COMP1730/COMP6730
Programming for Scientists

Functional abstraction
with robot example

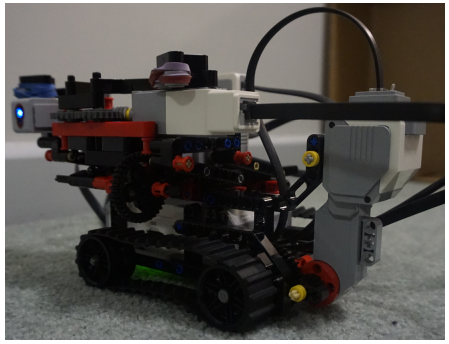
Some announcements

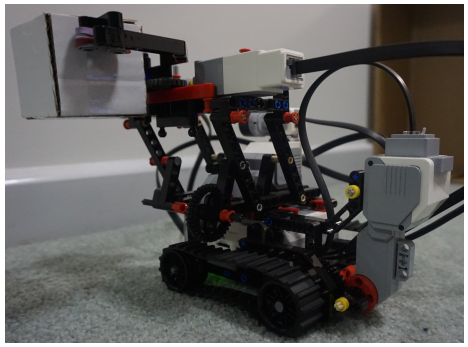
* Lectures will be livestream on echo360! (perhaps some delay)
* Using AI such as ChatGPT, Copilot is OK for everything **except assignments and exam**.
* Doing lab exercises is very important in this course, even more than lectures! **You are strongly encouraged to participate in labs from next week**
* Recommended text books:
  - Think Python. Allan Downey, *O'Reilly, 2015*
  - A Primer on Scientific Programming with Python, Hans Petter Langtangen, *Springer, 2017*

Lecture outline

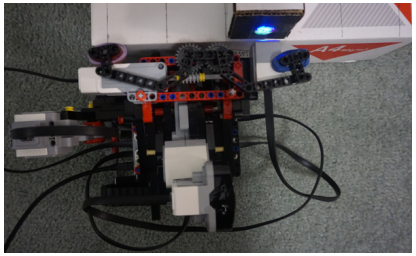
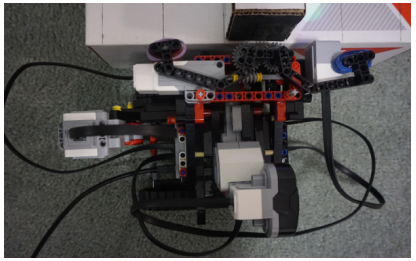
* **The warehouse robot**
* Importing modules
* Functional abstraction
* The python language: First steps

The robot

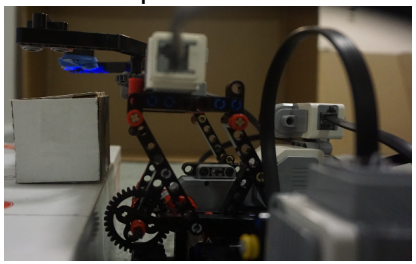
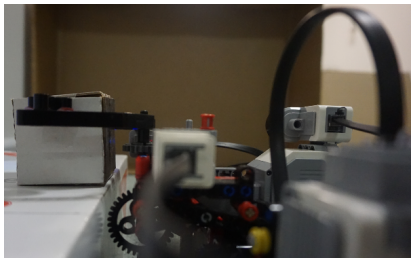




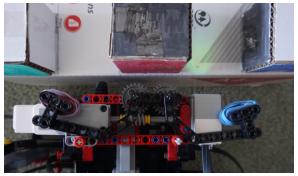
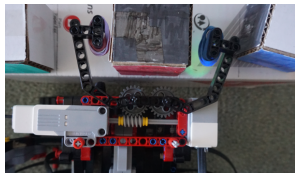
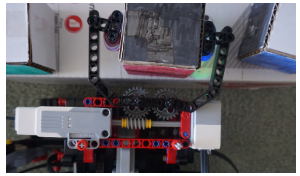
* Drive left/right along the shelf:


↔


* Move lift up/down:


↔


* Change position of the gripper:

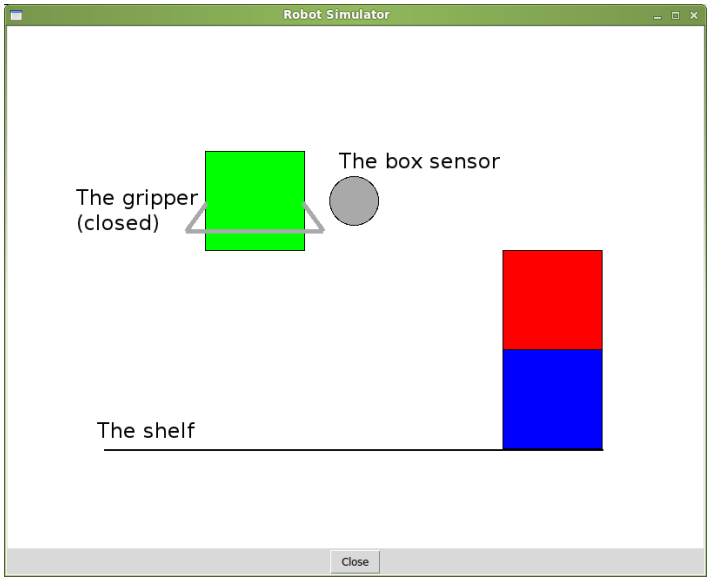




folded open closed

* Moving sideways or down, the gripper may hit boxes if it is not folded.
* Folding/unfolding the gripper may hit boxes in adjacent stacks.

