kinds.
R12	The power pellets give Pac-Man abilities.

Formal requirements II.

Identifier	Requirement
R13	The life pellet gives Pac-Man a new life.
R14	The maximum number of lives is five.
R15	If the maximum life number is reached and Pac-Man collects a life pellet, the pellet disappears without any effect.
R16	Pac-Man can collect bomb pellets.
R17	Pac-Man can collect at most five bomb pellets.
R18	If the maximum number of bomb pellets is reached, Pac-Man cannot collect any more, and the pellets remain in the maze.
R19	Pac-Man can place the collected bombs in the maze.
R20	The bombs have a timer ticking backwards.
R21	If the bomb's timer is expired, the bomb vanishes.
R22	If anyone (Pac-Man or a monster) touches the bomb before the time is expired, he dies.
R23	Collecting the bonus pellet gives 1000 points to Pac-Man.

Formal requirements III.

Identifier	Requirement
R24	Monsters cannot pick up pellets.
R25	Monsters apply different strategies for catching Pac-Man.
R26	Blinky always follows Pac-Man through the path Pac-Man used.
R27	Pinky goes toward Pac-Man on the shortest path.
R28	Inky is stupid and only wanders randomly.
R29	Clyde is a bit cleverer. He also wanders randomly, but when Pac-Man is near (within five steps), he starts chasing him using the shortest path.

CRC cards for Pacman

Entities

- Potential entities (nouns):
 - Player, Pacman, Maze, Pac-Dot, Pellet, Point, Stage, Enemy, Blinky, Pinky, Inky, Clyde, Life, Game, Dot, Large dot, Power pellet, Ability, Life pellet, Bomb pellet, Bomb, Timer, Bonus pellet, Strategy, Path, Step
- Additional artificial entities:
 - Field: a cell of the maze
- Synonyms:
 - Player = **Pacman**
 - Dot = Pac-Dot = **Pellet**
 - Large dot = **Power pellet**
 - Enemy = **Monster**
 - Stage = **Maze**
 - Step = **Field**
- Final list of potential entities:
 - Game, Pacman, Maze, Pellet, Point, Monster, Blinky, Pinky, Inky, Clyde, Life, Power pellet, Ability, Life pellet, Bomb pellet, Bomb, Timer, Bonus pellet, Strategy, Path, Field

Entities

- Final list of potential entities:
 - Game, Pacman, Maze, Pellet, Point, Monster, Blinky, Pinky, Inky, Clyde, Life, Power pellet, Ability, Life pellet, Bomb pellet, Bomb, Timer, Bonus pellet, Strategy, Path, Field
- Kind-of relationships:
 - Monsters: Blinky, Pinky, Inky, Clyde
 - Pellet: Power pellet
 - Power pellet: Life pellet, Bomb pellet, Bonus pellet
 - Abilities: Life, Bomb, Point

R01. The player controls Pac-Man through a maze.

Responsibility: move up, down, left or right

Pacman	
Move up, down, left or right	Field

Entities:

Game, Pacman, Maze, Pellet, Point, Monster, Blinky, Pinky, Inky, Clyde, Life, Power pellet, Ability, Life pellet, Bomb pellet, Bomb, Timer, Bonus pellet, Strategy, Path, Field

R02. Pac-Man eats pac-dots (also called pellets).

Responsibility: eat pellet

Pacman	
Move up, down, left or right	Field

Pellet	
Eat	Pacman

Entities:

Game, Pacman, Maze, Pellet, Point, Monster, Blinky, Pinky, Inky, Clyde, Life, Power pellet, Ability, Life pellet, Bomb pellet, Bomb, Timer, Bonus pellet, Strategy, Path, Field

R03. Pac-Man gets 20 points for eating a pac-dot.

Responsibility: add points

Pacman	
Move up, down, left or right	Field
Add points	Pellet

Entities:

Game, Pacman, Maze, Pellet, Point, Monster, Blinky, Pinky, Inky, Clyde, Life, Power pellet, Ability, Life pellet, Bomb pellet, Bomb, Timer, Bonus pellet, Strategy, Path, Field

R04. When all pac-dots are eaten, Pac-Man is taken to the next stage.

Responsibility:
go to next stage/maze
remove pellet

Game	
Go to next maze	Maze
Maze	
Remove pellet	Pellet
Pellet	
Eat	Pacman, Maze

Entities:
Game, Pacman, Maze, Pellet, Point, Monster, Blinky, Pinky, Inky, Clyde, Life, Power pellet, Ability, Life pellet, Bomb pellet, Bomb, Timer, Bonus pellet, Strategy, Path, Field

R05. Four enemies (Blinky (red), Pinky (pink), Inky (blue) and Clyde (orange)) roam the maze.

