

EECS 498 System Design of a Search Engine

Winter 2025

Lecture 3: Project planning

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agenda

1. Course details.
2. Result quality.
3. Your project.
4. Project planning.

agenda

1. Course details.
2. Result quality (that we didn't get to last time.)
3. Your project.
4. Project planning.

details

1. Really hoping everyone can find a team by this weekend.
2. Tell me the name of your team and your teammates by Sunday January 18, 11:59 pm.
3. Submit a group photo by Sunday January 25, 11:59 pm.
4. If you are joining late, I'll give you extensions to catch up on the previous assignments.
5. A final comment on MostPositiveSubsequence perf.
6. Mascot suggestions.

```

int ImprovedBenchmark( int a[ ], int n, int &bestL, int &bestR )
{
    assert( n );
    int sum, bestSum, L, R;
    bestSum = a[ 0 ];
    bestL = bestR = 0;

    for ( L = R = sum = 0; R < n; )
    {
        sum += a[ R ];
        if ( sum > bestSum ||
            sum == bestSum && R - L < bestR - bestL )
        {
            bestL = L;
            bestR = R;
            bestSum = sum;
        }
        R++;
        if ( sum <= 0 )
        {
            sum = 0;
            L = R;
        }
    }
    return bestSum;
}

```

*Can this be improved with
local variables?*

```

Student ticks    = 240777
Benchmark ticks = 304328
Ratio            = 0.791176
Perf limit       = 1.1
Performance is okay
Test succeeded

```

```

int ImprovedLocals( int a[ ], int n, int &bestL, int &bestR )
{
    assert( n );
    int sum, bestSum, L, R, bL, bR;
    bestSum = a[ 0 ];
    bL = bR = 0;

    for ( L = R = sum = 0; R < n; )
    {
        sum += a[ R ];
        if ( sum > bestSum ||
            sum == bestSum && R - L < bR - bL )
        {
            bL = L;
            bR = R;
            bestSum = sum;
        }
        R++;
        if ( sum <= 0 )
        {
            sum = 0;
            L = R;
        }
    }

    bestL = bL;
    bestR = bR;
    return bestSum;
}

```

It's not faster.

```

Student ticks    = 303140
Benchmark ticks  = 295698
Ratio            = 1.02517
Perf limit       = 1.1
Performance is okay
Test succeeded

```

homework

1. This weekend's Gantt chart assignment asks you to create a plan to apply to graduate school. Yes, I have an agenda.
2. This is your last individual homework assignment other than voting on stuff.

We need a cartoon mascot for a class tee shirt. What animal should it be?

The -121 Section

Burmese Rescue Dog

Fat Squirrel

Eagle

C++ Mascot (a Rat)

Hawk

Spider

Lady bug

Octopus

The -051 Section

Road Runner

Panda

Cute spider

Raccoon

Owl

Cheetah

Mole peeking out of a hole

Golden retriever

We'll turn this into a survey. Let you pick your top 3. Perhaps a runoff if we don't have a clear winner.

agenda

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result quality

To be useful as a search engine, it must produce good results quickly.

result quality

Traditional measures:

Precision The fraction of the results that are relevant.

Recall The fraction of all relevant results returned.

result quality

And because it matters that the top results be the best:

Relevance An estimate of the overall quality of the page as an result for this query that can be used for *ranking* (ordering) the results.

ranking: pick the best

Brand + Model		Overall Score	Price	Survey Results		Test Results		Features + Specs									
				Predicted reliability	Owner satisfaction	Sound quality	Noise reduction	Type	Design	Sports model	Ambient sound monitoring	Works with noise reduction off	Integrated volume control	Integrated player control	Integrated microphone	Call connect, disconnect control	Detachable cable
				NOISE-CANCELING WIRELESS OVER-EAR & ON-EAR HEADPHONES													
✓	Apple AirPods Max	79	\$550	⬆	⬆	⬆	⬆	Over-ear	Closed		•	•	•	•	•	•	•
✓	Bang & Olufsen Beoplay HX	78	\$750	⬆	⬆	⬆	⬆	Over-ear	Closed		•	•	•	•	•	•	•
✓	Sonos Ace	77	\$450	—	—	⬆	⬆	Over-ear	Closed		•	•	•	•	•	•	•
✓	Apple AirPods Max (USB-C)	77	\$530	⬆	⬆	⬆	⬆	Over-ear	Closed		•	•	•	•	•	•	•
✓	Bowers & Wilkins Px7 S2e	77	\$400	⬆	⬆	⬆	⬆	Over-ear	Closed		•	•	•	•	•	•	•
✓	Bowers & Wilkins PX7 S2	77	\$200	⬆	⬆	⬆	⬆	Over-ear	Closed		•	•	•	•	•	•	•
✓	Dyson OnTrac	76	\$500	—	—	⬆	⬆	Over-ear	Closed		•	•	•	•	•	•	•
✓	Bose QuietComfort Wireless Noise Cancelling	76	\$360	⬆	⬆	⬆	⬆	Over-ear	Closed		•	•	•	•	•	•	•
✓	Bose QuietComfort Ultra Headphone	76	\$450	⬆	⬆	⬆	⬆	Over-ear	Closed		•	•	•	•	•	•	•
✓	Sony WH-1000XM4	75	\$300	⬆	⬆	⬆	⬆	Over-ear	Closed		•	•	•	•	•	•	•
✓	Sony WH-1000XM5	73	\$400	⬆	⬆	⬆	⬆	Over-ear	Closed		•	•	•	•	•	•	•
✓	Beats by Dre Beats Studio Pro	73	\$250	⬆	⬆	⬆	⬆	Over-ear	Closed		•		•	•	•	•	•
✓	Cleer Alpha	72	\$200	—	—	⬆	⬆	Over-ear	Closed		•	•	•	•	•	•	•
💰	Soundcore Life Q20	72	\$60	—	—	⬆	⬆	Over-ear	Closed			•	•	•	•	•	•
💰	Soundcore Q20i Hybrid Active Noise Cancelling	72	\$70	—	—	⬆	⬆	Over-ear	Closed		•	•	•	•	•	•	•
✓	Sennheiser Momentum 4 Wireless	71	\$450	⬆	⬆	⬆	⬆	Over-ear	Closed		•	•	•	•	•	•	•
✓	Sennheiser Accentum	71	\$190	⬆	⬆	⬆	⬆	Over-ear	Closed		•	•	•	•	•	•	•
✓	Sennheiser Accentum Plus	71	\$225	⬆	⬆	⬆	⬆	Over-ear	Closed		•	•	•	•	•	•	•
💰	JBL Live 660NC	71	\$70	⬆	⬆	⬆	⬆	Over-ear	Closed		•	•	•	•	•	•	•
💰	JBL Tune 660NC	71	\$70	⬆	⬆	⬆	⬆	On-ear	Closed			•	•	•	•	•	•
✓	Puro Sound Labs PuroPro	71	\$150	—	—	⬆	⬆	Over-ear	Closed			•	•	•	•	•	•

