Module 1 Introduction to Software Engineering Basics – Part 3

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Content

- Other Software Processes
  - Project Management Process
  - Configuration Management Process
  - Process Management Process

Other Software Processes

Other Software Process

- Other Processes
  - Development process is the central process in software processes.
  - But, other processes are needed to properly execute development process and achieve desired characteristics of software processes.
  - These processes are for each of the activities in the development process, e.g. requirements, design, testing, etc.
  - We discuss here some of the important processes

Other Software Process

- Project Management Process
  - To meet cost, quality and schedule objectives of software development:
    - Resources have to be properly allocated to each activity
    - Progress of different activities has to be monitored
    - Corrective measures, if needed, need to be taken
    - Scheduling of each activity has to be done

Other Software Process

- Project Management Process
    - To meet cost, quality and schedule objectives of software development:
        - Project risk plan has to be created
        - Change requests have to be managed
    - These and many other activities that ensure cost, quality and schedule objectives are part of *Project Management Process*.

Other Software Process

- Project Management Process
  - Basic Task: To plan the detailed implementation of the development process chosen for a project and then ensure the plan is followed.
  - The focus is on issues like
    - Planning a project
    - Estimating resource and schedule
    - Monitoring and controlling the project

Other Software Process

- Project Management Process
  - Project Management process activities are broadly grouped in three phases:
    - Planning
    - Monitoring and Control
    - Termination Analysis

Other Software Process

- Project Management Process
  - Planning
    - First phase of project management process
    - Important phase and forms basis for *monitoring and control*
    - Goal: To develop a *plan* for software development to meet project objectives successfully and efficiently
    - Software plan is produced before the development begins
    - It is updated as development proceeds and project progress data becomes available.

Other Software Process

- Project Management Process
  - Planning
    - Major activities include
      - Cost estimation
      - Schedule and milestone determination
      - Project staffing
      - Quality control plans
      - Controlling and monitoring plans

Other Software Process

- Project Management Process
  - Monitoring and Control
    - Longest phase in terms of duration
    - Encompasses most of development process
    - It includes all activities that project management has to perform while development is going on
    - It also ensure that project objectives are met and development proceeds according to plan

Other Software Process

- Project Management Process
  - Monitoring and Control
    - Monitoring potential risk is important activity which focuses on potential risks, if any during the development of project.
    - Monitoring a development process requires proper information about the project.

Other Software Process

- Project Management Process
  - Monitoring and Control
    - Major activities include
      - Measuring planned performance vs actual performance.
      - Ongoing assessment of the project’s performance to identify any preventive or corrective actions needed.

Other Software Process

- Project Management Process
  - Monitoring and Control
    - Major activities include
      - Keeping accurate, timely information based on the project's output and associated documentation.
      - Monitoring the implementation of any approved changes or schedule amendments.

Other Software Process

- Project Management Process
  - Termination Analysis
    - Last phase of management process
    - Performed when the development is over
    - Goal: To provide the information about the development process and learn from the project in order to improve the process.
    - Also called as *postmortem analysis.*

Other Software Process

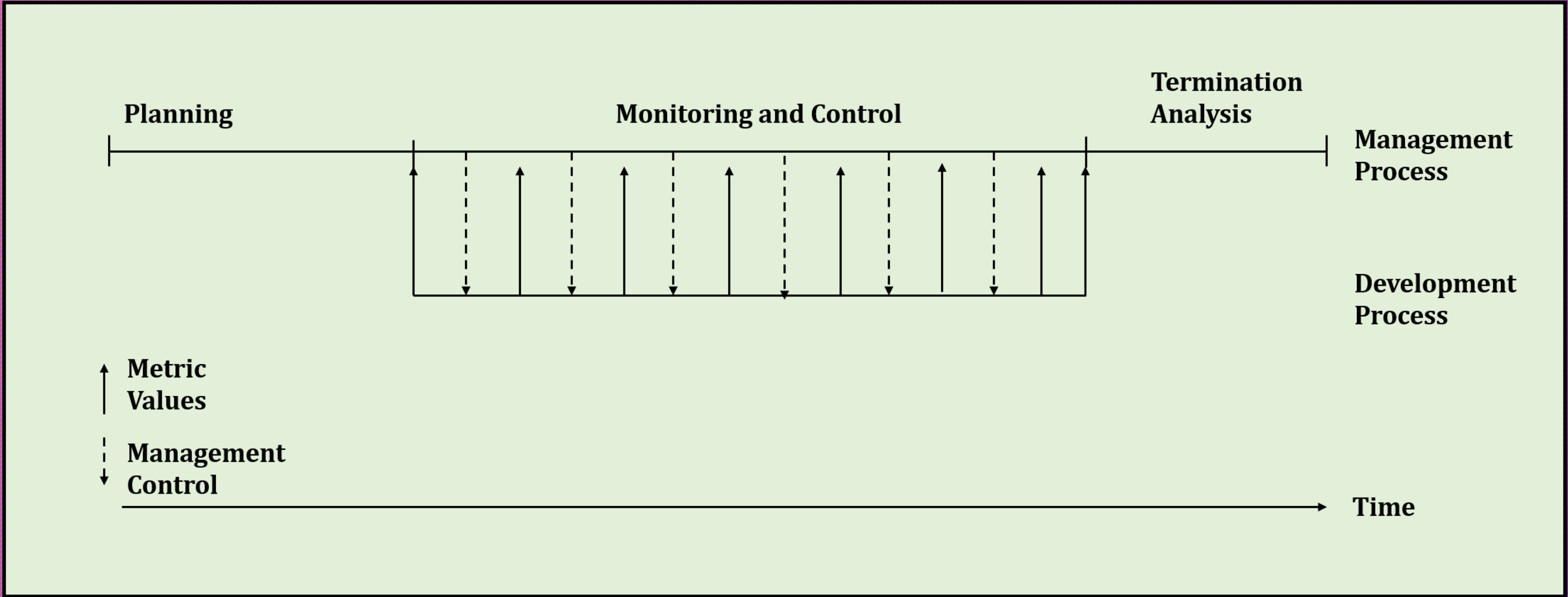

Fig. 1 Temporal Relationship Between Development and Management Process

Other Software Process

- Software Configuration Management Process
  - Changes continuously take place in a software development project
    - Changes due to evolution of work products
    - Changes due to bugs
    - Changes due to requirements changes
  - These changes are reflected as changes in the files containing source, data, documentation, manuals, other work products.

Other Software Process

- Software Configuration Management Process
  - To systematically control these changes *Configuration Management (CM)* or *Software Configuration Management (SCM)* is required.
  - IEEE defines SCM as

  "the process of identifying and defining the items in the system, controlling the change of these items throughout their life cycle, recording and reporting the status of items and change requests, and verifying the completeness and correctness of items."

Other Software Process

- Software Configuration Management Process
  - It is independent of development process.
    - Development models look at the macro picture and not on changes to individual files
  - Development process is brought under SCM, so changes are allowed in controlled manner.
  - SCM directly controls the products of a process
  - It indirectly influences the activities producing the products

Other Software Process

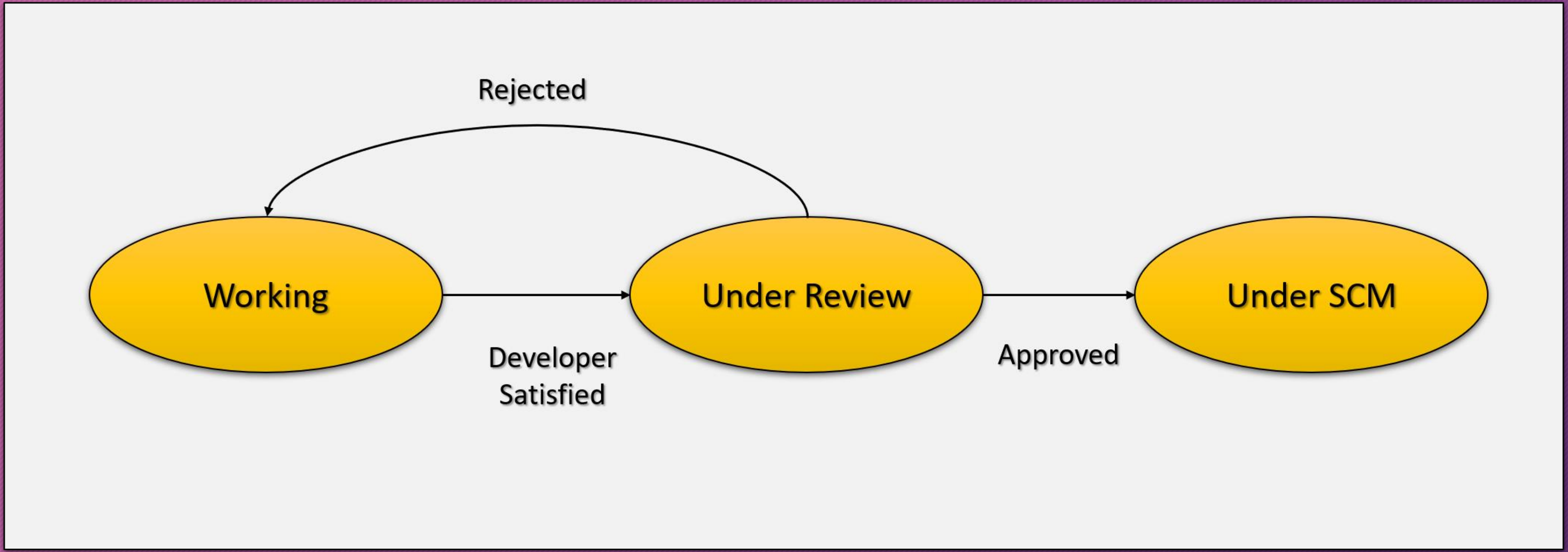

Fig. 2 Configuration Management and development process

Other Software Process

- Software Configuration Management Process Functionalities
    - Give latest version of a program
        - Changes should be done in the latest version of a file.
        - CM process will ensure that the latest version of a file can be obtained easily
    - Undo a change or revert back to a specified version
        - Change made in a program or many programs to implement some change request may sometimes need to be undone
        - The CM process must allow this to happen smoothly

Other Software Process

- Software Configuration Management Process Functionalities
  - Prevent unauthorised changes or deletions
    - A change in program may be done that has some adverse side effects
    - The CM process must ensure that the unapproved changes are not permitted

Other Software Process

- Software Configuration Management Process Functionalities
  - Gather all sources, documents and other information for the current system
    - All sources and related files are needed for releasing the product.
    - These files may be needed for reinstallation or recovery.
    - The CM process must provide this functionality.

Other Software Process

- Software Configuration Management Process
  - CM is essential to satisfy the basic objective of a project: Delivery of high quality software product to the client

Other Software Process

- Requirements Change Management Process
  - Project requirements can change any time during the life of a project.
  - The farther down in the life cycle the requirements change, the more severe the impact on the project.
  - Requirements changes can take as much as 40% of the total cost of the project.
  - Therefore project manager must be prepared to handle any change requests as and when they come.

Other Software Process

- Requirements Change Management Process
  - The change management process defines the set of activities that are performed when there are some new requirements or changes to existing requirements
  - This process also focuses on the major changes like design changes and bug fixes.

Other Software Process

- Requirements Change Management Process
  - This process has following steps:
    - Log the changes
    - Perform impact analysis on the work products
    - Estimate the impact on the effort and schedule
    - Review impact with concerned stakeholder
    - Rework work products

Other Software Process

- Requirements Change Management Process
  - A change is initiated by a *change request.*
  - A *change request log* is maintained to keep track of the change requests.
  - Each entry in the log contains
    - A change request number
    - A brief description of the change
    - The effect of the change
    - The Status of the change requests and key dates

Other Software Process

- Requirements Change Management Process
  - Then effect of a change request is assessed by performing *impact analysis.*
  - It involves
    - Identifying work products and configuration items that need to be changed
    - Evaluating quantum of change to each work product and items
    - Reassessing the project risks by revisiting the risk management plan

Other Software Process

- Requirements Change Management Process
  - It involves
    - Evaluating the overall implications of the changes for the effort and *schedule estimates.*
  - Once the change is reviewed and approved, then it is implemented.
  - i.e. changes to all items are made
  - The actual tracking of implementation may handled by SCM process.

Other Software Process

- Requirements Change Management Process
  - One danger: Even if some changes are not large, over the life of the project cumulative impact of changes are large.
  - So, cumulative impact of changes must also be monitored.
  - For this, the change log is used frequently as a spreadsheet.

Other Software Process

- Process Management Process
  - A software process is not a static entity.
  - To meet cost, quality and schedule objectives software process must continuously be improved.
  - Improving quality and productivity of the process is main objective of process management process.
  - Project management and process management process are different.

Other Software Process

- Process Management Process
  - Process management focuses on *improving the process which in turn improves the general quality and productivity for the products produced using the process.*
  - Project management focuses on *executing the current project and ensuring that the objectives of the project are met.*
  - Time duration for project management process is typically the duration of the project while process management has larger duration as each project provides a data point for the process.

Other Software Process

- Process Management Process – Capability Maturity Model
  - To improve the process
    - First need to understand current status of a process
    - Then, build a plan to improve the process
  - Changes to a process are best introduced in the small increments
  - Revolutionizing the whole process takes time as new methods require time to internalize and truly follow.

Other Software Process

- Process Management Process – Capability Maturity Model
  - The next question is what order should be followed or what small change should be introduced first?
  - This depends on the current status of a process.
  - This concept of introducing changes in small increments based on the current state of a process has been captured in *Capability Maturity Model (CMM) framework.*

Other Software Process

- Process Management Process – Capability Maturity Model
  - *Software process capability* describes the range of expected results that can be achieved by following the process.
  - It determines what can be expected from the organization in terms of quality and productivity.
  - The goal of process improvement is to improve the process capability.

Other Software Process

- Process Management Process – Capability Maturity Model
  - A *maturity level* is a well-defined evolutionary plateau towards achieving a mature software process.
  - CMM suggests that there are five levels of well-defined maturity levels for a software process.
  - These are initial (level 1), repeatable, defined, managed, and optimizing (level 5).
  - When a process improves it moves from one level to next until it reaches level 5.

Other Software Process

- Process Management Process – Capability Maturity Model
  - In each level it specifies the areas in which improved can be absorbed and will bring the maximum benefits.

Other Software Process

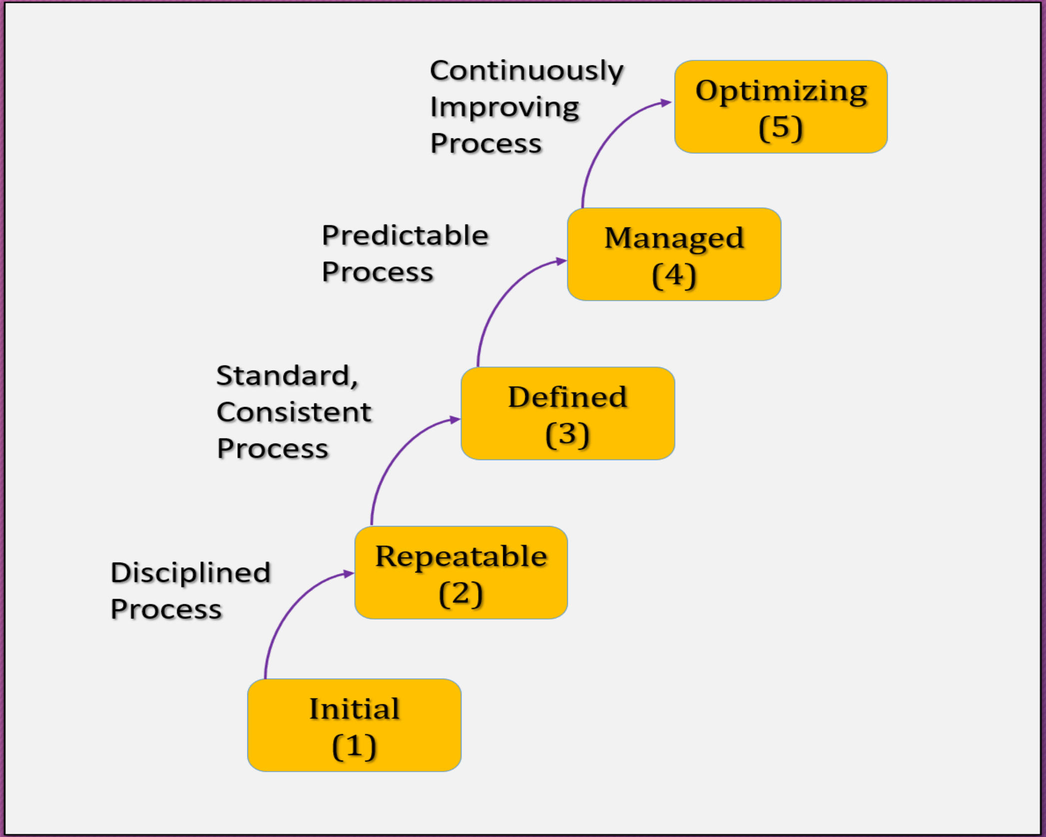

Fig. 3 Capability Maturity Model

Other Software Process

- Process Management Process – Capability Maturity Model
  - The initial process (level 1)
    - Ad hoc process
    - Has no formalized method for any activity
    - Basic project controls for ensuring the activity are done properly but there is no project plan
    - Unstable development environment
    - No basis for predicting the product quality, cost and schedule activity

Other Software Process

- Process Management Process – Capability Maturity Model
  - The initial process (level 1)
    - Success depends on the quality and capability of individuals
    - Need to improve project management, quality assurance and change control

Other Software Process

- Process Management Process – Capability Maturity Model
  - The repeatable process (level 2)
    - Project management policies for a software project are well defined.
    - Key characteristics are
      - Project commitments are realistic and based on the past experience with similar projects
      - Cost and schedule are tracked and problems are resolved when they arise

Other Software Process

- Process Management Process – Capability Maturity Model
  - The repeatable process (level 2)
    - Key characteristics are
      - Formal configuration control mechanisms are in place
      - Software project standards are defined and followed
    - The process is repeatable i.e. results obtained by this process can be repeated as project planning and tracking is formal.

Other Software Process

- Process Management Process – Capability Maturity Model
  - The defined level (level 3)
    - Organization has a standardized a software process and is well documented.
    - Organization has software process group that owns and manages the process
    - Key characteristics are
      - Each step/stage is carefully defined with verifiable entry and exit criteria, methodologies for performing the step,

Other Software Process

- Process Management Process – Capability Maturity Model
  - The defined level (level 3)
      - and verification mechanism for output
    - Both development and management processes are formal

Other Software Process

- Process Management Process – Capability Maturity Model
  - The managed level (level 4)
    - In this level quantitative goals exists for organization for process and products
    - Key characteristics are
      - Data is collected from software processes which is used to build models to characterize the process.
      - Hence organization has a good insights of the process capability and its deficiencies.

Other Software Process

- Process Management Process – Capability Maturity Model
  - The managed level (level 4)
    - Key characteristics are
      - The results can be predicted in quantitative terms.

Other Software Process

- Process Management Process – Capability Maturity Model
  - The optimizing level (level 4)
    - Highest level of process maturity in CMM
    - Focus is on continuous process improvement
    - Key characteristics are
      - Data is collected and routinely analysed to identify the areas that can be strengthened to improve the quality or productivity

Other Software Process

- Process Management Process – Capability Maturity Model
  - The optimizing level (level 4)
    - Key characteristics are
      - New technologies and tools are introduced and their effect is measured to improve the performance of the process
      - Best software engineering and management practices are used throughout the organization

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Module 1 Introduction to Software Engineering Basics – Part 1

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Content

- Software Crisis
- Need of Software Engineering Approach

Software Crisis

Software Crisis

- What is Software crisis?
- What caused the Software crisis?
- The Problem Domain
- The Software Engineering Challenges
- The Solution

What is Software crisis?

- Software Engineering (SE) is defined as

"the systematic approach to the development, operation, maintenance and retirement of software."

- IEEE, Software Engineering Standards, Technical Report

What is Software crisis?

- Coined by NATO Software Engineering Conference, 1968 at Garmisch, Germany
- The term is used in Computing Science for the ***difficulty in writing useful and efficient computer programs in the required time.***
- Reason - rapid increases in computer power and the complexity of the problems that could now be tackled

What is Software crisis?

“as long as there were no machines, programming was no problem at all; when we had a few weak computers, programming became a mild problem, and now we have gigantic computers, programming has become an equally gigantic problem”

- Edsger Dijkstra, The Humble Programmer (EWD340), Communications of the ACM

What caused the Software crisis?

- Linked to overall complexity of hardware and the software development process. It was evident in several ways:
  - Projects running over-budget
  - Projects running over-time
  - Software was very inefficient
  - Software was of low quality
  - Software often did not meet requirements
  - Projects were unmanageable and code difficult to maintain
  - Software was never delivered

The Solution

- There is no single solution to the crisis.
- One possible solution of software crisis is *Software Engineering* because software engineering is a systematic, disciplined and quantifiable approach.

The Solution

- For preventing software crisis, there are some guidelines:
  - Reduction in software over-budget
  - Reduction in software over-time
  - Software must be optimized to make it efficient
  - The quality of software must be high
  - Experienced working team member on software project
  - Using standard programming style rules
  - Software must be delivered

The Problem Domain

- Industrial Strength Software
- Software is Expensive
- Late and Unreliable
- Maintenance and Rework

The Problem Domain

- Industrial Strength Software
  - Consider the following example of Building a software
  - Q: How much time will a student require to develop a 10,000 lines of code (LOC) program/software in C/C++ at college?
  - A: 2 months approx.

Productivity = output/input

= 10,000 / 2

Productivity = 5,000 LOC per person-month

The Problem Domain

- Industrial Strength Software
  - For commercial software company,

    Productivity = 100 - 1000 LOC per person-month
  - Why is this difference?
  - What makes these novice students more productive than expert employees in the company?

