# CS4.301 Data & Applications

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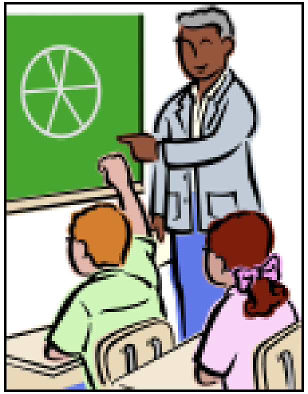
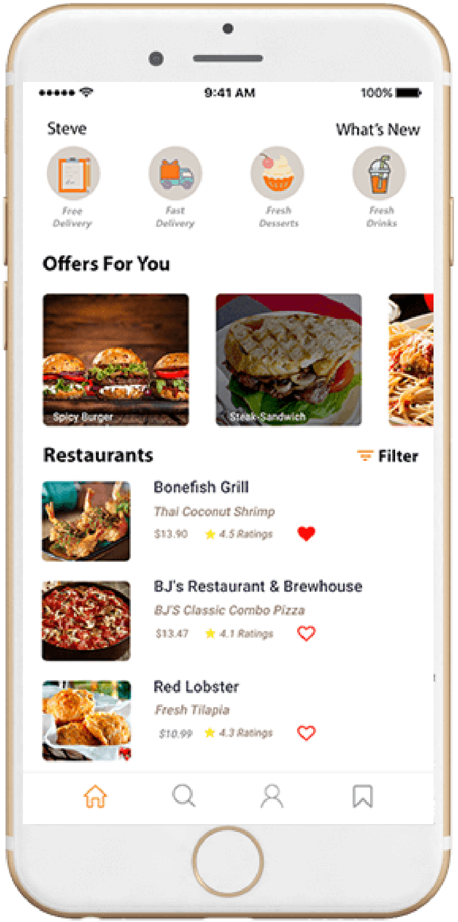
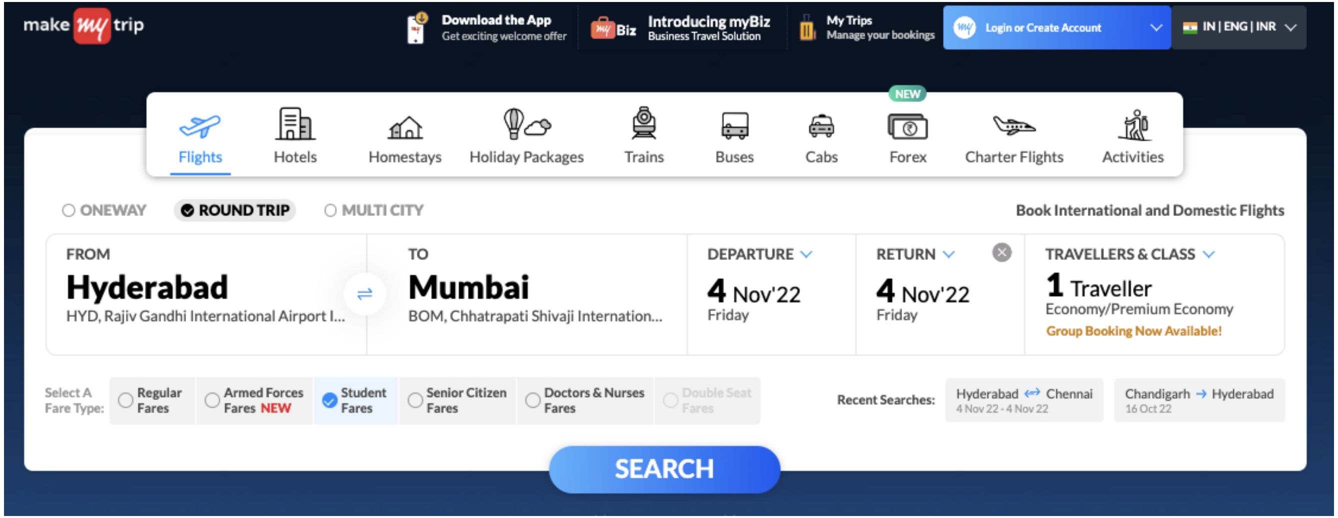
# Protocol




What kind of data are we generating here?

