Function-Oriented Software Design (continued):

Organization of this Lecture

- A larger example of Structured Analysis
- Structured Design
  - A major objective of this lecture is that you should be able to develop structured design from any DFD model.
- Examples
- Summary

Review of Last Lecture

- The goal of structured analysis:
  - perform functional decomposition.
  - represent using Data Flow Diagrams (DFDs).
- DFDs are a hierarchical model:
  - We examined why any hierarchical model is easy to understand
- During structured analysis:
  - Functional decomposition takes place
  - in addition, data decomposition takes place.
- At the most abstract level:
  - context diagram
  - refined to more detailed levels.

DFD

- Data flow diagram is graphical representation of flow of data in an information system.
- It is capable of depicting incoming data flow, outgoing data flow and stored data.
- The DFD does not mention anything about how data flows through the system.
- Difference between DFD and Flowchart.
  - The flowchart depicts flow of control in program modules.
  - DFDs depict flow of data in the system at various levels. DFD does not contain any control or branch elements.

Types of DFD

- Data Flow Diagrams are either Logical or Physical.
  - **Logical DFD** - This type of DFD concentrates on the system process, and flow of data in the system.
  - For example in a Banking software system, how data is moved between different entities.
  - **Physical DFD** - This type of DFD shows how the data flow is actually implemented in the system.
  - It is more specific and close to the implementation.

DFD Components

- DFD can represent Source, destination, storage and flow of data using the following set of components –

- **Entities** - Entities are source and destination of information data.

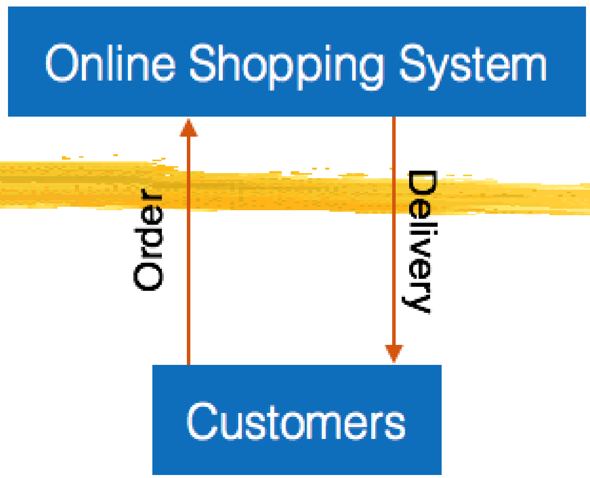
- **Process** - Activities and action taken on the data are represented by Circle or Round-edged rectangles.

- **Data Storage** - There are two variants of data storage - it can either be represented as a rectangle with absence of both smaller sides or as an open-sided rectangle with only one side missing.

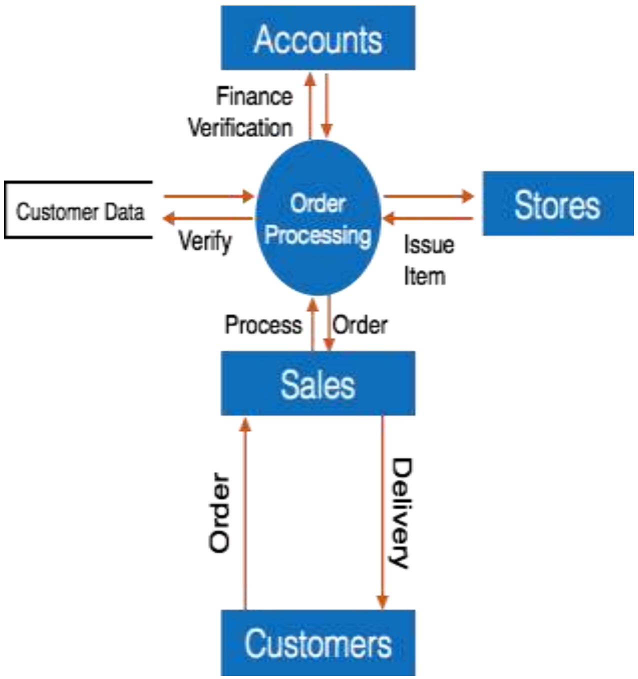
- **Data Flow** - Movement of data is shown by pointed arrows. Data movement is shown from the base of arrow as its source towards head of the arrow as destination.

Levels of DFD

- **Level 0** - Highest abstraction level DFD is known as Level 0 DFD, which depicts the entire information system as one diagram concealing all the underlying details.

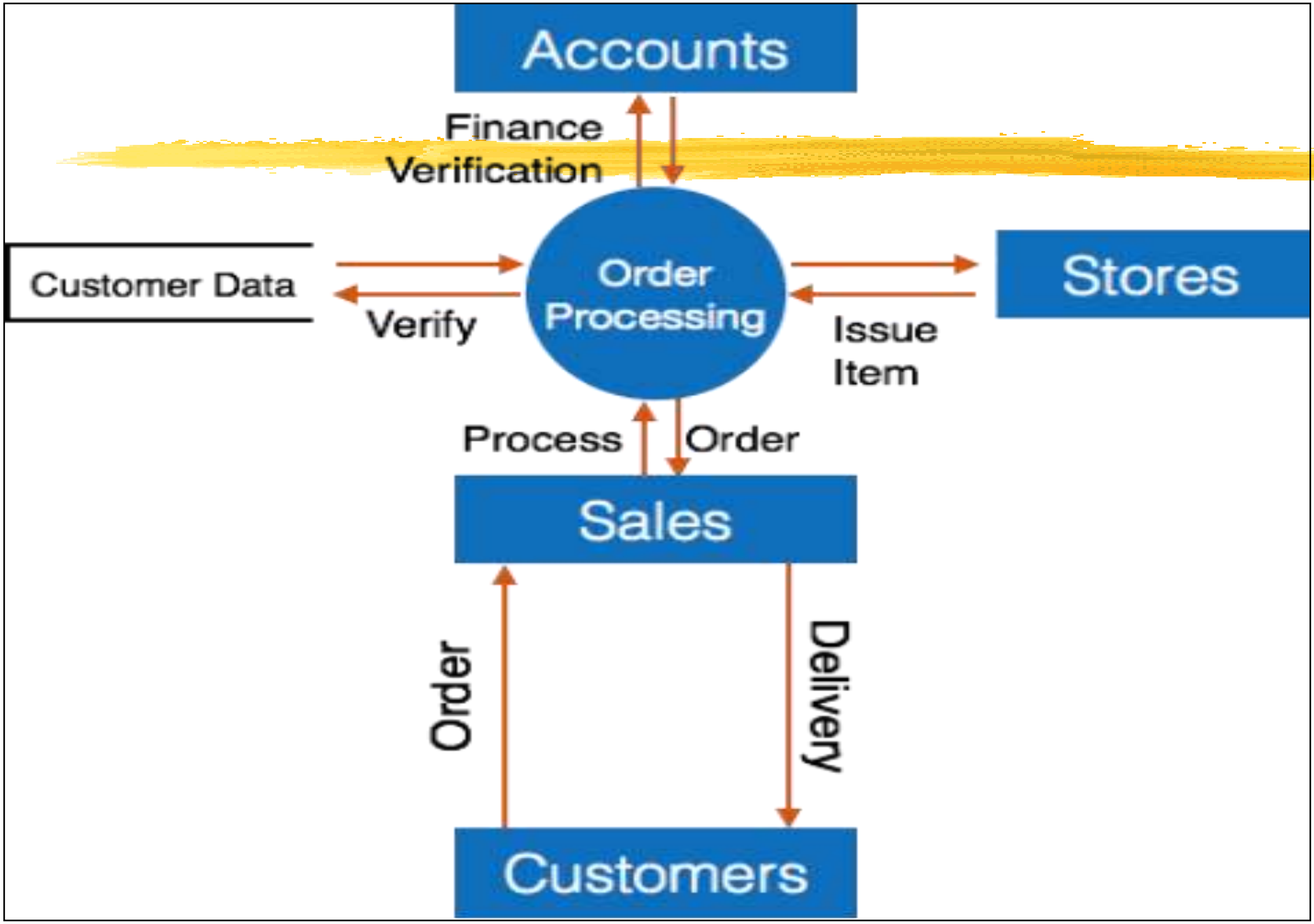


- Level 0 DFDs are also known as **context level** DFDs.