The Problem Domain

- Industrial Strength Software
  - The Problem Domain is the software that solves some problem of some users where larger systems or businesses may depend on the software, and where problems in the software can lead to significant direct or indirect loss.
  - This software is called as *industrial strength software* that is different from the one built by students which is called as *student software*.

The Problem Domain

Sr. No.	Student Software	Industrial Strength Software
1	Primarily meant for demonstration purposes; generally not used for solving any real problem of any organization.	Primarily meant for real usage; built to solve some problem of an organization
2	Developer is the client/user	Other organization is the user
3	Presence of bugs or faults in the software are tolerable	Presence of bugs or faults may lead to financial or business loss, etc. and hence are not tolerable

The Problem Domain

Sr. No.	Student Software	Industrial Strength Software
4	In general, there is no documentation	Documentation is necessary for users, organization and developing industry
5	No or very less focus on User Interface	User Interface is very important
6	No or very less amount of money is invested	High amount of money is invested; may cost about 10 times the student software

The Problem Domain

Sr. No.	Student Software	Industrial Strength Software
7	Focus on testing is less, even 5% efforts on testing may be too high	High focus on testing, about 30-50% efforts may be spent on testing
8	Standards and development processes/phases are not followed	Standards and development processes/phases are strictly followed to make it high quality
9	No requirement of backup, recovery, fault tolerance, portability, etc.	High requirement of backup, recovery, fault tolerance, portability, etc.

The Problem Domain

Sr. No.	Student Software	Industrial Strength Software
10	Productivity is higher as compared to industrial strength software	Productivity is lower as compared to student software
11	E.g. Mini Projects, Final Year Projects	E.g. Fusion 360, Solid Works, AutoCAD, MATLAB, HEC-HMS, Simulink, Microsoft Visual Studio, etc.

The Problem Domain

- Software is Expensive
  - Industrial strength software is expensive as it is labour-intensive
  - Let us have a look at the cost involved
    - Measure of software = lines of code (LOC) or thousands of lines of code (KLOC)
    - Software development cost measure = person-month (i.e. per person per month)
    - Productivity measure = LOC per person-month or KLOC per person-month

The Problem Domain

- Software is Expensive
  - In general, the productivity = ~300 to 1,000 LOC per person-month
  - Software companies charge the client = ~$100,000 per person-year or $8,000 per person-month
  - Cost per LOC = ~$8 to $25
  - Any small project has at least = ~50,000 LOC
  - Cost of the software = ~ $0.5 million to $1.25 million

The Problem Domain

- Software is Expensive
  - In general, the workstation or server that runs the software costs at most tens of thousands of dollars.
  - Earlier in 1980s the cost of hardware were high, but today the situation is reversed.
  - The cost of software is high as compared to that of hardware.

The Problem Domain

- Late and unreliable
  - Late software
  - Survey says, more than 35% software development projects are ***runaways.***
  - Runaway Project is a project where budget and schedule are out of control.
  - Hence, there was an emergence of consultancy companies.

The Problem Domain

- Late and Unreliable
  - Unreliable Software
  - Meaning the software does not do what it is supposed to do or does something it is not supposed to do
  - A survey says, more than 70% equipment failures were due to the software.
  - E.g. software with electrical, hydraulic and mechanical systems, Apollo flight failure, India’s test firing of missile, banking, etc.

The Problem Domain

- Late and Unreliable
  - Unreliable Software
  - Software failures are different from mechanical or electrical system failures
  - In mechanical or electrical, failure is mainly due to the change in physical or electrical properties due to aging.
  - In software, failure is due to the bugs or errors introduced during the design and development process i.e. at the start only.

The Problem Domain

- Maintenance and Rework
  - Maintenance
  - Once the software is delivered and deployed, it enters the maintenance phase.
  - Why software needs maintenance, if it does not age?
  - The answer is residual errors remained in the system.
  - It is believed that all the software has residual errors or bugs in it.

The Problem Domain

- Maintenance and Rework
  - Maintenance
  - They can be discovered only after the software has been in operation, sometimes for a long time.
  - This leads to the change in software, and is called as *corrective maintenance*.

The Problem Domain

- Maintenance and Rework
  - Maintenance
  - Software also undergoes changes (upgrades or updates) to add more features and services.
  - Change in software needs to change the environment.
  - This phenomenon is known as *law of software evolution* and the maintenance due to this phenomenon is called as *adaptive maintenance*.

The Problem Domain

- Maintenance and Rework
  - Rework
  - For large and complex software systems, all the requirement are not understood before the commencement of software development.
  - As time goes and client's understanding of software improves, they specify the additional requirement.
  - This leads to the change in the requirement, design and code to accommodate the change. This leads to the *rework*.

The Problem Domain

- Maintenance and Rework
  - Rework
  - As times change, needs also change.
  - This also leads to the rework.
  - It is estimated that the rework costs are 30-40% of the development cost.

The Software Engineering Challenges

- Basic Problem
- Primary challenges for Software Engineering
  - Scale
  - Quality and Productivity
  - Consistency and Repeatability
  - Change

The Software Engineering Challenges

- Basic Problem
- Systematic Approach: Methodologies used for development of software are repeatable.

Fig. 1 Systematic Approach

The Software Engineering Challenges

- Basic Problem
- Goal of Software Engineering:
  - Take Software development closer to science and engineering where outcomes are predictable as compared to the traditional ad-hoc approaches which are being used since many years.
- The Problem:
  - To systematically develop software to satisfy the needs of some users or clients

The Software Engineering Challenges

- Basic Problem

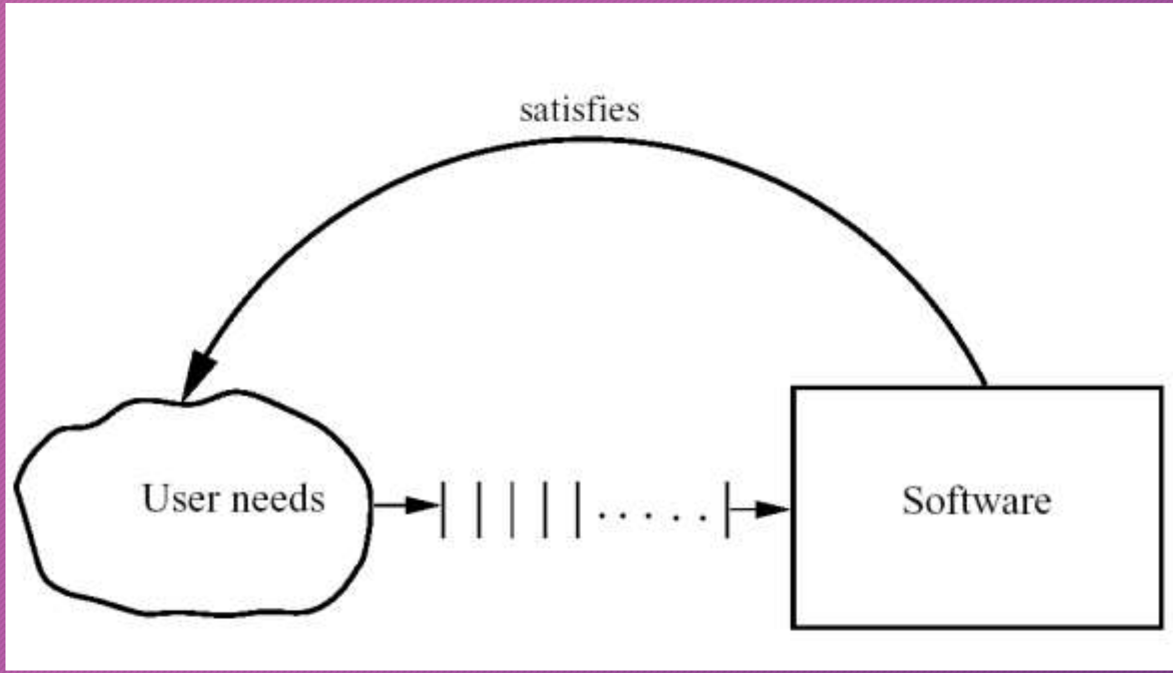

Fig. 2 Basic Problem

The Software Engineering Challenges

- Basic Problem
- There are some factors that affect the approaches selected to solve the problem.
- These factors are the primary forces that drive the *progress and development* in software engineering.
- These factors include scale, quality, productivity, consistency, repeatability and change.

The Software Engineering Challenges

- Scale
- It is measure, dimension or proportion of something.
- Methods for solving small problems do not scale up for large problems
- E.g. counting people in room vs taking census
- Methods required to develop large software must be different than that of small software

The Software Engineering Challenges

- Scale
- Two dimensions in this
  - Engineering methods – methods, procedures and tools
  - Project Management – managing the project by leading the work of a team to achieve the goals and meet success criteria at a specified time.
- Both must be more formal for developing large software.

The Software Engineering Challenges

- Scale

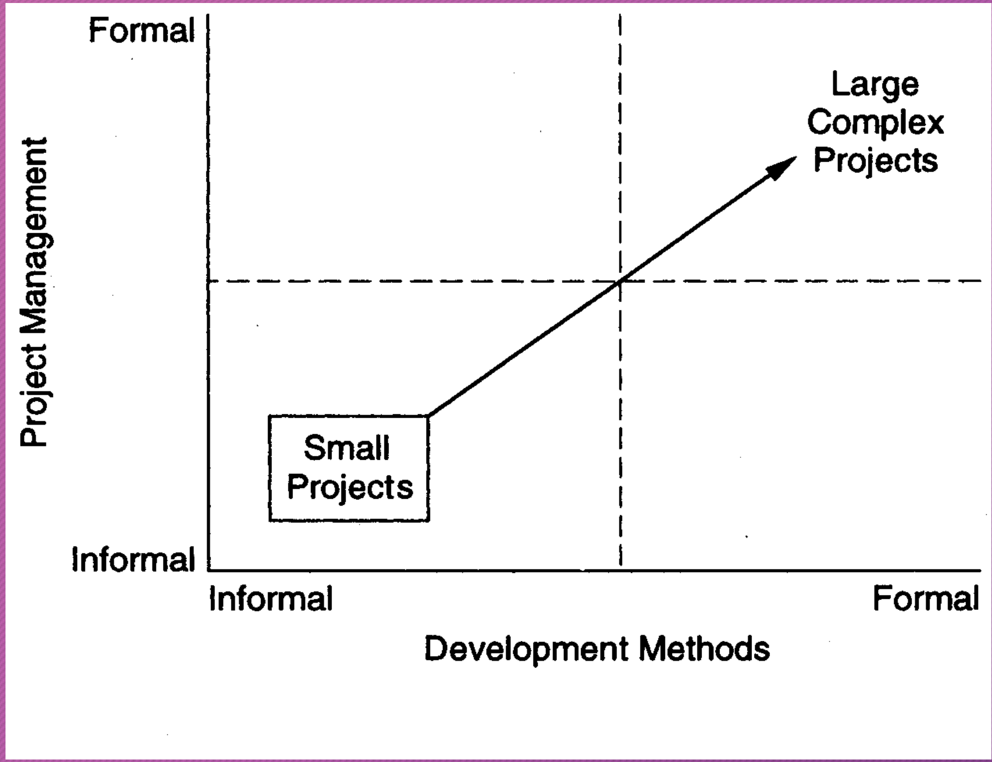

Fig. 2 The Problem of Scale

The Software Engineering Challenges

- Scale
- No universally accepted project scale
- But, informally,
  - Small Project – <10 KLOC
  - Medium Project – >10 KLOC and <100 KLOC
  - Large Project - >100 KLOC and < 1 million LOC
  - Very Large Project - >1 million LOC

The Software Engineering Challenges

- Productivity (P)
  - Software Engineering is driven by cost, schedule and quality.
  - Development cost is dominated by manpower cost.
  - Cost measure – person-month
  - Schedule – Software must be delivered within a time
    i.e. Cycle time from concept to delivery – as small as possible
  - Productivity measure – LOC (KLOC) person-month
  - It captures cost as well as schedule

The Software Engineering Challenges

- Productivity (P)
  - If P is higher then cost will be lower
  - If P is higher then time will be less
  - This means a development team with higher productivity will complete the software in lesser time than a same-size team with lower productivity.

The Software Engineering Challenges

- Quality (Q)
  - One of the major factor driving any production.
  - Quality is fundamental goal of software engineering.
  - Six attributes or characteristics of quality.

The Software Engineering Challenges

- Quality (Q)

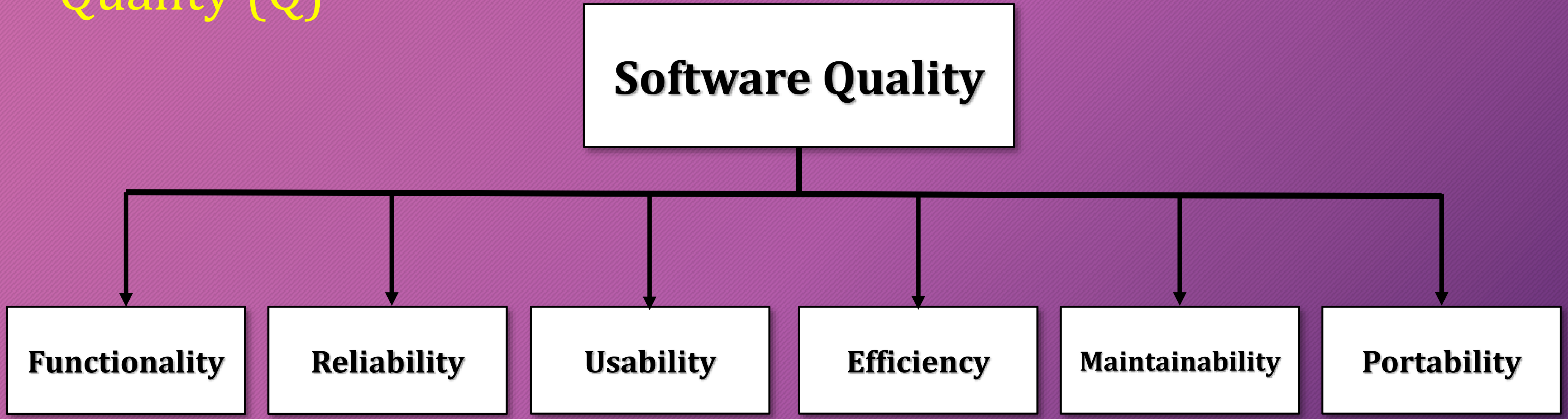

Fig. 4 Software quality attributes

The Software Engineering Challenges

- Quality (Q)
  - Two important consequences of multiple dimensions to quality
  - First – Software quality cannot be reduced to single parameter
  - Second – Concept of quality is project specific
  - In general, reliability is considered as main quality factor.

The Software Engineering Challenges

- Quality (Q)
  - Unreliable Software = Presence of defects
  - Quality measure = number of defects in software per unit size
  - Best practice is 1 defect per 1 KLOC
  - Quality objective is to reduce the number of defects per KLOC
  - What is defect?
  - Defect definition is project specific

The Software Engineering Challenges

- Consistency and Repeatability
  - A company may deliver high quality and high productivity software once.
  - Key challenge – repeating success for all projects and consistency in quality and productivity
  - Goal of Software Engineering – system after system can be produced with high quality and high productivity
  - This means – methods that are being used should be repeatable across projects leading to consistency in quality of software

The Software Engineering Challenges

- Consistency and Repeatability
  - Consistency allows organization to predict the output of project with accuracy.
  - Consistency can be achieved by using methodologies in consistent manner.
  - Frameworks like ISO9001 and Capability Maturity Model (CMM) encourage organizations to standardize methodologies, use them consistently and improve them based on experience.

The Software Engineering Challenges

- Change
  - Business changes very rapidly.
  - Business changed – Supporting software has to be changed
  - Software is easy to change as it lacks physical properties.
  - Software engineering challenge is to accommodate and embrace the change.

Need of Software Engineering Approach

Need of Software Engineering Approach

- Phased Development Process
- Managing the Process

Need of Software Engineering Approach

- We now understand the problem domain and the factors that drive the software engineering.
- Objective – To develop a software with high quality and productivity consistently for large scale problems under dynamics of changes.
- Q&P is governed by three main forces: People, Processes and Technology
- Called as the ***'Iron Triangle'***

Need of Software Engineering Approach

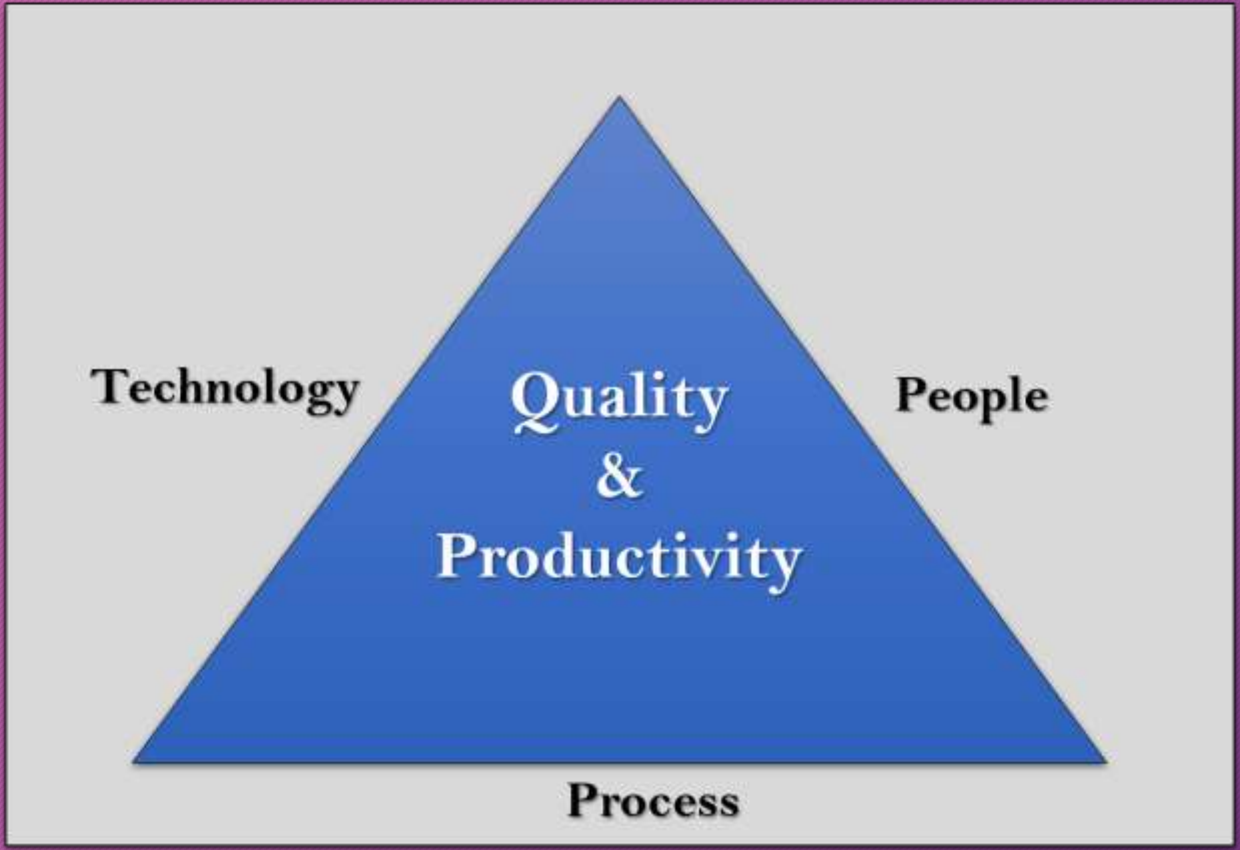

Fig. 5 The Iron Triangle

Need of Software Engineering Approach

- Technology has to be good (state-of-the-art)
- People doing the job have to be properly trained
- Good processes or methods have to be used
- Main focus: ***Processes*** i.e. systematic approach
- Approach: To separate the process for developing software from the developed product

Need of Software Engineering Approach

Fig. 6a Call of Duty: Mobile

Fig. 6b StrikeFortressBox

Need of Software Engineering Approach

- Premise: The software process determines the quality of the product and productivity.
- So, to tackle the problem domain and software engineering challenges, focus must be on software process.
- Other disciplines focus on the product while SE focuses on process for developing the product.
- Two aspects: Phased development process and Managing the process

Need of Software Engineering Approach

- Phased Development Process
  - Consists of various phases
  - Each phase ends with a defined output
  - Phase order is followed as specified by the *process model*
  - Why Phased Process?
    - It breaks the problem into phases each having its own concern.
    - Cost required will be lower as compared to that of whole project

Need of Software Engineering Approach

- Phased Development Process
  - Why Phased Process?
    - It allows proper checking for quality and progress at some defined time intervals (at the end of each phase).
  - It is central to the software engineering approach for solving the software crisis.
  - Basic software development phases: Requirement analysis, Software design, Coding and Testing

Need of Software Engineering Approach

- Phased Development Process
  - Requirement Analysis
    - Performed to understand the problem the software system is to solve
    - It focuses on identifying what is needed from the system
    - Two major activities: problem understanding or analysis and requirement specification
    - Output: Software Requirement Specification Document

Need of Software Engineering Approach

- Phased Development Process
  - Software Design
    - Purpose is to plan a solution of the problem specified by the requirements document.
    - Problem domain -> Solution domain
    - Output: architecture design, high level design and detailed design

Need of Software Engineering Approach

- Phased Development Process
  - Coding
    - The goal is to translate the design of the system into code in a given programming language
    - It affects testing and maintenance
    - Output: Program or set of programs

Need of Software Engineering Approach

- Phased Development Process
  - Testing
    - Quality control measure
    - Main function is to detect the defects in the system/software.
    - The goal is to uncover requirement, design and coding errors in the programs.
    - Types: unit testing, integration testing, system testing and acceptance

Need of Software Engineering Approach

- Managing the Process
  - Project management handles the issues relating to managing the development process of a project.
  - It revolves around a project *plan*.
  - Plan forms a baseline that is used for monitoring and controlling the development process
  - Includes how to allocate resources, scheduling different activities, how to divide work within a phase, etc.

