

CS245: Databases

Introduction

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Syllabus

Using DBMS as a black box

- ER model
- Relational model and algebras
- SQL
- Normalization

Syllabus

Internals of relational DBMS

- File organizations
- Indexing (tree, hash, and bitmap)
- Implementation of relational operators

Syllabus

Transaction management

- ACID properties
- Concurrency control
- Crash recovery

Syllabus

Non-relational DBMS

- When time permits
- Consistency and availability trade-offs
- NoSQL databases (key-value, document, and graph)

Text Books

- R. Ramakrishnan and J. Gehrke **Database Management Systems**, McGraw Hill, 2014
- H. Garcia-Molina, J. Ullman, J. Widom, **Database System: The Complete Book**, 2nd Edition, Pearson, 2013

Introduction

- Integral part of our day-to-day life
- Sometimes we have not paid close attention while interacting with the database systems
- Examples

Example - 01

List of courses

List of Courses Offered in the Winter Semester (Jan-May), 2022

| S. No. | Course No. | Course Title | L | T | P | C | Type of Course | Offered to | Exam Slot | Exam Date and Time | Name(s) of Course Instructor(s) |
|--------|------------|---|---|---|---|---|----------------|--|-----------|---------------------------|--|
| 1 | BT2026 | Molecular Biotechnology | 3 | 0 | 0 | 0 | Minor | B. Tech 4th semester | C | 10-05-2022 9:00 to 12:00 | Dr. Jayashree B.C |
| 2 | BT205 | Microbiology | 3 | 0 | 0 | 0 | Compulsory | B. Tech 4th semester | D | 07-05-2022 9:00 to 12:00 | Dr. Kumar Narayana, Dr. Asha Sengupta |
| 3 | BT207 | Genetic Engineering | 3 | 0 | 0 | 0 | Compulsory | B. Tech 4th semester | C | 06-05-2022 9:00 to 12:00 | Dr. Purna Sengupta, Dr. Kumar Saitin |
| 4 | BT209 | Transport Phenomena (Bioprocesses) | 3 | 1 | 1 | 0 | Compulsory | B. Tech 4th semester | A | 04-05-2022 9:00 to 12:00 | Dr. Banerjee |
| 5 | BT209 | Biostatistics Engineering | 3 | 0 | 0 | 0 | Compulsory | B. Tech 4th semester | B | 05-05-2022 9:00 to 12:00 | Dr. Neel S.K |
| 6 | BT211 | Basic Biotechnology Lab | 0 | 0 | 0 | 0 | Compulsory | B. Tech 4th semester | | | Dr. Prasad T. |
| 7 | BT305 | Computational Biology | 2 | 0 | 2 | 0 | Compulsory | B. Tech 8th semester | A1 | 04-05-2022 14:00 to 17:00 | Dr. Rakeshkrishnan V. |
| 8 | BT305 | Biocomputing Engineering | 3 | 0 | 2 | 0 | Compulsory | B. Tech 8th semester | B1 | 05-05-2022 14:00 to 17:00 | Dr. Rakesh A., Dr. Soumik Palit |
| 9 | BT307 | Biological Data Analysis | 2 | 0 | 2 | 0 | Compulsory | B. Tech 8th semester | C1 | 06-05-2022 14:00 to 17:00 | Dr. Basu Bhattacharya |
| 10 | BT308 | Biengineering | 1 | 0 | 0 | 0 | Compulsory | B. Tech 8th semester | D1 | 07-05-2022 14:00 to 17:00 | Dr. Gouram Prabab, Dr. Nandita D. |
| 11 | BT402 | B.Tech Project-II | 0 | 0 | 0 | 0 | Compulsory | B. Tech 8th semester | | | Dr. Arun Debnath, Dr. Rajendra P. Baruipuram |
| 12 | BT403 | Human Biology and Diseases | 3 | 0 | 0 | 0 | Dept. Elective | B. Tech 8th semester | C | 08-05-2022 9:00 to 12:00 | Dr. Umaysa A. M., Dr. Kumar Narayana |
| 13 | BT411 | Metagenomics | 3 | 0 | 0 | 0 | Dept. Elective | B. Tech 8th semester | A | 04-05-2022 9:00 to 12:00 | Dr. Tamal K. Ray |
| 14 | BT412 | Evolutionary Biology | 3 | 0 | 0 | 0 | Dept. Elective | B. Tech 8th semester | D | 07-05-2022 9:00 to 12:00 | Dr. Gopal Asan |
| 15 | BT414 | Environmental Engineering | 3 | 0 | 0 | 0 | Dept. Elective | B. Tech 8th semester | E | 08-05-2022 9:00 to 12:00 | Dr. Basu Bhattacharya |
| 16 | BT420 | Drug Design and Discovery | 3 | 0 | 0 | 0 | Dept. Elective | B. Tech 8th semester | B | 05-05-2022 9:00 to 12:00 | Dr. Kanupriya S. P., Dr. Kumar Saitin |
| 17 | BT502 | Quantitative Biology | 3 | 0 | 2 | 0 | Compulsory | M. Tech. 2nd semester | A | 04-05-2022 9:00 to 12:00 | Dr. Kanupriya S. P., Dr. Umaysa A.M. |
| 18 | BT504 | Biomaterials and Cellular Process Engineering | 3 | 0 | 0 | 0 | Compulsory | M. Tech. 2nd semester | B | 05-05-2022 9:00 to 12:00 | Dr. Suprabhatam S. |
| 19 | BT505 | Applied Biology and Bioprocessing Lab | 0 | 0 | 0 | 0 | Compulsory | M. Tech. 2nd semester | | | Dr. Basu Bhattacharya |
| 20 | BT501 | Analytical Biotechnology | 3 | 0 | 0 | 0 | Dept. Elective | B. Tech 8th semester, M. Tech. 2nd semester, PhD | F | 09-05-2022 9:00 to 12:00 | Dr. Ghosh B.S. |
| 21 | BT505 | Gene Therapy | 3 | 0 | 0 | 0 | Dept. Elective | M. Tech. 2nd semester, PhD | G1 | 10-05-2022 14:00 to 17:00 | Dr. Nagasri Srikrishna |
| 22 | BT508 | Microbial Biotechnology | 3 | 0 | 0 | 0 | Dept. Elective | B. Tech 8th semester, M. Tech. 2nd semester, PhD | G | 10-05-2022 9:00 to 12:00 | Dr. Neeraj Goenka |
| 23 | BT509 | Bioprocess Engineering | 3 | 0 | 0 | 0 | Dept. Elective | M. Tech. 2nd semester, PhD | D | 07-05-2022 9:00 to 12:00 | Dr. Basu Bhattacharya |
| 24 | BT510 | Essentials of Genetics (OPEN ELECTIVE) | 3 | 0 | 0 | 0 | Open Elective | B. Tech 8th semester, M. Tech. 2nd semester, PhD | F1 | 06-05-2022 14:00 to 17:00 | Dr. Chaturvedi Ratna |
| 25 | BT521 | Advances in Plant Genetic Engineering and Functional Genomics | 3 | 0 | 0 | 0 | Dept. Elective | M. Tech. 2nd semester, PhD | C | 06-05-2022 9:00 to 12:00 | Dr. Kanupriya S.P. |
| 26 | BT522 | Botany | 3 | 0 | 0 | 0 | Dept. Elective | M. Tech. 2nd semester, PhD | A1 | 04-05-2022 14:00 to 17:00 | Dr. Pakshapati K. |
| 27 | BT530 | Physical Cell Biology (OPEN ELECTIVE) | 3 | 0 | 0 | 0 | Open Elective | B. Tech 8th semester, M. Tech. 2nd semester, PhD | C | 10-05-2022 9:00 to 12:00 | Dr. Anand B. |
| 28 | BT534 | Animal Models in Biomedical Research | 3 | 0 | 0 | 0 | Dept. Elective | M. Tech. 2nd semester, PhD | A1 | 04-05-2022 14:00 to 17:00 | Dr. Kurnarayana A.B. |
| 29 | BT539 | NMR Spectroscopy: Principles and Applications | 3 | 0 | 0 | 0 | Dept. Elective | M. Tech. 2nd semester, PhD | C | 06-05-2022 9:00 to 12:00 | Dr. Chaudhury Mir |
| 30 | BT540 | Neural Imaging and Signal Systems | 3 | 0 | 0 | 0 | Dept. Elective | M. Tech. 2nd semester, PhD | F | 06-05-2022 9:00 to 12:00 | Dr. Gupta Nevin |
| 31 | BT543 | Biointerface Engineering | 3 | 0 | 0 | 0 | Dept. Elective | M. Tech. 2nd semester, PhD | G1 | 10-05-2022 14:00 to 17:00 | Dr. Pandey Lalit |
| 32 | BT550 | M. Tech Project-II (MTP-II) | 0 | 0 | 0 | 0 | Compulsory | M. Tech. 4th semester | | | Dr. Pradyumn Singh, Dr. Sayanika Patra |
| 33 | BT551 | Quantum Chemistry of Atoms and Molecules | 3 | 0 | 0 | 0 | Dept. Elective | M. Tech. 2nd semester, PhD | D | 07-05-2022 9:00 to 12:00 | Dr. Samirnath E. |
| 34 | CE201 | Surveying | 3 | 0 | 0 | 0 | Compulsory | B. Tech. 2nd year students of Civil Dept. | A | 04-05-2022 9:00 to 12:00 | Dr. Arijit Sarkar |
| 35 | CE205 | Statistical Analysis I | 3 | 0 | 0 | 0 | Compulsory | Statisticians Staff | B | 05-05-2022 9:00 to 12:00 | Dr. Arpan Datta |