What kind of data are we generating here?

# Grading, Relative

| Type of Evaluation | Weightage (in %) |
| --- | --- |
| Class Quizzes (3) | 15 |
| Assignments / Homeworks (4) | 20 |
| Mid sem exam (Quiz-2 as scheduled in almanac) | 15 |
| Project | 30 |
| End Sem Exam | 20 |

# TAs

~~12~~ TAs 13

Students will be assisged among TAs for all evaluations

Karthik George

24/3/18

Aditya Mishra
Anika Roy
Anirudh Vempati
Anish R Joishy
Chetan Mahipal
Debangan Mishra
Devika Umesh Bej
Jain Hemang Ashok
Pratishtha Saxena
Priyanshul Govil
Rohan Kumar
Shailender Goyal
Tejas Cavale

Memory challenge for me ☺

# Basic Definitions

swiggy order $$ food # of items

P.B.M → BS 300/-

**Database:**

A collection of related data.

**Data:**

Known facts that can be recorded and have an implicit meaning.

**Mini-world:**

Some part of the real world about which data is stored in a database. For example, student grades and transcripts at a university.

University DMS

**Database Management System (DBMS):**

A software package/ system to facilitate the creation and maintenance of a computerized database.

**Database System:**

The DBMS software together with the data itself. Sometimes, the applications are also included.

# What is a Database?

Data: factual (undoubted) information that can be recorded and have implicit meaning

University → Class / Classes → DnA – 243 – 13TAS –

Name –

Names.

A database is a collection of related data

– Username

– Parents

# What is a Database?

A database has the following implicit properties:

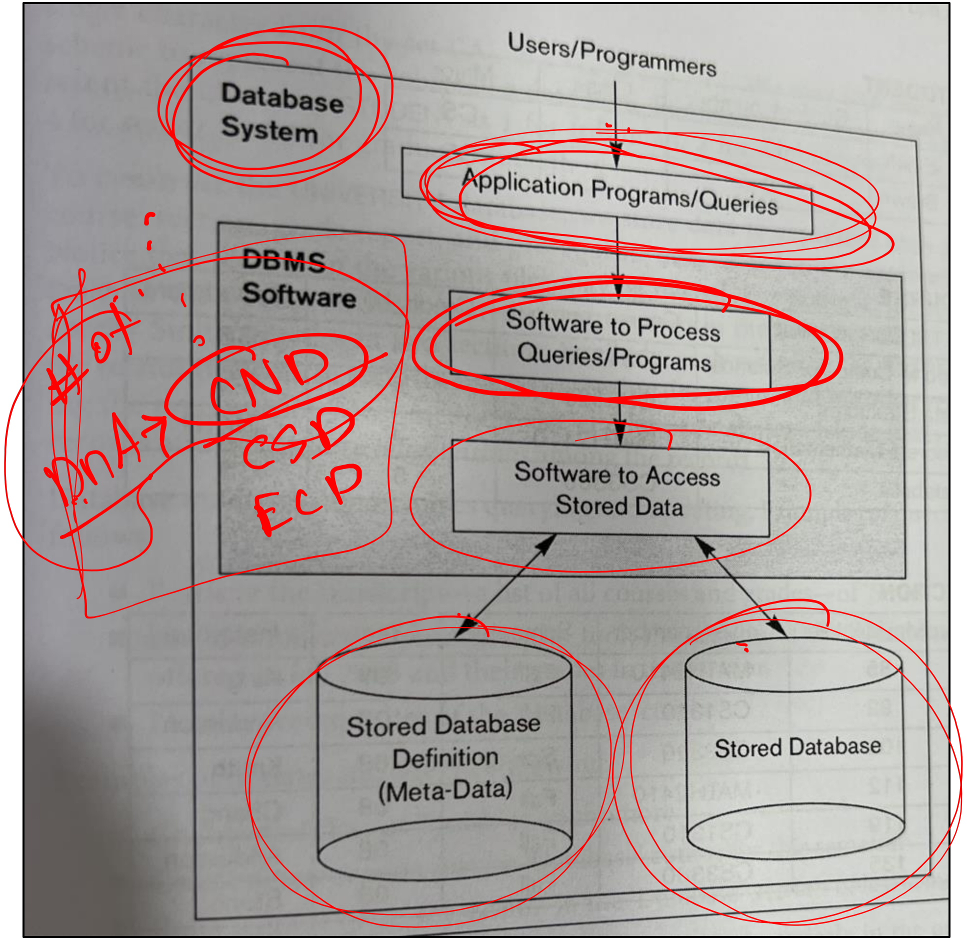
A database represents some aspect of the real world <u>(mini-world or Universe of Discourse (UoD))</u>

