# Instruction Manual
# Introduction to Programming in Python

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Fifth Edition

Published October 2017

VU UNIVERSITY AMSTERDAM

# Contents

# Origin of the manual

This manual is largely based on the third international edition of the Instruction Manual Introduction to Programming. A more detailed history of this manual can be found in the third international edition and the thirtieth edition of the Dutch *Practicumhandleiding Inleiding Programmeren*. This manual has been adapted to reflect the change of the programming language used during this practical. Previously, Java was the programming language used for all study programmes during practicals. Starting from the academic year 2012-2013, Java will be replaced by Python in the courses for *Information, Multimedia and Management* and *Lifestyle Informatics* students. This adaptation has been performed by Jan Stienstra in co-operation with a reviser; Bram Veenboer.

Jan Stienstra, July 2012

In the third edition of this manual, the MAC support for the ipy_lib is added. As well as some minor changes and fixes.

Marcel de Vries, October 2013

# 0 Syllabus

## Course format

This course features a series of lectures and parallel lab sessions. During the lectures, theory on programming using the Python programming language, is taught. During the lab sessions, programming is practiced by making assignments using the Python programming language. Assignments should be prepared in advance, at home. Students will be assigned to groups. Every group will have a teaching assistant, who will assist with the assignments and grade the deliverables.

### Course documents and assignments

**Book** During this course the online book *Learning with Python*, 2nd Edition, by Jeffrey Elkner, Allen B. Downey, and Chris Meyerswill be used. It can be found here. Parts of this book will be treated during the lectures. During the lab sessions, you are supposed to take your lecture notes with you.

**Modules** The course material is devided into five modules. These modules contain additional theory and assignments and will be used as an instruction manual during the lab sessions. Theory treated during the lectures will be repeated as little as possible in the modules. The modules will however feature notes on programming style.

**Assignments** Every module consists of theory and assignments. For module 3-4 only the last assignment of a module will be graded, in module five both assignments will be graded. This does not mean that the other assignments in module 3-4 are less important. All the assignments in a module will train essential skills needed to succesfully complete the graded assignment. *Every* assignment has to be approved by the teaching assistent to pass the course. You should not start working on an assignment before completing all previous assignments. This way, you will not make possible mistakes twice. Teaching assistants will therefore not answer any questions on an assignment, if the previous assignments have not yet been completed.

## Deadlines and assessment

Graded assignments have to be submitted to Practool. The teaching assistent will only provide help with an assignment if all previous ungraded assignments have been approved. When the quality of an ungraded assignment is not sufficient, it has to be corrected according to the provided feedback. Graded assignments cannot be resubmitted once a grade has been given. Feedback on these assignments can therefore not be used to improve a program in order to receive a higher grade. Nevertheless, it is advised to process the feedback received on graded assignments as well.

**Deadlines** Deadlines will be posted on Canvas. Late submission will be accepted, but a point is deducted for every day the assignment is late. Pay close attention: **no work will be accepted after the practicum is finished.** The grades are weighted in the following way:

| Chapter | Graded Assignment | Weight |
|---|---|---|
| 1 | HelloWorld2 | slipday |
| 2 | All | slipday |
| 3 | GeographyGrades | 1x |
| 4 | F-Administration | 1x |
| 5 | Pirate | 2x |
| 6 | Snake | 3x |
| 7 | Life | 0,5 bonus |

**Slipdays** The first two modules do not include graded assignments, however if you hand in these assignments correctly your TA can grant you a *slipday*. You can earn at most two slipdays. When a graded assignment is handed in late, one point will be deducted for each day. After the last module your TA will use your slipdays to reduce the 'late days' penalty on the most heavy weighted assignments. Both slipdays can be used for the same assignment.

| Chapter | grade | days late |
|---|---|---|
| 1 | 1 slipday | |
| 2 | 1 slipday | |
| 3 | 7 | 0 |
| 4 | 7 | 0 |
| 5 | 6 | 2 |
| 6 | 8 | 1 |
| 7 | 7 | 0 |

Table 1: Example of how to calculate with slipdays

Your final mark would've been: $\frac{7*1+7*1+(6-2+\mathbf{1})*2+(8-1+\mathbf{1})*3}{7}+0.5.$

**Want a higher grade?** Once you've gotten a grade for a graded assignment and you would like a higher grade, you can only do this by handing in a Supplementary Exercise. These can be found on Canvas. You cannot hand in the same assignment another time.
The last grade will count, even if this turn out to be a lower grade.

**Final Grade** You have passed the lab when the average grade of all the graded assignments is ($\geq 5,5$). Assignments that have not been submitted will be graded with a $1,0$.
You passed the "Programming in Python" course if the lab is passed: $\geq 5,5$.

# 1 Editing, Compiling and Executing

**Abstract**

This chapter will introduce the IDE (Integrated Development Environment) PyCharm and explain how to organize Python files and execute programs.

## Goals

- Use PyCharm to open, edit, save and organize Python-files
- Execute Python code

## Introduction to Python and PyCharm

### Installing Anaconda

**VU** Anaconda has already been installed on all the VU computers that will be used during the lab sessions.

**At home**

In this course we are going to program in **Python 2.7**, and use a library for graphical representations. This library makes use of the Python package "matplotlib". Since matplotlib has a lot of other dependencies, it is easiest to install a Python distribution that includes matplotlib. In this course we use the Python 2.7 distribution called "Anaconda".

- **64 bit Windows:** Download Anaconda from this link.
- **32 bit Windows:** Download Anaconda from this link.
- **MacOS:** Download Anaconda from this link.

Once you have downloaded the Anaconda installer, click the downloaded file and follow the instructions that appear on the screen.

### Installation and starting PyCharm

**VU** PyCharm has already been installed and configured on all the VU computers that will be used during the lab sessions.

**At home**

To download PyCharm, browse to `https://www.jetbrains.com/pycharm/download/` and download **PyCharm Community Edition**. Follow the instructions in the installer.

Once PyCharm has been installed, follow these steps to setup the editor:

1. Download the Practical plugin from `https://phoenix.labs.vu.nl/files/Practical.jar`.
2. Start PyCharm.
3. If this is the first time PyCharm is started, it will take you through some setup options.
4. Once you have gone through the setup steps, a welcome screen will appear.
5. At the bottom right of the welcome screen is a button called **Configure**. Click this button.
6. In the dropdown menu that appears, click **Plugins**.
7. At the bottom right of the plugins screen is a button called **Install plugin from disk...**. Click this button.
8. Select the Practical plugin that was downloaded from Canvas on the computer, then click **OK**.
9. Click **OK** again. If PyCharm asks you if you want to restart it, click **Yes**.

Now PyCharm and Practical should be installed.

**Creating a project** The *project* is a folder in which all created files are saved. For this course, only one project needs to be created. When PyCharm is started and no projects have been made yet, it will automatically ask you to create a new project (the button is called **Create New Project**). Click this button and create a **Pure Python** project. The *Location* field decides where on your computer the files in this project will be saved. The *Interpreter* field decides which Python interpreter will be used for this project. Select the Anaconda interpreter. Click **Create**, and the project will be created.

## Arranging files

After the project has been created, a new screen will show. On the left of the current window, the Package Explorer is shown. This is where you can see all files belonging to a project. Files can be organized in folders. The rest of this theory explains how to organize a module in PyCharm.

1. Create a new **Directory** (folder). To do this right-click in the Package Explorer and select New → Directory. The name of this directory will be **Module 1**.
2. Create a new **Directory** inside of the directory created in the previous step. To do this right-click the directory created in the previous step (called *Module 1* and select New → Directory. The name of this directory will be **Hello World 1**.
3. Every assignment will be in its own **Python File**. To do this, right-click on the directory created in the previous step (called *Hello World 1*) and select New → Python File. The name of the **Python File** will be the same as the name of the assignment.

## Compiling and executing programs

When a new Python File is created, it is called a *skeleton*; an empty program, that does nothing. As a start, create a new Python File called hello_world.py, and copy the following code to this Python File:

```
print "Hello World"
```

Programs are compiled automatically in PyCharm. Right-click on the file to be executed and select **Run** (the button with a green arrow next to it). The output of the program will be printed in the Console, at the bottom of the screen. If the program expects input, it can be typed into the Console as well.
Programs can only be executed if they are syntactically correct. If there are any errors, these are underlined in red. Hover the mouse over the underlined words to show an error message.

## Submitting assignments

A graded assignment needs to be submitted to PracTool (phoenix.labs.vu.nl/practool). The process of correctly submitting assignments is given below:

1. Export all the files of the assignment to a .zip-file. Right-click on the **Directory** in the Package Explorer to be exported and select Export as ZIP. Navigate to the folder where the ZIP file should be stored. Make sure the fila name is the name of the assignment and is followed by your VUnet-id seperated by a hyphen. For example: `pirate-rhg600.zip`.

   Click **Open** and the .zip-file has been created in the directory that has been selected.

2. Submit the .zip-file to PracTool. Login to PracTool (register an account if you do not already posses one, PracTool is NOT linked to VUnet or Canvas). Browse My Computer and select the .zip-file. Click on Submit. Wait for PracTool to confirm the submission and click on Finish.

If your VUnet-id is rhg600, the files you submit should be named in the following way:

| Module | Name |
|---|---|
| 1 | hello_world2-rhg600.zip |
| 2 | chapter2-rhg600.zip |
| 3 | geographygrades-rhg600.zip |
| 4 | administration-rhg600.zip |
| 5 | houseMarket-rhg600.zip |
| 6 | pirate-rhg600.zip |
| 7 | snake-rhg600.zip |
| 8 | life-rhg600.zip |

Note: chapter2-rhg600.zip contains all the assignments from chapter2.