Example - 02

List of open electives

| List of Open electives for Winter Semester(Jan - May 2021) of Academic year 2020-2021 | | | |
|--|-------------|---|------------|
| Sl.no | Course Code | Course Name | Class Slot |
| 1 | CE559 | Watershed Management & Remote Sensing Application | F |
| 2 | ME671 | Biomaterials: Design and Applications | F |
| 3 | ME674 | Soft Computing in Engineering | F |
| 4 | CS577 | C-Based VLSI Design: Synthesis, Optimization and Verification | F |
| 5 | DD606 | Product Detailing | F |
| 6 | BT633 | Human Biology and Diseases | F |
| 7 | BT622 | Biofuels | F |
| 8 | BT640 | Neural Imaging And Signal Systems | F |
| 9 | CL618 | Natural Gas Engineering | F |
| 10 | CL625 | Fundamentals of Micro-nano Fluidics and Micro-Fabrication | F |
| 11 | CL639 | Biofluid Mechanics | F |
| 12 | CL643 | Computer Aided Applied Optimization | F |
| 13 | EE626 | Pattern Recognition and Machine Learning | F |
| 14 | PH446 | Fundamentals of Astrophysics | F |
| 15 | PH465 | Optoelectronics | F |

Example - 03

HSS elective allotment

Indian Institute of Technology Guwahati

Academic Affairs

HSS Elective Allocation for January May 2021 Semester

| SL No | Roll No | Name | Course No | Course Name |
|-------|-----------|------------------------------|-----------|--|
| 1 | 170101001 | Aayush Patni | HS 424 | Economics of Uncertainty and Information |
| 2 | 170101002 | Abhishek Jaiswal | HS 415 | History of Contemporary India |
| 3 | 170101003 | Aditya Vardhan Gara | HS 415 | History of Contemporary India |
| 4 | 170101004 | Ajinkya Shivashankar | HS 420 | Writing Systems of the World |
| 5 | 170101005 | Aman Mishra | HS 401 | Management of Organizational Behaviour |
| 6 | 170101006 | Aman Raj | HS 429 | Indian Business History |
| 7 | 170101007 | Aniket Rajput | HS 401 | Management of Organizational Behaviour |
| 8 | 170101008 | Annanya Pratap Singh Chauhan | HS 429 | Indian Business History |
| 9 | 170101009 | Anubhav Tyagi | HS 424 | Economics of Uncertainty and Information |
| 10 | 170101011 | Aranya Aryaman | HS 415 | History of Contemporary India |
| 11 | 170101012 | Arpit Gupta | HS 429 | Indian Business History |
| 12 | 170101013 | Aryan Agrawal | HS 429 | Indian Business History |
| 13 | 170101014 | AVIRAL GUPTA | HS 424 | Economics of Uncertainty and Information |
| 14 | 170101015 | Avneet Singh Channa | HS 415 | History of Contemporary India |
| 15 | 170101016 | B Shri Raam Reddy | HS 424 | Economics of Uncertainty and Information |
| 16 | 170101017 | Rohith Chodavarapu | HS 424 | Economics of Uncertainty and Information |
| 17 | 170101018 | Bhavani Datt | HS 431 | Sociological Perspectives on Modernity |

Example - 04

List of Foreign Students

| Information about India (DOA) | Guwahati. He/she will also bear travel cost from his/her home country to India(Guwahati) | | | | |
|--|--|----------------------------|------------|----------------------|--------------------------------|
| Self-Financed Candidates | | | | | |
| Information for incoming exchange students | Student should attach either a bank statement showing that they have enough finances in their own bank account or a letter from their parents or sponsors certifying that they will support all the expenses incurred by the student as mentioned above in (1) | | | | |
| Information Regarding Internship | | | | | |
| Before Arriving at IITG | DOAER will forward the list of selected students to DOAA, (with the departmental approval/selection report) along with (1) and (2) received from the student for processing and obtaining the Director's approval. More... | | | | |
| After Arriving at IITG | | | | | |
| List of current International students | | | | | |
| Category | SL. NO. | NAME | COUNTRY | PROGRAM | DEPT. |
| 2019 | 1 | Dr. Md. Arther Rahmat Khan | Bangladesh | Post Doc | DSR |
| 2018 | 2 | Maria Orts Serrano | Spain | B.Tech. (Exchange) | EEE |
| 2017 | 3 | Dr. Soleyeh Mehdizadeh | Iran | Post Doc | ISAT |
| 2016 | 4 | Fusaku Ono | Japan | B.Tech. (Internship) | Mechanical Engineering |
| 2015 | 5 | Takafumi Hiramatsu | Japan | B.Tech. (Internship) | Mechanical Engineering |
| | 6 | Ms. Adejoke Naomi Kolawole | Nigeria | Research Intern | ESRE |
| | 7 | Mr. Alfonso W. L. Gonzalez | Spain | B.Tech. (Exchange) | Mechanical Engineering |
| | 8 | Mr. Ronan Drouet | France | M.Tech | Civil Engineering |
| | 9 | Mrs. Kawab Karjo | Syria | M.Tech | Biosciences and Bioengineering |
| | 10 | Mr. Ali Jazishan | Syria | M.Tech | Mechanical Engineering |
| | 11 | Ms. Reftash Marmoodi | Iran | M.Tech | Biosciences and Bioengineering |

Example - 05a

List of Hostels (static)

The screenshot shows a university website with a dark blue header. The header includes a logo, the text "STUDENTS' AFFAIRS", and a navigation menu with links: Home, Rule, Calendar, Tax, Events, SA Council, Hostels, Forms, Quick Links, and Help.

