Software Requirements Analysis and Specification

UNIT-3

Background

- Problem of scale is a key issue for SE
- For small scale, understand and specifying requirements is easy
- For large problem - very hard; probably the hardest, most problematic and error prone
- Input : user needs in minds of people
- Output : precise statement of what the future system will do

Background..

- Identifying and specifying req necessarily involves people interaction
- Cannot be automated
- Requirement (IEEE)= A condition or capability that must be possessed by a system
- Req. phase ends with a software requirements specification (SRS) document
- SRS specifies what the proposed system should do

Background..

- Requirements understanding is hard
  - Visualizing a future system is difficult
  - Capability of the future system not clear, hence needs not clear
  - Requirements change with time
  - …
- Essential to do a proper analysis and specification of requirements

Need for SRS

- SRS establishes basis of agreement between the user and the supplier.
  - Users needs have to be satisfied, but user may not understand software
  - Developers will develop the system, but may not know about problem domain
  - SRS is the medium to bridge the commn. gap and specify user needs in a manner both can understand

Need for SRS…

- Helps user understand his needs.
  - users do not always know their needs
  - must analyze and understand the potential
  - the goal is not just to automate a manual system, but also to add value through IT
  - The req process helps clarify needs
- SRS provides a reference for validation of the final product
  - Clear understanding about what is expected.
  - Validation - " SW satisfies the SRS "

Need for SRS…

- High quality SRS essential for high Quality SW
  - Requirement errors get manifested in final sw
  - to satisfy the quality objective, must begin with high quality SRS
  - Requirements defects are not few
    - 25% of all defects in one case; 54% of all defects found after UT
    - 80 defects in A7 that resulted in change requests
    - 500 / 250 defects in previously approved SRS.

Need for SRS…

- Good SRS reduces the development cost
  - SRS errors are expensive to fix later
  - Req. changes can cost a lot (up to 40%)
  - Good SRS can minimize changes and errors
  - Substantial savings; extra effort spent during req. saves multiple times that effort
- An Example
  - Cost of fixing errors in req. , design , coding , acceptance testing and operation are 2 , 5 , 15 , 50 , 150 person-months

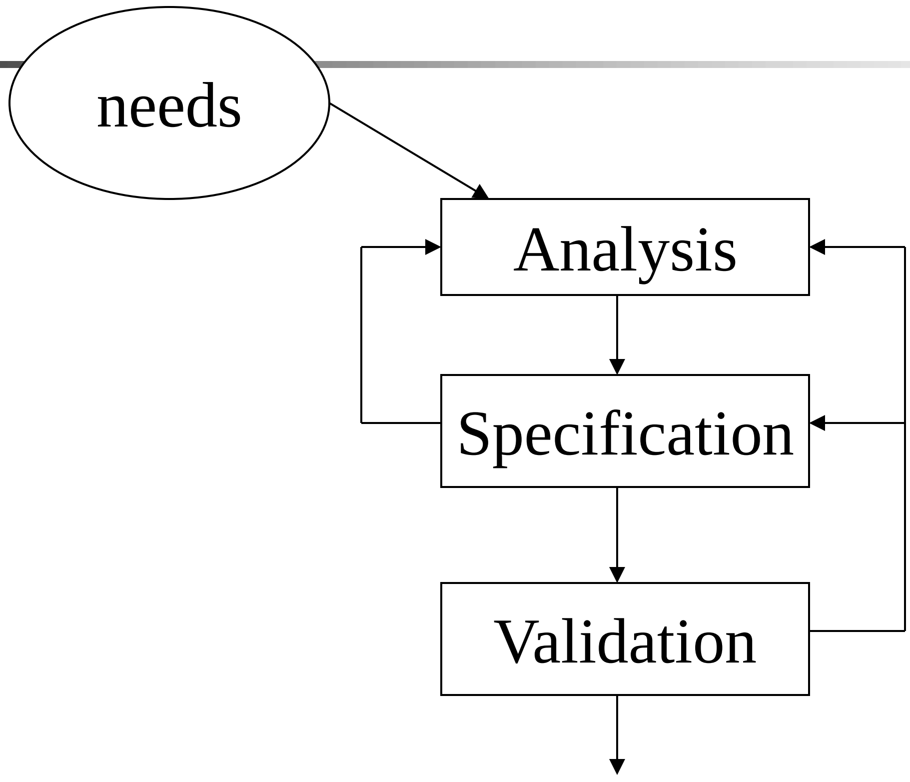
Need for SRS…

- Example …
  - After req. phase 65% req errs detected in design , 2% in coding, 30% in Acceptance testing, 3% during operation
  - If 50 requirement errors are not removed in the req. phase, the total cost
    32.5 *5 + 1*15 + 15*50 + 1.5*150 = 1152 hrs
  - If 100 person-hours invested additionally in req to catch these 50 defects , then development cost could be reduced by 1152 person-hours.
  - Net reduction in cost is 1052 person-hours

Requirements Process

- Sequence of steps that need to be performed to convert user needs into SRS
- Process has to elicit needs and requirements and clearly specifies it
- Basic activities
  - problem or requirement analysis
  - requirement specification
  - validation
- Analysis involves elicitation and is the hardest

Requirements Process..



Requirement process..

- Process is not linear, it is iterative and parallel
- Overlap between phases - some parts may be analyzed and specified
- Specification itself may help analysis
- Validation can show gaps that can lead to further analysis and spec

Requirements Process…

- Focus of analysis is on understanding the desired systems and it's requirements
- Divide and conquer is the basic strategy
  - decompose into small parts, understand each part and relation between parts
- Large volumes of information is generated
  - organizing them is a key
- Techniques like data flow diagrams, object diagrams etc. used in the analysis

Requirements Process..

- Transition from analysis to specs is hard
  - in specs, external behavior specified
  - during analysis, structure and domain are understood
  - analysis structures helps in specification, but the transition is not final
  - methods of analysis are similar to that of design, but objective and scope different
  - analysis deals with the problem domain, whereas design deals with solution domain

Problem Analysis

- Aim: to gain an understanding of the needs, requirements, and constraints on the software
- Analysis involves
  - interviewing client and users
  - reading manuals
  - studying current systems
  - helping client/users understand new possibilities
  - Like becoming a consultant
- Must understand the working of the organization , client and users

Problem Analysis…

- Some issues
  - Obtaining the necessary information
  - Brainstorming: interacting with clients to establish desired properties
  - Information organization, as large amount of info. gets collected
  - Ensuring completeness
  - Ensuring consistency
  - Avoiding internal design

Problem Analysis…

- Interpersonal issues are important
- Communication skills are very important
- Basic principle: problem partition
- Partition w.r.t what?
  - Object - OO analysis
  - Function - structural analysis
  - Events in the system – event partitioning
- Projection - get different views
- Will discuss few different analysis techniques

Characteristics of an SRS

- What should be the characteristics of a good SRS? Some key ones are
  - Complete
  - Unambiguous
  - Consistent
  - Verifiable
  - Ranked for importance and/or stability

