Essay Topics
Advanced Algorithms and Data Structures
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For the coursework grade in this module, 40% of this will come from your grade for an essay. This document lists the topics on which you can write an essay. It also includes information on how the essay will be marked.

Overall guidance:

- Include references, even lecture notes, if used

- Page limit of *5 pages*, excluding a references section

- Aim for 2000, with maximum of 2500 words (with at most 10% tolerance on maximum)

- Use an appendix to include non-essential examples, figures, pseudocode, or mathematics – this does not contribute to your page total

How you approach the essay will depend on whether you choose an algorithm or data structure topic (indicated below). General content of the essay should address some, or all, of the following relevant questions:

- *Algorithm* – What is the problem the algorithm is addressing? What is the algorithm, e.g. describe it with pseudocode? What is the worst-case time complexity for implementing the algorithm? Is it better or worse than other algorithms, and what are the other algorithms and why is it better or worse? Is the algorithm better in practice?

- *Data Structure* – What are the elements of data and how are they organised? What are the basic operations in the data structure? What is the main application of the data structure? What abstract data type can the data structure implement? What is the time complexity for implementing operations of an associated abstract data type? Is it better or worse than other data structures, for which ones, and why is it better or worse? Advanced question is what is the amortised complexity (beyond the scope of the module).

1   Marking criteria

Grades for the essay are in the boundaries of: $40\%+$ for a satisfactory essay; $50\%+$ for a good essay; $6\%+$ for a very good essay; $70\%+$ for an excellent essay; $80\%+$ for an outstanding essay. The idea is that an excellent performance achieves everything expected in the module to a high standard, and higher marks reward the ability of the student to go beyond the module content. The following indicates the marking criteria for the grades: A satisfactory essay will do the following:

- Attempt to describe the problem/abstract data type being solved/implemented

- Attempt to describe the algorithm/data structure used

A good essay will do the following:

- Competently describe the problem/abstract data type being solved/implemented

- Competently describe the algorithm/data structure used

- Attempt some analysis of the time complexity of operations/algorithm

A very good essay will do the following:

- Describe very well the problem/abstract data type being solved/implemented

- Describe very well the algorithm/data structure used

- Perform analysis of the time complexity of operations/algorithm

- Attempt comparison with other algorithms/data structures

An excellent essay will do the following:

- Describe very well the problem/abstract data type being solved/implemented

- Describe very well the algorithm/data structure used

- Perform excellent analysis of the time complexity of operations/algorithm

- Excellent comparison with other algorithms/data structures

In considering higher grades rewarding outstanding work, the ambition of the topic is taken into account (will be clear from context below) and whether it goes beyond the module content. Analysis such as amortised analysis can achieve higher grades, or good average-case analysis giving an idea of how something works in practice.

2 Topics

Here are the list of topics.

The following topics are from material covered in the module. Because of this, it will be harder to get higher marks, but it is easier to get a pass mark.

- *Huffman coding* – algorithm

- *Knapsack Problem and Dynamic Programming* – algorithm

The following topics go beyond the material in the module, but a description of them can be found in T. H. Cormen, C. E. Leiserson, R. L. Rivest, C. Stein *Introduction To Algorithms* (3rd edition) (MIT Press 2009) – the page reference is given next to the topic title. Since it goes beyond material in the module, you may be rewarded with higher marks.

- *Red-black trees* – data structure – p. 308

- *B-trees* – data structure – p. 484

- *Red-black trees* – data structure – p. 308

- *Fibonacci heaps* – data structure – p. 505

- *Parallel algorithm for merge sort* – algorithm – p. 797

- *The Bellman-Ford algorithm* – algorithm – p. 651

- *The Floyd-Warshall algorithm* – algorithm – p. 693

The next series of topics are for ambitious students who want a chance of getting very high marks. To write an essay on this topic you will need to some amount of independent research and be careful to reference your sources. Because you need to do some research, there is no reference provided for the topics.

- *Merkle trees* – data structure

- *Arithmetic coding* – algorithm

- *A* search algorithm* – algorithm

- *DPLL backtracking algorithm* – algorithm

- *Xorshift pseudo-random number generator* – algorithm

- *Karger's algorithm* – algorithm

- *Deutsch-Josza algorithm* – algorithm

2.1 Tips for researching topics

Using Google and Wikipedia as a tool to learn a subject is fine. Wikipedia can often include very useful descriptions of things and examples. But remember that websites and Wikipedia are open to manipulation from various users who can spread bad information. This is why you should use the References section in the Wikipedia pages and use these as your primary references. Papers can be accessed through the library, and some papers are freely available. Use the library to access other materials such as the textbook S. Dasgupta, C. Papadimitriou, U. Vazirani, *Algorithms*, p. 129, McGraw-Hill (2008), which may be useful for some of the topics.