The main content area features a large image of a wooden bench. Overlaid on the image are three blue rectangular boxes containing text:

- Are you feeling low?
- Are you confused with studies that you are not sure how to deal with?
- Or you feel it difficult to express in a face to face situation?

Below these boxes, the text "Visit our Online Anonymous Counselling Portal" is displayed.

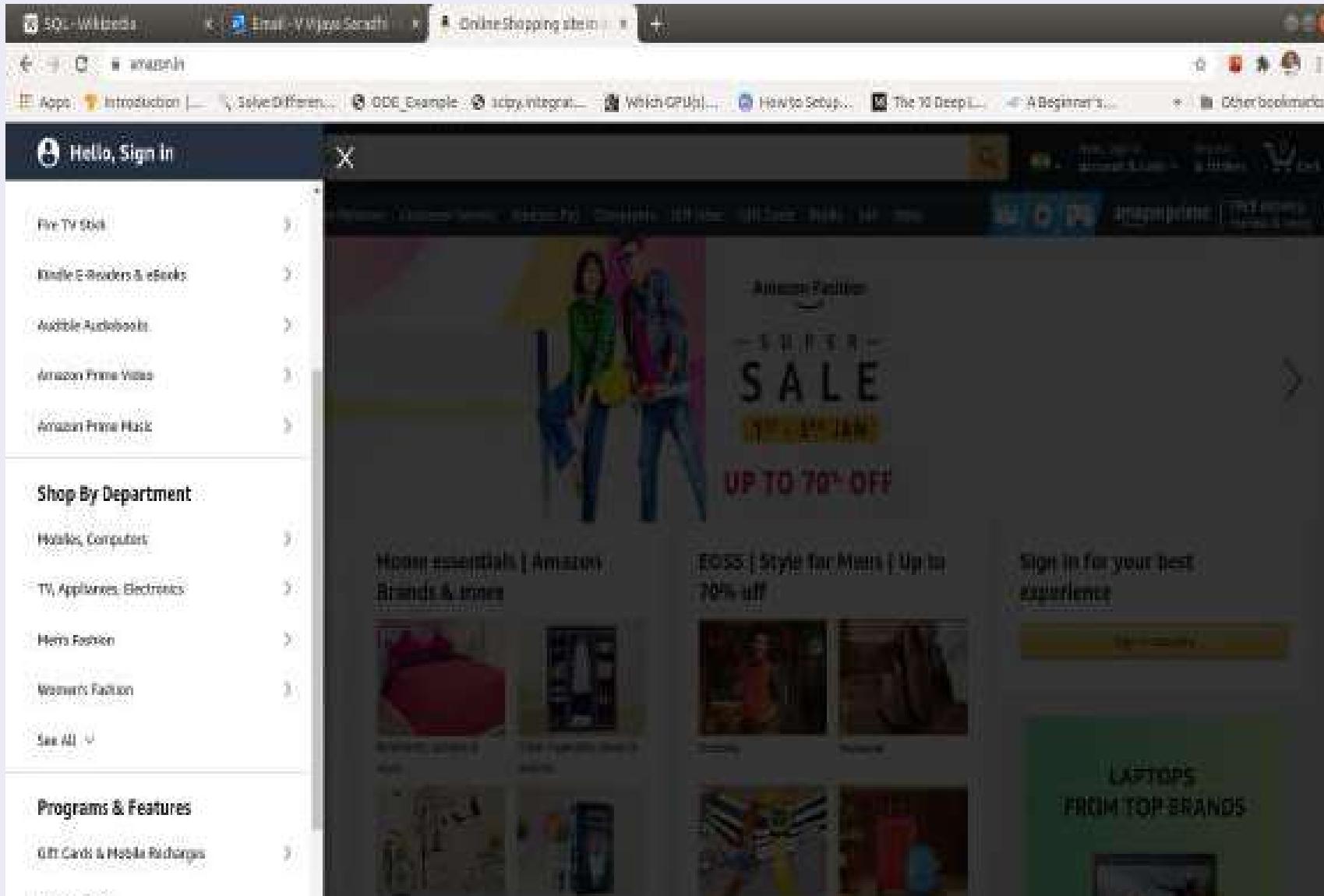
A vertical sidebar on the right lists various hostels:

- Dosti
- Brahmaputra
- Uttara
- Uttara
- Dwipati
- Kartik
- Kripal
- Uttar
- Mahan
- Mahan
- Surya
- Surya
- Devarshi
- Devarshi

At the bottom of the page, there are links for "Students' Achievements", "Recent Announcements", "Recent Announcements", and "Feedback". There are also two footer icons: one for "Tobacco Free Guidelines" and another for "E-Governance".

Example - 05b

List of Items (dynamic)



In the presented examples

- Examples 1 to 4 are in tabular form
- Each table has **fixed** number of columns
- Each table has **varying** number of rows
- Columns within a table hold values
- Example 5a/5b on the other hand not merely resembles data. However, they are stored in the table format

Application Specific

- Structured
- Un-structured

What Differentiates These?

- How elements are stored?
- How queries are formulated?
- How elements are retrieved?
- How elements are updated?
- How multiple user engagement is handled?
- How volume of the queries is handled?
- How data integrity is achieved?

Structured - Example 01

Banks



Queries

read What is my savings bank balance?

write Deposite 10000 rupees

write Withdraw 5000 rupees

read Provide me the last months bank statement

Structured - Example 02

Airlines



Queries

read List flights between Guwahati & Vizag on 15-Jan-2021

write Book a ticket of 5 passengers on flight 6E-512

write Pay money

read & write Modify the date of travel from 15-Jan-2021 to 16-Jan-2021 on the same flight with same set of passengers