Need of Software Engineering Approach

- Managing the Process
  - *Product metrics* and *process metrics* are used for the software development
  - They quantify the characteristics of product and process resp.
  - Product metrics – size, complexity, performance, design features, etc.
  - Process metrics – productivity, cost, and resource requirements, effect of development tools and techniques, etc.
  - These are important for managing a software development

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Module 2 Software Quality and Project Planning – Part 2

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Content

- Introduction
- Project Management

Introduction

- We have seen that software development can be split into two parts:
  - Project Development
  - Project Management
- Both have separate processes.
- Here we shall discuss need of project management, activities, scheduling, resource management, risk management and tools to for effective project management.

Software Project Management and its Need

- It is an integral part of software development.
- To achieve the goal of meeting the cost, quality and schedule objectives project management is important.
- To achieve this goal, resources have to be allocated properly, each activity has to be monitored and if necessary, corrective actions needs to be taken.
- It also focuses on planning a project, estimating resource and schedule and monitoring and controlling the project.

Software Project Management and its Need

- It also needs to consider the risks in the project and their management.
- Project management process specifies all these activities to ensure that the cost, quality and schedule goals are met.
- Fig. 1 shows these goals.

Software Project Management and its Need

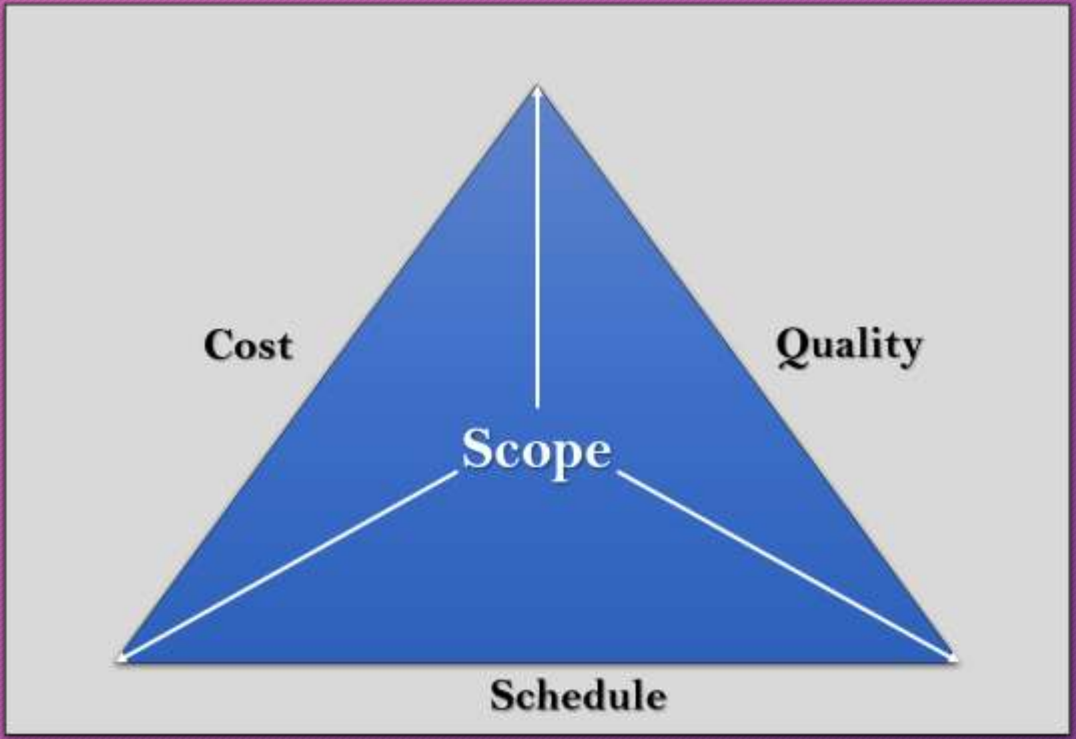

Fig. 1 Project Management Goals

Project Manager

- Project Manager is a person who undertakes the responsibility of executing the software project.
- He/she is thoroughly aware of all the SDLC phases of the project.
- He/she may not be involved in the development process directly but controls, manages and monitors all the activities in the project.

Project Manager - Responsibilities

- Managing People
  - Act as a project leader
  - Liaison with stakeholders
  - Managing human resources
  - Setting up reporting hierarchy etc.

Project Manager - Responsibilities

- Managing Project
  - Defining and setting up project scope
  - Managing project management activities
  - Monitoring progress and performance
  - Risk analysis at every phase
  - Take necessary step to avoid or come out of problems
  - Act as project spokesperson

Project Management Activities

- We have seen that project management activities are split into three categories:
  - Project Planning
  - Monitoring and Control
  - Termination Analysis

Project Management Activities

- Project planning
  - First phase
  - Performed before the production of the software starts.
  - Goal: To develop a plan for software development to meet project objectives successfully and efficiently.
  - It may include following tasks.

Project Management Activities

- Project planning – Scope Management
  - It defines the scope of the project.
  - It includes all the activities that a process need to be done in order to make a deliverable software product.
  - It is important as it creates the boundaries of project by defining what should be done in the project and what would not be done.

Project Management Activities

- Project planning – Scope Management
  - It is necessary during the scope management to –
    - Define the scope
    - Decide its verification and control
    - Divide the project into various smaller parts for ease of management
    - Verify the scope
    - Control the scope by incorporating changes to the scope

Project Management Activities

- Project planning – Project Estimation
  - To manage and control the project efficiently and effectively the accurate estimations of various measures is necessary.
  - It may involve - Software size estimation, Effort estimation, time estimation and Cost estimation

Project Management Activities

- Project planning – Project Estimation
  - Software size estimation
    - Measured in KLOC (Kilo Lines of Code)
    - Another measure is number of function points
    - KLOC depend on the coding practices
    - Function points depends on the user requirements.

Project Management Activities

- Project planning – Project Estimation
  - Effort estimation
    - Measured in personnel requirement and man-hour required to produce a software.
    - It may be based on the manager's experience, organization's historical data or software size.

Project Management Activities

- Project planning – Project Estimation
  - Time estimation
    - Software tasks are divided into smaller tasks, activities or events by Work Breakthrough Structure (WBS).
    - The tasks are scheduled on day-to-day basis or in calendar months.
    - The sum of time required to complete all tasks in hours or days is the total time invested to complete the project.

Project Management Activities

- Project planning – Project Estimation
  - Cost estimation
    - It is one of the difficult task.
    - Depends on many factors.
    - For estimating project cost, it is required to consider - Size of software, Software quality, Hardware, Additional software or tools, licenses etc., Skilled personnel with task-specific skills, Travel involved, Communication, Training and support, etc.

Project Management Activities

- Project planning – Project Estimation
  - Project manager can estimate the listed factors using two broadly recognized techniques –
    - Decomposition Technique
    - Empirical Estimation Technique

Project Management Activities

- Project planning – Project Estimation
  - Decomposition Technique
    - This technique assumes the software as a product of various compositions.
    - There are two main models -
      - **Line of Code Estimation** is done on behalf of number of line of codes in the software product.
      - **Function Points Estimation** is done on behalf of number of function points in the software product.

Project Management Activities

- Project planning – Project Estimation
  - Empirical Estimation Technique
    - This technique uses empirically derived formulae to make estimation.
    - These formulae are based on LOC or FPs.
    - There are two models –
      - Putnam Model
      - COCOMO

Project Management Activities

- Project planning – Project Estimation
  - Empirical Estimation Technique
  - Putnam Model
    - This model is made by Lawrence H. Putnam.
    - It is based on Norden's frequency distribution (Rayleigh curve).
    - Putnam model maps time and efforts required with software size.

Project Management Activities

- Project planning – Project Estimation
  - Empirical Estimation Technique
  - COCOMO
    - COCOMO stands for COnstructive COst Model.
    - It was developed by Barry W. Boehm.
    - It divides the software product into three categories of software: organic, semi-detached and embedded.

Project Management Activities

- Project planning – Project Scheduling
  - Project Scheduling in a project refers to roadmap of all activities to be done with specified order and within time slot allotted to each activity.
  - Project managers tend to define various tasks, and project milestones and arrange them keeping various factors in mind.

Project Management Activities

- Project planning – Project Scheduling
  - For scheduling a project, it is necessary to -
    - Break down the project tasks into smaller, manageable form
    - Find out various tasks and correlate them
    - Estimate time frame required for each task
    - Divide time into work-units
    - Assign adequate number of work-units for each task
    - Calculate total time required for the project from start to finish

Project Management Activities

- Project planning – Resource Management
  - To develop a software product many resources are involved.
  - These may include human resource, productive tools and software libraries.
  - They may be in limited quantity and their shortage may hamper the development process and project may lag behind the schedule.
  - Allocating extra resources may increase the development cost, so it is necessary to estimate and mange the resources correctly.

Project Management Activities

- Project planning – Resource Management
  - Resource management includes -
    - Defining proper organization project by creating a project team and allocating responsibilities to each team member
    - Determining resources required at a particular stage and their availability
    - Manage Resources by generating resource request when they are required and de-allocating them when they are no more needed.

Project Management Activities

- Project planning – Risk Management
  - Risk management involves all activities pertaining to identification, analyzing and making provision for predictable and non-predictable risks in the project.
  - It may include the following:
    - Experienced staff leaving project and new staff coming in
    - Change in organizational management
    - Requirement change or misinterpreting requirement

Project Management Activities

- Project planning – Risk Management
  - It may include the following:
    - Under-estimation of required time and resources.
    - Technological changes, environmental changes, business competition

Project Management Activities

- Project planning – Risk Management Process
  - Following activities are involved in the risk management process.
    - **Identification** - Make note of all possible risks, which may occur in the project.
    - **Categorize** - Categorize known risks into high, medium and low risk intensity as per their possible impact on the project.

Project Management Activities

- Project planning – Risk Management Process
  - Following activities are involved in the risk management process.
    - **Manage** - Analyze the probability of occurrence of risks at various phases. Make plan to avoid or face risks. Attempt to minimize their side-effects.
    - **Monitor** - Closely monitor the potential risks and their early symptoms. Also monitor the effects of steps taken to mitigate or avoid them.

Project Management Tools

- There are tools available, which aid for effective project management.
- Some of them are
  - Gantt Chart
  - PERT Chart
  - Resource Histogram
  - Critical Path Analysis

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Module 3 Software Development Phases – Part 2

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Content

- Design Principles
- Coding Standards
- Testing Fundamantals

Design Principles

Design Principles

- Introduction
  - Design activity begins when the SRS of the software becomes available and architecture has been designed.
  - *The design of a system is essentially a blueprint or a plan for the system.*
  - The design process often has two levels:
    - System design or top-level design
    - Logic design or detailed design

Design Principles

- Introduction
  - System design or top-level design
    - Focus is on deciding which modules are needed for the system, their specifications and how these modules should be interconnected.
  - Logic design or detailed design
    - The internal design of the modules or how the specifications of the module can be satisfied, is decided.

Design Principles

- Introduction
  - The design of a system should be correct, verifiable, complete and traceable.
  - The goal of design process is not simply to produce a design but is to find the best possible design within the limitations imposed by requirements and physical and social environment in which the system will operate.
  - Two most important properties are *efficiency* and *simplicity.*

Design Principles

- Introduction
  - *Efficiency* of any system is concerned with the proper use of scarce resources by the system.
  - If some resources are scarce and expensive, then they must be used efficiently.
  - *Simplicity* of any system is concerned with how simple and understandable the system is and it depends on the design.
  - Simplicity affects the maintainability of the system.

Design Principles

- Introduction
  - Only after having the thorough knowledge of the system, the maintainer can do necessary modification in the system and maintain the system.
  - Following design principles help achieve good design of a system.

Design Principles

- Problem Partitioning and Hierarchy
  - Small problems can be solved entirely, but it is quite difficult to solve large and complex problems all at once.
  - The basic principle is the *time-based principle of divide and conquer.*
  - The goal of software design is to divide the problem into manageable smaller pieces so that each piece can be conquered (solved) separately.

Design Principles

- Problem Partitioning and Hierarchy
  - It is believed that the cost of solving the entire problem is more than the sum of the cost of solving all the pieces.
  - However, all the pieces cannot work independently as they together form the system.
  - They have to cooperate and communicate to solve the larger problem.
  - This communication due to partitioning adds complexity which may not have existed in the original problem.

Design Principles

- Problem Partitioning and Hierarchy
  - Also, cost of partitioning and combining along with the complexity become more than saving achieved by partitioning.
  - It can be argued that maintenance is minimized if each part can be easily related to the application and each piece can be modified easily.

Design Principles

- Problem Partitioning and Hierarchy
  - Problem partitioning leads to the hierarchies in the design.
  - So, design can be represented as a hierarchy of components.
  - In general, hierarchical structure makes complex system easier to understand.

Design Principles

- Abstraction
  - Abstraction is used in all engineering disciplines.
  - *It is a tool that permits a designer to consider a component at an abstract level without worrying about the details of the implementation of the component.*
  - Every component provides a service to its environment.
  - An abstraction of a component describes the external behaviour of that component without bothering with the internal details that produce the behaviour.

Design Principles

- Abstraction
  - Abstraction is essential part of the design process and problem partitioning.
  - Various components interact with other components and to understand this the designer has to know the external behaviour of other components.
  - It should not determine the behaviour of other components.
  - To allow the designer to concentrate on one component at a time, abstraction of other components is used.

Design Principles

- Abstraction
  - Abstraction is used for existing components as well as components that are being designed.
  - Also, it helps during the maintenance phase.
  - Using the abstractions, behaviour of entire system can be understood which help determine how modifying a component affects the system.

Design Principles

- Abstraction
  - Two common abstraction mechanisms:
    - Functional Abstraction
    - Data Abstraction

Design Principles

- Abstraction – Functional Abstraction
  - In this a module is specified by the function it performs.
  - E.g. a module to sort an array can be shown by the specification of sorting, a module to compute the log of a value can be represented by the function log, etc.
  - It is a basis of partitioning in function-oriented design i.e. when the problem is being partitioned, the overall transformation function for the system is partitioned into smaller functions that comprise the whole system.

Design Principles

- Abstraction – Data Abstraction
  - In this data is treated as objects with some predefined operations on them.
  - The operations defined on a data object are the only operations that can be performed on those objects.
  - From the outside of the object, the internal details of the object are hidden; only operations are visible.
  - It forms a basis for *object-oriented design.*

Design Principles

- Modularity
  - A system is considered *modular* if it consists of discreet components so that each component can be implemented separately, and a change to one component has minimal impact of other components.
  - Modularity helps in system debugging, system repair and system building.

Design Principles

- Modularity
  - For modularity to work well in software system each module should
    - support a well-defined abstraction
    - have clear interface through which it can interact with other modules.
  - For easily understandable and maintainable system, modularity is important and partitioning and abstraction help achieve the modularity.

Design Principles

- Top-Down and Bottom-Up Strategies
  - In general, a system is a hierarchy of components and each component can have its sub-components.
  - Highest-level component corresponds to the whole system
  - To approaches to design a hierarchy:
    - Top-down approach
    - Bottom-up approach

Design Principles

- Top-Down and Bottom-Up Strategies – Top-down Approach
  - Top-down approach starts from highest-level component and proceeds through to lowest levels.
  - It starts by identifying the major components of the system, decomposing them into their lower-level components and iterating until the desired level is achieved.
  - It results in *stepwise refinement.*

Design Principles

- Top-Down and Bottom-Up Strategies – Top-down Approach
  - Design starts with abstract design and at each step the design is refined to more concrete level until no refinement is needed and design can be implemented directly.
  - This is suitable when the system specifications are well-known and the development is from scratch.

Design Principles

- Top-Down and Bottom-Up Strategies – Bottom-up Approach
  - Design starts with most basic or primitive components and proceeds to higher-level components that use these lower-level components.
  - It works with *layers of abstraction.*
  - Starts from very bottom, operations that provide the layer of abstraction are implemented.
  - The operations at this layer are then used to implement more powerful operations.

Design Principles

- Top-Down and Bottom-Up Strategies – Bottom-up Approach
  - This is continued until operations supported by the layer are those desired by the system.
  - This is suitable if a system is to be built from an existing system.

Coding Standards

Coding Standards

- Introduction
  - Programmers spend a little time on writing the code and more time on reading the code during debugging and enhancement.
  - People other than author spend a considerable time in reading as the code is often maintained by someone other than the author.
  - So, it is important that code should be easy to read, understand and maintain.

Coding Standards

- Introduction
  - Coding standards provide rules and guidelines for programmers for some aspects of programming in order to make the code easier to read, understand and maintain.
  - These guidelines may be regarding naming, file organization, statements and declarations and layouts and comments.
  - We discuss here some of the generalised guidelines with respect to Java programming language.

Coding Standards

- Coding Standards – Naming Conventions
  - Variable names should be nouns starting with *lower case (e.g. name, amount, sum)*
  - Constant names should be *upper case (e.g. PI, MAX, MIN)*
  - Method names should be verbs starting with *lower case (e.g. getValue(), computeArea())*
  - Package names should be *lower case (e.g. mypackage, game.ui)*
  - Loop iterators should be named *I, j, k, l, etc.*

Coding Standards

- Coding Standards – Naming Conventions
    - Boolean variable and method names should start with *is* to avoid the confusion (*e.g. isValid(), isNumber)*
    - Also negative Boolean names should be avoided (*e.g. isNotCorrect, instead use isFalse)*

Coding Standards

- Coding Standards – Files
  - Java source file should have the extension *.java*
  - Class name should be same as the file name
  - Line length should be less than 80 columns and special characters such as *, :, ;, etc should be avoided

Coding Standards

- Coding Standards – Statements
  - Variable should be initialised where declared
  - Related variables should be declared in a common statement *(e.g. num1, num2 and result should be declared as*

    int num1, num2, result=0;

  And not

      int num1;

      int num2;

      int result;

Coding Standards

- Coding Standards – Indentation
  - Proper indentation should be used as it makes the code readable. Some of the spacing conventions are:
    - Each nested block should be properly indented and spaced.
    - Proper Indentation should be there at the beginning and at the end of each block in the program.
    - All braces should start from a new line and the code following the end of braces also start from a new line.
    - There must be a space after giving a comma between two function arguments.

Coding Standards

- Coding Standards – Comments
  - *Comments are the textual statements that are meant for the program reader to aid the understanding of the code.*
  - In general comments should explain what the code is doing and why the code is written. Some guidelines are:
    - Single line comments for a block should aligned with the code they are meant for
    - Comments for major variables should be there
    - Trailing comments should be short

Coding Standards

```
import java.util.Scanner;
public class HelloWorld
{
public static void main(String[] args)
{
// Creates a reader instance which takes
// input from standard input - keyboard
Scanner reader = new Scanner(System.in);
System.out.print("Enter a number: ");
// nextInt() reads the next integer from the keyboard
int number = reader.nextInt();
// println() prints the following line to the output screen
System.out.println("You entered: " + number);
}
}
```

Fig. 1a Code without Indentation

```
import java.util.Scanner;
public class HelloWorld
{
    public static void main(String[] args)
    {
        // Creates a reader instance which takes
        // input from standard input - keyboard
        Scanner reader = new Scanner(System.in);
        System.out.print("Enter a number: ");
        // nextInt() reads the next integer from the keyboard
        int number = reader.nextInt();
        // println() prints the following line to the output screen
        System.out.println("You entered: " + number);
    }
}
```

Fig. 1b Code with Indentation

Testing Fundamentals

Testing Fundamentals

- Introduction
- Fundamentals Terms - Error, Fault and Failure
- Test Cases
- Testing Process

Testing Fundamentals

- Introduction
  - *Software testing is a process, to evaluate the functionality of a software application with an intent to find whether the developed software met the specified requirements or not and to identify the defects to ensure that the product is defect-free in order to produce the quality product.*
  - Testing performs a critical role for ensuring the software quality.
  - We discuss testing fundamentals here.

Testing Fundamentals

- Fundamentals Terms - Error
  - Error has two different meanings.
  - *An error refers to the discrepancy between a computed, observed or measured value and the true, specified, or theoretically correct value.*
  - That is error refers to the difference between the actual output of a software and the correct output.
  - *Error also refers to the human action that results in software containing a defect or fault.*

Testing Fundamentals

- Fundamentals Terms - Fault
  - *Fault is a condition that causes a system to fail in performing the required function.*
  - It is the basic reason for software malfunction.
  - It is commonly called as a *bug.*
  - Faults in software system are only because of design faults and not because of wear and tear in software.

Testing Fundamentals

- Fundamentals Terms - Failure
  - *Failure is the inability of a system or component to perform a required function according to its specifications.*
  - It occurs if the behavior of the software is different from the specified behavior.
  - It may be caused due to functional or performance reasons.

Testing Fundamentals

- Fundamentals Terms - Failure
  - It is produced only when there is a fault in the system.
  - Presence of fault is necessary but not sufficient condition for failure to occur.

Testing Fundamentals

- Test Cases
  - *A TEST CASE is a documented set of preconditions (prerequisites), procedures (inputs / actions) and postconditions (expected results) which a tester uses to determine whether a system under test satisfies requirements or works correctly.*
  - A test case can have one or multiple *test scripts* and a collection of test cases is called a *test suite*.

Testing Fundamentals

- Test Cases - Characteristics
  - **Accurate**: Exacts the purpose.
  - **Economical**: No unnecessary steps or words.
  - **Traceable**: Capable of being traced to requirements.
  - **Repeatable**: Can be used to perform the test over and over.
  - **Reusable**: Can be reused if necessary.