kinds of rank

Dynamic rank

How good a match this page is to this specific query.

Static rank

How good the page is, knowing nothing about the query.

static rank

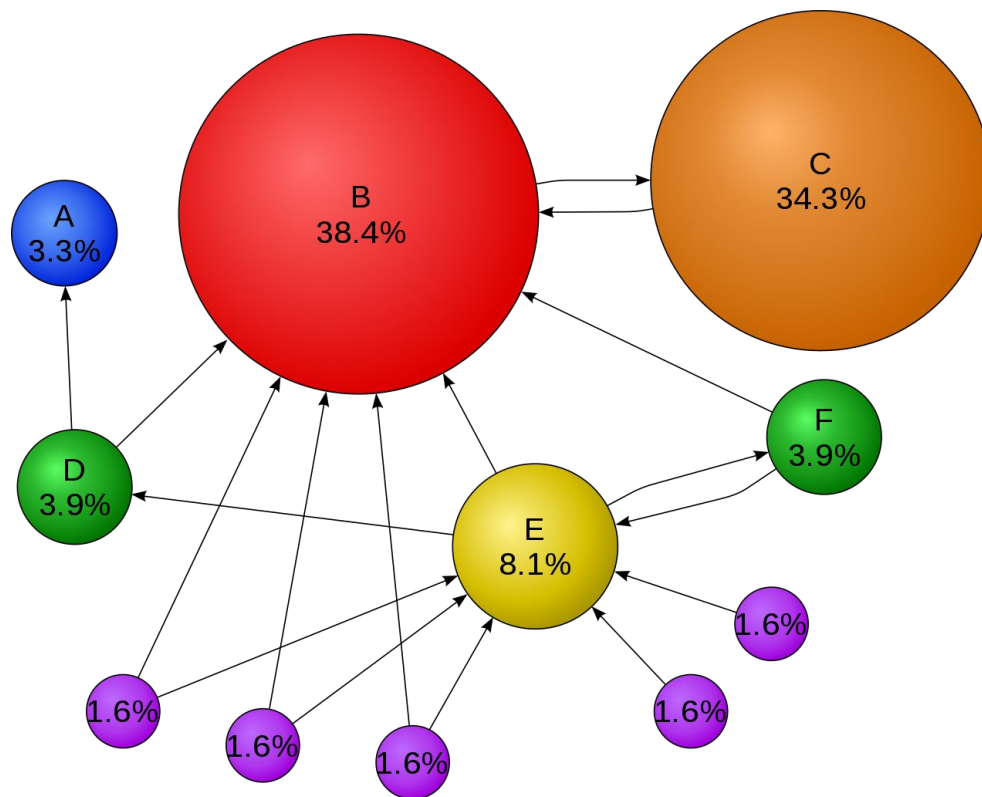
Some pages are just better than others before you know anything about the query.

static rank

1. Some domains are better than others, e.g., .gov or .edu over .biz.
2. Short URLs are better.
3. Short titles are probably better.
4. Some pages may be obvious spam.
5. Some pages may have lots of other pages pointing to them, e.g., PageRank.

PageRank

The basic idea: The more and better links to a page, the more likely it should rank higher.



PageRank

It obviously did work and they got better results.

It also gave halo of special legitimacy to their results, that they were scientific and unbiased.

at Microsoft

We gamely expected our version of PageRank to represent about half the overall rank value, largely based on the hype around it.

Turned out it was very expensive to calculate and represented only a small part of the final rank score.

dynamic rank

Estimate the quality of match between the page and the query.

Traditional methods in information retrieval considered the page as a *bag of words* and ostensibly measured the *mathematical* or *statistical similarity*.

For example, one method claimed to consider the *document and the query as vectors* and to calculate the *angle between them*.

bag of words

A scoring method that considers only that the search words occur in the document, not where or in what relation to each other.

tf-idf

Term-frequency, inverse document frequency.

Easily the most famous bag of words technique. The more occurrences of a rare word, the better.

Problem is, it doesn't work on the web.

bag of words

Here's a sample NY Times page from Jan 25, 2021.

The New York Times - Breaking News x +

File | C:/Users/hamil/Google%20Drive/eecs440/ExampleCode/HtmlParserSolution/nytimes.html

Seattle PI WSJ WSJ NY Times WaPost Canvas Course Info Center Crappy Scheduler BofA Wikipedia GSI/IA Applications Student evals Patents Other bookmarks

U.S. INTERNATIONAL CANADA ESPAÑOL 中文

The New York Times

Monday, January 25, 2021
Today's Paper

29°F 31° 26°
Nasdaq -0.02% ↓

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The Daily Listen to 'The Daily' Impeached, again.