Structured - Example 03

Railways



Queries

read List trains between Guwahati & Vizag on 15-Jan-2021

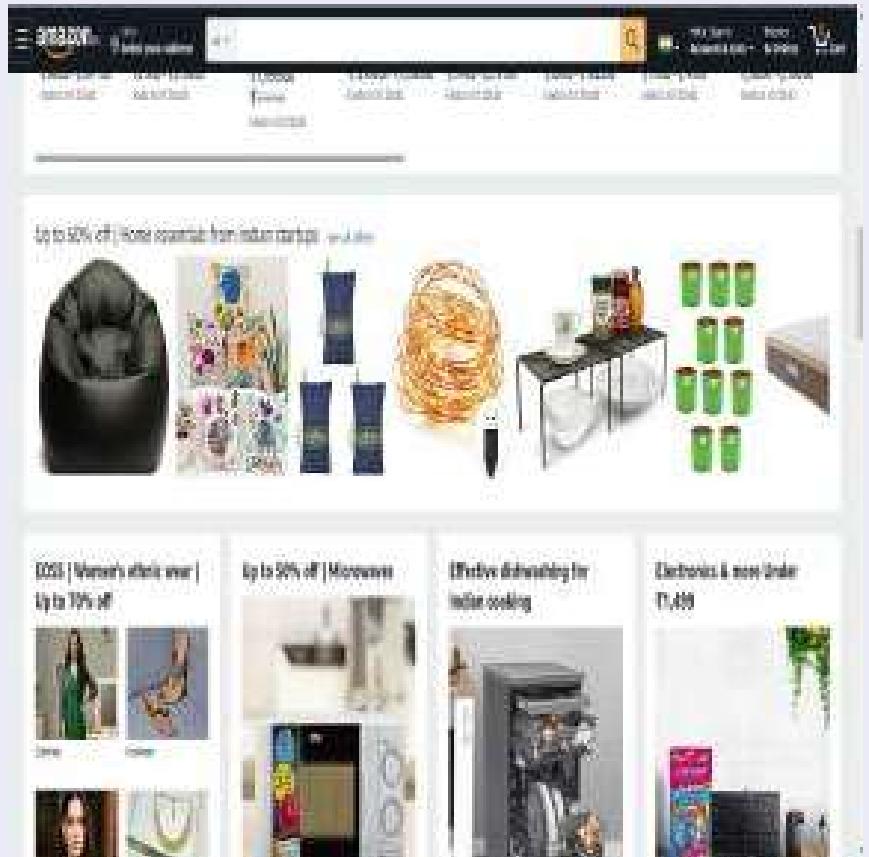
write Book a ticket of 5 passengers on train 12345 & 12842

write Pay money

read & write Modify the date of travel from 15-Jan-2021 to 16-Jan-2021 on the same train with same set of passengers

Structured - Example 04

E-commerce



Queries

read List books on database management systems

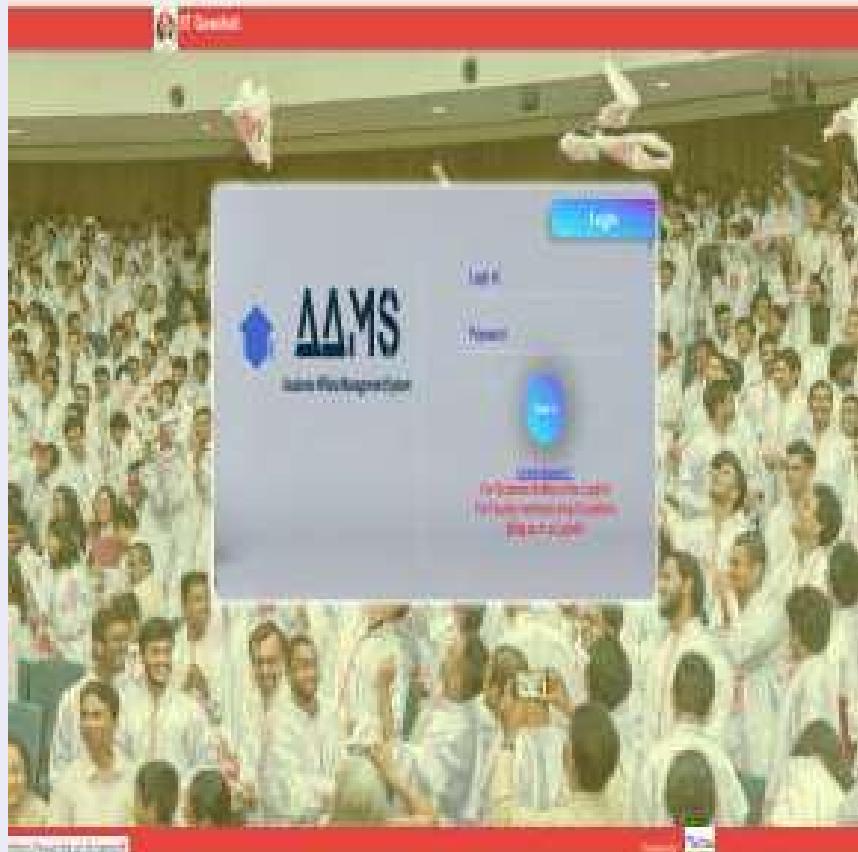
write Buy the book by Raghu Ramakrishnan

write Pay money

ready & write Modify the shipping address

Structured - Example 05

University



Queries

- read Show my transcript
- read Show the list of courses this semester
- write Add the elective CS544
- read & write Drop the added elective
- read & write Register

Structured - Example 06

Competitive Exams



Queries

- read Show my list of choices
- read Select IIT Roorkee, 4 years
B Tech in CSE
- read & write Delete IIT Ropar, 4 years B
Tech in Chemical
Engineering
- write Add NIT Warangal, 4 years
B Tech in ECE
- write Confirm my choices
- write Float my choices
- write Pay the fee

Structured - Example 07

Passport



Queries

- read Show the available free slots
- write Book the slot on 12-Jan-2021
- write Submit relevant documents
- write Pay the fee

Structured - Example 08

Land Registration

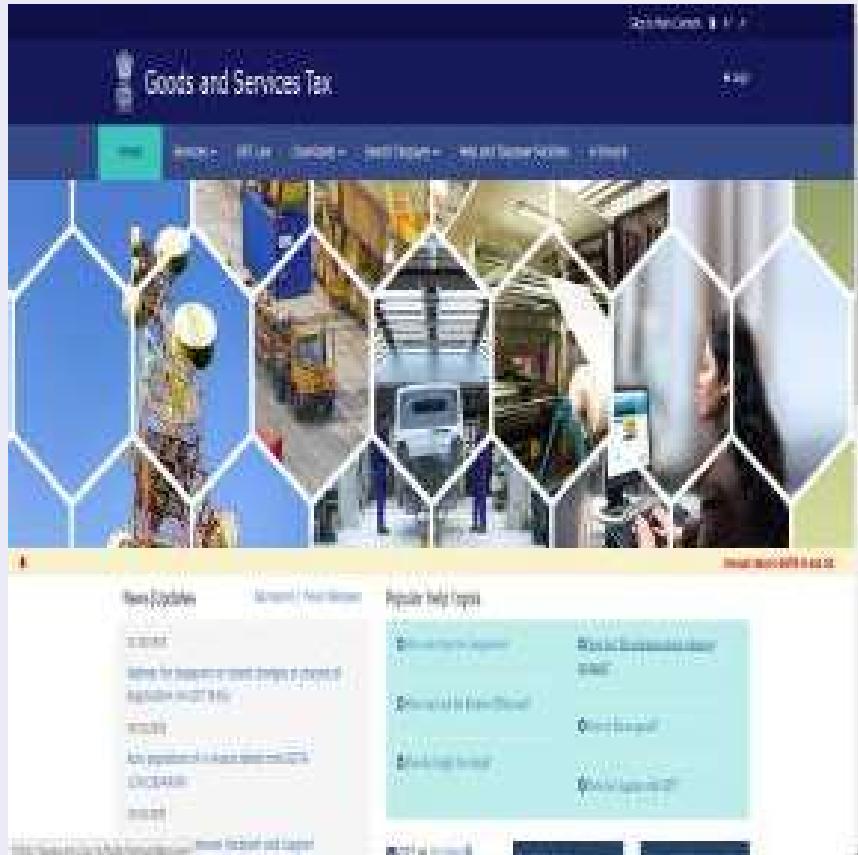


Queries

- read Show my land records
- write Book the available slot with the Registrar
- write Pay stamp duty
- write Register biometric data
- write Submit relevant documents
- write Register my land

Structured - Example 09

GST



Queries

- read** Show how much tax to be paid this month
- read & write** Pay the tax amount
- write** Claim tax concessions
- read** Show the tax paid history for last three months

Structured - Example 10

Income Tax



Queries

read Get the form number ITR-1

read & write Fill this years tax returns information

write Save the entered data

write Pay the remaining tax amount

write File the tax returns

What is the underlying structure?