☛ **Warning**
Assignments can only be processed if they are submitted in the format described above. Do not submit files in any other format!

## Trial submission

Create a new Python File hello_world2 and copy hello_world to hello_world2.

Edit the program in such way that it will ask for your name:

```
name = str(raw_input("Enter your name: "))

print "Hello world!! written by: %s" % name
```

Add a comment to the top of your code which includes the name of the assignment, the date of completion and your name. This ensures that your teaching assistant knows which assignment belongs to whom. For example:

```
''' Assignment: hello_world2
    Created on 25 aug. 2012
    @author: Jan Stienstra '''

name = str(raw_input("Enter your name: "))

print "Hello world!! written by: %s" % name
```

Test the program. Does it work as expected? If so, hand in the program by submitting it on Practool.

This program is not graded like the other assignments that have to be submitted. It is possible to earn a slipday if the program is submitted on time. The syllabus provides more details on slipdays. The goal of this assignment is to make sure that you can submit programs.

# 2 If statements and loops

**Abstract**

The first few programs in this chapters will read from *standard input* and write output to *standard output*. These programs will be very simple. The focus in the first part of this chapter will be on writing programs with a clear layout using well chosen names. The second part of this chapter will introduce if-statements and loops.

☛ **Warning**
This chapter contains nine assignments of variable size. Make sure to utilize the time given to you during the lab sessions. The lab sessions only provide sufficient time if you write your programs in advance. This way, any problems you encounter whilst writing your programs can be resolved during the lab sessions.

## Goals

- The use of clear identifiers.
- Familiarize with if, else and elif statements and recognize situations in which to apply these.
- Familiarize with for and while loops and recognize situations in which to apply these.

## Instructions

- Read the theory about **Efficient programming** and **Constants**. With this information in mind, make the assignments **VAT**, **Plumber** and **Othello 1**.
- Read the theory about **Identifiers** and **If-statements**. With this information in mind, make the assingments **Electronics** and **Othello 2**.

- Study your lecture notes on **Loops**. With this information in mind, make the assignments **Manny**, **Alphabet**, **Collatz** and **SecondSmallest**.

## Theory

### Efficient programming

Once upon a time, running a computer was so expensive that any running time that could be saved was worthwile. Programs had to contain as little lines of code as possible and programs were designed to run fast; clear code was not a priority. Such a programming style is called machine-friendly nowadays. Luckily, the situation has changed.
Programs that have been written in the past often need altering in one way or another. If a program was written in a machine-friendly, but incomprehensible programming style, it is almost impossible to edit it. After half a year, one easily forgets how the program works exactly. Imagine the problems that could occur, when the programmer that wrote the code no longer works for the company, that wants to edit it.
The logical implication of this programming style is that programs are not changed at all. Everyone has to work with the, then well-intentioned 'features', that are no longer maintainable.
Running programs is becoming increasingly less expensive. Programmers, on the other hand, are only getting more expensive. Efficient programming therefore does not mean:

> "writing programs that work as fast as possible."

but

> "writing programs that require as little effort and time possible to be
>
> - *comprehensible*
> - *reliable*
> - *easily maintained*."

This will be one of the major themes during this course. Assignments are not completed when the program does what the assignment asks them to do. Programs are only approved when they meet the standards described above.
Theory provided in this Instruction Manual is an addition to the lectures and book. The book will teach you the syntax and basic functionality, this instruction manual will teach you how to do this, taking the standards described above into account.

✎ **Rule of Thumb**
Try to refrain from writing lines of code longer than the screen width. If it is impossible to write code on a single line, a \ can be used to continue on a new line.

## Constants

Although Python does not support constants in the context of unchangeable variables, like those in the Java and C programming languages, the principles of using constants are upheld in Python. In other words, although Python does not support constants, variables can be used as if they were constants. Imagine a program that reads a number of addresses from a file and prints them on labels, thirty characters wide, six lines high. All of the sudden, the wholesale company changes the size of the labels to thirty-six characters wide and five lines high.
Fortunately, the program looks like this:

```
''' Assignment: Labels
    Created on 6 aug. 2012
    @author: Jan Stienstra '''


# This program reads adresses from input,
# and prints them in a specific format.

LABEL_WIDTH = 30 # characters
LABEL_HEIGHT = 6 # lines

# etc...
```

The only thing that needs to be done, is to change the two constants and recompile the program.

Errors that can occur when a program does not incorporate constants are:

- The code contains a `6` on 12 different places and is only replaced on 11 places by a `5`
- Derived values like `5` (= `LABEL_HEIGHT - 1`) are not changed to `4` (= `LABEL_HEIGHT - 1`)!

Constants do not only ease the maintenance of a program, but can increase the comprehensibility of the code as well. When a constant, like `LABEL_HEIGHT`, is used, it is imediately clear what this number represents instead of only knowing its numerical value. This property gives constants an added value. Therefore, it is advisable to always use constants in your programs.

**Rule of Thumb**
All numbers used in a program are constants, except 0 and 1.

**Example** The following example program will read a number of miles from the standard input and prints the equivalent number of kilometers on the output. Take special notice to the use of identifiers, constants and layout.

```
''' Assignment: MileInKilometers
    Created on 6 aug. 2012
    @author: Jan Stienstra '''


MILE_IN_KILOMETERS = 1.609344
```

```
number_of_miles = int(raw_input("Enter the number of miles: "))

number_of_kilometers = number_of_miles * MILE_IN_KILOMETERS

print "%f miles equals %f kilometer" % \
        (number_of_miles, number_of_kilometers)
```

☞ Make the assignments **VAT**, **Plumber** and **Othello 1**.

## Identifiers

All constants, types, variables, methods and classes have to be assigned a name. This name is called the identifier. This identifier has to be unique within the class that it is defined in. This might seem easier than it is. In this practical you will learn to choose the right identifier for the right object.

**The importance of the right name** The identifier that is assigned to an object should reflect the information it contains. When a variable to maintain a record of the number of patients in a hospital is needed, *n* would not suffice as a identifier for this variable. The identifier *n* does not specify the information the variable contains. When the identifier *number* is chosen, the problem seems to be resolved. However, it is still unclear to which number the identifier refers. Is it the number of doctors? Is it the number of beds? No, it is the number of patients. That is why this variable should be called *number_of_patients*. It might take some time to find an appropriate identifier in some cases, but it is certainly worth the effort. This ensures that everyone will understand your program, including the teaching assistant.

**Example** A long, long time ago, the maximum length of identifiers in some programming languages was limited. All information about the contents of the variable had to be contained in six or seven characters. This meant that it was very difficult to find clear and understandable identifiers. As a result, programs were often hard to read. A program that had to find travel times in a timetable would contain identifiers like:

```
ott # outward travel time, in minutes
rtt # return travel time, in minutes
```

The introduction of programming languages like Pascal significantly improved the readability of code by removing the restriction on identifier lengths. Like Pascal, Python does not limit the length of identifiers. Therefore the identifiers in the example can be rewritten:

```
outward_travel_time # in minutes
return_travel_time # in minutes
```

**Abbreviated identifiers** Uncommon abbreviations should not be used as identifiers, as the example above illustrates. Identifiers do not necessarily have to be long to be understandable. In mathematics for example, characters are often used to denote variables in equations. Let's have a look at the quadratic equation:

$$ax^2 + bx + c = 0$$

A quadratic equation has at most two solutions if the discriminant is larger than zero:

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

A program to solve a quadratic equation would contain the following code:

```
discriminant = (b * b) - (4.0 * a * c)
if discriminant >= 0:
    x1 = (-b + math.sqrt(discriminant)) / (2.0 * a)
    x2 = (-b - math.sqrt(discriminant)) / (2.0 * a)
```

Note that this implementation uses the identifiers *a*, *b* and *c* in the same way as the mathematical definition. Readability would not improve if these identifiers would be replaced by *quadratic_coefficient*, *linear_coefficient* and *constant_term*. It is clear that using *a*, *b* and *c* is the better choice. The identifier *discriminant* is used as no specific mathematical character is defined for it. The module `math` identifies the method to calculate a square root with `sqrt()`. The module `math` identifies a number of other methods with equally well known abbreviations. For example: `cos()`, `log()` and `factorial()`.

**Exceptions** There are some conventions for identifiers. An example for calculating the factorial of $n > 0$:

```
factorial = n
for i in range(1, n):
    factorial *= i
```

The identifier for the variable *n* is not changed into *argument*. Numerical arguments are by convention often identified as *n*. Variables that are used for iterations are similarly not identified as *counter*, but as *i*. When more than one iterator is used, it is common practice to use *j* and *k* as identifiers for the next iterators.
Let us look at another example. When programming a game of chess, the pieces on the board can be identified by *ki* (king), *qu* (queen), *ro* (rook), *bi* (bishop), *kn* (knight) and *pa* (pawn). Everyone with a elemental knowledge of chess will surely understand these abbreviations, one might think. However, if someone else reads this program *kn* might be interpreted as king and *ki* as knight. This example shows the need of *'psychological distance'* between two identifiers. The psychological distance between identifiers cannot be measured exactly. Psychological distance is roughly defined as large when the chance of confusion between identifiers is small. On the contrary, the psychological distance is small when confusion between identifiers is almost inevitable. Two identifiers with a very small psychological distance are the identifiers in the first timetable example.

**Rule of Thumb**
Identifiers which are used a lot in the same context, need to have a large psychological distance.

## Conventions

One important restriction for choosing identifiers is that they cannot contain whitespace. It is common practice to write identifiers consisting of multiple words by capitalising each word, except the first. In this practical the following guidelines are in place:

- Names of variables, methods and functions are written in lowercase, with words seperated by underscores.