The Book Review Podcast Charles Yu on his National Book Award-winning novel, "Interior Chinatown."

The Argument Listen to 'The Argument' Jane Coaston loves Section 230. Got a problem with that?

LIVE

Fractures in G.O.P. Widen After Impeachment Vote

- Some House Republicans have called on Representative Liz Cheney to resign from her leadership post after she voted to impeach President Trump.
- Ms. Cheney was one of 10 Republicans to break with the party on the vote, setting up a messy internal feud that could define its future.



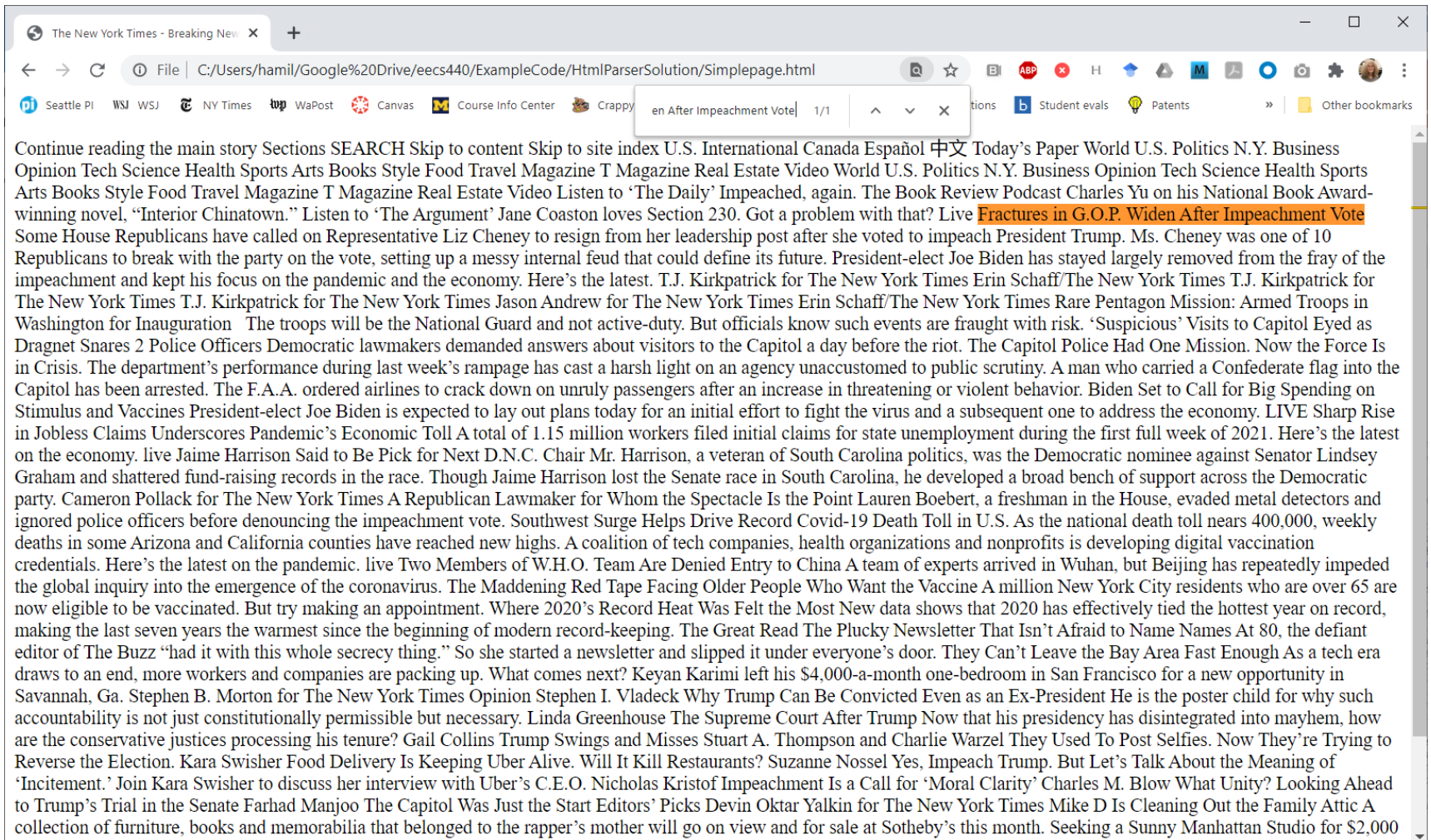
'Suspicious' Visits to Capitol Eyed as Dragnet Snares 2 Police Officers

Democratic lawmakers demanded answers about visitors to the Capitol a day before the riot.

<https://www.nytimes.com/2021/01/08/books/review/podcast-charles-yu-interior-chinatown-david-brown-henry-adams-last-american-aristocrat.html>

