Databases Systems
ICS 184

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CS 184 Course Web Server

- All course information will be posted on line
- URL:
  - http://www.ics.uci.edu/~dbclass/ics184/index.html
- Class Notes available before class on the Web.

Course Info

- TAs
  - Koushik Niyogi

    Office and office Hours:
    - Monday and Wednesday : 2:00-3:00 PM
  - Rajat Mathur

    Office and office Hours: TBA
- Instructor
  - Office Hours:
  - Tue 11-12 pm
  - (send email)
  - Email: sharad@ics.uci.edu
  - to contact me urgently, send email and mark subject line as CS 184 URGENT

Desiderata

- Course Text: (either of following two books will suffice)
  - A First Course in Database Systems, Ullman and Widom
    - we will cover the entire book
  - Database Systems Concepts, Silberschatz, Korth, and Sudarshan
    - we will cover chapters 1-9
- Software:
  - Course will involve significant programming.
  - You will get exposure to database programming in DB2

Desiderata (cont.)

- Course Requirements:
  - Problem sets ~ approx. every week to 10 days.
    - Total not to exceed 8
  - Midterm
  - Final (comprehensive)
  - Grades:
    - Problem sets 15%
    - Personal Database Assignment (project) 15%
    - Midterm 30%
    - Final 40%

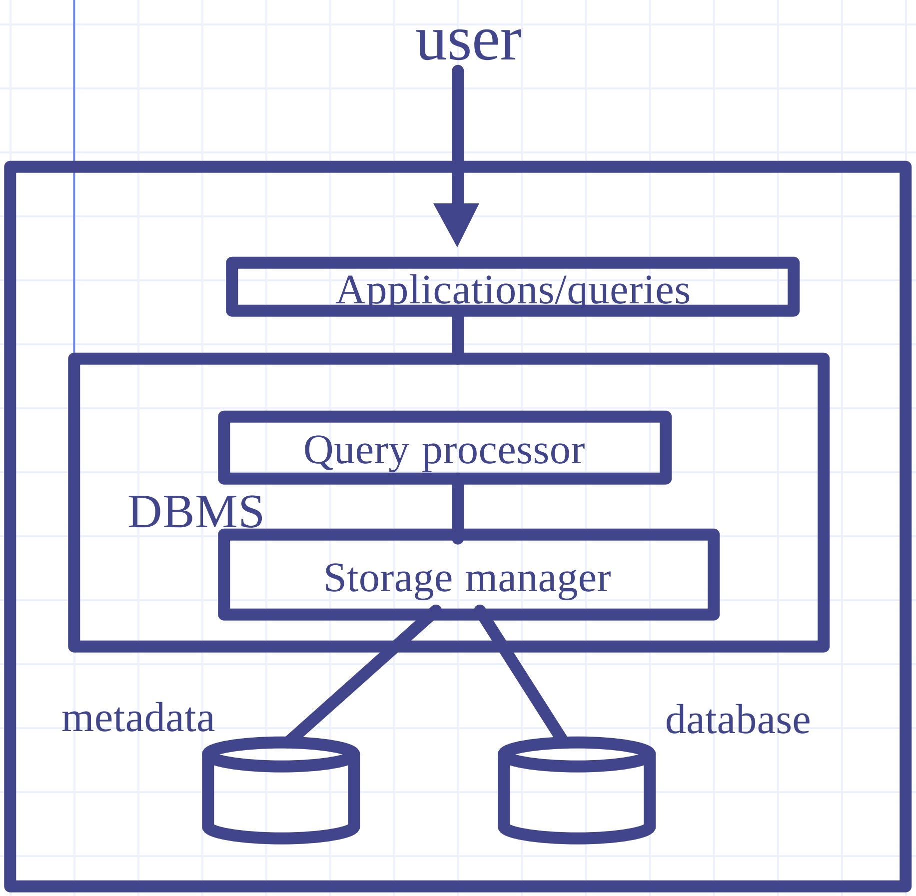
Policies

- Late Assignments
  - No grace period after due date.... except under exceptional circumstances
  - job interviews, out of town trip, breaks etc do not qualify as exceptional circumstances!
- Working in Groups
  - do your homework problem sets in group size not to exceed 3
  - learn more
  - get better grades
  - get used to working in groups (important to employers)
- Do exams individually!!