- **Level 1** - The Level 0 DFD is broken down into more specific, Level 1 DFD. Level 1 DFD depicts basic modules in the system and flow of data among various modules.

- Level 1 DFD also mentions basic processes and sources of information.


Accounts
Finance
Verification
Customer Data
Verify
Order
Processing
Stores
Issue
Item
Process
Order
Sales
Order
Delivery
Customers

Levels of DFD

- **Level 2** - At this level, DFD shows how data flows inside the modules mentioned in Level 1.

- Higher level DFDs can be transformed into more specific lower level DFDs with deeper level of understanding unless the desired level of specification is achieved.

DFD of RMS Calculator

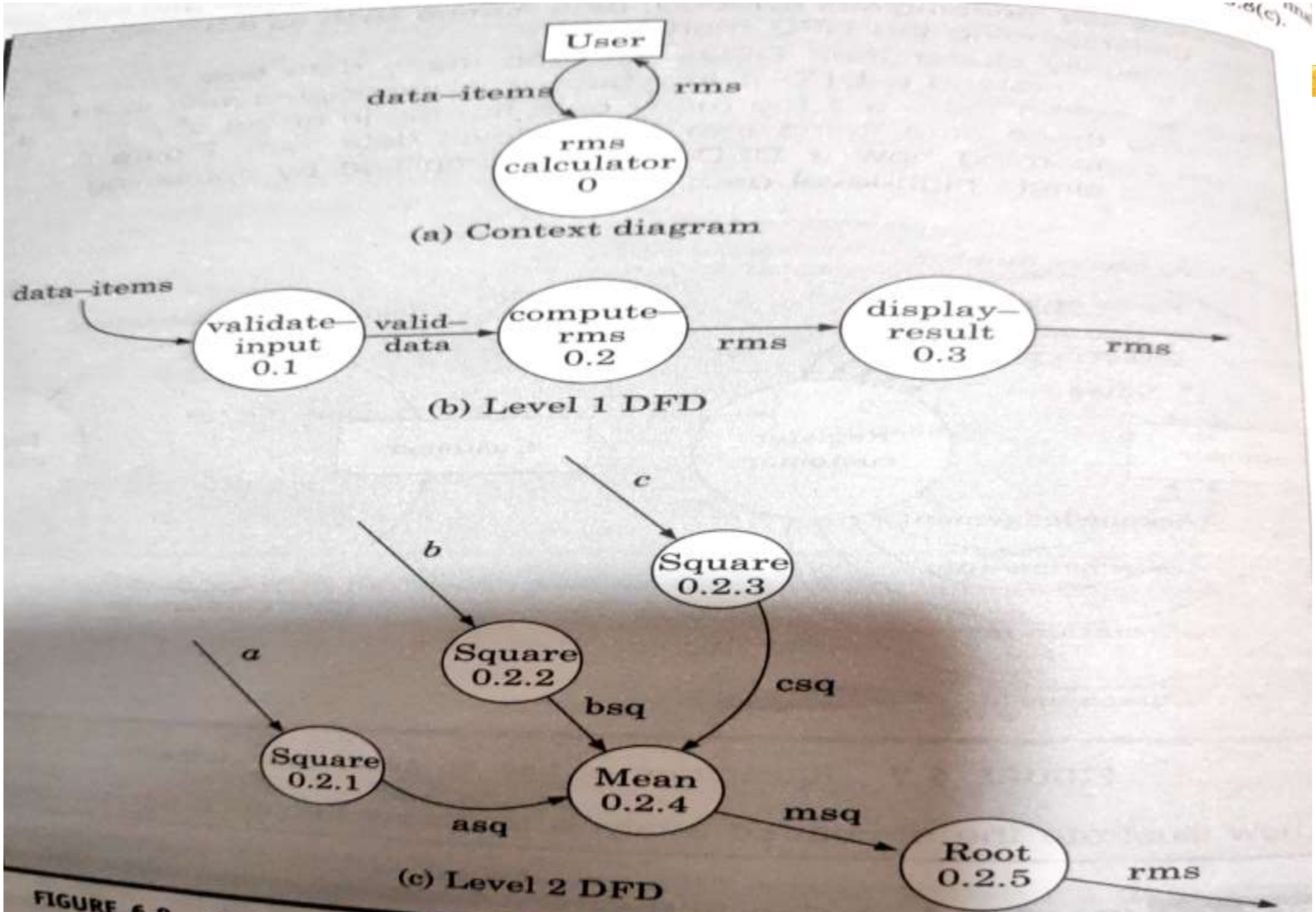
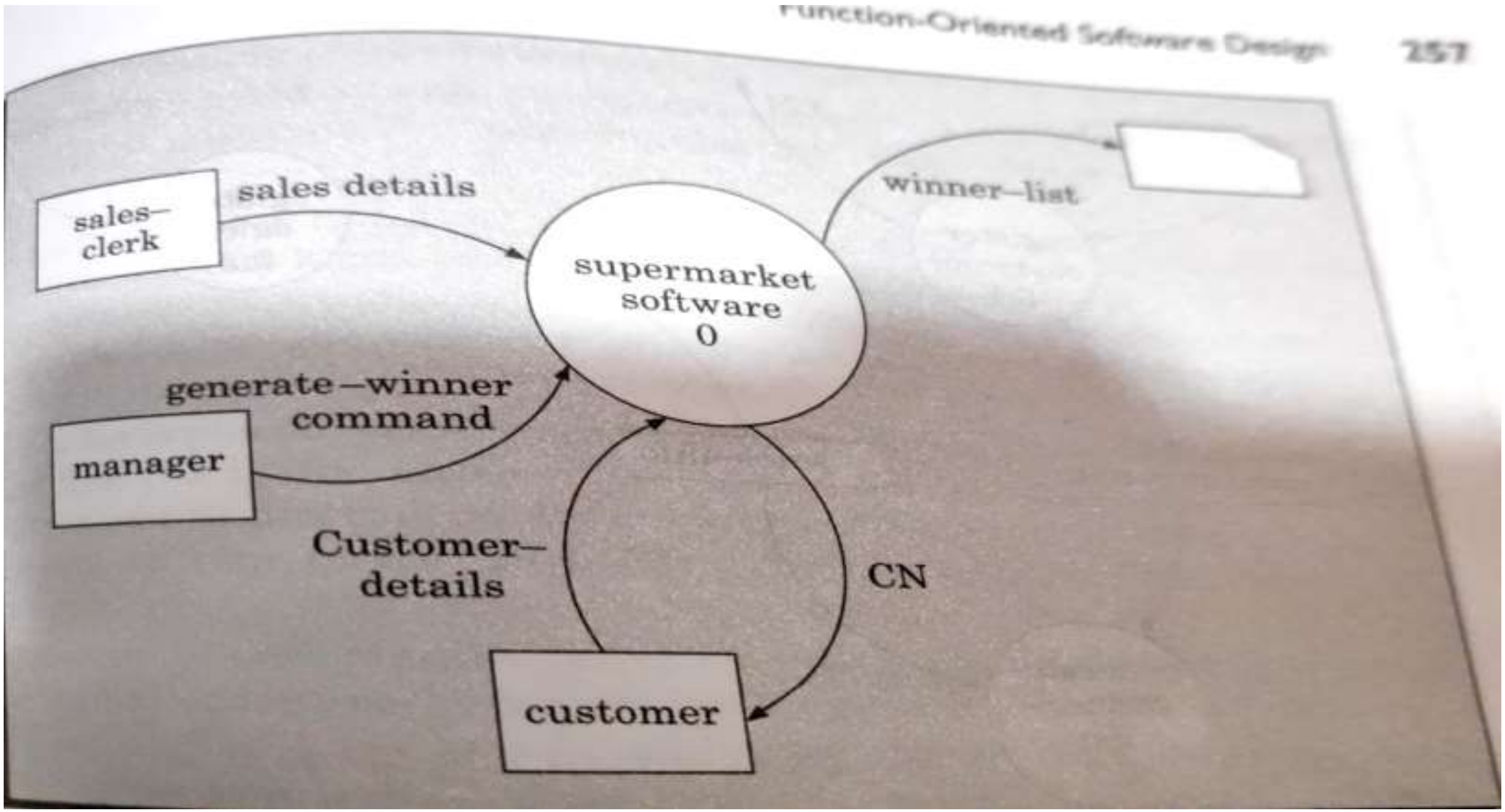