A database is a <u>logically coherent</u> (associated, related) collection of data with some inherent meaning

A database is designed, built and populated with data for a specific <u>purpose</u>

It has an <u>intended</u> group of users and some <u>preconceived (already thought of) applications</u> in which these users are interested

# Simplified Database




Book

TA hrs
my hrs

A. — CND
43 — CND

NL → MUQ..

# Example of Database: University

Data:

STUDENTs

COURSEs

SECTIONs (of COURSEs)

(academic) DEPARTMENTs

INSTRUCTORs

Relation:

SECTIONs are of specific COURSEs

STUDENTs take SECTIONs

COURSEs have prerequisite COURSEs

INSTRUCTORs teach SECTIONs

COURSEs are offered by DEPARTMENTs

STUDENTs major in DEPARTMENTs

ECE

AF →

MK → CS

CNP

# Database

**STUDENT**

| Name | Student Number | Class | Major |
|---|---|---|---|
| Smith | 17 | 1 | COSC |
| Brown | 8 | 2 | COSC |

**GRADE REPORT**

| Student Number | Section-Identifier | Grade |
|---|---|---|
| 17 | 85 | A |
| 18 | 102 | B+ |

**PREREQUISITE**

| Course Number | Prerequisite Number |
|---|---|
| COSC3380 | COSC3320 |
| COSC3320 | COSC1310 |

**COURSE**

| Course Name | Course Number | Credit Hours | Department |
|---|---|---|---|
| Intro to CS | COSC1310 | 4 | COSC |
| Data Structures | COSC3320 | 4 | COSC |
| Discrete Mathematics | MATH2410 | 3 | MATH |
| Data Base | COSC3380 | 3 | COSC |

**SECTION**

| Section-Identifier | Course Number | Semester | Year | Instructor |
|---|---|---|---|---|
| 85 | MATH2410 | Fall | 91 | King |
| 92 | COSC1310 | Fall | 91 | Anderson |
| 102 | COSC3320 | Spring | 92 | Knuth |
| 135 | COSC3380 | Fall | 92 | Stone |

# Database catalogue

**RELATIONS**

| Relation_name | No_of_columns |
|---|---|
| STUDENT | 4 |
| COURSE | 4 |
| SECTION | 5 |
| GRADE_REPORT | 3 |
| PREREQUISITE | 2 |

**COLUMNS**

| Column_name | Data_type | Belongs_to_relation |
|---|---|---|
| Name | Character (30) | STUDENT |
| Student_number | Character (4) | STUDENT |
| Class | Integer (1) | STUDENT |
| Major | Major_type | STUDENT |
| Course_name | Character (10) | COURSE |
| Course_number | XXXXNNNN | COURSE |
| .... | .... | ..... |
| .... | .... | ..... |
| .... | .... | ..... |
| Prerequisite_number | XXXXNNNN | PREREQUISITE |

*Note*: Major_type is defined as an enumerated type with all known majors. XXXXNNNN is used to define a type with four alphabetic characters followed by fou