Characteristics…

- Correctness
  - Each requirement accurately represents some desired feature in the final system
- Completeness
  - All desired features/characteristics specified
  - Hardest to satisfy
  - Completeness and correctness strongly related
- Unambiguous
  - Each req has exactly one meaning
  - Without this errors will creep in
  - Important as natural languages often used

Characteristics…

- Verifiability
  - There must exist a cost effective way of checking if sw satisfies requirements
- Consistent
  - two requirements don't contradict each other
- Ranked for importance/stability
  - Needed for prioritizing in construction
  - To reduce risks due to changing requirements

Components of an SRS

- What should an SRS contain ?
  - Clarifying this will help ensure completeness
- An SRS must specify requirements on
  - Functionality
  - Performance
  - Design constraints
  - External interfaces

Functional Requirements

- Heart of the SRS document; this forms the bulk of the specs
- Specifies all the functionality that the system should support
- Outputs for the given inputs and the relationship between them
- All operations the system is to do
- Must specify behavior for invalid inputs too

Performance Requirements

- All the performance constraints on the software system
- Generally on response time , throughput etc => dynamic
- Capacity requirements => static
- Must be in measurable terms (verifiability)
  - Eg resp time should be xx 90% of the time

Design Constraints

- Factors in the client environment that restrict the choices
- Some such restrictions
  - Standard compliance and compatibility with other systems
  - Hardware Limitations
  - Reliability, fault tolerance, backup req.
  - Security

External Interface

- All interactions of the software with people, hardware, and sw
- User interface most important
- General requirements of “friendliness” should be avoided
- These should also be verifiable

Specification Language

- Language should support desired char of the SRS
- Formal languages are precise and unambiguous but hard
- Natural languages mostly used, with some structure for the document
- Formal languages used for special features or in highly critical systems

Structure of an SRS

- Introduction
  - Purpose , the basic objective of the system
  - Scope of what the system is to do , not to do
  - Overview
- Overall description
  - Product perspective
  - Product functions
  - User characteristics
  - Assumptions
  - Constraints

Structure of an SRS…

- Specific requirements
  - External interfaces
  - Functional requirements
  - Performance requirements
  - Design constraints
- Acceptable criteria
  - desirable to specify this up front.
- This standardization of the SRS was done by IEEE.

Use Cases Approach for Functional Requirements

- Traditional approach for fn specs – specify each function
- Use cases is a newer technique for specifying behavior (functionality)
- I.e. focuses on functional specs only
- Though primarily for specification, can be used in analysis and elicitation
- Can be used to specify business or org behavior also, though we will focus on sw
- Well suited for interactive systems

Use Cases Basics

- A use case captures a contract between a user and system about behavior
- Basically a textual form; diagrams are mostly to support
- Also useful in requirements elicitation as users like and understand the story telling form and react to it easily

Basics..

- Actor: a person or a system that interacts with the proposed system to achieve a goal
  - Eg. User of an ATM (goal: get money); data entry operator; (goal: Perform transaction)
- Actor is a logical entity, so receiver and sender actors are different (even if the same person)
- Actors can be people or systems
- Primary actor: The main actor who initiates a UC
  - UC is to satisfy his goals
  - The actual execution may be done by a system or another person on behalf of the Primary actor

Basics..

- Scenario: a set of actions performed to achieve a goal under some conditions
  - Actions specified as a sequence of steps
  - A step is a logically complete action performed either by the actor or the system
- Main success scenario – when things go normally and the goal is achieved
- Alternate scenarios: When things go wrong and goals cannot be achieved

Basics..

- A UC is a collection of many such scenarios
- A scenario may employ other use cases in a step
- I.e. a sub-goal of a UC goal may be performed by another UC
- I.e. UCs can be organized hierarchically

Basics…

- UCs specify functionality by describing interactions between actors and system
- Focuses on external behavior
- UCs are primarily textual
  - UC diagrams show UCs, actors, and dependencies
  - They provide an overview
- Story like description easy to understand by both users and analysts
- They do not form the complete SRS, only the functionality part

Example

Use Case 1: Buy stocks

Primary Actor: Purchaser

Goals of Stakeholders:

- Purchaser: wants to buy stocks
- Company: wants full transaction info

Precondition: User already has an account

Example …

- Main Success Scenario
  1. User selects to buy stocks
  2. System gets name of web site from user for trading
  3. Establishes connection
  4. User browses and buys stocks
  5. System intercepts responses from the site and updates user portfolio
  6. System shows user new portfolio stading

Example…

- Alternatives
  - 2a: System gives err msg, asks for new suggestion for site, gives option to cancel
  - 3a: Web failure. 1-Sys reports failure to user, backs up to previous step. 2-User exits or tries again
  - 4a: Computer crashes
  - 4b: web site does not ack purchase
  - 5a: web site does not return needed info

Example 2

- Use Case 2: Buy a product
- Primary actor: buyer/customer
- Goal: purchase some product
- Precondition: Customer is already logged in

Example 2…

- Main Scenario
  1. Customer browses and selects items
  2. Customer goes to checkout
  3. Customer fills shipping options
  4. System presents full pricing info
  5. Customer fills credit card info
  6. System authorizes purchase
  7. System confirms sale
  8. System sends confirming email

Example 2…

- Alternatives
  - 6a: Credit card authorization fails
    - Allows customer to reenter info
  - 3a: Regular customer
    - System displays last 4 digits of credit card no
    - Asks customer to OK it or change it
    - Moves to step 6

Example – An auction site

- ***Use Case1:*** Put an item for auction
- ***Primary Actor:*** Seller
- ***Precondition:*** Seller has logged in
- ***Main Success Scenario:***
  - Seller posts an item (its category, description, picture, etc.) for auction
  - System shows past prices of similar items to seller
  - System specifies the starting bid price and a date when auction will close
  - System accepts the item and posts it
- ***Exception Scenarios:***
  - -- 2 a) There are no past items of this category

    * System tells the seller this situation

Example – auction site..

- ***Use Case2:*** Make a bid
- ***Primary Actor:*** Buyer
- ***Precondition:*** The buyer has logged in
- ***Main Success Scenario:***
  - Buyer searches or <u>browses</u> and <u>selects</u> some item
  - System shows the rating of the seller, the starting bid, the current bids, and the highest bid; asks buyer to make a bid
  - Buyer specifies bid price, max bid price, and increment
  - Systems accepts the bid; <u>Blocks funds in bidders account</u>
  - System updates the bid price of other bidders where needed, and updates the records for the item

- ***Exception Scenarios:***
  - -- 3 a) The bid price is lower than the current highest

    * System informs the bidder and asks to rebid

  - -- 4 a) The bidder does not have enough funds in his account

    * System cancels the bid, asks the user to get more funds

Example –auction site..

