

Software Design

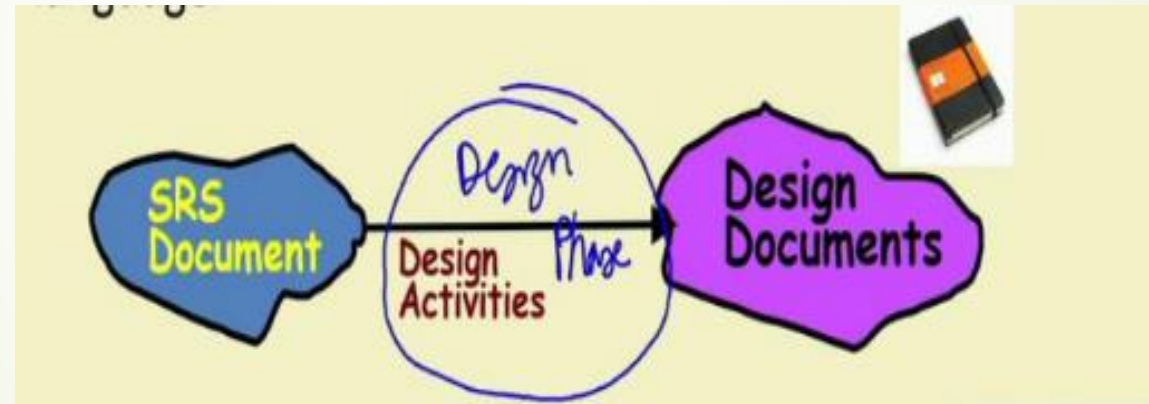
Courtesy:

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Prof Rajib Mall

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Introduction:

- The activities carried out during the design phase transform the SRS document into the design document.
 - A form easily implementable in some programming languages.



Outcome of the Design Process:

- The following items are designed and documented during the design phase.
 - Different Modules required
 - Control relationships among modules
 - Interfaces among different modules
 - Data structures of the individual modules
 - Algorithms required to implement the individual modules

Classification of Design Activities:

- A good software design is seldom realized by using a single step procedure, rather **it requires iterating over a series of steps** called the design activities.
- Two important stages
 - **Preliminary (or high-level) design:** Through high level design, a problem is decomposed into a set of modules. The control relationships among the modules are identified and also the interfaces among various modules are identified.
 - **Detailed design:** During detailed design each module is examined carefully to design its data structures and the algorithms.

Analysis vs Design:

- The **analysis results are generic and does not consider implementation** or the issues associated with specific platforms.
- The analysis model is usually documented using some graphical formalism.
- Function oriented approach:
 - Analysis model documented using DFDs.
 - Design would be documented using structure chart
- Object oriented approach
 - Both design model and analysis model documented using UML.
- **The design model reflects several decisions taken regarding the exact way system is to be implemented. The design model should be detailed enough to be easily implementable using a programming language.**

Classification of Design Methodologies:

- The design activities vary considerably based on the specific design methodology being used.
- Roughly classified as
 - **Procedural** and **Object Oriented** approach
- **Do design techniques result in unique solutions?**
- **How to distinguish superior design solution from an inferior one?**

How to characterize a good software design?

- The definition of a “good” software design can vary depending on the exact application being designed.
- **Correctness:** A good design should first of all be correct. It should correctly implement all the functionalities of the system.
- **Understandability:** A good design should be easily understandable. Unless a design solution is easily understandable, it would be difficult to implement and maintain it.
- **Efficiency:** A good design solution should adequately address resource, time, and cost optimization issues.
- **Maintainability:** A good design should be easy to change.
- **Otherwise, it would require tremendous effort to implement, test, debug, and maintain it.**

How to characterize a good software design?

- A design solution should have the following characteristics to be easily understandable:
 - It should assign consistent and meaningful names to various design components.
 - It should make use of the principles of decomposition and abstraction in good measures to simplify the design.
- A design solution is understandable, if it is modular and the modules are arranged in distinct layers.

Modularity:

- Modular design implies that the problem has been decomposed into a set of modules that have only limited interactions with each other.
- Decomposition of a problem into modules facilitates taking advantage of the **divide and conquer** principle.
- If different modules have either no interaction or little interactions with each other, then each module can be understood separately.
- A layered design can make the design solution easily understandable.
- A design solution is said to be highly modular, if the different modules in the solution have high cohesion and their intermodule coupling are low.

Cohesion and Coupling:

- When the function of the module co-operate with each other for performing a single objective, then module has **good cohesion**.
- Two modules are said to be highly coupled,
 - If the function calls between two modules involve passing large chunks of shared data, the modules are **tightly coupled**.
 - If the interactions occur through some shared data, then also we say that they are **highly coupled**.
- If two modules either do not interact with each other at all or at best interact by passing no data or only a few primitive data items, they are said to have **low coupling**.

Cohesion and Coupling:

- **Cohesion** is a measure of the functional strength of a module, whereas the **coupling** between two modules is a measure of the degree of interaction (or interdependence) between the two modules.
- A module that is highly cohesive and also has low coupling with other modules is said to be **functionally independent** of the other modules.
- Functional independence is a key to any good design because of...
 - Error Isolation
 - Scope of reuse
 - Understandability

Cohesion and Coupling:

- Cohesion is a measure of :
 - Functional strength of a module.
 - A cohesive module performs a single task or function.
- Coupling between two modules:
 - A measure of the degree of interdependence or interaction between the two modules.
- A module having high cohesion and low coupling:
 - Called functionally independent of other modules.
 - A functionally independent module needs very little help from other modules and therefore has minimal interaction with other modules.

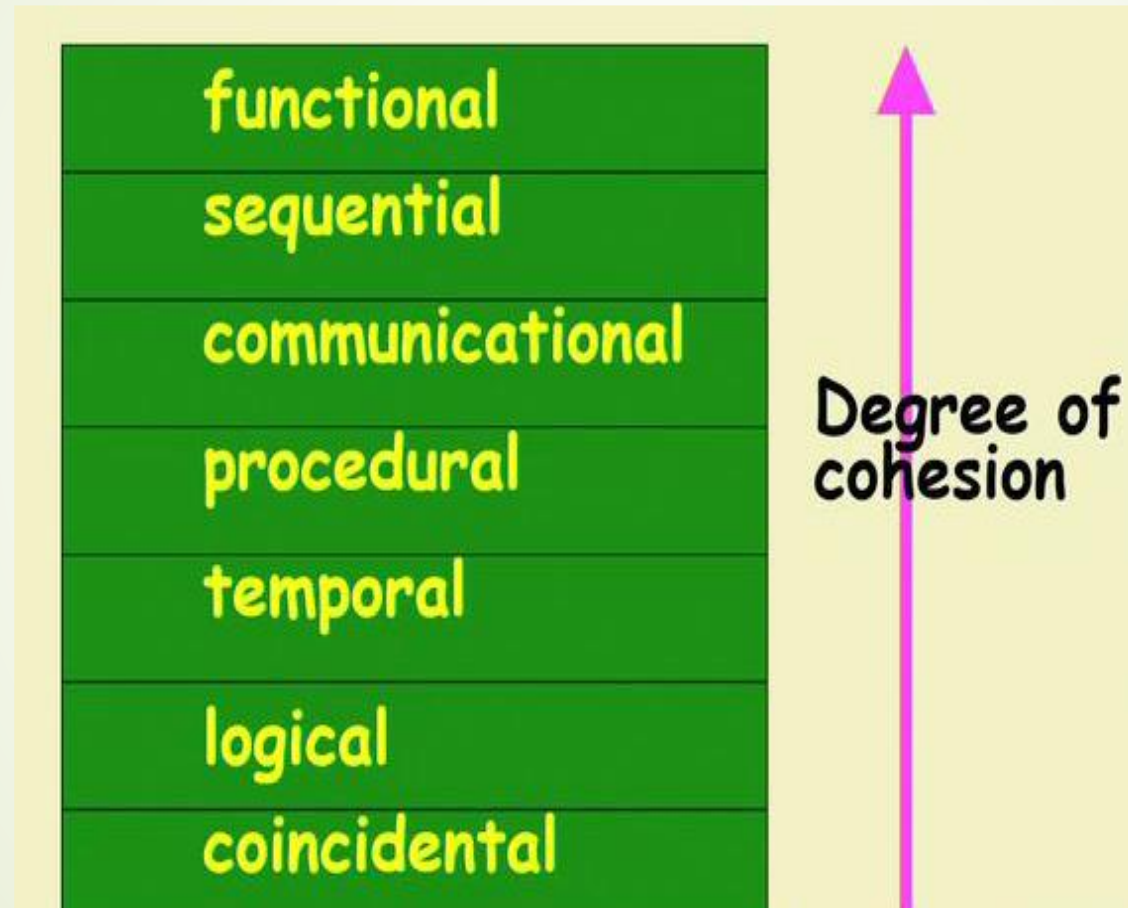
Advantages of Functional Independence

- Better understandability
- Complexity of the design is reduced,
- Different modules easily understood in isolation:
 - Modules are independent.
- Functional independence **reduces error propagation.**
 - Degree of interaction between modules is low.
 - An error in one module does not directly affect other modules.
- Also **Reuse of modules is possible.**
 - Each module does some well defined and precise function.
 - The interfaces of a module with other modules is simple and minimal.

Measuring Functional Independence:

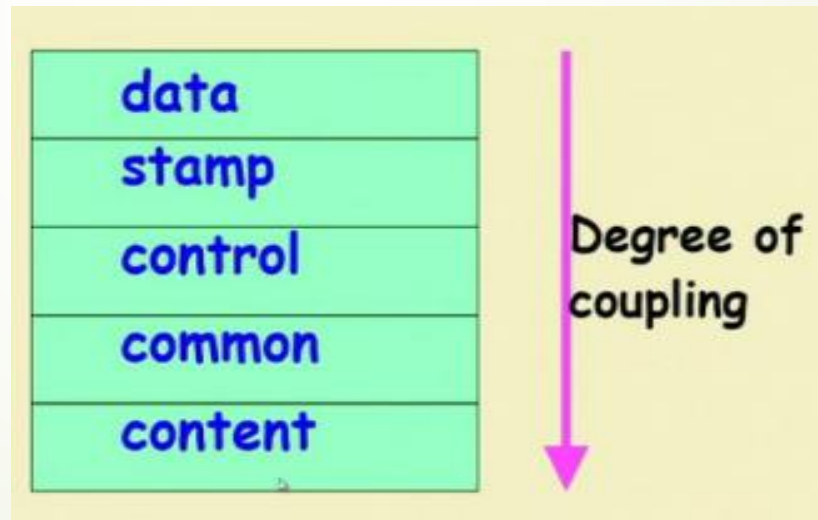
- Unfortunately, there are no ways:
 - To quantitatively measure the degree of cohesion and coupling.
 - At least classification of different kinds of cohesion and coupling will give us some idea regarding the degree of cohesiveness of a module.
- Classification can have scope for ambiguity:
 - Yet gives us some idea about cohesiveness of a module.
- By examining the type of cohesion exhibited by a module:
 - We can roughly tell whether it displays high cohesion or low cohesion.

Classification of Cohesiveness:



Classification of Coupling:

- There are no ways to precisely measure coupling between two modules:
 - Classification of different types of coupling will help us to approximately estimate the degree of coupling between two modules.



System modeling:

- System modeling is the process of developing abstract models of a system, with each model presenting a different view or perspective of that system.
- System modeling has now come to mean representing a system using some kind of graphical notation, which is now almost always based on notations in the Unified Modeling Language (UML).
- System modelling helps the analyst to understand the functionality of the system and models are used to communicate with customers.

System perspectives:

- An **external perspective**, where you model the context or environment of the system.
- An **interaction perspective**, where you model the interactions between a system and its environment, or between the components of a system.
- A **structural perspective**, where you model the organization of a system or the structure of the data that is processed by the system.
- A **behavioral perspective**, where you model the dynamic behavior of the system and how it responds to events.

Design Approaches:

- Two fundamentally different software design approaches:
 - **Function-Oriented Design**
 - **Object-Oriented Design**
- These two design approaches are radically different.
 - However, are complementary rather than competing techniques.
- Each technique is applicable at different stages of the design process.

Function-Oriented Design:

- A system is looked upon as something that performs a set of functions.
- Starting at this high-level view of the system:
 - Each function is successively refined into more detailed functions (top down decomposition).
 - Functions are mapped to a module structure.
- Identifying the set of functions to be performed is called as the **structured analysis**.
- Mapping the identified functions to module structure (**Structured design**).