Queries

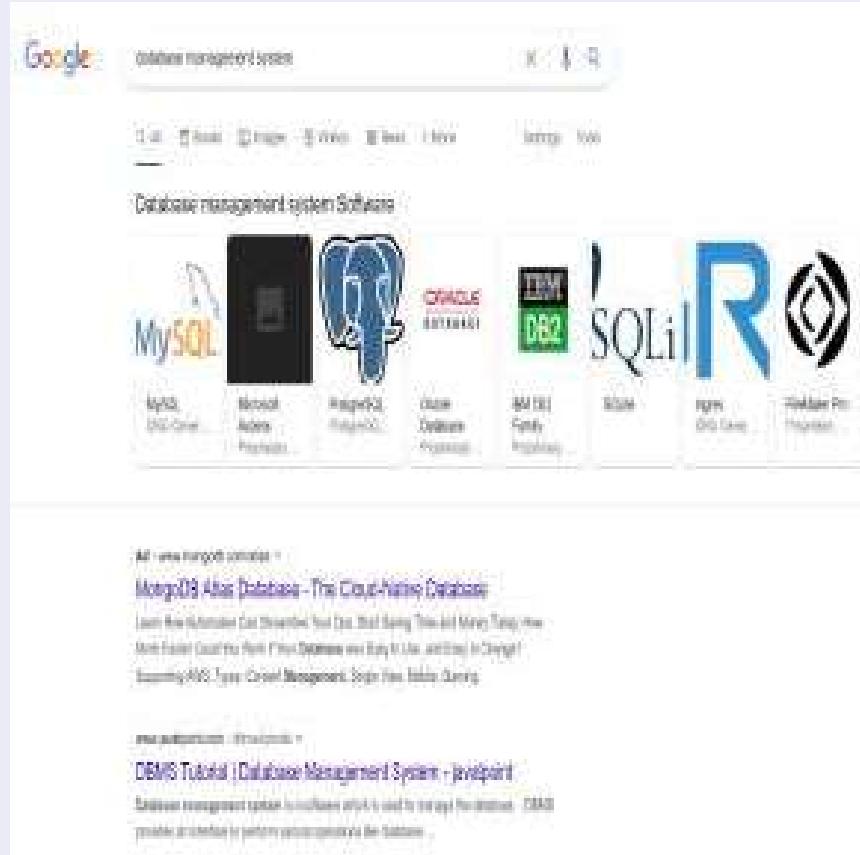
- Data is stored in a tabular format
- Stored data is from the system defined data types
- Operations are centered around tables
- Tables are manipulated; rows of tables are manipulated
- Multi-user, volume, scale, integrity etc.

Un-structured

- Text
- Documents
- Images
- Audio
- Videos
- Source code
- Software binaries
- Graphs
- Maps
- Biometric databases
- :

Unstructured - Example 01

Text

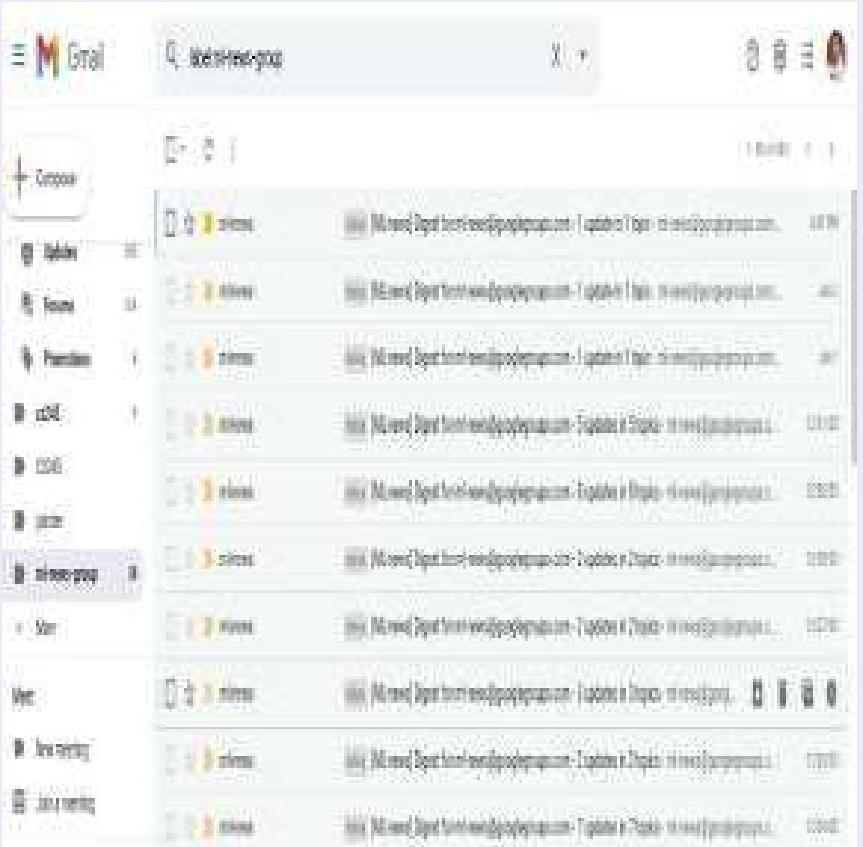


Queries

- Query expressed in natural language
- Retrieved data is text, pdf, ppt, etc
- Data: Only querying allowed
- Understanding user intent is important

Unstructured - Example 02

Text

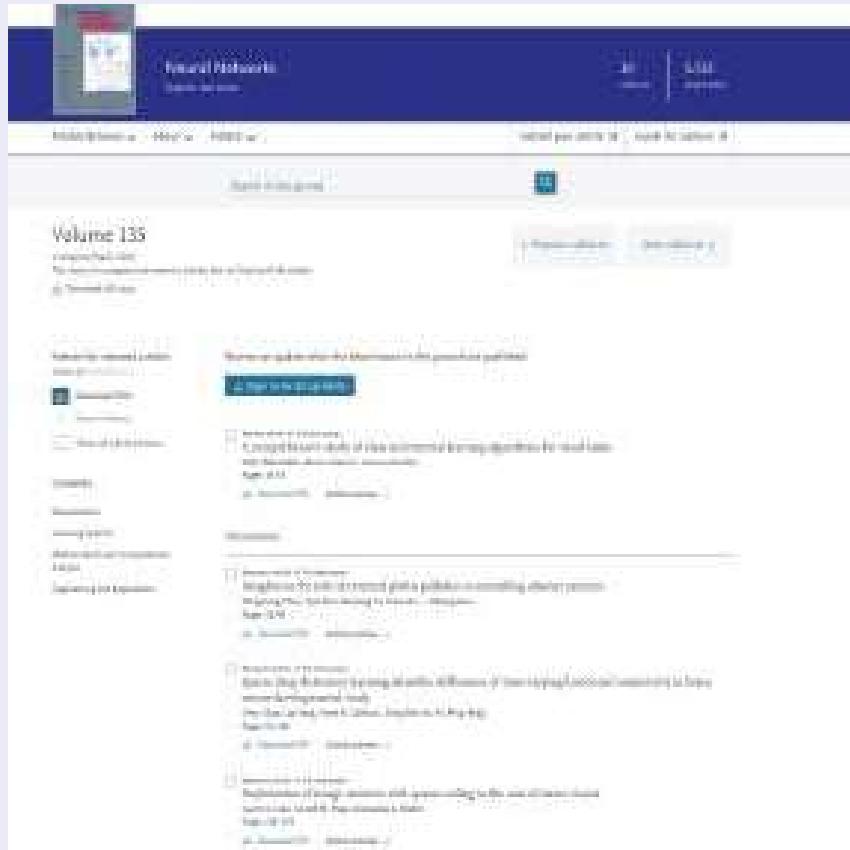


Queries

- Retrieve emails from specified cs245 course
- Retrieve emails containing text “database management”
- Compose email to course instructor
- Delete emails

