Lecture 2IP65 & 2IP70
Week 6

Specification
Exceptions

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Specification

Specification

```
int[] digitFreq(int n) {
    assert n>=0;
    int[] freqs = new int[10];
    //assert all elts of freqs are 0;

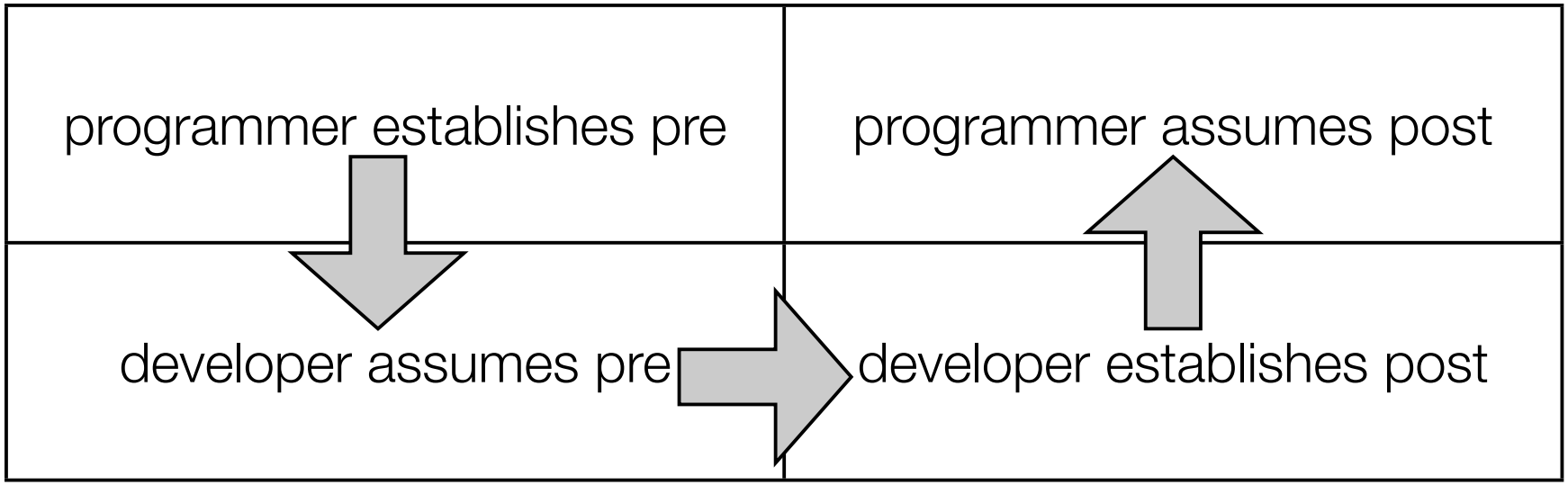
    ...
```

how do you know this?

- method only works correctly if current state (parameters, variables) satisfies some requirements:
  - **precondition (requires clause)**
- method caller may assume that method produces correct result
  - **postcondition (ensures clause)**

Specification

- See method as a *product*
  - developer offers a product
  - programmer uses product
  - delivery contract with rights and duties of parties