Testing Fundamentals

- Test Cases – Sample examples
  - **Test Case 1:** Check results on entering valid User Id & Password
  - **Test Case 2:** Check results on entering Invalid User ID & Password
  - **Test Case 3:** Check response when a User ID is Empty & Login Button is pressed

Testing Fundamentals

- Test Cases – Sample examples
  - Each test case costs money as efforts are needed to generate it, machine time to execute it and efforts to evaluate the results.
  - So, fundamental goal of testing is to *maximize the number of errors detected and minimize the number of test cases.*
  - To achieve this, *test selection criterion (or test criterion)* is used.

Testing Fundamentals

- Testing Process
  - *It is a process consisting of all lifecycle activities, both static and dynamic, concerned with planning, preparation and evaluation of a component or system and related work products to determine that they satisfy specified requirements, to demonstrate that they are fit for purpose and to detect defects.*

Testing Fundamentals

- Testing Process – Levels of Testing
  - Testing is usually relied upon to detect the faults from earlier stages, in addition to the faults introduced during coding itself.
  - So, to test the different aspects of the system, different levels of testing are used.
  - These are *unit, integration, system* and *acceptance testing.*
  - Figure 2 shows the relation of the faults introduced in different phases and different levels of testing.

Testing Fundamentals

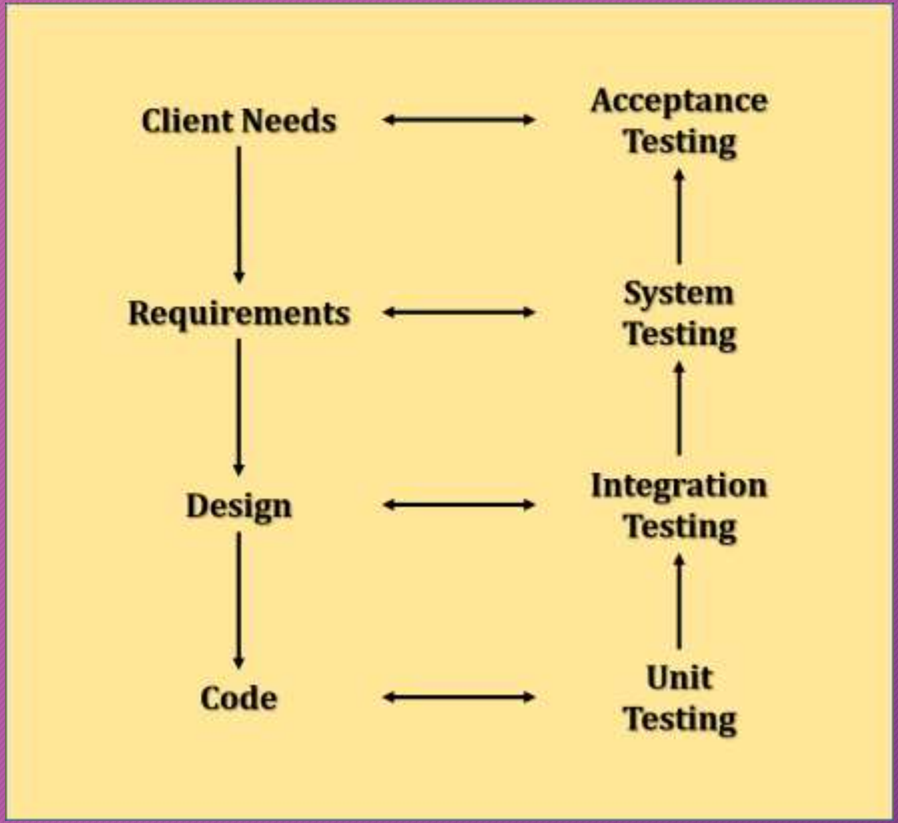

Fig. 2 Levels of Testing

Testing Fundamentals

- Testing Process – Levels of Testing
  - Unit Testing
    - In this different modules are tested against the specifications produced during design for the modules.
    - It is generally used for verification of code, hence the goal is to test the internal logic of the modules.
    - This testing is typically done by programmer of the module.

Testing Fundamentals

- Testing Process – Levels of Testing
  - Integration Testing
    - In this different unit tested modules are combined into subsystems, which are then tested.
    - The goal is to see if the modules can be integrated properly.
    - The emphasis is on testing interfaces between modules.
    - This can be considered testing the design.

Testing Fundamentals

- Testing Process – Levels of Testing
  - System and Acceptance Testing
    - In this entire software is tested against the requirements specified in the SRS.
    - The goal is to see if the software meets its requirements.
    - This is generally validation activity.
    - In acceptance testing, sometimes the realistic data from client is used to demonstrate that the software is working satisfactorily.

Testing Fundamentals

- Testing Process – Levels of Testing
  - System and Acceptance Testing
    - Here testing focuses on the behavior of the system and not the internal logic.
    - Mostly, functional testing is performed at these levels.

Testing Fundamentals

- Testing Process – Levels of Testing
  - Regression Testing
    - This testing is performed when some changes are made to an existing system.
    - It ensures the desired behavior of new services as well as the desired behavior of old services.

Testing Fundamentals

- Testing Process – Test Plan
  - *It is a general document for entire project that defines the scope, approach to be taken and the schedule of the testing and identifies the test items for the entire testing process and the personnel responsible for the different testing activities.*
  - Testing commences with test plan and terminates with acceptance testing.
  - Test plan can be defined before testing commences and can be done in parallel with design and coding activities.

Testing Fundamentals

- Testing Process – Test Plan
  - Inputs for test plan are: *project plan, requirements document* and *system design document.*
  - A test plan should contain:
    - Test Unit Specification: Module or few modules or entire system
    - Features to be tested: All software features or combination of features
    - Approach for testing: Generally, testing criterion for evaluating the test cases.

Testing Fundamentals

- Testing Process – Test Plan
  - A test plan should contain:
    - Test Deliverables: It can be list of test cases, detailed results including list of defects found, test summary reports, etc.
    - Schedule and Task Allocation: If test plan is separate document from project management plan, then it specifies the detailed schedule and task allocation to each testing activities.

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Module 4
Introduction and Database Modeling using ER Model - Part 1

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Content

- Introduction to Database Systems
- Advantages and Applications of Database Systems
- Data Models
- Data Abstraction
- Database Schema and Instance
- Database Languages
- Database System Architecture
- Database Users and Administrator
- Entity-Relationship Model

Introduction to Database Systems

- **What is Data?**

"facts and statistics collected together for reference or analysis."

Or

"the quantities, characters, or symbols on which operations are performed by a computer, which may be stored and transmitted in the form of electrical signals and recorded on magnetic, optical, or mechanical recording media."

- Oxford Dictionary

Introduction to Database Systems

- **What is Data?**
  - *Data is a collection of facts, such as numbers, words, measurements, observations or just descriptions of things which in turn may be qualitative or quantitative.*
  - Data can be in many formats such as numbers, text, images, audio, video, etc.
  - Data is used to produce the information.

Introduction to Database Systems

- **What is Database?**
  - *Database is a collection of related data stored electronically in a organized manner and used to insert, retrieve, update and delete the data efficiently.*
  - Data in the database is organized in the form of tables, views, schemas, reports, etc.
  - E.g. College database will have data related to students, faculty, departments, labs, etc. which are interrelated to each other.

Introduction to Database Systems

- **What is Database Management System (DBMS)?**
  - *DBMS is an application (software) which is used to manage the databases.*
  - The primary goal of a DBMS is to provide a way to store, retrieve, update and delete database information conveniently and efficiently.
  - E.g. MySQL, Oracle, MariaDB, PostgreSQL, Microsoft SQL Server, Amazon Aurora, etc.

File Processing Systems

- Initially file based systems were used to store and retrieve the data.
- In this simple files were stored on the electronic devices such as computers.
- There are many issues with this system which are as follows:
- **Data Redundancy**
  - Same data is duplicated in many places (files).
  - E.g. Student Email ID may be present at many sections.
  - This may lead higher storage and access cost.

File Processing Systems

- **Data Inconsistency**
  - Multiple copies of same data does not match with each other.
  - E.g. If Phone number is different in contact information section and profile section or accounts section, it will be inconsistent.
- **Difficulty in Accessing Data**
  - If a set of programs for performing a particular operation is not available then it becomes difficult to access or retrieve those data.
  - E.g. Getting a list of students who live in particular district.
  - No convenient or efficient way to access the data

File Processing Systems

- **Data Isolation**
  - Data are stored in multiple files and files may be in different formats.
  - Writing new programs to retrieve the appropriate data is difficult.
- **Integrity Problems**
  - There can be many consistency constraints that data must satisfy.
  - E.g. Account balance should not fall below Rs. 1000, etc.
  - Whenever new constraints are to be added, changes in programs is necessary which is very difficult task.

File Processing Systems

- **Atomicity Problems**
  - A computer system is subject to failure.
  - In case of failure occurs, it is necessary that the data must be restored to the consistent state that existed prior to the failure.
  - This means the operations should be atomic i.e. it must happen in its entirety or not at all.
  - E.g. Transferring money from one account to another
  - Achieving atomicity is difficult in file processing systems.

File Processing Systems

- **Concurrent Access Anomalies**
  - For the overall performance and faster response, many systems allow multiple users to access and update the database concurrently.
  - Concurrent updates may lead to inconsistency.
  - E.g. If an account with ₹10, 000 is debited by two clerks concurrently with ₹500 and ₹800 resp. If two programs run concurrently, they may both read the value ₹10, 000 and write back ₹9500 and ₹9200. But the correct value is ₹8700.
  - This should not happen for any of the programs.

File Processing Systems

- **Security Problems**
  - Not every user should be given access to all the data.
  - E.g. Accounts persons should not have access to personal information, Students should have access to only student portal to see their results and should not be able to change the data, etc.
  - It is difficult to provide security in file processing systems.
- **Backup and Recovery**
  - File processing systems does not incorporate any backup and recovery mechanism if the data is lost or file is corrupted.

Advantages of Database Systems

- All the issues with the file processing systems are tackled by the Database systems or DBMS.
- They follow ACID properties i.e. **A**tomicity, **C**oncurrency, **I**ntegrity and **D**urability.
- Control data redundancy
- Control concurrent access anomalies
- Provide security, backup and recovery.
- They also support multiple views for different users such as admin, user, manager, etc.
- Easy to maintain

Applications of Database Systems

- Database systems have very vast range of applications in every area.
- Some of the representative applications are mentioned on the next slides.

Applications of Database Systems

- **Enterprise Information**
  - **Sales:** For customer, product, and purchase information.
  - **Accounting**: For payments, receipts, account balances, assets, and other accounting information.
  - **Human resources:** For information about employees, salaries, payroll taxes, and benefits, and for generation of paychecks.
- **Manufacturing:** For management of the supply chain and for tracking production of items in factories, inventories of items in warehouses and stores, and orders for items.

Applications of Database Systems

- **Banking and Finance**
  - **Banking:** For customer information, accounts, loans, and banking transactions.
  - **Credit/Debit card transactions:** For purchases on credit cards and generation of monthly statements.
  - **Finance:** For storing information about holdings, sales, and purchases of financial instruments such as stocks and bonds; also for storing real-time market data to enable online trading by customers and automated trading by the firm.

Applications of Database Systems

- **Universities:** For student information, course registrations, and grades (in addition to standard enterprise information such as human resources and accounting).
- **Airlines:** For reservations and schedule information. Airlines were among the first to use databases in a geographically distributed manner.
- **Telecommunication:** For keeping records of calls, texts, and data usage, generating monthly bills, maintaining balances on prepaid calling cards, and storing information about the communication networks.

Applications of Database Systems

- **Web-based services**
  - **Social-media:** For keeping records of users, connections between users (such as friend/follows information), posts made by users, rating/like information about posts, etc.
  - **Online retailers:** For keeping records of sales data and orders as for any retailer, but also for tracking a user's product views, search terms, etc.,
  - **Online advertisements:** For keeping records of click history to enable targeted advertisements, product suggestions, news articles, etc.

Data Models

- Underlying structure of a database is known as data model.
- It is a collection of conceptual tools for describing data, data relationships, data semantics, and consistency constraints.
- The data models can be classified into four categories:
  - Relational Model
  - Entity-Relationship (E-R) Model
  - Semi-structured Data Model
  - Object-Based Data Model

Data Models

- **Relational Model**
  - It uses a collection of tables to represent both data and relationship between those data.
  - Each table consists of many columns and each column has unique name.
  - Tables are also known as *relations.*
  - This model is record-based model with fixed format.
  - It is one of the widely used model.

Data Models

- **Entity-Relationship (E-R) Model**
  - It graphically represents the objects and their relationships.
  - It uses a collection of basic objects called as *entities* and *relationships* among these objects.
  - An entity is a thing or object in the real world that distinguishable from other objects.
  - The E-R model is widely used in the database design.

Data Models

- **Semi-structured Model**
  - It permits the specification of data where individual data items of the same type may have different set of attributes.
  - It is different from previous data models.
  - XML and JSON are widely used semi-structured models.
- **Object-Based Data Model**
  - It is a object-oriented data model.
  - It can be seen extending relational model with object oriented concepts such as encapsulation, object identity, methods, etc.

Data Abstraction

- For the system to be usable, it must retrieve data efficiently.
- To achieve the efficiency, the database developers use complex data structures to represent data in the database.
- As many database-system users are not trained, complexity needs to be hidden from them.
- Developers achieve this using several levels of ***data abstraction.***
- *"Data abstraction is the process of hiding the background implementation details and providing only essential information to the users (outside world)."*
- Data abstraction simplifies the users' interactions with the system.

Data Abstraction

- There are three levels of abstraction in the database system: Physical Level, Logical Level and View Level
- **Physical Level**
  - Lowest level of abstraction
  - Describes *how* the data are actually stored
  - Describes the complex low-level data structures in detail
  - E.g. data stored can be described as block of storage (bytes, gigabytes), type of files, indexes in memory
  - Users: Programmers/Developers

Data Abstraction

- **Logical Level**
  - Next higher level of abstraction
  - Describes *what* data are stored in the database and what relationships exists among those data
  - Describes the entire database in terms of small number of relatively simple structures
  - It may still involve complex physical-level structures, but complexity is kept hidden from its users

Data Abstraction

- **Logical Level**
  - i.e. It hides the physical level and gives the logical view of the database.
  - This is called as *Physical Data Independence.*
  - Users: Database Administrator
  - E.g.

Department	Budget
Civil	500000
Electrical	450000
Electronics	450000
Mechanical	500000

Data Abstraction

- **View Level**
  - Highest level of abstraction
  - Describes only part of the entire database
  - It may still involve complexity, but complexity is kept hidden from its users
  - Users don't need access to entire database; they need only part of it.
  - The view level abstraction simplifies the interaction of end users with the system by providing many views of the same database.

Data Abstraction

- **View Level**
  - Users: authentic end users
  - E.g.
    - Checking only bank balance
    - Checking last 5 transactions
    - Deriving age of using date of birth
    - Employee can see only his/her salary and not the manager's salary, etc.
  - Figure shows relationship among three levels of abstraction.

Data Abstraction

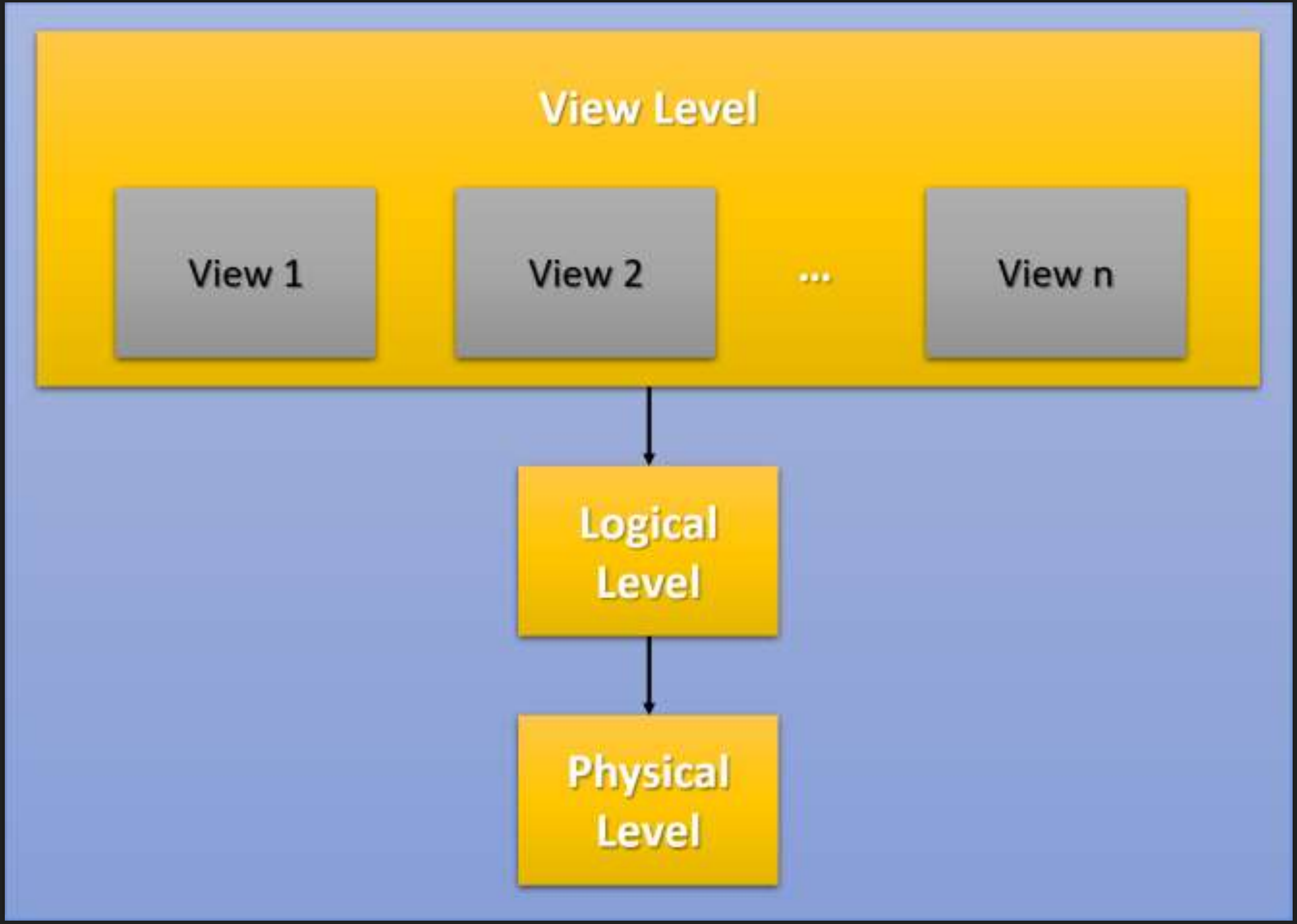


Fig. 1 Three levels of abstraction

Database Schema

- *"The overall design of a database is called as the schema."*
- It defines a structure in formal language supported by a DBMS.
- It shows the logical view of the entire database.
- It shows the organization of data and relationship among them.
- Various schemas are defined at various abstraction level.
- **Physical Schema**
  - Defines database design at physical level
  - Defines how data is stored on disk storage in terms of files and indices

Database Schema

- **Logical Schema**
  - Defines all the logical constraints that need to be applied on the data stored
  - It defines tables, views and integrity constraints.
- **Subschemas**
  - A database may also have several schemas at the view level.
  - These are called as “subschemas”.
  - They describe various views of the database.

Database Schema

```
CREATE TABLE student (
  studentExamNo int(11) NOT NULL,
  studentFullName varchar(70) NOT NULL,
  mobileNo varchar(50) NOT NULL,
  address varchar(50) NOT NULL,
  state varchar(50) DEFAULT NULL,
  country varchar(50) NOT NULL,
  PRIMARY KEY (StudentExamNo),
)
```

Fig. 1 Example of Database Schema in SQL

Database Instance

- Database is not a static, it is dynamic.
- This means it changes over time as new information is inserted, deleted and updated.
- *"The collection of information stored in the database at a particular moment is called as an **instance** of the database."*

Database Languages

- A database system provides two types of languages:
  - Data Definition Language (DDL)
  - Data Manipulation Language (DML)
- In practice, DDL and DML are not separate languages rather they are part of single database languages such as SQL.
- *SQL is employed in almost all relational databases.*

Database Languages

- **Data Definition Language (DDL)**
  - *DDL is a language that specifies a database schema by a set of definitions.*
  - DDL also specifies additional properties of data.
  - The implementation details provided by DDL are in general hidden from the end users. E.g.

```
create table department
(dept name char (20),
building char (15),
budget numeric (12,2));
```

Database Languages

- **Data Manipulation Language (DML)**
  - *DML is a language that enables users to manipulate or access the data as organized by the appropriate data model.*
  - The types of access are:
    - Insertion of new information into the database
    - Retrieval of information stored in the database
    - Modification of information stored in the database
    - Deletion of information from the database

Database Languages

- **Data Manipulation Language (DML)**
  - There are two types of DML: Procedural DML and Non-procedural (Declarative) DML
  - Procedural DMLs require a user to specify ***what*** data are needed and ***how*** to get those data.
  - Declarative DMLs require a user to specify ***what*** data are needed ***without*** specifying how to get those data.

Database Languages

- **Data Manipulation Language (DML)**
  - A ***query*** is a statement requesting the retrieval of information.
  - The portion of a DML that involves information retrieval is called a ***query language.***
  - SQL is widely used query language.