bag of words

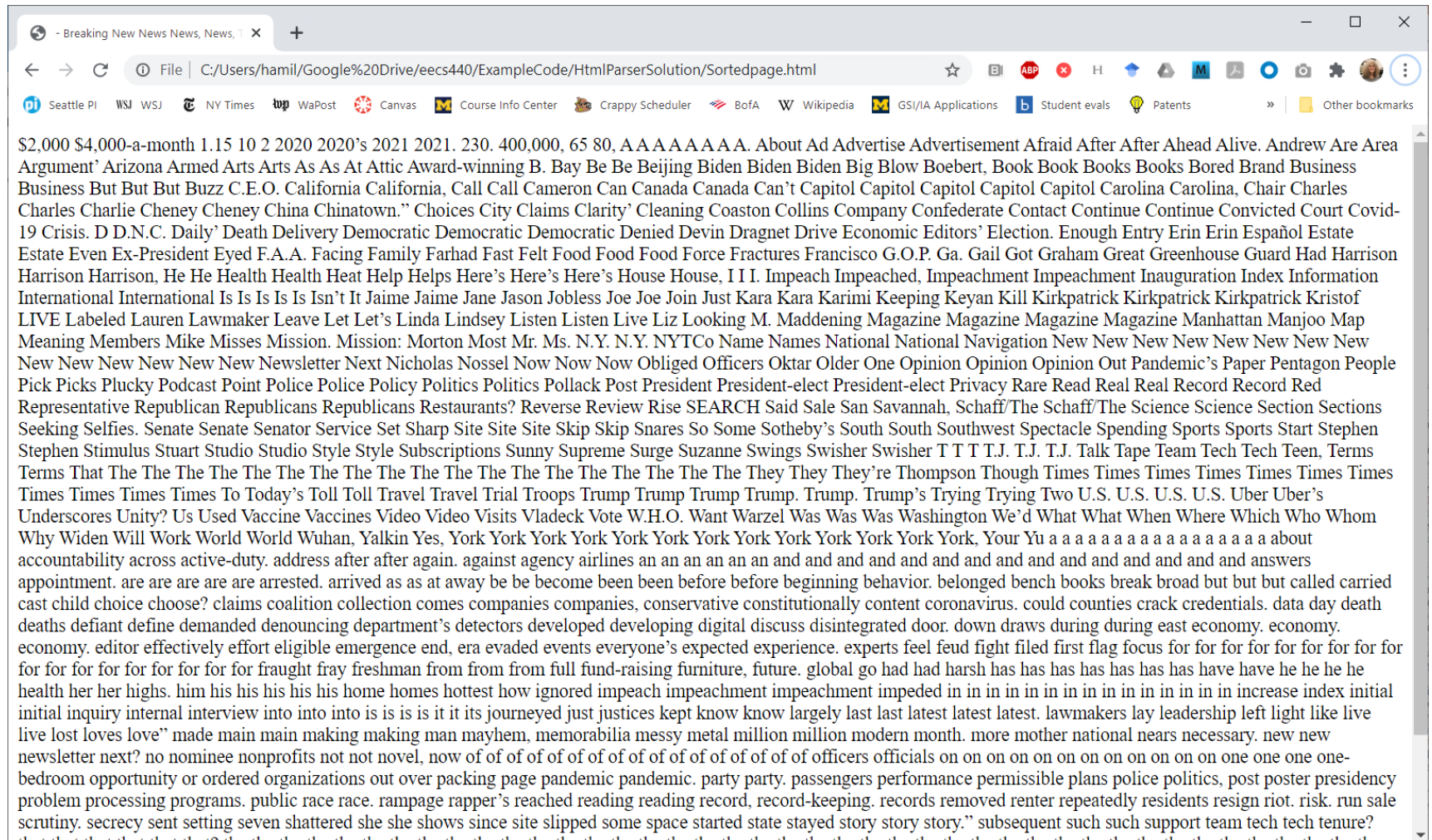
Here it is stripped of HTML and CSS but the text remains.



The screenshot shows a web browser window with a single tab titled "The New York Times - Breaking News". The address bar displays the file path: "C:/Users/hamil/Google%20Drive/eecs440/ExampleCode/HtmlParserSolution/Simplepage.html". The browser's bookmark bar is visible, containing links to Seattle PI, WSJ, NY Times, WaPost, Canvas, Course Info Center, and Crappy. The main content area of the browser shows a list of search results or a table of contents, with the following items visible: "Continue reading the main story", "Sections", "SEARCH", "Skip to content", "Skip to site index", "U.S. International Canada Español 中文", "Today's Paper", "World U.S. Politics N.Y. Business Opinion Tech Science Health Sports Arts Books Style Food Travel Magazine T Magazine Real Estate Video World U.S. Politics N.Y. Business Opinion Tech Science Health Sports Arts Books Style Food Travel Magazine T Magazine Real Estate Video Listen to 'The Daily' Impeached, again. The Book Review Podcast Charles Yu on his National Book Award-winning novel, 'Interior Chinatown.' Listen to 'The Argument' Jane Coaston loves Section 230. Got a problem with that? Live Fractures in G.O.P. Widen After Impeachment Vote". The text "Fractures in G.O.P. Widen After Impeachment Vote" is highlighted in orange. Below this list, the main body of the page contains a large block of text, which is a transcription of the HTML content, stripped of all HTML and CSS tags. The text begins with "Some House Republicans have called on Representative Liz Cheney to resign from her leadership post after she voted to impeach President Trump. Ms. Cheney was one of 10 Republicans to break with the party on the vote, setting up a messy internal feud that could define its future. President-elect Joe Biden has stayed largely removed from the fray of the impeachment and kept his focus on the pandemic and the economy. Here's the latest. T.J. Kirkpatrick for The New York Times Erin Schaff/The New York Times T.J. Kirkpatrick for The New York Times T.J. Kirkpatrick for The New York Times Jason Andrew for The New York Times Erin Schaff/The New York Times Rare Pentagon Mission: Armed Troops in Washington for Inauguration The troops will be the National Guard and not active-duty. But officials know such events are fraught with risk. 'Suspicious' Visits to Capitol Eyed as Dragnet Snares 2 Police Officers Democratic lawmakers demanded answers about visitors to the Capitol a day before the riot. The Capitol Police Had One Mission. Now the Force Is in Crisis. The department's performance during last week's rampage has cast a harsh light on an agency unaccustomed to public scrutiny. A man who carried a Confederate flag into the Capitol has been arrested. The F.A.A. ordered airlines to crack down on unruly passengers after an increase in threatening or violent behavior. Biden Set to Call for Big Spending on Stimulus and Vaccines President-elect Joe Biden is expected to lay out plans today for an initial effort to fight the virus and a subsequent one to address the economy. LIVE Sharp Rise in Jobless Claims Underscores Pandemic's Economic Toll A total of 1.15 million workers filed initial claims for state unemployment during the first full week of 2021. Here's the latest on the economy. live Jaime Harrison Said to Be Pick for Next D.N.C. Chair Mr. Harrison, a veteran of South Carolina politics, was the Democratic nominee against Senator Lindsey Graham and shattered fund-raising records in the race. Though Jaime Harrison lost the Senate race in South Carolina, he developed a broad bench of support across the Democratic party. Cameron Pollack for The New York Times A Republican Lawmaker for Whom the Spectacle Is the Point Lauren Boebert, a freshman in the House, evaded metal detectors and ignored police officers before denouncing the impeachment vote. Southwest Surge Helps Drive Record Covid-19 Death Toll in U.S. As the national death toll nears 400,000, weekly deaths in some Arizona and California counties have reached new highs. A coalition of tech companies, health organizations and nonprofits is developing digital vaccination credentials. Here's the latest on the pandemic. live Two Members of W.H.O. Team Are Denied Entry to China A team of experts arrived in Wuhan, but Beijing has repeatedly impeded the global inquiry into the emergence of the coronavirus. The Maddening Red Tape Facing Older People Who Want the Vaccine A million New York City residents who are over 65 are now eligible to be vaccinated. But try making an appointment. Where 2020's Record Heat Was Felt the Most New data shows that 2020 has effectively tied the hottest year on record, making the last seven years the warmest since the beginning of modern record-keeping. The Great Read The Plucky Newsletter That Isn't Afraid to Name Names At 80, the defiant editor of The Buzz "had it with this whole secrecy thing." So she started a newsletter and slipped it under everyone's door. They Can't Leave the Bay Area Fast Enough As a tech era draws to an end, more workers and companies are packing up. What comes next? Keyan Karimi left his \$4,000-a-month one-bedroom in San Francisco for a new opportunity in Savannah, Ga. Stephen B. Morton for The New York Times Opinion Stephen I. Vladeck Why Trump Can Be Convicted Even as an Ex-President He is the poster child for why such accountability is not just constitutionally permissible but necessary. Linda Greenhouse The Supreme Court After Trump Now that his presidency has disintegrated into mayhem, how are the conservative justices processing his tenure? Gail Collins Trump Swings and Misses Stuart A. Thompson and Charlie Warzel They Used To Post Selfies. Now They're Trying to Reverse the Election. Kara Swisher Food Delivery Is Keeping Uber Alive. Will It Kill Restaurants? Suzanne Nossel Yes, Impeach Trump. But Let's Talk About the Meaning of 'Incitement.' Join Kara Swisher to discuss her interview with Uber's C.E.O. Nicholas Kristof Impeachment Is a Call for 'Moral Clarity' Charles M. Blow What Unity? Looking Ahead to Trump's Trial in the Senate Farhad Manjoo The Capitol Was Just the Start Editors' Picks Devin Oктar Yalkin for The New York Times Mike D Is Cleaning Out the Family Attic A collection of furniture, books and memorabilia that belonged to the rapper's mother will go on view and for sale at Sotheby's this month. Seeking a Sunny Manhattan Studio for \$2,000