- ***Use Case3:*** **Complete auction of an item**
- ***Primary Actor:*** Auction System
- ***Precondition:*** The last date for bidding has been reached
- ***Main Success Scenario:***
  - Select highest bidder; send email to selected bidder and seller informing final bid price; send email to other bidders also
  - <u>Debit bidder's account</u> and <u>credit seller's account</u>
  - <u>Transfer from seller's account commission amount to organization's account</u>
  - <u>Unblock other bidders funds</u>
  - Remove item from the site; update records
- ***Exception Scenarios:*** None

Example – summary-level Use Case

- ***Use Case 0* : Auction an item**
- ***Primary Actor:*** Auction system
- ***Scope:*** Auction conducting organization
- ***Precondition:*** None
- ***Main Success Scenario:***
  - Seller performs put an item for auction
  - Various bidders make a bid
  - On final date perform Complete the auction of the item
  - Get feed back from seller; get feedback from buyer; update records

Requirements with Use Cases

- UCs specify functional requirements
- Other req identified separately
- A complete SRS will contain the use cases plus the other requirements
- Note – for system requirements it is important to identify UCs for which the system itself may be the actor

Developing Use Cases

- UCs form a good medium for brainstorming and discussions
- Hence can be used in elicitation and problem analysis also
- UCs can be developed in a stepwise refinement manner
  - Many levels possible, but four naturally emerge

Developing…

- Step 1: Identify actors and goals
  - Prepare an actor-goal list
  - Provide a brief overview of the UC
  - This defines the scope of the system
  - Completeness can also be evaluated
- Step 2: Specify main Success Scenarios
  - For each UC, expand main scenario
  - This will provide the normal behavior of the system
  - Can be reviewed to ensure that interests of all stakeholders and actors is met

Developing…

- Step 3: Identify failure conditions
  - List possible failure conditions for UCs
  - For each step, identify how it may fail
  - This step uncovers special situations
- Step 4: Specify failure handling
  - Perhaps the hardest part
  - Specify system behavior for the failure conditions
  - New business rules and actors may emerge

Other Approaches to Analysis

Data Flow Modeling

- Widely used; focuses on functions performed in the system
- Views a system as a network of data transforms through which the data flows
- Uses data flow diagrams (DFDs) and functional decomposition in modeling
- The SSAD methodology uses DFD to organize information, and guide analysis

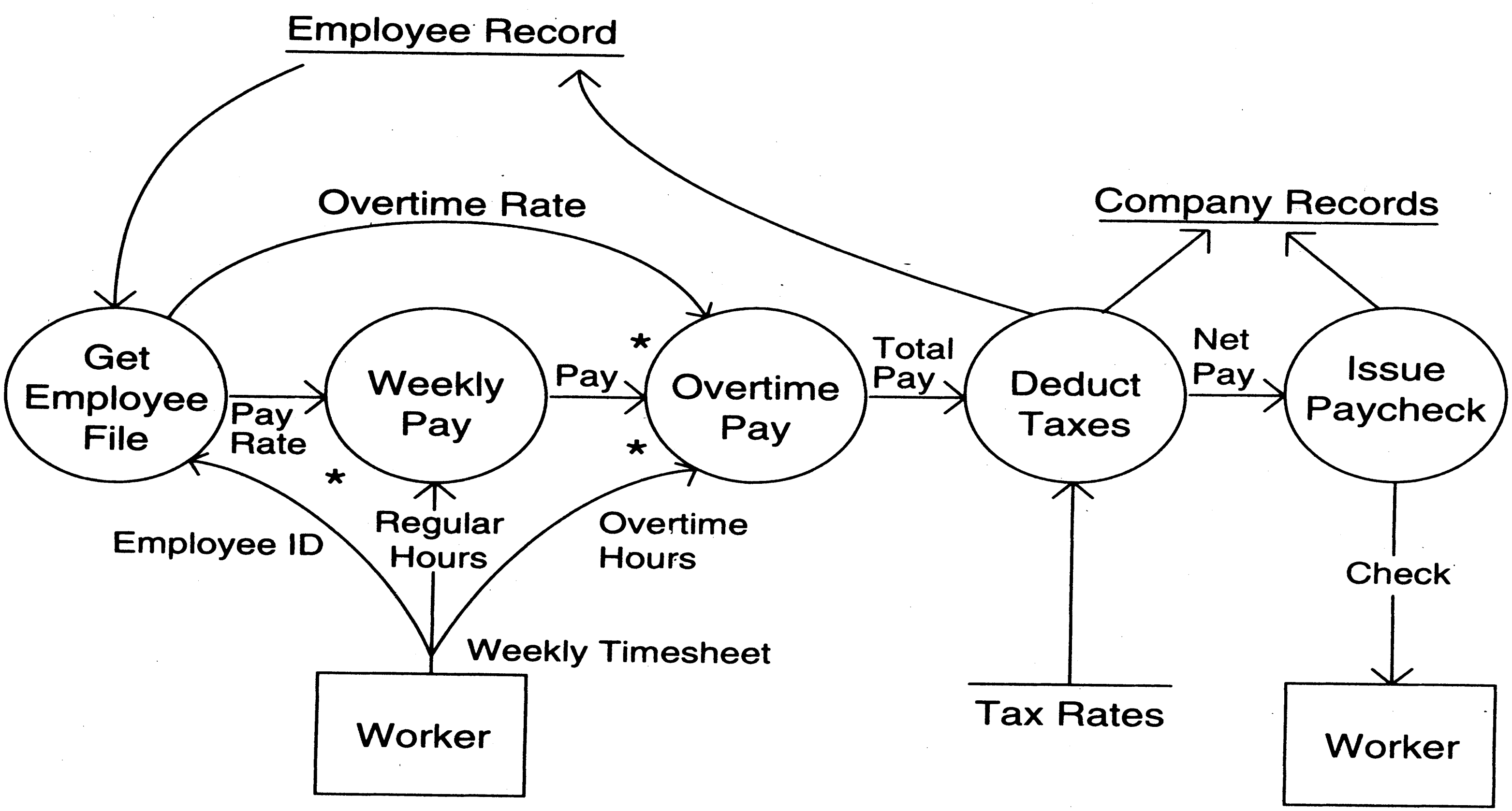
Data flow diagrams

- A DFD shows flow of data through the system
  - Views system as transforming inputs to outputs
  - Transformation done through transforms
  - DFD captures how transformation occurs from input to output as data moves through the transforms
  - Not limited to software

Data flow diagrams…

- DFD
  - Transforms represented by named circles/bubbles
  - Bubbles connected by arrows on which named data travels
  - A rectangle represents a source or sink and is originator/consumer of data (often outside the system)

DFD Example


Employee Record
Overtime Rate
Company Records
Get Employee File
Weekly Pay
Overtime Pay
Deduct Taxes
Issue Paycheck
Pay Rate
Pay
Total Pay
Net Pay
*
*
*
Employee ID
Regular Hours
Overtime Hours
Weekly Timesheet
Check
Worker
Tax Rates
Worker

DFD Conventions

- External files shown as labeled straight lines
- Need for multiple data flows by a process represented by * (means and)
- OR relationship represented by +
- All processes and arrows should be named
- Processes should represent transforms, arrows should represent some data

Data flow diagrams…

- Focus on what transforms happen , how they are done is not important
- Usually major inputs/outputs shown, minor are ignored in this modeling
- No loops , conditional thinking , …
- DFD is NOT a control chart, no algorithmic design/thinking
- Sink/Source , external files

Drawing a DFD

- If get stuck , reverse direction

- If control logic comes in , stop and restart
- Label each arrows and bubbles
- Make use of + & *
- Try drawing alternate DFDs

Leveled DFDs :

- DFD of a system may be very large
- Can organize it hierarchically
- Start with a top level DFD with a few bubbles
- then draw DFD for each bubble
- Preserve I/O when " exploding"

Drawing a DFD for a system

- Identify inputs, outputs, sources, sinks for the system
- Work your way consistently from inputs to outputs, and identify a few high-level transforms to capture full transformation
- If get stuck, reverse direction
- When high-level transforms defined, then refine each transform with more detailed transformations

Drawing a DFD for a system..