Database System Architecture

- The database system is divided into different modules having their set of responsibilities.
- These modules are
  - The storage manager
  - The query processor components and
  - The transaction management component

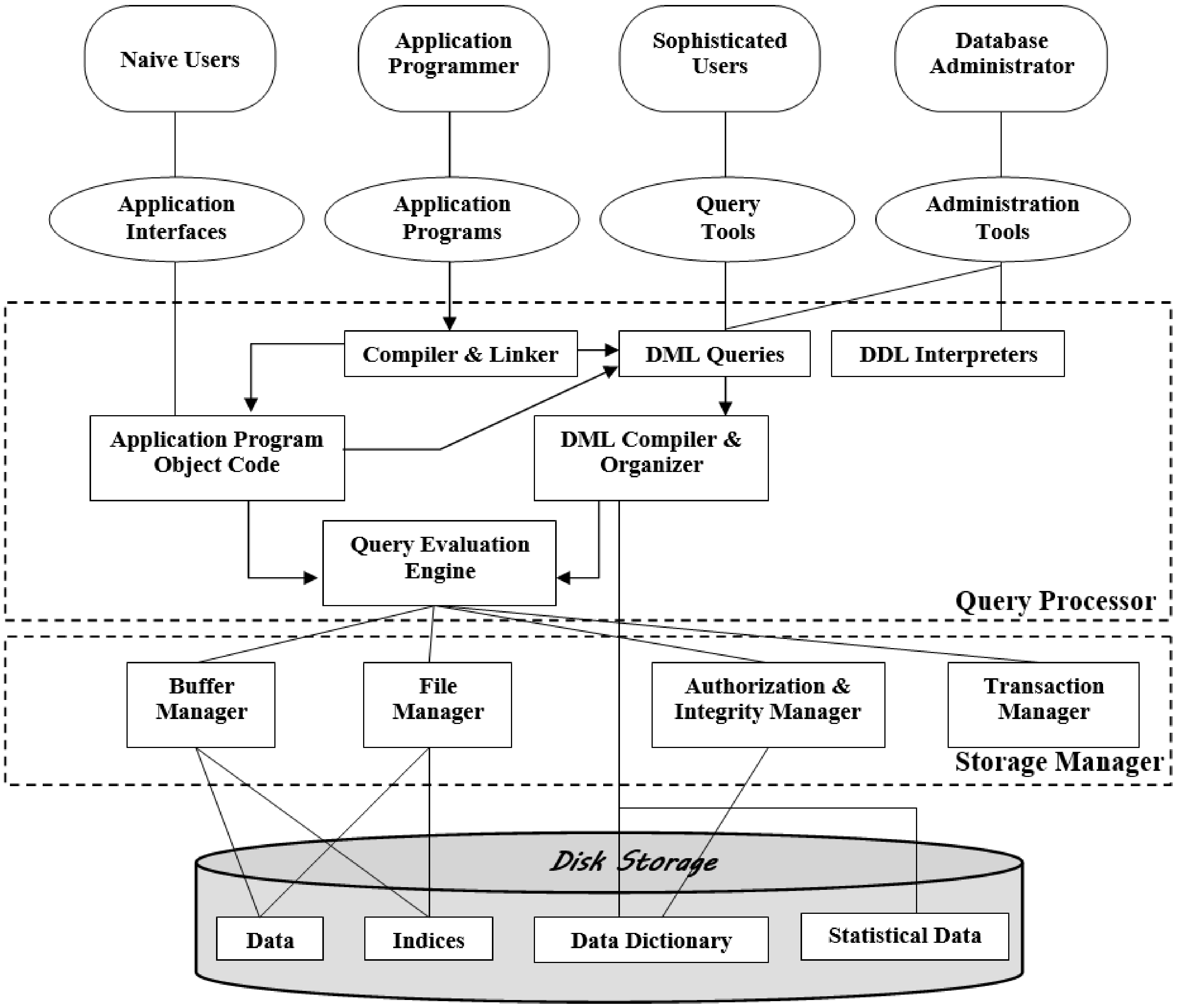


Figure: System Architecture

Database System Architecture

- **The Storage Manager**
  - It provides the interface between the low-level data stored in the database and the application programs and queries submitted to the system.
  - It is responsible for interaction with the file manager.
  - It translates DML statements into low-level file-system commands, hence is responsible for storing, retrieving, updating and deleting the data in the database.

Database System Architecture

- **The Storage Manager**
  - The components of storage manager are
    - Authorization and integrity manager
    - Transaction manager
    - File manager
    - Buffer manager
  - The data structures implemented by the storage manager are *data files, data dictionary* and *indices.*

Database System Architecture

- **The Query Processor**
  - It helps the database system to simplify and facilitate access to data.
  - It allows database users to achieve a good performance while working at the view level without focusing on physical level details of implementations.
  - The components of query processor are
    - DDL Interpreter
    - DML Compiler
    - Query Evaluation Engine

Database System Architecture

- **The Transaction Manager**
  - *A transaction is a collection of operations that performs a single logical function in a database application.*
  - Each transaction is a unit of both ***atomicity*** and ***consistency***.
  - It allows application developers to treat a sequence of database accesses as if they were a single unit that either happens in its entirety or not at all.

Database System Architecture

- While database engines were traditionally ***centralized computer systems***, today ***parallel*** and ***distributed*** databases which run faster and at different locations are widely used.
- Architectures of database applications that use databases can be two tier or three tier.
- In **two-tier architecture**, the application resides at the client machine, and invokes database system functionality (directly) at the server machine through query language statements.
- E.g. Desktop applications, games, music, etc.

Database System Architecture

- In **three-tier architecture**, the client machine acts as front end and there is no any database calls.
- User uses application clients such as web browsers, mobile applications, etc.
- The front end communicates with the application server (at another location).
- The application server then communicates with a database system to access data.
- The ***business logic*** of the application, which says what actions to carry out under what conditions, is embedded in the application server.

Database System Architecture

- E.g. Web-based applications, website, mobile applications, etc.

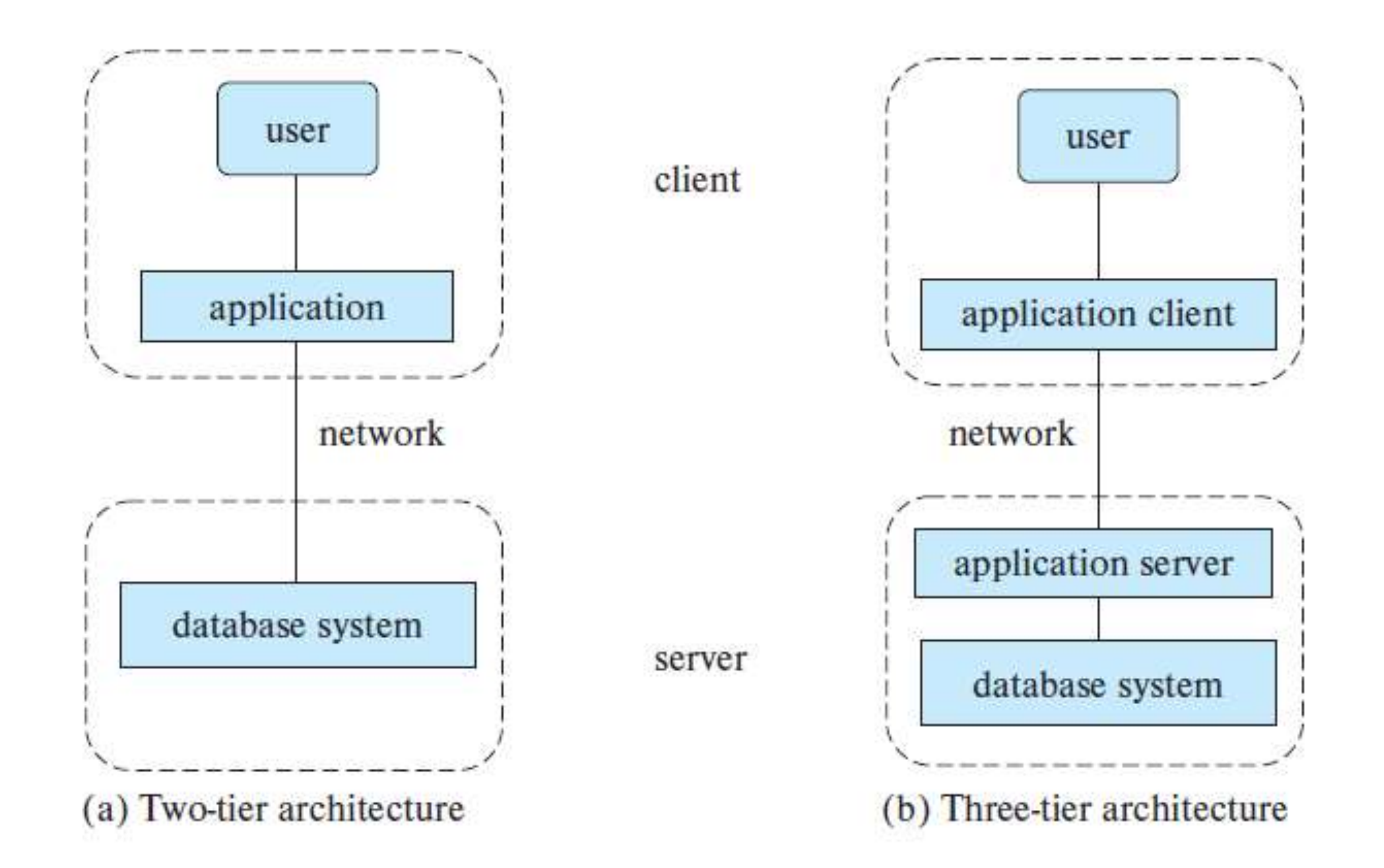


Fig. 3 Client-server 2-tier & 3-tier Architecture

Database Users and Administrator

- People who work with a database can be categorized as *database users* or *database administrators*.
- **Database Users and User Interface**
  - There are different types of database users, differentiated based on how they interact with the system.
  - For each of the user types different ***user interfaces (UI)*** have been designed.
  - These users are Naïve users, Application Programmers and Sophisticated users.

Database Users and Administrator

- **Naïve users**
  - *Unsophisticated users* who interact with the system by using predefined user interfaces, such as web or mobile applications
  - E.g. end users using any mobile or desktop applications or website users
- **Application Programmers**
  - *Computer professionals* who write application programs.
  - Application programmers can choose from many tools to develop user interfaces.
  - E.g. Programmers/Developers

Database Users and Administrator

- **Sophisticated users**
  - Sophisticated users interact with the system without writing programs.
  - They form their requests either using a database query language or by using tools such as data analysis software.
  - E.g. Analysts who submit queries to explore data in the database

Database Users and Administrator

- **Database Administrator**
  - A person who has *central control over the system (both data and programs to access those data)* is called a database administrator (DBA).
  - The functions of a DBA include:
    - Schema definition
    - Storage structure and access-method definition
    - Schema and physical-organization modification
    - Granting of authorization for data access
    - Routine maintenance such as backup, disk space requirements, etc.

Entity-Relationship Model

- **The Entity-Relationship (E-R) Model** is developed to design the structure of a database with the help of a diagram known as **The Entity-Relationship (E-R) diagram.**
- ER diagram expresses the overall logical structure of a database graphically.
- Here we discuss the main components of E-R model.
  - Entity Set
  - Relationship Set

Entity-Relationship Model

- **Entity Set**
  - *An entity is a "thing" or "object" in the real word that is distinguishable from all other objects.*
  - E.g. every student in a college is an entity, course in a college, a flight reservation, bank management system, etc.
  - An entity has a set of properties, and the values for some set of properties must uniquely identify an entity.
  - E.g. a student may have *examSeatNo* whose value uniquely identifies that person.

Entity-Relationship Model

- **Entity Set**
  - *An entity set is a set of entities of same type that share the same properties, or attributes.*
  - E.g. *student* can be an entity set that represents all students in the college, *teacher* can be an entity set that represents all teachers in the college, etc.
  - An entity set do not need to be disjoint.
  - E.g. *person* entity may represent a *student* entity, *teacher* entity, both or neither.

Entity-Relationship Model

- **Weak Entity Set**
  - *A **weak entity set** is an entity set which cannot be identified by its own attributes and whose existence is dependent on another entity set.*
  - The supporting entity set is called ***identifying entity set*** of weak entity set.
  - An entity set that is not weak entity set is called as ***strong entity set.***

Entity-Relationship Model

- **Weak Entity Set**
  - E.g.
  - ***Room*** is a weak entity set which cannot exist without a ***building***
  - ***Bank account*** cannot be uniquely identified without associating it to a particular ***bank***
  - ***Module/Chapter*** is a weak entity set which needs ***book***, ***paper***
  - ***Insurance Policy*** requires an ***employee***
  - ***Library*** is a strong entity set as it can exist without ***college/university***

Entity-Relationship Model

- **Attributes**
  - An entity is represented by a set of attributes.
  - ***Attributes*** are descriptive properties possessed by each member of an entity set.
  - The designation of an attribute for an entity set expresses that the database stores similar information concerning each entity in the entity set.
  - However, each entity may have its own value for each attribute.
  - E.g. *student* can have *examSeatNo, name, dept, class, etc.* attributes

Entity-Relationship Model

- **Value**
  - Each entity has a ***value*** for each of its attributes.
  - E.g. *student* entity can have value 2050BTECS00001 for *examSeatNo,* value Ram for *name,* value AI & ML for *dept,* and value First Year for *class.*
- **Primary Key**

Entity-Relationship Model

- **Types of Attributes**
  - An attribute in E-R model can be characterized by following types:
    - Simple and Composite
    - Single-valued and Multivalued
    - Derived

Entity-Relationship Model

- **Types of Attributes**
  - **Simple and Composite**
    - *An attribute which cannot be further subdivided into component attributes is called as simple attribute.*
    - E.g. examSeatNo, employeeID, ISBN, accountNo, etc.
    - *An attribute which can be further subdivided into component attributes is called as composite attribute.*
    - E.g. address (houseNo, streetNo, city, state, country), name(first, middle, last), phoneNo(STDCode, Number), etc.

Entity-Relationship Model

- **Types of Attributes**
  - **Single-valued and Multivalued**
    - *An attribute which takes up only single value for a particular entity is called as single-valued attribute.*
    - E.g. examSeatNo, age, height, weight, etc.
    - *An attribute which takes up two or more values for a particular entity is called as multivalued instance.*
    - E.g. mobileNo, emailID, address, course, hobby, etc.

Entity-Relationship Model

- **Types of Attributes**
  - **Derived**
    - *An attribute whose value can be derived from other related attributes or entities is called as derived attribute.*
    - E.g. totalMarks, averageMarks, age, BMI, etc.

Entity-Relationship Model

- **Relationship Set**
  - An association among several entities is called as ***relationship***.
  - E.g. Mr. R. Sharma is a *coach of* Mr. Virat Kohli
  - ***Relationship set*** is a set of relationships of the same type.
  - E.g. we define relationship set *coach* to denote the association between *instructor* and *player.*

Entity-Relationship Model

1	Ramakant Achrekar
2	Mr. R. Sharma

P1	Mr. Sachin Tendulkar
P2	Mr. Virat Kohli
P3	Mr. A. B. C
P4	Mr. X. Y. Z.

Entity-Relationship Model

- **Degree of Relationship Set**
  - It is number of entity sets participating in a relationship set.
  - There are following degrees exist:
  - **Unary Relationship**
    - When there is only ONE entity set participating in a relation, the relationship is called as unary relationship.
    - For example, one ***Person*** is married to only one ***Person***.
    - The degree of unary relationship is 1.

Entity-Relationship Model

- **Degree of Relationship Set**
  - **Binary Relationship**
    - When there TWO entity sets participating in a relation, the relationship is called as binary relationship.
    - For example, ***Student*** is enrolled in ***Course***.
    - The degree of binary relationship is 2.

Entity-Relationship Model

- **Degree of Relationship Set**
  - **Ternary Relationship**
    - When there THREE entity sets participating in a relation, the relationship is called as ternary relationship.
    - For example, ***Student*** is working on a ***Project*** under the guidance of ***Guide***.
    - The degree of ternary relationship is 3.
  - **N-ary Relationship**
    - When there ***n*** entity sets participating in a relation, the relationship is called as ternary relationship.
    - The degree of n-ary relationship is n.

Entity-Relationship Model

- **Mapping Cardinality/Cardinality Ratios**
  - *It expresses the number of entities to which another entity can be associated via a relationship set.*
  - *The number of times an entity of an entity set participates in a relationship set is known as cardinality.*
  - For a binary relationship set R between entity sets A and B, the mapping cardinality are as follows:

Entity-Relationship Model

- **Mapping Cardinality/Cardinality Ratios**
  - For a binary relationship set R between entity sets A and B, the mapping cardinality are as follows:
  - **One-to-One:**
    - An entity in A is associated with at most one entity in B, and an entity in B is associated with at most one entity in A.
    - The cardinality is one to one.

Entity-Relationship Model

- **Mapping Cardinality/Cardinality Ratios**
  - **One-to-Many:**
    - An entity in A is associated with any number (zero or more) of entities in B. An entity in B, however, can be associated with at most one entity in A.
    - The cardinality is one to many.
  - **Many-to-One:**
    - An entity in A is associated with any number (zero or more) of entities in B. An entity in B, however, can be associated with at most one entity in A.
    - The cardinality is many to one.

Entity-Relationship Model

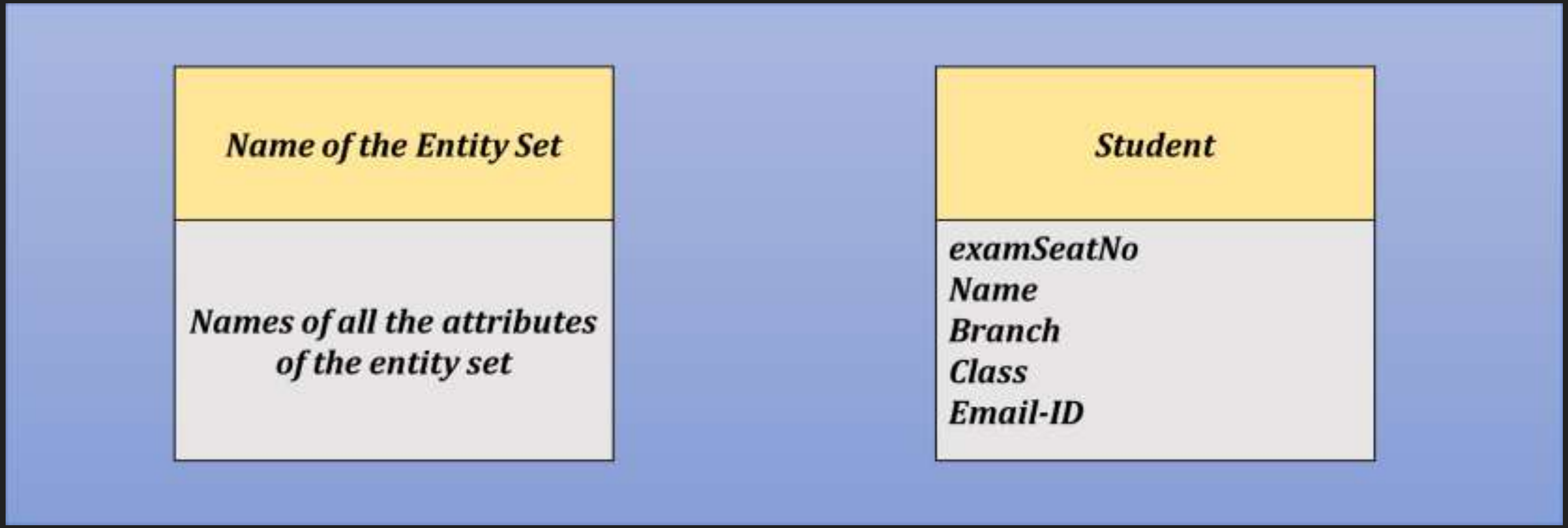
- **Mapping Cardinality/Cardinality Ratios**
  - **Many-to-Many:**
    - An entity in A is associated with any number (zero or more) of entities in B, and an entity in B is associated with any number (zero or more) of entities in A.
    - The cardinality is many to many.

Entity-Relationship Model

- **Participation Constraints**
  - **Total Participation**
    - The participation of an entity set E in a relationship set R is said to be ***total*** if every entity in E participates in at least one relationship in R.
  - **Partial Participation**
    - If only some entities in E participate in relationships in R, the participation of entity set E in relationship R is said to be ***partial***.