bag of words

Here it is with the words in the title and body sorted. Tf-idf can't tell the difference.



at Microsoft

At Microsoft, we separated the occurrences into four metastreams, in order of importance.

1. Anchor text.
2. URL.
3. Title.
4. Body text.

heuristics

1. Pick the rarest word in the query, then iterate over its occurrences on the page.
2. At each place, move the pointers to the other words to as close to the correct relative position as possible.
3. Score that that set, called a *span*, counting the number of spans, the number of exact phrases, in order, close together, etc.
4. Score the counts, weighting exact phrases the title as more important than other matches.

heuristics

Altogether, had about 700 heuristics in a linear combination.
Tuned them using gradient descent and approximately 150K labeled pages and queries.

But W25, several teams got great results hand-tuning with only about 12 to 20 heuristics using this algorithm.

what we found

Finding the search words in the right order and close together was more important than simply finding lots of them.

Added tf-idf because under pressure that of course we should consider it. Removed it because it added nothing to our relevance but slowed our crawl.

It mattered a lot where we found the matching terms.

Anchor > URL > Title > Body text

agenda

1. Course details.
2. Result quality.
3. **Your project.**
4. Project planning.

overall plan

1. Get you crawling ASAP on your laptops.
2. Cover the OS topics you'll need.
3. Explain how each piece works just in time for you to build it, starting with the crawler.
4. Get your engines working on the cloud.

Your project

I've broken your engines into 9 slightly arbitrary levels of functionality:

- 0 Basic plan for your project.
- 1 Parse text files into a hash table.
- 2 Build a crawler.
- 3 Build a reverse word index.
- 4 Create a user interface.
- 5 Build a constraint solver and query parser.
- 6 Build a ranker.
- 7 Deploy on the cloud.
- 8 Advanced functionality.

level 0: create a plan

1. Decide what information you'll collect.
2. Decide whether to keep a copy of every document you crawl and index.
3. Estimate the required storage and when will you need it.
4. Break the problem down into pieces. Decide (guess!) what each piece does, how it works, and the LOC required.
5. Decide how you'll work as a team, meetings, source control, common libraries, etc.
6. Prepare a written plan (which you will submit) with deliverables, milestones, responsibilities, and a schedule.

level 1: parse text files into a hash table

1. Parse text files into tokens, stripping out most HTML but identifying links and anchor text.
2. Create a hash table as a memory-mapped index on disk of the parsed content.
3. Given a search word, list the occurrences by searching the index.

level 2: build a crawler

1. Given a list of URLs, retrieve the documents by HTTP and HTTPS, following redirects.
2. Create a crawler to manage a frontier of URLs to be explored, eliminating URLs already seen.
3. Ensure it can be restarted.
4. Decide what makes one URL better than another. Be polite.
5. Define a seed list to start crawling.
6. Parallelize the tasks of crawling, parsing and index build.