  Example: `number_of_students`
  Example: `read_line() { ... }`
  Example: `calculate_sum_of_profit(x)`

- Identifiers identifying constants are written in upper case. If an identifier for a constant consists of multiple words they are separated by underscores.

  Example: `MAXIMUM_NUMBER_OF_STUDENTS = ...`

- Identifiers identifying a module are written in the same way as variables.

- Identifiers identifying a class are written in lowercase, with the first letter of all the words capitalized.

  Example: `Library`
  Example: `AgeRow`

## Self test

## Expressions 1

The following questions are on expressions. These questions do not need to be turned in. Do make sure you are able to answer all the questions posed below, as this knowledge is vital in order to make the exam in good fashion. For all questions write the generated output, or indicate an error. In addition write down every expression in a question and denote the type of the resulting value of the expression.

### Question 1

```
result = 2 + 3
```

### Question 2

```
result = 1.2 * 2 + 3
```

### Question 3

```
result = "ab" + "cd"
```

### Question 4

```
result = ord('c') - ord('a') + ord('A')
result = chr(result)
```

### Question 5

```
result = True or False
```

### Question 6

```
result = 17 / 4
```

### Question 7

```
result = 17 % 4
```

### Question 8

```
if True :
    print "not not true"
```

### Question 9

```
if False :
    print "really not true"
```

### Question 10

```
if 2 < 3 :
    print "2 is not larger or equal to 3"
```

### Question 11

```
if (3 < 2 and 4 < 2 and (5 == 6 or 6 != 5)) or True :
    print "too much work"
```

### Question 12

```
number = '7'
print "%c" % number
```

### Question 13

```
if False and (3 > 2 or 7 < 14 or (5 != 6)) :
    print "finished quickly"
```

## Expressions 2

The following questions are on expressions. For all questions write the generated output, or indicate an error. In addition write down every expression in a question and denote the type of the resulting value of the expression.

### Question 1

```
def function() :
    number = 2
    return number / 3

result = function() * 3
```

### Question 2

```
def world_upside_down() :
    numbers_upside_down = 2 > 3
    booleans_upside_down = True == False

    return numbers_upside_down and booleans_upside_down

if world_upside_down() :
    print "The world is upside down!"
else :
    print "The world is not upside down."
```

## Question 3

```
def awkward_number() :
    character = 'y'
    return 'z' - character


print "The result is awkward " + "result: \%s" %
            awkward_number()"
```

## Question 4

```
if 'a' < 'b' :
    print "smaller"
```

## Question 5

```
if 'a' > 'B' :
    print "hmmm"
```

## Question 6

```
number = '7'
print "%d" % number - 1
```

## If-statements

☞ Study your lecture notes on if-statements. Section 3.1 in the book will provide additional information on if-statements.

**Example** This example program will read an exam grade and prints whether this student has passed.

```
''' Assignment: MileInKilometer
    Created on 6 aug. 2012
    @author: Jan Stienstra '''


PASS_MINIMUM = 5.5

grade = float(raw_input("Enter a grade: ")

if grade >= PASS_MINIMUM :
    print "The grade, %0.2f, is a pass." % grade
else :
    print "The grade, %0.2f, is not a pass." % grade
```

This example can also be implemented using a ternary operator as described in the section Layout.

☞ Make the assignments **Electronics** and **Othello 2**.

## Assignments

### 1. VAT

☞ Before starting with this assignment, read the theory about **Efficient programming** en **Constants**.

Write a program that takes the price of an article including VAT and prints the price of the article without VAT. The VAT is currently 21.00%.

**Example** Using an input of 121 the output will be:[1]

```
Enter the price of an article including VAT: 121
This article will cost 100.00 euro without 21.00% VAT.
```

### 2. Plumber

The employees at plumbery 'The Maverick Monkey' are notorious bad mathmaticians. Therefore the boss has decided to use a computer program to calculate the cost of a repair. The cost of a repair can be calculated in the following way: the hourly wages multiplied by the number of billable hours plus the call-out cost. The number of billable hours is the number of hours worked rounded to the nearest integer. Plumbing laws fix the call-out cost at €16,00.

**Example** A plumber earning €31.50 an hour, working for 4.5 hours should get the following output.

```
Enter the hourly wages: 31.50
Enter the number of hours worked: 4.5
The total cost of this repair is: 173.50 euro
```

### 3. Othello 1

The goal of this assignment is to give some information about the outcome once a game has finished. This information is obtained by two measurements:

- The percentage of black pieces of all the pieces on the board.
- The percentage of the board covered in black pieces.

The Othello board measures eight squares by eight squares, making the total number of squares sixty-four.
Write a program that takes the number of white pieces followed by the number of black pieces as input. Print the two percentages as output.

**Example**

```
Enter the number of white pieces on the board: 34
Enter the number of black pieces on the board: 23
The percentage of black pieces on the board is: 35.94%
The percentage of black pieces of all the pieces on the board is: 40.35%
```

In case you have gotten interested in the game of Othello, you can find more information about it here. You will not need this information for this course.

[1]Examples will have input printed in italics.

## 4. Electronics

☞ Before starting this assignment, read the theory about **Identifiers** and **If-statements**.

The electrics company 'The Battered Battery' is nearly bankrupt. To avoid total disaster, the marketing branch has come up with a special sale to attract more customers. Whenever a customer buys three products, he or she receives a 15% discount on the most expensive product. Write a program that takes the prices of three products as input and prints the discount and final price as output. Remember that the goal of making the assignments in this chapter is to practice the use of if statements. Therefore, do not use the built-in function max in this assignment.

**Example** Determine the reduction and final price if the three products cost €200, €50 and €25 respectively.

```
Enter the price of the first article: 200
Enter the price of the second article: 50
Enter the price of the third article: 25
Discount: 30.00
Total: 245.00
```

## 5. Othello 2

During a game of Othello the time a player spends thinking about his moves is recorded. Write a program that takes the time that two players have thought, one human, one computer, in millisecond as input. The program determines which of the two players is human and prints the thinking time of the human in the following format: *hh*:*mm*:*ss*. It may be assumed that a computer always has less thinking time than a human.

**Example**

```
Enter the time the black player thought: 21363
Enter the time the white player thought: 36
The time the human player has spent thinking is: 00:00:21.
```

## 6. Manny

☞ The following four assignments use loops. Use the right loop for the right assignment; use both the for statement and the while statement twice.

Mobster Manny thinks he has found the perfect way to part money from their rightfull owners, using a computer program. Mobster Manny secretly installs the program on someone's computer and remains hidden in a corner, waiting for the program to finish. The program will ask the user how much he or she wants to donate to charity, thirsty toads in the Sahara (Manny's Wallet). If the unsuspecting victim wants to donate less than €50, the program will ask again. The program will continue to ask for an amount until the user has agreed to donate €50 or more, after which Mobster Manny will show up to collect the money.
Write this malicious program, but make sure it does not fall in the wrong hands.

**Example** An example of a correct execution of the program is shown below:

```
Enter the amount you want to donate:
0
Enter the amount you want to donate:
10
Enter the amount you want to donate:
52
Thank you very much for your contribution of 52.00 euro.
```

## 7. Alphabet

Write a program that prints the alphabet on a single line. Print every character seperated by a space. Do not use the ascii_lowercase constant, or other constants from the string module.

Hint: use the ord() and chr() functions. To make sure Python does not print a newline after each print statement use a comma at the end of the print statement.
You should get the following output:

```
a b c d e f g h i j k l m n o p q r s t u v w x y z
```

## 8. Collatz

One of the most renowned unsolved problem is known as the Collatz conjecture. The problem is stated as follows:

> Start out with a random number $n$.
>
> - if $n$ is even, the next number is $n/2$
> - is $n$ is odd, the next number is $3n + 1$.
>
> This next number is treated exactly as the first. This process is repeated. An example starting with 11: 11 34 17 52 26 13 40 20 10 5 16 8 4 2 1 4 2 1 4 2 1 . . .
> Once the sequence has reached 1, the values repeat indefinitely. The conjecture is that every sequence ends with 4 2 1 4 2 1 . . .

This conjecture is probably correct. Using computers all numbers up to $10 * 2^{58}$ have been found to end with this sequence. This problem might seem very simple, but no one has proved the conjecture since Collatz stated it in 1937. There have even been mathmaticians that have spent years of continued study on the conjecture, without success. Fortunately, writing a program that generates the Collatz sequence is a lot less challenging.
Write a program that takes any positive integer and prints the corresponding Collatz sequence. End the sequence when it reaches one.

**Hint** Use the % (modulo) operator to test whether a number is even or odd.

## 9. SecondSmallest

Take an unknown number of positive integers as input. Assume that the first number is always smaller than the second, all numbers are unique and the input consists of at least three integers. Print the second smallest integer.

### Example

```
10 12 2 5 15
The second smallest number is:5
```

Do not use the method sort(), min() or max().

# 3 Methods and functions

**Abstract**

The programs written in the previous module use if-statements and loops. Writing complicated programs with these statements will quickly result in confusing code. Introducing methods and functions to the code can solve this problem. This chapter will provide the neccesary knowledge on how to use these constructs, but more important on how introduce structure to code using these constructs.

## Goals

- Familiarize with methods, functions and parameters.
- Use methods and functions to structure programs.

## Instructions

- Read the theory about **Methods and functions**. With this knowlegde in mind, make the assignments **NuclearPowerPlant**, **Palindrome 1**, **Palindrome 2**, **Pyramid** and **Pizza**.
- Now make the graded assignment **Geography Grades 1**.