FIGURE 6.8 Context diagram, level 1, and level 2 DFDs for Example 6.1.

Supermarket prize scheme context diagram



DFD of Supermarket prize scheme

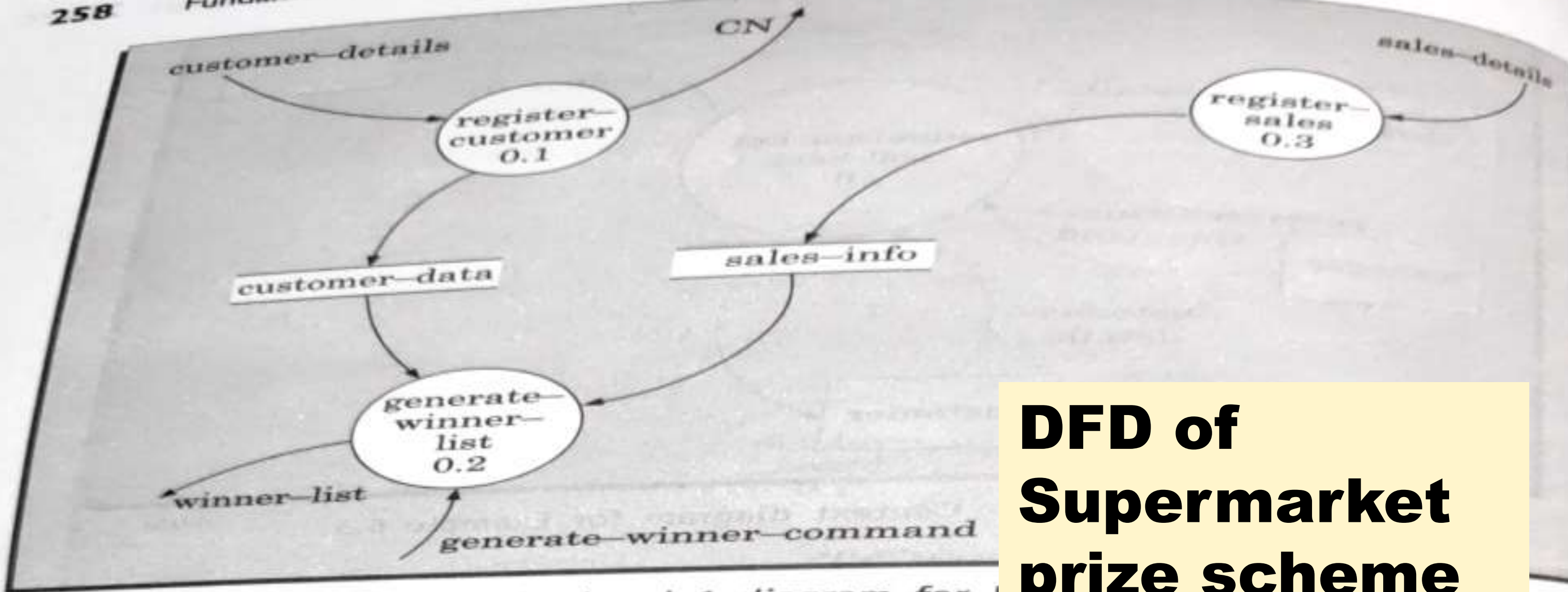


FIGURE 6.11 Level 1 diagram for

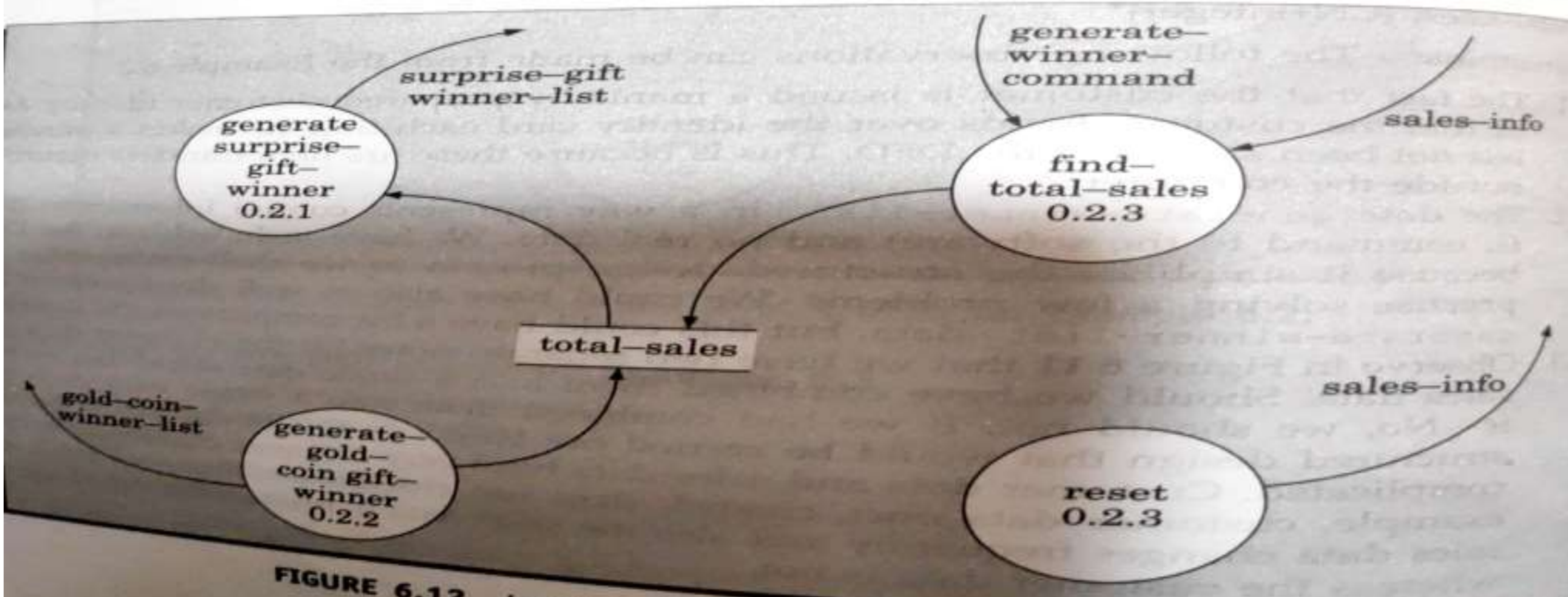


FIGURE 6.12 Level 2 diagram for Exam...

