

Using the Turing Tumble Simulator to improve teaching in Computer Architecture

Motivation and Rationale

The Context: Computer Architecture is a fundamental topic of Computer Science that provides key concepts/rules that explain how a computer system functions, the processes behind it, and the organisation and implementation of it. The understanding of the concepts taught in Computer Architecture are very important for Computer Science students as it is relevant to learning the key principles of programming. Some of the key topics taught include digital logic, microarchitecture, assembly language and data types. In University, these are usually taught at a basic level through lectures supported by self-directed study, to learn the information. There is usually not enough time to cover all the concepts in heavy detail and Computer Architecture is usually taught as an individual module over one University term.

The Problem: Teaching Computer Architecture is a very hard subject to teach students in University studying a Computer Science related degree. This is due to the complexity and vast amount of technical information required to fully appreciate and understand the topic. Finding the right method of teaching the topic can be subjective and is hard to keep students motivated and engaged with learning all the required content; many academic staff even find the teaching a challenge itself. Many different discussions and research approaches have been conducted to try and understand why it is exactly so challenging. Common issues associated with the teaching of Computer Architecture have been identified. For example: "Architecture as such is a fuzzy concept" [1], "Students' motivation falters due to 'the perception that the subject matter is both difficult and tedious'" [2] and "learners find the traditional way of learning computer architecture subject "dry" and "not very interesting"." [3]. Consequently, some students spend longer understanding some of these concepts by going online to find other resources and online simulators they can use to cement their understanding.

My Proposed Approach: In my project, I will be exploring the current teaching methods of Computer Architecture using visual interactive resources to aid in showing some of the fundamental topics. I will reflect upon the general consensus's opinion towards the difficulties and current limitations of Computer Architecture through content alone. Through all this feedback, an online repository will be introduced that contains interactive teaching resources and demonstrations of some of these topics to help improve teaching of some concepts in Computer Architecture, whilst increasing student motivation, understanding and engagement. This will be done through the development of visual representations and exercises using an open source simulator, the Turing Tumble [4] which can help to solidify the teaching experience of students. The simulator is an online version of the Turing Tumble – a marble powered computer. [5]

Aims & Objectives

Aim: To explore how simulators and online resources have been used to aid in the teaching of Computer Architecture, discuss the challenges faced when teaching it and evaluate how an open source resource – the Turing Tumble, can be used to overcome these challenges.

Objective	Explanation
1. Explore and identify the current limitations and difficulties of teaching Computer Architecture	In my background reading, I will research into the current teaching methods of teaching Computer Architecture. Comparisons will be made to see the different opinions that researchers and academic staff have about the topic in general and how challenging they have found it to teach the subject as well as the engagement and motivation students have for it.
2. Identify and evaluate how simulators and online resources are being used to help teach	Currently, there are lots of resources and simulators available online that help to teach some topics in Computer Architecture (i.e. Logic Gates). I will be evaluating some of these resources using a strict set of criteria, measuring the usability, intuition, ease of understanding, visual learning aspects and flexibility of teaching. This will be used to create a set of guidelines that my dissertation project will achieve.