Book

# Views

Many users to DB

Each users may require a different view

View may be a subset or virtual data derived



**TRANSCRIPT**

| Student_name | Student_transcript | | | | |
|---|---|---|---|---|---|
| | Course_number | Grade | Semester | Year | Section_id |
| Smith | CS1310 | C | Fall | 08 | 119 |
| | MATH2410 | B | Fall | 08 | 112 |
| Brown | MATH2410 | A | Fall | 07 | 85 |
| | CS1310 | A | Fall | 07 | 92 |
| | CS3320 | B | Spring | 08 | 102 |
| | CS3380 | A | Fall | 08 | 135 |

(a)

**COURSE_PREREQUISITES**

| Course_name | Course_number | Prerequisites |
|---|---|---|
| Database | CS3380 | CS3320 |
| | | MATH2410 |
| Data Structures | CS3320 | CS1310 |

(b)

**Figure 1.5**
Two views derived from the database in Figure 1.2. (a) The TRANSCRIPT view. (b) The COURSE_PREREQUISITES view.

IMS DB

D(A) Dy. Acad

D(R) D. Y. Kishore.

# This lecture

# No replies this year ☹

**Re: Good morning.. Good luck with the course....**
by Mayaank Ashok - Monday, 25 September 2023, 4:51 AM

Looking forward to see you too sir :)

**Re: Good morning.. Good luck with the course....**
by Kavish Kapoor - Monday, 25 September 2023, 4:52 AM

Looking forward to see you too sir.

**Re: Good morning.. Good luck with the course....**
by Maneesh Manoj - Monday, 25 September 2023, 4:54 AM

Eagerly waiting your lectures sir :)

**Re: Good morning.. Good luck with the course....**
by Nitin Avuthu - Monday, 25 September 2023, 4:58 AM

Eager for tomorrow sir

**Re: Good morning.. Good luck with the course....**
by Madhav Jayachandran Ramachandran - Monday, 25 September 2023, 5:24 AM

I am eagerly looking forward to attending your class, sir.

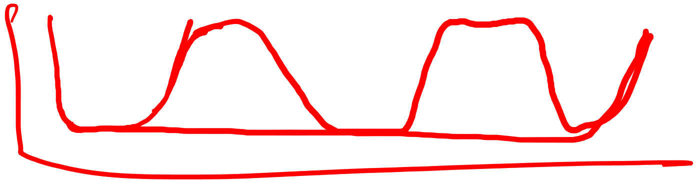
# Online Transaction Processing (OLTP)

Multiuser DB

Concurrency control

Flight ticket booking, seats available

# Transaction



Executing program or process that includes one or more database accesses, reading or updating of database records

Properties [ACID]

- Atomicity: either all are executed or none are executed [A/c A (Read, Write) → A/c B (Read, Write)]
- Consistency: any data written to a DB must be valid according to the defined rules [telephone number]
- Isolation: each transaction appears to execute in isolation, even though 100s may be executing at the same time [updating the seat preference]
- Durability: guarantees that once a transaction has been committed, it will remain committed even in the case of a system failure

# Actors on the Scene: Day-to-Day use of DB

Database administrators

authorizing access to DB, coordinating & monitoring its use, accountable for security breaches & response time

Database designers

responsible for identifying the data to be stored in the DB, interact with potential group of users and develop *views* of the DB

End Users: Casual, naïve / parametric, sophisticated, stand-alone users

Casual: occasional users, typically middle or high-level managers

Naïve / parametric: constantly updating the db using *canned transaction,* done using mobile apps

bank tellers checking balances post withdrawals & deposits

reservation agents checking for availability

social media users post and read items on platforms

# Actors on the Scene: Day-to-Day use of DB

End Users: Casual, naïve, sophisticated, stand-alone users

- sophisticated: thoroughly familiarize themselves with all facilities of DBMS, implement their own, complex requirements
- stand-alone: maintain personal DB using ready-made programs; TALLY