Function Oriented Software Design

- Function oriented design techniques are currently being used in many software development projects.
- These techniques,
 - **view a system as a black-box** that provides a set of services to the users of the software.
 - These services provided by a software to its user are also known as the **high-level functions supported by the software.**
- The top down decomposition is carried out and different identified functions are mapped to modules and a module structure is created.
- **The design techniques are structured analysis/structured design (SA/SD) methodology.**

Function Oriented Design Example:

- **The function create new library member:**
 - Creates the record for a new member,
 - Assigns the unique membership number,
 - Prints a bill towards the membership
- **The system state is centralized:**
 - **Accessible to different functions**
 - Member Records: available for reference and updation to several functions:
 - Create new member
 - Delete member
 - Update member record

Function Oriented Software Design

- The structured analysis activity transforms the SRS document into a graphic model called the DFD model.
- During structure design, all the functions identified during structured analysis are mapped to a module structure (high level design). This is represented using structure chart.
- The **purpose of structure analysis** is to capture the detailed structure of the system as perceived by the user.
- The **purpose of the structured design** is to define the structure of the solution that is suitable for implementation in some programming language.

Structured Analysis and Structured Design

➤ During Structured Analysis:

- High level functions are successively decomposed into more detailed functions.
- The purpose of structure analysis is to capture the detailed structure of the system as the user views it.

➤ During Structured Design:

- The detailed functions are mapped to a module structure.
- The purpose of structured design is to arrive at a form that is suitable for implementation in some programming language.

Structured Analysis:

- Textual problem description converted into a graphic model.
 - Done using data flow diagrams (DFDs).
 - DFD graphically represents the results of structured analysis.
- The results of structured analysis can be easily understood even by ordinary customers:
 - Does not require computer knowledge.
 - Directly represents customers perception of the problem.
 - Uses customers terminology for naming different functions and data.
- Results of structured analysis can be reviewed by customers to check whether it captures all their requirements.

Structured Analysis:

- The structure analysis technique is based on the following underlying principles:
 - **Top-down decomposition approach**
 - **Application of divide and conquer principle.**
 - **Graphical representation of the analysis results using data flow diagrams(DFDs).**
- The DFD model only represents the data flow aspects and does not show the sequence of execution of the different functions and the conditions based on which a function may or may not be executed.

Data Flow Diagram (DFD):

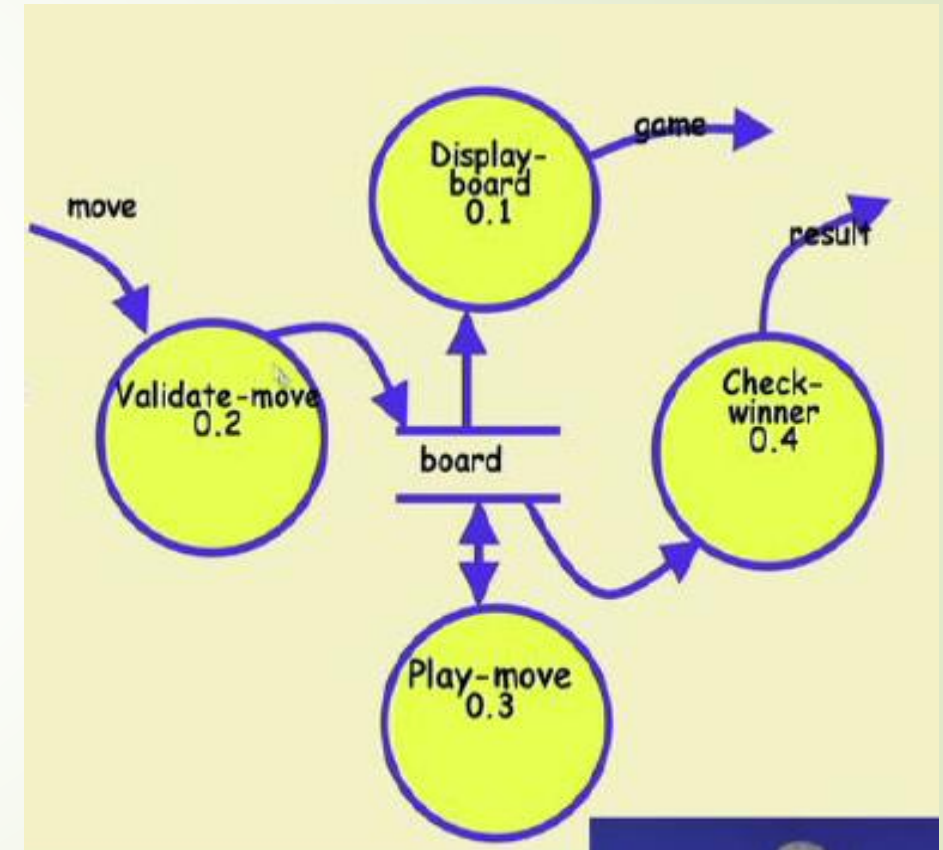
- A data flow diagram (DFD) maps out the flow of information for any process or system. It uses defined symbols like rectangles, circles and arrows, plus short text labels, to show data inputs, outputs, storage points and the routes between each destination.
- It shows how data enters and leaves the system, what changes the information, and where data is stored.
- The objective of a DFD is to show the scope and boundaries of a system as a whole.
- A neat and clear DFD can depict the right amount of the system requirement graphically.
- DFD represents data flow and not control flow.

Data Flow Diagrams (DFDs)

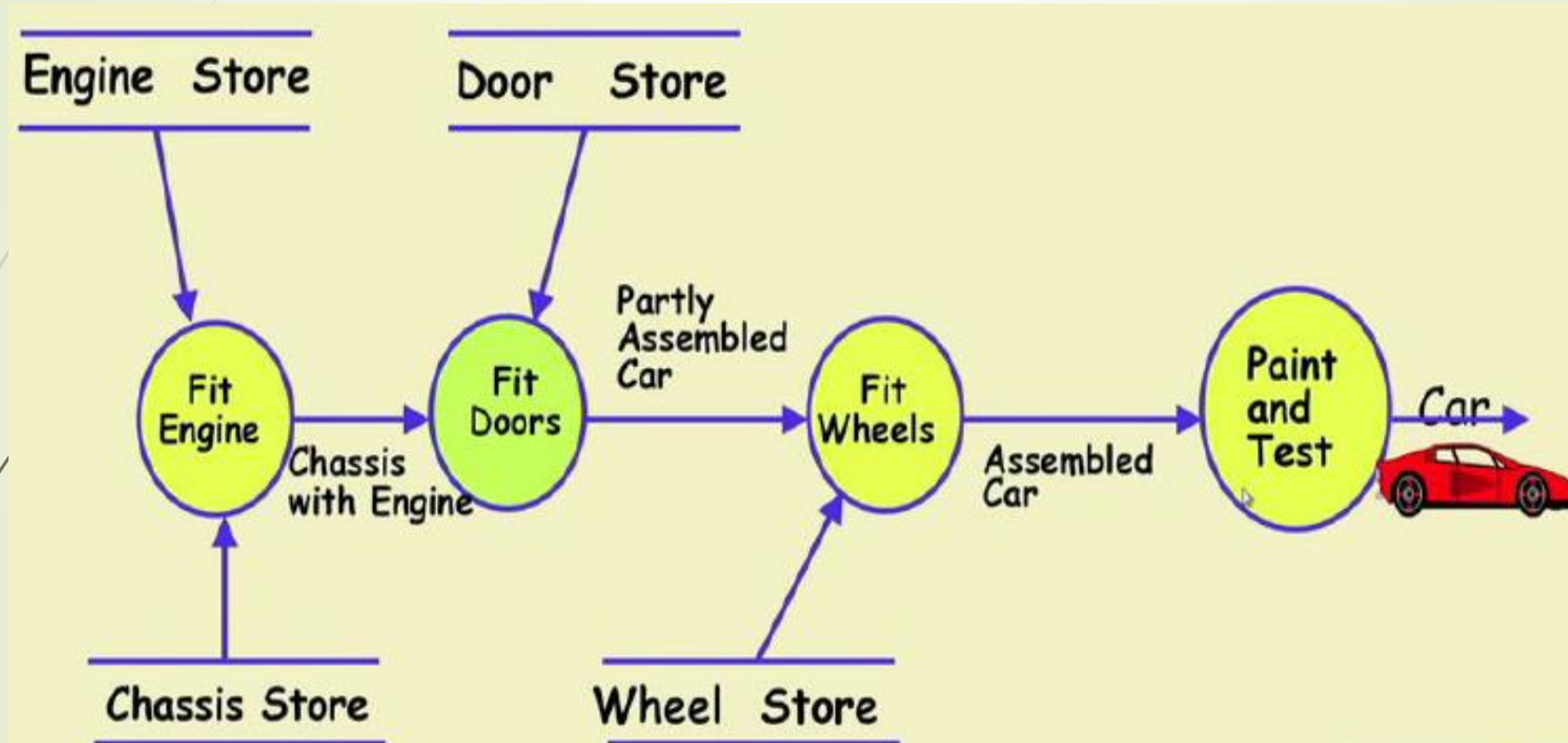
- The DFD (also known as bubble chart) is a simple graphical formalism that can be used to represent
 - **a system in terms of the input data to the system,**
 - **various processing carried out on those data, and**
 - **the output data generated by the system.**
- A DFD is a hierarchical graphical model of a system that shows the different processing activities or functions that the system performs and the data interchange among those functions.
- A DFD model uses a very limited number of primitive symbols to represent the functions performed by a system and the data flow among these functions.

Data Flow Diagrams (DFDs)

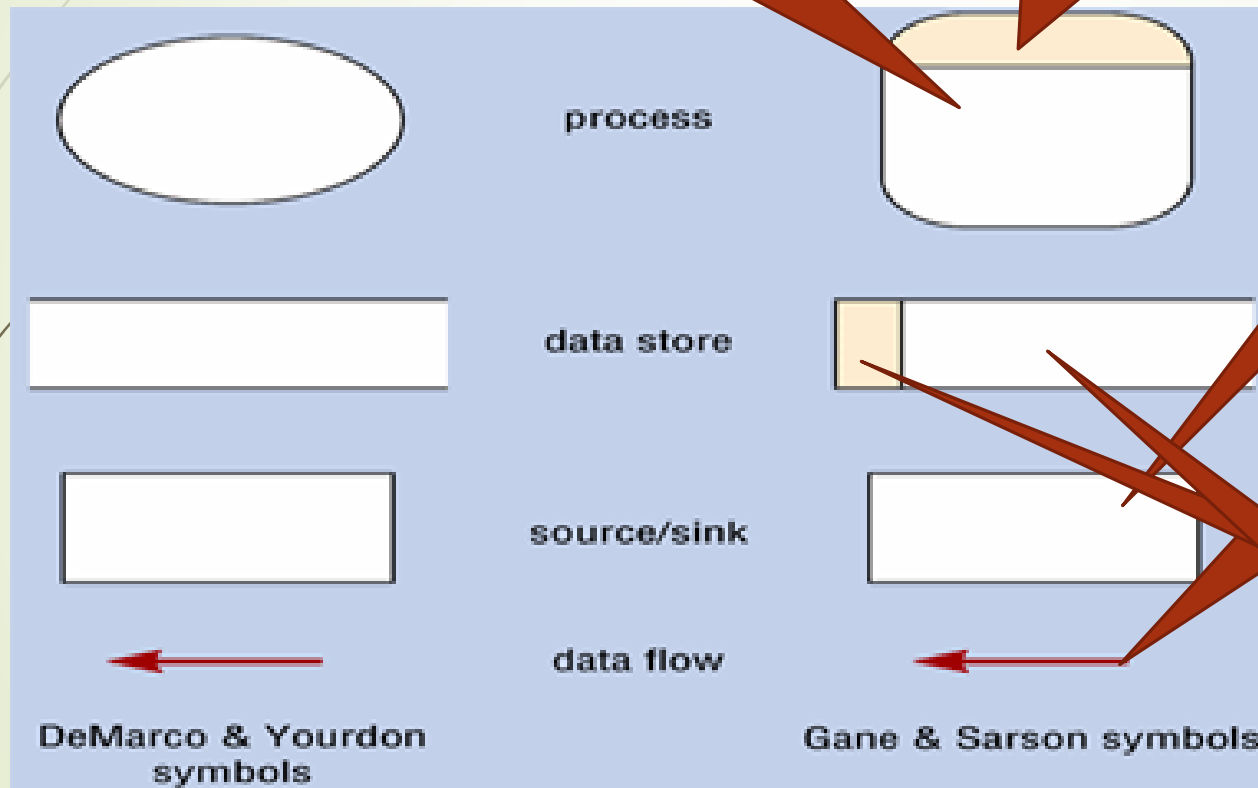
- DFD is a hierarchical graphical model:
 - Shows the different functions (or processes) of the system
 - Data interchange among the processes
- A DFD model:
 - Uses limited types of symbols.
 - Simple set of rules.
 - Easy to understand--- a hierarchical model
- It is useful to consider each function as a processing station:
 - Each function consumes some input data.
 - Produces some output data.



