



Designing classes

How to write classes in a way that they are easily understandable, maintainable and reusable

Software changes

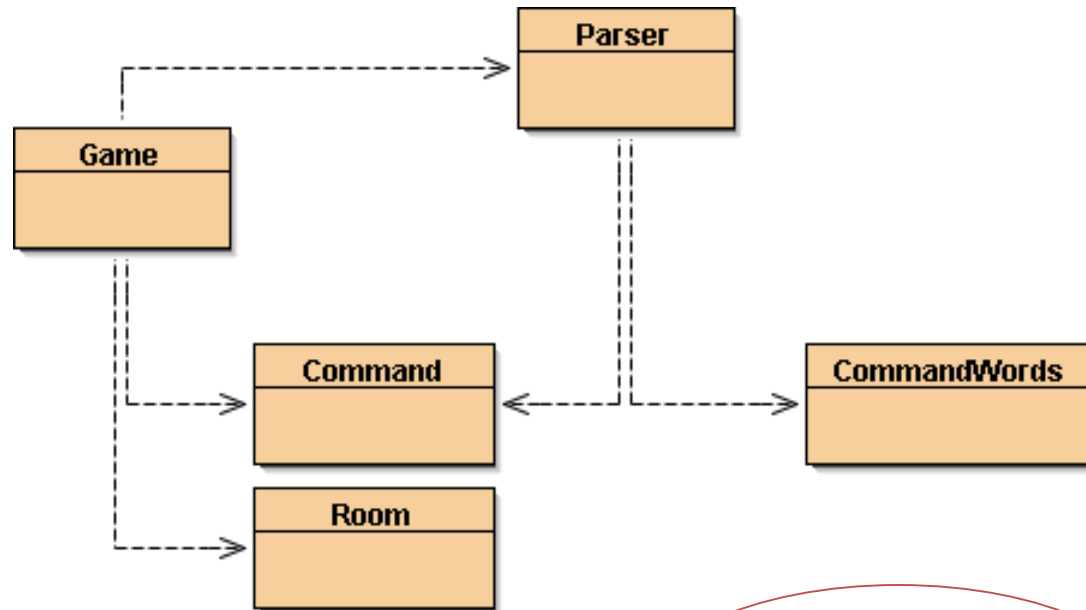
- Software is not like a novel that is written once and then remains unchanged
- Software is extended, corrected, maintained, ported, adapted, etc...
- The work is done by different **people** over time (often decades)



Change or die

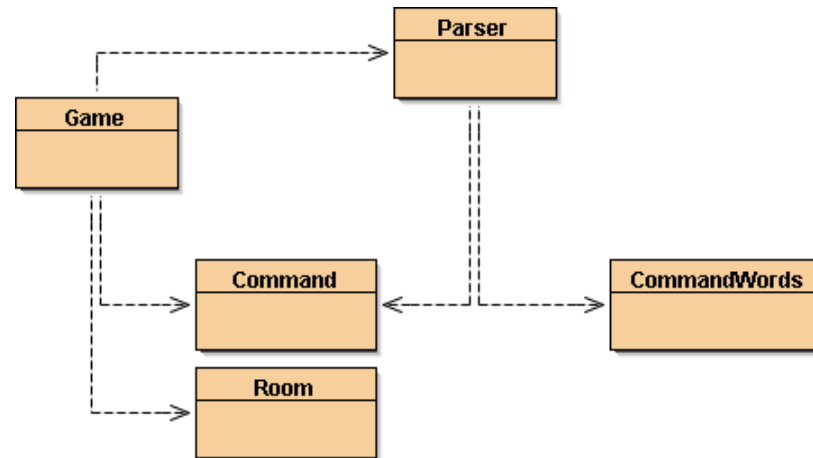
- There are only two options for software:
 - Either it is continuously maintained
 - or it dies
- Software that cannot be maintained will be thrown away

