# Basics of Computer Programming & Software Engineering.

ENGF0002: Design and Professional Skills

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Term 1, 2018

## Introduction

## Introducing Basics.

In the ‘Basics’ topic we will:

- Introduce basic Python **language** concepts.
- Illustrate **algorithms**, to perform numerical computations.
- Expose you to the problems of **correctness**, and **testing**.
- Introduce **good practices** when programming.

## What is Computer Science & Software Engineering?

Computer Science:

- Studies the nature of **information, computation, complexity** of algorithms, and their **correctness**.
- Deep mathematical foundations, including logic, algebra and probability theory.

Software Engineering:

- Studies how teams can repeatably **build high quality, correct, usable and efficient software**, to meet **people's needs**.
- Programming is a foundational and important part of it.

The two are interlinked, and we will study them together.

## Programming & languages (I).

Programming & Programmability:

- A device is programmable if it allows a programmer (developer, engineer) to **alter its behavior**. This is the act of programming.
- We usually think of a device as programmable, when the **program itself takes the form or information**, rather than physical modification.
- A computer is the **ultimate programmable device**, and can execute all computations. Simpler ones include video recording devices, microwave ovens, and alarm clocks.
- **Programming is specializing** a device to solve **a problem that people have**.

## Programming & languages (II).

Programming Languages:

- The **information describing the program** (code), is expressed in a programming language.
- **Trivial** programming languages: button pressed to program an alarm clock. They are very **low-level ways**, and lead to errors and inflexibility.
- Full computers are programmed in **higher-level formal languages**. Programmers may express their intent directly, build complex abstractions, and compose programs from smaller fragments.
- Programming languages are formal languages but also **human languages**. Programmers, use them to **express and communicate their intent**.

## Why Python?

- **Real-world**, widely used programming language (4th in 2018 TIOBE ranking.)
- **Multi-paradigm**: scripting, procedural, functional elements, object oriented, generics.
- Extensive **eco-system** of tools and libraries. Great documentation.
- Significant **industrial uses**.
- **High-productivity**, and perfect for rapid prototyping.

A **weakness** we will turn to a strenth:

- It does not force you to adopt **good programming practices**.
- It **supports them**, but you must learn them!

## Other languages you might want to learn.

**Different problems** may require **different tools**:

- Lower-level: Rust∗, C++, **C** — COMP0002.
- Static typing: Go∗, **Java**, C# — COMP0004.
- Web: Javascript∗.
- Functional: **Haskell**, Scala∗ — COMP0002.

∗ - trendy languages at the moment

All programming languages mix and match a few principles.
Good computer scientists **know those principles**,
and can **work in any language**.

## Using Python interactively.

- Python 3.7.
  (https://www.python.org/about/gettingstarted/)
- Open a command line console, and run the Python interpreter.
- Type your fist command:

  ```
  print("Hello World!")
  ```
- You should see it executing!

  ```
  mjh$ python3
  Python 3.7.0 (default, Jun 28 2018, 05:55:06)
  [Clang 9.1.0 (clang-902.0.39.2)] on darwin
  Type "help", "copyright", "credits" or "license" for more information
  >>> print("Hello World!")
  Hello World!
  >>>
  ```

## Key resources and tools.

The interactive interpreter is only good for quick experimentation.

- **Code editor**: atom (hip!), Sublime (hip!), Visual Studio Code. Must haves: Good syntax highlighting, good handling of files & folders, whitespace, looks very cool.
- **Browser** with Python **Documentation**: `https://docs.python.org/3/`. (including Python **tutorial** and **Library reference**.)
- **Command line** & learn how to use it. `https://www.lynda.com/Linux-tutorials/Learn-Linux-Command-Line-Basics/435539-2.html`
- **Stack Overflow** for Q&A. `https://stackoverflow.com/`
- **Install pytest**. `https://docs.pytest.org/`

## Your physical & mental well being.

- Approach the physical activity of programming with **professionalism**.
- Think of the **ergonomics** of your physical environment: chair height, desk, posture, keyboard style, monitor type and positioning.
- Make sure you **enjoy your working environment**: light, sounds, distractions.
- **Take breaks**, at least every hour.

## The ‘Hello World!’ program in Python.

Programs live in files. A simple Python program:

```
# File: hello_world.py

def hello_world():
    print("Hello World!")

# run if called as `python hello_world.py'
if __name__ == "__main__": # Python idiom
    hello_world()          # `Call' the function `hello_world'
```

Execute your first program, by running:

```
$ python3 hello_world.py
Hello World!
```

## Comments

Comments are not executed by Python, but form part of your program.

- Comments **communicate intent** to your future self and others.
- Express in comments concepts you cannot directly express in code.
- Prefer to express concepts directly in code.
- Keep comments local to the relevant code.
- Do not overcomment; avoid duplicate, redundant or wrong comments.
- Every comment will have to be maintained in the future.