Material Covered in CS 184

- Four aspects of studying DBMSs
  - Modeling and design of databases
    - allows exploration of issues before committing to an implementation
  - Programming: queries and DB operations like update.
    - SQL == “intergalactic dataspeak”
  - DBMS implementation
  - Effect of technology and application advances to database technology.
- CS 184 == (1) + (2)
- CS 214 == (3)
- CS215 == (3) + (4)

Database Management Environment



Database: collection of interrelated information about world being modeled

DBMS:general purpose software to define, create, modify, retrieve, delete and manipulate a database

Vendors: Informix, Oracle, O2, Sybase, IBM, DEC

Traditional DBMS Goals

- *Efficient management* of (faster than files) *large amounts of* (gigabytes) of *persistent* (outlasts creator), *reliable* (outlasts crashes) *shared information* (multiple users).

- DBMS Users:
  - small and large corporations
    - E-commerce companies, banks, airlines, transportation companies, corporate databases, government agencies, defense.
    - Anyone you can think of!

Databases and File Systems

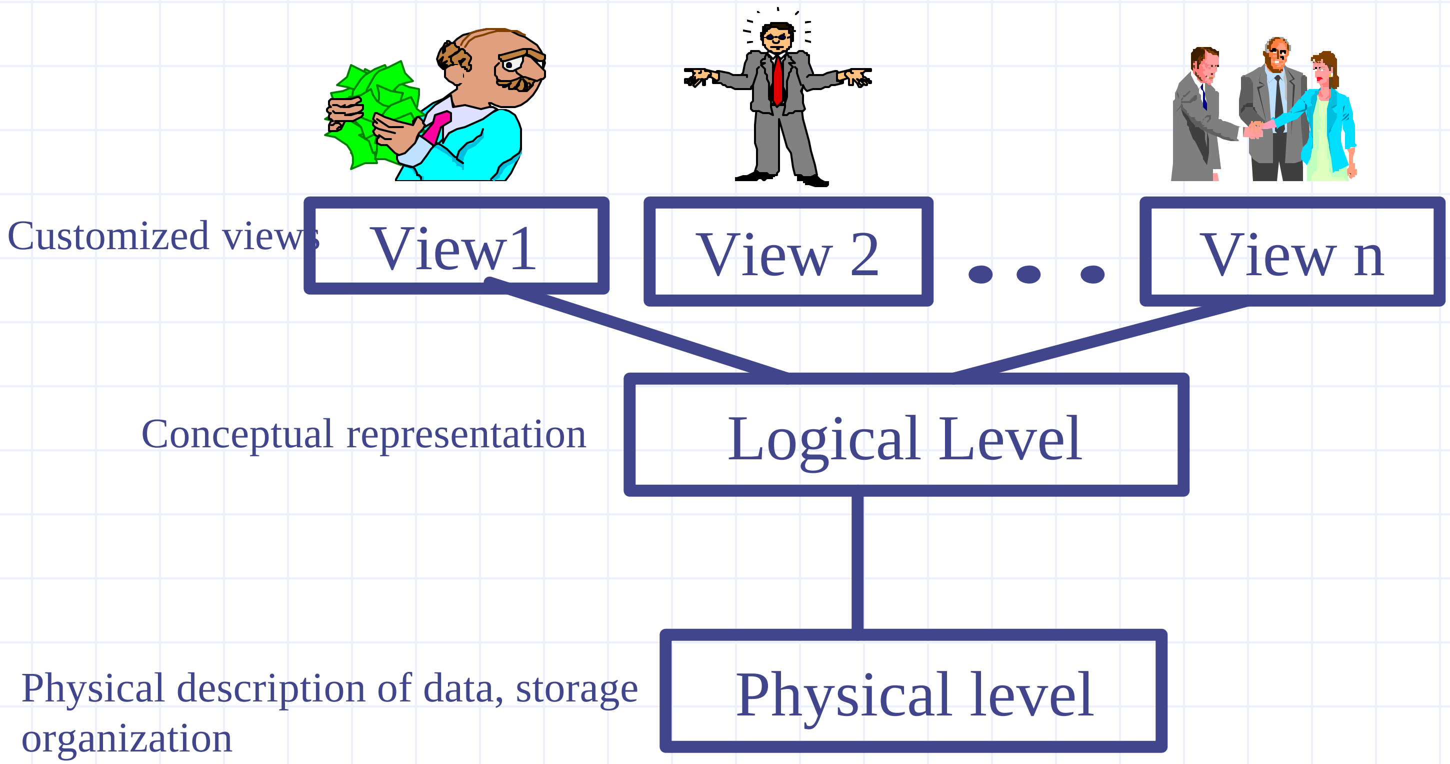
- DBMSs evolved from file systems.
- DBMSs provide many features that traditional file systems do not.
  - Support for concurrent access and data sharing. Data consistency in presence of concurrency
  - Reliability in presence of failures and system crashes.
  - Efficient associative access to very large amounts of data
  - A high level Query language (SQL) to define, create, access, and manipulate data. Support for unanticipated queries
  - support for multiple data views
  - security and authorization
  - data abstraction
  - prevention of data redundancy and inconsistencies