Data Flow Model of a Car Assembly Unit:



Data Programming Models



Meaningful label for process

- Generate PayCheck
- Calculate overtime pay
- Compute GPA

Used to number process

Has a name which state what the external agent is

- Customer
- Teller
- Account office

Inventory Control System

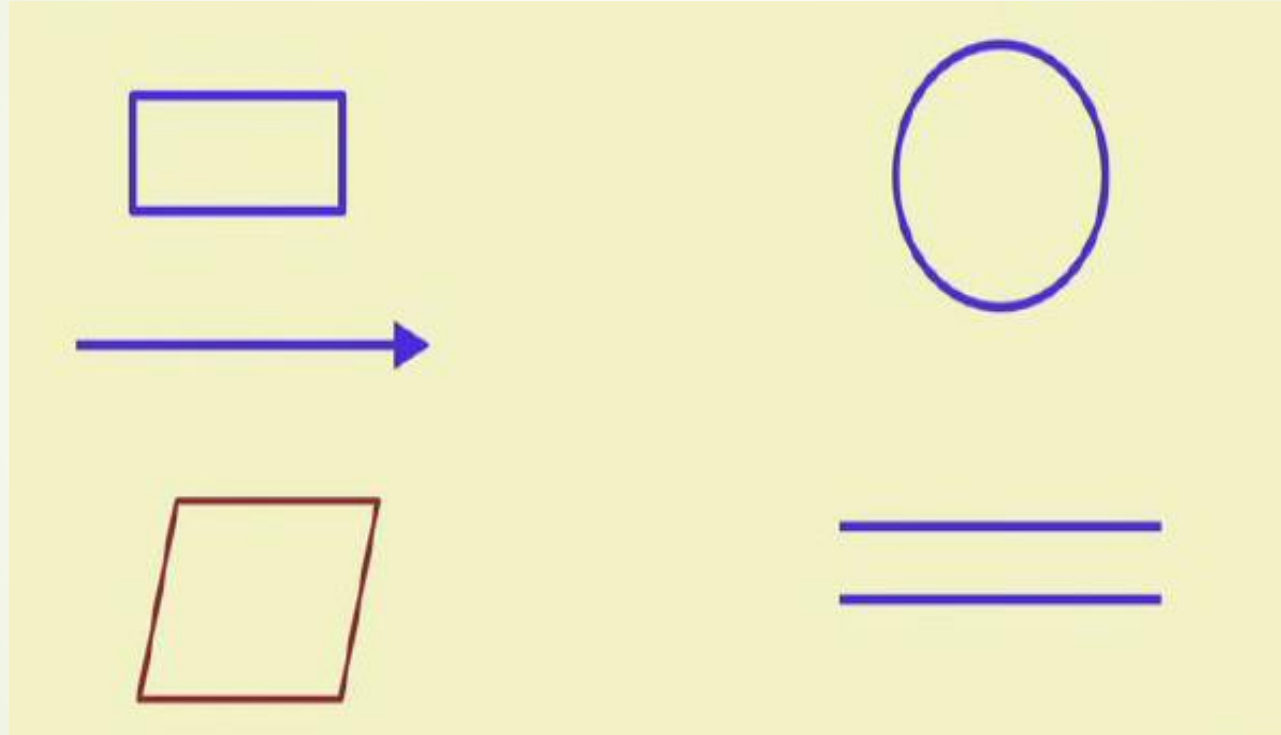
name for the data in motion

- Customer Order
- Sales Receipt
- PayCheck

Meaningful label for data store

- Student File
- Transcripts

Basic Symbols used for Constructing DFDs



Symbols and Notations Used in DFDs:

- **External entity:** An outside system that sends or receives data, communicating with the system being diagrammed. They are also known as terminators, sources and sinks or actors.
- **Process:** Any process that changes the data, producing an output. It might perform computations, or sort data based on logic, or direct the data flow based on business rules.
- **Data store:** Files or repositories that hold information for later use, such as a database table or a membership form.
- **Data flow:** The route that data takes between the external entities, processes and data stores.

External Entity Symbol:

- Represented by a rectangle
- External entities are either users or external systems:
 - Input data to the system or
 - Consume data produced by the system
 - Sometimes external entities are called as terminator or source.



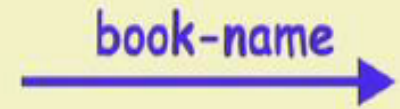
Function Symbol:

- A function such as “search-book” is represented using a circle:
- This symbol is called a **process or bubble or transform**.
- Bubbles are annotated with corresponding function names.
- A function represents some activity, **Function names should be verbs**.



Data Flow Symbol:

- A directed arc or line.
- Represent data flow in the direction of the arrow.
- Data flow symbols are annotated with names of data they carry.



Data Store Symbol:

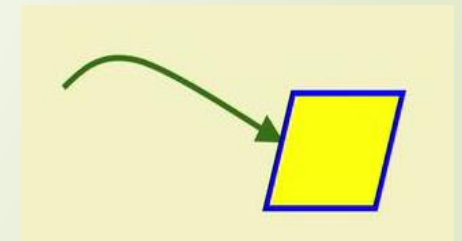
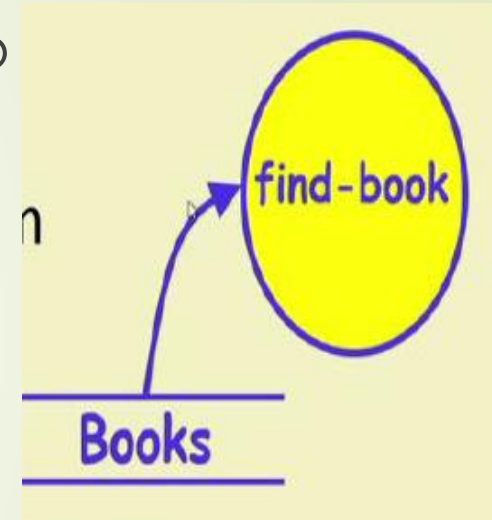
- Represent a logical file
- A logical file can be
 - A data structure
 - A physical file on disk.
- Each data store is connected to a process:
 - By means of a data flow symbol.



Data Store Symbol:

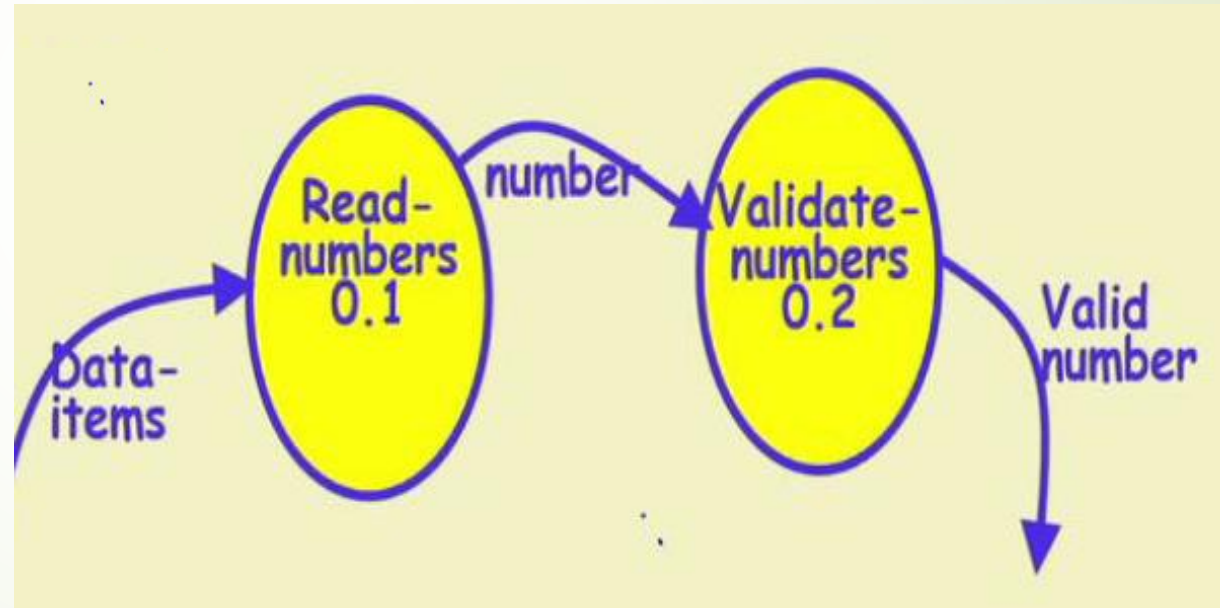
- Direction of data flow arrow:
 - Shows whether data is being read from or written into it.
- An arrow into or out of data store:
 - Implicitly represents the entire data of the data store
 - Arrows connecting to a data store need not be annotated with any data name.

Output Produced by the system is represented by parallelogram.



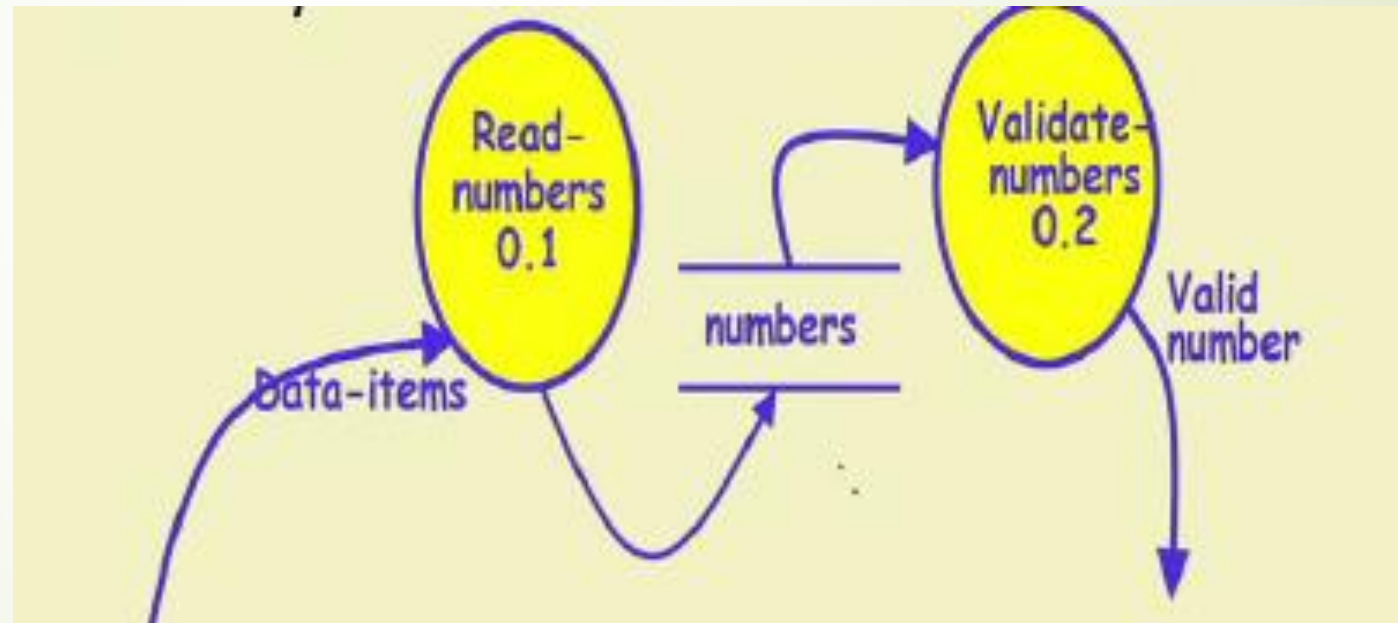
Synchronous Operation

- If two bubbles are directly connected by a data flow arrow, they are synchronous.