World of Zuul



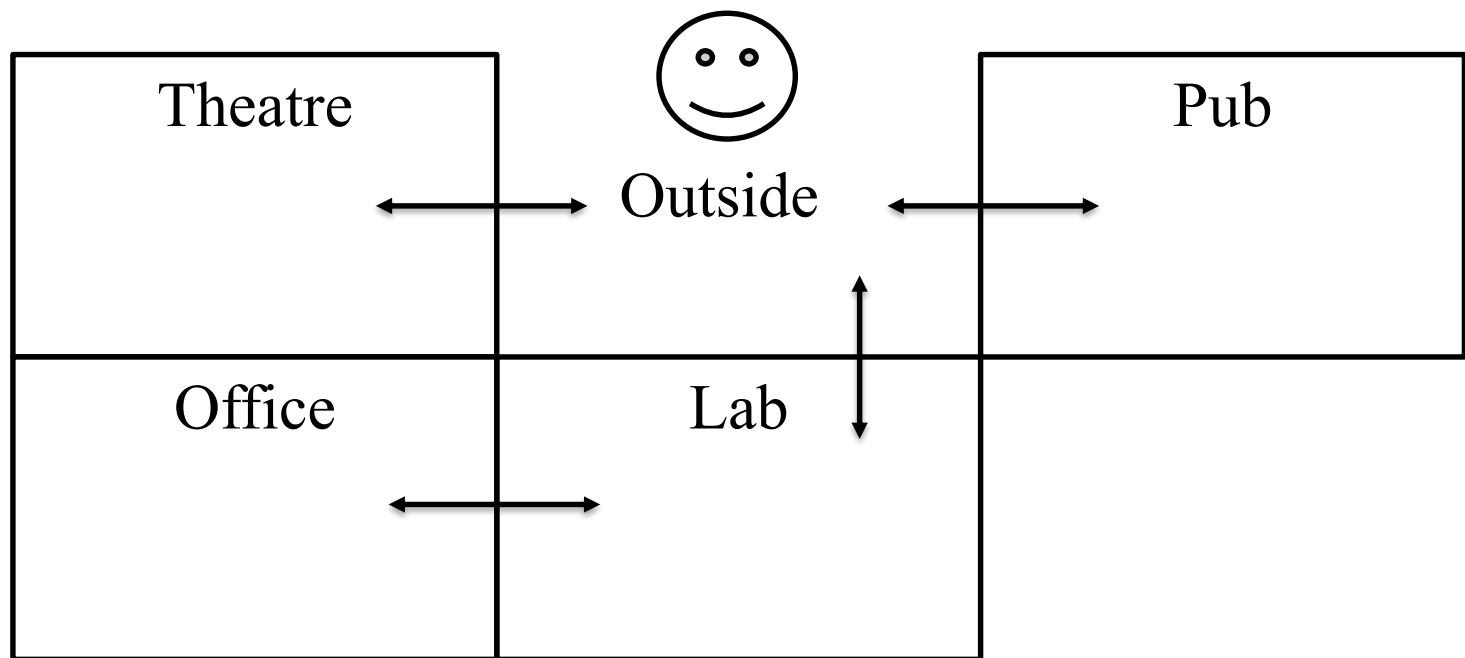
Explore
zuul-bad

The Zuul Classes



- **Game**: The starting point and main control loop
- **Room**: A room in the game
- **Parser**: Reads user input
- **Command**: A user command
- **CommandWords**: Recognized user commands

Designed Rooms





Code and design quality

- Criteria needed to define how to evaluate code quality
- Two important concepts for assessing the quality of code are:
 - Coupling
 - Cohesion

Coupling

- Coupling refers to links between separate units of a program
- If two classes depend closely on many details of each other, we say they are *tightly coupled*
- However, we aim for *loose coupling*
 - where classes are not so inter-connected
- A class diagram provides (limited) hints at the degree of coupling
 - fewer arrow(-->) == less dependencies == encapsulation

Loose coupling

- We aim for loose coupling
- Loose coupling makes it possible to:
 - understand one class without reading others
 - change one class with little or no effect on other classes
- Thus ... loose coupling increases maintainability

Tight coupling

- We try to avoid tight coupling
- Changes to one class bring a cascade of changes to other classes
- Classes are harder to understand in isolation
- Flow of control between objects of different classes is complex

Cohesion

- Cohesion refers to the number and diversity of tasks that a single unit is responsible for
- If each unit is responsible for one single logical task, we say it has *high cohesion*
- We aim for high cohesion
 - responsible for only one cohesive task
- A *unit* applies to classes, methods and modules (packages)
 - for reusability and maintainability

High cohesion

- We aim for high cohesion
- High cohesion makes it easier to:
 - understand what a class or method does
 - use descriptive names for variables, methods and classes
 - reuse classes and methods
- Allows for **readability** and **reuse**



Loose cohesion

- We aim to avoid loosely cohesive classes and methods
- Methods perform multiple tasks
- Classes have no clear identity



Cohesion applied at different levels

- Class level:
 - Classes should represent one single, well defined entity
- Method level:
 - A method should be responsible for one and only one well defined task
- Module/Package level:
 - Groups of related classes



An example to test quality

- Add two new directions to the 'World of Zuul':
 - up
 - down
- What do you need to change to do this?
- How easy are the changes to apply thoroughly?

