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CS 1010 Discrete Structures

Lecture 0:

Introduction & Logistics

Maria Francis

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Welcome to CS1010

- Introductory course to Discrete Structures.
- It is a theoretical course.
- It is the mathematics underlying almost all of computer science.
- In computer science you are either building/designing different computer systems or designing algorithms that can run on computer systems.
- A computer systems need not be a single machine but an entire ecosystem that includes, for example, networks that connect various systems.

Examples in Computer Science

- Below are a few cases where we need discrete mathematics in computer science:
 1. Designing high-speed networks and message routing paths. **Graph theory, Counting techniques, Recursion, etc.**
 2. Finding good algorithms. **Counting techniques, Graph Theory, Algebra, Recursion, Probability Theory, etc.**
 3. Web searches. **Graph Theory, Recursion, Probability Theory, Linear Algebra, etc.**
 4. Analysing algorithms for correctness and efficiency. **Counting techniques, Graph Theory, Algebra, Recursion, Probability Theory, etc.**
 5. Cryptography **Algebra, Probability Theory, etc.**
 6. Machine learning **Graph Theory, Probability Theory, Linear Algebra**

Illustrative Examples

```
for ( $i = 1; i \leq n; i++$ )  
  for ( $j = 1; j \leq i; j++$ )  
    for ( $k = 1; k \leq j; k++$ )  
       $x = x + 1;$ 
```

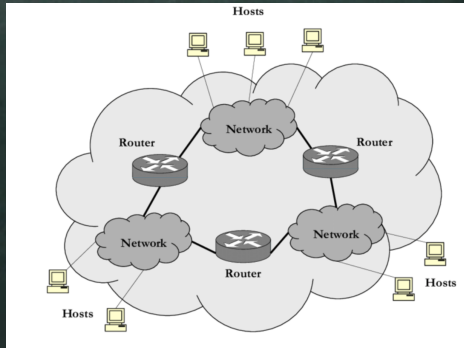
How many times will the statement $x = x + 1$ be executed?

- Equal to the number of triples (a, b, c) where $a \leq b \leq c \leq n$.

Counting Technique - Combinations with Repeats.

- There are $C(3 + n - 1, n - 1) = C(n + 2, n - 1) = \frac{n(n+1)(n+2)}{6}$ such sequences.
- Can be generalized to m inner loops, $C(m + n - 1, n - 1)$.

Network as a graph



Can be viewed as a graph and we can apply graph algorithms like **algorithms to find the shortest path** on the network.

Strong Foundations

- Forget direct applications, discrete mathematics is required for strong foundations in computer science.
- You will keep seeing it in other areas of computer science and you will rely on the tools you learned here.
- It helps you develop a more rigorous, structured mathematical thinking.

Strong Foundations

- One expected outcome from this course: Start making mathematically precise statements and develop rigorous proofs to validate the statements you make.
- For e.g: you will interpret a simple "if and only if" differently/more rigorously.
 - ▶ Prove: $S \subseteq T$ and $T \subseteq S$ iff $S = T$.
 - ▶ Your proof needs to prove the following two directions :
 1. If $S \subseteq T$ and $T \subseteq S$ then this implies (\Rightarrow) $S = T$, and
 2. If $S = T$ then $S \subseteq T$ and $T \subseteq S$.
 - ▶ More often than not (especially for more technical results) this rigorous treatment is abandoned.
 - ▶ Result: One of the directions is not proved!

Syllabus

Concept of Mathematical Proof, Logic, Proof by contradiction, Mathematical Induction, Constructive Proofs, Sets, Relations. Illustration of Proof Techniques.

Combinatorics: Basic Counting Principles, Inclusion-Exclusion Principle, Binomial/Multinomial Coefficients. Bijections, Double Counting, Pigeon-Hole Principle, Recurrence Relations.

Graphs: Basic terminology/Definitions, Isomorphism, Connectivity, Trees, Planarity, Optional: Matchings, Colorings.