Data Abstraction

- *program data independence*:
  - ability to hide details of how data is stored and maintained from application programs
- *program-operation independence*:
  - ability to hide details of operation implementation from application programs (Object-Orientation)

Data Abstraction

- Hiding system complexity, physical storage details from users and application programs



Schemas and Instances

- Instance:
  - set of data currently instantiated in database
  - changes frequently
- Schema:
  - overall design, structure, and constraints over the database
  - referred to as metadata
  - changes infrequently
- Example:

Schema

Tables

Emp (ename, dep#)

Dept(dep#, dname, mgr)

Constraints

each department has

a single manager

Instance

Emp

(John, 10), (Cindy, 15), (Martha, 10)

dept

(10, Toy, John), (15, Sales, Cindy)

Data Model

- Set of concepts and tools used to describe the database schema
- Different schemas at different abstraction levels:
  - *physical schema:* describes physical organization of data
  - *logical schema:* describes data at conceptual level
  - *sub schema:* defines data at view level
- Different models used describe schemas at different abstraction levels

Types of Data Models

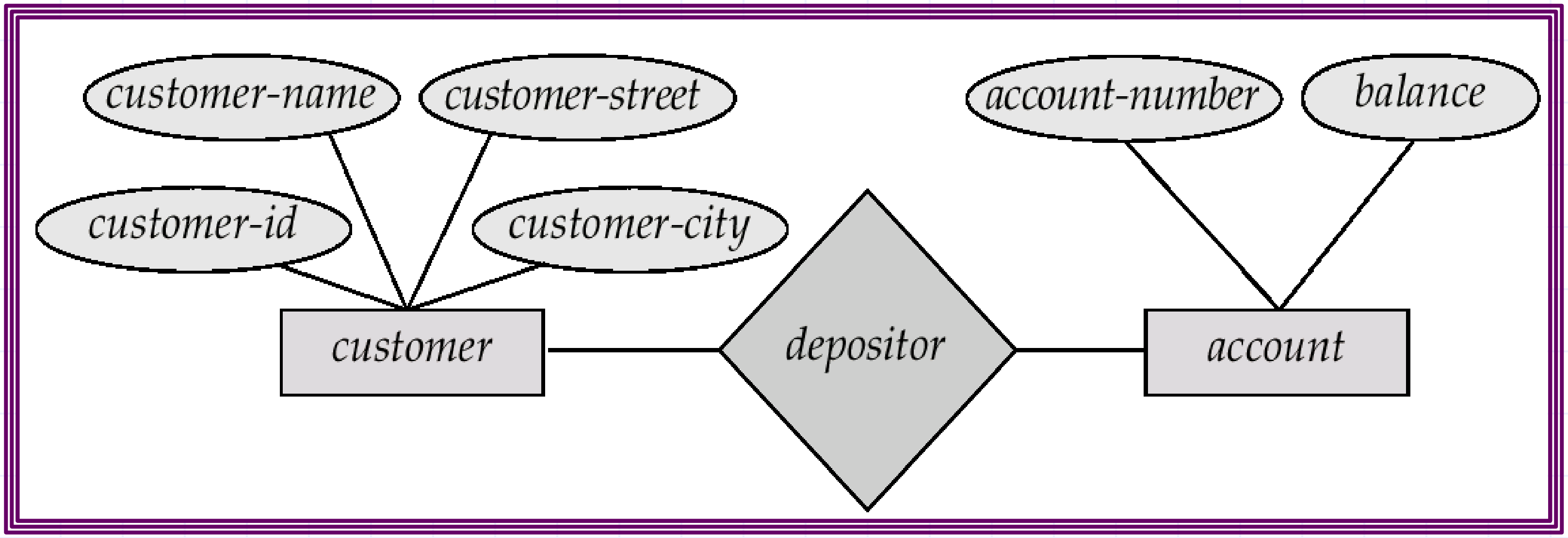
- Object based Logical Models
  - Used to describe schema at view and logical levels.
  - Support abstract view of data as objects, relationships, constraints
  - Example: Entity Relationship Model, Functional data Model, Semantic Model, Object Oriented Model like ODL