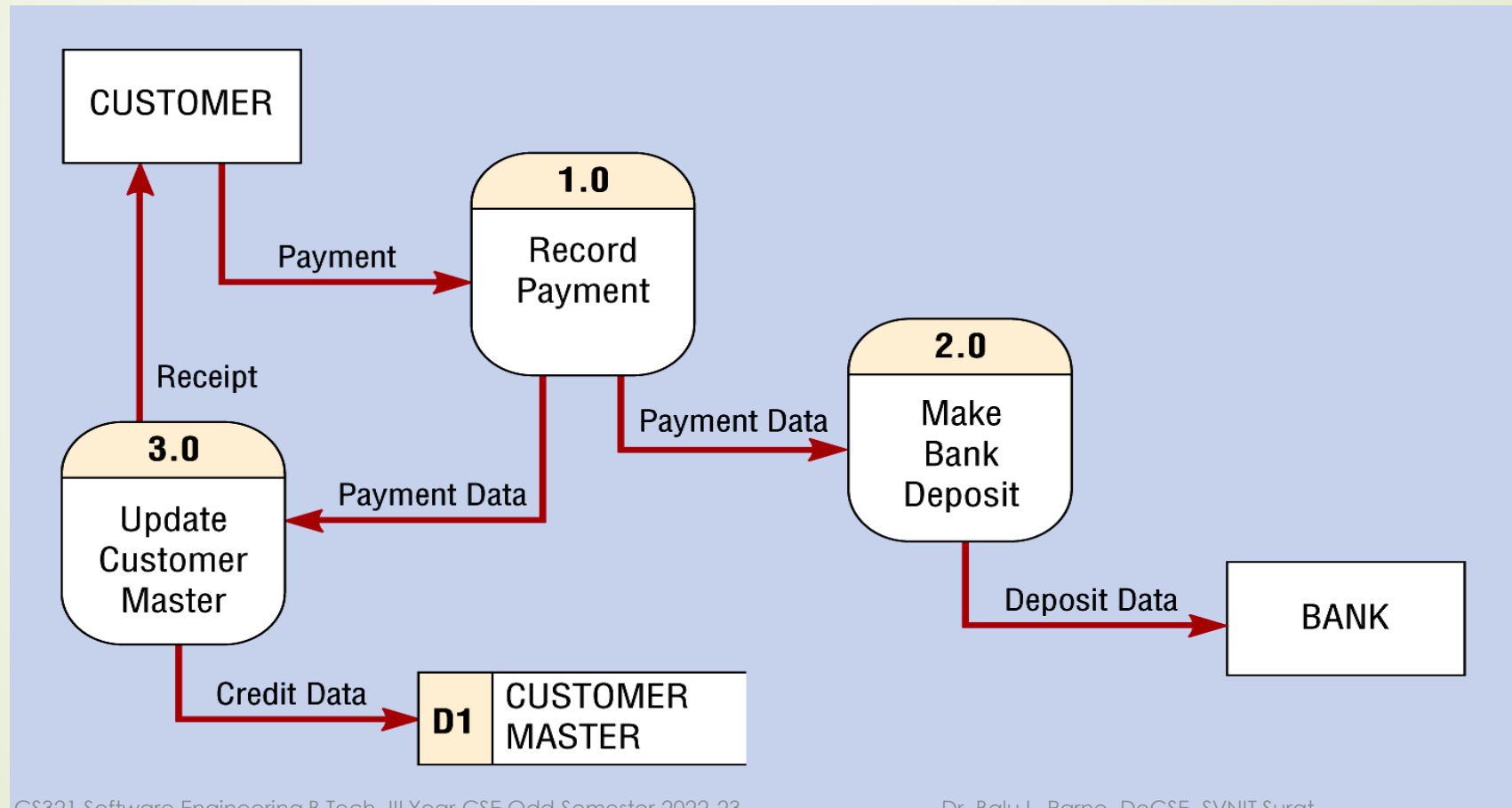


Asynchronous Operation

- If two bubbles are connected via a data store, they are not synchronous.

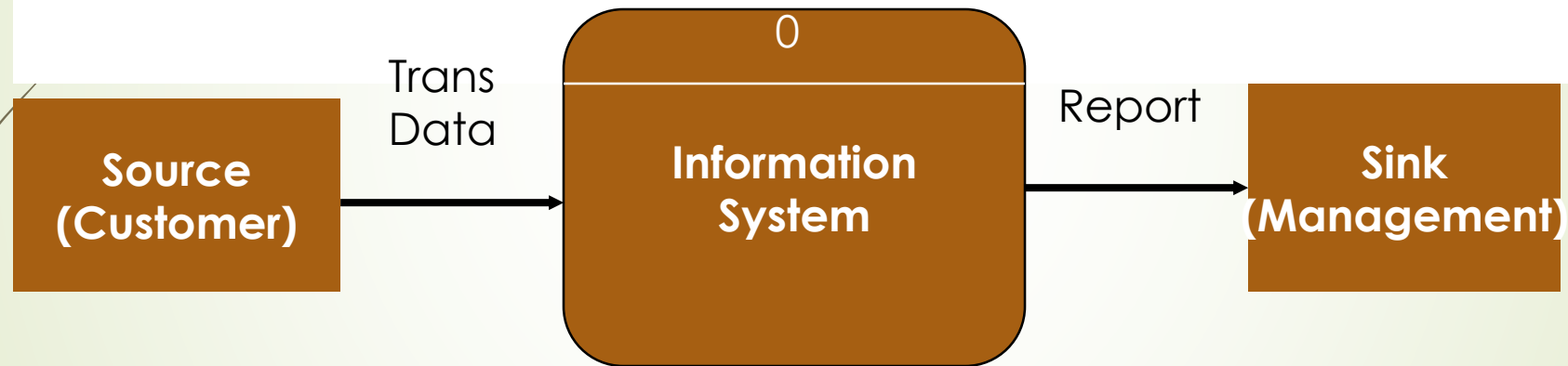


An Example - A Data Flow Diagram for a Banking System



An Information System : A Generic View

In general, a system could be viewed as a single Process



There can be multiple sources and sinks!

This generic diagram is called “**Context Diagram**”

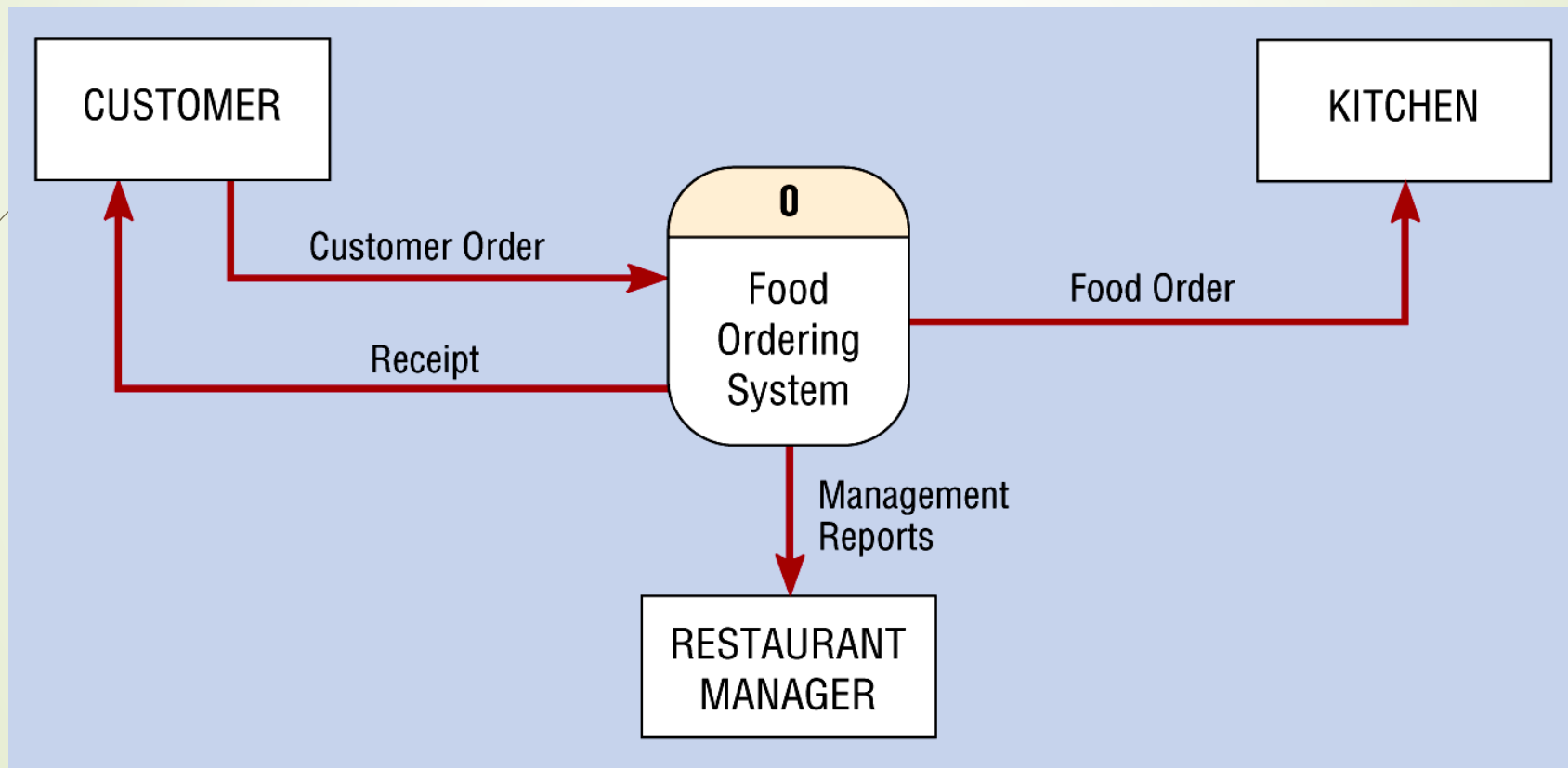
A Context Diagram

- An overview of an organizational system that shows the system boundary, sources / sinks that interact with the system, and the major information flows between the entities and the system
- The context diagram establishes the context in which the system operates; that is, who are the users, what data do they input to the system, and what data they receive from the system.
- A Context Diagram addresses **only one process**.

A Context Diagram

- Construction of context diagram: **Examine the SRS document to determine**
 - Different high level functions that the system needs to perform.
 - Data input to every high level function.
 - Data output from every high level function.
 - Interaction (data flow) among the identified high level functions.
- Represents these aspects of the high level functions in a diagrammatic form. This would form the top-level DFD usually called the DFD 0.
- For example....

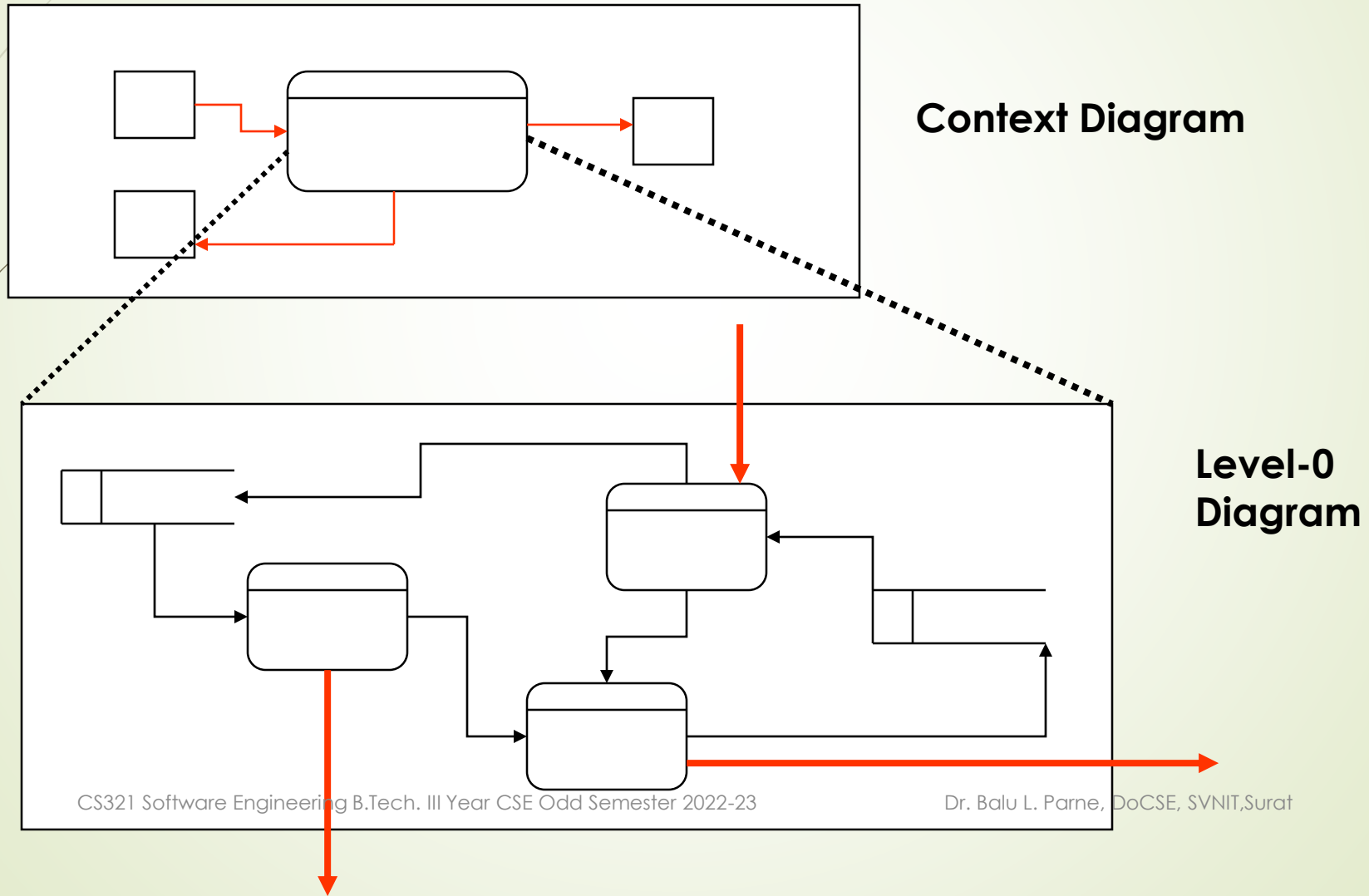
An Example - A Context Diagram for a Fast-Food IS