## Theory

### Methods and functions

The theory about how functions work, what they are used for and how to call them has been explained in the lectures. But as a small reminder: functions and methods are both "self-made commands", however functions are commands in your program and methods are commands in an object. Since objects are not covered in this course, you'll only be making functions. Even though you won't be making methods you will be using methods. For example from the String object you'll be using the method "split()".
A function call is just another statement. The execution of this statement is slightly more complicated than the execution of a normal Python statement; instead of executing a single statement, a whole function, possibly calling other functions, has to be executed. The great thing about using functions is that at the moment that a function is called, it does not matter how the function is executed. The only thing that matters is *what* the function does, and not *how* the function does this.
An example. A program that translates Dutch text into flawless English will most likely feature a piece of code like this:

```
for line in text:
    dutch_sentence = read_sentence(line)
    english_sentence = translate_sentence(dutch_sentence)
    write_sentence(english_sentence)

    # etc
```

It is very unlikely that someone will doubt the correct execution of this piece of code. Whilst writing a part of the program, it is assumed that the functions read_sentence(), translate_sentence() and write_sentence() exist. The way that these functions work, does not matter. Without knowing how these functions work, it cán be concluded that this piece of code is correct.
The function readSentence() is not that difficult to write. A sketch of this function:

```
def read_sentence(line):
    # Returns a Dutch sentence.

    sentence = ''
    for word in line:
        sentence += read_word(word) + " "

    return sentence
```

Functions are used to split the program into smaller parts, that have a clear and defined use. This can all be done without knowing how other functions do what they are supposed to do. When writing a part of the program, it is important not to be distracted by a detailed implementation somewhere else in the program. This also works the other way around. When writing a function, it is not important what it is used for in the piece of program that calls it. The only thing that matters, is that the function does exactly what it is supposed to do according to the function's name.
Small pieces of code can easily be understood and can be checked easily whether they do what they are supposed to do in the right way.

**Rule of Thumb**
A function consists of no more than 15 lines.

An elaborate example is provided below. Study the structured way of parsing the input. This technique will be extensively used in the GeographyGrades assignments.

**Example** The world-renowned Swiss astrologer Professor Hatzelklatzer has discovered a new, very rare disease. This disease will be known to the world as the Hatzelklatzer-syndrom. The disease is charactarized by seizures lasting for approximately one hour.
Professor Hatzelklatzer suspects that these seizures happen more often in odd months. He has asked his assistant to write a program that will test this hypothesis. Professor Hatzelklatzer has observed a group of test subjects. A file contains all the reported seizures. Each line indicates the date on which one of the test subjects suffered from a seizure. The input is structured in the following way:

```
12 01 2005
28 01 2005
etc...
```

The following example program will parse this input.

```
import sys

''' Assignment: Hatzelklatzer
    Created on 29 sep. 1997
    @author: Heinz Humpelstrumpf '''

STARTING_YEAR = 1950
FINAL_YEAR = 2050

def print_percentage_of_cases(percentage) :
    print "The percentage of illnesses that match " + \
            "the hypothesis is: %.2f" % percentage

# Reads a number from the input string. If the number is not
# in range the program will print an error message and
# terminates. Otherwise, the number is returned.
def read_in_range(input_string, start, end) :
    result = int(input_string)
    if result < start or result > end :
        print "ERROR: %d is not in range (%d, %d)" % \
                (result, start, end)
        sys.exit(1)

    return result


def odd_month(input_string) :
        date = input_string.split()

        # the day is read, but not saved
        read_in_range(date[0], 1, 31)

        # the month is read and saved in the variable "month"
        month = read_in_range(date[1], 1, 12)

        # the year is read, but not saved
        read_in_range(date[2], STARTING_YEAR, FINAL_YEAR)

        return month % 2 != 0


'''Start Program'''
total_number_of_seizures = 0
number_in_odd_months = 0

lines = open('input.txt').readlines()
for line in lines :
    if odd_month(line) :
        number_in_odd_months += 1

    total_number_of_seizures += 1

percentage = (float(number_in_odd_months) /
                total_number_of_seizures) * 100.0

print_percentage_of_cases(percentage)
```

☞ You should now have sufficient knowledge to make the assignments **NuclearPowerPlant**, **Palindrome 1**, **Palindrome 2**, **Pyramid** and **Pizza**.

## Parsing input

Using methods from the file and string modules, structured input can be read. Until now, all input was quite simple; a number was read by reading an entire line and converting it to an integer afterwards. Using the aforementioned methods much more sophisticated input can be read.

**Reading strings** As seen before, using the method readline() an entire line can be read. Using the method read() the entire input can be read. The input in the rest of this practical will mostly consist of multiple lines of the same input. Calling the method readlines() will read all lines on the standard input and return them as a list. This list can subsequently be iterated through with a for-statement.

Strings can be read from a file by using the open() function. This function takes as argument the path of the file that will be opened. For example, a file called example.txt can be opened by calling open('example.txt') if the file is in the same directory as where the code is ran from. In PyCharm this can be done by placing the input file in the same folder as the Python file.

**Reading from a string** When a string contains more than one word or number, it is often required to parse it further. This can be done using the split() method from the string module.

Using split() without an argument will split the string on any *whitespace* string. These include spaces, tabs and newlines. For example:

```
string = "a,b,c,d 2#4#6#8"
strings = string.split()

letters = strings[0]
```

```
numbers = strings[1]
```

**Reading using delimiters** Strings can not only be split on whitespace, but on any string. To do this, an argument has to be supplied to the split() method. Splitting the string "2#4#6#8" with split() would just return a list containing a single element, "2#4#6#8". To split this string into four separate strings, use split("#"). For example:

```
string = "2#4#6#8"
numbers = string.split("#")

# read all the numbers, and print the sum of all the numbers.
result = 0
for number in numbers :
    result += int(number)

print result
```

Hint: Split has an optional argument maxsplit which limits the amount of splits to this number. This is useful if one only wants to remove the first line of a file for example.

**Example** Input is often structured, this means that the input is made up of different parts, often themselves divided in separate parts. Such input can be read in a structured way by first reading the large parts and forwarding these parts to a different function that will read the sub-parts.

The example uses the following structured input:

```
Melissa White-Admiral Nelsonway;12;2345 AP;Seaty
Richard of Hughes-Green Lawn;1;2342 SS;Seaty
Godwyn Large-Calferstreet;101;2341 NG;Seaty
Petronella Diesel-The Mall;1102;2342 MW;Seaty
etc...
```

The input is read from a file called input.txt by calling open('input.txt').readlines() and is made up of an unknown number of students. Every line states the name and address of a single student. The name is separated from the address by a '-'. The address consists of a street, house number, postal code and city. The components are separated by a ';'.

One of the most important skills is to recognize such structures. Luckily this is not that hard. Study the example and the explanation provided below. The program will read the input defined above and print the addresses in format suitable for letters.

```
import sys


''' Assignment: Addresses
    Created on 6 aug. 2012
    @author: Jan Stienstra '''


def print_address(input_address) :
    address = input_address.split(";")

    street = address[0]
    house_number = int(address[1])
    postal_code = address[2]
    city = address[3]

    print "%s %d\n%s %s" %(street, house_number,
                   postal_code, city)

def print_student(student) :
    student_details = student.split("-")

    full_name = student_details[0]
    address = student_details[1]

    print_address(address)


'''Start Program'''
students = open('input.txt').readlines()

for student in students :
    print_student(student)
```

The program is very comprehensible, even without comments. The program has three functions, each reading a different aspect of the input:

- The start of the program splits the input into separate students:

  ```
  Melissa White-Admiral Nelsonway;12;2345 AP;Seaty
  Richard of Hughes-Green Lawn;1;2342 SS;Seaty
  Godwyn Large-Calferstreet;101;2341 NG;Seaty
  Petronella Diesel-The Mall;1102;2342 MW;Seaty
  ```
  *etc...*

- print_student(student) then reads the name and address separately and forwards the address to the printAddress function.

  ```
  Melissa White-Admiral Nelsonway;12;2345 AP;Seaty
  ```

- print_address(input_address) then reads every component, and prints them in a desired format:

  ```
  Admiral Nelsonway;12;2345AP;Seaty
  ```

## Assignments

### 1. NuclearPowerPlant

☞ Before starting this assignment, read the theory about **Methods and functions**.

The nuclear powerplant at Threeyedfish will automatically run a program to print a warning message when the reactor core becomes unstable. The warning message reads:

```
NUCLEAR CORE UNSTABLE!!!
Quarantine is in effect.
Surrounding hamlets will be evacuated.
Anti-radiationsuits and iodine pills are mandatory.
```

Since the message contains crucial information, it should be printed three times. To do this, write a function that prints this message. This function has to be used three times.

### 2. Palindrome 1

Write a program that will print the the following string:

```
    abcdefghijklmnopqrstuvwxyzyxwvutsrqponmlkjihgfedcba
```

It is not allowed to do this hardcoded.

Hint: This line consists of three parts:

- a to y
- z
- y to a

### 3. Palindrome 2

This assignment takes of where Palindrome 1 has finished. Make a copy of Palindrome 1 and edit the code so that the program will:

- read a letter from standard input
- print the string from Palindrome 1 up to this letter

For example, if the letter was c, the output would be:

```
    abcba
```

### 4. Pyramid

Write a program that prints a pyramid made of letters in the middle of the screen. Use functions with parameters for this assignment. The example shows the expected output, a pyramid of 15 levels. It can be assumed that the screen width is 80 characters.