Computer Architecture	
3. Compare topics that can be taught with these available resources and with the Turing Tumble	Using the background reading and analysis of other available resources attained in the previous objective, I will be testing the Turing Tumble to see if this can teach the same concepts as other resources online. This will compare the ease of understanding the concept, how intuitive the Turing Tumble is and how advanced and challenging the teaching can go.
4. Hold several focus groups with students to evaluate the practicality of the Turing Tumble in teaching resources	Using the resources' developed in this dissertation, I will demonstrate them to groups of students in first, second and third year to let them test out the repository resources. Surveys and questionnaires will be used to evaluate the response of the students. This will provide me with the feedback required to conclude the aim of my dissertation and further add to and develop new resources. If the feedback is positive, this will meet my objective and aim.
5. Discuss and develop ways in which how using a Turing Tumble could be integrated in teaching of CSC1024	I will be attending developing curriculum meetings for CSC1024 - Computer Architecture with the current teaching staff of it. It will be here that I get feedback on the current module layout and know what topics the staff would like an interactive simulator to help teach them. They should be shown the simulator and learning resources that I've created and test out the resources to make sure they are useful in visually explaining the concepts. From this, a decision will be made as to whether it will be used in the module in the new curriculum.
6. Develop an online repository of demonstrative resources that can be used to teach Computer Architecture using a Turing Tumble Online Simulator [4]	The repository will be the development for my dissertation that should reflect all the main points found in all the other objectives. It will contain an embedded version of the Turing Tumble which can be used alongside the resources from the site to show visual representations of some of the Computer Architecture topics presented in CSC1024. It should contain various useful teaching resources: audio and video demonstrations, interactive walkthroughs and downloadable topic notes. These should be useful to both academic staff and students.

Background

Resource	Info
'What Makes Teaching Software Architecture Difficult?' [1]	<p><i>Description:</i> This paper discusses the results attained by researchers attempting to show the difficulties and challenges faced when teaching Software (Computer) Architecture and how it differs from other fundamental Computer Science topics. The aim is for educators to be able to use what is discussed to improve the way the topic is taught and find different approaches for this.</p> <p><i>Reason:</i> This paper sums up a lot of the issues faced when teaching Computer Architecture; which is what I'm looking to discuss and improve as part of my aims and objectives. It further validates my motivation for the project as well as gives me an idea on what is useful for both academic staff and students in its teaching.</p>
'Teaching Computer Architecture Labs Using A MCU Platform.' [2]	<p><i>Description:</i> The paper highlights some of the issues staff face when trying to teach Computer Architecture to students with no visual representations. It also tests the use of a microcontroller (MCU) hardware platform to improve the teaching of Computer Architecture.</p> <p><i>Reason:</i> It discusses the improvement of student understanding and engagement of learning Computer Architecture with the introduction of a visual learning platform, which is what I am planning to do for my dissertation (like paper above).</p>
'An Educational Game For Teaching Computer Architecture: Evaluation Using	<p><i>Description:</i> The paper tries to highlight the improved engagement and learning of Computer Architecture for students when taught using an interactive game using Learning Analytics. It compares the results of tests conducted before and after the introduction of the game to find a definite conclusion to the papers discussion.</p>

Learning Analytics.’ [3]	<i>Reason:</i> This highlights the use of a different resource to approach the teaching of Computer Architecture. It also gives an insight to how I can conduct the testing of my resources to see how useful they are for teaching Computer Architecture.
‘The Knob & Switch Computer: A Computer Architecture Simulator For Introductory Computer Science’ [6]	<i>Description:</i> This paper discusses the use of the Knob & Switch Computer Simulator [6], that can be used in the teaching of Computer Architecture. It highlights the positive impact a simulator makes for beginner students and discusses other simulators that have previously been used. <i>Reason:</i> The discussions of this paper highlight the usefulness of using a simulator to teach some topics of Computer Architecture and that is what I’m expecting to achieve as a result of my aims and objectives. The simulator is very intuitive and easy to understand – this opinion should be met when using the Turing Tumble.
‘A Survey And Evaluation Of Simulators Suitable For Teaching Courses In Computer Architecture And Organization’ [7]	<i>Description:</i> This paper provides a survey and evaluation of many online resources and resources that are suitable to teach Computer Architecture. It uses a strict set of evaluation criteria to compare all the simulators and gives a list of topics that the simulators can teach. <i>Reason:</i> It points me in the right direction to achieve several of the objectives I plan to complete. I can use the evaluation criteria as a guidance for the criteria I will use to test other online simulators as well as the Turing Tumble.
Logisim [8]	<i>Description:</i> It is a free to download simulator that can be used to develop an understanding of logic gates in a circuit board. Elements of the circuit board can be dragged and dropped to simulate simple and complex circuits. <i>Reasoning:</i> This helps to provide an understanding of logic gates, which is a fundamental Computer Architecture concept. The Turing Tumble can also teach this concept. I will compare both the simulator features and students understanding of the concepts.
Logic.ly [9]	<i>Description:</i> It is an online simulator that also uses a circuit board to help teach logic gates as well as other useful topics not related to Computer Architecture. It is a drag and drop simulator like Logisim above. <i>Reason:</i> It helps to provide a detailed understanding of logic gates in a circuit. You can add multiple logic gates to a circuit and understand the concept behind it; which will be useful to compare against the Turing Tumble and evaluate as one of the resources in my objectives.