## Whitespace.

Python is **sensitive to indentation** using whitespace. Use 3 or 4 spaces (not a tab) to indent blocks of code. More about this later . . . .

```python
# File: hello_world.py

def hello_world():
    print("Hello World!")

# run if called as `python hello_world.py'
if __name__ == "__main__": # Python idiom
    hello_world()          # `Call' the function `hello_world'
```

## How do we know a program does what it should?

**Correctness is the most important problem** in software engineering and computer science!

**Testing is the key technique** to produce high quality, correct programs. It is an activity that is continuous, and performed in parallel with programming.

Complimentary techniques for ensuring program correctness include **formal verification**. Those are more expensive, but necessary to reason about very complex problems.

Finally, formal periodic **code reviews**, or continuous reflection through **pair programming** also improve quality.

## Test Code Continuously.

**Testing** is the most important technique to gain confidence a program does what it should:

- Unit Test every 2-5 lines of code you write. Think how to **test every snippet of code** just before, while, or just after you write it.
- Use a mature **tool for testing** your programs. We will use `pytest`. `https://docs.pytest.org/`.
- **Different testing techniques** for code correctness, integration, security, performance and user experience.
- Shortcomings of testing: **lack of completeness**.

## Testing the ‘Hello World!’ program.

**Tests are snippets of code** executing parts of your program.
Eg. the test of the simple Python program is:

```python
# File: test_hello_world.py
from hello_world import hello_world

def test_hello_world(capsys):
    hello_world()
    out, _ = capsys.readouterr()
    assert out == "Hello World!\n"
```

We run the **test suite**, by executing `pytest test_hello_world.py` on the command line.

## Code documentation and its tests.

**Code documentation** is not executed, but forms part of the program. It is useful to your future self, or others that want to use part of your program. Hence, **document reusable units of code**.

```python
# File: hello_world_doc.py

def hello_world():
    """ Print a welcoming message to stdout.

        >>> hello_world()
        Hello World!
    """
    print("Hello World!")
```

You must **test code in documentation**.

`pytest -vs -doctest-modules test_hello_world.py`.

## Example of a successful test run.

Executing `pytest` runs all tests in functions named `test_*` and documentation strings.

```
$ pytest -vs --doctest-modules src/*hello*.py
=================================== test session starts ==============================
platform darwin -- Python 3.7.0, pytest-3.7.4, py-1.6.0, pluggy-0.7.1 -- /opt/loca
cachedir: .pytest_cache
rootdir: /Users/mjh/teaching/engf0002/Design_and_Professional_Skills/Topics/01_Bas
collected 2 items

src/hello_world_doc.py::hello_world_doc.hello_world PASSED
src/test_hello_world.py::test_hello_world PASSED

================================= 2 passed in 0.02 seconds ========================
```

## Summary and next steps.

The rhythm-of-the-programming-business:

- **Think** of the problem → **Code** feature (2-5 lines) → **Write test** for feature → Run **all** tests → Fix until **all tests pass** → Think . . .
- Working programmers **run tests a few times per minute**.
- Testing practice imposes an **incremental approach** to software building.
- Professional standards: aspire to deliver programs with **zero bugs**. Remember that **'bugs' may cost millions or even kill**.

Still to cover: functions and function calls (`def`, `()`), modules (`from`, `import`) and a lot more python . . .

## Algorithms

## What is an ‘algorithm’?

An algorithm describes a sequence of steps leading to the solution of a computational problem.

You are familiar with a number of algorithms from maths:

- How to perform long multiplication and division with a pencil and paper.
- How to find the roots of a quadratic equation $ax^2 + bx + c = 0$.
- How to expand brackets for $(a + b)(c + d) = ?$

**Beyond maths . . .**

Once we express wider parts of the world as information, algorithms can solve more exciting tasks: eg. rendering a 3D scene in a computer game, encrypt communications, build interactive social networks on-line, and program cars to drive autonomously.

## Lifts

### Problem Statement

A building has a lift.
Inside the lift are buttons to choose floors.
Outside the lift are buttons to call the lift.
**How should the lift choose which floor to go to next?**

## Lifts

**Algorithm 1**

Go to the nearest floor that is selected.

**Algorithm 1**

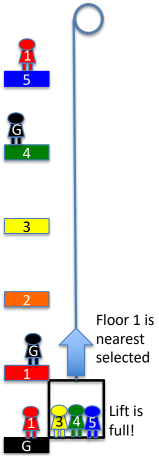
Go to the nearest floor that is selected.

**Bug report**

- Under certain workloads, people in the lift starve to death before they reach the destination floor.