Responsibility: move up, down, left or right

Monster	
Move up, down, left or right	Field

Entities:

Game, Pacman, Maze, Pellet, Point, Monster, Blinky, Pinky, Inky, Clyde, Life, Power pellet, Ability, Life pellet, Bomb pellet, Bomb, Timer, Bonus pellet, Strategy, Path, Field

R06. The enemies are trying to catch Pac-Man.

Responsibility: catch Pac-Man

Pacman	
Move up, down, left or right	Field
Add points	Pellet
Catch	Monster

Entities:

Game, Pacman, Maze, Pellet, Point, Monster, Blinky, Pinky, Inky, Clyde, Life, Power pellet, Ability, Life pellet, Bomb pellet, Bomb, Timer, Bonus pellet, Strategy, Path, Field

R07. Pac-Man is faster than the monsters.

Responsibility: Pac-Man and Monsters have speed

Pacman	
Move up, down, left or right	Field
Add points	Pellet
Catch	Monster
Has speed	

Monster	
Move up, down, left or right	Field
Has speed	

Entities:

Game, Pacman, Maze, Pellet, Point, Monster, Blinky, Pinky, Inky, Clyde, Life, Power pellet, Ability, Life pellet, Bomb pellet, Bomb, Timer, Bonus pellet, Strategy, Path, Field

R08. If an enemy touches Pac-Man, a life is lost and the Pac-Man dies.

Responsibilities:
touch Pac-Man = catch Pac-Man
Pac-Man has lives
die = lose life = catch

Pacman	
Move up, down, left or right	Field
Add points	Pellet
Has speed	
Has lives	
Die (instead of Catch)	Monster

Entities:

Game, Pacman, Maze, Pellet, Point, Monster, Blinky, Pinky, Inky, Clyde, Life, Power pellet, Ability, Life pellet, Bomb pellet, Bomb, Timer, Bonus pellet, Strategy, Path, Field

R09. When all lives have been lost, the game ends.

Responsibilities:

lose life = die

game ends

Pacman	
Move up, down, left or right	Field
Add points	Pellet
Has speed	
Has lives	
Die	Monster, Game
Game	
Go to next maze	Maze
End	Pacman

Entities:

Game, Pacman, Maze, Pellet, Point, Monster, Blinky, Pinky, Inky, Clyde, Life, Power pellet, Ability, Life pellet, Bomb pellet, Bomb, Timer, Bonus pellet, Strategy, Path, Field

R10. Sometimes larger dots known as power pellets appear randomly in the maze for a limited time.

Responsibilities:

power pellet appears -> who creates it? Game, Maze or Field?

a power pellet has a timer

Maze	
Remove pellet	Pellet
Create power pellet	Field, Power pellet

Power pellet	
Has timer	
Decrease time	Field

Field	
Add pellet	Pellet
Remove pellet	Pellet

Entities:

Game, Pacman, Maze, Pellet, Point, Monster, Blinky, Pinky, Inky, Clyde, Life, Power pellet, Ability, Life pellet, Bomb pellet, Bomb, Timer, Bonus pellet, Strategy, Path, Field

R11. The power pellets have many kinds.

No new responsibilities -> nothing to do

Entities:

Game, Pacman, Maze, Pellet, Point, Monster, Blinky, Pinky, Inky, Clyde, Life, Power pellet, Ability, Life pellet, Bomb pellet, Bomb, Timer, Bonus pellet, Strategy, Path, Field

R12. The power pellets give Pac-Man abilities.

No new responsibilities -> nothing to do

Entities:

Game, Pacman, Maze, Pellet, Point, Monster, Blinky, Pinky, Inky, Clyde, Life, Power pellet, Ability, Life pellet, Bomb pellet, Bomb, Timer, Bonus pellet, Strategy, Path, Field

R13. The life pellet gives Pac-Man a new life.

Responsibility: add new life

Pacman	
Move up, down, left or right	Field
Add points	Pellet
Has speed	
Has lives	
Die	Monster, Game
Add life	Life pellet

Entities:

Game, Pacman, Maze, Pellet, Point, Monster, Blinky, Pinky, Inky, Clyde, Life, Power pellet, Ability, Life pellet, Bomb pellet, Bomb, Timer, Bonus pellet, Strategy, Path, Field

R14. The maximum number of lives is five.

