NANYANG TECHNOLOGICAL UNIVERSITY
SINGAPORE

Laboratory Manual
for
CE/CZ1003
Introduction to Computational Thinking

Practical Exercise #5:
Data Abstraction
(Data Structure)

SCHOOL OF COMPUTER SCIENCE AND ENGINEERING
NANYANG TECHNOLOGICAL UNIVERSITY

Ex. #5 – Data Abstraction

Learning Objectives

The manual provides information and practical exercises to let you learn how data abstraction can be used in program to support and simplify the implementation of an algorithm.

Intended Learning Outcomes

At the end of this exercise, you should be able to

- make use of appropriate data structure to improve the sructure of a program.
- apply various concepts learnt in earlier topics (conditional selection, looping) and various functions to develop more complex programs.

Equipment and accessories required

i) Raspberry Pi 3 Model B (RPi3) board with Sense HAT add-on display module/board.
ii) A USB power source to power the RPi3 board (E.g. Power Bank, Adaptor or USB port of a desktop computer).
iii) A computer (desktop PC or notebook) with Ethernet port and cable for remote access of RPi3. Software (open source) to be installed on the computer – PuTTY, VNC Viewer and WinSCP

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1. Data Structure

A data structure is an organization of data in such a way to allow more efficient manipulation of the data by a program. For instance, you have been using integer and string in your programming exercises, which are basic (known as primitive in Python) data structure that contain single value of a data, consisting of a sequence of numbers and characters respectively. With data arranged in certain structure, you can then apply various operations to these data structure; such as arithmetic operations for integers and string manipulation (e.g. isdigit() function).

In this exercise, you will learn how to use two data structures that store a collection of values (instead of single value) to simplify your program organization. They are **Tuple** and **List** (which are known as non-primitive data structure in Python).

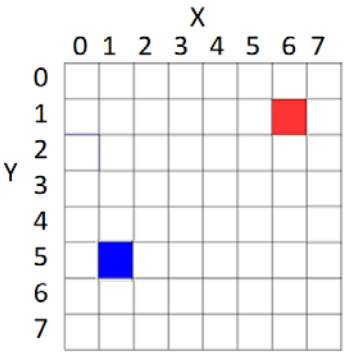
For example, you can use (and had been using) Tuple data structure (which is immutable) to specify the R-G-B element of various colours in terms of numbers when displaying message on the Sense Hat module, such as the following:

```
red = (255,0,0)
yellow = (255,255,0)
```

You can further combine it with the List data structure (which is mutable) to display image on the Sense Hat display, which you will learn in this exercise.

2. Pixel display on Sense Hat board

The Sense Hat board's display is organized using an 8x8 LED matrix, where each LED can be used as one pixel of an image and addressed by using the x-y coordinate system. The numbering of both axes begins at 0 in the top left-hand corner as shown here. The red pixel is hence at coordinate (6, 1), while the blue pixel is at coordinate (?, ?). You can then set the colour of the individual pixel by using the **`set_pixel()`** function as follows:




```
set_pixel(6, 1, red)
```

Coding Exercise 5a

- Code a program that makes use of the appropriate Tuple data structure to light up the LED on the four corners of the Sense Hat display with four different colours.
- Change your program such that it displays the 4 colours at random positions on the Sense Hat display.
  The following functions will be useful to implement these features:
  a) The **`sleep()`** function, which can be imported through the **`time`** module. For example **`sleep(1)`** will provide a 1 second delay in your program.
  b) The **`randint()`** function, which can be imported through the **`random`** module. For example **`randint(1,10)`** will produce a random integer with value between 1 and 10 (inclusive).
  c) The clear() function from the Sense Hat module.

3. Image display on Sense Hat board

To display an image, you can set multiple pixels individually using multiple (64) **`set_pixel()`** function calls, but this will obviously be very tedious to code, and prone to error. Instead, you can use the **List** data structure to construct an image, and then display the whole image using one function call. A List data structure consists of multiple elements, and is defined by using the square brackets [e1, e2,…]. (Compare this with Tuple which uses parentheses, i.e. the round bracket (e1, e2, ..)).