- Never show control logic; if thinking in terms of loops/decisions, stop & restart
- Label each arrows and bubbles; carefully identify inputs and outputs of each transform
- Make use of + & *
- Try drawing alternate DFDs

Leveled DFDs

- DFD of a system may be very large
- Can organize it hierarchically
- Start with a top level DFD with a few bubbles
- then draw DFD for each bubble
- Preserve I/O when " exploding" a bubble so consistency preserved
- Makes drawing the leveled DFD a top-down refinement process, and allows modeling of large and complex systems

Data Dictionary

- In a DFD arrows are labeled with data items
- Data dictionary defines data flows in a DFD
- Shows structure of data; structure becomes more visible when exploding
- Can use regular expressions to express the structure of data

Data Dictionary Example

- For the timesheet DFD

Weekly_timesheet – employee_name + id + [regular_hrs + overtime_hrs]*

Pay_rate = [hourly | daily | weekly] + dollar_amt

Employee_name = last + first + middle

Id = digit + digit + digit + digit

DFD drawing – common errors

- Unlabeled data flows
- Missing data flows
- Extraneous data flows
- Consistency not maintained during refinement
- Missing processes
- Too detailed or too abstract
- Contains some control information

Prototyping

- Prototyping is another approach for problem analysis
- Discussed it earlier with process – leads to prototyping process model

Requirements Validation

- Lot of room for misunderstanding
- Errors possible
- Expensive to fix req defects later
- Must try to remove most errors in SRS
- Most common errors
  - Omission - 30%
  - Inconsistency - 10-30%
  - Incorrect fact - 10-30%
  - Ambiguity - 5 -20%

Requirements Review

- SRS reviewed by a group of people
- Group: author, client, user, dev team rep.
- Must include client and a user
- Process – standard inspection process
- Effectiveness - can catch 40-80% of req. errors

Summary

- Having a good quality SRS is essential for Q&P
- The req. phase has 3 major sub phases
  - analysis , specification and validation
- Analysis
  - for problem understanding and modeling
  - Methods used: SSAD, OOA , Prototyping
- Key properties of an SRS: correctness, completeness, consistency,unambiguousness

Summary..

- Specification
  - must contain functionality , performance , interfaces and design constraints
  - Mostly natural languages used
- Use Cases is a method to specify the functionality; also useful for analysis
- Validation - through reviews

Software Architecture

Background

- Any complex system is composed of sub-systems that interact
- While designing systems, an approach is to identify sub-systems and how they interact with each other
- Sw Arch tries to do this for software
- A recent area, but a lot of interest in it

Background…

- Architecture is the system design at the highest level
- Choices about technologies, products to use, servers, etc are made at arch level
  - Not possible to design system details and then accommodate these choices
  - Arch must be created accommodating them
- Is the earliest place when properties like rel/perf can be evaluated

Architecture

- Arch is a design of the sw that gives a very high level view of parts and they relate to form the whole
  - Partitions the sys in parts such that each part can be comprehended independently
  - And describes relationship between parts
- A complex system can be partitioned in many diff ways, each providing a useful view
  - Same holds true of software also
  - There is no unique structure; many possible

Architecture

- Defn: Software arch is the structure or structures which comprise elements, their externally visible properties, and relationships among them
  - For elements only interested in external properties needed for relationship specification
  - Details on how the properties are supported is not important for arch
  - The defn does not say anything about whether an arch is good or not – analysis needed for it
- An arch description describes the different structures of the system

Key Uses of Arch Descriptions

- Understanding and communication
  - By showing a system at a high level and hiding complexity of parts, arch descr facilitates communication
  - To get a common understanding between the diff stakeholders (users, clients, architect, designer,…)
  - For negotiation and agreement
  - Arch descr can also aid in understanding of existing systems

Uses…

- Reuse
  - A method of reuse is to compose systems from parts and reuse existing parts
  - This model is facilitated by reusing components at a high level providing complete services
  - To reuse existing components, arch must be chosen such that these components fit together with other components
  - Hence, decision about using existing components is made at arch design time

Uses..

- Construction and evolution
  - Some structures in arch descr will be used to guide system development
  - Partitioning at arch level can also be used for work allocation to teams as parts are relatively independent
  - During sw evolution, arch helps decide what needs to be changed to incorporate the new changes/features
  - Arch can help decide what is the impact of changes to existing components on others

Uses…

- Analysis
  - If properties like perf, reliability can be determined from design, alternatives can be considered during design to reach the desired perf levels
  - Sw arch opens such possibilities for software (other engg disciplines usually can do this)
  - E.g. rel and perf of a system can be predicted from its arch, if estimates for parms like load etc is provided
  - Will require precise description of arch, as well as properties of the elements in the description

Architectural Views

- There is no unique arch of a sys
- There are different *views* of a sw sys
- A view consists of *elements* and *relationships* between them, and describes a *structure*
- The elements of a view depends on what the view wants to highlight
- Diff views expose diff properties
- A view focusing on some aspects reduces its complexity

Views…

- Many types of views have been proposed
- Most belong to one of these three types
  - Module
  - Component and Connector
  - Allocation
- The diff views are not unrelated – they all represent the same system
  - There are relationships between elements of diff views; this rel may be complex

Views…

- Module view
  - A sys is a collection of code units i.e. they do not represent runtime entitites
  - I.e. elements are modules, eg. Class, package, function, procedure,…
  - Relationship between them is code based, e.g. part of, depends on, calls, generalization-specialization,..

Views…

- Component and Connector (C&C)
  - Elements are run time entities called components
  - I.e. a component is a unit that has identity in executing sys, e.g. objects, processes, .exe, .dll
  - Connectors provide means of interaction between components, e.g. pipes, shared memory, sockets

Views…

- Allocation view
  - Focuses on how sw units are allocated to resources like hw, file system, people
  - I.e. specifies relationship between sw elements and execution units in the env
  - Expose structural properties like which process runs on which processor, which file resides where, …

Views…

- An arch description consists of views of diff types, each showing a diff structure
  - Diff sys need diff types of views depending on the needs
  - E.g. for perf analysis, allocation view is necessary; for planning, module view helps
- The C&C view is almost always done, and has become the primary view
  - We focus primarily on the C&C view
  - Module view is covered in high level design, whose focus is on identifying modules