Process Decomposition

- In general, a system could be too complex to understand when viewed as a single Process
- We need a Process Decomposition scheme
 - i.e., to separate a system into its subsystems (sub-processes), which in turn could be further divided into smaller subsystems until the final subsystems become manageable units (i.e., primitive processes!)
- **A divide and conquer strategy!!**

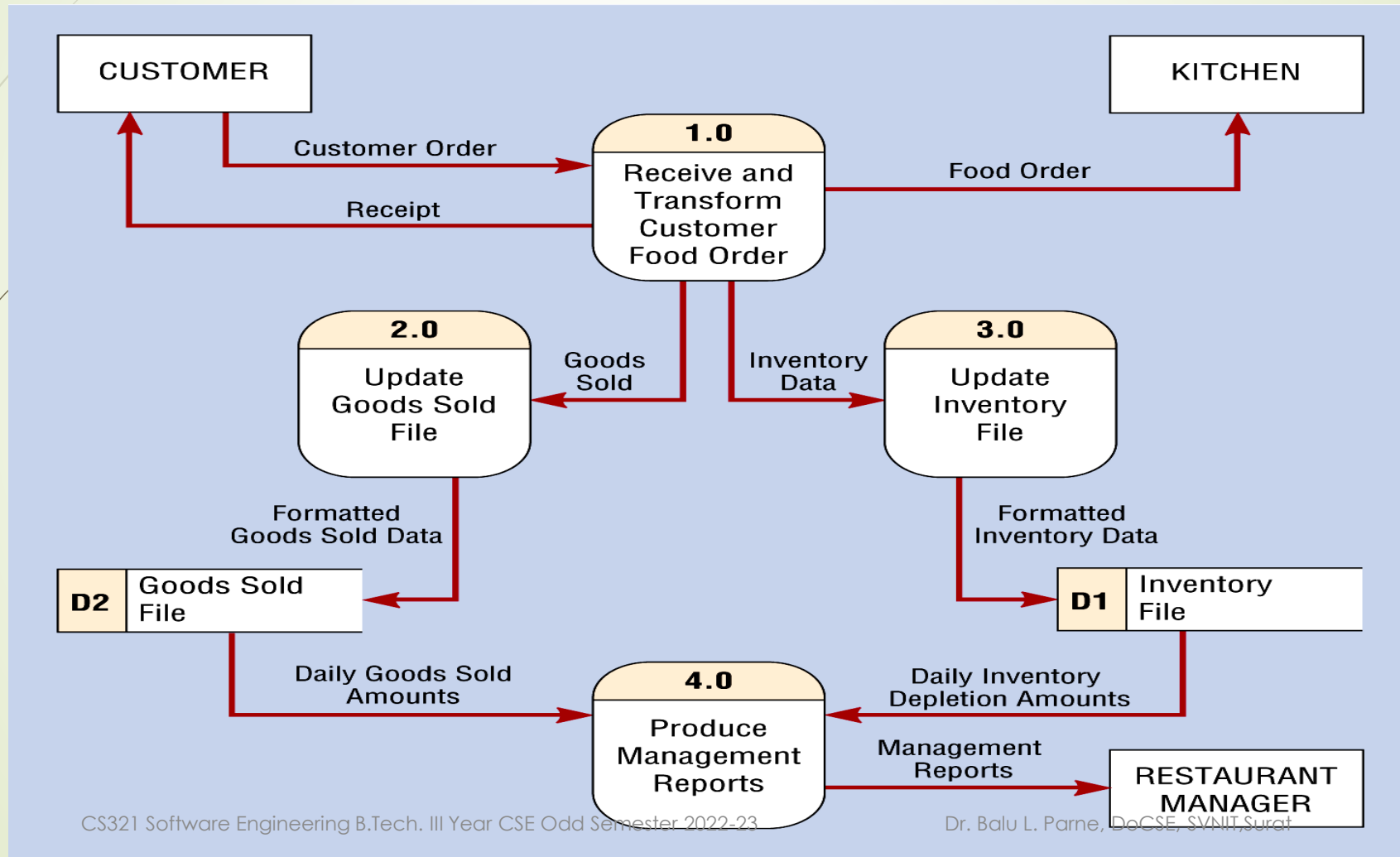
Decomposition Overview



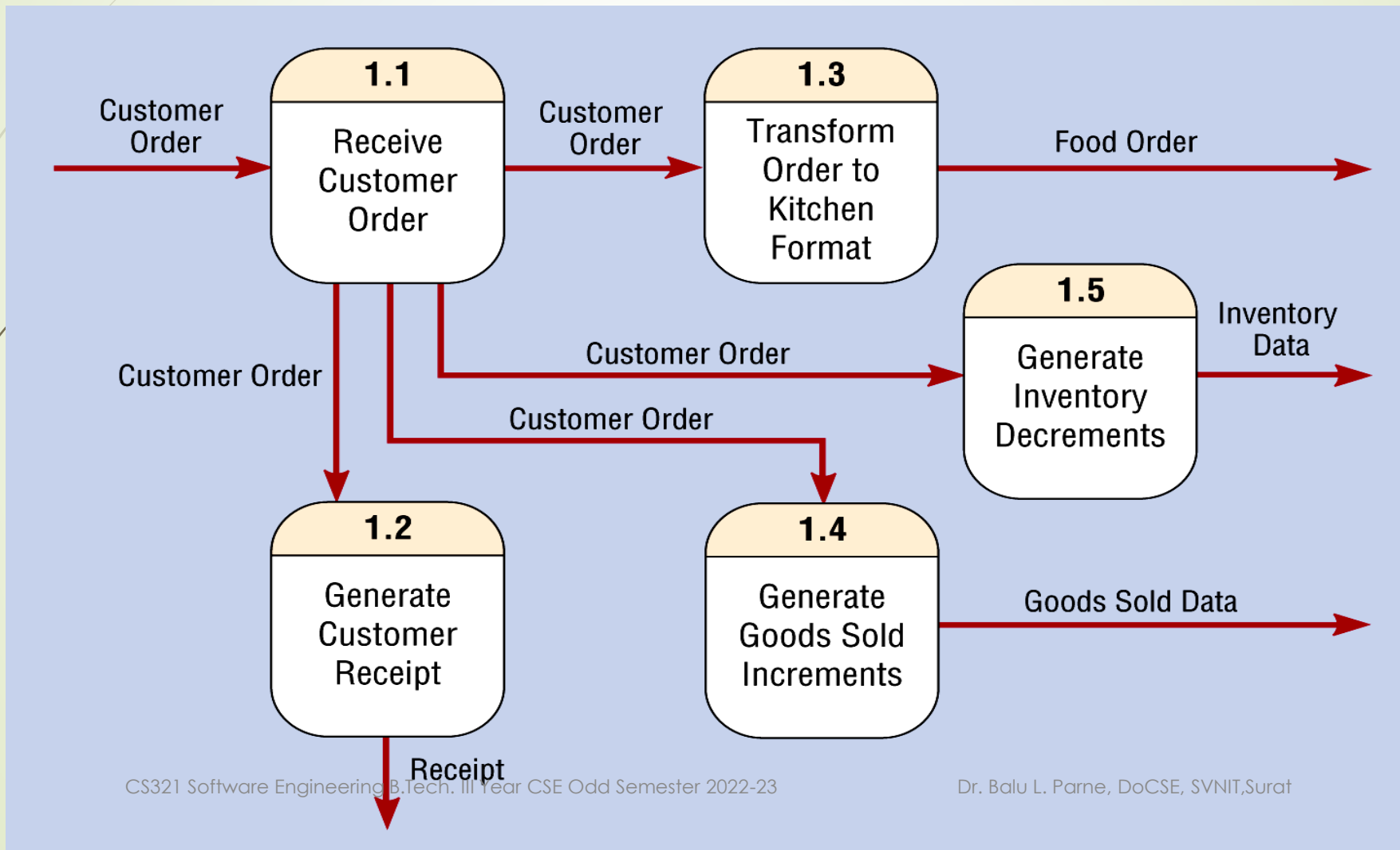
Constructions of Lower Level Diagrams:

- Decompose each high level function into its constituent sub-functions through the following set of activities:
 - Identify the different sub-functions of the high level function.
 - Identify the data input to each of these sub-functions.
 - Identify the data output from each of these sub-functions.
 - Identify the interactions (data flow) among these sub-functions.
- Recursively repeat above steps for each sub-function until a sub-function can be represented by using a simple algorithm.

An Example - A decomposed Context Diagram - Level 0 Diagram



An Example - A further decomposition A Level-1 Data Flow Diagram



Process Decomposition Rules

- Generic Decomposition Rules:
 - A process in a DFD could be either a parent process or a child process, or both.
 - A parent process must have two or more child processes.
 - A child process may further be decomposed into a set of child processes.

Three Major Types of Process

➤ **Function Process**

- A function is a set of related activities of the business (e.g., Marketing, Production, etc.)

➤ **Event Process**

- An event process is a logical unit of work that must be completed as a whole. (e.g., Process customer credit verification)

➤ **Primitive Process**

- a primitive process is a discrete, lowest-level activity/task required to complete an event. (e.g., Check the credit card balance)

Naming Rules for Processes

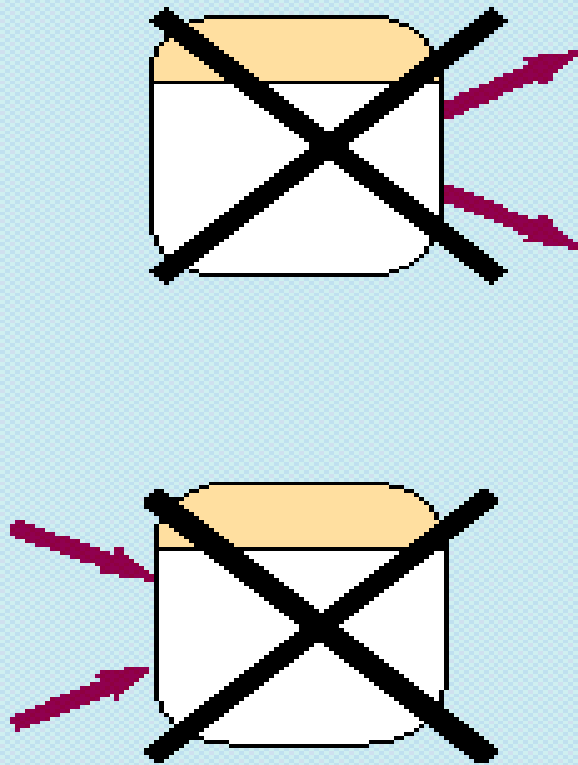
- Function Process - use a **Noun**
- Event Process - Use a **general action verb**
 - Process Student registration.
 - Respond to ...
 - Generate ...
- Primitive Process - use a **strong action verb**
 - Validate Student ID
 - Check ...
 - Calculate ...