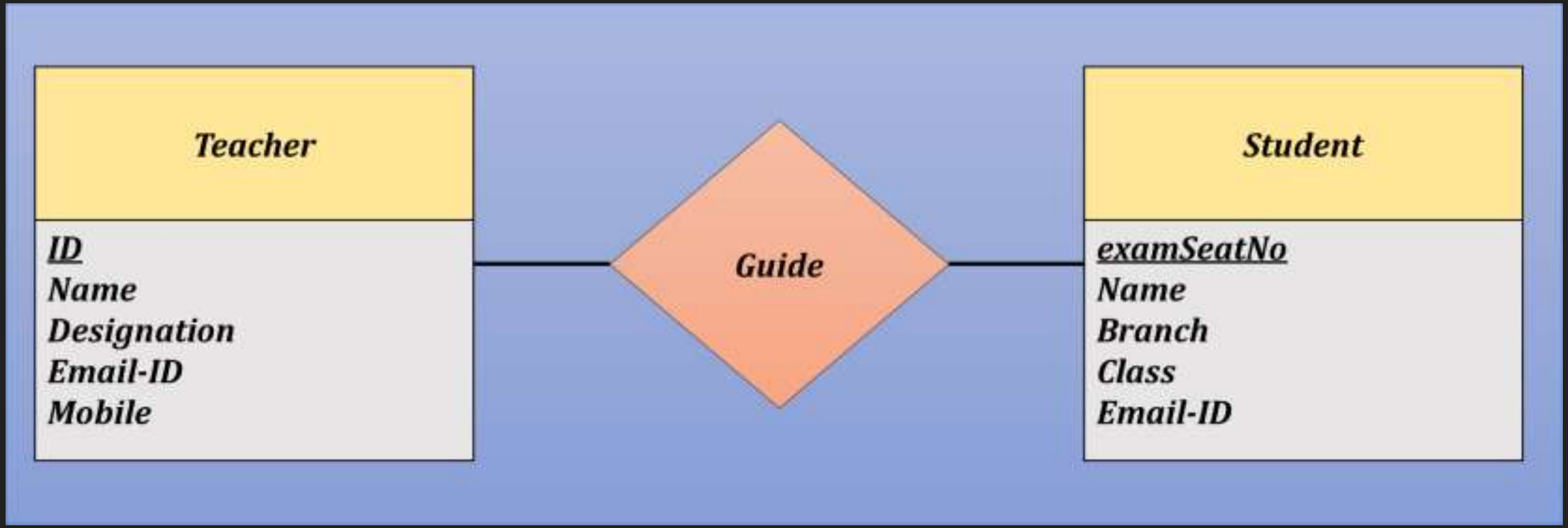
Entity-Relationship Model

- **E-R Diagrams – Basic Structure**
  - An E-R diagram consists of following components:
  - **Rectangles divided into two parts:** Represent **entity sets**



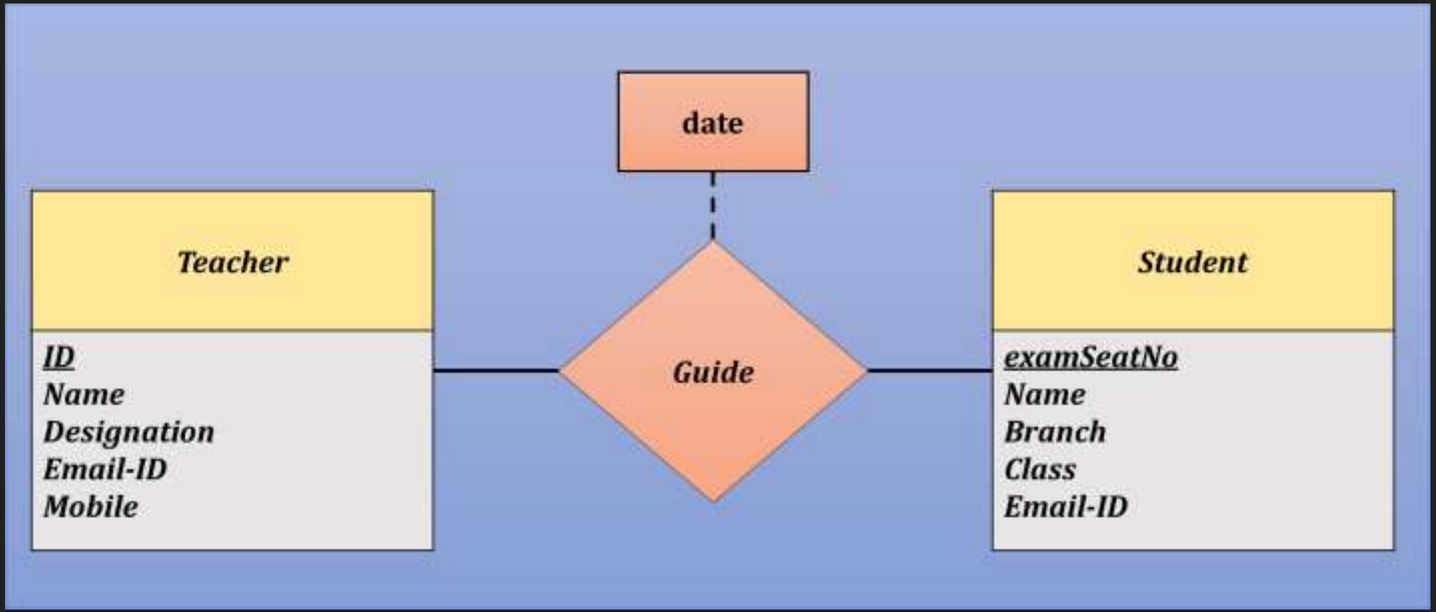
Entity-Relationship Model

- **E-R Diagrams – Basic Structure**
  - **Lines:** link entity sets to relationship sets.
  - **Diamonds:** Represent **Relationship sets**



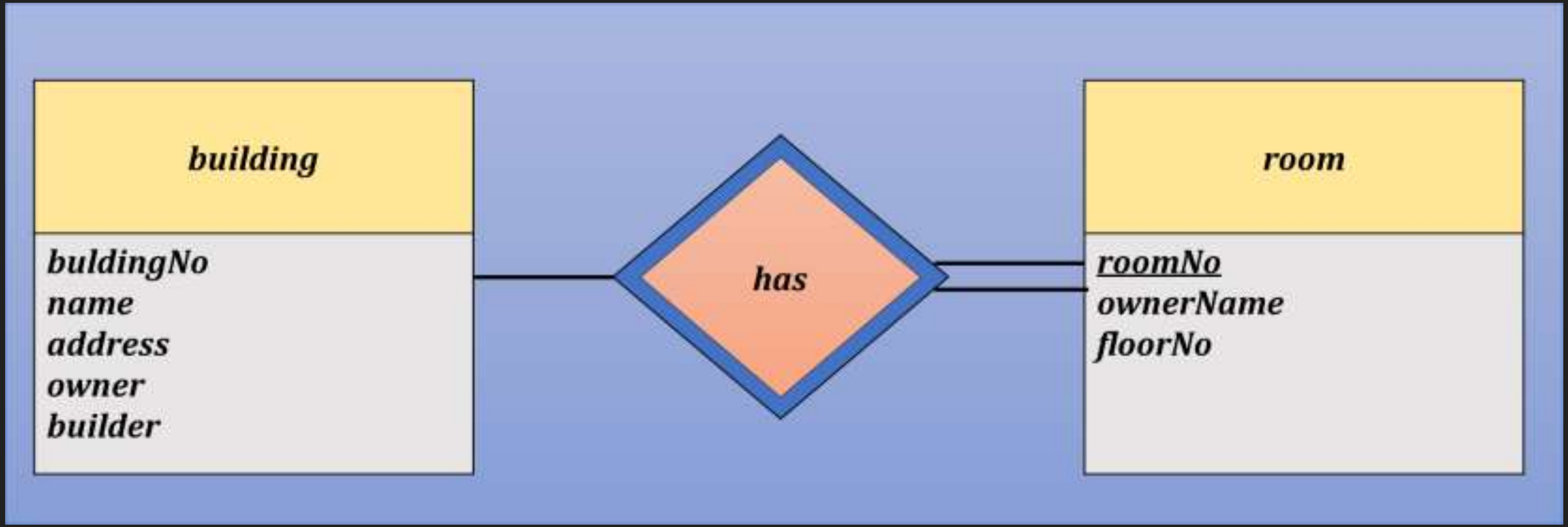
Entity-Relationship Model

- **E-R Diagrams – Basic Structure**
  - **Undivided rectangles:** Represent **the attributes of a relationship set.**
  - **Dashed lines** link attributes of a relationship set to the relationship set.



Entity-Relationship Model

- **E-R Diagrams – Basic Structure**
  - **Double lines** indicate total participation of an entity in a relationship set.
  - **Double diamonds** represent identifying relationship sets linked to weak entity sets

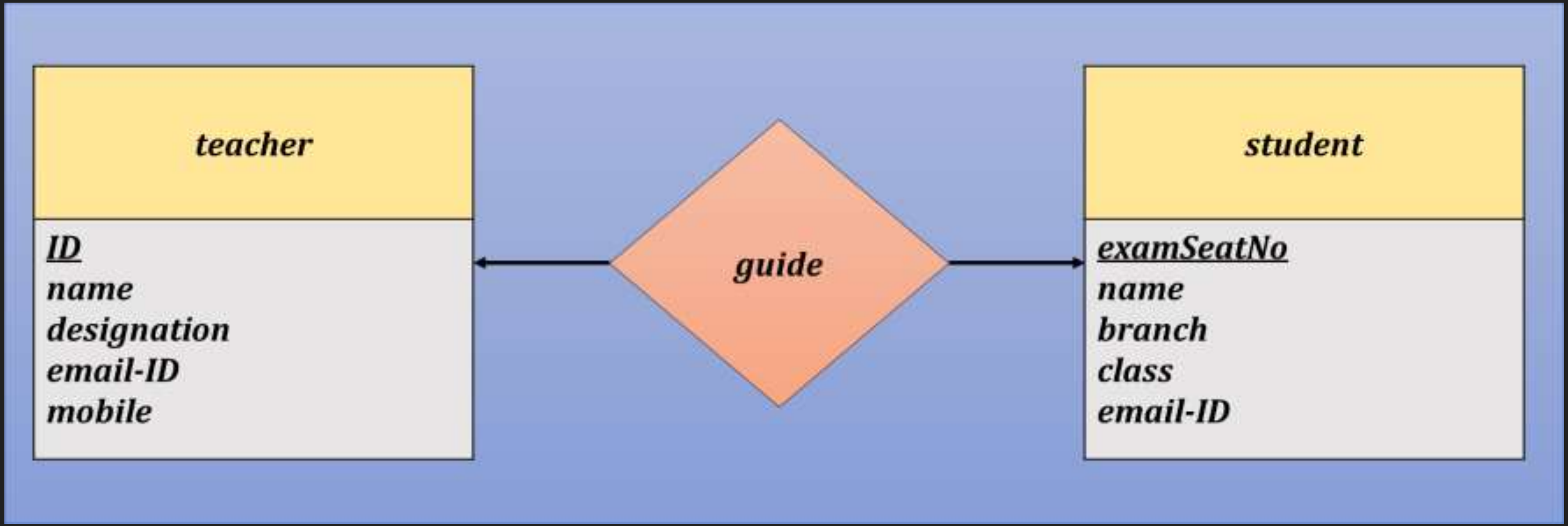


Entity-Relationship Model

- **E-R Diagrams – Basic Structure**
  - **Double rectangle** represent weak entity
  - **Primary key attribute** is always underlined. It helps identify each of the member in an entity uniquely.

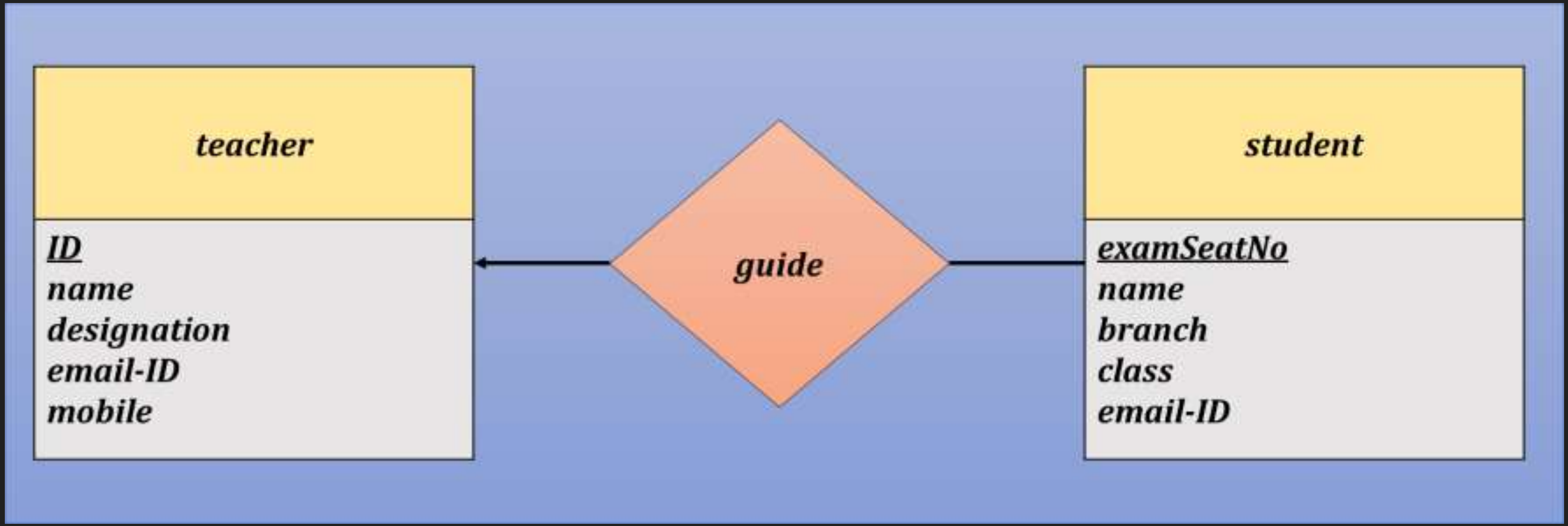
Entity-Relationship Model

- **E-R Diagrams – Basic Structure**
  - **One-to-One Relationship**



Entity-Relationship Model

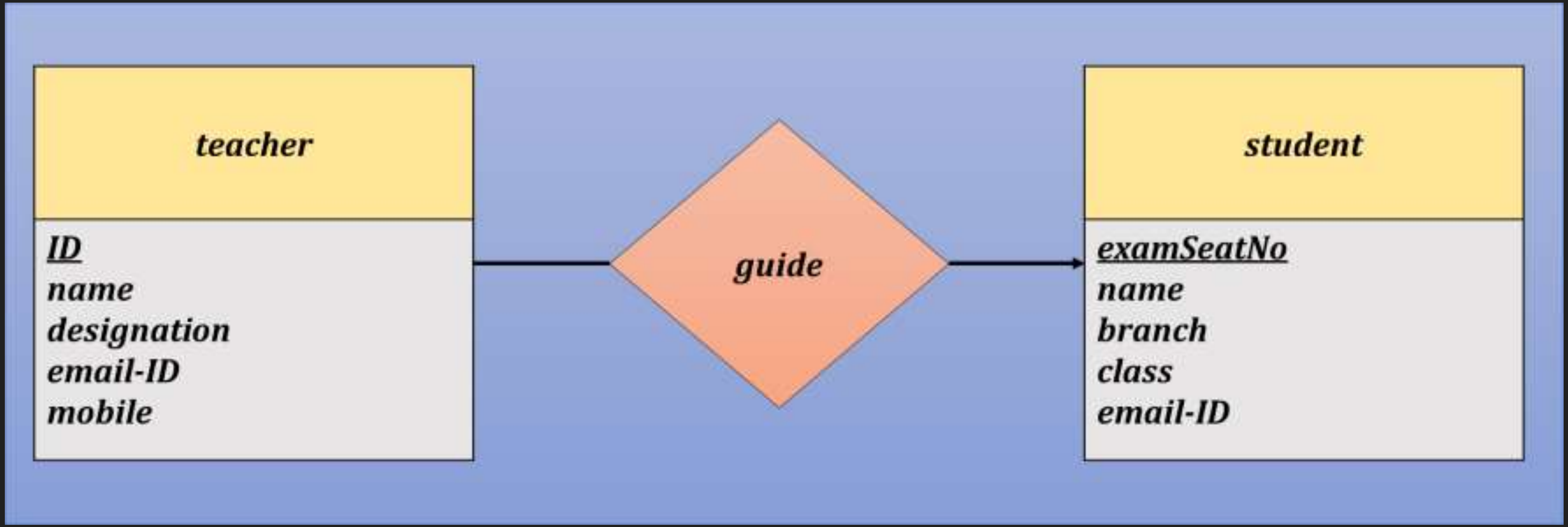
- **E-R Diagrams – Basic Structure**
  - **One-to-Many Relationship**



Entity-Relationship Model

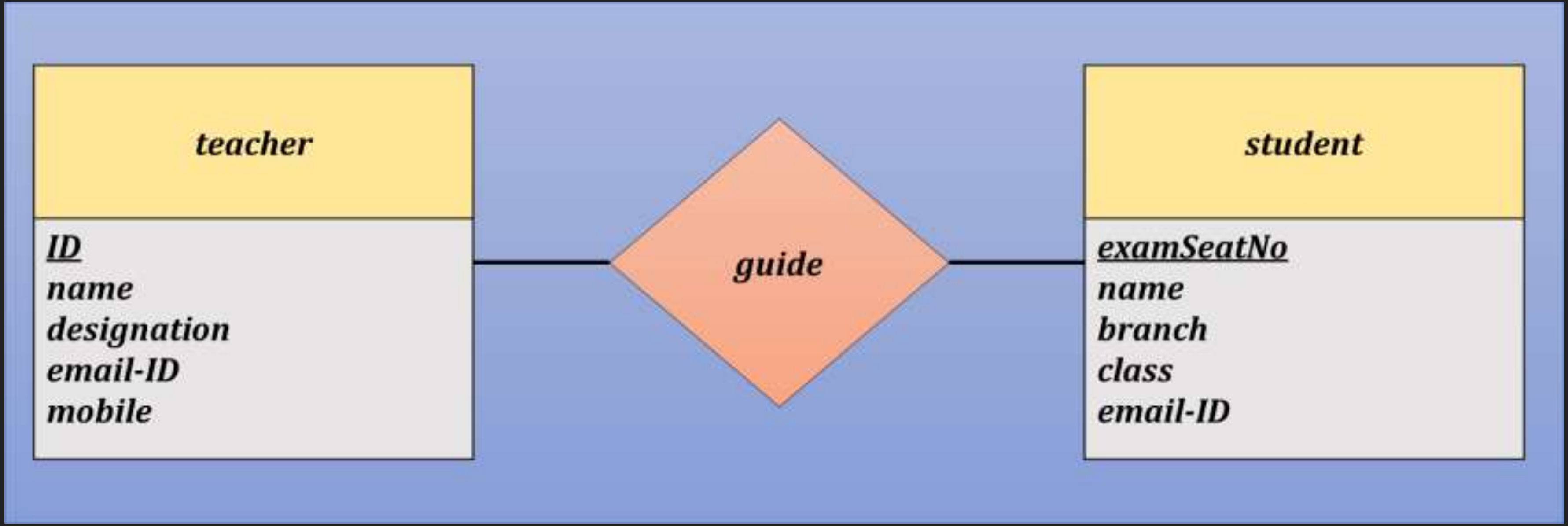
➢ **E-R Diagrams – Basic Structure**

- **Many-to-One Relationship**



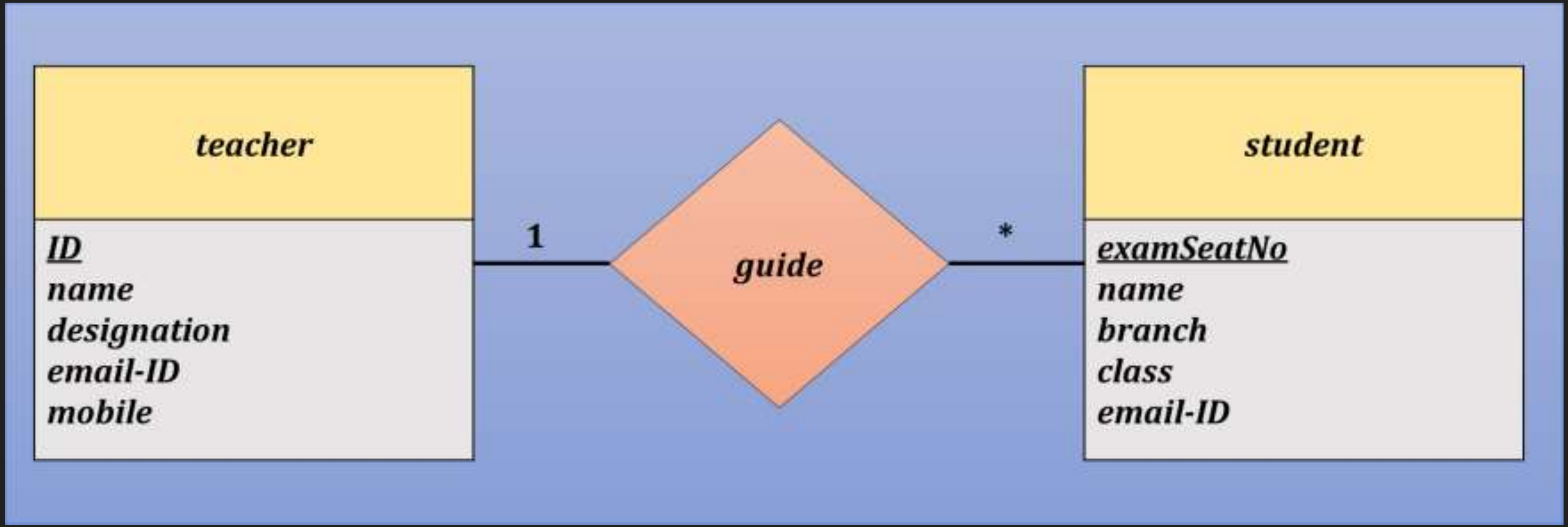
Entity-Relationship Model

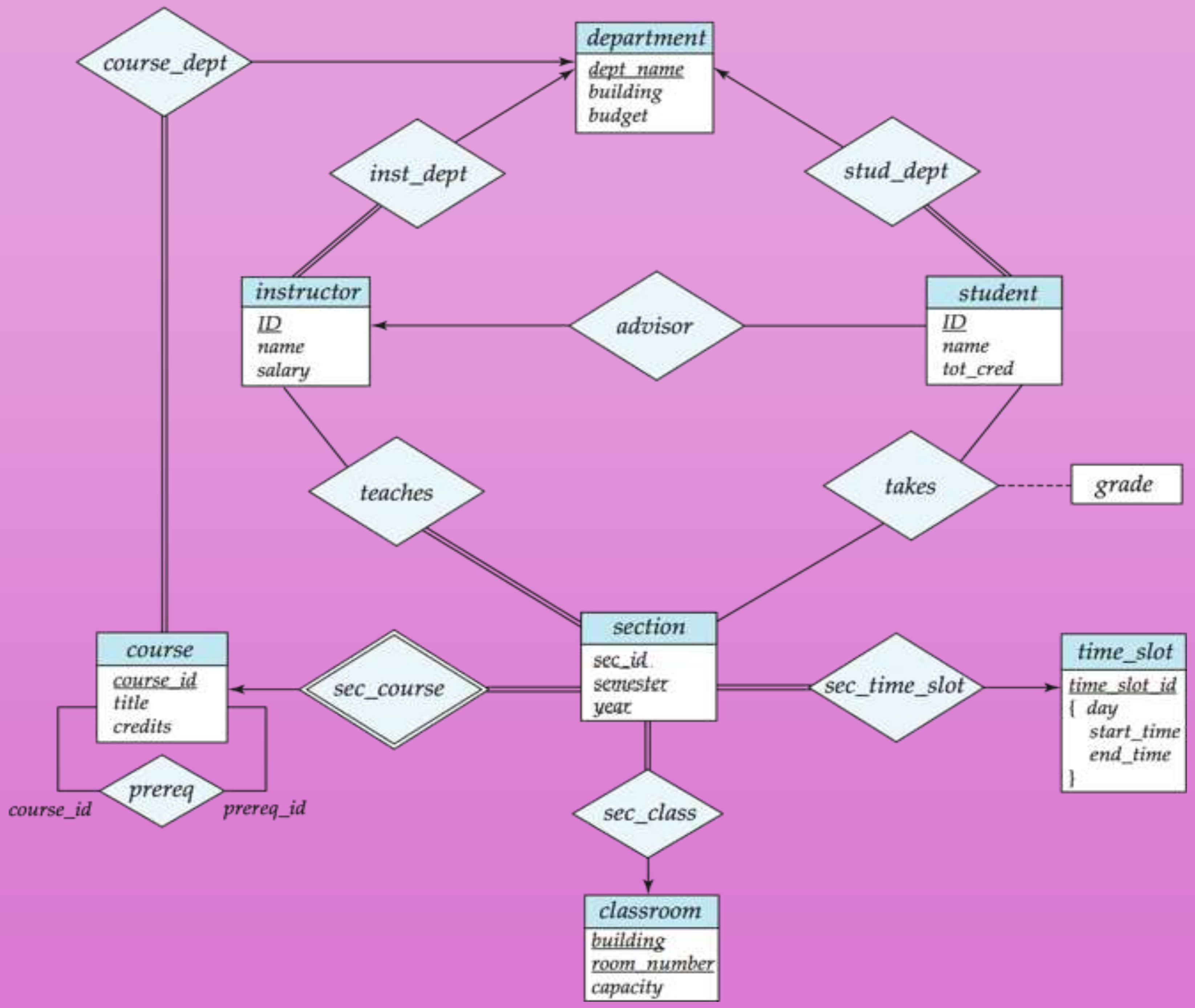
- **E-R Diagrams – Basic Structure**
  - **Many-to-Many Relationship**



Entity-Relationship Model

- **E-R Diagrams – Basic Structure**
  - **Mapping Cardinality Limit (Another way)**




department
dept_name
building
budget
course_dept
inst_dept
stud_dept
instructor
ID
name
salary
advisor
student
ID
name
tot_cred
teaches
takes
grade
section
sec_id
semester
year
course
course_id
title
credits
sec_course
sec_time_slot
time_slot
time_slot_id
{ day
start_time
end_time
}
prereq
course_id
prereq_id
sec_class
classroom
building
room_number
capacity

References

- Abraham Silberschatz, Henry F. Korth and S. Sudarshan, “Database System Concepts”, Mc-Graw Hill, 7th Edition.