Unstructured - Example 03

Documents

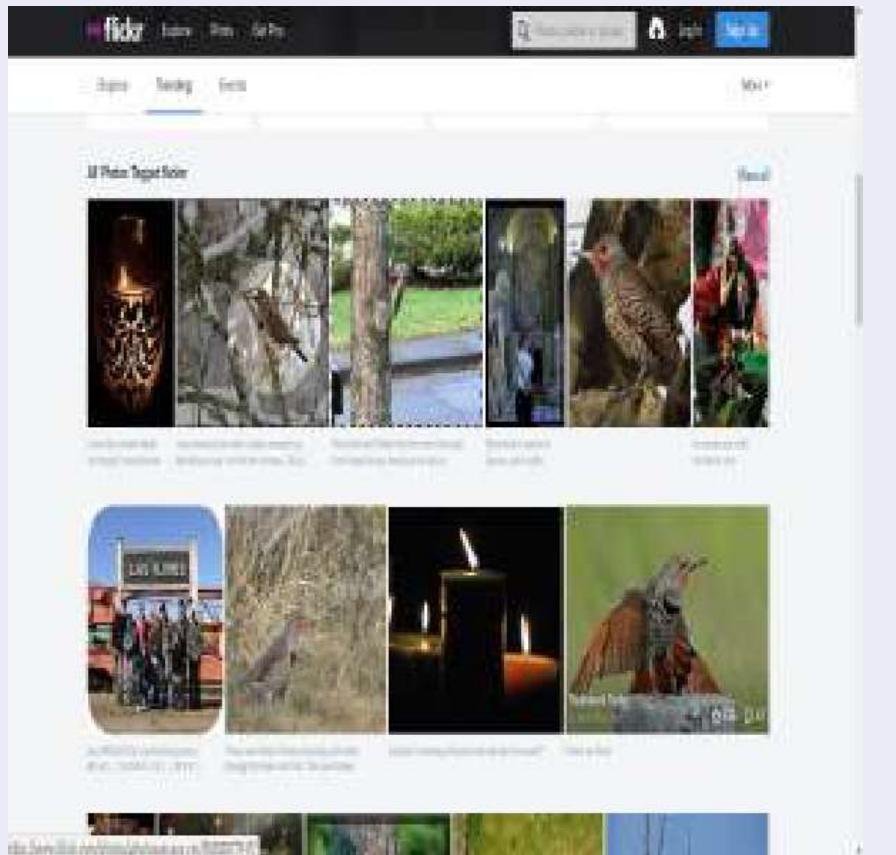


Queries

- List all the articles published in March 2018
- List all the articles containing “SQL”
- Show the article titled “A Relational Model of Data For Large Shared Data Banks”
- List all the articles published by the author E. F. Codd

Unstructured - Example 04

Images



Queries

- Show the images with IIT Guwahati
- Show the images containing serpentine lake
- Show the images in the year 2020
- Show the images from the author

Unstructured - Example 05

Audio

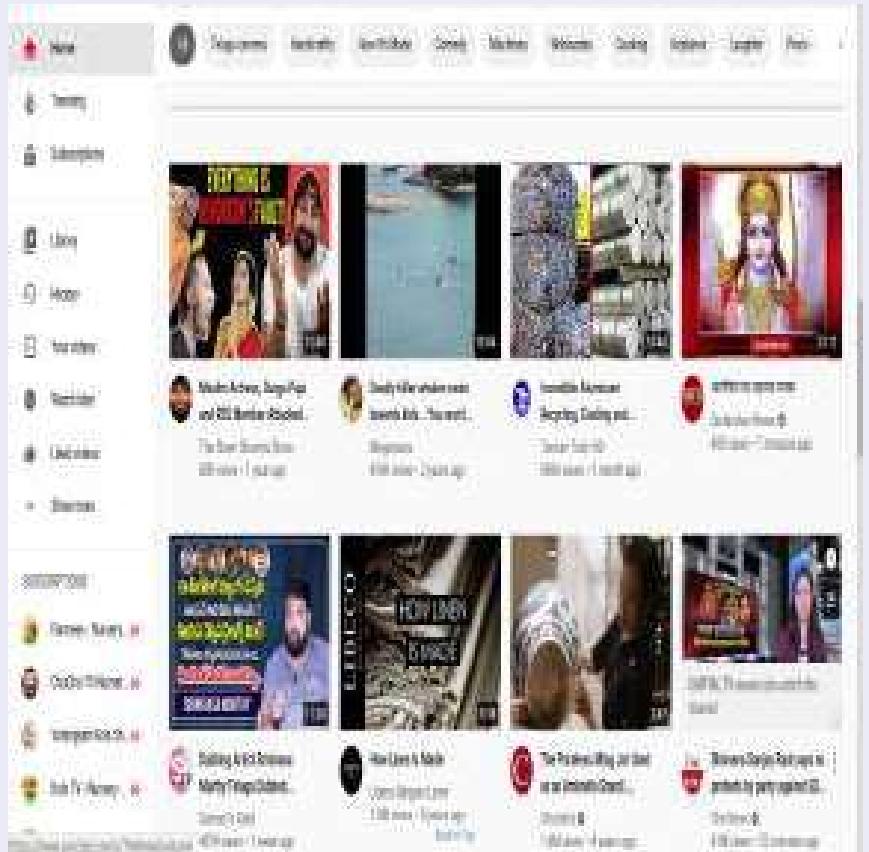


Queries

- List all songs by Shri. S. P. Balasubrahmaniam
- List all songs by Smt. Lata Mangeshkar
- List all the songs in the movie Gadar
- Play the song “Main Nikla”

