Course Introduction

SCIS 313: Data Structures and Algorithm Analysis

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Spelman College

Welcome to SCIS 313!

What is this course about?

We'll study how to analyze and design efficient algorithms:

- Algorithm complexity analysis (Big-O notation)
- Advanced data structures (trees, graphs, heaps)
- Algorithm design techniques (recursion, greedy, dynamic programming)
- Theoretical limits of computation (P vs NP)

Why does this matter?

- Write faster, more efficient code
- Ace technical interviews at top companies
- Understand what's computationally possible (and impossible)
- Think like a computer scientist

Meme


Kylie Jenner
@ikyliejenner
Can you guys please recommend books that made you cry?
Saransh Garg @saranshgarg
Replying to @ikyliejenner
Data Structures and Algorithms in Java (2nd Edition) 2nd E
by Robert Lafore (Author)

Course Topics

Weeks 1-7: Foundations

- Empirical analysis
- Big-O notation
- Analyzing loops & code
- Mathematical foundations
- Recursion & recurrences
- Searching & sorting
- Data structures review

Weeks 8-13: Advanced Topics

- Amortized analysis
- AVL trees
- Graph algorithms
- Greedy algorithms
- Dynamic programming
- Complexity theory

By the end: Analyze any algorithm and understand fundamental CS theory

Grading Breakdown

Component	Weight
Exams (3-4 total)	**65%**
Exam 1 (Week 6)	15%
Exam 2 (Week 9)	15%
Exam 3 (Week 12)	15%
Final Exam (Week 15)	20%
Projects (3-4 presentations)	**25%**
Homework (weekly)	**10%**

Homework: Completion-based (submit screenshots + work)

Projects: Group presentations on advanced topics (2-3 students)

Weekly Schedule

Tuesday:

- New content lecture
- Work through examples
- Theory and applications

Thursday:

- Finish content (first 30 minutes)
- **Homework review** (last 30-45 minutes)
  - Students present solutions (popcorn style)
  - Mandatory participation - everyone presents $\sim$once per month
  - Build your presentation skills!

Homework due: Thursday before class

How to Succeed in This Class

How To Do Well:

- **Attend class!**
- **Ask questions**
- Start homework early
- Come to office hours
- Practice coding
- Form study groups

How to Fail:

- **Skip class!**
- **Never communicate**
- Procrastinate
- Try to memorize
- Work alone when stuck

Reality: This material is **abstract**. You won't get everything immediately. That's normal! Keep working, ask for help, and it will click.

Homework: Programming + Written Problems

Weekly homework (∼8-10 problems):

- Mix of written analysis and coding
- **Data Structures and Algorithms (LeetCode) problems** (3-5 per week starting Week 5)
- Completion-based grading

Why LeetCode?

- Industry standard for technical interviews
- Auto-graded (instant feedback!)
- Build your problem-solving portfolio
- Practice implementation, not just theory

Submission:

- LeetCode: Screenshot showing green "Accepted"
- Written: Photos or typed solutions

Projects

3-4 group projects throughout semester

Each project:

- 15-20 minute presentation
- 3-5 page written report
- Research advanced topics not covered in depth

Example topics:

- Red-Black trees vs AVL trees
- Dijkstra's shortest path
- String matching (KMP)
- Stern-Brocot tree
- Approximation algorithms

What Makes This Course Different?

First course: Implement data structures

This course: *Analyze* algorithms and understand *why* they work

We focus on:

- **Efficiency:** Is this $O(n)$ or $O(n^2)$? Why?
- **Correctness:** Does this always work?
- **Limits:** What *can't* be solved efficiently?
- **DSA Questions:** Companies ask these questions!

This is **theoretical computer science** - more math and proofs than typical programming.

But it's also **practical** - these concepts appear in real interviews.

The Red Thread of This Course

Core themes we'll explore:

1. **Programming requires algorithmic design**
   - How do we solve problems systematically?
2. **Computers are founded on universal computation**
   - What can and cannot be computed?
3. **We will study fundamental data structures and algorithms**
   - The building blocks of all software
4. **Some problems are undecidable**
   - Even simple-looking problems may have no algorithmic solution
5. **Some problems are computationally hard (NP-complete)**
   - Traveling salesman, graph coloring - probably cannot be solved efficiently
   - Critical question: Does P = NP?