System analysts & application programmers

- determine the requirements of end-users, including naïve, develop specifications for canned transactions
- map implement above specifications as programs, they test – debug maintain these canned transactions
- software developers / engineers play these roles sometimes

# Actors Behind the Scene: Maintain the DB

DBMS designers & implementers

design and implement the DBMS modules; complex modules like query language processing, interface processing, controlling concurrency, handling data recovery & security

Tool developers

design & implement tools; optional packages that are often purchased separately; facilitate DB modeling & design, system design, and improved performance

Operators & maintenance personnel

responsible for running & maintenance of the hardware & software environment for DB

# Advantages of using DBMS approach

Controlling redundancy

- redundancy in storing the same data multiple times
- e.g. student details in university maintained by acad & finance office separately
- duplication of efforts, storage space, inconsistent data [Jan-19-1998 vs Jan-29-1998]
- ideally student details in only one place, *data normalization*
- keeping all needed data together, *denormalization*

# Advantages of using DBMS approach

Restricting unauthorized access

your grades accessible to only some; my salary and personal details only to some [hopefully ☺]

Providing storage structures and search techniques for efficient query processing

efficiently executing queries & updates; creating *indexes* and maintaining it; *buffering* & *caching* modules

# Advantages of using DBMS approach

Providing backup & recovery

provide facilities for recovering from hardware & software failures

complex updates, should not crash; if crash what state to recover

Providing multiple user interfaces

apps for mobile users; query language for causal; programming language for application programmers; forms / command codes for parametric; menu & natural language interfaces for standalone

# Advantages of using DBMS approach

Representing Complex relationship among data

DBMS must have the capability to represent a variety of complex relationships among the data, to define new relationships as they arise, and to retrieve / update related data easily & efficiently

Enforcing integrity constraints

student name: 30 alphabetic characters; record in one file must be related to records in other files [e.g. every SECTION record must be related to a COURSE record] *referential integrity*

uniqueness on data item values [e.g. every COURSE record must have a unique value for COURSE_NUMBER] *key or uniqueness constraint*

# Advantages of using DBMS approach

Permitting inferencing and actions using rules and triggers

- triggers associated with tables; trigger is a rule activated by updates to the table results in performing some addition operations to other tables, sending messages, etc.
- stored procedures are invoked appropriately when some conditions are met

# Historical Development of Database Technology

Early Database Applications:

- The Hierarchical and Network Models were introduced in mid 1960s and dominated during the seventies.
- A bulk of the worldwide database processing still occurs using these models, particularly, the hierarchical model using IBM’s IMS system.

Relational Model based Systems:

- Relational model was originally introduced in 1970, was heavily researched and experimented within IBM Research and several universities.
- Relational DBMS Products emerged in the early 1980s.

# Historical Development of Database Technology (continued)

Object-oriented and emerging applications:

- Object-Oriented Database Management Systems (OODBMSs) were introduced in late 1980s and early 1990s to cater to the need of complex data processing in CAD and other applications.
  - Their use has not taken off much.
- Many relational DBMSs have incorporated object database concepts, leading to a new category called *object-relationa*l DBMSs (ORDBMSs)
- *Extended relational* systems add further capabilities (e.g. for multimedia data, text, XML, and other data types)

# Historical Development of Database Technology (continued)

Data on the Web and E-commerce Applications:

- Web contains data in HTML (Hypertext markup language) with links among pages.
- This has given rise to a new set of applications and E-commerce is using new standards like XML (eXtended  Markup Language). (see Ch. 13).
- Script programming languages such as PHP and JavaScript allow generation of dynamic Web pages that are partially generated from a database (see Ch. 11).
  - Also allow database updates through Web pages

# Extending Database Capabilities (1)

New functionality is being added to DBMSs in the following areas:

- Scientific Applications – Physics, Chemistry, Biology - Genetics
- Earth and Atmospheric Sciences and Astronomy
- XML (eXtensible Markup Language)
- Image Storage and Management
- Audio and Video Data Management
- Data Warehousing and Data Mining – a very major area for future development using new technologies (see Chapters 28-29)
- Spatial Data Management and Location Based Services
- Time Series and Historical Data Management

The above gives rise to *new research and development* in incorporating new data types, complex data structures, new operations and storage and indexing schemes in database systems.