Unstructured - Example 06

Video

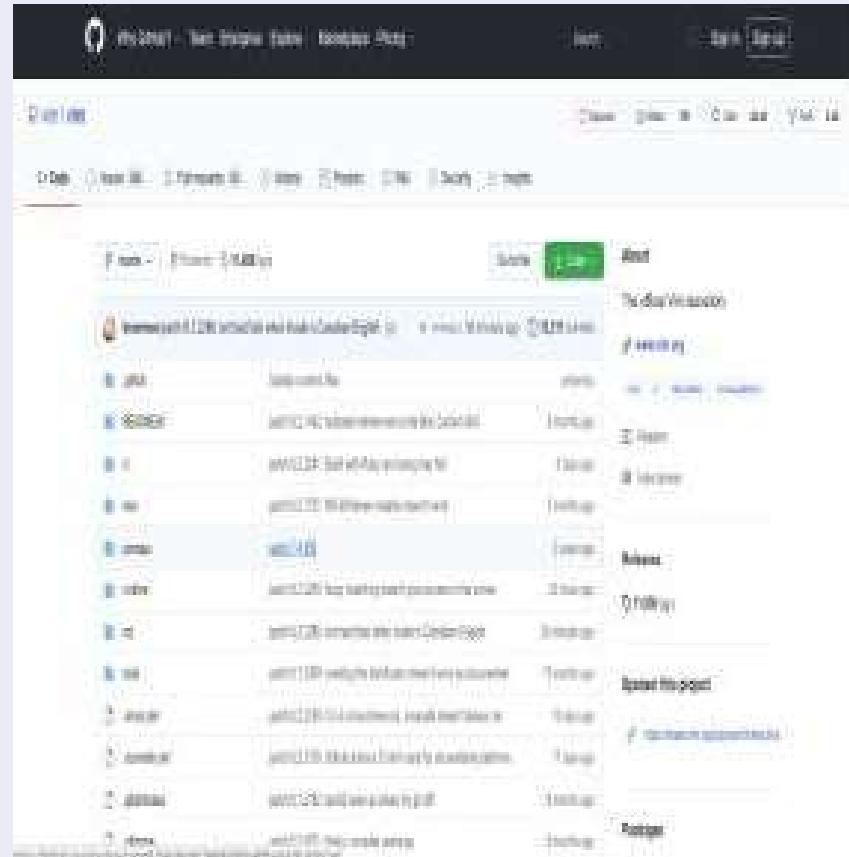


Queries

- Search videos by a natural language query (IIT Guwahati)
- Show the videos by a particular author
- Play a selected video
- Show the live show TV debate

Unstructured - Example 07

Source Code

A screenshot of a web-based source code management system, likely GitHub. The interface shows a list of commits in a repository. Each commit includes the author, date, file changes, and a 'View' link. The commits are listed in chronological order from top to bottom.

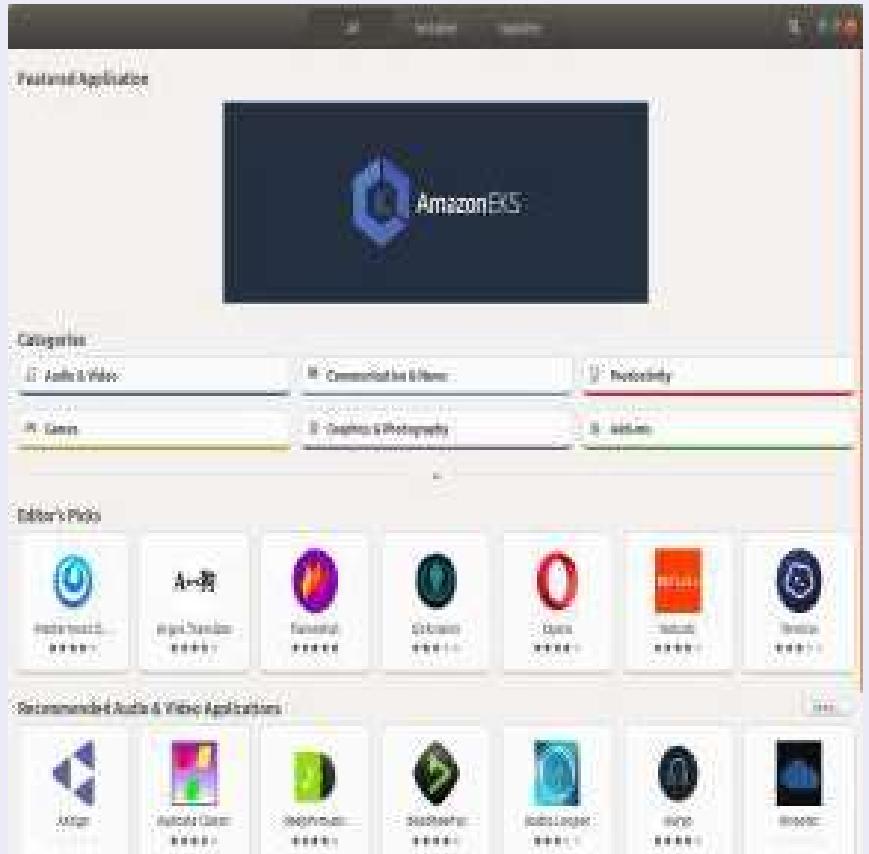
| Author | Date | File Changes | Action |
|------------|-------------|--------------|--------|
| [Redacted] | 30 Dec 2020 | edit.c | View |
| [Redacted] | 30 Dec 2020 | insert.c | View |
| [Redacted] | 30 Dec 2020 | menu.c | View |
| [Redacted] | 30 Dec 2020 | main.c | View |
| [Redacted] | 30 Dec 2020 | readme.md | View |
| [Redacted] | 30 Dec 2020 | style.css | View |
| [Redacted] | 30 Dec 2020 | util.c | View |
| [Redacted] | 30 Dec 2020 | util.h | View |
| [Redacted] | 30 Dec 2020 | version.c | View |
| [Redacted] | 30 Dec 2020 | version.h | View |
| [Redacted] | 30 Dec 2020 | write.c | View |
| [Redacted] | 30 Dec 2020 | write.h | View |

Queries

- List the changes made to **edit.c** on Wednesday, 30-Dec-2020
- Un-do changes made on Wednesday, 30-Jan-Dec-2020
- List who all modified the file **insert.c** between 01-Jan-2021 and 05-Jan-2021
- Insert a new file **menu.c**

Unstructured - Example 08

Binaries

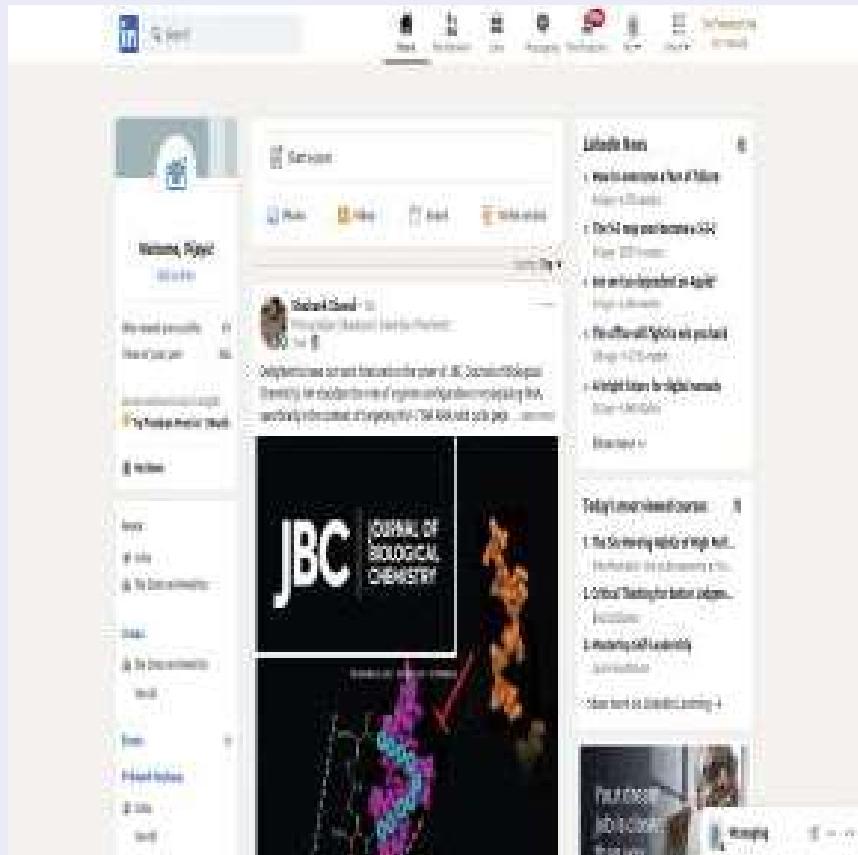


Queries

- Update vim
- Install firefox new version
- Delete all the previous installed versions of firefox
- Update all libraries