The following code snippet shows how you can use the List data structure, whose elements in turn consists of Tuples, to define an image and has it displayed on the Sense Hat board by calling the **`sense.set_pixels()`** function.

```
y = (255, 255, 0)
b = (0, 0, 0)
image_pixels =[b, b, b, b, b, b, b, b,
               b, b, b, y, b, b, b, b,
               b, b, y, y, y, b, b, b,
               b, y, b, y, b, y, b, b,
               b, b, b, y, b, b, b, b,
               b, b, b, b, y, b, b, b,
               b, b, b, y, b, b, b, b,
               b, b, b, b, b, b, b, g]

set_pixels(image_pixel)
```

Coding Exercise 5b

- Code a program that includes the above code, run it and observe the image that is coded in the List based data structure.
- Optional - Change the image to something to your liking
- Modify your program such that the image will automatically switch between two colours (e.g. yellow and green colour) at 1 second interval.
- Modify your program such that the image will also rotate in 4 random orientations with the image displayed in alternate colours (keep this program for exercise 5d later)

Coding Exercise 5c(Optional)

- Modify your program such that the image can switch between random colours.

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Coding Exercise 5d(Optional)

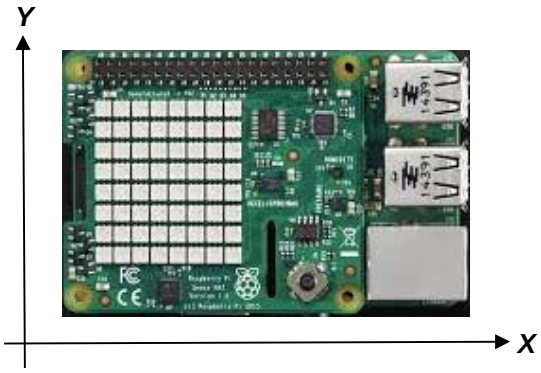
The Sense HAT display board contains 3 sensors integrated in the form of an IMU (Inertial Measurement Unit) chip:

- A gyroscope
- An accelerometer
- A magnetometer

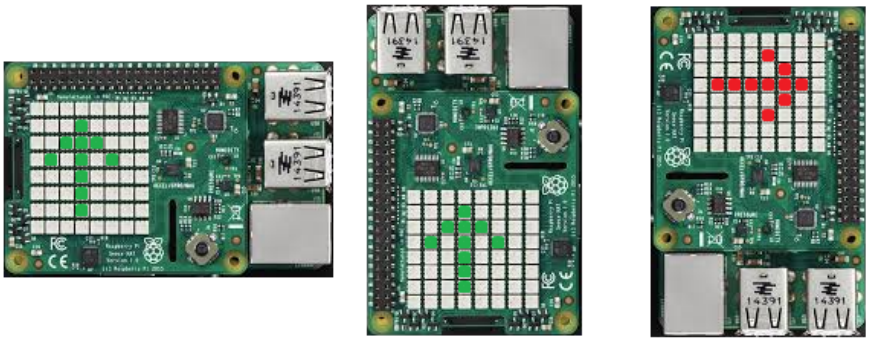
With the accelerometer, you can use the **`sense.get_accelerometer_raw()`** method to detect the amount of G-force acting on each axis (*x,y,z*) of the board.

```
acceleration = sense.get_accelerometer_raw()
x = acceleration['x']
y = acceleration['y']
z = acceleration['z']
```

By holding the RPi board vertically as shown below, you can detect the board's ***X-Y*** rotation orientation (and hence switches between 'portrait' and 'landscape' modes as on a mobile phone when watching video).



- Using the program you developed in exercise 5b that randomly orients the image you created in any one of the four orientations, this exercise is to develop the code to also detect the orientation of the board, and check whether it corresponds to the orientation of the image after it is randomly changed. The idea is to create a game that requires you to rotate the board within 1 second such that the randomly oriented image (in green colour) is always pointing in the 'UP' direction, which otherwise the image will change to red colour and the game is terminated.



Tips: You may want to round the **x** and **y** values obtained through the accelerometer to a single digit number for easier detection of the orientation of the board.

- Reduce the 1-second time allowance progressively until you 'lose' the game. Show the number of successful trials on the board when the game is terminated.