# Extending Database Capabilities (2)

Background since the advent of the 21st Century:

First decade of the 21st century has seen tremendous growth in user generated data and automatically collected data from applications and search engines.

Social Media platforms such as Facebook and Twitter are generating millions of transactions a day and businesses are interested to tap into this data to "understand" the users

Cloud Storage and Backup is making unlimited amount of storage available to users and applications

# Extending Database Capabilities (3)

Emergence of Big Data Technologies and NOSQL databases

- New data storage, management and analysis technology was necessary to deal with the onslaught of data in petabytes a day (10**15 bytes or 1000 terabytes) in some applications – this started being commonly called as "Big Data".
- Hadoop (which originated from Yahoo) and Mapreduce Programming approach to distributed data processing (which originated from Google) as well as the Google file system have given rise to Big Data technologies (Chapter 25). Further enhancements are taking place in the form of Spark based technology.
- NOSQL (Not Only SQL- where SQL is the de facto standard language for relational DBMSs) systems have been designed for rapid search and retrieval from documents, processing of huge graphs occurring on social networks, and other forms of unstructured data with flexible models of transaction processing (Chapter 24).

# When not to use a DBMS

Main inhibitors (costs) of using a DBMS:

- High initial investment and possible need for additional hardware.
- Overhead for providing generality, security, concurrency control, recovery, and integrity functions.

When a DBMS may be unnecessary:

- If the database and applications are simple, well defined, and not expected to change.
- If access to data by multiple users is not required.

When a DBMS may be infeasible:

- In embedded systems where a general purpose DBMS may not fit in available storage

# Any questions?

# Late submission

8 late days you can use

20% reduction beyond this 8 days

Maximum of 2 late days in one submission

# Data Models

**Data Model:**

A set of concepts to describe the ***structure*** of a database, the ***operations*** for manipulating these structures, and certain ***constraints*** that the database should obey.

**Data Model Structure and Constraints:**

Constructs are used to define the database structure

Constructs typically include ***elements*** (and their ***data types***) as well as groups of elements (e.g. ***entity, record, table***), and ***relationships*** among such groups

Constraints specify some restrictions on valid data; these constraints must be enforced at all times

# Data Models (continued)

**Data Model Operations:**

These operations are used for specifying database *retrievals* and *updates* by referring to the constructs of the data model.

Operations on the data model may include ***basic model operations*** (e.g. generic insert, delete, update) and ***user-defined operations*** (e.g. compute_student_gpa, update_inventory)

# Categories of Data Models

**Conceptual (high-level, semantic) data models:**

Provide concepts that are close to the way many users perceive data.

(Also called ***entity-based*** or ***object-based*** data models.)

**Physical (low-level, internal) data models:**

Provide concepts that describe details of how data is stored in the computer. These are usually specified in an ad-hoc manner through DBMS design and administration manuals

**Implementation (representational) data models:**

Provide concepts that fall between the above two, used by many commercial DBMS implementations (e.g. relational data models used in many commercial systems).

**Self-Describing Data Models:**

Combine the description of data with the data values. Examples include XML, key-value stores and some NOSQL systems.

# Schemas versus Instances

Database Schema:

The ***description*** of a database.

Includes descriptions of the database structure, data types, and the constraints on the database.

Schema Diagram:

An ***illustrative*** display of (most aspects of) a database schema.

Schema Construct:

A ***component*** of the schema or an object within the schema, e.g., STUDENT, COURSE.