Unstructured - Example 09

Graphs

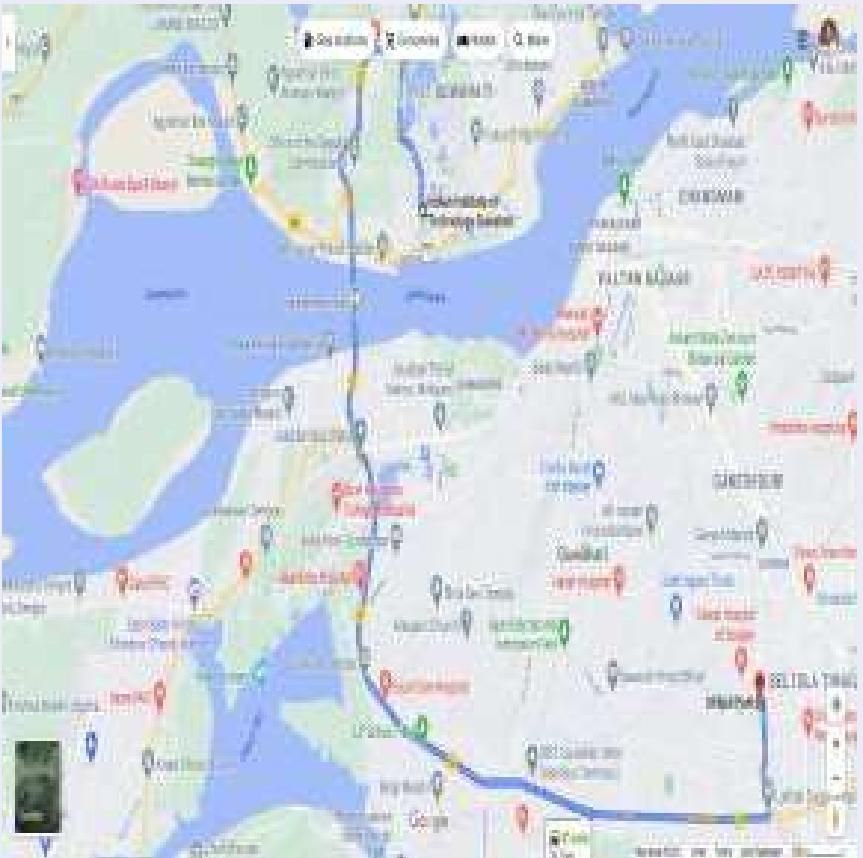


Queries

- List all my school friends
- List all my colleagues at previous company
- Make a new connection with the HR of that company
- Post a job requirement which reach to all my known contacts and their contacts only.

Unstructured - Example 10

Maps



Queries

- Show the map at my location at specified resolution
- Show all the ATMs only
- Show all the hotels near by my area
- Show the route between place A to place B.
- Show all the alternate routes between A and B

Unstructured - Example 11

Biometric databases



Queries

- Verify the person with the given finger print!
- Verify the person with given AADHAR number
- Verify the person with face

What it contains?

- A DBMS is a collection of programs that enables users to create and maintain a database
- DBMS is a general-purpose software system
- It facilitates the process of
 - Defining
 - Constructing
 - Manipulating and
 - Sharing database among various users and applications

Elements

Defining a database involves specifying

- the **data types**
- **data structures**
- **constraints** on the data to be stored in the database
- Database descriptive information is also stored by the DBMS
- The description is in the form of database catalog which is the **meta-data**

Elements

- Constructing the database is the process of storing the data on some **storage medium** that is controlled by the DBMS
- **Manipulating** a database includes functions such as
 - Querying the database to retrieve specific data
 - Updating the database to reflect changes in the mini-world
 - Generating reports from data
- **Sharing** a database allows multiple **users and programs** to access the database simultaneously

University Database

- Storing information about students, courses, & grades
- Database structure and a few samples of data for such a database

An Example

Student

| name | student_number | class | major |
|-------|----------------|-------|-------|
| Smith | 17 | 1 | CS |
| Brown | 8 | 2 | CS |

Course

| name | number | credit_hours | department |
|-----------------|--------|--------------|------------|
| Intro to CS | CS1310 | 4 | CS |
| Data structures | CS3320 | 4 | CS |
| Discrete Maths | MA2410 | 3 | MATH |
| Databases | CS3380 | 3 | CS |

An Example

Section

| sid | number | semester | year | instructor |
|-----|--------|----------|------|------------|
| 85 | MA2410 | Fall | 2007 | King |
| 92 | CS1310 | Fall | 2007 | Anderson |
| 102 | CS3320 | Spring | 2008 | Knuth |
| 112 | MA2410 | Fall | 2008 | Chang |
| 119 | CS1310 | Fall | 2008 | Anderson |
| 135 | CS3380 | Fall | 2008 | stoneson |

An Example

Grade_Report

| stdent_number | sid | grade |
|---------------|-----|-------|
| 17 | 112 | B |
| 17 | 119 | C |
| 8 | 85 | A |
| 8 | 92 | A |
| 8 | 102 | B |
| 8 | 135 | A |

Prerequisite

| course_number | prerequisite |
|---------------|--------------|
| CS3380 | CS3320 |
| CS3380 | MATH2410 |
| CS3320 | CS1310 |

University Database

- The database is organized in five files
- Each of which stores data records of same type
- STUDENT file stores records of all the students
- COURSE file stores records of all the courses
- ...

Define

- To *define* this database, structure of records of each file must be specified
- Specify different *types of data elements* to be stored for each record
- STUDENT record includes: Name, Student_number, Class and Major
- A similar description should be done for all the files
- Descriptions specify domain example: grade must be from the set {'A', 'B', 'C', 'D', 'F', 'I'}

Construct

- To *construct* this database, we store data to represent each student, course, section, grade report, and prerequisite
- Each of these must be in different **files**
- Records in various files may be **related**
- Example: Record **Smit** in Student file is **related to** two records in Grade_Report file
- Similarly, each record in **Prerequisite** file relates to two course records
 - One representing course
 - Other representing prerequisite
- Such relations are prevalent in **relational databases**

An Example

Manipulate - Querying

- Involve querying and updating
- Example: Retrieve the transcript of ‘Smith’
- List names of students who took database course in fall 2008 and their grades in that section
- List the pre-requisites of database course

Manipulate - Updating

- Change the class of ‘Smith’ to sophomore
- Create a new section for database course for this semester
- Enter a grade of ‘A’ for ‘Smith’ in the database section of last semester