# Set 01: Introduction and Basic Concepts

## CS240: Data Structures and Data Management

Jérémy Barbay

# Outline

# When and Where

CS240
Tuesday, Thursday
8:30-9:50am or 11:30-12:50am
MC 4061

# Who

- Instructor: Jérémy Barbay (Lectures)
  - hours – Thursday 2-3pm, DC 2332
  - email – jbarbay (at) uwaterloo.ca
- Tutor: Margarita Ackerman (Writing assignments)
  - hours – : MC4065, Mondays 2-3pm, Wed 2:30-4:30pm
  - email – cs240 (at) student.cs.uwaterloo.ca
- IA: Tariq Islam (Programming assignments)
  - hours – DC2550, Tuesday 2-3pm
  - email – tmislam (at) uwaterloo.ca
- IA: Vlad Ciubotariu (Remarking)
  - hours – DC3324, Monday 3pm
  - email – vlad (at) swen.uwaterloo.ca
- Administrative: Fenglian Qiu (Administration)
  - contact – DC 3115, Ext.2753
  - email – f2qiu (at) cs.uwaterloo.ca

# Electronic Resources

Web Page — `http://www.student.cs.uwaterloo.ca/~cs240`

- Before the class: slide handout and lecture summary.
- Every two weeks: a new assignment.
- Useful links and policies.

News Group — `news:uw.cs.cs240`

# References

*Introduction to Algorithms* [CLRS]

- Covers 40% of our course material.
- Required readings for the course are given in the web page under the “Schedule” link.

*Algorithm Design* [Goodrich/Tamassia]

- Additional coverage for some specific topics.

# Mark Breakdown

Prospective Mark Breakdown:

- Assignments 20%
- Midterm 30%
- Final Exam 50%

You pass the course iff your total average is ¿50%.

# Assignments

- One assignment every two weeks, five in total.
- Hand-in and hand-out electronically.
- Release and retrieval on Thursdays.
  Each assignment is worth $20/5 = 4$ marks,
  there is no late policy.
- Programming can be done in either Java or C++

All programming assignments will be tested in the Undergrad Math/CS Unix Environment.

# Policies – Academic Discipline

University Policy 71 ("Student Academic Discipline Policy") contains relevant information and is available from the Web site of the University Secretariat at
`http://www.adm.uwaterloo.ca/infosec/`

- First offense:
  - $-100\%$ on the assignment,
  - at least $-5\%$ on your final course grade.
- Second offense: suspension for a term.

# Summary

- All the information is on the webpage of the course at

  `http://www.student.cs.uwaterloo.ca/~cs240/`

- Regurly check the newsgroup to be informed of last minute changes.

  `news://uw.cs.cs240`

- See me or the tutor if necessary:
  - Jérémy Barbay, DC2332

# Outline

# Course Objectives.

- Sequel to CS134.
- Now focus on Data Structures, and Abstract Data Types.
- On the way:
  - Some more (light) mathematic analysis.
  - Some notions of the limits of computation.
  - some SQL.

# Course Topics

- Our Computational Model
- Time and Space Analysis
- Lists
- Graphs
- Search Trees
- Priority Queues
- Hashing
- Text Compression
- Pattern Matching
- Sorting
- Database Systems
- Memory Management

# Story Line

1. Analysis (Measuring Tape)
   - asymptotic Worst Case.
   - some Average Case.
2. Abstract Data Types (Kind of Tool: a hammer or a saw?)
   - Stack.
   - Queue.
   - Graph.
   - Tree.
   - Dictionary.
3. Data Structures (Material: Metal or Rubber hammer?)
   - array, matrix.
   - pointers, list.
   - hash
4. Applications (What to build: a chair or a table?)
   - Sorting
   - Text Compression
   - Text Search
   - Database
   - Memory Management

# Summary

- Abstract Data Types ADT and Data Structures.
- From the Theory to the Applications.
- Some lower bounds.
- Some SQL.