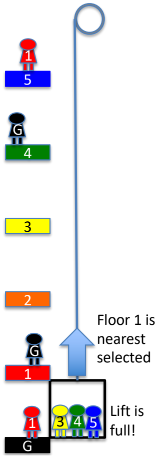
## Algorithm 1

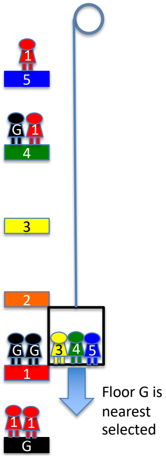
Go to the nearest floor that is selected.



# Algorithm 1

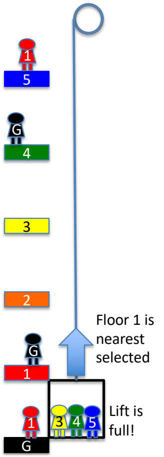
Go to the nearest floor that is selected.

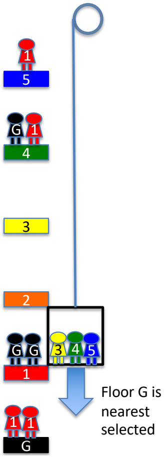


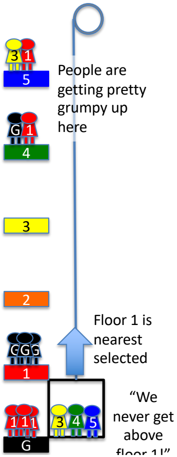


# Algorithm 1

## Go to the nearest floor that is selected.






3 1
5
People are getting pretty grumpy up here
G 1
4
3
2
G G G
1
1 1 1
3 4 5
G
Floor 1 is nearest selected
"We never get above floor 1!"

**Algorithm 1**

Go to the nearest floor that is selected.

**Bug report**

- Under certain workloads, people in the lift starve to death before they reach the destination floor.

**Diagnosis**

Need to prioritse going to the floor selected by people in the lift.

## Lifts

### Algorithm 2

- Go to the nearest floor selected by people in the lift.
- If no floor selected in the lift, go to nearest floor where someone has pressed a call button.

## Algorithm 2

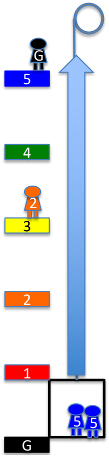
- Go to the nearest floor selected by people in the lift.
- If no floor selected in the lift, go to nearest floor where someone has pressed a call button.

## Bug report

- Under certain workloads, people waiting for the lift starve to death because the lift always goes past their floor.

## Algorithm 2

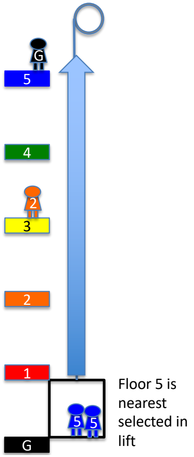
- Go to the nearest floor selected by people in the lift.
- If no floor selected in the lift, go to nearest floor where someone has pressed a call button.

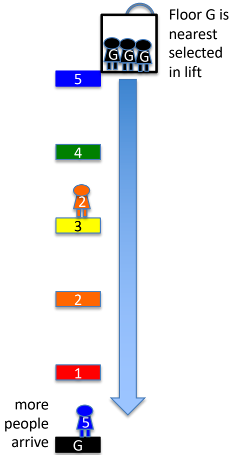


Floor 5 is nearest selected in lift

## Algorithm 2

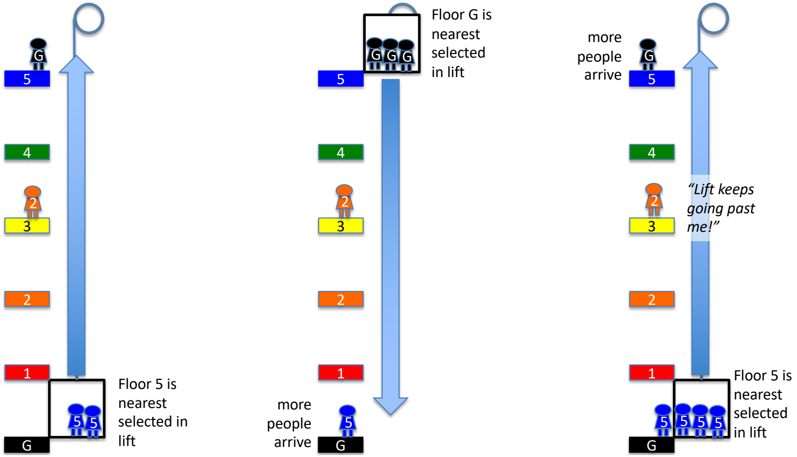
- Go to the nearest floor selected by people in the lift.
- If no floor selected in the lift, go to nearest floor where someone has pressed a call button.





