PyPiGame: Using the Raspberry Pi and games to teach programming
Project Proposal

Martin D Flanagan
University of Cape Town
Rondebosch, Cape Town, South Africa
FLNMAR011@myuct.ac.za

ABSTRACT

Programming in computer science can be challenging for the new students. Students tend to struggle because they usually need to learn the syntax and the various concepts of a programming language. In a traditional coding assignment, a student is only working with text as input and output. This project aims to help students who are taking an introductory course to programming by creating assignments which are game-based to help students to understand the programming concepts while learning a programming language like Python. The students will be able to visually see how the code written affects an environment, be it 2D or 3D. All the programming assignments will be done on a computer with a Raspberry PI and the Sense HAT as inputs.

It also aims to find out whether using a single board computer with a add-on board with a 5-button joystick to act as the input for the games engages the students more in their work and whether using a game-based approach on the assignments would be useful as an alternative to standard programming assignments (which are mainly text based, with little to no graphical visualisation of the code).

CCS CONCEPTS

• **Applied computing** → **Interactive learning environments**; • **Hardware** → **Sensor devices and platforms**; **Sensor applications and deployments**.

KEYWORDS

Computer Science, Education, Games, Raspberry Pi, Programming, Python, 2D programming

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1 PROJECT DESCRIPTION

An introductory course to computer science intends to educate the students about various programming concepts along with teaching students a programming language. Analysing the literature shows that programming is challenging to learn [2, 3, 9] and high failure rates are common [6] because of this and that students can become demotivated.

The approaches which were used to keep the students engaged in the work and eager to learn more was the inclusion of single-board computers into the assignments [7, 10, 11] and by creating the assignments in the form of a game [1, 3, 8]. Using a single-board computer helped the students to gain a more 'hands on' approach and to keep the interest of students in the course itself [10, 11]. The programmable electronic devices which were used were the Arduino board [10] and the Raspberry Pi [11]. Similarly, by the inclusion of games in the assignments, the students were also found to be more engaged in the course and liked the assignments as it was fun to complete [3, 8, 11].

The Raspberry Pi (RPi) is a "low-cost, credit card sized computer" [5] that is just as powerful as a normal computer and the Sense HAT is an add-on board for the RPi which has an 8x8 LED matrix, a 5-button joystick and a few sensors [4].

The aim of this project is to combine these two methods, by having the students connect their laptop/workstation to the RPi, complete the code for the project on the RPi and test it out by running the assignment (which is effectively playing the game), using the Sense HAT as the input for the game. To do this the assignments will need to be coded in such a way that it would be easy enough for the students to complete, yet testing their knowledge about a certain aspect of programming in each assignment.

The RPi and Sense HAT were chosen over the Arduino board because the RPi is a mini computer and comes pre-installed with Python on it and the Sense HAT functions library (a code library containing all the various functions for the Sense HAT) is written in Python.

This research is necessary as it will assist in understanding whether changing the format of the programming assignments and including the use of the RPi will aid the students to better understand programming concepts and whether they might be motivated with this kind of approach. It will also help lecturers to assess whether setting up these types of assignments are worth the effort and resources needed to do so. It also aims to produce some programming assignments which can be used in conjunction with the curriculum which is currently being taught.

2 PROBLEM STATEMENTS

Both games and programmable computing devices have become common in the world today and through their use we can create innovative solutions to current problems. This research aims to understand whether using the RPi and introducing game-based assignments helps students to engage themselves and whether the students learn better with assignments of these types. Here are the questions we aim to answer:

- Could creating usable 2D game assignments allow students to effectively learn course materials?
- Could game-based assignments requiring an external input device be a motivating factor for programming students?

These questions aim to see whether using both the RPi and game-based assignments together may increase the students engagement in the assignment and motivate the students as well. An API (Application Programming Interface) is a set of communication protocols that are used between applications.