**Example**

```
              a
             aba
            abcba
           abcdcba
          abcdedcba
         abcdefedbca
        abcdefgfedcba
       abcdefghgfedcba
      abcdefghihgfedcba
     abcdefghijihgfedcba
    abcdefghijkjihgfedcba
   abcdefghijklkjihgfedcba
  abcdefghijklmlkjihgfedcba
 abcdefghijklmnmlkjihgfedcba
abcdefghijklmnonmlkjihgfedcba
```

## 5. Pizza

Mario owns a pizzeria. Mario makes all of his pizzas from 10 different ingredients, using 3 ingredients on each pizza. Mario's cousin Luigi owns a pizzeria as well. Luigi makes all his pizzas from 9 ingredients, using 4 ingredients on each pizza. Mario and Luigi have made a bet: Mario believes that customers can order a larger selection of pizzas in his pizzeria than they can order in Luigi's pizzeria.
Write a program that calculates the number of pizzas Mario and Luigi can make. Use functions for this assignment. Make your own implementation of the factorial() function from the math module. The outcome should look like this:

```
Mario can make 120 pizzas.
Luigi can make 126 pizzas.
Luigi has won the bet.
```

**Hint** When choosing $k$ items from $n$ possible items, the number of possibilities can be obtained using the following formula:

$$\binom{n}{k} = \frac{n!}{k!(n-k)!}$$

## Graded assignment

### 6. Geography Grades 1

In the input file, grades are listed for the geography tests of group 2b. There have been three tests of which the grades will be included in the half-yearly report that is given to the students before the Christmas break.

On each line of the input you can find the name of the student, followed by one or more under scores ('_'). These are succeeded by the grades for the tests, for example:

```
Anne Adema____________6.5 5.5 4.5
Bea de Bruin__________6.7 7.2 7.7
Chris Cohen___________6.8 7.8 7.3
Dirk Dirksen__________1.0 5.0 7.7
```

The lowest grade possible is a 1, the highest a 10. If somebody missed a test, the grade in the list is a 1.

Your assignment is to make the report for the geography course of group 2b, which should look like this:

```
Report for group 2b
Anne Adema has an average grade of 5.5
Bea de Bruin has an average grade of 7.2
Chris Cohen has an average grade of 7.3
Dirk Dirksen has an average grade of 4.6
End of report
```

# 4 Parsing input

**Abstract**

A lot of programs depend on some sort of input. In previous chapters only simple input was used. This module will introduce the notion of *structured reading* of *structured input* to parse complex input and write structured programs.

## Goals

- Understand the notion of structured reading.
- Write well structured code that reflects the way the input is parsed.

## Theory

### Layout

A good layout is essential to make comprehensible programs. There are a lot of different layouts that will result in clear programs. There is no single best layout, but it is important to maintain the same layout throughout the whole program. Examples of a good layout can be found in all the examples in the book and in this instruction manual. A couple of rules of thumb:

> **Rule of Thumb**
> In for, while, if or elif statements, all code in the body is indented by four spaces, usually the width of one tab.

> **Rule of Thumb**
> Functions are separated by at least one blank line. The initialization of variables and assignments are also separated by a blank line. White lines can be added anywhere, if this increases clarity.

Novice programmers often lack enough space in their programs. If the code does reach the end of the page, by indenting twelve times, the code is probably too complicated. It will have to be simplified by introducing new methods and functions. The TAB key is useful for indenting pieces of code.
The layout of an if-statement is one of the most difficult statements to define. The layout is greatly influenced by the code following the statement. These examples show possible layouts:

```
if boolean expression:
    statement
```

```
if boolean expression:
    statement
else:
    statement
```

```
if boolean expression: short statement
```

```
if boolean expression: short statement
else : short else-statement
```

```
if boolean expression:
    a lot of statements
    ...
else: # opposite of the boolean expression
    statements
    ...
```

```
if boolean expression 1:
    statement 1
elif boolean expression 2:
    statement 2
elif boolean expression 3:
    statement 3
else: # explanation on the remaining cases
    statement 4
```

## The ternary operator

When a choice between two cases can be made based on a short expression, the following statement can be used:

```
value, if expression is true if expression else value, if expression is false
```

This way, the following piece of code:

```
if a < b :
    minimum = a
else :
    minimum = b
```

can be shortened to:

```
minimum = a if a < b else b
```

## Comments

"Comments make sure that a program is readable. Everyone knows this, a truism. In the past, when no one could program, someone would sometimes write a program without comments. This is considered by many to be old-fashioned, offensive even. Comments are the programmer's cure-all. When a comment is added to all cleverly thought over pieces of code, nothing can go wrong."

*Wrong!*

Comments are not meant to explain dodgy programs to a reader. A program that can be understood without comments, is better than a program that cannot be understood without comments. This ís ofcourse a truism. Comments may never replace clear programming.
Comments should not be written wherever possible, but on those occasions where they are neccesary. An example of unneccesary commenting:

```
# the sum of all values is assigned to result.
result = 0
for input in inputs :
    result += input
```

It can be assumed the reader can understand Python. A clear piece of code does not need additional explanation.
There are some cases in which it is advisable to add comments in the middle of a function (for example, the previous if-statements). But usually comments are placed at the top of the function. These comments are usually placed to explain a complex function, describing:

- what the function does
- (if neccessary) how it does this
- (if neccessary) how the function changes external values. If, for example, a global variable is changed within the function, it might be useful to write this in a comment.

A well written program contains a lot of functions without any comments. Usually, the name of a function will indicate precisely what will happen and the code will be readable. For example:

```
def print_row(row) :
```

does not require explanation telling the reader that a row is printed. However, the function

```
# Sorts the list using "rapidsort";
# see Instruction Manual.

def sort(row) :
```

does require this kind of explanation. The execution of a sorting algorithm is not trivial. This can be solved in two ways: explaining the algorithm within the program, or reference another document describing the precise execution of this piece of code. In the latter case, the code has to exactly match the description of course.

✎ **Rule of Thumb**

If the *name* of a function explains *what* it does and it is trivial *how* it does this, no comments are neccessary.
If one or both of the prerequisites are not met, a comment is needed.
There are very little or no comments within a function.

## Assignments

### 1. Geography Grades 2

☞ Before starting this assignment, read the theory about **Parsing input**.

Make a copy of your program for the problem Geography Grades 1 and change the code in such a way that your program no longer prints the average grade, but the final grade.

The final grade is calculated by rounding the average grade to the nearest multiple of a half. So, for example, a 7.2 becomes a 7.0 and 7.3 becomes a 7.5. If this calculation results in a 5.5, the final grade becomes a 6.0

Your assignment is to make the report for the geography course of group 2b, that, with the same example input as for the problem Geography Grades 1, should look like this:

```
Report for group 2b
Anne Adema has a final grade of 6.0
Bea de Bruin has a final grade of 7.0
Chris Cohen has a final grade of 7.5
Dirk Dirksen has a final grade of 4.5
End of report
```

### 2. Geography Grades 3

Make a copy of your program for the problem Geography Grades 2 and change the code in such a way that your program can process multiple groups.

These groups are on the input separated by '=\n'. Every group starts with a first line that contains the name of the group and the lines after contain the information about the students in the same way as is specified for the problem Geography Grades 1.

With the input

```
1b
Erik Eriksen__________4.3 4.9 6.7
Frans Franssen________5.8 6.9 8.0
=
2b
Anne Adema____________6.5 5.5 4.5
Bea de Bruin__________6.7 7.2 7.7
Chris Cohen___________6.8 7.8 7.3
Dirk Dirksen__________1.0 5.0 7.7
```

The output should be:

```
Report for group 1b
Erik Eriksen has a final grade of 6.0
Frans Franssen has a final grade of 7.0
End of report

Report for group 2b
Anne Adema has a final grade of 6.0
Bea de Bruin has a final grade of 7.0
Chris Cohen has a final grade of 7.5
Dirk Dirksen has a final grade of 4.5
End of report
```

## Graded assignment

### 3. Administration

For the end of year administration of Programming for History of Arts students you are to write a program that can do 2 things:

1. calculate a final grade
2. print a small graph of similarity scores and, if applicable, list the students under investigation

The input is structured as follows:

```
Piet van Gogh___5 6 7 4 5 6
5=20=22=10=2=0=0=1=0=1;Vincent Appel,Johannes Mondriaan
Karel van Rijn___7 8 6 6
2=30=15=8=4=3=2=0=0=0;
```

The first line should be interpreted as follows:

```
<Name of the student><one or more underscores><one or more grades separated by spaces>
```

You have to calculate the final grade of the student. All grades have the same weight. The final grade is rounded as follows:

- a grade that is >= 5.5 AND < 6 should be noted as a "6-"
- otherwise a grade will be rounded to the nearest half

The second line should be interpreted as follows:

```
<10 numbers separated by '='>;<zero or more names separated by ','>
```

The first 10 numbers are the similarity scores. These scores represent the number of programs matching a certain percentage of the current program in steps of 10%. This means the first numbers indicates the matches from 1%-10% and the last number indicates the matches from 91%-100%.

Since this is not very readable, the professor would like a simple graph according to these rules:

- if there are zero matches, display an underscore: _
- if there are less than 20 matches, display a minus sign: $-$
- if there are 20 or more matches, display a caret: $\wedge$

The names of the students after the semicolon are the names of the students with matches in the final 3 categories. The names of these students should be printed under the graph. If there are no matches, the program should print "No matches found".

The output for the aforementioned input should be:

```
Piet van Gogh has an average of 6-
        -^^--__-_-
        Vincent Appel
        Johannes Mondriaan
Karel van Rijn has an average of 7.0
        -^-----___
        No matches found
```

# 5 Modules, classes and lists

**Abstract**

Classes are used to encapsulate a number of relating methods and variables. In the previous chapters methods and functions were used to structure a program. Using classes, a program can be structured even further. For instance, it is possible to represent real-world objects using classes. This module shows how to use classes.