## Algorithm 2

- Go to the nearest floor selected by people in the lift.
- If no floor selected in the lift, go to nearest floor where someone has pressed a call button.


5
4
3
2
1
G
Floor 5 is nearest selected in lift
Floor G is nearest selected in lift
more people arrive
more people arrive
"Lift keeps going past me!"
Floor 5 is nearest selected in lift

## Algorithm 2

- Go to the nearest floor selected by people in the lift.
- If no floor selected in the lift, go to nearest floor where someone has pressed a call button.

## Bug report

- Under certain workloads, people in the lift starve to death before they reach the destination floor.

## Diagnosis

Should not skip a floor where someone wants to go in the direction the lift is going.

## Algorithm 3

- Go to the next floor selected by people in the lift, but don't go past a floor where someone wants to go in the same direction the lift is going.
- If no floor is selected, go to the nearest floor where someone has pressed a button.

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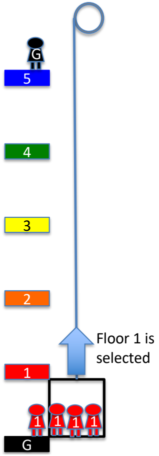
- Go to the next floor selected by people in the lift, but don't go past a floor where someone wants to go in the same direction the lift is going.
- If no floor is selected, go to the nearest floor where someone has pressed a button.

## Bug report

- Under certain workloads, people in the lift starve to death before they reach the destination floor.

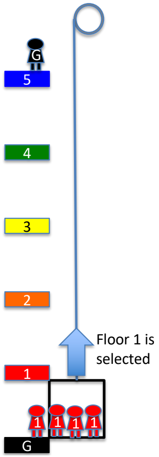
## Algorithm 3

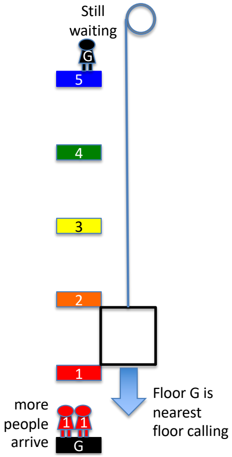
- Go to the next floor selected by people in the lift, but don’t go past a floor where someone wants to go in the same direction the lift is going.
- If no floor is selected, go to the nearest floor where someone has pressed a button.



## Algorithm 3

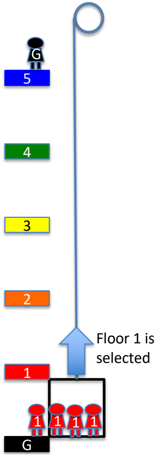
- Go to the next floor selected by people in the lift, but don’t go past a floor where someone wants to go in the same direction the lift is going.
- If no floor is selected, go to the nearest floor where someone has pressed a button.

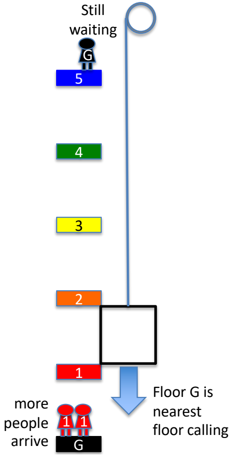


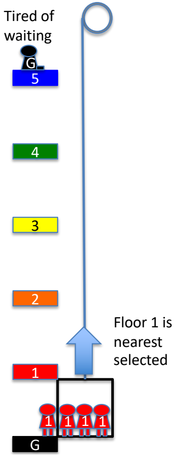


# Algorithm 3

- Go to the next floor selected by people in the lift, but don't go past a floor where someone wants to go in the same direction the lift is going.
- If no floor is selected, go to the nearest floor where someone has pressed a button.







## Algorithm 3

- Go to the next floor selected by people in the lift, but don’t go past a floor where someone wants to go in the same direction the lift is going.
- If no floor is selected, go to the nearest floor where someone has pressed a button.

## Bug report

- Under certain workloads, people in the lift starve to death before they reach the destination floor.

## Diagnosis

Lift should not turn round if it’s heading towards people who are waiting.

## Algorithm 4

- Go in one direction, stopping at floors where:
  - people outside want to go in that direction, or
  - where people in the lift want to go in that direction.
- Change direction only when there are no more selected floors or call buttons pressed in that direction.

## Algorithm 4

- Go in one direction, stopping at floors where:
  - people outside want to go in that direction, or
  - where people in the lift want to go in that direction.
- Change direction only when there are no more selected floors or call buttons pressed in that direction.

## Bug reports

- — NO BUG REPORTS FILED —

## Challenge 1

- What should the lift do if no call button is pressed?

## Challenge 2

- Extend the algorithm so it works efficiently to control two lifts.