Finding relevant source code

- What do we change to add 2 new directions?

Class Room

- exits of each room stored as *fields*
- exits assigned in *setExits* method

Class Game

- exit info printed in *printWelcome* method
 - exits defined in *createRoom* method
 - exits used in *goRoom* to find next room
- Where and how easy is it to apply?

Must add *up* and *down* options to ALL of these places ... making it VERY difficult.

Encapsulation to reduce coupling

```
public class Room
{
    public String description;
    public Room northExit;
    public Room southExit;
    public Room eastExit;
    public Room westExit;
    ...
}
```

What is wrong with the fields of this class *Room*?

Encapsulation to reduce coupling

```
public class Room
{
    public String description;
    public Room northExit;
    public Room southExit;
    public Room eastExit;
    public Room westExit;
    ...
}
```

What is wrong with the fields of this class *Room*?

Fields are declared as public!!

- allows direct access from ANY other class
- exposes how exit information is stored
- no longer hides *implementation* from view
- breaks encapsulation guideline suggesting only what a class does is visible to the outside



Reducing coupling

- Encapsulation supports loose coupling
 - private elements cannot be referenced from outside the class
 - Reduces the impact of internal changes

Changing the type of storing data in Room class

```
public class Room
{
    private String description;
    private HashMap<String, Room> exits;           // stores exits of this room.

    /**
     * Create a room described "description". Initially, it has
     * no exits. "description" is something like "a kitchen" or
     * "an open court yard".
     * @param description The room's description.
     */
    public Room(String description)
    {
        this.description = description;
        exits = new HashMap<String, Room>();
    }

    /**
     * Define an exit from this room.
     * @param direction The direction of the exit.
     * @param neighbor The room to which the exit leads.
     */
    public void setExit(String direction, Room neighbor)
    {
        exits.put(direction, neighbor);
    }
}
```

Code duplication

(Loose cohesion)

Both the *printWelcome* & *goRoom* methods contain the following lines of code to print the current room details:

```
System.out.println("You are " +
                    currentRoom.getDescription());
System.out.print("Exits: ");
if(currentRoom.northExit != null) {
    System.out.print("north ");
}
if(currentRoom.eastExit != null) {
    System.out.print("east ");
}
if(currentRoom.southExit != null) {
    System.out.print("south ");
}
if(currentRoom.westExit != null) {
    System.out.print("west ");
}
System.out.println();
```




Avoid code duplication for high cohesion

- Code duplication
 - is an indicator of bad design
 - makes maintenance harder
 - increases chance of inconsistencies
 - leads to errors during maintenance
 - not all copies of code are changed
 - *loose cohesion* with parts of multiple method doing the same thing
 - separate into more cohesive units

printLocationInfo()

```
private void printLocationInfo()
{
    System.out.println("You are " +
                       currentRoom.getDescription());
    System.out.print("Exits: ");
    if(currentRoom.northExit != null) {
        System.out.print("north ");
    }
    if(currentRoom.eastExit != null) {
        System.out.print("east ");
    }
    if(currentRoom.southExit != null) {
        System.out.print("south ");
    }
    if(currentRoom.westExit != null) {
        System.out.print("west ");
    }
    System.out.println();
}
```



Responsibility-driven design

**Where should we add a new method
(which class)?**

- Each class should be responsible for manipulating its own data
- The class that owns the data should be responsible for processing it
- RDD leads to low coupling

Responsibility-driven design

```
/**
 * Return a description of the room in the form:
 *     You are in the kitchen.
 *     Exits: north west
 * @return A long description of this room
 */
public String getLongDescription()
{
    return "You are " + description + ".\n" + getExitString();
}
```

```
/**
 * Return a string describing the room's exits, for example
 * "Exits: north west".
 * @return Details of the room's exits.
 */
private String getExitString()
{
    String returnString = "Exits:";
    Set<String> keys = exits.keySet();
    for(String exit : keys) {
        returnString += " " + exit;
    }
    return returnString;
}
```