level 3: build a reverse word index

1. Define a file format. Decide how you will merge multiple index files.
2. Decide how you will structure and encode your data.
3. Decide how to number locations across documents. Accumulate useful statistics.
4. Demonstrate you can build the index.
5. Demonstrate you read the index.
6. Create index stream readers for words and documents.

level 4: create a user interface

1. Initially, a simple command line interface.
2. Later, a simple HTTP server to act as a wrapper UI.
3. Allow the user to enter a query and get a response.
4. Report title, clickable URL, possibly other interesting information for matching pages.

level 5: constraint solver and query parser

1. Create a basic index stream reader for an individual words and document boundaries.
2. Create derived stream readers for AND, OR, phrase and NOT.
3. Build a top-down recursive descent parser to compile queries into index stream readers.
4. Demonstrate the ability to find the next document matching a query.

level 6: build a ranker

1. Hopefully, something better than a bag-of-words technique.
2. Rank using static attributes of the page, e.g., length of the URL, number of words on the page, length of the title.
3. Rank using heuristics or other means that consider the quality of match, e.g., exact phrases, words found in the title or URL, etc.
4. Demonstrate ability to produce a useful “10 best” list of search results.

level 7: deploy on the cloud

1. Distribute crawling, indexing. and query processing across a small network of cloud machines.

Level 7: Advanced functionality

Examples:

1. Support anchor text.
2. Index PDFs.
3. Create a snippet to go with a reported hit.
4. Implement PageRank.
5. Achieve 3 second response.
6. Support stemming and stop words.
7. Create a training set and use it to improve your ranker.
8. Rank using a neural net or other ML technique.

project plan

Your plan is due February 1, 2026. Here are some things to consider.

1. Your project plan must satisfy functionality level 0.
2. Presentation April 12.
3. Final report by April 21.
4. Team debrief with me by April 28.

project plan

5. Your title page must include your group photo.
6. Identify your group and tell me about yourselves.
7. Briefly outline how your group formed and how you expect to work together as a group.

project plan

8. Outline your basic technical strategy.
9. Identify what information you expect collect, how much storage you'll need at each stage, and where you'll get it.
10. Break your engine down into major pieces, list what each will do, and identify the inputs and outputs.

project plan

11. If you can, identify which pieces will run as separate processes or threads or on different or multiple machines, which will need to be restarted after a crash, etc.
12. Create a high-level diagram of your engine.
13. Estimate the lines of code you think you may be needed for each piece and who will do it.

project plan

Due February 14, 2021

14. Create a Gantt chart of the activities.
15. Identify a major milestone you expect to achieve before leaving for spring break.
16. Identify what you expect to have at the milestone and in your final product.

organizing your team

1. Success on this project is critically tied to your ability to work cooperatively and effectively as a team.
2. You will need to come to decisions quickly and they will need to be based on consensus, not who's in charge.
3. You will need to involve everyone all the time. You will all need to step up to do right by your teams.
4. Decide how you'll organize the work, e.g., should everyone test their own code or do you test each others'?
5. Check in often.
6. Questions? Pitfalls?

agenda

1. Course details.
2. Search basics: Ranking
3. Your project.
4. **Project planning.**

Problem-solving versus problem-choosing

A fabulous solution to a problem nobody cares about is still a solution nobody cares about.

But even a mediocre solution to a really important problem can be important.

A lot of *problem-solving* is coming up with ideas of how to do something.

A lot of *problem-choosing* is deciding *what you won't do*.

A lot of making it actually happen is *planning*.

planning

Planning in industry is usually done in two parts:

1. A business plan or market requirements document (MRD) defines the objectives and why they're worthwhile.
2. A project plan describes how the objectives will be achieved.

Usually starts with an opportunity.

project planning

1. Decide your objectives.
2. Decompose it into pieces.
3. Estimate the size of each piece and how you'll do it.
4. Layout a timeline for the project.
5. Specify deliverables and milestones with *exit criteria*.
6. Measure your progress against the plan.

What is the biggest difference between a big software project and a little one?

The number of lines of code.

decomposition

To plan a complex project, you break it down into understandable pieces.

You may not know how to do each piece but you can try to list them.

decomposition

To plan a complex project, you break it down into understandable pieces.

You may not know how to do each piece but you can try to list them.

You keep doing this recursively.

When a piece is small enough, you estimate the LOC it will require.

Add up the pieces, use that to decide how long it will take.

Gantt charts

Project timelines usually laid out a Gantt chart, named after the inventor, Henry Gantt (1861 to 1919).

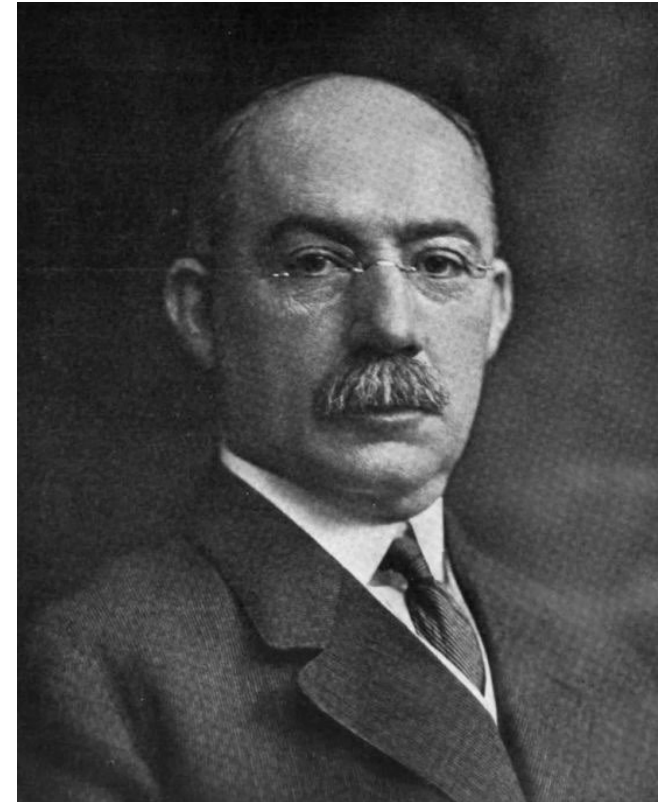


Image source: https://en.wikipedia.org/wiki/Henry_Gantt#/media/File:Henry_L._Gantt.jpg

