Please download the activity slide on the course webpage!

Welcome!

CSE 312 Summer 21
Lecture 1

Meet the Staff!

Instructor: Kushal Jhunjhunwalla

B.S. and M.S. from UW CSE with a focus in Distributed Systems and Security

First time lecturer

Interests: Cooking, Dancing!

Email: kushaljh@cs.washington.edu

Meet the Staff!

TA: Alice Wang

Rising Junior studying Computer Science

Interests: Drawing, pin-collecting, and watching anime

Email: alicew3@cs.washington.edu

Meet the Staff!

TA: Claris Winston

Rising Sophomore studying Computer Science

Interests: Gymnastics, drawing, and composing music

Email: clarisw@cs.washington.edu

Meet the Staff!

TA: Justin Tysdal

Rising Junior studying Computer Science and Mathematics

Interests: Cooking, reading, singing, practicing guitar, and playing osu!mania

Email: justinjt@cs.washington.edu

Meet the Staff!

TA: Pascal Sturmfels

Third-year PhD student in ML and Computational Biology

Email: psturm@cs.washington.edu

Remote Instruction Logistics

We will always have a TA watching chat – if you have a question, ask it there (either general or direct to a TA – TAs are co-hosts of the call).

Don’t send a direct message to me, I won’t see it

TA may answer directly, interrupt me, or wait a few minutes and have me answer at a good stopping point.

If you are comfortable to turn on your video (and have reliable infrastructure), please do!

Nodding/confusing looks/glazed over eyes help me know if I need to repeat myself or give an alternate explanation.

Recording of the lecture will be put up on Canvas.

Remote Instruction Logistics

Lecture meeting time: MWF 12 pm – 1 pm

Section meeting time: Thursday 12 pm – 1 pm

Both sections are meeting at the same time. Please go to your assigned section.

Sections will not be recorded for your privacy

We will have section “walkthrough” videos for those who cannot attend sections.

Syllabus

It may take a few days for the syllabus to be published.

When in doubt refer to the syllabus on the website:

https://courses.cs.washington.edu/courses/cse312/21su

Work Breakdown

Concept Checks (10%)

Short "quiz" for each lecture on Gradescope; helps identify misconceptions right away.

All three for a week due Monday morning; recommend you do them the day of lecture.

About 7 assignments (60%)

Mostly written problems, but a few programming exercises

2 Probability in the Real World mini-projects (10%)

A chance to think about applying concepts to real life / some ethical implications of the tools we are introduced to in this class.

3 Review Summaries – in place of a Midterm (10%)

Review assignment to reflect on what was learnt in the past few weeks.

Final (10%)

Details TBD. No proctor-based exams.

Communication

Ed Discussion board will be the primary means of communication

There will be FAQs for lectures, announcements, which you should check for frequently.

If you want to contact us:

- Private post on Ed (only visible to staff)
- Email Kushal (kushaljh@cs)
- Anonymous feedback form on the webpage

Collaboration Policy

PLEASE collaborate! Please talk to each other and work with each other.

(subject to the policy – details in the syllabus)

Collaboration is difficult in this remote environment.

There are a few things to help you get started:

- Message on the pinned Ed post to meet people
- Stay after section to meet people
- Let us know how we can help!

What is 312?

We are going to learn the fundamentals of probability theory

A ***beautiful*** and ***useful*** branch of mathematics

Applications in:

- Machine Learning
- Natural Language Processing
- Cryptography
- Error-correcting codes
- Data Structures
- Data Compression
- Complexity Theory
- Algorithm Design
- and much more!

Content

Combinatorics (*fancy* counting)

Permutations, combinations, inclusion-exclusion, pigeonhole principle

Formal definitions of Probability

Probability space, events, conditional probability, independence, expectation, variance

Common patterns in probability

Equations and inequalities, common random variables, tail bounds

Continuous Probability

Density, sample distributions, Central Limit Theorem, Estimating probabilities

Applications

Across CS

Themes

Precise mathematical communication

Both reading and writing dense statements

Probability in the real world

A mix of CS applications

Some actual “real life” ones

Refine your intuition

Most people have some base feeling of what the chances of some event are.