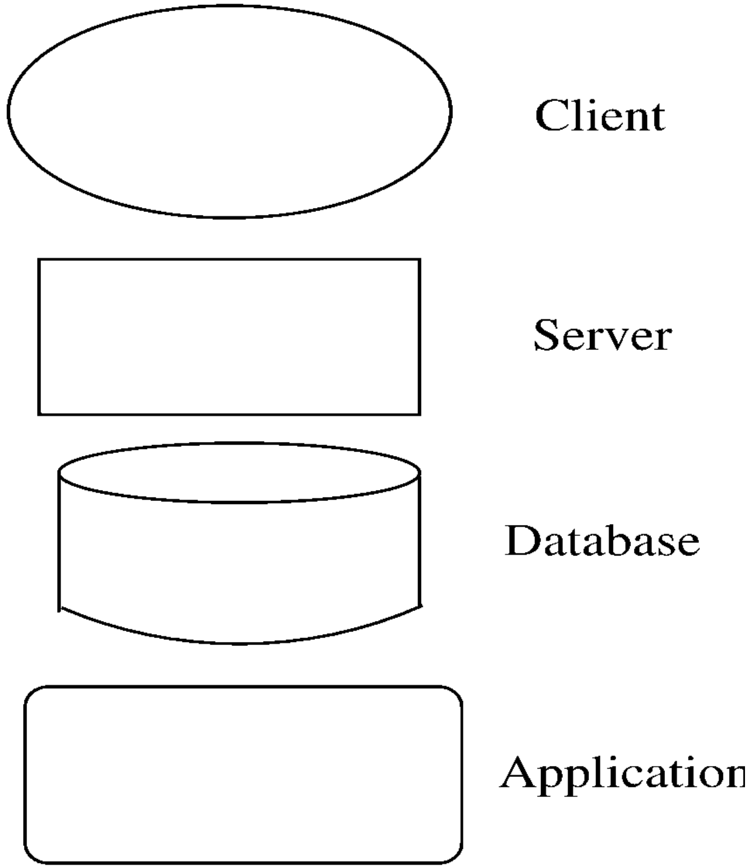
Component and Connector View

- Two main elements – components and connectors
- Components: Computational elements or data stores
- Connectors: Means of interaction between comps
- A C&C view defines the comps, and which comps are connected through which connector
- The C&C view describes a runtime structure of the system – what comps exist at runtime and how they interact during execution
- Is a graph; often shown as a box-and-line drawing
- Most commonly used structure

Components

- Units of computations or data stores
- Has a name, which represents its role, and provides it identity
- A comp may have a type; diff types rep by diff symbols in C&C view
- Comps use ports (or interfaces) to communicate with others
- An arch can use any symbols to rep components; some common ones are shown

Some Component examples…



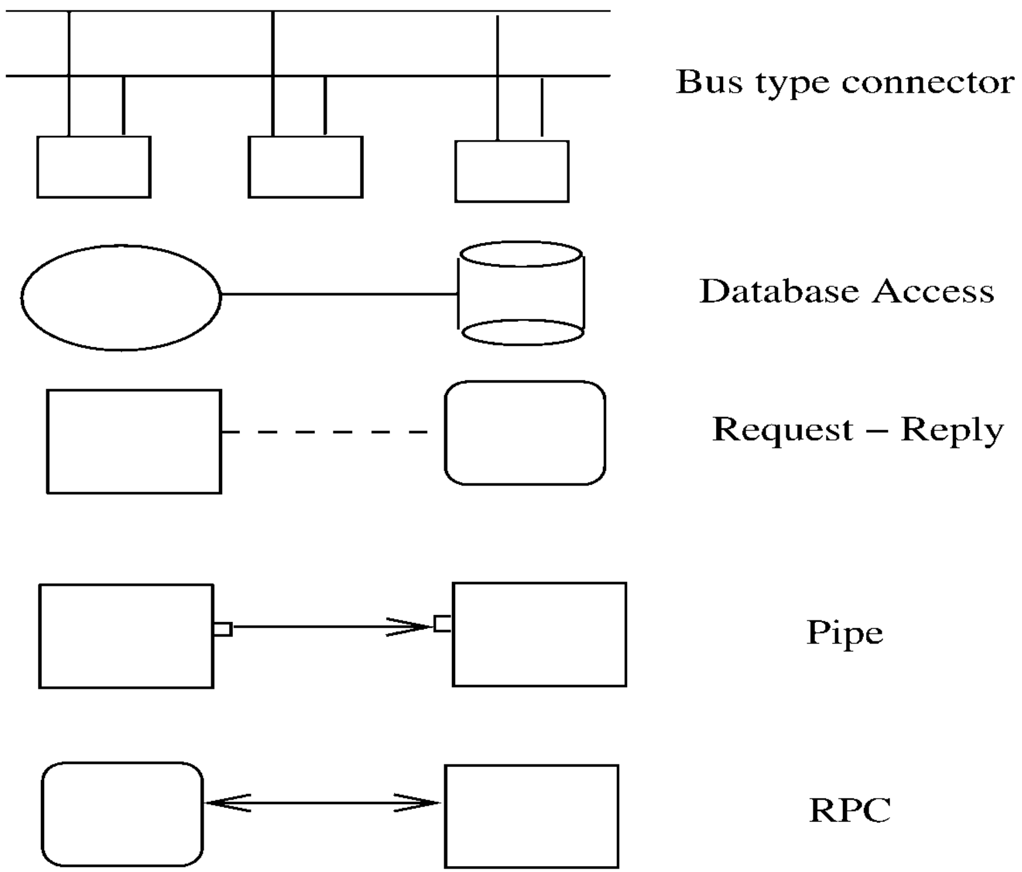
Connectors

- Interaction between components happen through connectors
- A connector may be provided by the runtime environment, e.g. procedure call
- But there may be complex mechanisms for interaction, e.g http, tcp/ip, ports,…; a lot of sw needed to support them
- Important to identify them explicitly; also needed for programming comps properly

Connectors…

- Connectors need not be binary, e.g. a broadcast bus
- Connector has a name (and a type)
- Often connectors represented as protocol – i.e. comps need to follow some conventions when using the connector
- Best to use diff notation for diff types of connectors; all connectors should not be shown by simple lines

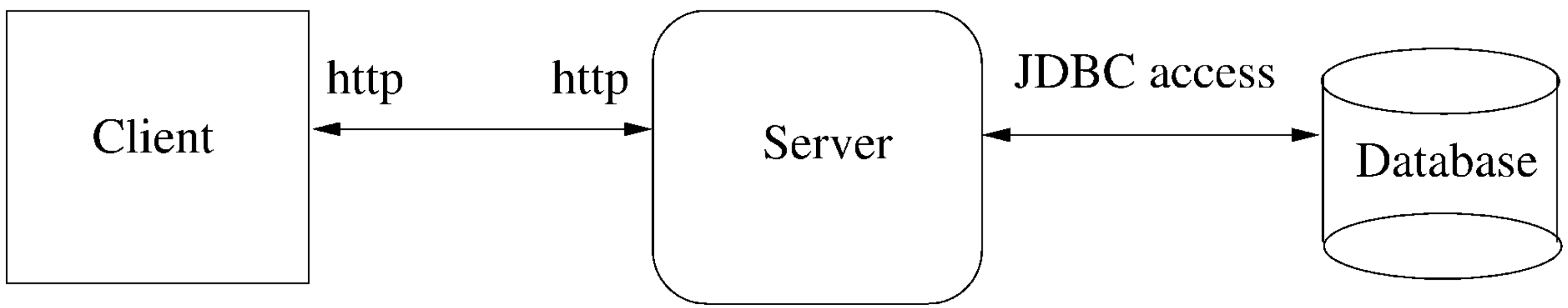
Connector examples



An Example

- Design a system for taking online survey of students on campus
  - Multiple choice questions, students submit online
  - When a student submits, current result of the survey is shown
- Is best built using web; a 3-tier architecture is proposed
  - Has a client, server, and a database components (each of a diff type)
  - Connector between them are also of diff types