Types of Data Model (cont.)

- Record-Based Logical Models
  - Used to define data at view and logical levels.
  - Provide a high level description of implementation
  - Examples:Relational Model, Hierarchical Model, Network Model
- Physical Models
  - Used to describe data at implementation level.
  - Examples: Frame Memory Model, Unifying Model

Entity-Relationship Model

Example of schema in the entity-relationship model



Entity Relationship Model (Cont.)

- E-R model of real world
  - Entities (objects)
    - E.g. customers, accounts, bank branch
  - Relationships between entities
    - E.g. Account A-101 is held by customer Johnson
    - Relationship set *depositor* associates customers with accounts
- Widely used for database design
  - Database design in E-R model usually converted to design in the relational model (coming up next) which is used for storage and processing

Relational Model

- Example of tabular data in the relational model

Attributes

Customer-id	*customer-name*	*customer-street*	*customer-city*	*account-number*
192-83-7465	Johnson	Alma	Palo Alto	A-101
019-28-3746	Smith	North	Rye	A-215
192-83-7465	Johnson	Alma	Palo Alto	A-201
321-12-3123	Jones	Main	Harrison	A-217
019-28-3746	Smith	North	Rye	A-201

A Sample Relational Database

customer-id	*customer-name*	*customer-street*	*customer-city*
192-83-7465	Johnson	12 Alma St.	Palo Alto
019-28-3746	Smith	4 North St.	Rye
677-89-9011	Hayes	3 Main St.	Harrison
182-73-6091	Turner	123 Putnam Ave.	Stamford
321-12-3123	Jones	100 Main St.	Harrison
336-66-9999	Lindsay	175 Park Ave.	Pittsfield
019-28-3746	Smith	72 North St.	Rye

(a) The *customer* table

account-number	*balance*
A-101	500
A-215	700
A-102	400
A-305	350
A-201	900
A-217	750
A-222	700

(b) The *account* table

customer-id	*account-number*
192-83-7465	A-101
192-83-7465	A-201
019-28-3746	A-215
677-89-9011	A-102
182-73-6091	A-305
321-12-3123	A-217
336-66-9999	A-222
019-28-3746	A-201

(c) The *depositor* table

Classification of DBMSs based on Data Model

- Relational DBMSs:
  - modeling concept: tables and constraints on tables
  - Query Language: SQL
  - Applications: suited for traditional business processing applications
- Object Oriented DBMSs
  - modeling concepts: objects, classes, inheritance
  - Query Language: object oriented OQL
  - Applications: suited for CAD databases, CASE databases, office automation
- Object Relational DBMSs:
  - incorporate OO concepts into relational model
  - similar functionality as OODBMSs though different in implementations
  - Language extended to process objects.

DBMS Languages

- Data Definition Language (DDL)
  - DDL = the language used to describe a schema
  - Data dictionary/directory = a compiled description of a schema
- Data Manipulation Language (DML)
  - DML= Language users use to ask questions about (query) the database, and to change the data in the database.
- Storage Definition Language (SDL)
  - SDL = language to define the internal schema
- View Definition Language (VDL)
  - VDL = view definition language

Data Definition Language (DDL)

- Specification notation for defining the database schema
  - E.g.
    create table *account* (
    account-number **char**(10),
    balance **integer**)
- DDL compiler generates a set of tables stored in a *data dictionary*
- Data dictionary contains metadata (i.e., data about data)
  - database schema
  - Data *storage and definition* language
    - language in which the storage structure and access methods used by the database system are specified
    - Usually an extension of the data definition language