3 PROCEDURES AND METHODS

An iterative approach will be used for this development process. Firstly a set of 2D games will have to be decided upon. The genre for these games will be retro (such as the famous Snake game, Tetris, Pong, Tic-tac-toe). The aim is to have one game per assignment. Then the complete game will be implemented and from this implementation, some code will be removed to create the code scaffold needed for the assignment. To make sure that the scaffold is correct for the students we will be in consultation with a lecturer(s) from the Computer Science (CS) department from the University of Cape Town (UCT). We will also ensure that the scaffold has enough comments in order to guide the students as to where their code needs to be placed. Each assignment will require the students to use a different programming control structure(s) (for loops, while loops, conditional statements, etc). The assignments will be coded in such a way that the students do not have to know anything about 2D coding, as well as game development theory. They will only test what they will learn throughout the course.

After the first phase of development is completed, we will consult with lecturers, masters students and teaching assistants (TAs) from the CS department from UCT. They will be asked to evaluate the code scaffold and do the implementation for each of the assignments, then they will be asked to fill out a questionnaire and to leave any comments on what can be done differently. The general idea of the questionnaire is to determine whether the assignments are suitable for first year programming courses and the students in those courses. The questionnaire will focus on whether:

- the assignments will be useful for the intended first year students
- they thought it was too easy or too difficult
- the question was clear enough
- they could find where to implement the code
- they think that this game based approach will motivate the first year students to work harder
- the game-based assignment would be better to use than the current assignments that first year students are doing in those courses.

The feedback from the testing will tell us whether we are on the right track, what we can improve in the questions, be it making the question clearer, or making the question more difficult (by removing more code from the scaffold for them to implement) or more easier for them.

Then the second iteration of the development will start and the changes will be made. This will be followed by another stage of testing with feedback and with that feedback, we will make the final adjustments.

The assignments will be implemented in the Python programming language, using a suitable 2D graphics engine for the game models. The programming will be done on a desktop machine or laptop. The RPi's Sense HAT will be the source of the input for the games as the libraries needed for the Sense HAT are also coded in Python. The RPi will connect to a student's desktop machine or laptop and will run VNC in order to visually display the desktop of the RPi. The students will then code the assignment on their desktop and run the assignment (play the game), using the Sense HAT's joystick as a source of input.

A challenge which is expected is that even if we are granted clearance to do the research, it will be difficult to recruit the students needed to do the study as the students will only be returning to campus in the fourth quarter due to the Corona virus pandemic. It has therefore been decided to consult with the teaching assistants (TAs), lecturers and some masters students in the CS department. They will then evaluate whether there is enough scaffolding code for the students to complete the assignment successfully and whether we are clear enough in the assignment question.

4 ETHICAL, PROFESSIONAL AND LEGAL ISSUES

This research requires user testing and studying. This will be done with lecturers, masters students and TAs from the UCT and because of this, we are required to obtain clearance from the university. The deadline for this currently stands at 24 July 2020. We do not anticipate any problems with acquiring clearance as they will only be completing assignments and filling out a questionnaire once they have completed all assignments. In the event that the clearance is not granted, it would be difficult to find another method of testing as the user studies would be a crucial part of this research.

There are no anticipated legal and professional issues.

The software system, which will be available as an open source project, will be built using open source tools and libraries which can be freely acquired.

5 RELATED WORK

In the literature Leutenegger et al. [8] included games in the course projects and found that the students liked this approach and that they retained the information that they learnt better. Feldgen et al. [3] found that introducing a game-based approach increased the success rate of the students. They focused on starting by teaching small constructs and using the assignments as building blocks and growing them to become a more complete game application.

Ak et al. [1] conducted a study comparing the differences between traditional assignments and 2D and 3D game assignments and found that they are similarly matched in terms of the students'

performances, but the students preferred doing 2D game assignments.

Rubio et al. [10] conducted a study using the Arduino board to teach computer programming concepts, by using breadboards and circuits which connected to the Arduino. The RPi was used to teach a course at Indiana University Purdue University Indianapolis (IUPUI) to teach the internet of things [11]. They made use of the sensors on the RPi itself in the assignments and the final assignment was a "Raspberry Pi stock ticker" [11].

6 ANTICIPATED OUTCOMES

6.1 System

The system which will be produced during this project should have the following features:

- Scaffolded code testing different programming concepts
- The joystick from the Sense HAT will be used as input for the games
- The RPi connects to another computer which will run VNC which will serve as the interface for the RPi and the assignment.