What This Course Is (Not) About

This is NOT:

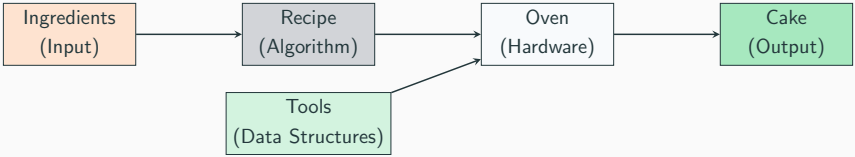
- A programming course
  - No computer labs
- A pure theory course
  - Proofs sketched, not rigorous

This IS:

- Crucial for becoming a good programmer
  - Algorithms and data structures
- Foundations of computer science
  - Computability and complexity
- Exploration of computation models
  - Classical (and possibly quantum) computing

Balance: Practical programming skills + theoretical understanding

Algorithms in Real Life: Baking a Cake



Key insight:

- **Algorithm** = step-by-step instructions (recipe)
- **Data structures** = how we organize ingredients (tools)
- **Hardware** = physical computer (oven)
- **Software** = recipe implemented in programming language

Classic Example: Euclid's Algorithm

Greatest Common Divisor (circa 300 BC)

Problem: Find the greatest common divisor (GCD) of two numbers $n \geq m$

Euclid's Algorithm:

- If $m = 0$, return n
- Otherwise, compute $\gcd(m, n \bmod m)$

Example: $\gcd(129, 57)$

$$\begin{aligned}\gcd(129, 57) &= \gcd(57, 129 \bmod 57) = \gcd(57, 15) \\ &= \gcd(15, 57 \bmod 15) = \gcd(15, 12) \\ &= \gcd(12, 15 \bmod 12) = \gcd(12, 3) \\ &= \gcd(3, 12 \bmod 3) = \gcd(3, 0) \\ &= 3\end{aligned}$$

Note: This algorithm uses recursion - a function calling itself!

Euclid's Algorithm in Pseudocode

Algorithm 1 Euclid(m, n)

```
1: if m = 0 then
2:     return n
3: end if
4: if n = 0 then
5:     return m
6: end if
7: if m ≤ n then
8:     return Euclid(m, n mod m)
9: else
10:    return Euclid(m mod n, n)
11: end if
```

Pseudocode is algorithm description that:

- Resembles programming language syntax
- Is more abstract and language-independent
- Focuses on logic, not implementation details

What is an Algorithm?

Definition: A list of precise instructions that captures the essence of solving a problem

Three critical aspects:

1. **Termination:** Does the algorithm always finish?
   - Must produce output in finite time
2. **Correctness:** Does it solve the problem?
   - Must meet its specifications
   - Produces correct output for all valid inputs
3. **Efficiency:** How fast is it?
   - Time complexity: How many steps?
   - Space complexity: How much memory?

This course focuses heavily on analyzing efficiency!

Our Model of Computation

We will use these abstractions throughout the course:

Computer: Random Access Machine (RAM)

- Theoretical model of a computer
- Unlimited memory cells (registers)
- Basic operations take constant time

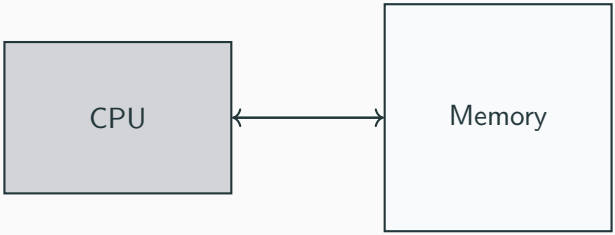
Data Structure: Abstract Data Type (ADT)

- Specification of operations, not implementation
- Example: Stack with push() and pop()

Algorithm: Pseudocode

- Language-independent description
- Focus on logic and structure

Random Access Machine (RAM)



Assumptions:

- Unlimited number of memory cells (registers)
- Primitive operations (read, write, arithmetic) take constant time
- Simplifies analysis - focus on algorithm, not hardware details

What is a Data Structure?

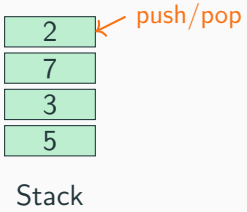
Definition: A particular way of organizing data in a computer for efficient use

Abstract Data Type (ADT): Specification by operations, not implementation

Example: Stack ADT

Operations:

- `push(d)`: Add item d to top
- `pop()`: Remove and return top item
- Exception: pop() on empty stack



Different data structures suit different applications!

Pseudocode: Our Language for Algorithms

Pseudocode is more abstract than real code, includes:

Basic elements:

- Input and output
- Variable declarations
- Parameters
- Abstract data types
- Memory operations (read/write)

Control flow:

- `if ... then ... else ...`
- `while ... do ...`
- `for ... to ... do ...`
- Recursive calls

Key features:

- Uses indentation instead of explicit block delimiters
- Language-independent (not Python, not Java, not C++)
- Focuses on algorithm logic, not syntax details

Topics We'll Cover This Semester

Weeks 1-5: Foundations

- Running time analysis
- Asymptotic notation (Big-O)
- Recurrence relations
- Mathematical induction

Weeks 6-7: Sorting

- Comparison sorts
- Quicksort, Mergesort, Heapsort
- Lower bounds

Weeks 8-10: Data Structures

- Stacks, queues, lists
- Trees (BST, AVL, heaps)
- Hash tables
- Graphs

Weeks 11-13: Advanced Topics

- Greedy algorithms
- Dynamic programming
- NP-completeness

Questions?

Next: Lesson 1 - Empirical Analysis

Learn how to measure algorithm performance.