Data Manipulation Language (DML)

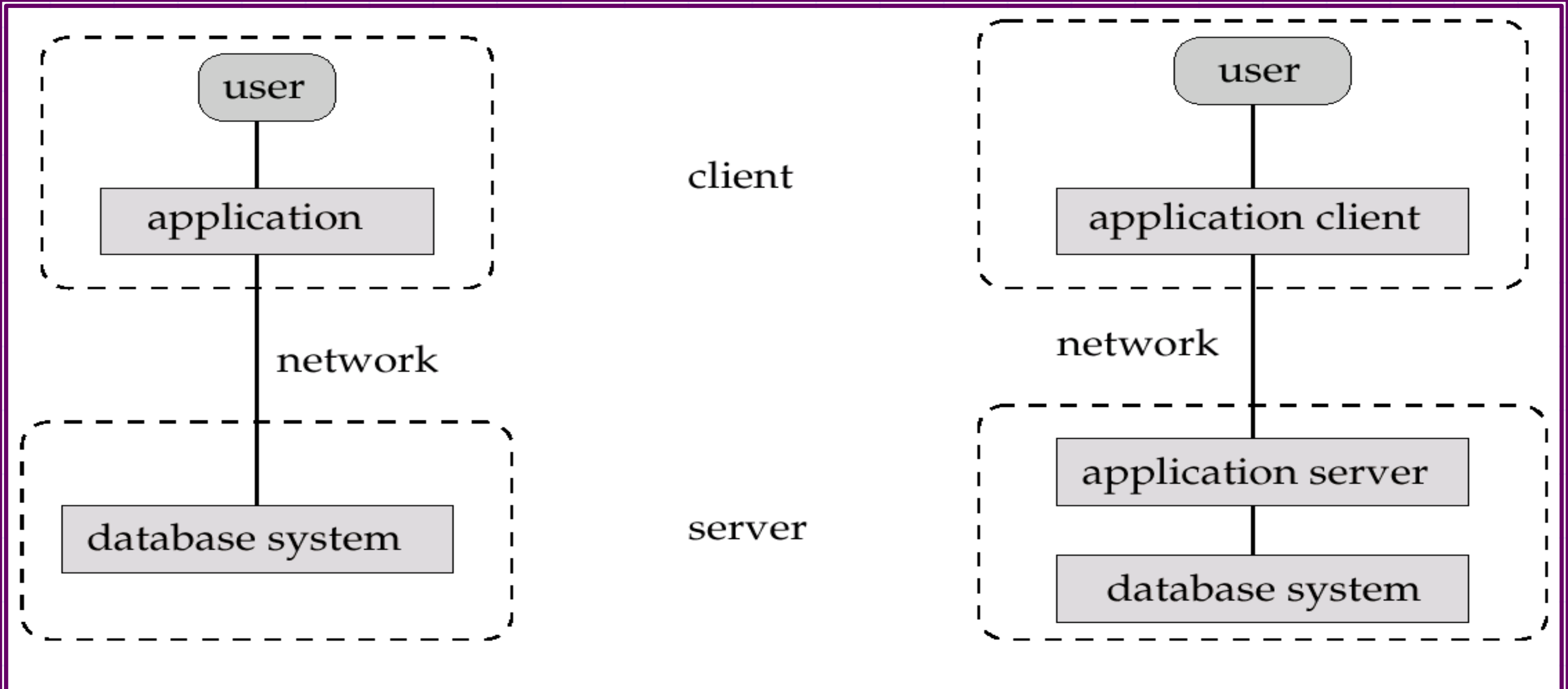
- Language for accessing and manipulating the data organized by the appropriate data model
  - DML also known as query language
- Two classes of languages
  - Procedural – user specifies what data is required and how to get those data
  - Nonprocedural – user specifies what data is required without specifying how to get those data
- SQL is the most widely used query language

SQL

- SQL: widely used non-procedural language
  - E.g. find the name of the customer with customer-id 192-83-7465

    select *customer.customer-name*
    from *customer*
    where *customer.customer-id* = '192-83-7465'
- Basic SQL has limited expressability
  - cannot implement any arbitrary function in SQL
- Application programs generally access databases through one of
  - Language extensions to allow embedded SQL
  - Application program interface (e.g. ODBC/JDBC) which allow SQL queries to be sent to a database