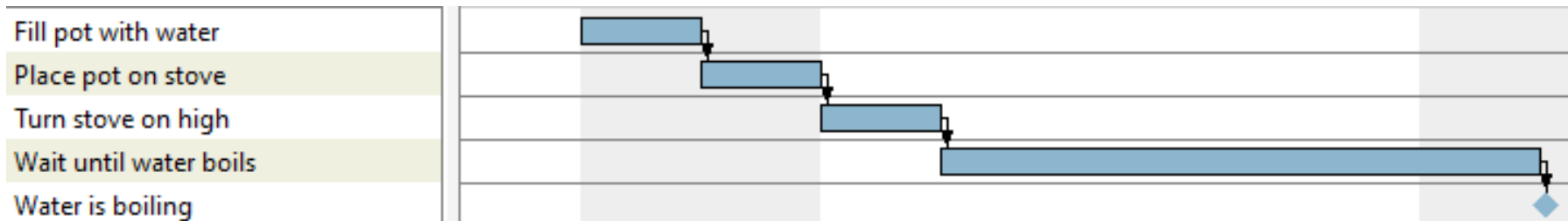
Gantt charts

Bar chart showing a project schedule.

Tasks listed vertically, horizontal axis is time.

Bars represent the duration of each task.

Example project: Boiling water

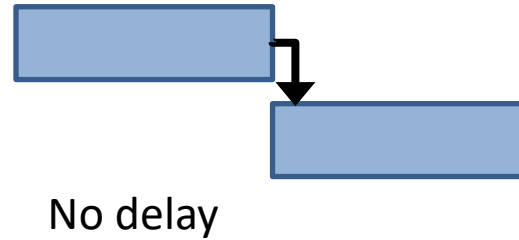


Most popular project planning software is Microsoft Project but it's not free.

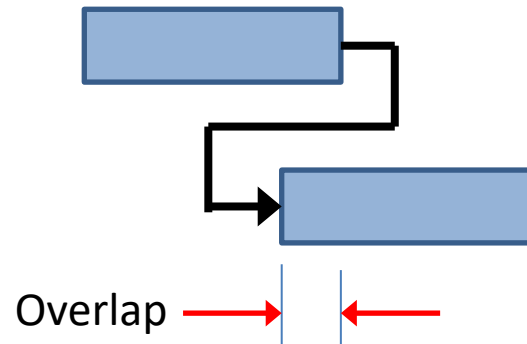
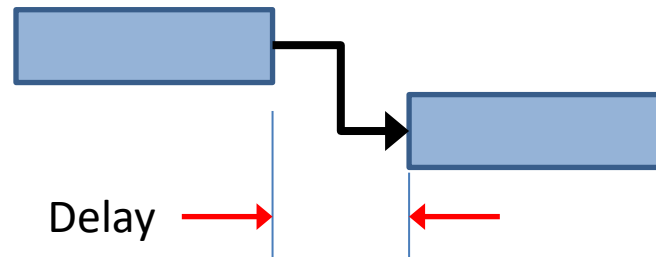
A good free alternative is GanttProject from <https://www.ganttproject.biz/>.

dependencies

Dependencies between tasks are represented by arrows between them.

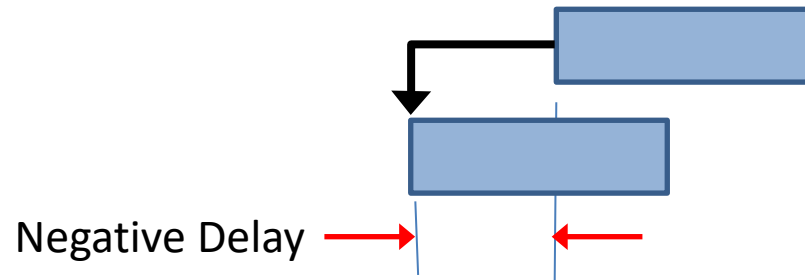
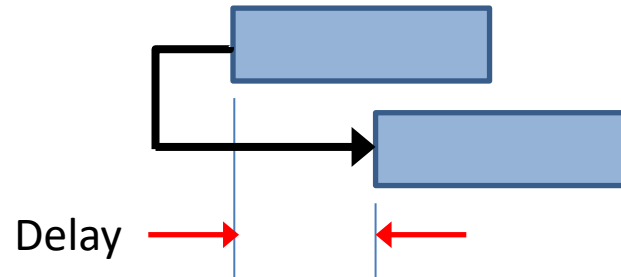
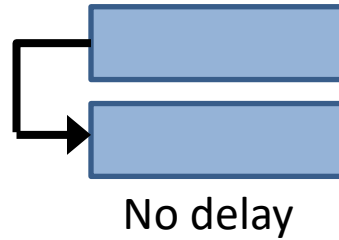


Shown here: Finish-to-start dependencies.