Example 3: Trading-House Automation System (TAS)

- A large trading house wants us to develop a software:
  - to automate book keeping activities associated with its business.
- It has many regular customers:
  - who place orders for various kinds of commodities.
- The trading house maintains names and addresses of its regular customers.
- Each customer is assigned a unique customer identification number (CIN).

- As per current practice when a customer places order:
  - the accounts department first checks the credit-worthiness of the customer.

Example: Trading-House Automation System (TAS)

- The credit worthiness of a customer is determined:
  - by analyzing the history of his payments to the bills sent to him in the past.
- If a customer is not credit-worthy:
  - his orders are not processed any further
  - an appropriate order rejection message is generated for the customer.
- If a customer is credit-worthy:
  - items he/she has ordered are checked against the list of items the trading house deals with.
- The items that the trading house does not deal with:
  - are not processed any further
  - an appropriate message for the customer for these items is generated.

Example: Trading-House Automation System (TAS)

- The items in a customer's order that the trading house deals with:
  - are checked for availability in the inventory.
- If the items are available in the inventory in desired quantities:
  - a bill with the forwarding address of the customer is printed.
  - a material issue slip is printed.
- The customer can produce the material issue slip at the store house:
  - take delivery of the items.
  - inventory data adjusted to reflect the sale to the customer.

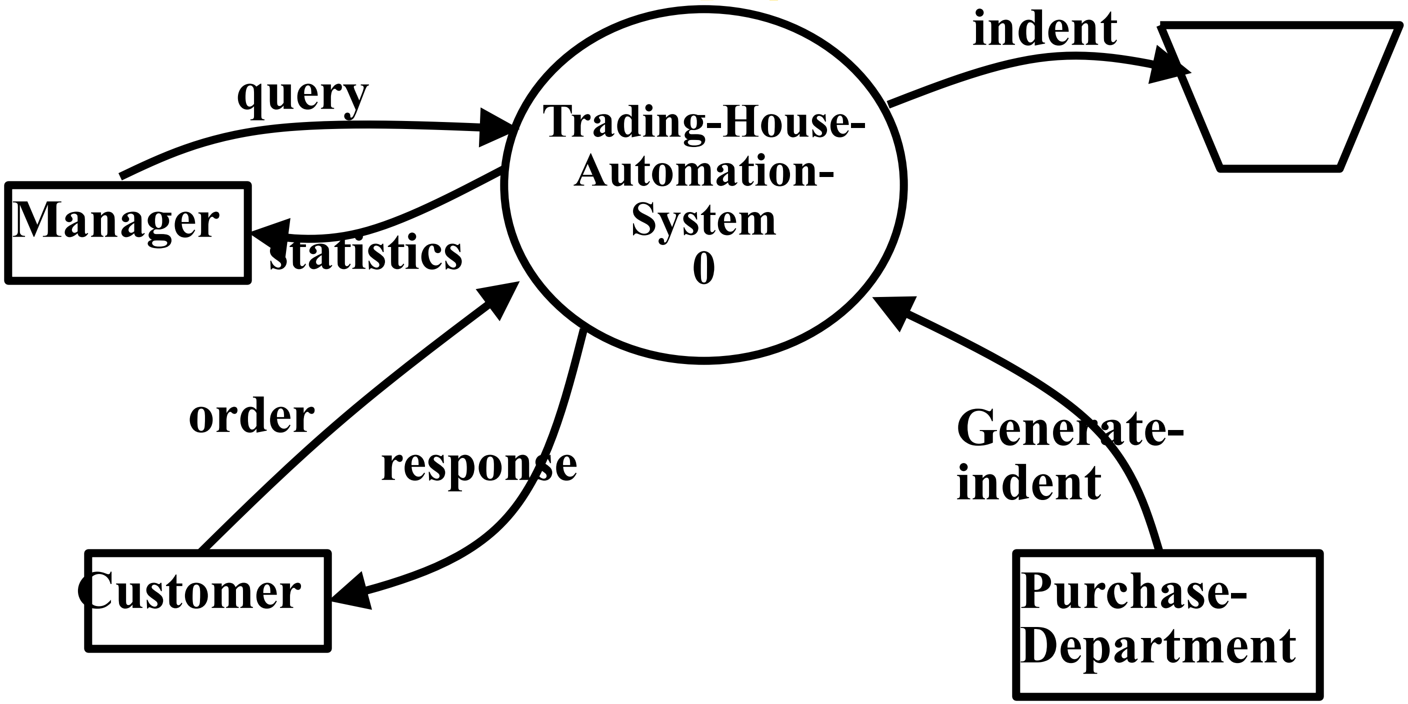
Example: Trading-House Automation System (TAS)

- If an ordered item is not available in the inventory in sufficient quantity:
  - to be able to fulfill pending orders store details in a "pending-order" file :
    - out-of-stock items along with quantity ordered.
    - customer identification number
- The purchase department:
  - would periodically issue commands to generate indents.
- When generate indents command is issued:
  - the system should examine the "pending-order" file
  - determine the orders that are pending
  - total quantity required for each of the items.

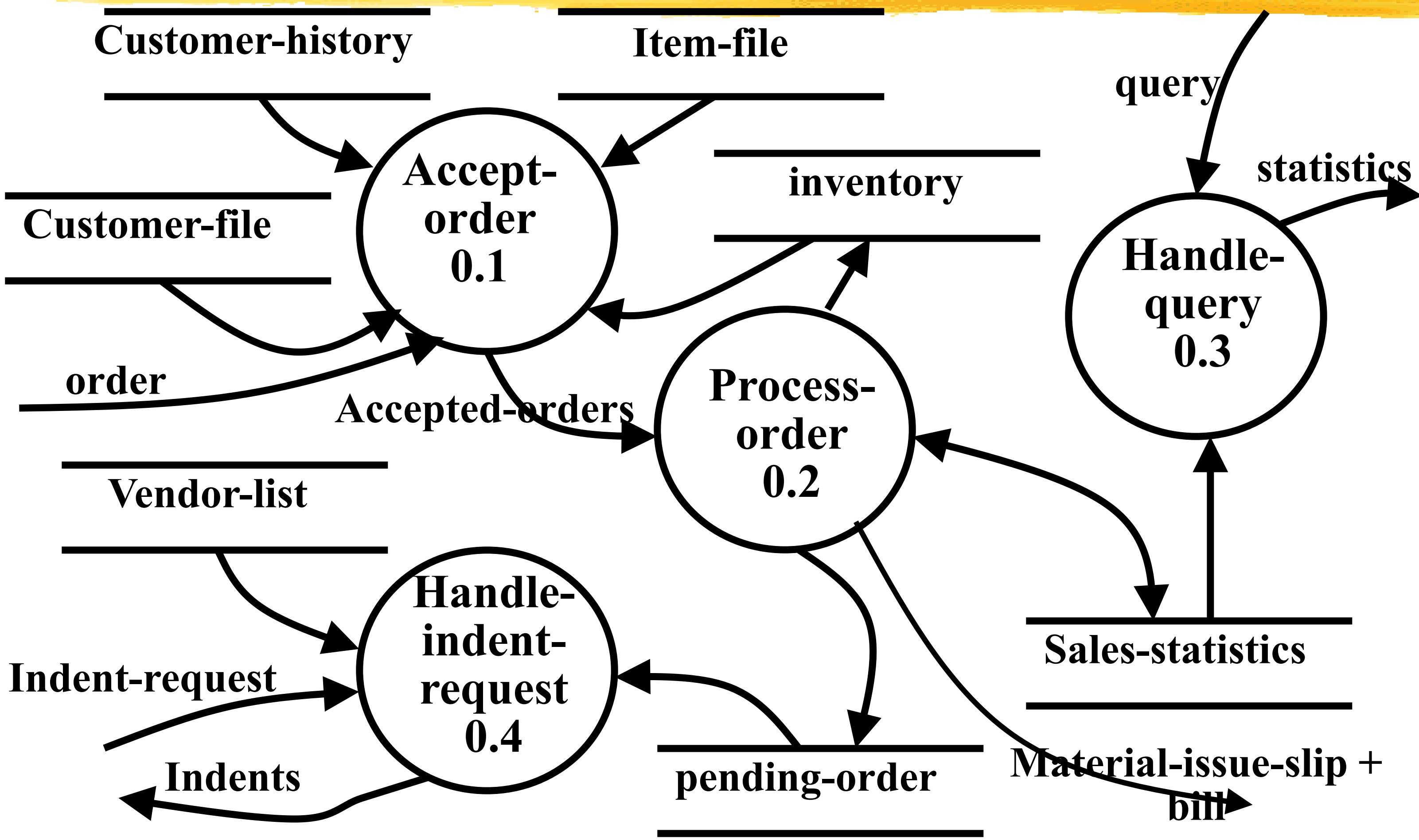
Example: Trading-House Automation System (TAS)