## Goals

- Using lists to save a (un)known number of values.
- Using more classes and modules and recognising when to use extra classes and/or modules.
- Recognizing the right class/module for the right method, variable or constant.

## Theory

### Modules and classes

A python source file is called a module. Modules can contain a program, methods, a class, or all of these. A class defines an object from the real world. Complex programs almost always require the use of two or more modules or classes. To decide whether a new module should contain a class consider the following:

1. Modules contain several logically connected methods do not become classes. An example of such a module is the math module. This module contains various methods used to perform mathematical operations. All resulting programs from the previous assignments also belong to this set of modules as well.

2. Classes are modules that define an object from the real world. An example of such a class is the class Person. This class could contain data like: name, address, date of birth, etc. In addition, this class could contain a function age(), which returns the age of this person by using the date of birth and the current date. Another example of such a class is Circle, This class contains a center and a radius. Methods that are logically connected to these class are for example surface_area() and circumference().

In the first four modules, only modules of the first category were required. Assignment from this module onwards will also use classes. An example will show how to make and use such a class. It is good practice to use separate files for different classes.

**Example** This example will feature a program used by airline 'FlyLo' to calculate the profit of a flight to London. The airline uses four different fares:

1. Toddlers, aged 0 to 4 years old are charged 10% of the regular fare.

2. Children, aged 5 to 12 years old are charged half the regular fare.

3. Adults are charged the regular fare.

4. Elderly peoply, aged 65 years or more pay an extra 10% on top of the regular fare, as they have more money anyway.

The regular fare for a single ticket to London is €99. A Boeing 747, the largest plane in the airline's fleet, will accomodate 400 passengers.
The airline wants to know what consequences a change in the maximum age of a toddler may have. The airline wants to know what the new profit of a flight will be, and if there is an increase or decrease in the profit.

The program uses a two-line input. The first line contains all the passenger's ages. The second line contains the new maximum toddler age. The program will print the two profits and the difference between the two. It is useful to save all the ages in a row. This way, the row can simply be 'asked' how many passengers will fit each category. This data will allow the program to calculate the total profit. A row, such as the one proposed above is a good example of a class. The class holds data, the ages of all the passengers and the number of passengers. Apart from the constructor, the class has a method to add an age to the row and a method to calculate how many passengers fit into a certain category.

This row can be implemented using a list. The method add() will add a new age to the back of the row. The function number_in_range(from, to) calculates the number of passengers that fit this range. The methods read_age_row() and calculate_total_profit() are self-explanatory.

```
class AgeRow (object):

    def __init__(self) :
        self.age_row = []

    def add(self, age) :
        self.age_row.append(age)

    def number_in_range(self, start, end) :
        # Calculates how many passengers are in the range
        # bounded by start and end

        result = 0

        for age in self.age_row :
            if start <= age and age <= end :
                result += 1

        return result
```

```
import sys
from age_row import AgeRow

''' Assignment: Airplane
    Created on 6 aug. 2012
    @author: Jan Stienstra '''

MAX_TODDLER_AGE = 4 # year
MAX_CHILD_AGE = 12 # year
MAX_ADULT_AGE = 64 # year
MAX_AGE = 135 # year

ADULT_FARE = 99.0 # euro
TODDLER_FARE = ADULT_FARE * 0.1 # euro
CHILD_FARE = ADULT_FARE * 0.5 # euro
ELDERLY_FARE = ADULT_FARE * 1.1 # euro


def read_in_range(input_string, start, end) :
    result = int(input_string)

    if result < start or result > end :
        print "ERROR: %d is not in range (%d, %d)" % (result, start, end)
        sys.exit(1)

    return result


def read_age(input_string) :
    return read_in_range(input_string, 0, MAX_AGE)

def read_age_row(passengers) :
    result = AgeRow()

    for passenger in passengers :
        age = int(passenger)
        result.add(age)

    return result

def calculate_profit(start, end, fare, ageRow) :
    return ageRow.number_in_range(start, end) * fare

def calculate_total_profit(max_toddler_age, age_row) :
    toddler_profit = calculate_profit(0, max_toddler_age, TODDLER_FARE, \
                     age_row)

    children_profit = calculate_profit(max_toddler_age + 1, \
                      MAX_CHILD_AGE, CHILD_FARE, age_row)

    adult_profit = calculate_profit(MAX_CHILD_AGE + 1, \
                   MAX_ADULT_AGE, ADULT_FARE, age_row)

    elderly_profit = calculate_profit(MAX_ADULT_AGE + 1, \
                     MAX_AGE, ELDERLY_FARE, age_row)

    return toddler_profit + children_profit + \
           adult_profit + elderly_profit

def print_change_in_profit(old_profit, new_profit) :
    print "When using the new age limits for " + \
            "toddlers and children \n the profit" + \
            "changes from EUR %8.2f to EUR %.2f." % \
            (old_profit, new_profit)
    print "The difference is EUR %8.2f." % \
            (new_profit - old_profit)


'''Start Program'''

file = open('input.txt')
passengers = file.readline().split()
ages = file.readline()

age_row = read_age_row(passengers)
new_max_toddler_age = read_age(ages)

normalProfit = calculate_total_profit(MAX_TODDLER_AGE, age_row)
newProfit = calculate_total_profit(new_max_toddler_age, age_row)

print_change_in_profit(normal_profit, new_profit)
```

## Assignments

### 1. Weave 1

The goal of this exercise is to weave two series of numbers into a single series. The input consists of two lines of exactly ten numbers, which need to be woven into one. To weave the two series into one, consecutively take one number from the first series, followed by a number from the second series. Do not use a class yet.

The example below illustrates the desired behaviour.

```
1 2 3 4 5 6 7 8 9 10
10 9 8 7 6 5 4 3 2 1
1 10 2 9 3 8 4 7 5 6 6 5 7 4 8 3 9 2 10 1
```

### 2. Weave 2

In this exercise, the weaving process is programmed into a NumberRow class. For this exercise create a class NumberRow which at least includes a method weave(number_row), which weaves one NumberRow with another. The problem to solve is extended to include a third series of numbers. The goal of this exercise is to weave the first and second series into a single series and consecutively weave a third series through the resulting series.

The example below illustrates the desired behaviour.

```
1 2 3 4 5 6 7 8 9 10
10 9 8 7 6 5 4 3 2 1
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
1 1 10 2 2 3 9 4 3 5 8 6 4 7 7 8 5 9 6 10 6 11 5 12 7 13 4 14 8 15 3 16 9 17 2 18 10 19 1 20
```

### 3. BodyMassIndex

Professor Hatzelklatzer has researched the extremely rare Hatzelklatzer-sydrome. There appear to be less cases of the sydrome in odd months than in even months. Further research should reveal if the syndrome affects people more often if they are too heavy.

A way of determining whether someone is too heavy is the *body-mass index* (BMI). This is a measure of a person's weight taking into account their height. The BMI is defined as $weight/length^2$. The World Health Organization (WHO) considers a BMI between 18,5 and 25 as ideal and considers people with such a BMI healthy.

The program receives input consisting of two persons with their name, sex, length and weight.

```
Dean Johnson M 1.78 83
Sophia Miller V 1.69 60
```

Process this input into structured data. To achieve this, use an useful class with useful methods to enhance the structure of the program. Use this structured data to print for each person: an appropriate style of address, surname, the BMI and a statement whether this is considered healthy or not.

**Example**

```
Mr. Johnson's BMI is 26.2 and is unhealthy.
Mrs. Miller's BMI is 21.0 and is healthy.
```

## 4. BodyMassIndex2

Professor Hatzelklatzer has realized that although the program written in the BodyMassIndex assignment provides some usefull information on the effects of the BMI on the Hatzelklatzer syndrome, its output is quite difficult to process. To make the output easier to understand, the program should be adapted to analyze a group of test subjects.
The program should read the input, determine the average BMI and count the number of cases of the Hatzelklatzer syndrome amongst people with a lower than average BMI and amongst people with a higher than average BMI. To this end, Professor Hatzelklatzer has provided you with the information of his diagnoses of all the test subjects.

The input of the program now looks like this:

```
Dean Johnson M 1.78 83 Yes
Sophia Miller V 1.69 60 No
...
```

Just as in the previous BMI excercise, the input consists of people with their name, sex, length and weight. In addition, the word `"Yes"` has been added if the person suffers from the Hatzelklatzer syndrome, whilst `"No"` is added if the person did not suffer from the Hatzelklatzer syndrome. Instead of only two people, the input now consists of an unknown number of people, who all need to be analyzed. The input file can be found on Canvas.

The output should look like this:

```
The average BMI of the test subjects is x.
There are y cases of the syndrome amongst people with a BMI >= x.
There are z cases of the syndrome amongst people with a BMI < x.
```

## Graded assignment

### 5. Pirate

During his completely miserable life, pirate Abraham Blaufelt has been in search of the lost treasure of Atlantis. On a very fortunate day in the year of the Lord 1642 he enters an abandoned cathedral of a long gone sect in the ancient forests of Poland. Inside he finds a mysterious ancient parchment. The parchment reads:

> *Traveler, if riches are to be achieved,*
> *the solution only has to be weaved.*
>
> *5,4 4,5 8,7*
> *Weave 6,3 3,2 9,6 4,3*
> *Weave 7,6*
> *Weave 9,8*
> *Weave 5,5 7,8 6,5 6,4*

Abraham Blaufelt immediately knew what he was dealing with. A puzzle of which the result is a safe route to the treasure. This route was essential, the sea was crawling with monsters in those days. Since this most fortunate day, almost four hundred years ago, the European tectonic plate has shifted significantly. As a result all coordinates have to be shifted by $(1, 0)$.