Example…



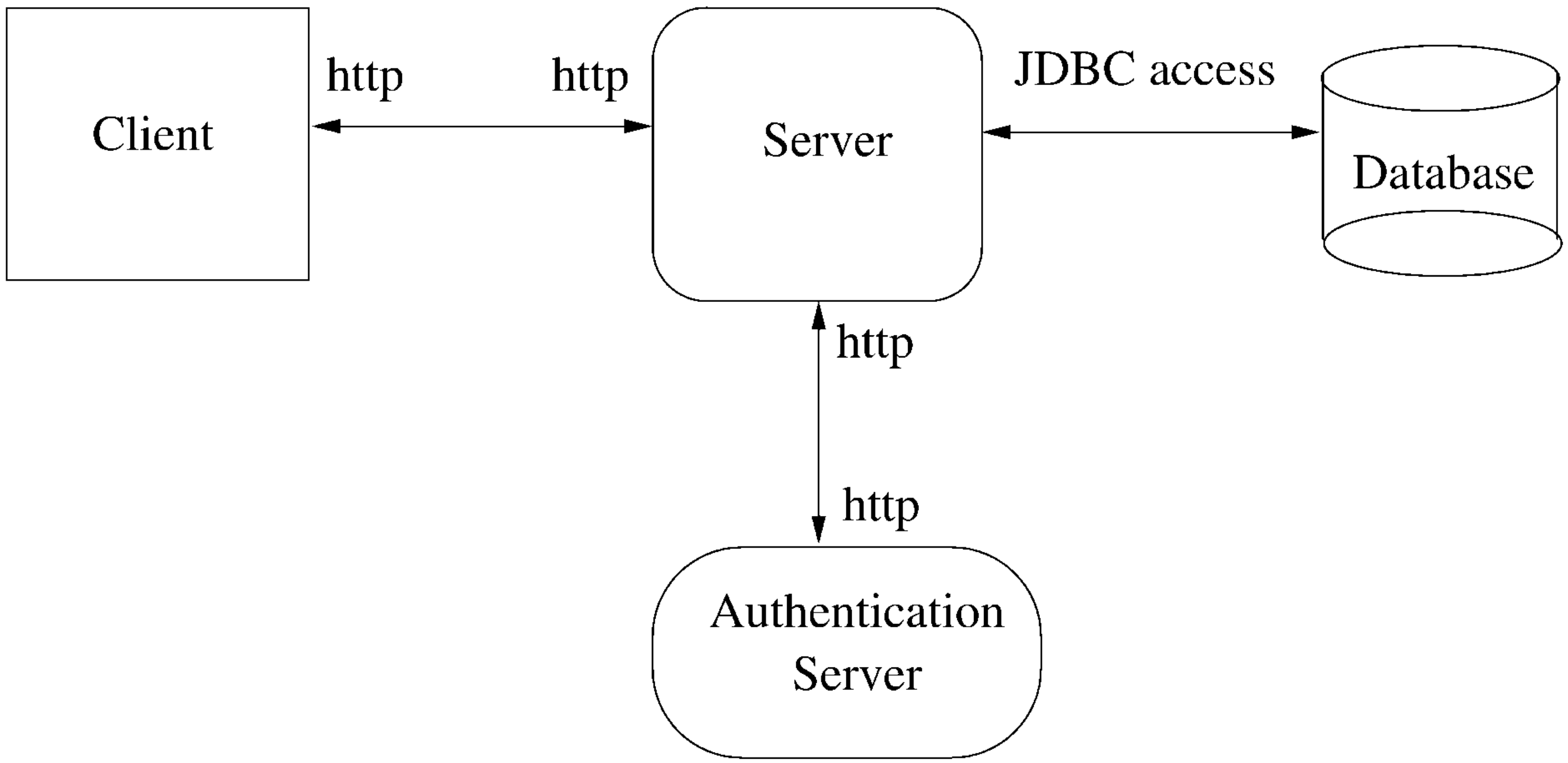
Example…

- At arch level, details are not needed
- The connectors are explicitly stated, which implies that the infrastructure should provide http, browser, etc.
- The choice of connectors imposes constraints on how the components are finally designed and built

Extension 1

- This arch has no security – anyone can take the survey
- We want that only registered students can take the survey (at most once)
  - To identify students and check for one-only submission, need a authentication server
  - Need to use cookies, and server has to be built accordingly (the connector between server and auth server is http with cookies)