- TAS should find out the addresses of the vendors who supply the required items:
  - examine the file containing vendor details (their address, items they supply etc.)
  - print out indents to those vendors.
- TAS should also answers managerial queries:
  - statistics of different items sold over any given period of time
  - corresponding quantity sold and the price realized.

Context Diagram



Level 1 DFD


Customer-history
Item-file
query
Accept-order 0.1
inventory
statistics
Customer-file
Handle-query 0.3
order
Process-order 0.2
Accepted-orders
Vendor-list
Handle-indent-request 0.4
Sales-statistics
Indent-request
Indents
pending-order
Material-issue-slip + bill

Example: Data Dictionary

- response: [bill + material-issue-slip, reject-message]
- query: period /* query from manager regarding sales statistics*/
- period: [date+date,month,year,day]
- date: year + month + day
- year: integer
- month: integer
- day: integer
- order: customer-id + {items + quantity}*
- accepted-order: order /* ordered items available in inventory */
- reject-message: order + message /* rejection message */
- pending-orders: customer-id + {items+quantity}*
- customer-address: name+house#+street#+city+pin

Example: Data Dictionary

- item-name: string
- house#: string
- street#: string
- city: string
- pin: integer
- customer-id: integer
- bill: {item + quantity + price}* + total-amount + customer-address
- material-issue-slip: message + item + quantity + customer-address
- message: string
- statistics: {item + quantity + price }*
- sales-statistics: {statistics}*
- quantity: integer

Observation

- From the examples,
  - observe that DFDs help create:
    - data model
    - function model
- As a DFD is refined into greater levels of detail:
  - the analyst performs an implicit functional decomposition.
  - At the same time, refinements of data takes place.

Guidelines For Constructing DFDs

- **Context diagram should represent the system as a single bubble:**
  - **Many beginners commit the mistake of drawing more than one bubble in the context diagram.**
- **All external entities should be represented in the context diagram:**
  - **external entities should not appear at any other level of DFD.**
- **Only 3 to 7 bubbles per diagram should be allowed:**
  - **each bubble should be decomposed to between 3 and 7 bubbles.**

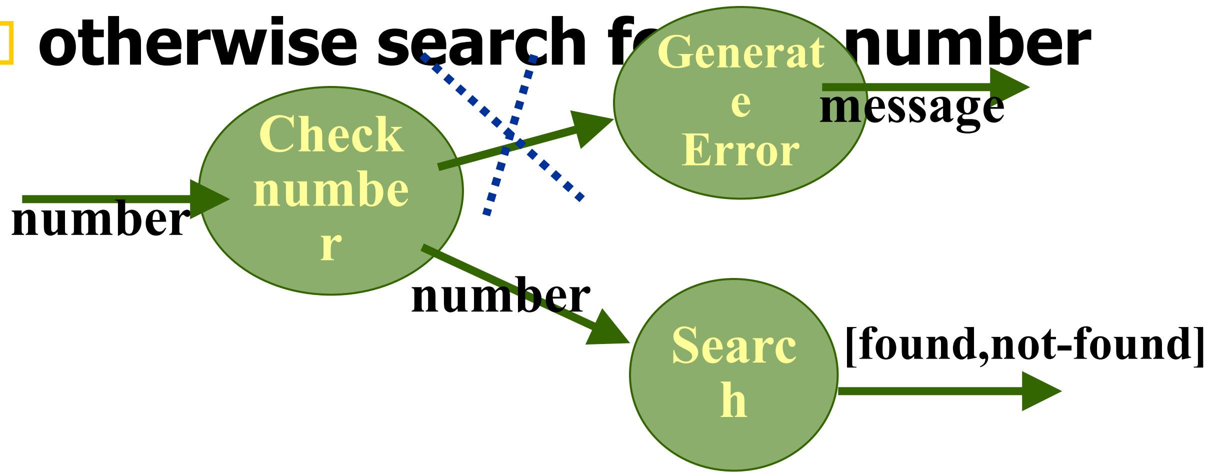
Guidelines For Constructing DFDs

- A common mistake committed by many beginners:
  - attempting to represent control information in a DFD.
  - e.g. trying to represent the order in which different functions are executed.

- A DFD does not represent control information:
  - when or in what order different functions (processes) are invoked
  - the conditions under which different functions are invoked are not represented.
  - For example, a function might invoke one function or another depending on some condition.

Example-1

- Check the input value:
  - If the input value is less than -1000 or greater than +1000 generate an error message
  - otherwise search fo number