Responsibility: number of lives is limited when a life is added

Pacman	
Move up, down, left or right	Field
Add points	Pellet
Has speed	
Has lives	
Die	Monster, Game
<i>Add life</i>	<i>Life pellet</i>

Entities:

Game, Pacman, Maze, Pellet, Point, Monster, Blinky, Pinky, Inky, Clyde, Life, Power pellet, Ability, Life pellet, Bomb pellet, Bomb, Timer, Bonus pellet, Strategy, Path, Field

R15. If the maximum life number is reached and Pac-Man collects a life pellet, the pellet disappears without any effect.

Responsibility:

collect pellet = eat pellet

remove pellet

Pacman	
Move up, down, left or right	Field
Add points	Pellet
Has speed	
Has lives	
Die	Monster, Game
Add life	Life pellet

Field	
Add pellet	Pellet
<i>Remove pellet</i>	<i>Pellet</i>

Life pellet	
Eat	Pacman

R16. Pac-Man can collect bomb pellets.

Responsibility: collect bomb pellet = eat pellet

Pacman	
Move up, down, left or right	Field
Add points	Pellet
Has speed	
Has lives	
Die	Monster, Game
Add life	Life pellet
Has bombs	
Add bomb	Bomb pellet

Bomb pellet	
Eat	Pacman

R17. Pac-Man can collect at most five bomb pellets.

Responsibility: number of bombs is limited when a bomb is added

Pacman	
Move up, down, left or right	Field
Add points	Pellet
Has speed	
Has lives	
Die	Monster, Game
Add life	Life pellet
Has bombs	
<i>Add bomb</i>	<i>Bomb pellet</i>

Entities:

Game, Pacman, Maze, Pellet, Point, Monster, Blinky, Pinky, Inky, Clyde, Life, Power pellet, Ability, Life pellet, Bomb pellet, Bomb, Timer, Bonus pellet, Strategy, Path, Field

R18. If the maximum number of bomb pellets is reached, Pac-Man cannot collect any more, and the pellets remain in the maze.

Life pellets and bomb pellets have different behavior!

Pacman	
Move up, down, left or right	Field
Add points	Pellet
Has speed	
Has lives	
Die	Monster, Game
Add life	Life pellet
Has bombs	
Add bomb	Bomb pellet

Bomb pellet	
Eat	Pacman

R19. Pac-Man can place the collected bombs in the maze.

Responsibility: place bomb

Pacman	
Move up, down, left or right	Field
Add points	Pellet
Has speed	
Has lives	
Die	Monster, Game
Add life	Life pellet
Has bombs	
Add bomb	Bomb pellet
Place bomb	Bomb, Field

Field	
Add pellet	Pellet
Remove pellet	Pellet
Add bomb	Pacman, Bomb

R20. The bombs have a timer ticking backwards.

Responsibilities:
a bomb has a timer
timer ticks backwards

Bomb	
Has time	
Decrease time	

Entities:

Game, Pacman, Maze, Pellet, Point, Monster, Blinky, Pinky, Inky, Clyde, Life, Power pellet, Ability, Life pellet, Bomb pellet, Bomb, Timer, Bonus pellet, Strategy, Path, Field

R21. If the bomb's timer is expired, the bomb vanishes.

Responsibility: bomb vanishes

Bomb	
Has time	
Decrease time	Field

Field	
Add pellet	Pellet
Remove pellet	Pellet
Add bomb	Pacman, Bomb
Remove bomb	Bomb

Entities:

Game, Pacman, Maze, Pellet, Point, Monster, Blinky, Pinky, Inky, Clyde, Life, Power pellet, Ability, Life pellet, Bomb pellet, Bomb, Timer, Bonus pellet, Strategy, Path, Field

R22. If anyone (Pac-Man or a monster) touches the bomb before the time is expired, he dies.

Responsibilities: touch bomb; die = lose life for Pacman

Bomb	
Has time	
Decrease time	Field
Touch	Pacman, Monster

Field	
Add pellet	Pellet
Remove pellet	Pellet
Add bomb	Pacman, Bomb
Remove bomb	Bomb
Remove Monster	Monster

Monster	
Move up, down, left or right	Field
Has speed	
Die	Bomb

R22. If anyone (Pac-Man or a monster) touches the bomb before the time is expired, he dies.

Responsibilities: touch bomb; die = lose life for Pacman

Bomb	
Has time	
Decrease time	Field
Touch	Pacman, Monster

Field	
...	
Remove Monster	Monster
Remove Pacman	Pacman

Pacman	
...	
Die	Monster, Game, Bomb

R23. Collecting the bonus pellet gives 1000 points to Pac-Man.

Responsibilities:

collect pellet = eat pellet

add points

Pacman	
Move up, down, left or right	Field
Add points	Pellet, Bonus pellet
Has speed	
Has lives	
Die	Monster, Game
Add life	Life pellet
Has bombs	
Add bomb	Bomb pellet
Place bomb	Bomb, Field

Bonus pellet	
Eat	Pacman, Pellet

R24. Monsters cannot pick up pellets.