Extension 1…

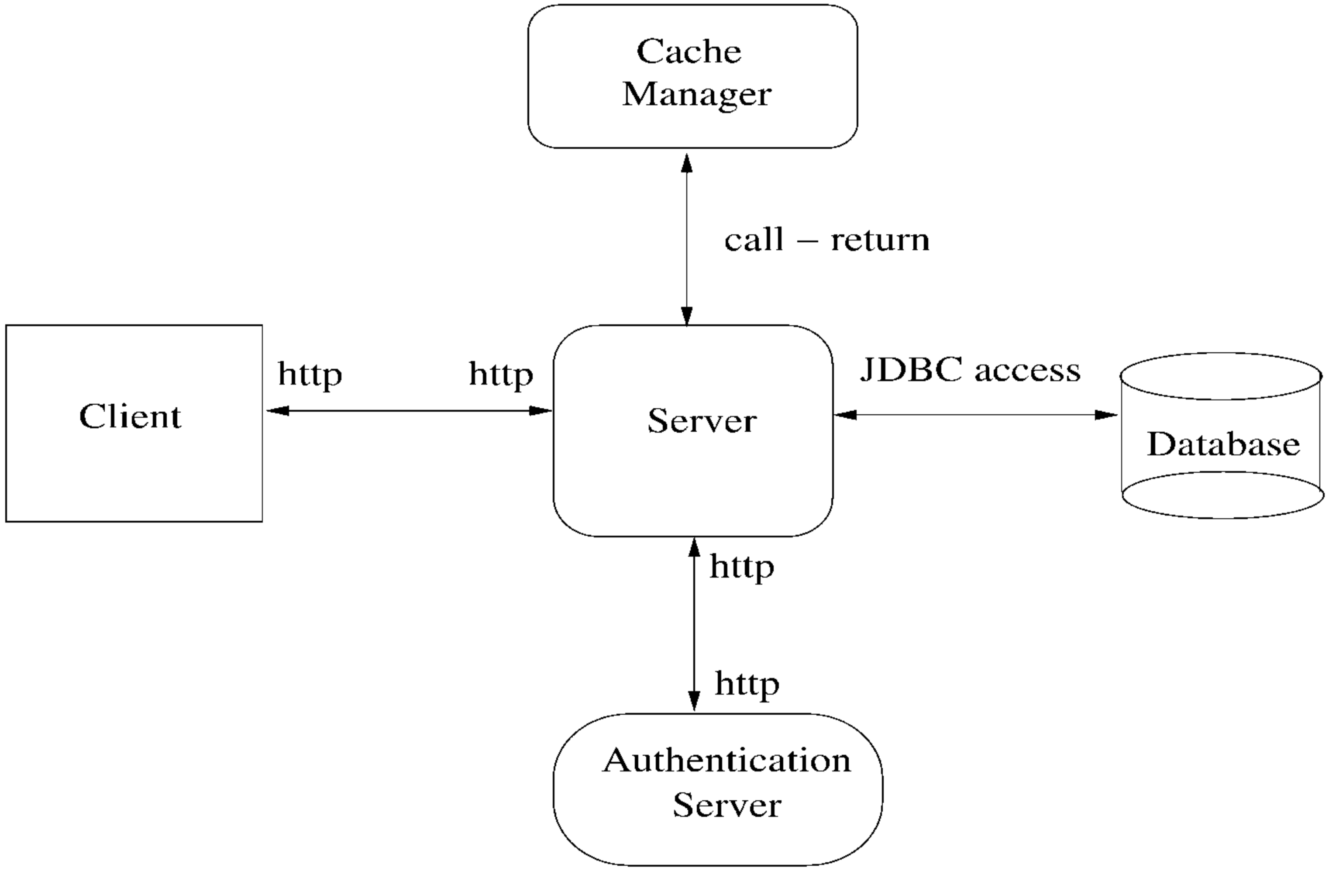


Client
http
http
Server
JDBC access
Database
http
http
Authentication
Server

Extension 2

- It was found that DB is frequently down
- For improving reliability, want that if DB is down, student is given an older survey result and survey data stored
- The survey data given can be outdated by at most 5 survey data points
- For this, will add a cache comp, which will store data as well as results

Extension 2…


Cache
Manager
call – return
Client
http
http
Server
JDBC access
Database
http
http
Authentication
Server

Example…

- One change increased security, 2nd increased performance and reliability
- I.e. Arch level choices have a big impact on system properties
- That is why, choosing a suitable arch can help build a good system

Architectural Styles for C&C View

- Diff systems have diff C&C structure
- Some structures are general and are useful for a class of problems – architectural styles
- An arch style defines a family of archs that satisfy the constraint of that style
- Styles can provide ideas for creating arch for a sys; they can be combined also
- We discuss a few common styles

Pipe and filter

- Well suited for systems that mainly do data transformations
- A system using this style uses a network of transforms to achieve the desired result
- Has one component type – filter
- Has one connector type – pipe
- A filter does some transformation and passes data to other filters through pipes

Pipe and Filter…

- A filter is independent; need not know the id of filters sending/receiving data
- Filters can be asynchronous and are producers or consumers of data
- A pipe is unidirectional channel which moves streams of data from one filter to another
- A pipe is a 2-way connector
- Pipes have to perform buffering, and synchronization between filters

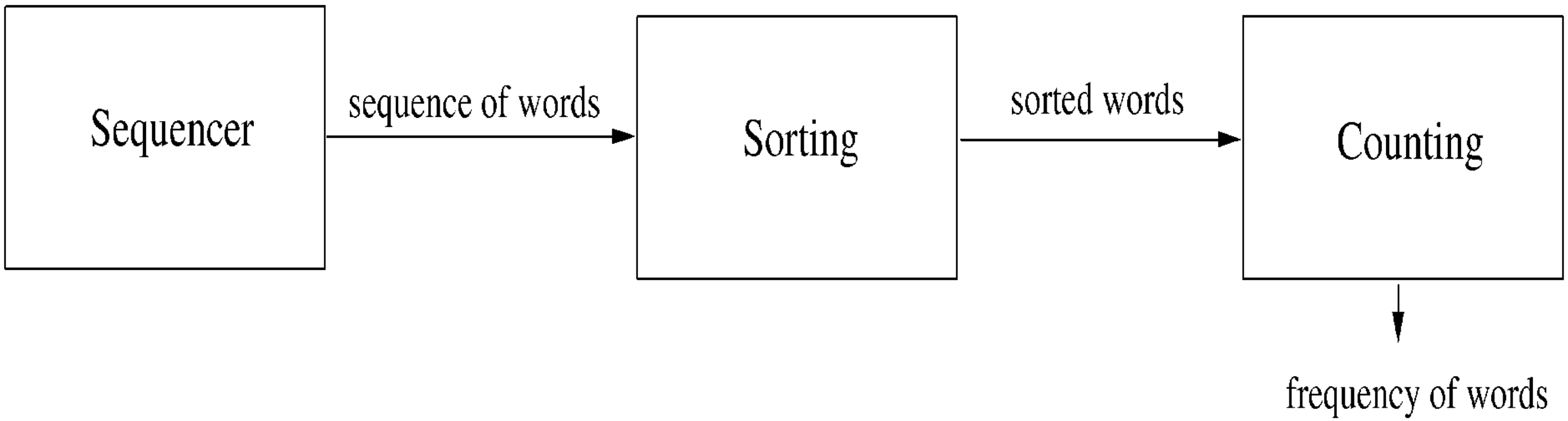
Pipe and filter…

- Pipes should work without knowing the identify of producers/consumers
- A pipe must connect the output port of one filter to input port of another
- Filters may have indep thread of control

Example

- A system needed to count the frequency of different words in a file
- One approach: first split the file into a sequence of words, sort them, then count the #of occurrences
- The arch of this system can naturally use the pipe and filter style

Example..



Sequencer
sequence of words
Sorting
sorted words
Counting
frequency of words

Shared-data style

- Two component types – data repository and data accessor
- Data repository – provides reliable permanent storage
- Data accessors – access data in repositories, perform computations, and may put the results back also
- Communication between data accessors is only through the repository