Work Plan Explanation

What I’ve done so far: To begin with, I’ve done some background research around the teaching methods of Computer Architecture. I investigated research papers and journals that discuss the issues and limitations of teaching Computer Architecture and offers ways in which the teaching and student interest can be improved, which meets my 1st objective. After the first few papers, I began to explore research journals that tested the use of resources and simulators to aid the teaching of Computer Architecture and understanding the key concepts that could be taught on these. I began to test the Turing Tumble [5], which I was introduced to as part of the School of Computing Outreach Program. I’ll be developing the interactive resources for the simulator version, to understand how it works and learning what concepts can be visually demonstrated using it – part of my 3rd objective.

To complete my 3rd objective, I chose some online resources that help to develop students understanding of Computer Architecture concepts. I tested them using a set of evaluation criteria and compared them against some basic goals the Turing Tumble simulator [4] can achieve. As I’ve developed resources that can be used to teach basic Computer Science concepts with the Turing Tumble for the School of Computing Outreach Program, I conducted a survey with some of the Outreach Ambassadors. These were a mixture of students from all stages in Computer Science, where I asked them about their opinions on the way Computer Architecture is taught in Stage 1 and after an initial overview of the Turing Tumble, their opinions on it being used in Computer Architecture. This feedback presented me with mix opinions on the current teaching methods of Computer Architecture – many students found it hard to understand some of the concepts

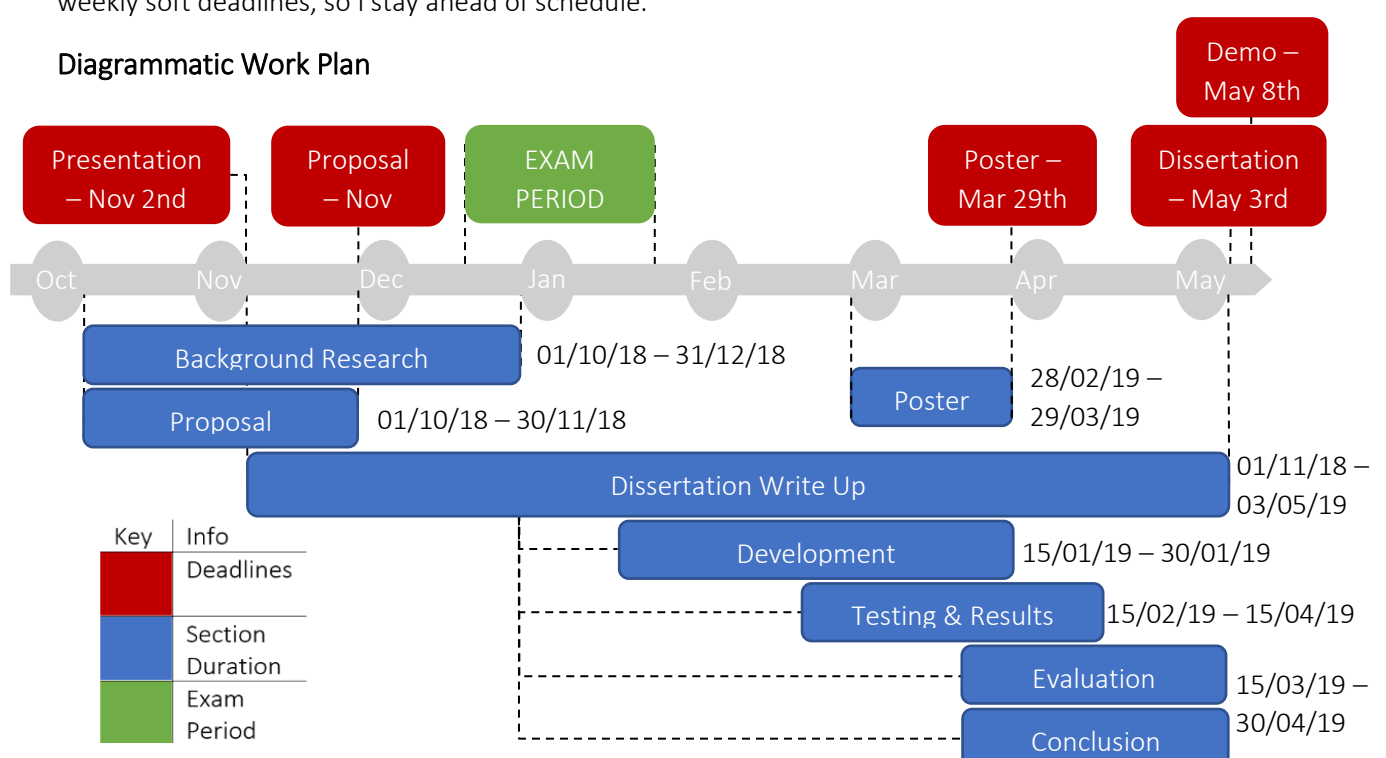
without having to study independently out of class. This was very useful and has helped me to know what needs to be asked during my focus groups.