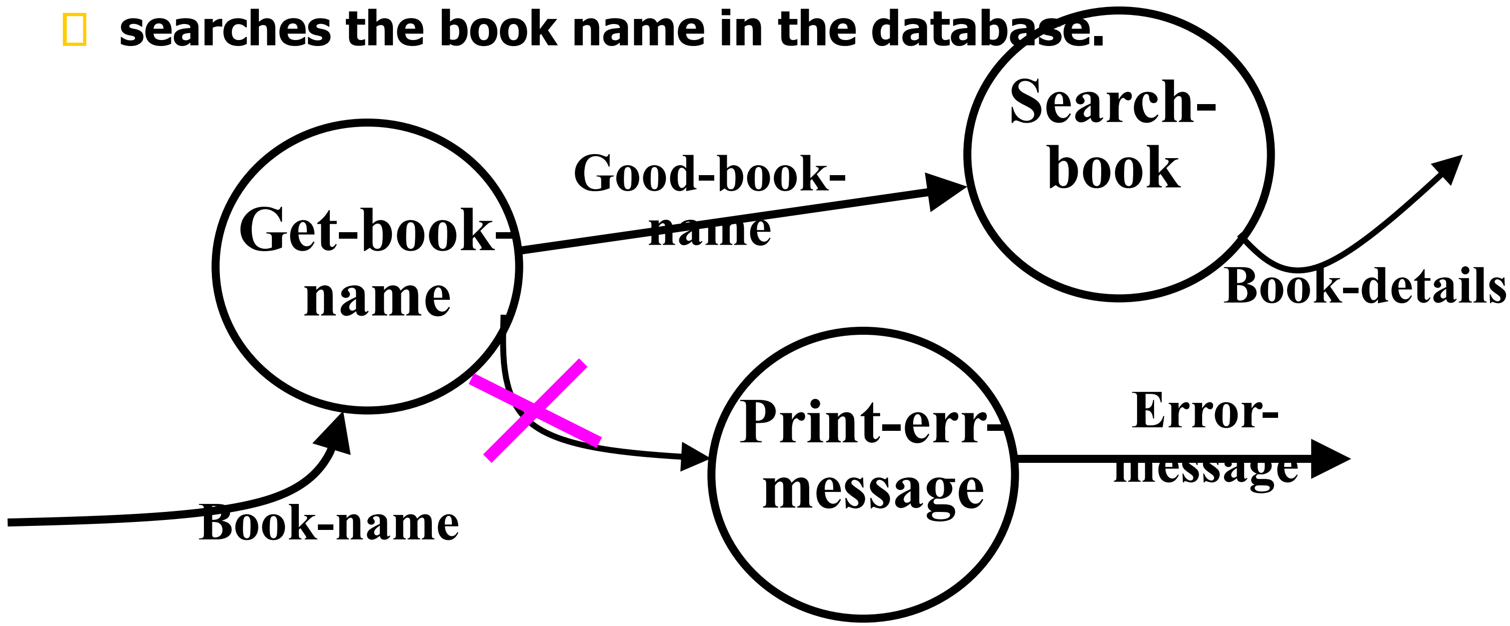


Guidelines For Constructing DFDs

- If a bubble A invokes either bubble B or bubble C depending on some conditions:
  - represent the data that flows from bubble A to bubble B and bubbles A to C
  - not the conditions depending on which a process is invoked.

Example-2

- A function accepts the book name to be searched from the user
- If the entered book name is not a valid book name
  - generates an error message,
- If the book name is valid,
  - searches the book name in the database.



Guidelines For Constructing DFDs

- All functions of the system must be captured in the DFD model:
  - no function specified in the SRS document should be overlooked.

- Only those functions specified in the SRS document should be represented:
  - do not assume extra functionality of the system not specified by the SRS document.

Commonly made errors

- Unbalanced DFDs
- Forgetting to mention the names of the data flows
- Unrepresented functions or data
- External entities appearing at higher level DFDs
- Trying to represent control aspects
- Context diagram having more than one bubble
- A bubble decomposed into too many bubbles in the next level
- Terminating decomposition too early
- Nouns used in naming bubbles

Shortcomings of the DFD Model

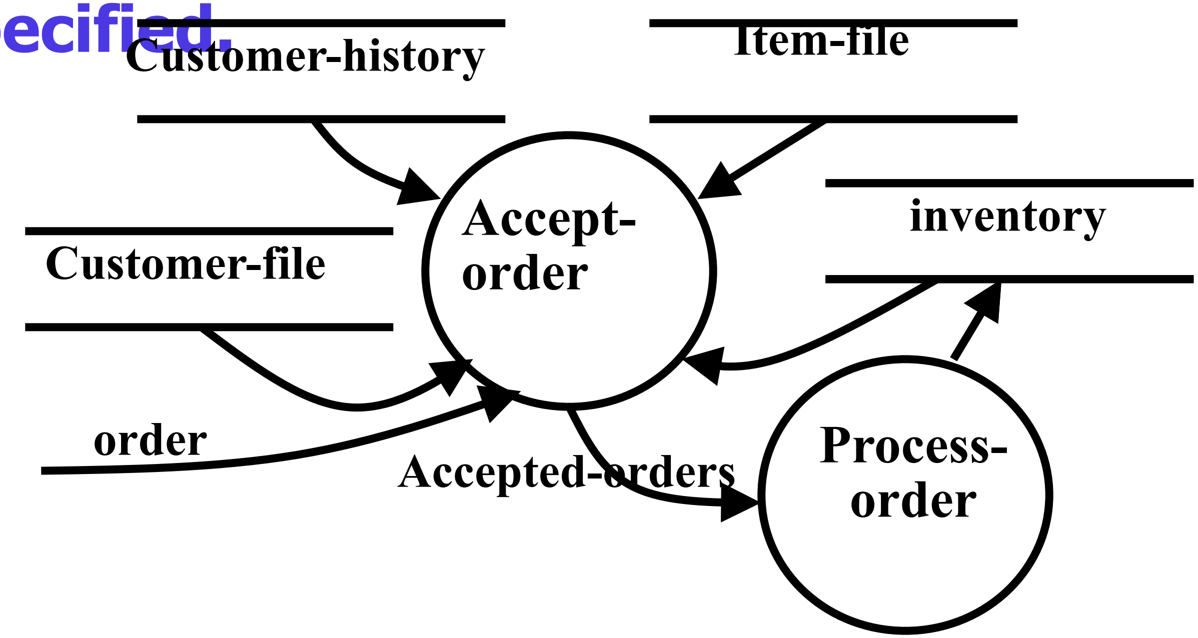
- DFD models suffer from several shortcomings:
- DFDs leave ample scope to be imprecise.
  - In a DFD model, we infer about the function performed by a bubble from its label.
  - A label may not capture all the functionality of a bubble.

Shortcomings of the DFD Model

- For example, a bubble named find-book-position has only intuitive meaning:
  - does not specify several things:
    - what happens when some input information is missing or is incorrect.
    - Does not convey anything regarding what happens when book is not found
    - or what happens if there are books by different authors with the same book title.

Shortcomings of the DFD Model

- Control information is not represented:
  - For instance, order in which inputs are consumed and outputs are produced is not specified.



Creating Data Flow Diagrams

Lemonade Stand Example

Creating Data Flow Diagrams

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**
   - **Old way: no Use-Case Diagram**
   - **New way: use Use-Case Diagram**
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