Application Architectures



a. two-tier architecture b. three-tier architecture

- **Two-tier architecture**: E.g. client programs using ODBC/JDBC to communicate with a database
- **Three-tier architecture**: E.g. web-based applications, and applications built using "middleware"

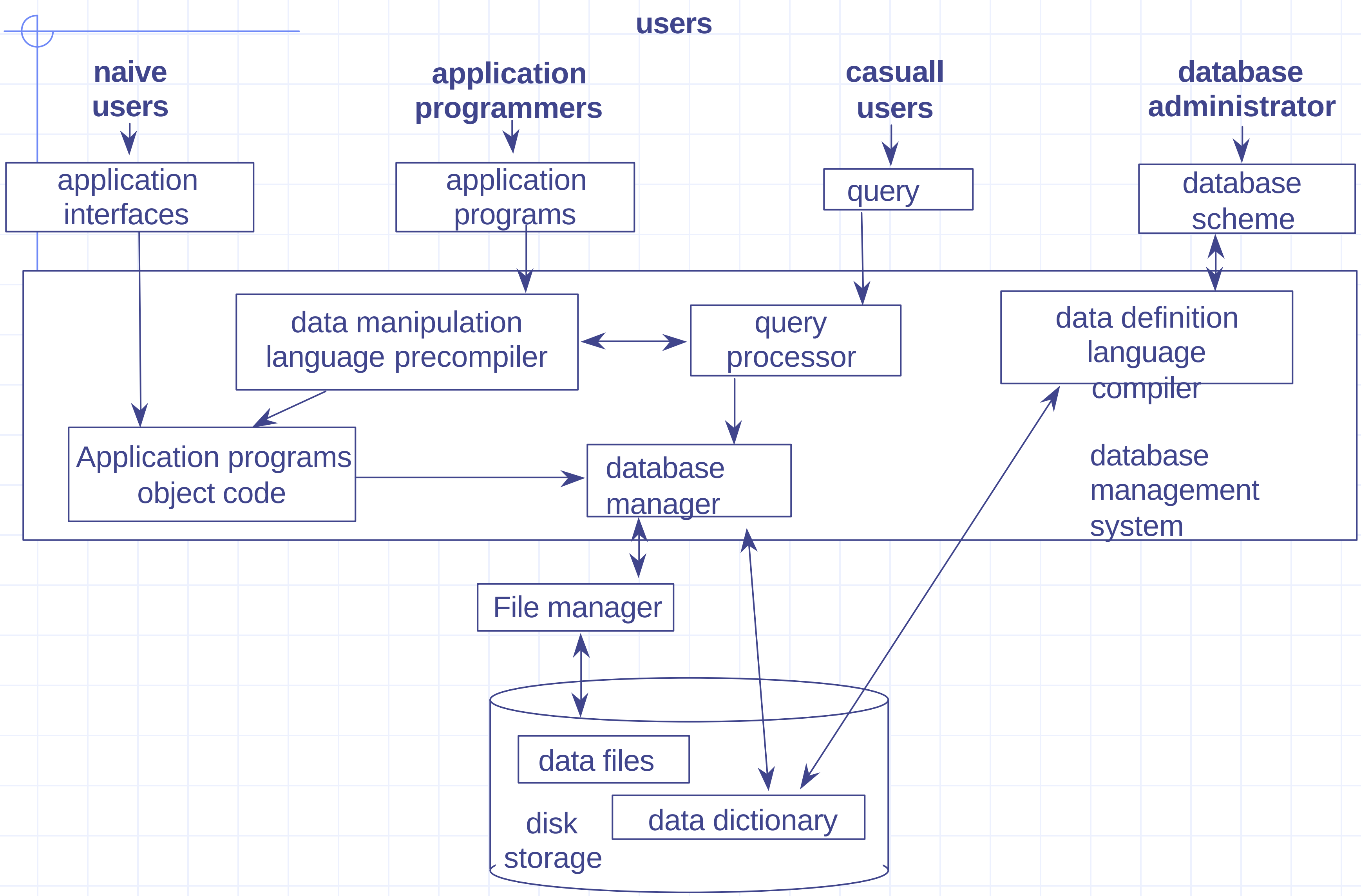
DBMS Interface

- Provides users means to interact with database.
- Where we are today:
  - Menu driven interface, Graphical interface, Forms based interface, Natural Language Interface, WWW connectivity.
- Interface design is a tremendous challenge not only for DBMS researchers but to HCI and human cognition researchers.
- Future interfaces to databases:
  - virtual reality, immersive environments, speech, natural languages, gestures, handwriting, eye tracking brain waves, tactile interfaces, multimodal input and outputs -- combination of more than one modality.