We are going to train you to have better gut feelings.

Counting

Why Counting?

$\{\emptyset, \{\_\}, \{\_\}, \ldots, \{\_,\_\}, \ldots\}$ 0 0

Sometimes useful for algorithm analysis

- The easiest code to write for "find X" is "try checking every spot where X could be"
- "Given an array, find a set of elements that sum to 0" $\leftarrow$ 2^n
- "Given an array, find a set of 2 elements that sum to 0" $\leftarrow$ n^2

Gut check of "we can 'brute force' this or we can't" is super helpful

Generally: Question boils down to computing cardinality $|S|$ of some set S.

Why Counting?

A building block toward probability theory

“What are the chances” is usually calculated by

$$= \frac{\text{how many ways can I succeed}}{\text{how many ways can I succeed} + \text{how many ways can I fail}}$$

$$\frac{\#\ \text{successes}}{\#\ \text{total}}$$

$$\frac{1}{6}$$

Counting Rules

- Sum Rule

- Product Rule

Sum Rule

How many options do I have for dinner?

I could go to Sizzle & Crunch where there are 2 meals I choose from, or I could go to Noodle Nation where there are 8 meals I choose from (and none of them are the same between the two restaurants).

How many total choices?

$2 + 8 = 10$

Sum Rule

How many options do I have for dinner?

I could go to Sizzle & Crunch where there are **2** meals I choose from, or I could go to Noodle Nation where there are **8** meals I choose from (and none of them are the same between the two restaurants).

3

How many total choices?

$2 + 8 = \underline{10}$

$2+8+3 = \underline{13}$

Sum Rule

How many options do I have for dinner?

I could go to Sizzle & Crunch where there are 2 meals I choose from, or I could go to Noodle Nation where there are 8 meals I choose from (and none of them are the same between the two restaurants).

How many total choices?

2 + 8 = 10

Sum Rule: If you are choosing one thing between n options in one group and m in another group with no overlap, the total number of options is: $n + m$.

Product Rule

I now want dessert

I decide to go to Sweet Alchemy. There are a variety of ways to customize my ice-cream:

One flavor (chocolate, vanilla, strawberry)

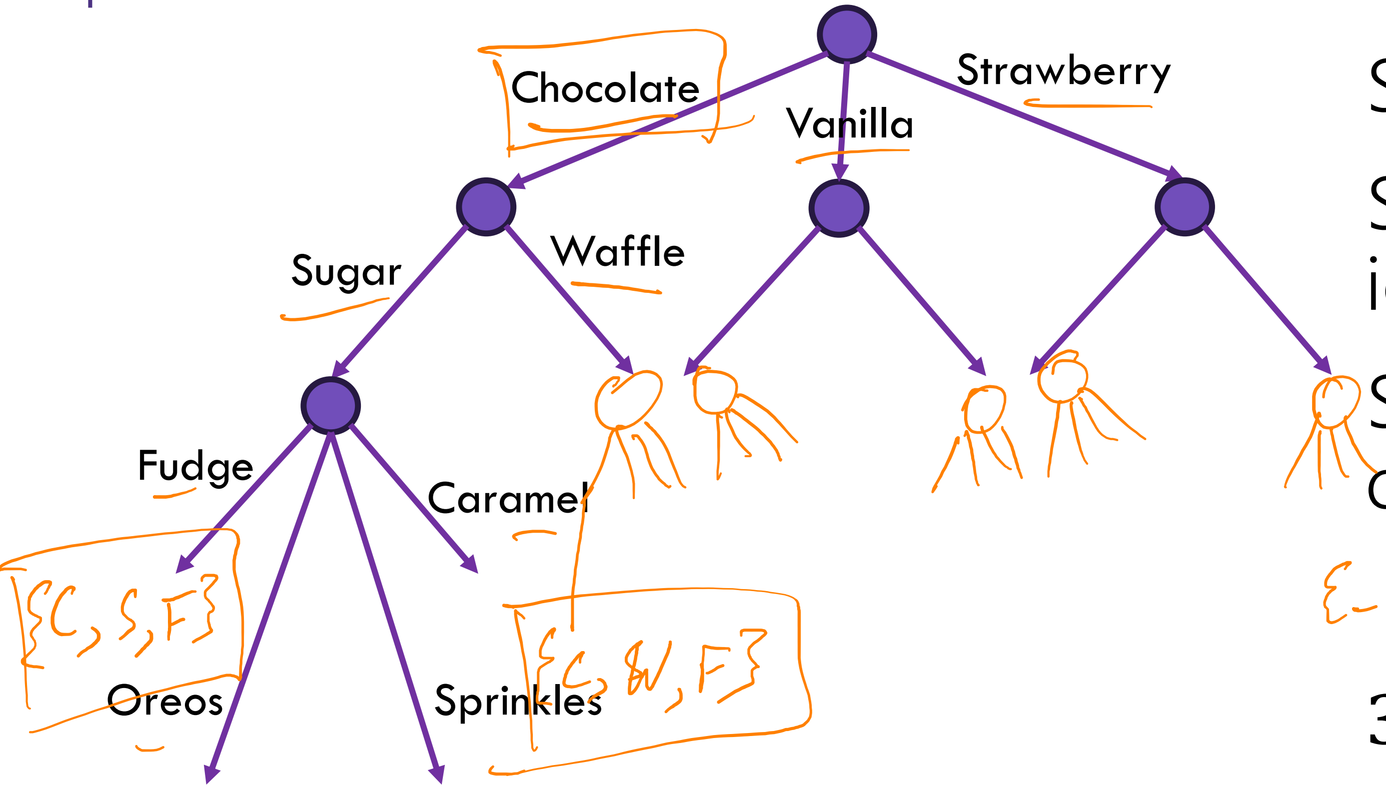
One cone (sugar, waffle)