Rules for Processes

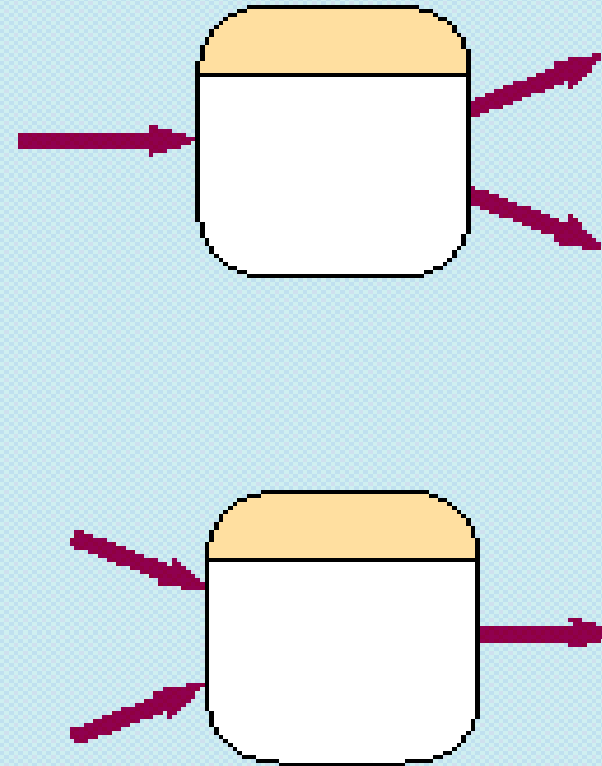
- No process can have only outputs (a miracle!)
- No process can have only inputs (a black hole!)
- No process can produce outputs with insufficient inputs (a gray hole!)

Processes in a DFD- Correct vs. Incorrect

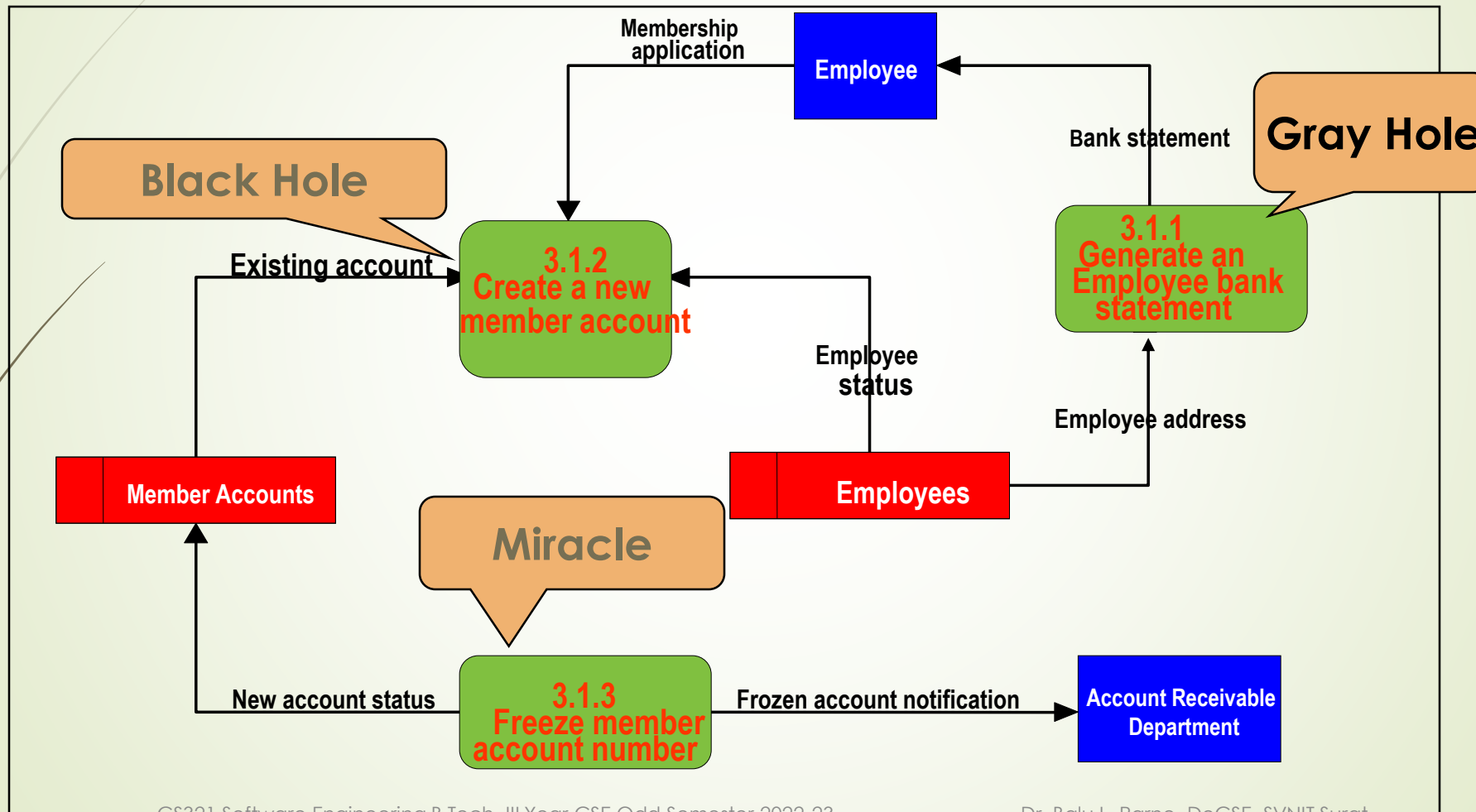
Incorrect



Correct



Can You Identify Errors in This Diagram?



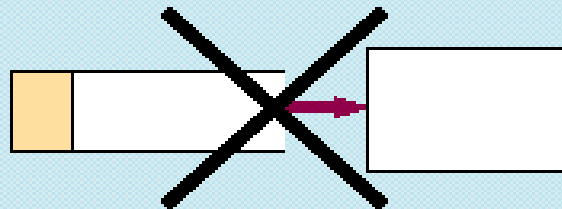
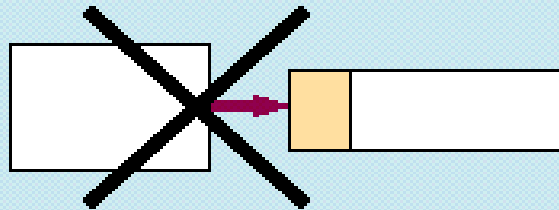
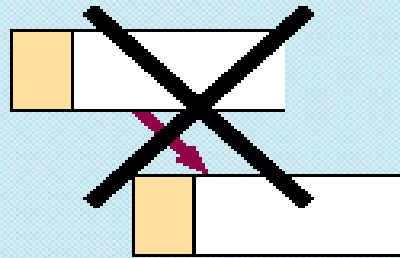
Rules for Data Stores

- Data cannot move directly from one data store to another data store
 - it must be moved by a process.
- Data cannot move directly from an outside source to a data store
 - it must be moved by a process.
- Data cannot move directly to an outside sink from a data store
 - it must be moved by a process.
- You need to use a Noun phrase to label each data flow

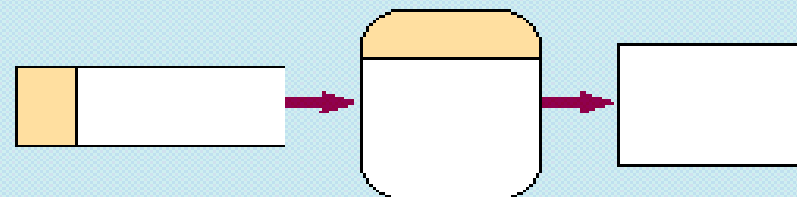
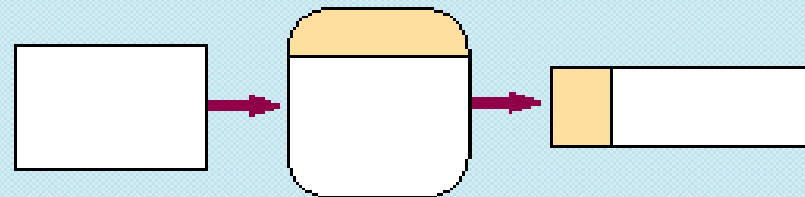
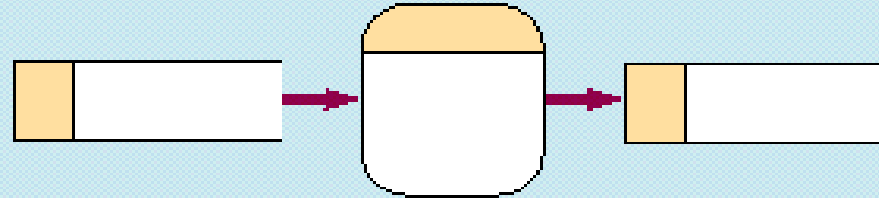
Data Flows in a DFD: Incorrect vs. Correct

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Incorrect



Correct



Naming Rules Data Flow

- Use a *singular noun phrase* for each data flow
 - Ex: customer data, shipping report, ..., etc.
- Carry logical meaning only,
 - i.e., *no implication on data form* or *data structure*
- Minimum flow (no data flooding!!)
- Should *never be “Unnamed!!”*
 - otherwise, there might be a modeling error.

Naming Scheme for Other DFD Components

➤ **Process (Event)**

- Use an Action Verb Phrase
- Process member order, Generate bank statement, ...

➤ **External Agent (Sink/Source)**

- Use a singular descriptive noun
- Ex: Student, Customer, etc.

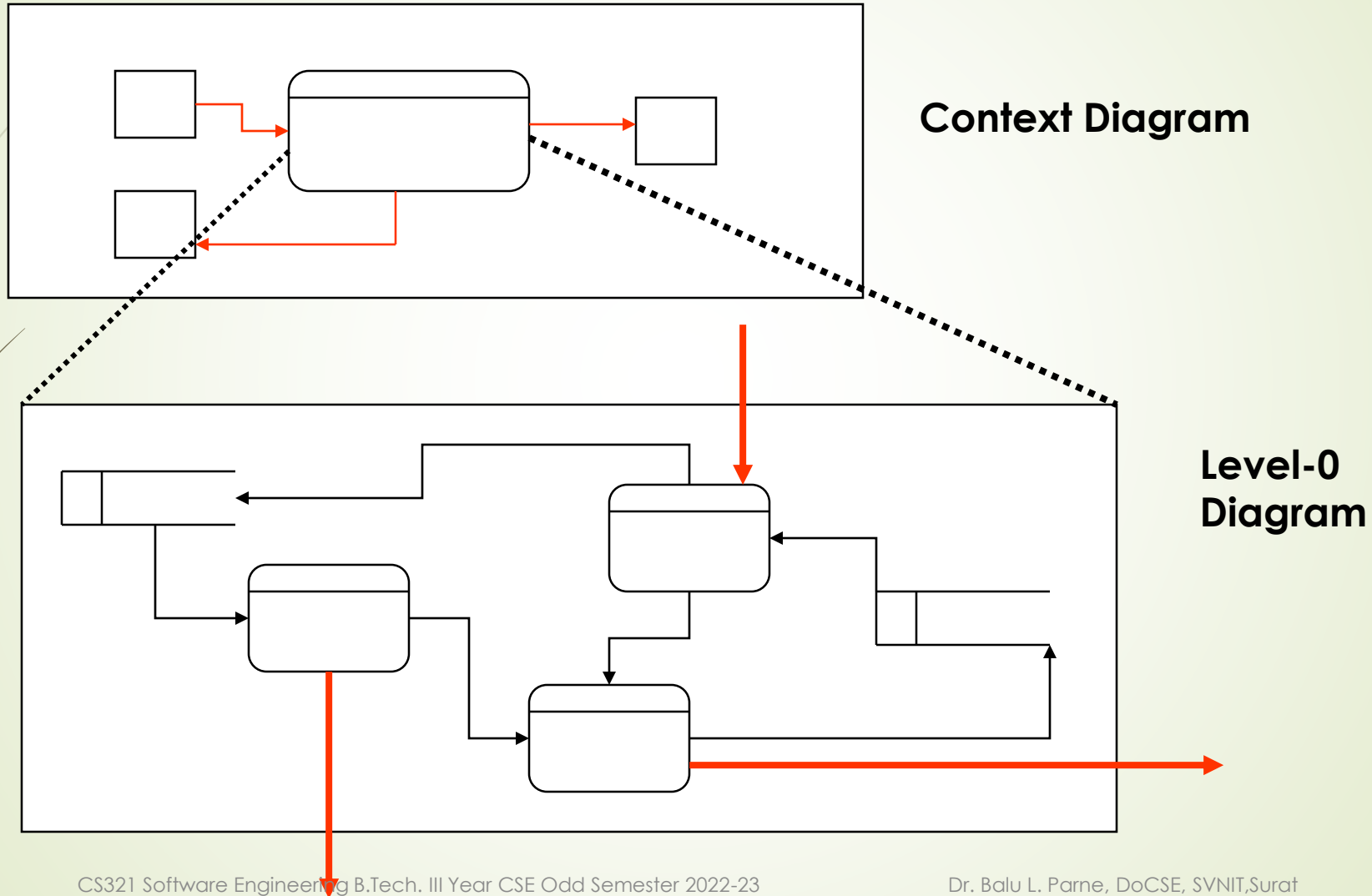
➤ **Data Store**

- Use a plural descriptive noun (Members, Customers, etc.)
- Or use a noun + file (Inventory file, Goods sold file)

Basic Rule in DFD Decomposition

- Balancing Principle
 - the decomposed DFD (i.e., the next lower level DFD) should retain the same number of inputs and outputs from its previous higher level DFD (i.e., No new inputs or outputs when a DFD is decomposed)

Basic Rule in DFD Decomposition...