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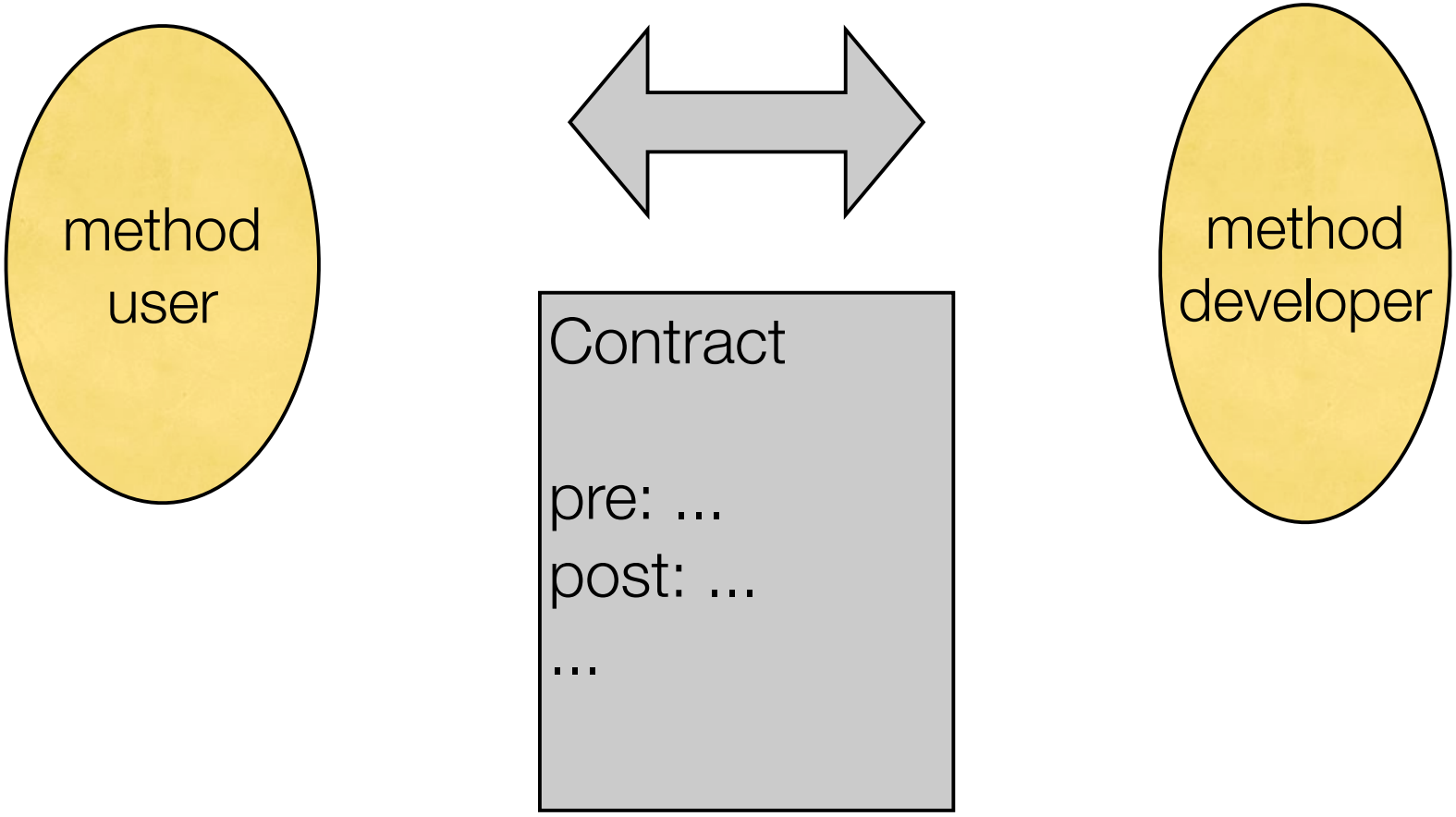
Design by contract



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Specification example

What are the pre- and postcondition?

```
//pre: n>=0
//post: result == r && r*r <= n && n < (r+1)*(r+1)
f(int n) {
    int r = 0;
    while (r+1)*(r+1) <= n {
        r +=1;
    }
 }
```

pre: $n \geq 0$

post: $r^2 \leq n < (r+1)^2$
or $r == \lfloor \sqrt{n} \rfloor$ (floor)

At the call

```
assert x >= 0;
w = f( x );
assert w*w <= x && x < (w+1)*(w+1);
```

apply pre- and post to *actual parameters*

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Exceptions

How to deal with the unexpected

- `consumption = assistant.getBeer();`
- what to do with `consumption` if there is no beer?

1. immediately terminate program

   not elegant, no solution

2. assign some arbitrary value to `consumption`

   dangerous

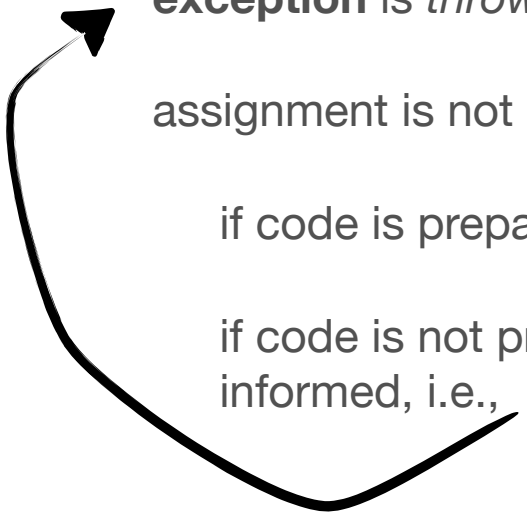
3. tell about the problem without producing result

   out of band message

Out of band message

```
n = scanner.nextInt();
```

if input contains no integer, but something else:



exception is *thrown*

assignment is not executed

if code is prepared for exception => special *catch* code is executed

if code is not prepared => method is aborted and caller of method is informed, i.e.,