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

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

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

Example

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

Customer Order
Serve Product
Collect Payment

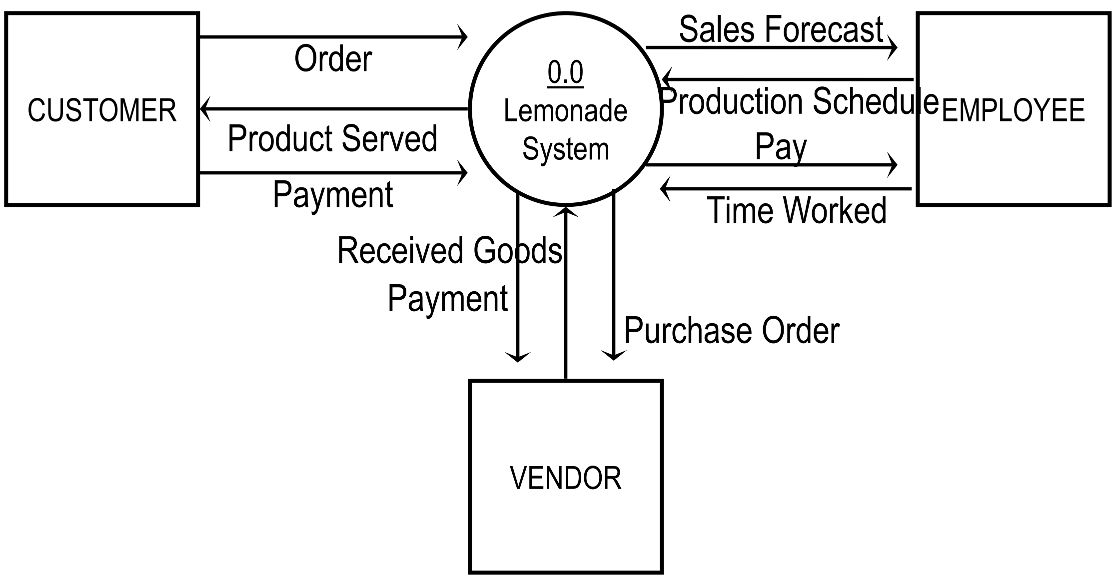
Produce Product
Store Product

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

Example

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

Customer Order
Serve Product
Collect Payment

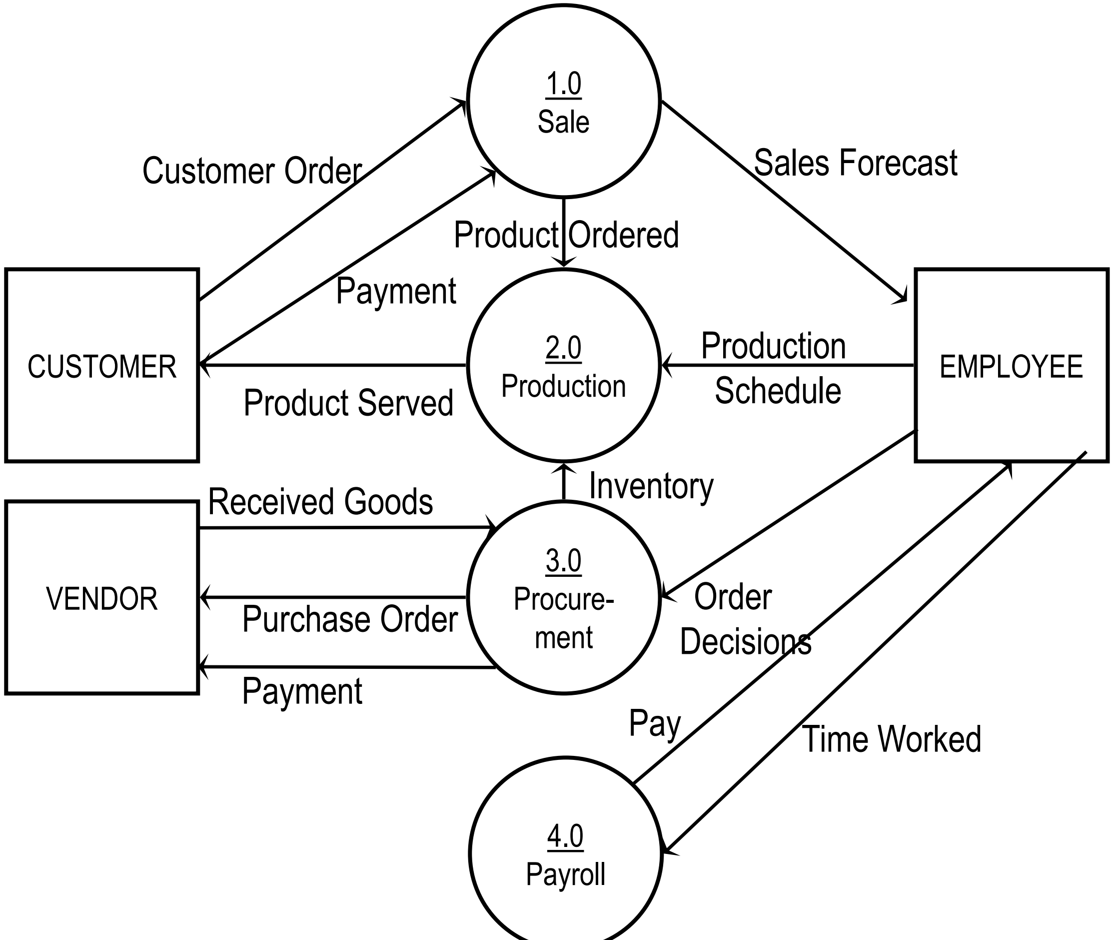
Produce Product
Store Product

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

Example

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

Customer Order
Serve Product
Collect Payment

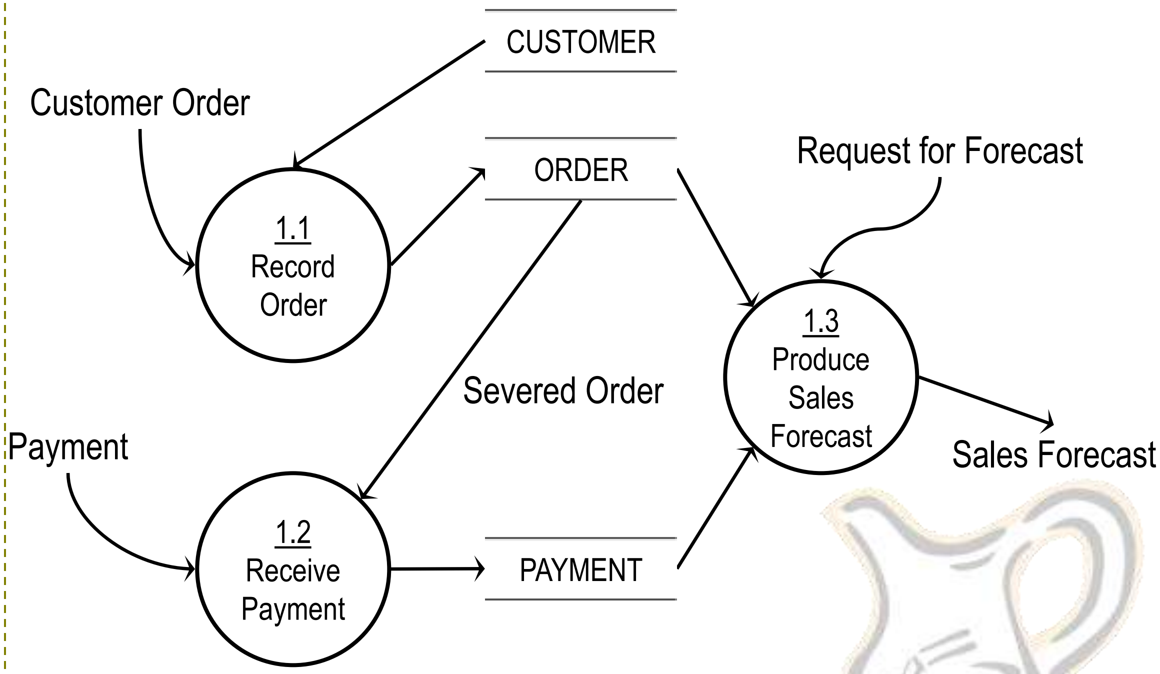
Produce Product
Store Product

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