Australian National University

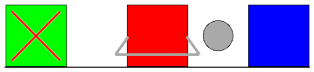
The robot simulator




```
# import a module, a file robot.py must be in the same folder
import robot

# start a new simulation
robot.init()

# start a new simulation with larger area:
robot.init(width = 11, height = 6)

# start a new simulation with random boxes:
robot.init(width = 11, height = 6, boxes = "random")

# Drive right/left one step:
robot.drive_right()
robot.drive_left()
```

```
# Move the lift up one step:
robot.lift_up()

# Move the lift down one step:
robot.lift_down()

# Change the gripper position:
robot.gripper_to_open()
robot.gripper_to_closed()
robot.gripper_to_folded()
```

* If the robot hits a box, no command works until a new simulation is started.



Australian National University

Programming problem

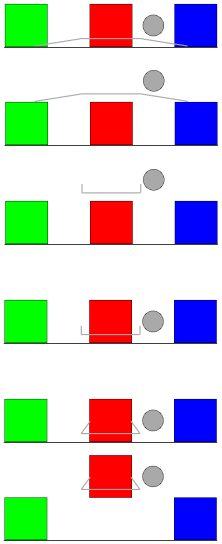
* How to pick up a box without hitting the box(es) next to it?

Australian National University

* How to pick up a box without hitting the box(es) next to it?

```
robot.lift_up()
robot.gripper_to_open()
robot.lift_down()
robot.gripper_to_closed()
robot.lift_up()
```

* A *program* is a sequence of instructions.



Australian National University

Lecture outline

* The warehouse robot
* **Importing modules**
* Functional abstraction
* The python language: First steps

Libraries, modules, namespaces

- *Library* is a generic term for a collection of (useful) functions, data structures, etc.
- In python, libraries are called *modules*.
- *Importing* a module,

```
import math   # math is a built-in module
import robot  # robot is our own self-written module
```

makes its content available to use.

- Imported names are prefixed with the module name, as in `math.pi`, `robot.lift_up`, etc.
  - They are placed in a separate *namespace* (more about namespaces later in the course).
- How does python find modules?
  - Standard modules (e.g., `math`) are installed in a specific location on the file system.
  - Non-standard modules (e.g., `robot`) must be in the *current working directory* (cwd).

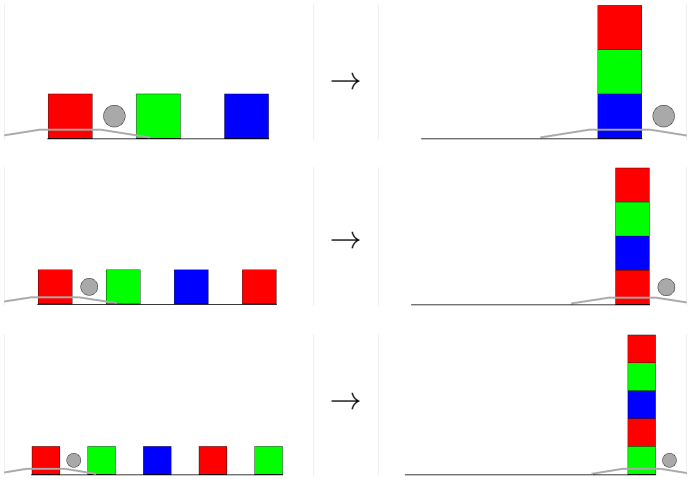
Australian National University

Lecture outline

- The warehouse robot
- Importing modules
- **Functional abstraction**
- The python language: First steps

Australian National University

Problem: Building a tower



```
robot.init(width = 7, boxes = "flat")
robot.drive_right()
robot.lift_up()
robot.gripper_to_open()
robot.lift_down()
robot.gripper_to_closed()
robot.lift_up()
robot.drive_right()
robot.drive_right()
robot.gripper_to_open()
robot.lift_down()
robot.gripper_to_closed()
robot.lift_up()
robot.drive_right()
robot.drive_right()
robot.gripper_to_open()
robot.lift_down()
...
```

Australian National University

Functional abstraction

* In programming, a *function* (also known as “procedure” or “subroutine”) is a piece of the program that is given a name.
  - The function is *called* by its name.
  - A function is defined once, but can be called any number of times.