Write a program that solves this puzzle. This has to be done in the following way: Start with the coordinates on the first row, weave the coordinates of the second row through the first row, then weave the coordinates of the third row through the resulting row etc. Note, if two rows of unequal length have to be woven, the two rows are woven as far as possible. After the elements of the shortest row have been exhausted, the row is completed by adding the remaining elements of the longest row.
Make a new Coordinate and CoordinateRow class for this assignment. The latter class has a method to weave a CoordinateRow into itself.
The coordinates of the puzzle are in a file on Canvas. Every CoordinateRow is seperated from another by an `'='`. Every coordinate in a row is seperated by a space. The $x$ and $y$ values of a coordinate are seperated by a comma.
After all data has been read, the program will print the treasure route on the standard output. The correct route can also be found on Canvas.

# 6 Events and animations

**Abstract**

This chapter introduces events and animations. These notions are essential for programming interactive programs. The graded assignment of this module will involve programming the game *Snake*. A game such as *Snake* is quite complex and therefore requires a careful approach. Using *stepwise refinement* one begins with a rough sketch of a program, which is developed with increasing detail. Before starting with programming the graded assignment it is compulsary to make such a sketch of the program, which has to be approved before being allowed to continue.

## Goals

- Familiarize with events.
- Use events to program an animated program.
- Use events to program an interactive program.
- Use *stepwise refinement* to create complex programs.

## Theory

### Importing the IPy library

Some assignments in the remainder of this manual require the IPy library. The IPy library is a collection of classes and methods that enables the use of a graphical interface instead of the console as input and output. Such a collection of classes, providing additional features, is called a library.
To use this library in PyCharm, download the IPy library from Canvas, then move the downloaded file to the root folder of your workspace.
Import-statements can now enable the use of specific elements of the UI-library. For example, if the program requires the SnakeUserInterface from the ipy_lib, add the following line to the top of the program:

```
from ipy_lib import SnakeUserInterface
```

For **MAC-users**:
The library is now compatible with MAC. To make sure everything works accordingly, make sure to add the following bit of code to the end**(!)** of your code:

```
#example
#import interface
from ipy_lib import SnakeUserInterface

#create GUI object
ui = SnakeUserInterface (10, 10, 0.75)
#keep window open after code finishes
ui.stay_open()
```

The *ui.stay_open()* line is especially important, since this keeps the window from closing when it is done running the program

**Selecting input using the IPy library** Using the ipy_lib library, PyCharm can use files as input instead of the *standard input*, the keyboard. To select a file as input, add the following statement before any other statement relating to the input:

```
file_input()
```

When a program is executed that includes the above mentioned statement, the program will open a browser to select the input file. Browse to the location of the file and press Enter. The entire contents of the file will be returned in a string.
For more information on the possibilities of the IPy library, visit https://phoenix.labs.vu.nl/doc/python/.

**Using the IPy library on laptops** Using the IPy library on a laptop with a small screen resolution may cause a part of the user interface to disappear off screen. To prevent this, supply an additional third argument to the constructor:

```
ui = SnakeUserInterface(width, height, scale)
```

for example:

```
WIDTH = 40
HEIGHT = 40
SCALE = 0.5

ui = SnakeUserInterface(WIDTH, HEIGHT, SCALE)
```

## Events

This assignment will introduce a Graphical User Interface (GUI). To make a program interact with the user, this course uses *events*. An event is for example a mouse-click, a keystroke or even the fact that it is 2 o'clock.
Using the following functions from the GUI will allow the program to work with events.

```
get_event()
```

Calling this function will make the program halt and wait for an event to arise. After an event has risen, the function returns an Event-object containing information on the event. The Event class looks like this:

```
class Event:
    def __init__(self, name, data):
        self.name = name
        self.data = data
```

Pressing the letter 'a' will generate an Event-object containing the name `"letter"` and the data `"a"`. Clicking field 4,3 will return an Event-object containing the name `"click"` and the data `"4 3"`.

An interactive program, a program that reacts to input generated by the user, works as follows:

1. wait for an event to arise
2. process event
3. repeat.

In Python this can be implemented like this:

```
while True : # infinite loop
    event = ui.get_event()
    process_event(event)
```

The method process_event needs to determine what has happened, and what should happen as a result. Such a method, that calls different methods according to a specific condition is called a *dispatch*-method.

```
def process_event(event) :
    if event.name == "click" :
        process_click(event.data)
    elif event1 :
        process_event1(event.data)
    elif (event2) :
        process_event2(event.data)
    else :
        ....
```

☞ Make the assignment **Events**.

## Animations

The way events have been used so far, only allows the program to react to input given by the user. It is not possible for the program to change anything on the screen on it's own account. An animated program has to be able to do something without requiring input from the user.
Computer games like snake are called interactive animations. In these programs, the user can influence an animation. To regulate the speed of an animation, the SnakeUserInterface contains the following method:

```
set_animation_speed(frames_per_second)
```

When this method is called with, for example 24.0 frames per second, the program will generate 24 events per second. These event all have the name `"alarm"` and data `"refresh"`. The program can now be made to react to these events by refreshing the screen. This way, both events generated by the user as well as an animation can be processed using events.

☞ Make the assignment **Animation**.

## Stepwise refinement

An important part of writing structured programs is *stepwise refinement*. This can be defined roughly in the following way:

- Write down exactly what the program should do, in English or in another natural language.
- Next, step by step elaborate on the description of the program. Again, write in a natural language, or, when it is trivial, directly in Python.
- This process is repeated until the whole program is written in Python.

When the algorithm is correctly executed, the result will be a flawless structured program.

**Example** Write a program that reads a date in the format: day month year, seperated by spaces. The program prints whether the date is correct. This program will be made using stepwise refinement. Important to note is that all programs are a version of precisely the same assignment. The only difference is the amount of English replaced by Python.

### Program 1

```
''' Assignment: DateCheck
    Created on 6 aug. 2012
    @author: Jan Stienstra '''


'''Start Program'''
    # read the date
    # check the date
    # print output
```

### Program 2

```
import sys


''' Assignment: DateCheck
    Created on 6 aug. 2012
    @author: Jan Stienstra '''

def is_correct(day, month, year) :
    # return true if date is correct,
    # return false otherwise

def read_in_range(input_string, start, end) :
    # read an integer and return this int if
    # it is between start and end. Print
    # an error message otherwise and
    # terminate.


'''Start Program'''
date = open('input.txt').readline().split()

day = read_in_range(date[0], 1, DAYS_IN_MONTH);
month = read_in_range(date[1], 1, MONTHS_IN_YEAR);
year = read_in_range(date[2], 0, YEAR_LIMIT);

if is_correct(day, month, year) :
    print "The date is correct."
else :
    print "The date is not correct."
```

### Program 3

```
import sys


''' Assignment: DateCheck
    Created on 6 aug. 2012
    @author: Jan Stienstra '''

DAYS_IN_MONTH = 31
MONTHS_IN_YEAR = 12
YEAR_LIMIT  = 2500

NUMBER_OF_DAYS_IN_A_MONTH = [
        # list of thirteen values, for each month
        # the maximum number of days, and a random
        # value at index 0
    ]

def is_leap_year(year) :
    # return true if the year is a leap year
    # return false, otherwise

def is_correct(day, month, year) :
    if day == 29 and month == 2 :
        return is_leap_year(year);
    else :
        return day <= NUMBER_OF_DAYS_IN_A_MONTH[month]

def read_in_range(input_string, start, end) :
    result = int(input_string)

    if result < start or result > end :
        print "ERROR: %d is not in range (%d, %d)" % (result, start, end)
        sys.exit(1)

    return result


'''Start Program'''
date = open('input.txt').readline().split()

day = read_in_range(date[0], 1, DAYS_IN_MONTH);
month = read_in_range(date[1], 1, MONTHS_IN_YEAR);
year = read_in_range(date[2], 0, YEAR_LIMIT);

if is_correct(day, month, year) :
    print "The date is correct."
else :
    print "The date is not correct."
```

## Program 4

```
import sys


''' Assignment: DateCheck
    Created on 6 aug. 2012
    @author: Jan Stienstra '''

DAYS_IN_MONTH = 31
MONTHS_IN_YEAR = 12
YEAR_LIMIT  = 2500

NUMBER_OF_DAYS_IN_A_MONTH = [0, 31, 29, 31, 30, 31, 30, 31, 31, 30, 31, 30, 31]

def is_leap_year(year) :
    return year % 400 == 0 or \
        (year % 4 == 0 and year % 100 != 0)

def is_correct(day, month, year) :
    if day == 29 and month == 2 :
        return is_leap_year(year);
    else :
        return day <= NUMBER_OF_DAYS_IN_A_MONTH[month]

def read_in_range(input_string, start, end) :
    result = int(input_string)

    if result < start or result > end :
        print "ERROR: %d is not in range (%d, %d)" % (result, start, end)
        sys.exit(1)

    return result


'''Start Program'''
date = open('input.txt').readline().split()

day = read_in_range(date[0], 1, DAYS_IN_MONTH);
month = read_in_range(date[1], 1, MONTHS_IN_YEAR);
year = read_in_range(date[2], 0, YEAR_LIMIT);
```

```
if is_correct(day, month, year) :
    print "The date is correct."
else :
    print "The date is not correct."
```

## Assignments

### 1. Events

☞ Before starting this assignment, read the theory about **Events**.

Write a program using a SnakeUserInterface of $40 \times 30$ which has the following features:

- Clicking on a square results in a piece of wall to be placed on that square.
- Pressing the space bar erases all the walls.
- The program prints the name and data of all events that occur.