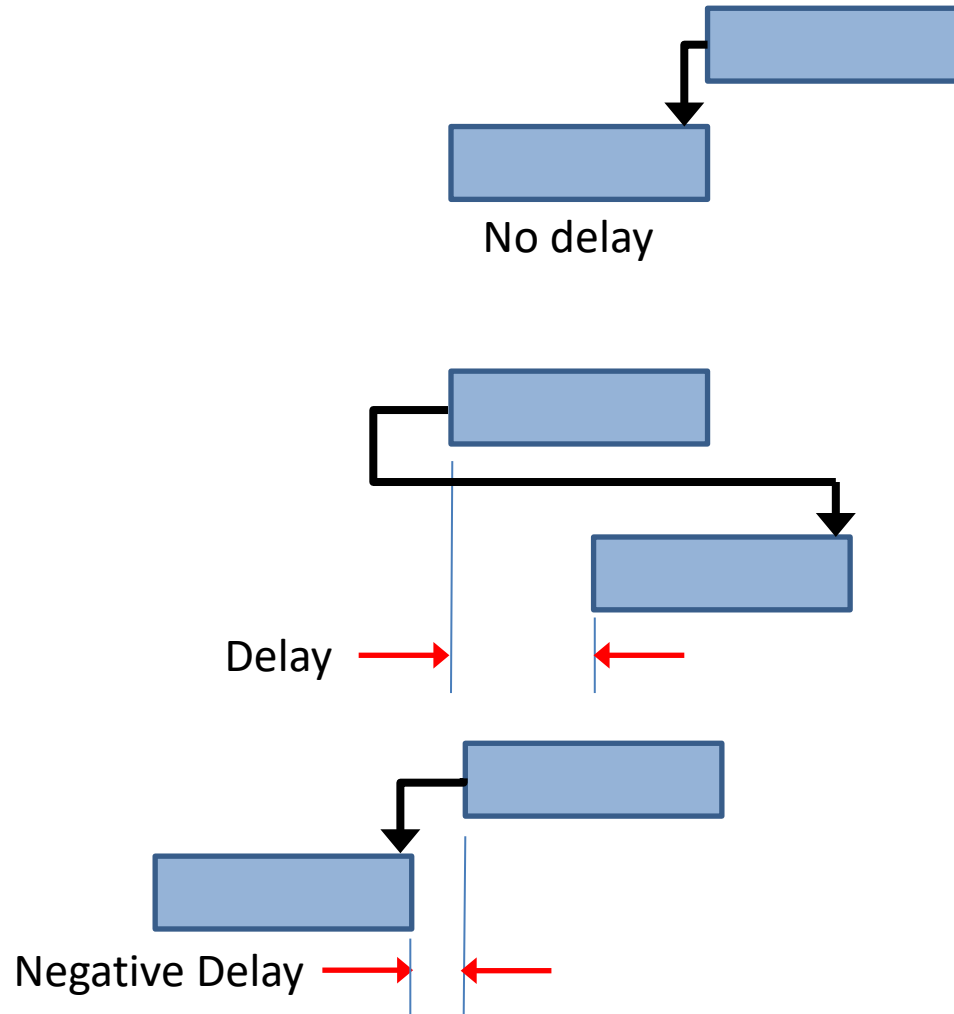
Dependencies

Start-to-start dependencies.



dependencies

Start-to-finish
dependencies.

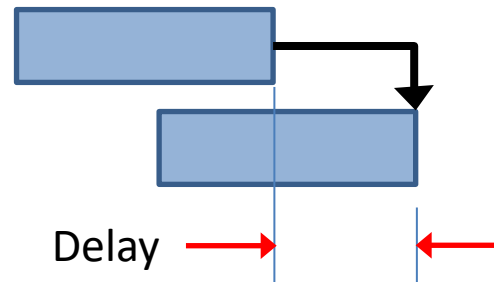


dependencies

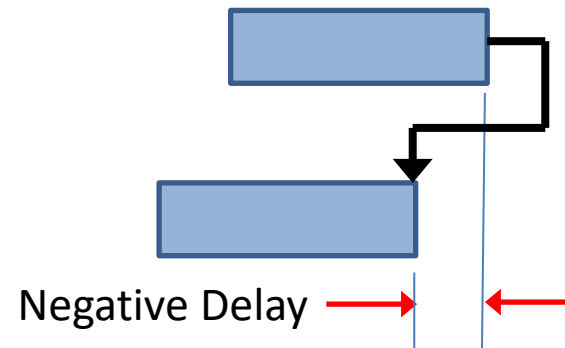
Finish-to-finish dependencies.



No delay



Delay



Negative Delay



Gantt

Resources Chart



Zoom In

Zoom Out



Name

Begin date▲

End date

Gather names of contractors

1/16/25

1/16/25

Arrange meetings

1/17/25

1/17/25

Review bids

1/20/25

1/20/25

Pick materials

1/21/25

1/21/25

Choose a contractor

1/21/25

1/21/25

Work starts

1/22/25

1/22/25

January 2025

15

16

17

20

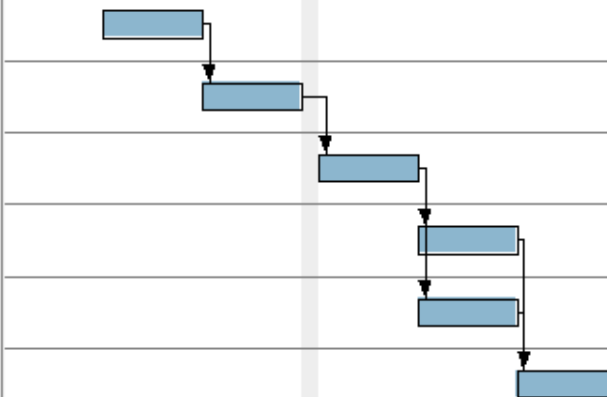
21

22

23

24

27



Cloud: disconnected

RSS

Warning

Errors

an exercise

You've been invited to a job interview in Mountain View, CA. They've given you several possible dates and asked that you make your own travel arrangements, which they will reimburse. Draw a sensible Gantt chart of the following activities.

Book a flight and a hotel.

Catch an Uber to the airport.

Decide what day is best.

Pack your bags.

To keep your chart simple and easy for us to grade, draw it simply as boxes and arrows with the one-word name of the activity ***inside*** each box.

Spoiler alert

The next page contains a solution.

Did you get something like this?