Developing the DFD Model of a System:

- A DFD model of a system graphically represents how each input data is transformed to its corresponding output data through a hierarchy of DFDs.
- The top level DFD is called the level 0 DFD or the context diagram. This is the most abstract level (simplest) representation of the system.

Lemonade Stand Example

Creating Data Flow Diagrams

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Example

The operations of a simple lemonade stand will be used to demonstrate the creation of dataflow diagrams.`

Steps:

1. Create a list of activities
2. Construct Context Level DFD (identifies sources and sink)
3. Construct Level 0 DFD (identifies manageable sub processes)
4. Construct Level 1- n DFD (identifies actual data flows and data stores)

Creating Data Flow Diagrams

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Example

Think through the activities that take place at a lemonade stand.

1. Create a list of activities

Customer Order
Serve Product
Collect Payment
Produce Product
Store Product

Creating Data Flow Diagrams

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Example

Also think of the additional activities needed to support the basic activities.

1. Create a list of activities

Customer Order
Serve Product
Collect Payment
Produce Product
Store Product
Order Raw Materials
Pay for Raw Materials
Pay for Labor

Creating Data Flow Diagrams

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Example

Group these activities in some logical fashion, possibly functional areas.

1. Create a list of activities

Customer Order
Serve Product
Collect Payment

Produce Product
Store Product

Order Raw Materials
Pay for Raw Materials

Pay for Labor

Creating Data Flow Diagrams

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Example

Create a context level diagram identifying the sources and sinks (users).

Customer Order
Serve Product
Collect Payment

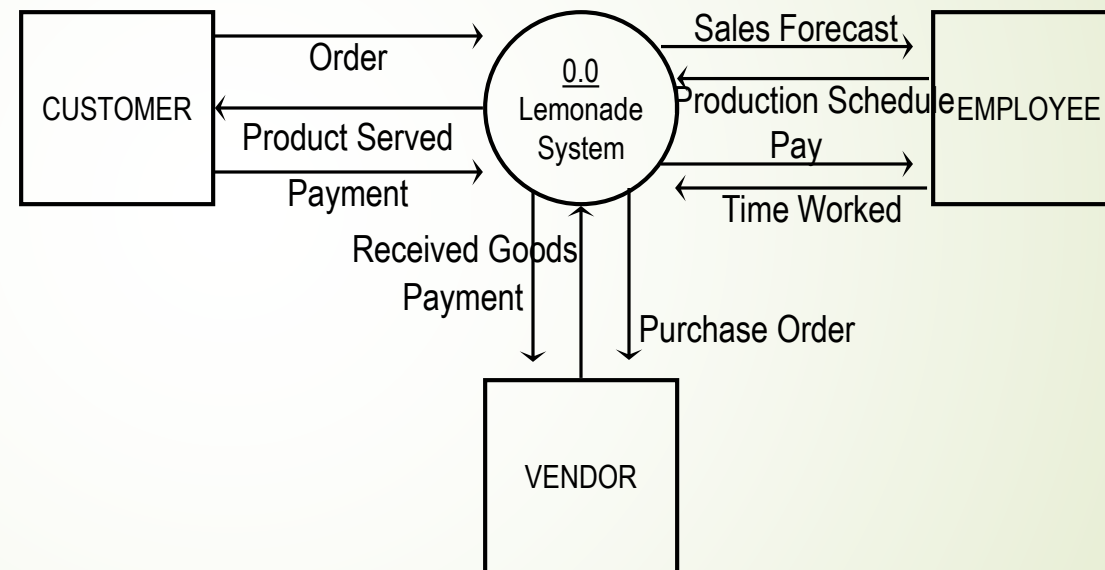
Produce Product
Store Product

Order Raw Materials
Pay for Raw Materials

Pay for Labor

2. Construct Context Level DFD (identifies sources and sink)

Context Level DFD



Creating Data Flow Diagrams

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Example

Create a level 0 diagram identifying the logical subsystems that may exist.

Customer Order
Serve Product
Collect Payment

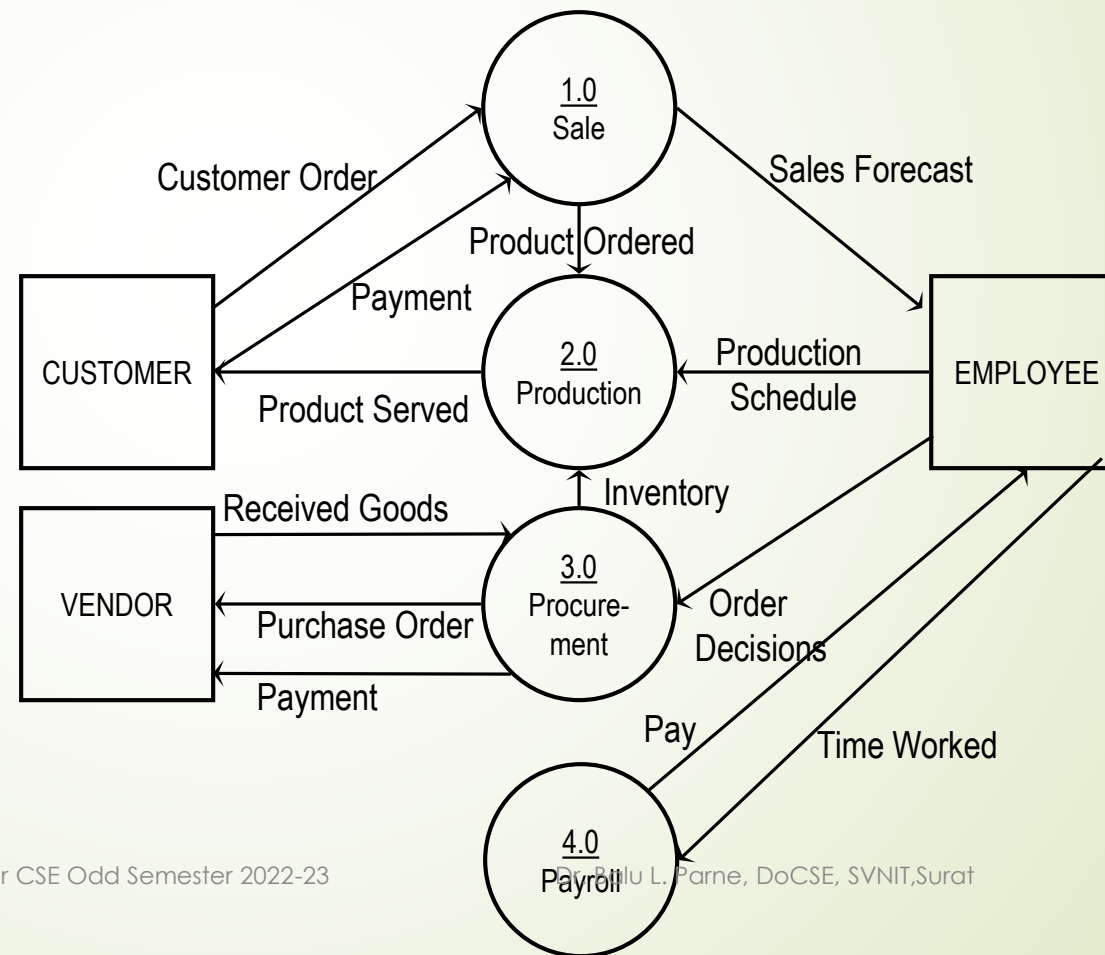
Produce Product
Store Product

Order Raw Materials
Pay for Raw Materials

Pay for Labor

3. Construct Level 0 DFD
(identifies manageable sub processes)

Level 0 DFD



Creating Data Flow Diagrams

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Example

Create a level 1 decomposing the processes in level 0 and identifying data stores.

Customer Order
Serve Product
Collect Payment

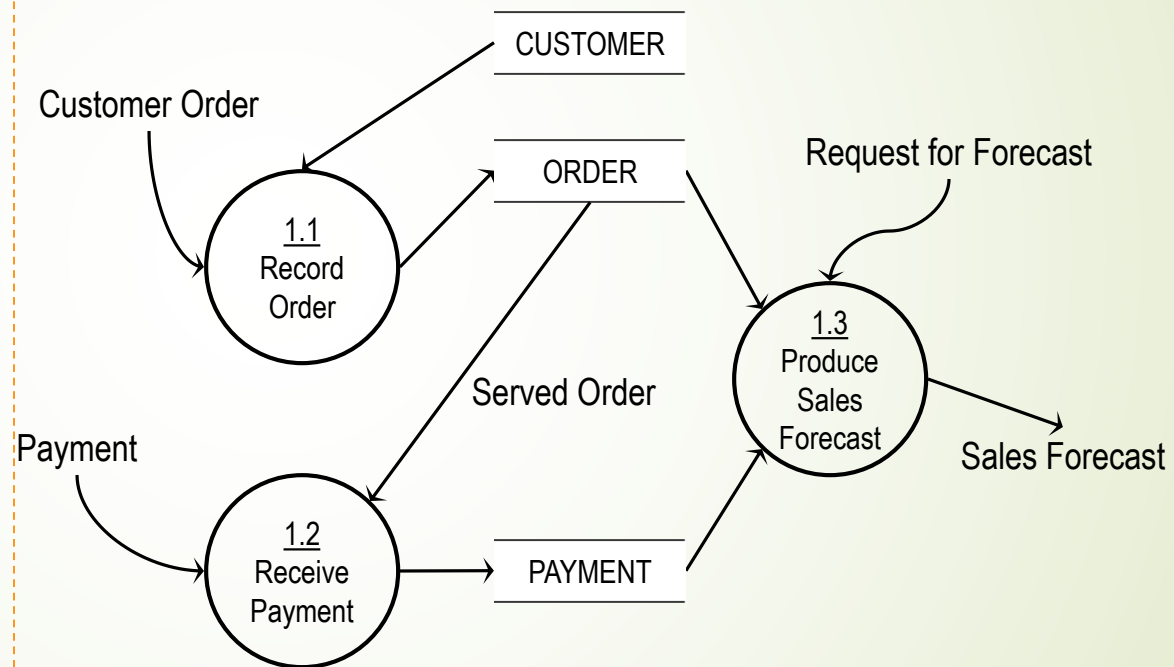
Produce Product
Store Product

Order Raw Materials
Pay for Raw Materials

Pay for Labor

4. Construct Level 1- n DFD
(identifies actual data flows and data stores)

Level 1 DFD



Creating Data Flow Diagrams

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Example

Create a level 1 decomposing the processes in level 0 and identifying data stores.