One topping (fudge, oreos, sprinkles, caramel)

How many ice-cream choices do I have?

Ice-creams!

$2 \cdot 4 \cdot 3 = 24$



Step 1: choose one of the flavors

Step 2: regardless of the choice of ice-cream, choose one cone

Step 3: regardless of the previous choices, choose one topping

$\{\ \} \times \{\ \} \times \{\ \}$

$3 \cdot 2 \cdot 4 = 24$

$3 \cdot 2 \cdot 4 = 24$

Product Rule: If you have a sequential process, where step 1 has n_1 options, step 2 has n_2 options,…,step k has n_k options, and you choose one from each step, the total number of possibilities is $n_1 \cdot n_2 \cdots n_k$

Counting Rules

Sum Rule: If you are choosing one thing between n options in one group and m in another group with no overlap, the total number of options is: $n + m$.

Product Rule: If you have a sequential process, where step 1 has $\boldsymbol{n_1}$ options, step 2 has $\boldsymbol{n_2}$ options,…,step $\boldsymbol{k}$ has $\boldsymbol{n_k}$ options, and you choose one from each step, the total number of possibilities is $\boldsymbol{n_1 \cdot n_2 \cdots n_k}$

Applications of the product rule

Remember Cartesian products?

$S \times T = \{(x, y) : x \in S, y \in T\}$

$\{1,2\} \times \{a, b, c, d\} = \{(1, a), (1, b), (1, c), (2, a), (2, b), (2, c)\}$

How big is $S \times T$? (i.e., what is $|S \times T|$?)

Step 1: choose element from S

Step 2: choose element from T

Total options: $|S| \cdot |T|$

Power Sets

$\{X : X \subseteq S\}$

$\{1, \cancel{1}, \cancel{1}\} = \{1\}$

$\mathcal{P}(S) = \cancel{\{X : S \subseteq X\}}$

$\mathcal{P}(\{1,2,3\}) = \{\, \emptyset,\ \{1\}, \{2\}, \{3\},\ \{1,2\}, \{1,3\}, \{2,3\},\ \{1,2,3\}\,\}$ 8

How many subsets are there of S, i.e., what is $|\mathcal{P}(S)|$?