Example: without preparation

```
 void calculateResults() {
     level = sc.next();
     goalsFor = sc.nextInt();
     goalsAgainst = sc.nextInt();
     ...
}

public static void main(String[] a) {
        new Competition().calculateResults();
}
```

```
Exception in thread "main" java.util.InputMismatchException
  at java.util.Scanner.throwFor(Scanner.java:840)
  at java.util.Scanner.next(Scanner.java:1461)
  at java.util.Scanner.nextInt(Scanner.java:2091)
  at java.util.Scanner.nextInt(Scanner.java:2050)
  at Competition.calculateResults(Competition.java:41)
  at Competition.main(Competition.java:83)
```

- program is aborted

Example: handling exception immediately

```
void readMatch() {
    do {
        try {
            ...
            goalsFor = sc.nextInt();
            ok = true;
        } catch(InputMismatchException e) {
            System.out.println(
               "Wrong input, enter a number");
            ok = false;
        }
    } while (!ok);
    ... continue with rest of input
}
```

blue: **not** executed in case of exception

purple: **only** executed in case of exception

- **try-block**
- **catch clause**
- program is not aborted, exception is *handled*

Example: passing an exception to caller

```
void readMatch() throws InputMismatchException {
    ...
    goalsFor = sc.nextInt();
    goalsAgainst = sc.nextInt();
    matches += 1;
    ...
}

void readAll() {
    while (...) {
        try {
            readMatch();
        } catch(InputMismatchException e) {
            System.out.println(e + "Match input ignored");
        }
    }
}
```

blue: **not** executed in case of exception

purple: **only** executed in case of exception

- **throws clause**
- *method* is aborted, exception is *passed to caller*
- chain can be as long as you want

Note

- Exceptions should be used to handle the unexpected
- Doubtful if this is the case here
- Probably better is to use `sc.hasNextInt()`

Typical Exceptions

- IO problems
  - file not found
  - permissions not ok
- Network problems
  - host does not exist
  - connection broken
- Programming problems
  - array index out of bounds
  - division by zero *(**not** overflow!)*

Example: home cooked Exception

```
int plus(int a, int b) throws OverflowException {
      int a;
      int b;

      if (a>0 && b>0 && a+b<0) {
          throw new OverflowException();
      }
      return a+b;
}
...


class OverflowException extends Exception {
}
```

Hierarchy of Exceptions

- Exceptions are actually *objects* with their classes ordered in hierarchy (next course more about this)

- Exception: any “regular” exception fits in this class

  ↳ IOExecption: several exceptions dealing with IO

    ↳ FileNotFoundException: specific IOException

- Catching respects hierarchy:

```
try {
   ...
} catch (FileNotFoundException e1) {
   // if it is a FNFExc
} catch (IOException e2) {
   // if it is a IOExc, but not a FNFExc
} catch (Exception e3) {
   // if it is not a FNFExc
   // but any other exception
}
```

Exceptions are checked

- Most exceptions *must* be either be caught inside the method or declared (with `throws BlahBlahException`) in the method header
- Compiler checks this and refuses compilation if not ok
- will appear in the API: part of the contract
- sometimes annoying, in general beneficiary
- exceptions are part of the contract

Unchecked Exceptions

- Special class of exceptions need not to be declared
  - can occur in many places, often not tied to a specific method
  - often due to (avoidable) programming errors
  - declaring all these would make program unwieldy
- Class is **RuntimeException**
- Examples:
  - **IndexOutOfBoundsException**: when using wrong index into array
  - **ArithmeticException**: division by zero etc., not overflow :-(
  - **NullPointerException**: when method (or instance var) is accessed via null value (more about this later)

Specification of Exceptions

- add clause that describes which exception can occur and when

```
// normal behaviour:
// ...
// exceptional behaviour:
// pre: b == 0
// signals: DivisionByZeroException

int divide(int a, int b) throws DivisionByZeroException {
  ...
}
```

- trade off between normal precondition and exception
  - *pre: b != 0* could be added and exception removed from interface

Why exceptions

- give possibility of *out-of-band* message to caller
- let you separate code in normal behaviour and exceptional behaviour: better structure
- ditto in specification
- don't use exceptions to code normal behaviour:

```
// to read all input from scanner:
try {
    while (true) {
        a[i] = scanner.next();
        i++;
    }
} catch(NoSuchElementException e) { }
// continue with rest of program
```

example from API

PrintWriter

`public PrintWriter(File file)`
`throws FileNotFoundException`

Creates a new PrintWriter, without automatic line flushing, with the specified file. This convenience constructor creates the necessary intermediate `OutputStreamWriter`, which will encode characters using the default charset for this instance of the Java virtual machine.