Introduction to abstract algebra: Basics of Groups, Optional: Rings, Fields, Polynomial Rings. Introduction to number theory, modular arithmetic, prime factorization, Optional: Chinese Remainder theorem.

References

Textbooks:

- Discrete Mathematics and its applications by Kenneth Rosen
- Discrete Mathematics with applications by Susanna S Epp

Other References:

- Building Blocks for Theoretical Computer Science – Margaret Fleck
- A course in discrete structures – Rafael Pass
- Mathematics for Computer Science – Eric Lehman
- Sets, Groups and Mappings – Andrew Hwang

Other References

- Online resources are available in plenty since it is a basic course.
- Explore and utilize all resources -
 - ▶ lecture notes,
 - ▶ video lectures (from reputed sources like university lectures, Simons Institute, Institute for Advanced Study, etc),

Online Classes

- The lecture hours are Q slot: Mon (04 : 00pm – 5 : 25pm) and Thurs (2 : 30pm – 3 : 55pm).
- A 1 hour video will be uploaded over YouTube before Thursday. The link to that will be provided in Google classroom.
- **Recommended: View in the Thursday lecture slot.** You can watch the video anytime when it works best for you. **Do not keep postponing though!**
- **We will meet on Mondays to discuss the lecture and your queries and do practice questions.**
- Monday lecture will also have a small quiz (of the previous lecture).
- TAs for this course: Shubham Ingole (cs19mtech11015 @ iith.ac.in), Nabhasmita Sen(cs17resch11001 @ iith.ac.in)

Evaluation!!

- Attendance - 10% ($\leq \frac{1}{3}$ - 0 marks, $\leq \frac{2}{3}$ - 6 marks, $\geq \frac{2}{3}$ - 10 marks).
- Quizzes - 40% (Previously announced, online 15 – 20 minute quizzes)
- Assignments - 30% (Have to submit soft copy!)
- Report - 20% (A topic of your interest related to discrete structures. Have to submit soft copy!)
- Not a perfect method!
- Plagiarism or any form of cheating will be an automatic F and will be reported to the dept.

Quizzes

- Will be given as a Quiz Assignment (MCQs and short answers) in Google classroom or over SAFE app.
- After it is assigned you will have **15-20 minutes** to give your answers.
- Late submissions are allowed by Google forms **but the marks will NOT be recorded under any circumstances.**
- Dates of the quizzes will be announced in advance.
- The plan is to conduct approx. 8 quizzes and **to account for network issues we will only consider best 4 quizzes.**
- The exact numbers may vary a bit.

Assignments

- About 3 – 4 assignments, should be submitted as PDFs.
- If you compile it with LaTeX you get an extra 5 marks.
- LaTeX tools are freely available for different OSes and there are lots of online resources on how to use it.
- One basic resource:
<http://web.mit.edu/rsi/www/pdfs/new-latex.pdf>
- With no long written exams, assignments have become **very very important** - the only way for you to apply the concepts!
- Do not copy or cheat! **Plagiarism or any form of cheating will be an automatic F and will be reported to the dept.**

Report - Instructions

- You need to prepare a report on a topic of your choice by **Feb 15**.
- The topic has to be related to discrete structures and the title should be submitted by **Jan 15**.
- Coming up with a topic will be scored out of 5 marks and the report will be marked out of 15.
- 3 marks when I approve your title and 5 marks if I find that your title needed some research. **That is an almost free 5 marks!**

Report - Instructions

- The report (2-3 pages) should be typeset properly, preferably using LaTeX editors.
- Material cannot be copy pasted from other sources - it should reflect your understanding!
- What are possible topics?
 - ▶ An application of the results we saw in the course.
 - ▶ A game that uses mathematical principles.
 - ▶ A more advanced result of what we saw in class. For eg: suppose we saw a result over integers then you can write a report on the more advanced case, say over polynomials.

Conclusion

- This is one of your first introductory courses in computer science, one that builds a theoretical foundation.
- Let me know if any point if you have any difficulties in understanding the material, or have connectivity issues or any other difficulties.
- You can email me directly and set up an appointment.