# Outline

# Log and Exponent Identities

The more common identities you will likely use:

- $\log_b b^a = a$
- $b^{\log_b a} = a$
- $(b^a)^c = b^{ac}$
- $b^a b^c = b^{a+c}$
- $\log_b(ac) = \log_b a + \log_b c$
- $\log_b(a^c) = c \log_b a$
- $\log_b a = \frac{\log_c a}{\log_c b}$
- $b^{\log_c a} = a^{\log_c b}$

For short, note $\log_2 a$ as $\lg a$

# Log/Exponent Identities (Cont')

- **Example**. Simplify:

$$\begin{aligned} \lg(2^n) + n^2 2^{3 \lg n} &= n + n^2 2^{3 \lg n} \\ &= n + n^2 n^3 \\ &= n + n^5 \\ &= n^5 + n \end{aligned}$$

- May need floors and ceilings:
  - $\lfloor 3.14159265 \rfloor = 3$
  - $\lceil 3.14159265 \rceil = 4$

# Common Summations

- Arithmetic series:

$$\sum_{i=1}^{n} i = \frac{n(n+1)}{2}$$

$$\sum_{i=1}^{n} i^2 = \frac{n(n+1)(2n+1)}{6}$$

# Common Summations (cont')

- Useful approximation:

$$\sum_{i=1}^{n} i^k \approx \frac{n^{k+1}}{k+1}$$

- Geometric series (where $a \neq 1$):

$$\sum_{i=0}^{n} a^i = \frac{a^{n+1}-1}{a-1}$$

- Infinite series (where $0 < a < 1$):

$$\sum_{i=0}^{\infty} a^i = \frac{1}{1-a}$$

# Derivations

**Example**:

$$
\begin{aligned}
\sum_{i=0}^{\infty} \frac{1}{2^i} &= \sum_{i=0}^{\infty} \left(\frac{1}{2}\right)^i \\
&= \frac{1}{1 - \frac{1}{2}} \\
&= 2
\end{aligned}
$$

# Factorial

- The number of arrangements of $n$ distinct objects is $n!$.
- $n! = n \times (n-1) \times \cdots \times 2$
- Stirling's approximations:
  - $n! \approx \sqrt{2\pi n}\left(\frac{n}{e}\right)^n$
  - $\log(n!) \approx n \lg(n) - n + \frac{\ln n}{2} + \frac{\ln 2\pi}{2}$

# Comparison of Algorithms

How do we find out which of these algorithms is the best?

- Selection Sort
- Merge Sort
- Counting Sort

# Selection sort

```
for i:=1 to n
| min:=i;
| for j:=i+1 to n
| | if a[min]>a[j] min:=j;
| tmp:=a[i]; a[i]:=a[min]; a[min]:=tmp;
```

# Merge sort

```
function sort(from,to)
| if (from<to)
| | mid:=floor(from+to/2);
| | sort(from,mid); sort(mid+1,to);
| | merge(from,mid,to);

function merge(from,mid,to)
| copy a[from..mid] to a new array b
| copy a[mid+1..to] to a new array c
| add infinity to both b and c as the last element
| k:=1; m:=1;
| for j:=from to to
| | if b[k]<c[m] then
| | | a[j]:=b[k]; k++;
| | else
| | | a[j]:=c[m]; m++;
```

# Counting sort

Assume that all numbers in the array are between 1 and 1000:

```
clear array count[1..1000];
for i:=1 to n
| count[a[i]]++;
k:=0;
for i:=1 to 1000
| for j:=1 to count[i];
| | a[k]:=i; k++;
```

# Comparison of Algorithms

How do we find out which of these algorithms is the best?

- Study worst/average case on instances of same size
- Measure time by key operations
- Suppose Uniform Time Access (RAM model)

# Summary

- There are some Math Formula worth remembering.
- There are some algorithms worth studying.