Parameters:

`file` - The file to use as the destination of this writer. If the file exists then it will be truncated to zero size; otherwise, a new file will be created. The output will be written to the file and is buffered.

Throws:

`FileNotFoundException` - If the given file object does not denote an existing, writable regular file and a new regular file of that name cannot be created, or if some other error occurs while opening or creating the file

`SecurityException` - If a security manager is present and `checkWrite(file.getPath())` denies write access to the file

From this, you can conclude that you have to catch, or pass on, an FileNotFountException when you create a PrintWriter this way.
The Java API can be consulted at http://java.sun.com/javase/6/docs/api/.

Files and I/O

General idea

- Several *classes* (such as Scanner) exist in package *java.io*
- Make object of such a class by **`new Scanner(...)`**
- On the dots fill in an object that does part of the task
- Example
  - `System.in` is object that handles input from keyboard
  - `scanner = new Scanner(System.in)` creates object that processes keyboard input on higher level (separates them into *tokens* (words), etc.)

Scanner (java.util)

- **Scanner** processes input from **arbitrary source**, chops them into *tokens* and offers tokens via:
  - `next()`: consume next token from input. Default: whitespace separated *words*
  - `nextInt()`: consume next token and interpret as integer (if possible)
  - `nextDouble()`, `nextBoolean()`,...: ditto
  - `nextLine()`: reads the rest of the current line and goes to the next one
  - `hasNext()`: returns true if there are tokens on input, false otherwise
    - note: usually true on keyboard input (`next()` will wait to see if there is more)
  - other token separating behaviour can be specified (with `useDelimiter`)
  - hasNextInt(), etc.: true if next token is in int (etc.) format

File (java.io)

- When program terminates, all data is lost
- Files store data more permanently
- an object of class `File` records information about a file on disk
- `new File("funnyfile.txt")` creates a File object that can be connected to the disk file *funnyfile.txt*
  - path names are possible: `new File("C:\\My Documents\\funny.doc")`
- it doesn't create or connect to a file by itself

Connecting

- a File object can be connected to a Scanner object:

- ```
  File file = new File(“funnyfile.txt”);
  Scanner scanner = new Scanner( file );
  ```

- then reading all lines into array **a** (which should be big enough):

```
int i = 0;
while ( scanner.hasNext() ) {
    a[i] = scanner.nextLine();
    i++;
}
```
```

PrintWriter (java.io)

- has objects that can perform `print` and `println` like `System.out`

- `File file = new File("funnyfile.txt");`
  `PrintWriter pw = new PrintWriter(file);`
  creates the file *funnyfile.txt* and an object to write into it.

  - if *funnyfile.txt* exists already, it is overwritten (contents is removed)

- Suppose **`a`** is an array of Strings, then writing the contents of **`a`** as lines into the file *funnyfile.txt*:

```
for (int i=0; i<a.length; i++) {
    pw.println(a[i]);
}
```

- Fixing its contents and making the file available for, e.g., input:
  `pw.close();`

Example

```
// copies a text file line by line
import java.util.*;
import java.io.*;

public class FileCopy {
    Scanner scanner;
    File source;
    File target;
    PrintWriter pw;
    String filenameSource = "rhubarb.txt";
    String filenameTarget = "rhubarb_copy.txt";

    void copy() {
        try {
            String line = null;
            source = new File( filenameSource ) ;
            scanner = new Scanner( source );
            target = new File( filenameTarget );
            pw = new PrintWriter( target );

            while (scanner.hasNext()) {
                line = scanner.nextLine();
                pw.println( line );
            }

            pw.close();
        } catch(FileNotFoundException e) {
            System.out.println("Could not open file due to");
            System.out.println(e);
        }
    }

    public static void main(String[] args) {
        new FileCopy().copy();
    }
}
```