Future Plans: Up until the end of Term 1 (Mid-December), I will be working towards the write-up for the first sections in my dissertation the paper – the introduction, background research and literature review. This includes the evaluation of each resource I’m comparing against the Turing Tumble under a strict set of criteria. After this point, it will be the December break followed by my Exam Period. Due to this, I will restrict the amount of dissertation work I complete in order to concentrate on these. However, some development ideas are to be planned and meetings with academic staff in order to see what topics need resources to be developed; which will help meet my 5th objective. I’ll also continue to advance my knowledge of the Turing Tumble Simulator. I’ve set myself a target of 3 months, for me to complete my background reading.

After my Exam Period is over, I’ll begin the development process of my project. To meet my 6th objective, I will first plan and create the site for my online repository using the Dr Lindsay Marshall’s framework [10]. Once the initial layout is complete, I will begin to develop the resources for the topics discussed in the developing curricula meetings and attempt to embed the Turing Tumble Online Simulator. Throughout the development of the resources, I will evaluate the usefulness and understanding of the concepts through testing involving focus groups and demonstrative sessions with students in 1st, 2nd and 3rd years and demonstrations to the staff. One risk I must try to avoid is the lack of students and student participation for the focus groups and sessions – there is always the possibility of using the academic staff to test my resources. As shown in the timeline, I’ve allocated a month to complete my dissertation poster. This will work towards my 4th and 5th objectives, continuing towards my 6th objective at the same time.

I’ve allocated 2 and a half months for the development of my project, which will take up until the Easter break and the testing will take 2 months, up until mid- April. At this point I will begin the evaluation and conclusion of my dissertation, where I’ve allocated a month and a half for completion. The evaluation will summarise all the key feedback and results I’ve attained from my objectives and project aim. This should provide me with the conclusion to my project. My write up will be completed for the dissertation deadline. Within reason, my development period can be extended in order to implement some Python and Typescript code, to add some extra features to the simulator. This could add to the interactivity of the simulator and visual learning aspects. As part of my contingency plan, I’ve allocated myself more time to complete each section in my dissertation project – an extra 2 weeks have been allotted to each section. There will be bi-weekly soft deadlines, so I stay ahead of schedule.

Diagrammatic Work Plan



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