# Data Structures and Algorithms

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## 1 Programming Assignment 01

### 1.1 Introduction

For this assigment, I work with a MacBook Aluminum latex 2008, with a 2 GHz Intel Core 2 Duo processor and 8 GB 1067 MHz DDR3 in RAM.
All the experiments run for this assignment are with a complete graph, so generating $|V|(|V|-1)/2$ edges might not feasible for certain values. The number of nodes the program is expected to handle is shown in Table 1, which helps to determine what values can be computed straightforward and what values required special treatment. If we consider $n = 2^k$, then the number of edges is $2^k(2^k-1)/2 < 2^k \cdot 2^k/2 = 2^{2k}/2 = 2^{2k-1}$, then we have an upper bound for the number of edges as a power of 2.

Table 1: Cardinality of nodes and edges

| Nodes | | Edge | Upper bound | |
|---|---|---|---|---|
| 16 | $2^4$ | 120 | 128 | $2^7$ |
| 32 | $2^5$ | 496 | 512 | $2^9$ |
| 64 | $2^6$ | 2,016 | 2,048 | $2^{11}$ |
| 128 | $2^7$ | 8,128 | 8,192 | $2^{13}$ |
| 256 | $2^8$ | 32,640 | 32,768 | $2^{15}$ |
| 512 | $2^9$ | 130,816 | 131,072 | $2^{17}$ |
| 1,024 | $2^{10}$ | 523,776 | 524,288 | $2^{19}$ |
| 2,048 | $2^{11}$ | 2,096,128 | 2,097,152 | $2^{21}$ |
| 4,096 | $2^{12}$ | 8,386,560 | 8,388,608 | $2^{23}$ |
| 8,192 | $2^{13}$ | 33,550,336 | 33,554,432 | $2^{25}$ |
| 16,384 | $2^{14}$ | 134,209,536 | 134,217,728 | $2^{27}$ |
| 32,678 | $2^{15}$ | 533,909,503 | 536,870,912 | $2^{29}$ |

Considering how much RAM I have, we have that 8 GB = 8,192 MB = 8(1,024) MB = 8,388,608 KB = $8(1,024)^2$ KB = 8,589,934,592 B = $8(1,024)^3$ B = $8(2^{10})^3 B = 8(2^{30})$

Table 2: Running time with different values of $n$

| $n$ | Time in milliseconds |
|---|---|
| 16 | 0 |
| 32 | 3 |
| 64 | 5 |
| 128 | 9 |
| 256 | 239 |
| 512 | 436 |
| 1,024 | 1,800 |
| 2,048 | 14,371 |
| 4,096 | 39,714 |
| 8,192 | 177,060 |
| 16,384 | 466,158 |
| 32,678 | 2,190,921 |

B, so this gives an idea of how much I can compute.
if I assign 4,096 MB for memory heap and I tried to create a complete graph with $16,384$ nodes in $\mathbb{R}^4$, I get an OutOfMemoryError while trying to create the edge number $38, 293, 002$. If I increase the memory heap to 6,144 MB, then I get the error while creating the edge $50,331,651$. Hence it is not going to be possible to create $134,217,728$ edges and keep all of them at the same time in memory.

For the cases $2^{13}+1$ nodes and more, $8,193$ nodes, weight computed from points in $\mathbb{R}^3$, my own MergeSort implementation, and using