# Schemas versus Instances

Database State:

- The actual data stored in a database at a ***particular moment in time***. This includes the collection of all the data in the database.
- Also called database instance (or occurrence or snapshot).
  - The term *instance* is also applied to individual database components, e.g. *record instance, table instance, entity instance*

# Database Schema vs. Database State

Database State:

Refers to the ***content*** of a database at a moment in time.

Initial Database State:

Refers to the database state when it is initially loaded into the system.

Valid State:

A state that satisfies the structure and constraints of the database.

Distinction

The ***database schema*** changes very infrequently.

The ***database state*** changes every time the database is updated.

# Example of a Database Schema

**STUDENT**

| Name | Student_number | Class | Major |
|---|---|---|---|

**COURSE**

| Course_name | Course_number | Credit_hours | Department |
|---|---|---|---|

**PREREQUISITE**

| Course_number | Prerequisite_number |
|---|---|

**SECTION**

| Section_identifier | Course_number | Semester | Year | Instructor |
|---|---|---|---|---|

**GRADE_REPORT**

| Student_number | Section_identifier | Grade |
|---|---|---|

**Figure 2.1**
Schema diagram for the database in Figure 1.2.

**COURSE**

| Course_name | Course_number | Credit_hours | Department |
|---|---|---|---|
| Intro to Computer Science | CS1310 | 4 | CS |
| Data Structures | CS3320 | 4 | CS |
| Discrete Mathematics | MATH2410 | 3 | MATH |
| Database | CS3380 | 3 | CS |

**SECTION**

| Section_identifier | Course_number | Semester | Year | Instructor |
|---|---|---|---|---|
| 85 | MATH2410 | Fall | 04 | King |
| 92 | CS1310 | Fall | 04 | Anderson |
| 102 | CS3320 | Spring | 05 | Knuth |
| 112 | MATH2410 | Fall | 05 | Chang |
| 119 | CS1310 | Fall | 05 | Anderson |
| 135 | CS3380 | Fall | 05 | Stone |

**GRADE_REPORT**

| Student_number | Section_identifier | Grade |
|---|---|---|
| 17 | 112 | B |
| 17 | 119 | C |
| 8 | 85 | A |
| 8 | 92 | A |
| 8 | 102 | B |
| 8 | 135 | A |

**PREREQUISITE**

| Course_number | Prerequisite_number |
|---|---|
| CS3380 | CS3320 |
| CS3380 | MATH2410 |
| CS3320 | CS1310 |

**Figure 1.2**
A database that stores student and course information.

# Example of a database state

# Three-Schema Architecture

Defines DBMS schemas at ***three*** levels:

- **Internal schema** at the internal level to describe physical storage structures and access paths (e.g indexes).
  - Typically uses a **physical** data model.
- **Conceptual schema** at the conceptual level to describe the structure and constraints for the whole database for a community of users.
  - Uses a **conceptual** or an **implementation** data model.
- **External schemas** at the external level to describe the various user views.
  - Usually uses the same data model as the conceptual schema.