### 2. Animation

☞ Before starting this assignment, read the theory about **Animations**

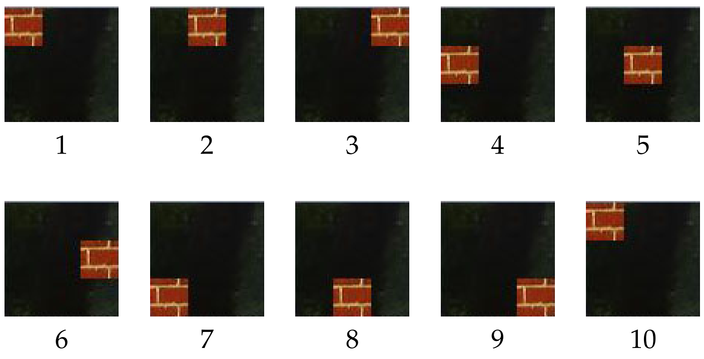
The goal of this assignment is to make an animated program in which a piece of wall moves across the screen. The piece of wall starts out on (0,0) and moves right a square at a time. Upon reaching the end of a row, the piece of wall will move to the first square of the next row. When the piece off wall reaches the end of the last row, it is transferred back to the initial (0,0) position.

On top of this make sure the program implements the following features:

- The animation should slow down 0.5 frames per second when $\leftarrow$ (left arrow) is pressed.
- The animation should speed up 0.5 frames per second when $\rightarrow$ (right arrow) is pressed.
- The piece of wall should change into a green sphere (a part of a snake) when g is pressed. Pressing g again will revert the change.

Use the SnakeUserInterface for this assignment.

#### Example



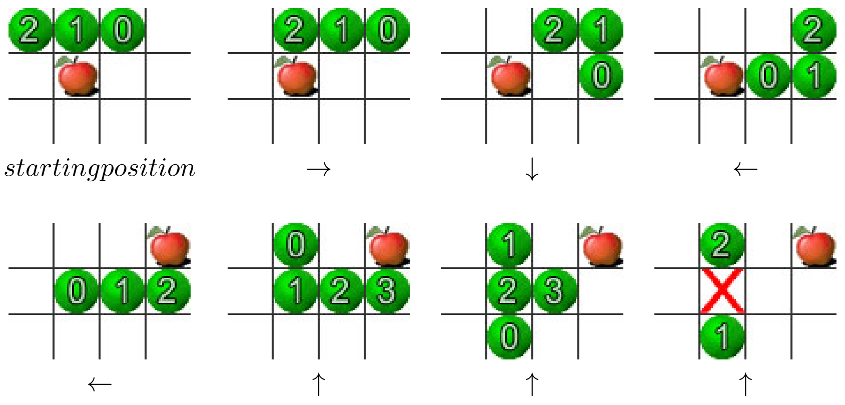
## Graded assignment

### 3. Snake

☞ Before starting this assignment, read the theory about **Stepwise refinement**. In addition, before starting with programming, a draft of the program **has** to be approved.

A logical step forward from interactive animated programs is games. The goal of this assignment is to program the classic computer game, *Snake*.
The goal of Snake is to create a snake as long as possible. This is achieved by guiding the snake to apples, lying about on the field. The snake cannot stop moving, and dies whenever it hits something. Because the snake is growing longer and longer as the game progresses, it is increasingly difficult to avoid collisions with the snake itself.
At the start of the game, the snake consists of two pieces at the coordinates (0,0) and (1,0). As said before, the snake is always moving. At the start of the game, it moves to the right. When the user presses one of the arrow keys, the snake changes direction.
At every moment in the game, there is always an apple somewhere in the field. If the snake hits an apple, the snake becomes one piece longer in the next screen refresh. A new apple is placed on a random location, excluding all places covered by the snake.
When the snake reaches the end of the screen, it will re-emerge at the other end.

**Example** The example below shows a short game of snake, played on a 4x3 field. The game to be designed in this assignment will have a field measuring 32x24. The arrow indicates in which direction the snake is traveling. The numbers on the snake indicate its position in the row.



This assignment uses the SnakeUserInterface.

**Bonus** Edit the program in such a way that it accept a level as input. A level defines a number of walls, which the player has to avoid. Levels can be found on Canvas. The structure of these files is as follows: first the coordinates at which the snake is initialized are given followed by an =. Next, the initial direction of the snake is given, again followed by an =. Finally, all the coordinates at which to place walls are given.

Coordinates are formatted in the following way: one coordinate per line, in the format: $x$<space>$y$. The initial direction is one of four strings: `"L"` (Left), `"R"` (Right), `"U"` (Up) of `"D"` (Down).
An example of a piece of such a file:

```
1 0
0 0=R=3 3
4 3
5 3
6 3
7 3
8 3
etc...
```

# 7 Bonus

**Abstract**

This chapter contains the bonus assignment. Students who complete the bonus assignment will be given half a point on top of their final grade.

☛ **Warning**

As this is a bonus assignment, there is no time reserved for this assignment during the lab sessions. This assignment is solely meant for those students who have finished all other assignments. Students are only allowed to start on this assignments if all other assignments have been submitted.

## Graded assignment

### 1. Life

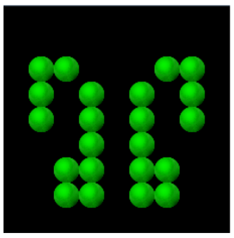
The Game of Life was invented by J.H. Conway. Two publication in the "Scientific American" by Martin Gardner saw the game introduced to the public. Life is played on a board of n x n squares, representing a population of dead and living cells. A living cell can either die or continue to live, based on a set of rules. A dead cell can either become alive again, or remain dead. Every cell has eigth neighbours, except the cells on the edge of the board:

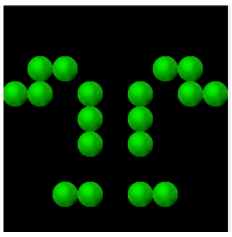
| | | |
|---|---|---|
| 1 | 2 | 3 |
| 4 | * | 5 |
| 6 | 7 | 8 |

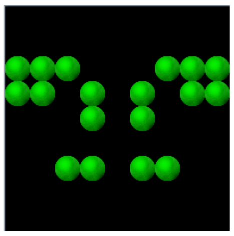
The set of rules determining the fate of a cell:

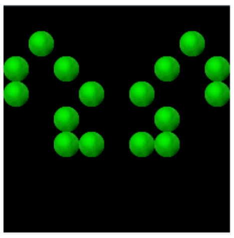
1. X is currently dead: If X has exactly three living neighbours, X becomes alive again. In all other cases, X remains dead.
2. X is currenly alive: If X has zero or one neighbour(s), X dies of loneliness. If X has two or three living neighbours, X remains alive. In all other cases X dies of a shortage of living space.

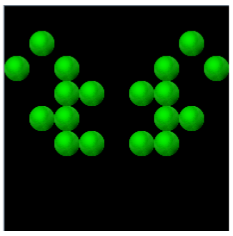
An example using a 9 x 9 board:

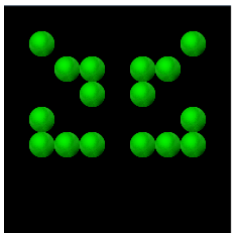

1

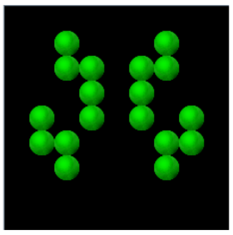

2

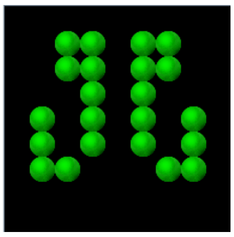

3

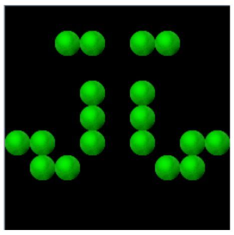

4

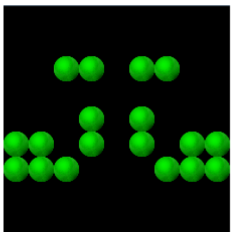

5

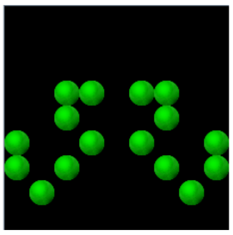

6

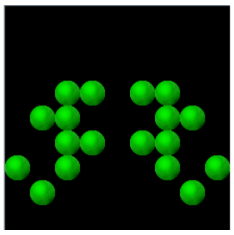

7

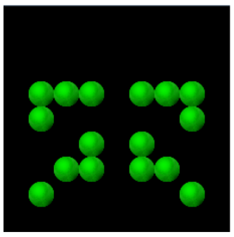

8

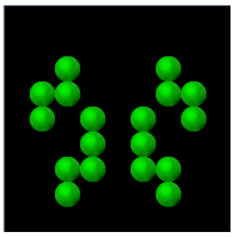

9


10


11


12


13


14

It is possible for a figure to die (an empty board) or become an oscillator, i.e. generation n = generation n + p, for any n above a certain value. If the period equals 1 (p=1), it is called a still figure.
Write a program that takes a starting configuration from a file and generates generations as long as the figure has not died, become an oscillator with a certain p, or exceeds the maximum number of generations. When the program terminates, print a message stating why the program has terminated and if the figure has become an oscillator, its period. If the period of the oscillator is 1, the message should read "Still figure" instead of "Oscillator". The input files on Canvas have the following structure:

- On the first line, the maximum number of generations, ranging from 1 to 100.
- On the second line, the largest period for which the figure should be tested to oscillate, ranging from 2 to 15.
- After this, a starting configuration for a 9 x 9 board, made up from 9 line of 9 characters. A living cell is represented by an 'x', a dead cell is represented by ' '

This assignment uses the LifeUserInterface.