The outputs for this project will be the completed and scaffolded code for the game-based assignments, the documentation for the questions and instructions for the students and the documentation for the questionnaire.

6.2 Key Success Factors

The key success factors for this research project are expected to come from the user testing and these are:

- The assignments are of a standard which one would expect from an introductory course to programming
- The survey is set up in a way to find out whether students could possibly feel more engaged in the assignments
- The evaluators can make a case that the game-based assignments are better than the traditional assignments used in introductory programming courses
- The RPi allows the students to successfully interact with the game via the Sense HAT

6.3 Expected Impact of the Project

We expect the results of this project to be carefully considered by lecturers when creating assignments for an introductory programming course as well as the assignments from this project to be used as a benchmark for those assignments.

7 PROJECT PLAN

7.1 Resources

The hardware required for this research is:

- A desktop computer or laptop
- RPis and Sense HAT add-on boards
- Power supply cables and ethernet cables for the RPi

The software required for this research is:

- A suitable IDE to code in
- The Python programming language and associated libraries
- Sense HAT function libraries
- A 2D game engine (PyGame or Arcade)
- VNC

All this software are freely available online.

7.2 Risks and Management Strategies

Table 1 shows the risks and risk management strategies.

Risk	Probability (1-10)	Impact (1-10)	Mitigation
RPi or Sense HAT is faulty	2	5	Have a backup of each of these boards
Computer Failure / Crashes	3	4	Ensure that all data and resources are backed up and easily retrievable
Surveys fail to produce a conclusion	4	9	Perform another survey or consult lecturers and masters students
Lack of students willing to participate in the user study	7	9	Introduce some incentive for completing the survey
Scope Creep as more and more functions and games are implemented	4	7	Ensure that only what needs to be implemented is implemented. Have regular meetings with supervisor
Game engine limits implementation of the games	1	8	Find another game engine or find a work around solution that the game engine can support
Source code is unmanaged	3	7	Use version control and ensure that code is well documented and commented
Inability to meet deadlines	2	10	Regular meetings with supervisor and frequent check-ins

Table 1: Table of risks

7.3 Project Timeline and Gantt Chart

The project commenced on 19 March 2020 with the literature review and will terminate on 19 October 2020 when the web page is completed. The Gantt chart for this project can be found in Appendix A.

7.4 Deliverables

Below in table 2 with all project deliverables and their respective due dates.

7.5 Project Milestones

Below in table 3 the project milestones which correlate with the Gantt chart.

Project Deliverables	Due Date
Project Proposal	4 June 2020
Revised Project Proposal	10 July 2020
Final Paper Scaffold Completed	1 August 2020
Initial Software Feasibility Demonstration	3-11 August 2020
Theory Section of Paper Completed	12 August 2020
Implementation and Testing Completed	14 August 2020
First Phase: User testing and write up completed	21 August 2020
Second Phase: User testing and write up completed	28 August 2020
Final Implementation and Testing Completed	1 September 2020
Final Draft of Paper Completed	11 September 2020
Project Paper Final Submission	21 September 2020
Project Code Final Submission	25 September 2020
Project Demonstration	5-9 October 2020
Project Poster Due	12 October 2020
Project Web Page Due	19 October 2020

Table 2: Table showing project deadlines

Milestones	Due Date
Project Proposal	4 June 2020
Review of staff feedback on proposals	18 June 2020
Revised Project Proposal Submission	10 July 2020
Initial Software Feasibility Demonstration	3-11 August 2020
Weighting for project marking decided	17 August 2020
Final Draft of Paper Completed	11 September 2020
Project Paper Final Submission	21 September 2020
Project Code Final Submission	25 September 2020
Project Demonstration	5-9 October 2020
Project Poster Due	12 October 2020
Project Web Page Due	19 October 2020

Table 3: Table showing project milestones

7.6 Work Allocation

As I am the only person working on this project due to unforeseen circumstances, the development of the system (2D completed game assignments), the skeleton code for the assignments and all the related documentation will be my responsibility.

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A GANTT CHART