No new responsibilities -> nothing to do

Entities:

Game, Pacman, Maze, Pellet, Point, Monster, Blinky, Pinky, Inky, Clyde, Life, Power pellet, Ability, Life pellet, Bomb pellet, Bomb, Timer, Bonus pellet, Strategy, Path, Field

R25. Monsters apply different strategies for catching Pac-Man.

Responsibilities:
monster steps

Monster	
Move up, down, left or right	Field
Has speed	
Die	Bomb
Step	

Entities:

Game, Pacman, Maze, Pellet, Point, Monster, Blinky, Pinky, Inky, Clyde, Life, Power pellet, Ability, Life pellet, Bomb pellet, Bomb, Timer, Bonus pellet, Strategy, Path, Field

R26. Blinky always follows Pac-Man through the path Pac-Man used.

Responsibilities:

Blinky steps

find the Path of Pacman -> Who finds this? Blinky, Maze, Fields, Pacman?

Blinky	
--------	--

Step	Path
------	------

Path	
------	--

Contains a list of fields	Field
---------------------------	-------

Field	
-------	--

Add pellet	Pellet
Remove pellet	Pellet
Add bomb	Pacman, Bomb
Remove bomb	Bomb
Remove Monster	Monster
Time since Pacman	Maze
Reset time since Pacman	Pacman

R26. Blinky always follows Pac-Man through the path Pac-Man used.

Responsibilities:

Blinky steps

find the Path of Pacman -> Who finds this? Blinky, Maze, Fields, Pacman?

Blinky	
Step	Maze, Path
Maze	
Remove pellet	Pellet
Create power pellet	Field, Power pellet
Get Pacman's Path	Field, Path, Blinky

R27. Pinky goes toward Pac-Man on the shortest path.

Responsibilities:

Pinky steps

shortest Path to Pacman -> Who finds this? Blinky, Maze, Fields, Pacman?

Pinky	
Step	Maze, Path
Maze	
Remove pellet	Pellet
Create power pellet	Field, Power pellet
Get Pacman's Path	Field, Path, Blinky
Get shortest Path to Pacman	Field, Path, Pinky

Entities:

Game, Pacman, Maze, Pellet, Point, Monster, Blinky, Pinky, Inky, Clyde, Life, Power pellet, Ability, Life pellet, Bomb pellet, Bomb, Timer, Bonus pellet, Strategy, Path, Field

R28. Inky is stupid and only wanders randomly.

Responsibilities:
Inky steps

Inky	
Step	

Entities:

Game, Pacman, Maze, Pellet, Point, Monster, Blinky, Pinky, Inky, Clyde, Life, Power pellet, Ability, Life pellet, Bomb pellet, Bomb, Timer, Bonus pellet, Strategy, Path, Field

R29. Clyde is a bit cleverer. He also wanders randomly, but when Pac-Man is near (within five steps), he starts chasing him using the shortest path.

Responsibilities:
Clyde steps

Clyde	
Step	Maze, Path

Maze	
Remove pellet	Pellet
Create power pellet	Field, Power pellet
Get Pacman's Path	Field, Path, Blinky
Get shortest Path to Pacman	Field, Path, Pinky, Clyde

Entities:

Game, Pacman, Maze, Pellet, Point, Monster, Blinky, Pinky, Inky, Clyde, Life, Power pellet, Ability, Life pellet, Bomb pellet, Bomb, Timer, Bonus pellet, Strategy, Path, Field

Other considerations

Something needs to decrease timers, and make monsters move: Timer entity

Timer	
Ticks	
Notifies Bomb	Bomb
Notifies Power pellet	Power pellet
Notifies Monster	Monster

Bomb	
Has time	
Decrease time	Field
Touch	Pacman, Monster

Power pellet	
Has timer	Timer
Decrease time	Field, Timer

Other considerations

Something needs to decrease timers, and make monsters move: Timer entity

Timer	
Ticks	
Notifies Bomb	Bomb
Notifies Power pellet	Power pellet
Notifies Monster	Monster

Monster	
Move up, down, left or right	Field
Has speed	
Die	Bomb
Step	Timer

Class diagram for Pacman

Class diagram

- Create classes from the CRC cards
- Create methods from the responsibilities
- Create common ancestors
 - Thing: Pacman, Monster, Pellet, Bomb
 - Steppable: Power pellet, Bomb, Monster
- Rename common responsibilities
 - HitBy: Eat, Touch
- Add new responsibilities if necessary