# The three-schema architecture

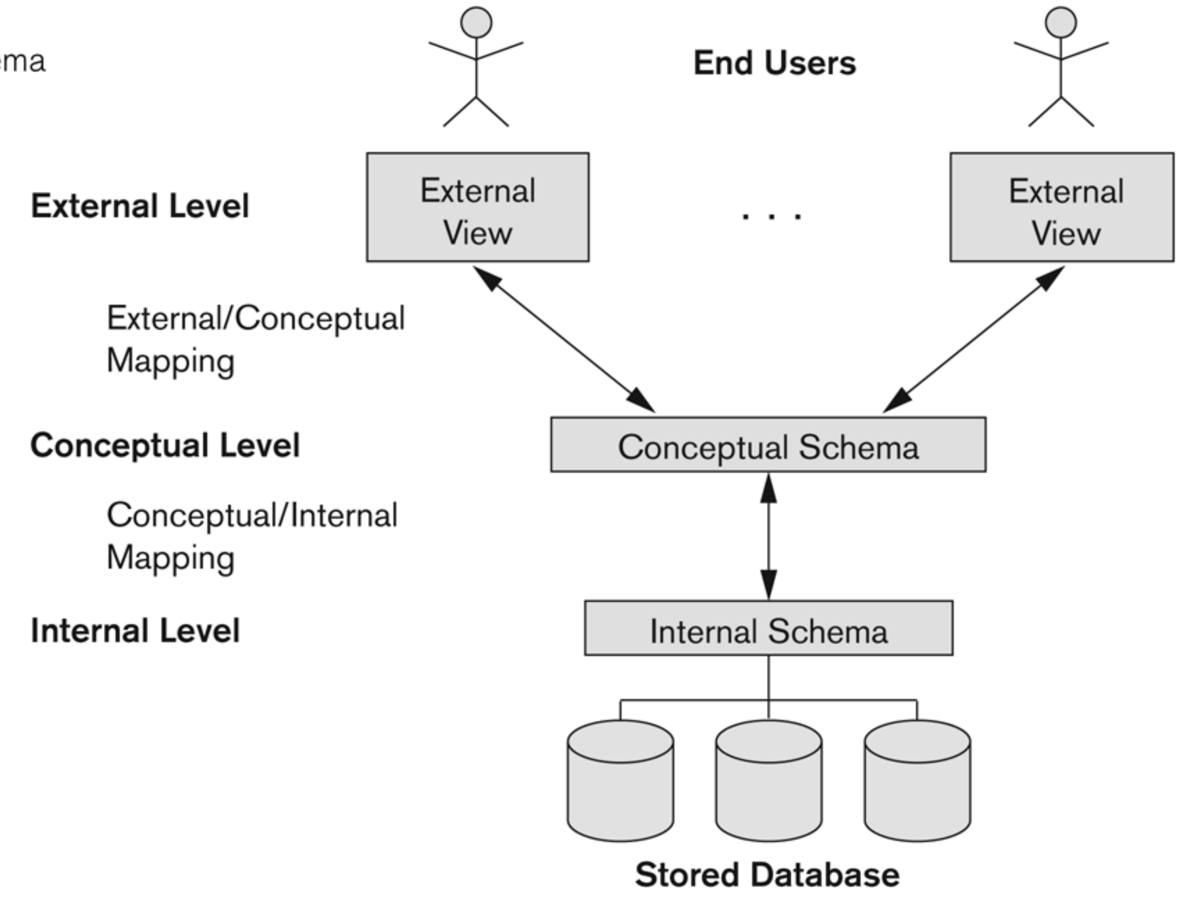



**Figure 2.2**
The three-schema architecture.

# DBMS Languages

Data Definition Language (DDL)

Data Manipulation Language (DML)

# DBMS Languages

**Data Definition Language (DDL):**

- Used by the DBA and database designers to specify the conceptual schema of a database.
- In many DBMSs, the DDL is also used to define internal and external schemas (views).
- In some DBMSs, separate **storage definition language (SDL)** and **view definition language (VDL)** are used to define internal and external schemas.
  - SDL is typically realized via DBMS commands provided to the DBA and database designers

# DBMS Languages

**Data Manipulation Language (DML):**

- Used to specify database retrievals and updates
- DML commands (data sublanguage) can be *embedded* in a general-purpose programming language (host language), such as COBOL, C, C++, or Java.
  - A library of functions can also be provided to access the DBMS from a programming language
- Alternatively, stand-alone DML commands can be applied directly (called a *query language*).

# Types of DML

Select * from Students.

**High Level or Non-procedural Language:**

For example, the SQL relational language

Are "set"-oriented and specify what data to retrieve rather than how to retrieve it.

Also called **declarative** languages.

QBE – Query By Example

**Low Level or Procedural Language:**

Retrieve data one record-at-a-time;

Constructs such as looping are needed to retrieve multiple records, along with positioning pointers.

COBOL / FORTRAN

# Bibliography / Acknowledgements

Instructor materials from Elmasri & Navathe 7e

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Thank you for attending the class!!!