Module 5
Relational Model and SQL - Part 1

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Content

- Introduction to Relational Model
- Structure of Relational Database
- Keys
- Relational Algebra

Introduction to Relational Model

- Proposed by Dr. E. F. Codd in 1970
- Received The Turing Award in 1981
- Relational model forms the basis for relational databases i.e. it represents how data is stored in the relational databases.
- In relational model all data is represented in terms of ***tuples*** and grouped into ***relations***.
- A database organized in terms of relational model is ***relational database***.

Introduction to Relational Model

- After designing the conceptual model of Database using ER diagram, we need to convert the it in the relational model which can be implemented using any RDMBS languages like Oracle SQL, MySQL, etc.
- It is one of the primary data model used for commercial data processing applications because of its simplicity.

Structure of Relational Databases

- A database organized in terms of relational model is ***relational database***.
- **Relations**
  - A relational database consists of a collection of **relations** each having a unique name.
  - Relations are also known as tables.
  - Data is stored in rows and columns.

Structure of Relational Databases

- **Tuple**
  - Each row in the table is known as a tuple.
  - It represents data related to an entity or object.
  - It represents the relationship between the values.
- **Attribute**
  - Each column in the table represents the attribute.
  - Each column name must have unique attribute name.

Structure of Relational Databases

exam_seat_no	name	Department	mobile
2050BTECS001	Ram	Computer Science	11111111111
2050BTEEN001	Shyam	Electronics	22222222222
2050BTEEL001	Ganesh	Electrical	33333333333
2050BTECV001	Ravi	Civil	44444444444
2050BTEME001	Mahesh	Mechanical	55555555555

Table 1. Student relation (table)

Structure of Relational Databases

➢ **Domain**

- For each column/attribute of table, there is a set of permitted values called as domain of that attribute.
- E.g. For the attribute *exam_seat_no,* domain is set of all exam seat numbers, for *name,* it is a set of all possible names.
- A domain is said to be ***atomic*** if elements of the domain are considered to be indivisible units.
- E.g. *phone_number*: it can have multiple values and even its single value can be sub divided (into *country code, area code,* and *local number*)

Structure of Relational Databases

- **Domain**
  - **null value** is a special values that signifies that the value is unknown or does not exist.
  - E.g. It may be possible that value for *phone_number* for *student* relation may not exist or is unlisted.

Structure of Relational Databases

- **Database Schema**
  - It is a logical design of a database.
  - In general, it is physical level, logical level and view level.
- **Database Instance**
  - It is a snapshot of the data in the database at a given instant in time.

Structure of Relational Databases

- **Relation Schema**
  - It is a programming language notion of type definition.
  - It consists of a list of attributes and their corresponding domains.
  - In general, it does not change with time.
- **Relation Instance**
  - It is a programming language notion of a value of a variable.
  - It refers to a specific instance of a relation that contains a specific set of rows.
  - They do not contain duplicate values.
  - In general, it changes with time as the relation is updated.

Structure of Relational Databases

```
student (
  studentExamNo int(11) NOT NULL,
  studentFullName varchar(70) NOT NULL,
  mobileNo varchar(50) NOT NULL,
  address varchar(50) NOT NULL,
  state varchar(50) DEFAULT NULL,
  country varchar(50) NOT NULL,
  PRIMARY KEY (StudentExamNo),
)
```

Fig. 1. Sample Relation Schema

Structure of Relational Databases

- **Relation Instance**
  - E.g.

student (*st_id, st_nm, st_email, st_dept, st_course*)

teacher (*tr_id, tr_nm, tr_email, tr_dept, tr_course*)

teaches (*tr_id, course_id, dept, sem, year*)

Keys

- A relation consists of large number of tuples.
- Each tuple has a set of values for given set of attributes/columns.
- To uniquely identify every tuple, attribute values should be uniquely specified.
- These attributes that are used to uniquely identify tuples in the relation are called as *keys.*
- There are following types of keys: Superkey, candidate key, primary key and foreign key

Keys

- **Superkey**
  - *A superkey is a set of one or more attributes that, taken collectively, allows us to identify uniquely a tuple in a relation.*
  - E.g. In STUDENT *(examSeatNo, stName, stMobile, stBranch)* relation,

    an attribute *examSeatNo* is a superkey as it is sufficient to identify one student record (tuple) from another.

    However, *stName* or *stBranch* cannot be a superkey as values for both the attributes may be same.

    {examSeatNo, stName} or {examSeatNo, stMobile}, {examSeatNo, stBranch} are also superkeys for STUDENT relation

Keys

- **Candidate key**
  - *A candidate key is a minimal set of attributes which can uniquely identify a tuple in a relation.*
  - In general, superkey may contain extraneous attributes like *stName* in *{examSeatNo, stName}*
  - If K is a superkey, any of its superset is also a superkey.
  - But, *candidate key is a minimal superkeys for which no proper subset is a superkey.*

Keys

- **Candidate key**
  - E.g. In STUDENT (*examSeatNo, stName, stMobile, stBranch*) relation.

Some Superkeys are: {examSeatNo}, {examSeatNo, stName}, {examSeatNo, stMobile} and {examSeatNo, stBranch}.

{stName, stMobile} is also sufficient to uniquely identify the tuple in STUDENT.

So, Candidate keys are: {examSeatNo} and {stName, stMobile}.

Remaining keys are only superkeys and not candidate kays as they contain {examSeatNo} which alone is a candidate key.

Keys

- **Candidate key**
  - E.g. In EMPLOYEE (*employeeID, empName, empSalary, empPAN, empAadharNo*) relation.

So, Candidate keys are: {employeeID}, {empPAN} and {empAadharNo}.

All other combinations of attributes may form superkeys such as

{employeeID, empName}, {empName, empPAN}, etc.

Keys

- **Points to remember**
  - A superkey is a superset of candidate keys, but vice versa is not true.
  - There can be one or more superkeys in a relation.
  - There can be one or more candidate keys in a relation.
  - Superkey and candidate key cannot be null.
  - Adding 0 or more attributes in a candidate key generates superkey.
  - Superkey and candidate can be simple or composite.

Keys

- **Primary key**
  - *A primary key is a candidate key that is chosen by the database designer as a principal means of identifying tuples in within a relation.*
  - There can be ***only one*** primary key for a relation (chosen out of many candidate keys).
  - *The candidate key other than primary key is called as alternate key.*
  - E.g. In STUDENT relation, *examSeatNo* is a primary key.

  In EMPLYEE relation, *employeeID* is a primary key.
  - Primary key cannot be **null** and **duplicate**.

Keys

- **Foreign key**
  - A *foreign-key constraint* from attribute(s) A of relation *r1* to the primary-key B of relation *r2* states that on any database instance, the value of A for each tuple in *r1* must also be the value of B for some tuple in *r2*.
  - Attribute set A is called a *foreign key* from r1, referencing r2.
  - The relation *r1* is also called the *referencing relation* of the foreign-key constraint, and r2 is called the *referenced relation*.
  - In simple words, foreign keys are the column of one table which is used to point to the primary key of another table.

Keys

Foreign Key

Primary Key

student
examSeatNo
fullName
departmentID
Class
emailAddress

Referencing Relation

department
departmentID
departmentName
estdYear

Referenced Relation

Keys

- **Points to Remember**
  - Primary key cannot be **null** and **duplicate**.
  - A foreign key can be null as well as may contain duplicate values.
  - Primary keys are also referred to as *primary key constraints.*
  - Primary key attributes are <u>underlined.</u>
  - A *referential integrity constraint* requires that the values appearing in specified attributes of any tuple in the referencing relation also appear in specified attributes of at least one tuple in the referenced relation.

Relational Query Languages

- **Query Language**
  - *It is a language in which a user requests information from the database.*
  - There are three types of query languages:
    - Imperative
    - Functional
    - Declarative

Relational Query Languages

- **Imperative Query Language**
  - In imperative query language, the user instructs the system to perform a specific sequence of operations on the database to compute the desired result.
  - It uses the state variables, which are updated in the course of the computation.
  - Requires deep technical and language knowledge.
  - They are not user friendly and may prone to human error.
  - E.g. No pure imperative query languages, Gremlin and JavaAPI (for Neo4j)

Relational Query Languages

- **Functional Query Language**
  - In functional query language, the computation is expressed as the evaluation of functions that may operate on data in the database or on the results of other functions.
  - The functions are side-effect free, and they do not update the program state.
  - E.g. Relational Algebra which forms the basis for SQL language

Relational Query Languages

- **Declarative Query Language**
  - In declarative query language, the user describes the desired information without giving a specific sequence of steps or function calls for obtaining that information.
  - The desired information is typically described using some form of mathematical logic.
  - It is the job of the database system to figure out how to obtain the desired information.
  - E.g. Tuple relational calculus, domain relational calculus and SQL

Relational Query Languages

- **Declarative Query Language**
  - SQL actually includes the elements of imperative, functional and declarative approaches.

Relational Algebra

- The relational algebra consists of a set of operations that take or two relations as inputs and produce a new relation as their result.
- The operations can be either unary or binary.
- Unary operations are those which operate on only one relation to produce a desired result.
- Select, project and rename operations are unary operations.
- Binary operations are those which operate on a pair relations to produce a desired result.
- Union, Cartesian-Product and set difference are binary operations.

Relational Algebra

- **The Select operation**
  - This is a unary operation used *select tuples* that satisfy the given predicate.
  - It is denoted by lowercase Greek letter *sigma* (σ).
  - The predicate appears as a subscript to σ and the argument relation is in the parenthesis after the σ.
  - In general, comparisons are allowed using =, ≠, <, ≤, > and ≥.
  - Several predicates can be combined into larger one using *and(∧), or(∨) and not (¬)* operators.

Relational Algebra

- **The Select operation**
  - E.g. 1. Select all the tuples of *instructor relation* where instructor is in Physics department.

$$\sigma_{\text{dept\_name}=\text{"Physics"}}\ (instructor)$$

  - E.g. 2. Select all the tuples of instructor relation where instructor has salary greater than 90000

$$\sigma_{\text{salary}>90000}\ (instructor)$$

Relational Algebra

- **The Select operation**
  - E.g. 3. Select all the tuples of *instructor relation* where instructor is in Physics department *and* has salary greater than 90000.

$$\sigma_{\text{dept\_name="Physics"} \land \text{salary} > 90000}\ (instructor)$$

  - E.g. Select all the tuples of *department relation* where department name is same as building name.

$$\sigma_{\text{dept\_name=building}}\ (department)$$

Relational Algebra

ID	name	dept_name	salary
1	A	Mechanical	90000
2	B	Electrical	80000
3	C	Physics	75000
4	D	Physics	150000
5	E	Civil	200000
6	F	Electronics	300000

Table 2. instructor relation

Relational Algebra

ID	name	dept_name	salary
3	C	Physics	75000
4	D	Physics	150000

Table 2-1. Output of the E.g.1

Relational Algebra

ID	name	dept_name	salary
4	D	Physics	150000
5	E	Civil	200000
6	F	Electronics	300000

Table 2-2. Output of the E.g.2

Relational Algebra

ID	name	dept_name	salary
4	D	Physics	150000

Table 2-3. Output of the E.g.3

Relational Algebra

- **The Project operation**
  - This is a unary operation used *return its argument relation with certain attributes left out*.
  - That is this operation shows the list of those attributes that we wish to appear in the result.
  - It is denoted by uppercase Greek letter *pi* (Π).
  - The predicate appears as a subscript to Π and the argument relation is in the parenthesis after the Π.

Relational Algebra

- **The Project operation**
  - E.g. 1. (Refer Table 2) Return ID, name and salary from *instructor* relation.

$$\Pi_{\text{ID, name, salary}}\ (instructor)$$

  - A basic version of project operation $\Pi_L\ (E)$ allows only attributes names to be present in the list (L) but generalised version allows expressions involving attributes to appear in the list (L).
  - E.g. To get monthly salary of instructor:

$$\Pi_{\text{ID, name, salary/12}}\ (instructor)$$

Relational Algebra

ID	name	salary
1	A	90000
2	B	80000
3	C	75000
4	D	150000
5	E	200000
6	F	300000

Table 2-4. Output of the E.g. 1 of Project Operation

Relational Algebra

- **The Composition of Relational Operations**
  - Fact: The result of a relational operation is itself a relation.
  - Because of this fact, these operations can be composed together into a relational algebra expression.
  - For e.g., To find the names of all instructors in the Physics department:

$$\Pi_{name}\ (\sigma_{dept\_name=\text{“Physics”}}\ (instructor))$$

Here there is no relation name given as an argument of project operation. Instead, expression is given that evaluates to a relation.

Relational Algebra

- **The Rename operation**
  - In general, results of relational-algebra expressions do not have name.
  - But, if you want to give the name to the result rename operation is used.
  - This is unary operation and is denoted by lowercase Greek letter *rho* (ρ).
  - E.g. Given relational algebra expression E,

$$\rho_x (E)$$

returns the result of expression E under the name x

Relational Algebra

- **The Rename operation**
  - Another form includes a relational algebra expression E with arity *n.*

$$\rho_{x(A_1, A_2, \ldots, A_n)} \ (E)$$

returns the result of expression E under the name x and with the attributes names renamed to $A_1, A_2, \ldots, A_{n.}$

E.g. Find the ID and name of those instructors who earn more than the instructor whose ID is 1.

$$\Pi_{i.ID,\ i.name} ((\sigma_{i.salary > w.salary} (\rho_i(instructor) \times \sigma_{w.ID=1} (\rho_w(instructor)))))$$

Relational Algebra

- **The Cartesian-Product operation**
  - The Cartesian-Product operation allows us to combine information from any two relation.
  - It is denoted by a Cross (×).
  - E.g. Cartesian-Product of relation *r1* and *r2* is **r1×r2.**
  - A Cartesian-Product of set produces pairs but a Cartesian-Product of database relations concatenates two tuples t1 and t2 into a single tuple.
  - This is a binary operation.

Relational Algebra

➢ **The Cartesian-Product operation**

- As the same attribute name may appear in the both relations, we use following naming schema:
- E.g. The relation schema *r = instructor* × *teaches* is

(instructor.ID, instructor.name, instructor.dept_name, instructor.salary, teaches.ID, teaches.course_ID, teaches.sec_ID, teaches.semester, teaches.year)

- Relation name is dropped for the tttributes that appear in only one relation.
- *(instructor.ID, name, dept_name, salary, teaches.ID, course_ID, sec_ID, semester, year)*

Relational Algebra

- **The Cartesian-Product operation**
  - What tuples appear in *r*, if *r = instructor* × *teaches?*
  - r contains each possible pair of tuples: one from *instructor* relation and another from *teaches* relation.
  - i.e. if *instructor* has *n1* tuples and *teaches* has *n2* tuples then resulting relation *r* will have *n1*n2* tuples in it.

Relational Algebra

ID	name	dept_name	salary
1	A	Mechanical	90000
2	B	Electrical	80000
3	C	Physics	75000
4	D	Physics	150000
5	E	Civil	200000
6	F	Electronics	300000

Table 2. instructor relation

Relational Algebra

ID	course_ID	sec_ID	semester	year
1	CV1	A1	1	First
2	ME2	A1	2	First
3	EL1	B1	1	Second
4	ET2	B2	2	Third
5	CS1	C1	1	Final
5	CS2	C2	2	Final

Table 3. teaches relation

Relational Algebra

ID	name	dept_name	salary	ID	course_ID	sec_ID	semester	year
1	A	Mechanical	90000	1	CV1	A1	1	First
1	A	Mechanical	90000	2	ME2	A1	2	First
1	A	Mechanical	90000	3	EL1	B1	1	Second
1	A	Mechanical	90000	4	ET2	B2	2	Third
1	A	Mechanical	90000	5	CS1	C1	1	Final
1	A	Mechanical	90000	5	CS2	C2	2	Final
2	B	Electrical	80000	1	CV1	A1	1	First
2	B	Electrical	80000	2	ME2	A1	2	First
…	…	…	…	…	…	…	…	…

Table 4. r = instructor × teaches

Relational Algebra

- **The Join operation**
  - Cartesian-product operation associates every tuple of one relation with every tuple of another relation regardless of their actual association.
  - A join operation is binary operation which combines related tuples from different relations, if and only if the given condition is specified.
  - A join operation allows us to *combine* a *selection* and a *Cartesian-Product* operation into a single operation.

Relational Algebra

- **The Join operation**
  - If *r1* and *r2* are two relations, then join operation can be represented as

$$r1 \bowtie_{\theta} r2$$

and it is defined as

$$r1 \bowtie_{\theta} r2 = \sigma_{\theta}(r1 \times r2)$$

where, θ is a predicate and $\times$ is Cartesian-Product of r1 and r2

It can also be written as

$$r1 \bowtie_{\theta} r2$$

Relational Algebra

- **The Join operation**
  - E.g. find the information about all instructors together with the course_id of all courses they have taught.
  - It is represented as

$$\sigma_{instructor.ID=teaches.ID}(instructor \times teaches)$$

  - This states that take Cartesian-Product of *instructor* and *teaches,* and then select all tuples from the resulting relation where *instructor.ID matches with the teaches.ID*

Relational Algebra

ID	name	dept_name	salary
1	A	Mechanical	90000
2	B	Electrical	80000
3	C	Physics	75000
4	D	Physics	150000
5	E	Civil	200000
6	F	Electronics	300000

Table 5. instructor relation

Relational Algebra

ID	course_ID	sec_ID	semester	year
1	CV1	A1	1	First
1	CV2	A1	2	First
3	EL1	B1	1	Second
4	ET2	B2	2	Third
5	CS1	C1	1	Final
5	CS2	C2	2	Final

Table 6. teaches relation

Relational Algebra

ID	name	dept_name	salary	ID	course_ID	sec_ID	semester	year
1	A	Mechanical	90000	1	CV1	A1	1	First
1	A	Mechanical	90000	1	CV2	A1	2	First
1	A	Mechanical	90000	3	EL1	B1	1	Second
1	A	Mechanical	90000	4	ET2	B2	2	Third
1	A	Mechanical	90000	5	CS1	C1	1	Final
1	A	Mechanical	90000	5	CS2	C2	2	Final
2	B	Electrical	80000	1	CV1	A1	1	First
2	B	Electrical	80000	1	CV2	A1	2	First
…	…	…	…	…	…	…	…	…

Table 7. instructor × teaches

Relational Algebra

ID	name	dept_name	salary	ID	course_ID	sec_ID	semester	year
1	A	Mechanical	90000	1	CV1	A1	1	First
1	A	Mechanical	90000	1	CV2	A1	2	First
3	C	Physics	75000	3	EL1	B1	1	Second
4	D	Physics	150000	4	ET2	B2	2	Third
5	E	Civil	200000	5	CS1	C1	1	Final
5	E	Civil	200000	5	CS2	C2	2	Final

Table 8. r = instructor ⋈ teaches

Relational Algebra

- **The Set operations - Union**
  - Union operation combines results of two or more relational algebra operations and provides a single relation as its output.
  - It is denoted as ∪.
  - If *r* and *s* are two relations then their union is

$$r \cup s$$

  - It displays the attributes or tuples that are present in either or both of the relations.