$\{ 2 \cdot 2 \cdot 2 \}$

Power Sets

$\mathcal{P}(S) = \cancel{\{X : S \subseteq X\}}$ $\{X : X \subseteq S\}$

$\mathcal{P}(\{1,2,3\}) = \{\ \emptyset,\ \{1\}, \{2\}, \{3\},\ \{1,2\}, \{1,3\}, \{2,3\},\ \{1,2,3\}\ \}$

How many subsets are there of S, i.e., what is $|\mathcal{P}(S)|$?

If $S = \{e_1, e_2, \cdots, e_{|S|}\}$ $|S| = n$

Step 1: is e_1 in the subset?

Step 2: is e_2 in the subset?

…

Step $|S|$: is $e_{|S|}$ in the subset?

Total options: $2 \cdot 2 \cdots 2$, $|S|$ times, i.e., $\underline{2^{|S|}}$ 2^n

Baseball Outfits

The Husky baseball team has three hats (purple, black, gray)

Three jerseys (pinstripe, purple, gold)

Three pairs of pants (gray, white, black)

How many outfits are there (consisting of one hat, a jersey, and a pair of pants) if we have the following constraints:

- The pinstripe jersey cannot be worn with gray pants ← 2
- The purple jersey cannot be worn with white pants ← 2
- The gold jersey cannot be worn with black pants ← 2

Baseball Outfits

Step 1: 3 choices for hats

Step 2: 3 choices for jerseys

Step 3: 3 choices for pants???

Baseball Outfits

$3 \cdot 3 \cdot 3 = 27$

Step 1: 3 choices for hats

Step 2: 3 choices for jerseys

Pinstripe + gray $\quad 3 \cdot 1 \cdot 1 \;|\; 3 \cdot 1 \cdot 1 \;|\; 3 \cdot 1 \cdot 1$

~~Step 3: 3 choices for pants???~~

Step 3: 2 choices for pants as we have 2 options for pants regardless of the jersey we choose (even though there are 3 options for pants overall)