People Involved with DBMSs

- DBMS designers and implementers
- tool designers
- database administrator (DBA)
  - DBA = ‘super-user’ for a database, similar to a system administrator.
  - DBA can define schemas, views, authorization, indexes, tuning parameters, etc.
- application programmers
- database designers
  - interact with users to define database at all levels
- database and system operators.
- end users
- large number of jobs available for each of the above tasks!!

DBMS Architecture



Key Database Technologies

- **Data Models**
  - allow specification of database structure at all the levels of abstraction
- **Design tools**
  - that help in the database design process. These tools automates or facilitate some aspects of the design
- **Access Methods**
  - data structures to support efficient access of data on disk
- **Query Optimization and Processing**
  - efficient query processing techniques for good query performance. These techniques usually minimize the amount of disk I/O
- **Transaction processing techniques**
  - to support concurrent access and reliability in the presence of failures

Need for Query Optimization

- Consider two tables
  - Employee(ename, salary, department)
    - say 1000 entries
  - Manager(mname, department)
    - say 10 entries
- Query:
  - List the names of employees for the department of which Sharad is the manager

Strategies 1

- For each entry M in Manager
  - read record M
  - For each entry E in employees
    - read Entry E

      If (E.department == M.department) and (M.mname = “sharad”)

      print E.ename
- Cost Analysis:
  - Outer loop 10 iterations. 1 read operation each time.
  - Inner loop 1000 iterations. 1 entry read each time.
  - total number of reads = 10 + 1000*10 = 10,010.

Strategy 2

- For each entry M in Manager
  - If M.mname = “sharad”

    temp = M.department
- For each entry E in Employees
  - If E.department == temp

    print E.ename
- Cost Analysis:
  - first loop 10 iterations. 1 read operation each time.
  - Second loop 1000 iterations. 1 read operation each times.
  - Total number of reads = 1010.

Transaction Concept

- ***Atomicity:***
  - all or nothing execution.
- ***Consistency:***
  - execution of a transaction leaves system state as well as the state of the real world consistent.
- ***Isolation:***
  - partial effects of a transaction are hidden from each other.
- ***Durability:***
  - a successful transactions effects survives future system malfunctions.

Example of Transaction

- *Withdraw $100 checking account using an ATM.*
- Atomicity:
  - account debited if and only if t user gets money from the ATM
- Consistency:
  - balance of account is always positive.
- Isolation:
  - concurrent execution of withdraw, deposit, transfers does not result in an incorrect balance of account.
- Durability:
  - After withdraw terminates, and the ATM dispenses money account reflects that $100 withdrawn despite failures.

Motivation of Isolation

- Consider two transactions--
  - read account A, debit the value by $100 and write the new value to A.
  - read account A, credit the value by $200 and write the new value to A.
- Let initial value of A be $1000.
- Final value should be $1100.
- Consider the following execution if concurrency is permitted:
  - read1(A,1000) read2(A,1000) write2(A,1200) write1(A,900)
  - for the above execution the value of A is 900!

Importance of the Transactions

- Transaction concept supports:
  - simple failure semantics -- either all the effects of the transaction appear or none do-- all or nothing
  - an isolated view of the world -- protection from partial effects of concurrently executing transactions
- Makes application development easy
  - complex, possibly distributed applications that share data and resources can be developed without explicitly dealing with synchronization and fault-tolerance.

Transactions versus Other Concurrent Programming Environments

- concurrent programs prevalent in a variety of other areas in CS
  - operating systems, parallel programming, distributed systems.
- support Powerful Language Constructs:
  - to specify concurrent behavior of applications (programmers responsibility to deal with failures and concurrency issues).
- In contrast transactions relieve the application programmers of these tasks.