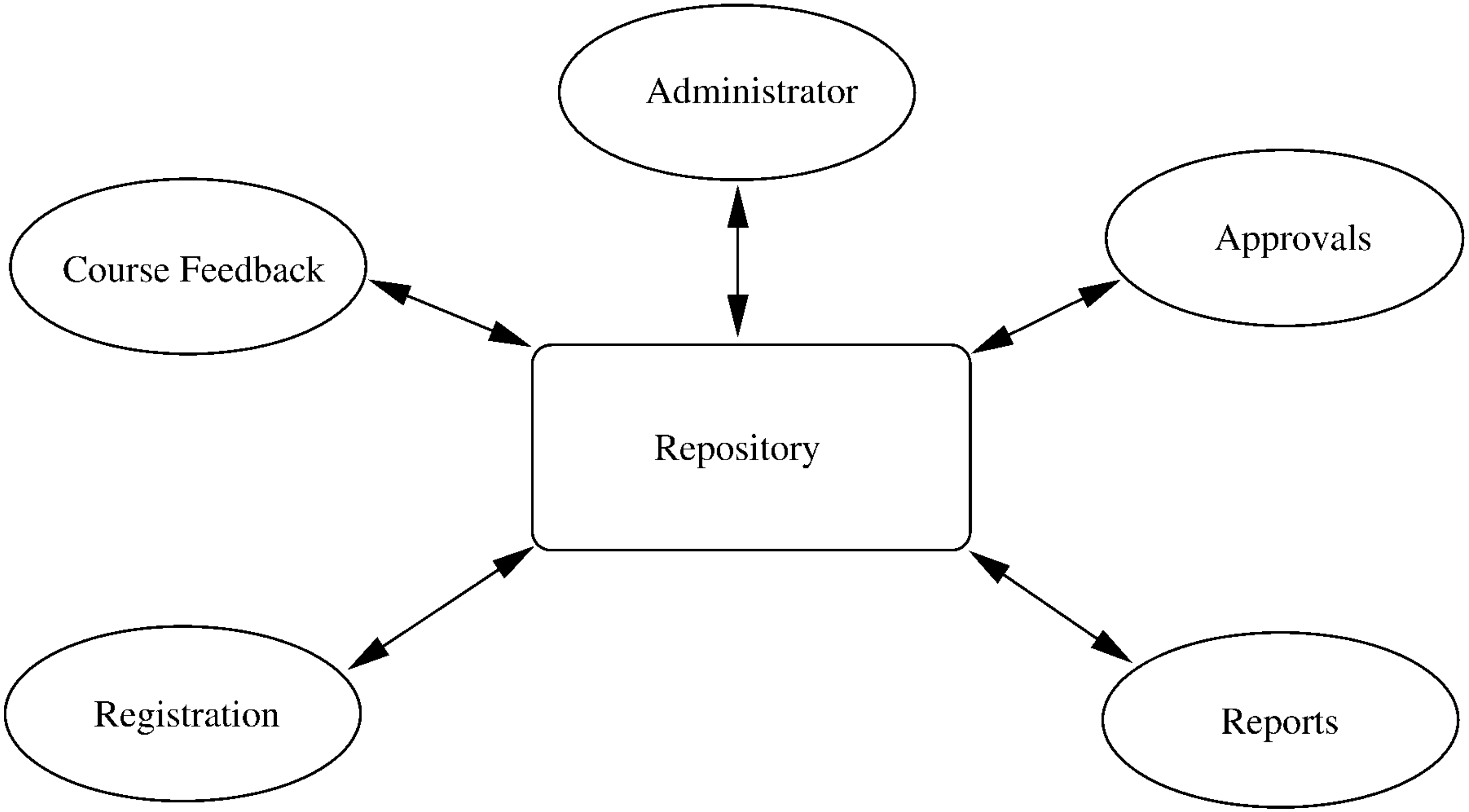
Shared-data style…

- Two variations possible
  - Black board style: if data is posted in a repository, all accessors are informed; i.e. shared data source is an active agent
  - Repository style: passive repository
- Eg. database oriented systems; web systems; programming environments,..

Example

- A student registration system of a university
- Repository contains all the data about students, courses, schedules,…
- Accessors like admin, approvals, registration, reports which perform operations on the data

Example…


Administrator
Course Feedback
Approvals
Repository
Registration
Reports

Example..

- Components do not directly communicate with each other
- Easy to extend – if a scheduler is needed, it is added as a new accessor
  - No existing component needs to be changed
- Only one connector style in this – read/write

Client-Server Style

- Two component types – clients and servers
- Clients can only communicate with the server, but not with other clients
- Communication is initiated by a client which sends request and server responds
- One connector type – request/reply, which is asymmetric
- Often the client and the servers reside on different machines

Client-server style…

- A general form of this style is the n-tier structure
- A 3-tier structure is commonly used by many application and web systems
  - Client-tier contains the clients
  - Middle-tier contains the business rules
  - Database tier has the information

Some other styles

- Publish-subscribe style
  - Some components generate events, and others subscribe to them
  - On an event, those component that subscribe to it are invoked
- Peer-to-peer style
  - Like object oriented systems; components use services from each other through methods
- Communication processes style
  - Processes which execute and communicate with each other through message passing

Architecture and Design

- Both arch and design partition the system into parts and their org
- What is the relationship between design and arch?
  - Arch is a design; it is about the solution domain, and not problem domain
  - Can view arch as a very high level design focusing on main components
  - Design is about modules in these components that have to be coded
  - Design can be considered as providing the module view of the system

Contd…

- Boundaries between architecture and design are not clear or hard
- It is for designer and architect to decide where arch ends and design begins
- In arch, issues like files, data structure etc are not considered, while they are important in design
- Arch does impose constraints on design in that the design must be consistent with arch

Preserving the Integrity of Architecture

- What is the role of arch during the rest of the development process
- Many designers and developers use it for understanding but nothing more
- Arch imposes constraints; the implementation must preserve the arch
- I.e. the arch of the final system should be same as the arch that was conceived
- It is very easy to ignore the arch design and go ahead and do the development
- Example – impl of the word frequency problem

Documenting Arch Design

- While designing and brainstorming, diagrams are a good means
- Diagrams are not sufficient for documenting arch design
- An arch design document will need to precisely specify the views, and the relationship between them

Documenting…

- An arch document should contain
  - System and architecture context
  - Description of architecture views
  - Across view documentation
- A context diagram that establishes the sys scope, key actors, and data sources/sinks can provide the overall context
- A view description will generally have a pictorial representation, as discussed earlier

Documenting…

- Pictures should be supported by
  - Element catalog: Info about behavior, interfaces of the elements in the arch
  - Architectural rationale: Reasons for making the choices that were made
  - Behavior: Of the system in different scenarios (e.g. collaboration diagram)
  - Other Information: Decisions which are to be taken, choices still to be made,..

Documenting…

- Inter-view documentation
  - Views are related, but the relationship is not clear in the view
  - This part of the doc describes how the views are related (eg. How modules are related to components)
  - Rationale for choosing the views
  - Any info that cuts across views
- Sometimes views may be combined in one diagram for this – should be done if the resulting diagram is still easy to understand

Evaluating Architectures

- Arch impacts non-functional attributes like modifiability, performance, reliability, portability, etc
  - Attr. like usability etc are not impacted
- Arch plays a much bigger impact on these than later decisions
- So should evaluate a proposed arch for these properties
- Q: How should this evaluation be done?
  - Many different ways

Evaluating Architectures…

- Procedural approach – follow a sequence of steps
  - Identify the attributes of interest to different stakeholders
  - List them in a table
  - For each attribute, evaluate the architectures under consideration
  - Evaluation can be subjective based on experience
  - Based on this table, then select some arch or improve some existing arch for some attribute

Summary

- Arch of a sw system is its structures comprising of elements, their external properties, and relationships
- Arch is a high level design
- Three main view types – module, component and connector, and allocation
- Component and connector (C&C) view is most commonly used

Summary…

- There are some C&C styles that are commonly used, e.g. pipe-and-filter, shared data, client server,….
- An arch description should document the different views and their relationship – views can be combined
- Rationale and other supporting information should also be captured

Summary…

- Arch can be analyzed for various non-functional attributes like performance, reliability, security, etc
- ATAM is one approach for analyzing architectures, which evaluates attributes of interest under different scenarios