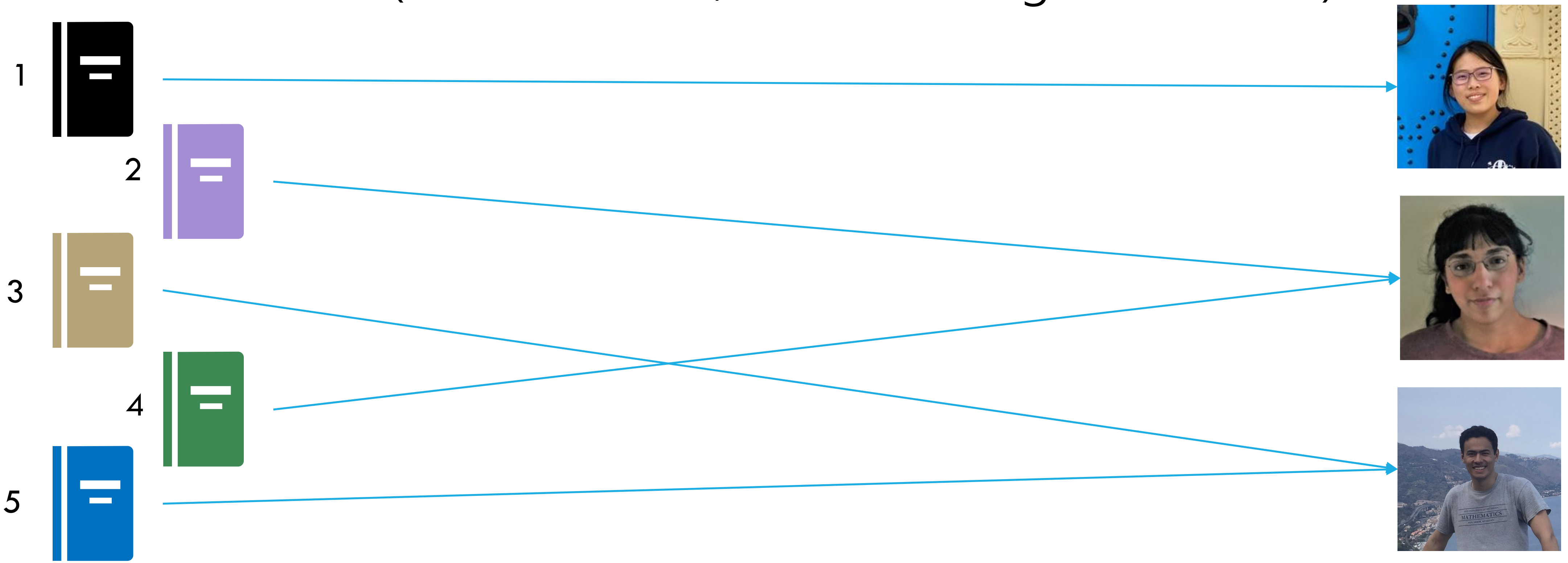
$3 \cdot 3 \cdot 2 = 18$

$27 - 3 - 3 - 3 = 18$

Assigning books

We have 5 books to split among 3 people (Alice, Claris, and Pascal)

Every book goes to exactly one person, but each person could end up with no books (or all of them, or something in between).



Assigning books

We have 5 books to split among 3 people (Alice, Claris, and Pascal)

Every book goes to exactly one person, but each person could end up with no books (or all of them, or something in between).

$A \Rightarrow \{1, 2, 3, 4, 5\}$

$\{1, 2\}$ ...

Attempt 1: We are choosing subsets!

Alice could get any of the $2^5 = 32$ subsets of books.

Claris could get any of the $2^5 = 32$ subsets of books.

Pascal could get any of the $2^5 = 32$ subsets of books.

The total is the product of the three steps: $32 \cdot 32 \cdot 32 = 32768$ assignments

Activity: Assigning books

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Introduce yourselves!

- If you can turn on your video, please do.
- If you can't, please unmute and say hi.
- If you can't do either, please say hi in chat.

Choose someone to share screen, showing this slide

Fill out the Poll Everywhere for Kushal to adjust his explanation
Go to pollev.com/cse312su21

Activity: Assigning books

Attempt 1: We are choosing subsets!

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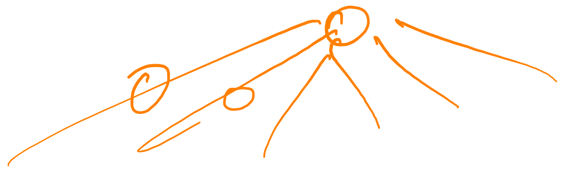
$\{3,4,5\} - 2^3$ $\quad 2^5 \cdot 2^5 \cdot 2^5$

We overcounted!

If Alice gets books 1 and 2, Claris cannot get a subset of all 5 books, she can only get a subset of books {3,4,5}. Finally, Pascal can only be assigned what is leftover after Alice and Claris get their books

Fixing the Assignment!



We **could**

List out all the options for Alice. 2^5

For each of the above options, list out the possible options for Claris and Pascal

Use the Summation rule to combine

OR

We could come at the problem from a different angle.

Fixing the Assignment!

Instead of figuring out which books Alice gets, choose book by book which person they go to.

Step 1: Book 1 has 3 options
Step 2: Book 2 has 3 options
...
Step 5: Book 5 has 3 options

The total is the product of the five steps: $3 \cdot 3 \cdot 3 \cdot 3 \cdot 3 = 3^5 = 243$ assignments

Lesson and Tips

Representation of what we are counting is very important!

- Use different methods to double check your solution
- Think about counter examples to your own solution

$32 \cdot 32 \cdot 32$

More Practice

Strings

How many strings of length 5 are there over the alphabet $\{A, B, C, \dots, Z\}$? (repeated characters allowed)

E.g., **LINDY, SALSA, SWING, TANGO, WALTZ**

26^5

How many binary strings of length n are there?

E.g., $0 \cdots 0, 1 \cdots 1, 1 \cdots 01, \dots$

Strings

How many strings of length 5 are there over the alphabet $\{A, B, C, \ldots, Z\}$? (repeated characters allowed)

E.g., LINDY, SALSA, SWING, TANGO, WALTZ

26^5

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2^n