Australian National University

* Why use functions?
  - **Abstraction**: To use a function, we only need to know *what* it does, *not how*.
  - Break a complex problem into smaller parts.

“*Engineering succeeds and fails because of the black box*”
Kuprenas & Frederick, “101 Things I Learned in Engineering School”

Australian National University

Function definition in python

```
def move_to_next_stack():
    robot.drive_right()
    robot.drive_right()
```

* `def` is a python keyword (“reserved word”).
* The *function’s name* is followed by a pair of parentheses and a colon.
  - Inside the parentheses are the function’s parameters (more on this in coming lectures).
* The *function suite* is the sequence of statements that will be executed when the function is called.

Function definition in python

```
def grasp_box_on_shelf():
    robot.lift_up()
    robot.gripper_to_open()
    robot.lift_down()
    robot.gripper_to_closed()
    robot.lift_up()
```

* In python, a suite is delimited by *indentation*.
  - All statements in the suite **must be preceded by the same number of spaces/tabs** (standard is 4 spaces).

Australian National University

Function definition in python

```
def release_and_pickup_next():
    robot.gripper_to_open()
    robot.lift_down()
    robot.gripper_to_closed()
    robot.lift_up()
```

* The `def` statement only *defines* the function – it does not execute the suite.
* The whole definition is itself a statement.

Australian National University

Building a tower of 5 boxes

```
robot.init(width = 9, boxes = "flat")
robot.drive_right()
grasp_box_on_shelf()
move_to_next_stack()
release_and_pickup_next()
move_to_next_stack()
release_and_pickup_next()
move_to_next_stack()
release_and_pickup_next()
move_to_next_stack()
robot.gripper_to_folded()
robot.lift_down()
```

Australian National University

Lecture outline

* The warehouse robot
* Importing modules
* Functional abstraction
* **The python language: First steps**

Syntax

* The *syntax* of a (programming) language is the rules that define what is a valid program.
* A python program is a sequence of *statements*:
  - defining a function:
```
def move_twice():
    robot.drive_right()
    robot.drive_right()
```
  - calling a function:
```
move_twice()
robot.lift_up()
```
  - importing a module: `import robot`
  - ...and a few more.

Australian National University

Whitespace

* Spaces, tabs and end-of-line are known as *whitespace*.
* The whitespace before a statement is called *indentation*.
* In python, whitespace has two special roles:
  - end-of-line marks the end of a statement (some exceptions, more later in the course);
  - indentation defines the extent of a *suite* of statements.
* Other than this, whitespace is ignored.

Australian National University

Permitted names in python

* A function name in python may contain letters, numbers and underscores (_), but must begin with a letter or undescore.

Allowed	Not allowed
`moverighttwice`	`move right twice`
`move_right_2`	`2_steps_right`
`is_box_red`	`is_box_red?`
`imPort`	`import`

* Reserved words cannot be used as names.
* Names are *case sensitive*: upper and lower case letters are not the same.

Australian National University

Comments

* A hash sign (#) marks the beginning of a *comment*; it continues to end-of-line.

```
robot.init(width = 7) # use a wider shelf
# grasp the first box:
robot.lift_up()
...
```

* Comments are ignored by the interpreter.
  - Comments are for *people*.
  - Use comments to state what is not obvious.
* *If it was hard to write, it's probably hard to read. Add a comment.*

* Write comments to describe *what* a function does, and *when* it should be expected to work.

```
# Pick up a box from the shelf, without
# hitting adjacent boxes.
# Assumptions: The robot (gripper) is in
# front of the box; the gripper is folded
# and the lift is down.
def grasp box on shelf():
    ...
```

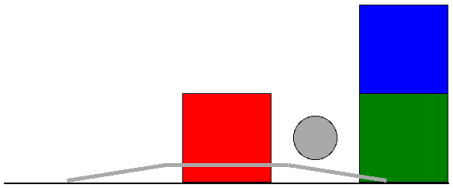
Australian National University

Testing and debugging

Australian National University

Test, test, test

* How do we know our program works?
  - Specify the assumptions under which the program (or function) is meant to work.
  - Test it with a variety of cases that fall under those assumptions.
  - Particularly, “edge cases”.



Australian National University

Errors

```
Traceback (most recent call last):
  File "stack-3-v1.py", line 35, in <module>
    robot.lift_up()
  File "/.../robot.py", line 40, in lift_up
    _robot.lift_up()
  File "/.../robot.py", line 600, in lift_up
    + " and can't go any higher!")
robot.RobotError: Robot Error: The lift is at
level 1 and can't go any higher!
```

* Errors will happen.
* Read the error message!

* Some common errors:
  - `SyntaxError`:
    You have broken the rules of python syntax.
  - `NameError` or `AttributeError`:
    You have used a (function) name that doesn't exist. Check for typos.
  - `IndentationError`:
    Too much or too little indentation.
    - All statements in a function suite must have the same indentation.
    - All statements outside function definitions must have no indentation.