Relational Algebra

- **The Set operations - Union**
  - E.g. Find the set of all courses taught in the Fall of 2017 semester, Spring 2018 semester or both semesters.
  - To find the set of all courses taught in the Fall of 2017, we write

$$\Pi_{course\_id}\ (\sigma_{semester=\text{“Fall”}\ \wedge\ year=2017}\ (section))$$

  - To find the set of all courses taught in the Spring of 2018, we write

$$\Pi_{course\_id}\ (\sigma_{semester=\text{“Spring”}\ \wedge\ year=2018}\ (section))$$

Relational Algebra

- **The Set operations - Union**
  - E.g. Find the set of all courses taught in the Fall of 2017 semester, Spring 2018 semester or both semesters.
  - Finally their ***union*** can be written as

$$\Pi_{course\_id}\ (\sigma_{semester=\text{“Fall”}\ \wedge\ year=2017}\ (section))\ \cup$$
$$\Pi_{course\_id}\ (\sigma_{semester=\text{“Spring”}\ \wedge\ year=2018}\ (section))$$

Relational Algebra

ID	course_id	sec_id	semester	year
1	CV1	1	Fall	2017
1	CV2	1	Spring	2017
2	CS1	2	Summer	2018
3	EL1	2	Winter	2017
3	EL2	1	Fall	2017
4	ET1	1	Spring	2018
4	ET2	2	Spring	2018
5	ME1	2	Summer	2018
6	ME2	1	Fall	2017

Table 9. section relation

Relational Algebra

course_id
CV1
EL2
ET1
ET2
ME2

Table 10. union of given statement

Relational Algebra

- **The Set operations - Intersection**
  - Intersection operation allows us to find the tuples that are present in both input relations.
  - It is denoted as ∩.
  - E.g. If *r* and *s* are two relations then their intersection is

$$r \cap s$$

Relational Algebra

- **The Set operations - Intersection**
  - E.g. Find the set of all courses taught in the Fall of 2017 semester and Spring 2018 semester.
  - To find the set of all courses taught in the Fall of 2017, we write *r* as

$$\Pi_{course\_id}\ (\sigma_{semester=\text{“Fall”} \wedge year=2017}\ (section))$$

  - To find the set of all courses taught in the Spring of 2018, we write *s* as

$$\Pi_{course\_id}\ (\sigma_{semester=\text{“Spring”} \wedge year=2018}\ (section))$$

Relational Algebra

- **The Set operations - Intersection**
  - E.g. Find the set of all courses taught in the Fall of 2017 semester and Spring 2018 semester.
  - Finally their ***intersection r ∩ s*** can be written as

$$\Pi_{course\_id}\,(\sigma_{semester=\text{“Fall”} \land year=2017}\,(section)) \cap$$
$$\Pi_{course\_id}\,(\sigma_{semester=\text{“Spring”} \land year=2018}\,(section))$$

Relational Algebra

ID	course_id	sec_id	semester	year
1	CV1	1	Fall	2017
1	CV2	1	Spring	2017
2	CS1	2	Summer	2018
3	EL1	2	Winter	2017
3	EL2	1	Fall	2017
4	ET1	1	Spring	2018
4	CV1	2	Spring	2018
5	ME1	2	Summer	2018
6	ME2	1	Fall	2017

Table 11. section relation

Relational Algebra

course_id
CV1

Table 12. intersection of given statement

Relational Algebra

- **The Set operations – set-difference**
  - Set-difference operation allows us to find the tuples that are present in one relation but are not in the other relation.
  - It is denoted as –.
  - E.g. If *r* and *s* are two relations then their set-difference is

$$r - s$$

which produces a relation containing those tuples in *r* but not in *s.*

Relational Algebra

- **The Set operations – set-difference**
  - E.g. Find all the courses taught in the Fall 2017 semester but not in Spring 2018 semester.
  - To find the set of all courses taught in the Fall of 2017, we write *r* as

$$\Pi_{course\_id}\ (\sigma_{semester=\text{“Fall”} \land year=2017}\ (section))$$

  - To find the set of all courses taught in the Spring of 2018, we write *s* as

$$\Pi_{course\_id}\ (\sigma_{semester=\text{“Spring”} \land year=2018}\ (section))$$

Relational Algebra

- **The Set operations – set-difference**
  - E.g. Find all the courses taught in the Fall 2017 semester but not in Spring 2018 semester.
  - Finally their ***set-difference r – s*** can be written as

$$\Pi_{course\_id} (\sigma_{semester=\text{“Fall”} \wedge year=2017} (section)) -$$
$$\Pi_{course\_id} (\sigma_{semester=\text{“Spring”} \wedge year=2018} (section))$$

Relational Algebra

ID	course_id	sec_id	semester	year
1	CV1	1	Fall	2017
1	CV2	1	Spring	2017
2	CS1	2	Summer	2018
3	EL1	2	Winter	2017
3	EL2	1	Fall	2017
4	ET1	1	Spring	2018
4	CV1	2	Spring	2018
5	ME1	2	Summer	2018
6	ME2	1	Fall	2017

Table 13. section relation

Relational Algebra

course_id
EL2
ME2

Table 13. set-difference of given statement

Relational Algebra

- **The Set operations – Points to remember**
  - For union, intersection and set difference operations to make sense:
    - We must ensure that the input relations to the union operation have the same number of attributes; the number of attributes of a relation is referred to as its ***arity***.
    - When the attributes have associated types, the types of the i^{th} attributes of both input relations must be the same, for each i.
  - Such relations are referred to as ***compatible relations***.

Relational Algebra

- **The assignment operation**
  - For ease of understanding and convenience, parts of a relational algebra expression can be assigned to temporary relation variables.
  - This can be done with the help of ***assignment operator*** which is denoted as ←.
  - It works like assignment operator in programming language.

Relational Algebra

- **The assignment operation**
  - E.g. Find the set of all courses taught in the Fall of 2017 semester, Spring 2018 semester or both semesters. We could write it as:

$courses\_fall\_2017 \leftarrow \Pi_{course\_id} (\sigma_{semester=\text{"Fall"} \wedge year=2017} (section))$

$courses\_spring\_2018 \leftarrow \Pi_{course\_id} (\sigma_{semester=\text{"Spring"} \wedge year=2018} (section))$

And

$courses\_fall\_2017 \cup courses\_spring\_2018$

References

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Module 5
Relational Model and SQL - Part 2

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Content

- Introduction to SQL
- SQL Data Definition
- SQL Operators
- Aggregate Functions
- Modification of the Database
- Basic Structure of SQL Queries
- Set Operations
- Nested Subqueries

Introduction to SQL

- Original version called ***'Sequel'*** was developed by IBM as a part of System R project in 1974.
- Later the name changed to **SQL (Structured Query Language)**
- SQL was standardized in 1986 by ANSI and ISO, called SQL-86.
- Recent version of standard is SQL:2016 (stable)
- SQL has clearly established itself as the standard relational database language.

Introduction to SQL

- SQL language has several parts:
  - **Data Definition Language (DDL)**
    - Has commands for defining relation schemas, deleting relations and modifying relation schemas
  - **Data Manipulation Language (DML)**
    - Provides commands to retrieve the information from the database and to insert tuples into, delete tuples from and modify tuples in the database

Introduction to SQL

- SQL language has several parts:
  - **Integrity**
    - Provides commands for specifying the integrity constraints that the data stored in the database must satisfy
    - Operations that violates integrity constraints are not allowed.
  - **View Definition**
    - Provides commands for defining views

Introduction to SQL

- SQL language has several parts:
  - **Transaction Control**
    - Provides commands for specifying the beginning and end points of transactions
  - **Authorization**
    - Provides commands for specifying access rights to relations and views

Introduction to SQL

- SQL language has several parts:
  - **Embedded SQL and Dynamic SQL**
    - Embedded and Dynamic SQL define how SQL statements can be embedded within general-purpose programming languages, such as C, C++, Java, Python, etc.

SQL Data Definition

- The set of relations in the database are specified using Data Definition Language (DDL).
- DDL also specifies the following information about each relation:
  - The schema for the relation
  - The types of values associated with each attribute
  - The integrity constraints
  - The set of indices to be maintained for each relation.
  - The security and authorization information for each relation.
  - The physical storage structure of each relation on disk.

SQL Data Definition

- **Basic Types**
- SQL supports a variety of built-in types. Some of them are:
  - char(n): character: A fixed-length character string with user-defined length n
  - varchar(n): character varying: A variable-length character string with user-defined maximum length n
  - int: integer: a finite subset of the integers that is machine dependent
  - smallint: A small integer: a machine-dependent subset of the integer type

SQL Data Definition

- **Basic Types**
- SQL supports a variety of built-in types. Some of them are:
  - Numeric(p,d): A fixed-point number with user-defined length precision. The number consists of *p* digits in total (plus a sign) and *d* of the *p* digits are to the right of the decimal points.
  - Real, double precision: Floating-point and double-precision floating-point numbers with machine-dependent precision
  - float(n): A floating-point number with precision of at least *n* digits

SQL Data Definition

- **Basic Schema Definition**
- SQL relation can be defined using **create table** command.
- The general form of create command is

create table table_name
(
$A_1\ D_1$,
$A_2\ D_2$,
...
$A_n\ D_n$,
<integrity-constraint$_1$>,
...
<integrity-constraint$_k$>
);

Fig. 1 General form of create table

SQL Data Definition

- **Basic Schema Definition**
- Here,

  Each Ai is an attribute name,

  Each Di specifies the domain of attribute Ai
- Some of the integrity constraints are
  - primary key ($A_{j_1} \ldots A_{j_n}$)
  - Foreign key ($A_{k_1} \ldots A_{k_n}$) references s
  - not null

SQL Data Definition

- **Basic Schema Definition**
- Example: instructor relation

```
create table instructor
(
        ID              varchar(5),
        name            varchar(50) not null,
        dept_name       varchar(20),
        salary          numeric(8,2),
        primary key (ID),
        foreign key (dept_name) references department (dept_name)
);
```

Fig. 2 create *instructor* table

SQL Data Definition

- **Basic Schema Definition**
- Example: department relation

```
create table department
(
        dept_name        varchar(20),
        building         varchar(20),
        budget           numeric(12,2),
        primary key (dept_name)
);
```

Fig. 3 create *department* table

SQL Data Definition

- **Basic Schema Definition**
  - A newly created relation is empty initially.
  - Inserting tuples into a relation, updating them, and deleting them are done by data manipulation statements insert, update, and delete

SQL Data Definition

Demonstration

SQL Data Definition

- **Basic Schema Definition**
  - **drop table**
  - To remove a relation from an SQL database drop table command is used.
  - This command deletes all information about the dropped relation from the database.
  - This deletes all tuples from table as well the table.
  - E.g. **drop table table_name;**

drop table instructor;

SQL Data Definition

- **Basic Schema Definition**
  - **delete from**
  - This command deletes all tuples from the relation but do not delete table.
  - Table becomes empty
  - E.g. **delete from table_name;**

delete from instructor;

SQL Data Definition

- **Basic Schema Definition**
  - **alter table**
  - This command is used to alter the table i.e. to add new attributes to existing relation or drop attributes from a relation.
  - E.g. **alter table *table_name* add *A D;***
  - This will add attribute A with its domain D in the specified table.
  - E.g. **alter table *table_name* drop A;**
  - This will drop an attribute A from specified table.

SQL Data Definition

Demonstration

SQL Data Definition

- **Demonstration**
- Offline Tool
  - XAMPP
- Online Compiler
  - https://www.w3schools.com/sql/trysql.asp?filename=trysql_op_in

SQL Operators

- SQL supports following operators that can be combined with queries.
  - Arithmetic (+,-,*,/ and %)
  - Bitwise (&, | and ^)
  - Comparison (=, >, >=, <, <= and <>)
  - Compound (+=, -=, etc.)
  - Logical
    - ALL - TRUE if all of the subquery values meet the condition
    - AND - TRUE if all the conditions separated by AND is TRUE
    - ANY - TRUE if any of the subquery values meet the condition

SQL Operators

- SQL supports following operators that can be combined with queries.
  - Logical
    - BETWEEN - TRUE if the operand is within the range of comparisons
    - EXISTS - TRUE if the subquery returns one or more records
    - IN - TRUE if the operand is equal to one of a list of expressions
    - LIKE - TRUE if the operand matches a pattern
    - NOT - Displays a record if the condition(s) is NOT TRUE
    - OR - TRUE if any of the conditions separated by OR is TRUE
    - SOME - TRUE if any of the subquery values meet the condition

SQL Aggregate Functions

- ***Aggregate functions*** are functions that take a collection (a set or multiset) of values as input and return a single value.
- SQL offers five standard built-in aggregate functions:
  - Average (**avg**)
  - Minimum (**min**)
  - Maximum (**max**)
  - Total (**sum**)
  - Count (**count**)

Modification of the Database

- Modification of database includes the commands to add, remove and update the database information.
- **Insertion**
  - To insert data into a relation, we need to specify a tuple to be inserted.
  - The attribute values for inserted tuples must be members of the corresponding attribute's domain.
  - Command used for inserting a tuple is

insert into *table_name* values ('value 1', 'value 2', …, 'value N');

Modification of the Database

```
create table department
(
        dept_name       varchar(20),
        building        varchar(20),
        budget          numeric(12,2),
        primary key (dept_name)
);
```

Fig. 4 *department* table

Modification of the Database

- To insert a tuple into ‘department’ relation we write

insert into department values (‘Civil’, ‘Wing-A’, 2500000.00);

Insert into department values (‘Mechanical’, ‘Wing-B’, 2500000.00);

- Here order of values is important.
- Values should be specified in the order in which the corresponding attributes are listed in the relation schema.
- To ease this process, another way to write insert query is

Modification of the Database

insert into department (*dept_name, building, budget*)
values ('Civil', 'Wing-A', 2500000.00);

Insert into department (*dept_name, building, budget*)
values ('Mechanical', 'Wing-B', 2500000.00);

Modification of the Database

- **Deletion**
- We can delete whole tuple from the relation using **delete command.**
- We cannot delete values on only particular attributes.
- The general form of deletion in SQL is

delete from *r*

where *P;*

Modification of the Database

- **Deletion**
- Here, *P* represents a predicate and *r* represents a relation.
- The delete statement first finds all the tuples *t* in *r* for which *P(t)* is true and then deletes them from *r.*

Modification of the Database

- **Deletion**
- **from clause**
  - The from clause is a list of the relations to be accessed in the evaluation of the query.
- **where clause**
  - The where clause is a predicate involving attributes of the relation in the from clause.
  - In deletion, if where clause is omitted then whole relation i.e. all tuples from the specified relation will be deleted.

Modification of the Database

- **Deletion**
- E.g. To delete all tuples from *department* relation, we write

  delete from *department*;

  To delete tuples where dept_name is Civil, we write

  delete from *department*

  where *dept_name*='Civil';

Modification of the Database

- **Deletion**
- E.g. To delete tuples where dept_name is Civil, we write

delete from *department*

where *dept_name*='Civil';

To delete tuples where *budget* is between 100000 and 200000, we write

delete from *department*

where *budget* between 100000 AND 200000;

Modification of the Database

- **Updates**
- To update/change the particular value of a tuple without changing all values of that tuple, **update** statement is used.
- Similar to the **insert** and **delete,** we can update any tuple in a relation using a query.
- The general form of **update** is

update table_name

set A = <new value>;

Modification of the Database

- **Updates**
- E.g. To update budget of all departments by 5%,

update department
set budget=budget*1.05;

To update budget of departments by 5% where current budget is 150000.00 or less

update department
set budget=budget*1.05
where budget <=150000.00

SQL Data Definition

Demonstration

Basic Structure of SQL Queries

- A basic structure of an SQL query consists of three clauses: select, from and where.
- A query takes as its input the relations listed in the ***from*** clause, operates on them as specified in the ***where*** and ***select*** clauses, and then produces a relation as the result.
- ***Select*** clause will return relation based on the predicate specified in the ***where*** clause.
- It performs the select and project operations of relational algebra.

Basic Structure of SQL Queries

- **Queries on a Single Relation**
  - Here, only one relation will be specified in the query.
  - The general form is

select $A_1, A_2, ..., A_n$
from *table_name*
where *P;*

Basic Structure of SQL Queries

- **Queries on a Single Relation**
  - E.g. Find the department names of all instructors

    select *dept_name*

    from *instructor*;

  - If we don't want duplicates, then distinct keyword is used after select.
  - E.g. For the above query, if we want department name only once then

    select distinct *dept_name*

    from *instructor*;

Basic Structure of SQL Queries

Queries on a Single Relation

- If we want duplicates, then **all** keyword is used after select which *explicitly* specifies that include duplicates in the resulting relation.
- E.g. For the above query, if we want all department names then we write

select all *dept_name*

from *instructor*;

- By default SQL allows duplicates, so we don't need to use ***all*** keyword.
- But, ***distinct*** keyword is mandatory if we don't want duplicates.

Basic Structure of SQL Queries

- **Queries on a Single Relation**
  - ***Select*** clause may also contain *arithmetic expressions* involving +,-,* and / operators
  - E.g. Following query returns a relation that is same as the instructor relation, except the salary is incremented by 10%.

select *ID, name, dept_name, salary*1.1*

from *instructor*;

Basic Structure of SQL Queries

- **Queries on a Single Relation**
  - The ***where*** clause allows us to select only those rows in the resulting relation of the ***from*** clause that satisfy a specified predicate.
  - E.g. To find the names of all instructors in the Electrical department who have salary greater than $70,000

select *name*

from *instructor*

where *dept_name*='Electrical' and *salary* > 70000

Basic Structure of SQL Queries

- **Queries on a Single Relation**
  - The ***where*** clause may also include comparison and logical operators as you can see in the above example.

Basic Structure of SQL Queries

- **Queries on a Multiple Relations**
  - A single SQL query can specify two or more relations.
  - The general form is

$$\textbf{select } A_1, A_2, \ldots, A_n$$
$$\textbf{from } r_1, r_2, \ldots, r_m$$
$$\textbf{where } P;$$

  - Each A_i represents an attribute, and each r_i a relation. *P* is a predicate. If the where clause is omitted, the predicate *P* is true.

Basic Structure of SQL Queries

- **Queries on a Multiple Relations**
  - E.g. To retrieve the names of all instructors, along with their department names and department building name, we write

select ***name, instructor.dept name, building***

from ***instructor, department***

where ***instructor.dept name=department.dept name;***

Basic Structure of SQL Queries

- **Queries on a Multiple Relations**
  - In the similar manner, we can retrieve the Cartesian-Product of any two(or more) relations.
  - E.g. Cartesian-Product of *instructor* and *department* can be written as

select *ID, name, instructor.dept name, salary, department.dept_name, building, budget*

from *instructor, department*

Basic Structure of SQL Queries

- **Queries on a Multiple Relations**
  - To retrieve all the attributes of a relation we use *.
  - E.g. To retrieve the all attributes of instructor and department relation we write

select * from *instructor, department;*

Or

select instructor.*, department.*
from *instructor, department;*

Basic Structure of SQL Queries

➢ Ordering the Resulting Relation

- The ***order by*** clause causes the tuples in the result of a query to appear in sorted order.
- E.g. To retrieve the all attributes of department relation sorted based on the *dept_name*, we write

select * from *department*

order by *dept_name;*

Basic Structure of SQL Queries

- **The Rename Operation**
  - The ***rename operation*** is used to rename the attributes or relations in the query.
  - To rename we use ***as*** clause.
  - It can be used in both ***select*** and ***from*** clause.
  - E.g. To retrieve the *name* as *instructor_name* from instructor relation, we write

select name as *instructor_name*

from instructor;

Basic Structure of SQL Queries

- **The Rename Operation**
  - E.g. To retrieve the *name* as *instructor_name* and *dept_name* from *instructor* as T relation, we write

    select *T.name as instructor_name, T.dept_name*

    from *instructor* as T;

SQL Data Definition

Demonstration

Basic Structure of SQL Queries

- **Set Operations**
  - The mathematical set operations union, intersection and set intersection can be represented in SQL with the help of ***union, intersection*** and ***except.***
- **Union**
  - This operation combines results of two ***select*** statements and provides a single result.
  - It by default, automatically removes all the duplicates.
  - To retain duplicates, use ***union all.***

Basic Structure of SQL Queries

- **Union**
  - E.g. To find the set of all courses taught in the Fall 2017, Spring 2018 or in both, we write

```
(select course id
from section
where semester = 'Fall' and year= 2017)
union
(select course id
from section
where semester = 'Spring' and year= 2018);
```

Basic Structure of SQL Queries

- **Union**
  - Some databases allow parenthesis for each separate part of statements and some don’t.
  - Parenthesis are useful for ease of reading.

Basic Structure of SQL Queries

- **Intersect**
  - This operation combines results of two select statements and provides a single result.
  - It returns the common tuples from two (or more) relations.
  - It by default, automatically removes all the duplicates.
  - To retain duplicates, use ***intersect all***.

Basic Structure of SQL Queries

- **Intersect**
  - E.g. To find the set of all courses taught in both the Fall 2017 and Spring 2018,

```
(select course id
from section
where semester = 'Fall' and year= 2017)
intersect
(select course id
from section
where semester = 'Spring' and year= 2018);
```

Basic Structure of SQL Queries

- **except**
  - This operation combines results of two select statements and provides a single result.
  - It returns the tuples from that are present in one relation but not present in another relation.
  - It by default, automatically removes all the duplicates.
  - To retain duplicates, use ***except all***.

Basic Structure of SQL Queries

- **except**
  - E.g. To find the set of all courses taught in the Fall 2017 but not in Spring 2018,

(select course id

from section

where semester = 'Fall' and year= 2017)

except

(select course id

from section

where semester = 'Spring' and year= 2018);

References

- Abraham Silberschatz, Henry F. Korth and S. Sudarshan, “Database System Concepts”, Mc-Graw Hill, 7th Edition.