Localizing change

- One aim of reducing coupling and responsibility-driven design is to localize change
- When a change is needed, as few classes as possible should be affected

Thinking ahead

- When designing a class, try to think what changes are likely to be made in the future
- We aim to make those changes easy

Suppose an existing program is upgraded from a text interface to graphical:

- replace ALL `System.out.println` statements
- too many *hard-coded* instances to change
- better to *encapsulate* all information about the user interface in a single class ... at the start
- then other classes should *produce* information to pass to the “*user interface*” class to present
- so changes to the user interface would be localized to only 1 class ... the “*user interface*”

Refactoring

- When classes are maintained or changed, often code is added
- Classes and methods tend to become longer, possibly losing high cohesion and loose coupling
- Every now and then, classes and methods should be *refactored* to maintain its high cohesion and low coupling
- Refactoring means rethinking and redesigning the program's class and method structures

Refactoring and testing

HOWEVER ...

- When refactoring code, separate the refactoring from making other changes
- First, do the refactoring ONLY without changing the functionality
- Test before and after refactoring to ensure that nothing was broken
- Then, continue with maintenance or changes on



Design questions

- Common questions:
 - How long should a class be?
 - How long should a method be?
- These can now be answered in terms of cohesion and coupling



Design guidelines

How complex should a class be?

- A class is too complex if it represents more than one logical entity

How long should a method be?

- A method is too long if it does more than one logical task

Note: these are just *guidelines* - they still leave much open to the designer

Enumerated Types

- A language feature defining a type
- Declared like a class using *enum* instead of *class* to introduce a type name
- Used to define a list of variable names denoting the set of values belonging to this type:
 - Alternative to static *int* constants
 - When the constants' values would be arbitrary

A basic enumerated type

```
public enum CommandWord
{
    GO, QUIT, HELP, UNKNOWN
}
```

- By convention, names are defined in CAPS
- Each name represents an *object* of the enum type, e.g. **CommandWord.HELP**
- Enum objects are not created directly
- Enum definitions can also have fields, constructors and methods

Using enumerated types

```
public enum CommandWord
{
    GO, QUIT, HELP, UNKNOWN
}
```

```
String commandWord = command.getCommandWord();
if (commandWord.equals("help")) {
    printHelp();
}
else if (commandWord.equals("go")) {
    goRoom(command);
}
else if (commandWord.equals("quit")) {
    wantToQuit = quit(command);
}
```

*String type
commandWord*

CHANGE

*data type
using enum*

*CommandWord type
commandWord*

```
if(commandWord.equals("help")) {  
    printHelp();  
}  
else if(commandWord.equals("go")) {  
    goRoom(command);  
}  
else if(commandWord.equals("quit")) {  
    wantToQuit = quit(command);  
}
```

```
public enum CommandWord  
{  
    GO, QUIT, HELP, UNKNOWN  
}
```

```
if(commandWord == CommandWord.HELP) {  
    printHelp();  
}  
else if(commandWord == CommandWord.GO) {  
    goRoom(command);  
}  
else if(commandWord == CommandWord.QUIT) {  
    wantToQuit = quit(command);  
}
```


BEST

```
if(commandWord == CommandWord.HELP) {  
    printHelp();  
}  
else if(commandWord == CommandWord.GO) {  
    goRoom(command);  
}  
else if(commandWord == CommandWord.QUIT) {  
    wantToQuit = quit(command);  
}
```

Use *switch* to express code intent even more clearly ...

```
switch (commandWord) {  
    case HELP:  
        printHelp();  
        break;  
    case GO:  
        goRoom(command);  
        break;  
    case QUIT:  
        wantToQuit = quit(command);  
        break;  
}
```


Review

- Programs are continuously changed
- It is important to make this change possible
- Quality of code requires much more than just performing correct at one time
- Code must be understandable and maintainable

Review

- Good quality code avoids duplication, displays high cohesion, low coupling
- Coding style (commenting, naming, layout, etc.) is also very important
- There is a big difference in the amount of work required to change poorly-structured and well-structured code ... so make your code count!!

شعر امروز

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من به بوی سران زلف پریشان بروم
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چون صبا با تن بیمار و دل بی طاقت
به هواداری ان سرو خرامان بروم
در ره او چو قلم گر به سرم باید رفت
با دل زخم کش و دیده گریان بروم
نذر کردم گر از این غم به درآیم روزی
تا در میکده شادان و غزل خوان بروم

حافظ