Customer Order
Serve Product
Collect Payment

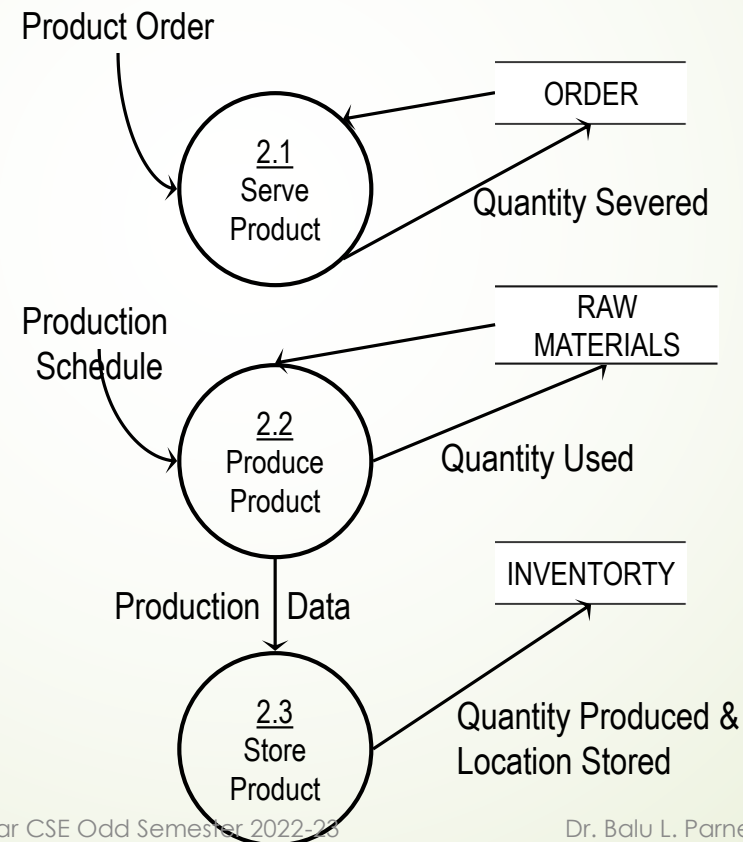
Produce Product
Store Product

Order Raw Materials
Pay for Raw Materials

Pay for Labor

4. Construct Level 1 (continued)

Level 1 DFD



Creating Data Flow Diagrams

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Example

Create a level 1 decomposing the processes in level 0 and identifying data stores.

Customer Order
Serve Product
Collect Payment

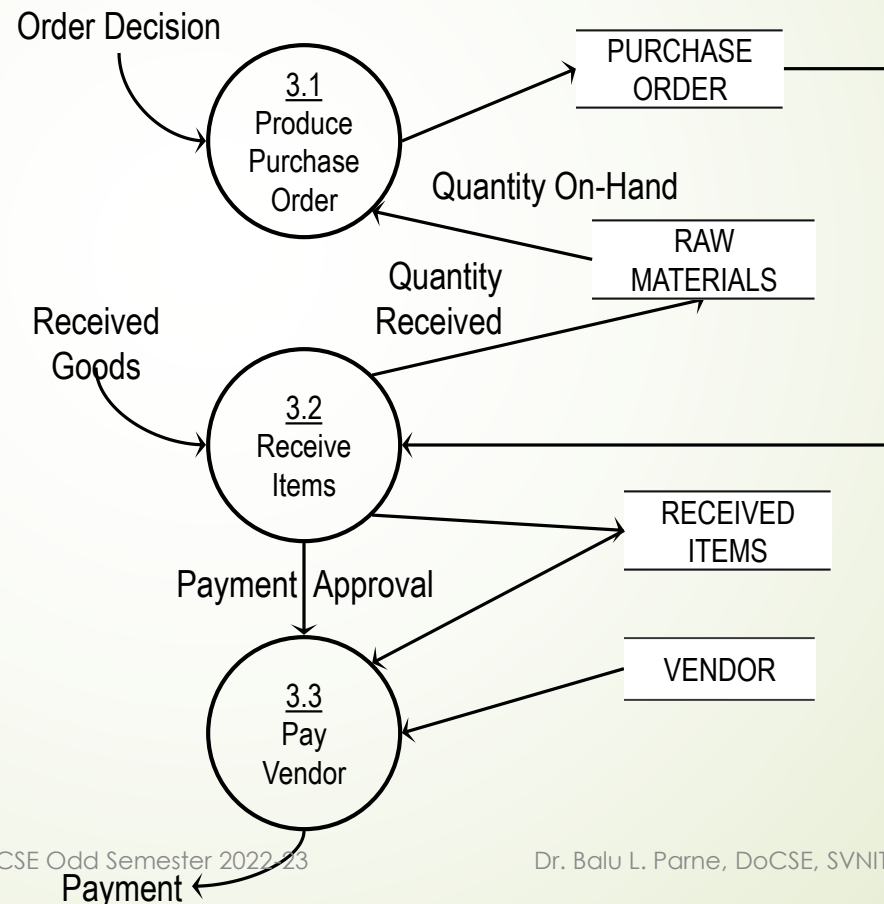
Produce Product
Store Product

Order Raw Materials
Pay for Raw Materials

Pay for Labor

4. Construct Level 1 (continued)

Level 1 DFD



Creating Data Flow Diagrams

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Example

Create a level 1 decomposing the processes in level 0 and identifying data stores.

Customer Order
Serve Product
Collect Payment

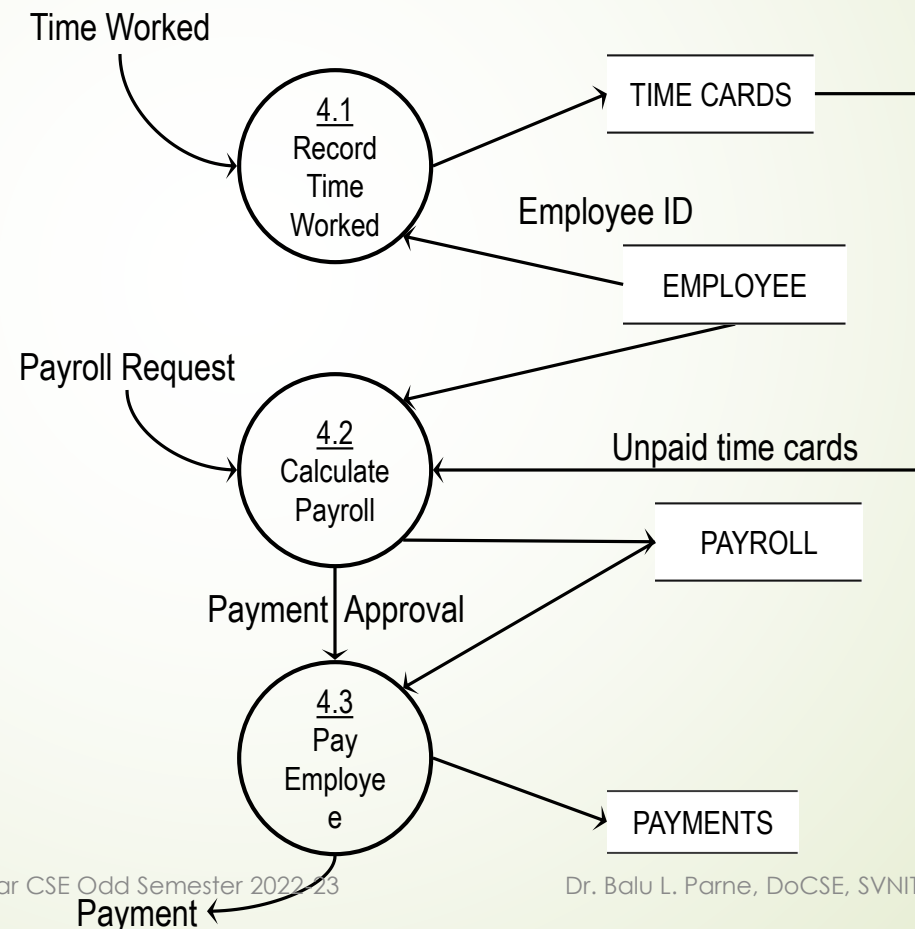
Produce Product
Store Product

Order Raw Materials
Pay for Raw Materials

Pay for Labor

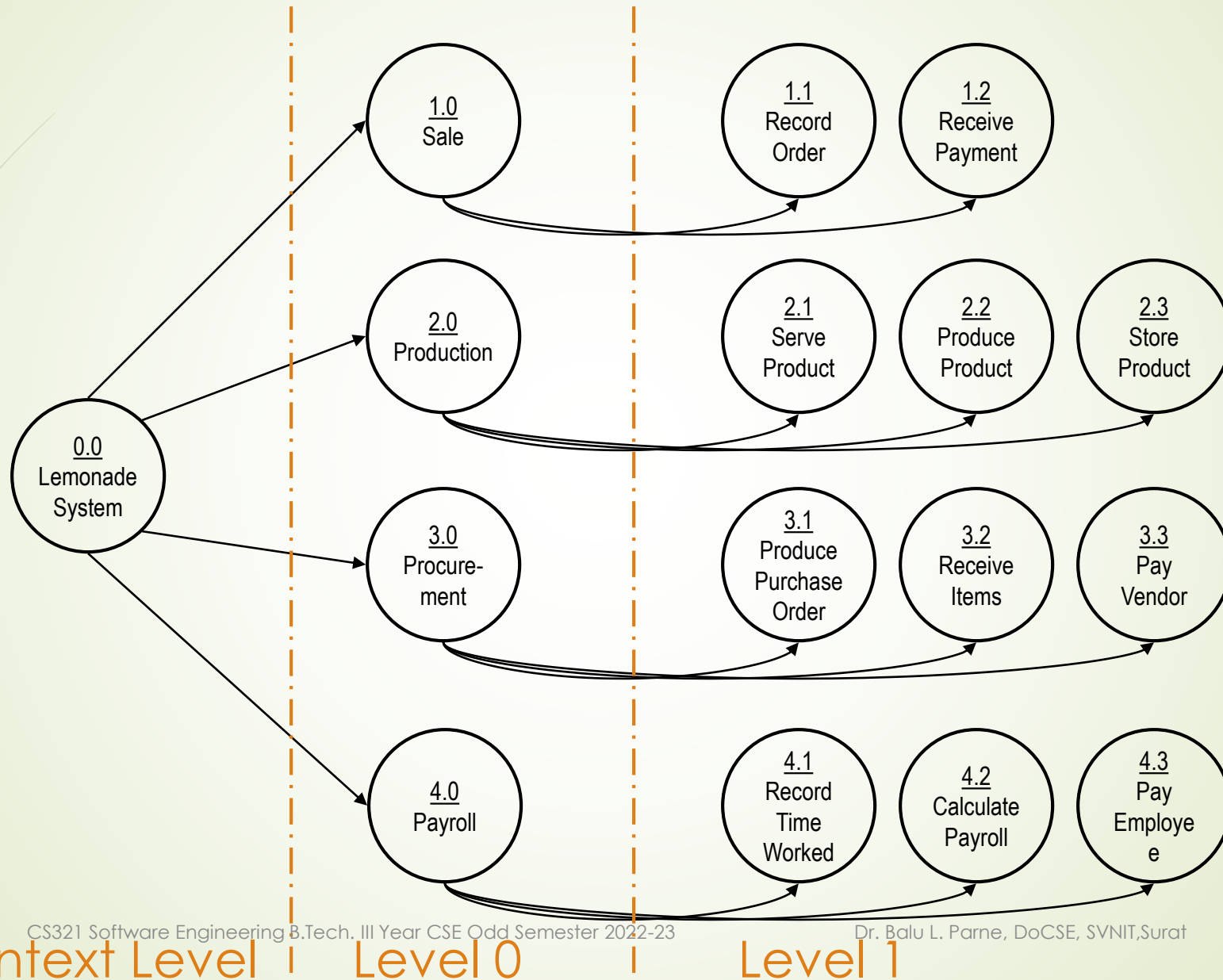
4. Construct Level 1 (continued)

Level 1 DFD



Process Decomposition

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Common Mistakes while Constructing DFD:

- Drawing more than one bubble in the context diagram.
- External entities appearance at all level of DFDs.
- It is common oversight to have either too few or too many bubbles in a DFD. Three to seven are expected.
- Possibility of unbalanced DFD.
- Attempt to represent control flow information in a DFD.

Shortcomings of DFD model

- **Imprecise DFDs leave ample scope to be imprecise**

- Function is judged by its label

e.g. Imprecision in DFD of Information Management systems we have discussed so far (e.g. labels like Sales Forecast, Search a book etc.)

- **Control aspects are not defined by a DFD**

- The order in which inputs are consumed and outputs are produced by a process is not specified
 - Does not specify the order in which different functions are executed

- **Decomposition method is highly subjective**

- Depends on the choice and judgment of the analyst
 - For same problem, several alternative DFDs may exist

Thank You.