Example

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

Customer Order
Serve Product
Collect Payment

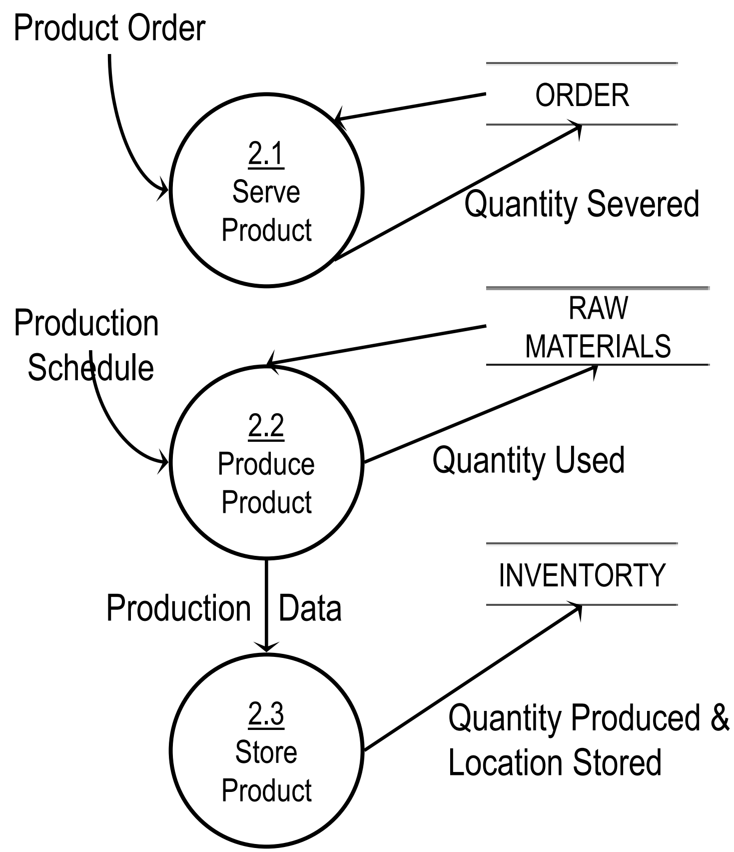
Produce Product
Store Product

Order Raw Materials
Pay for Raw Materials

Pay for Labor

4. Construct Level 1 (continued)

Level 1 DFD



Creating Data Flow Diagrams

Example

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Collect Payment

Produce Product
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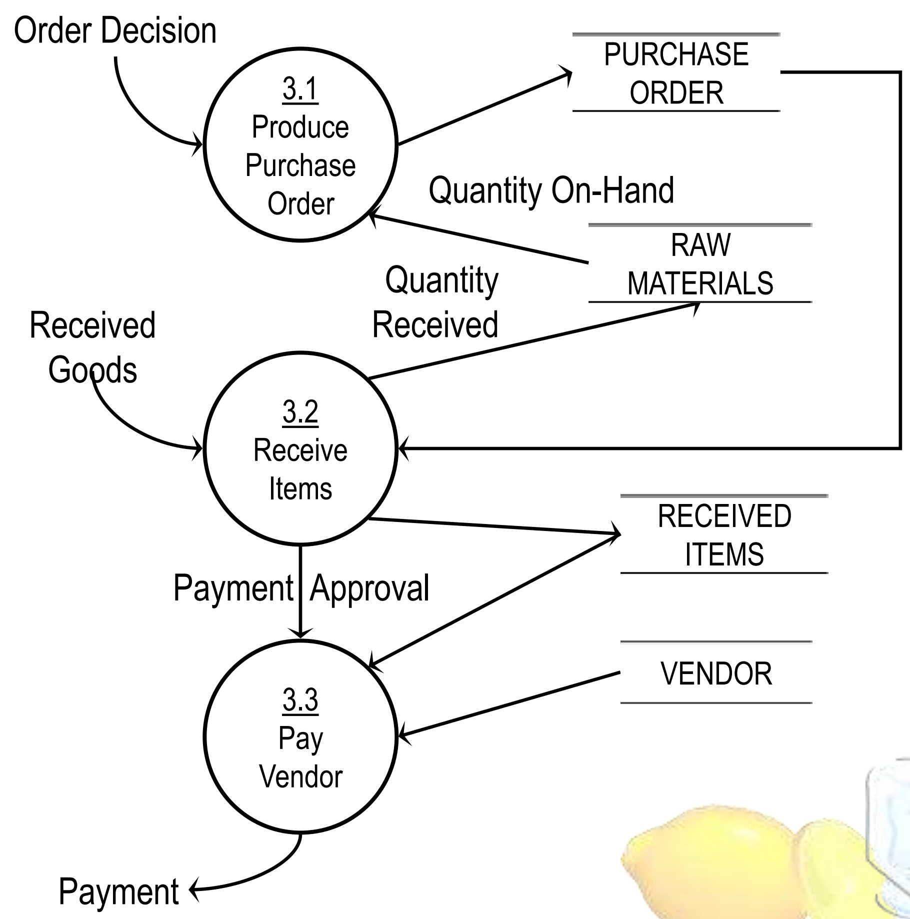
Order Raw Materials
Pay for Raw Materials

Pay for Labor

4. Construct Level 1 (continued)

Level 1 DFD



Creating Data Flow Diagrams

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

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Pay for Raw Materials

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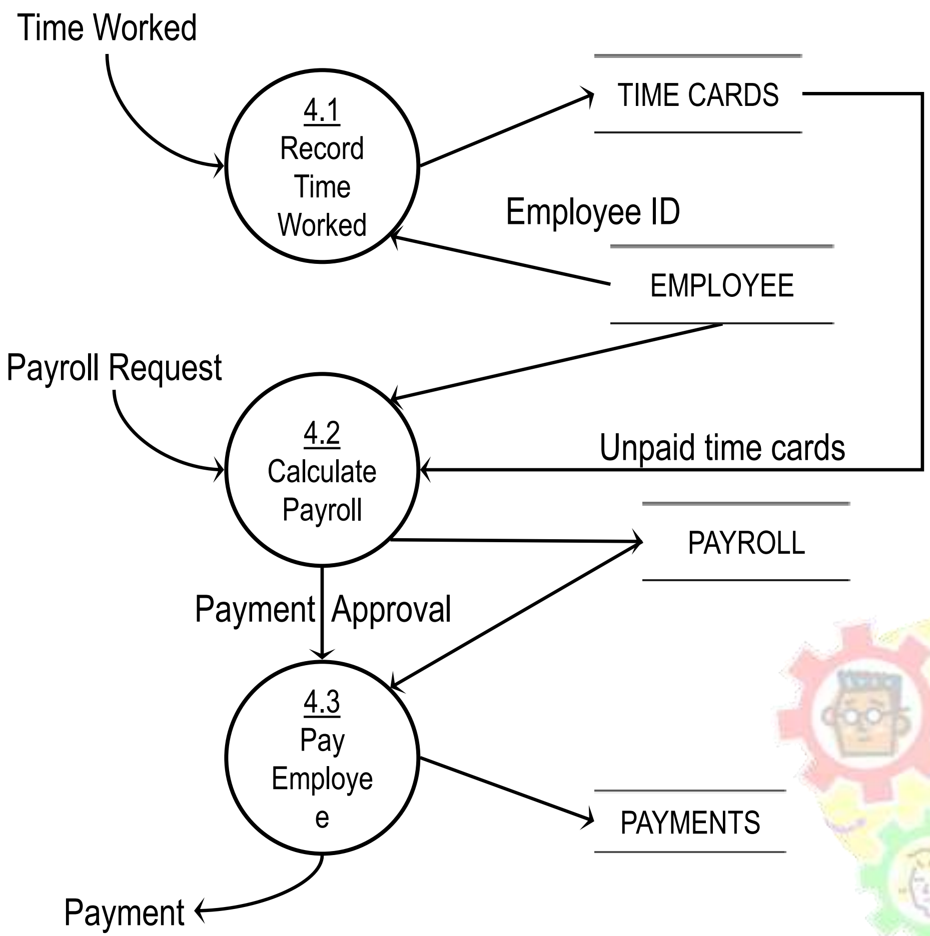
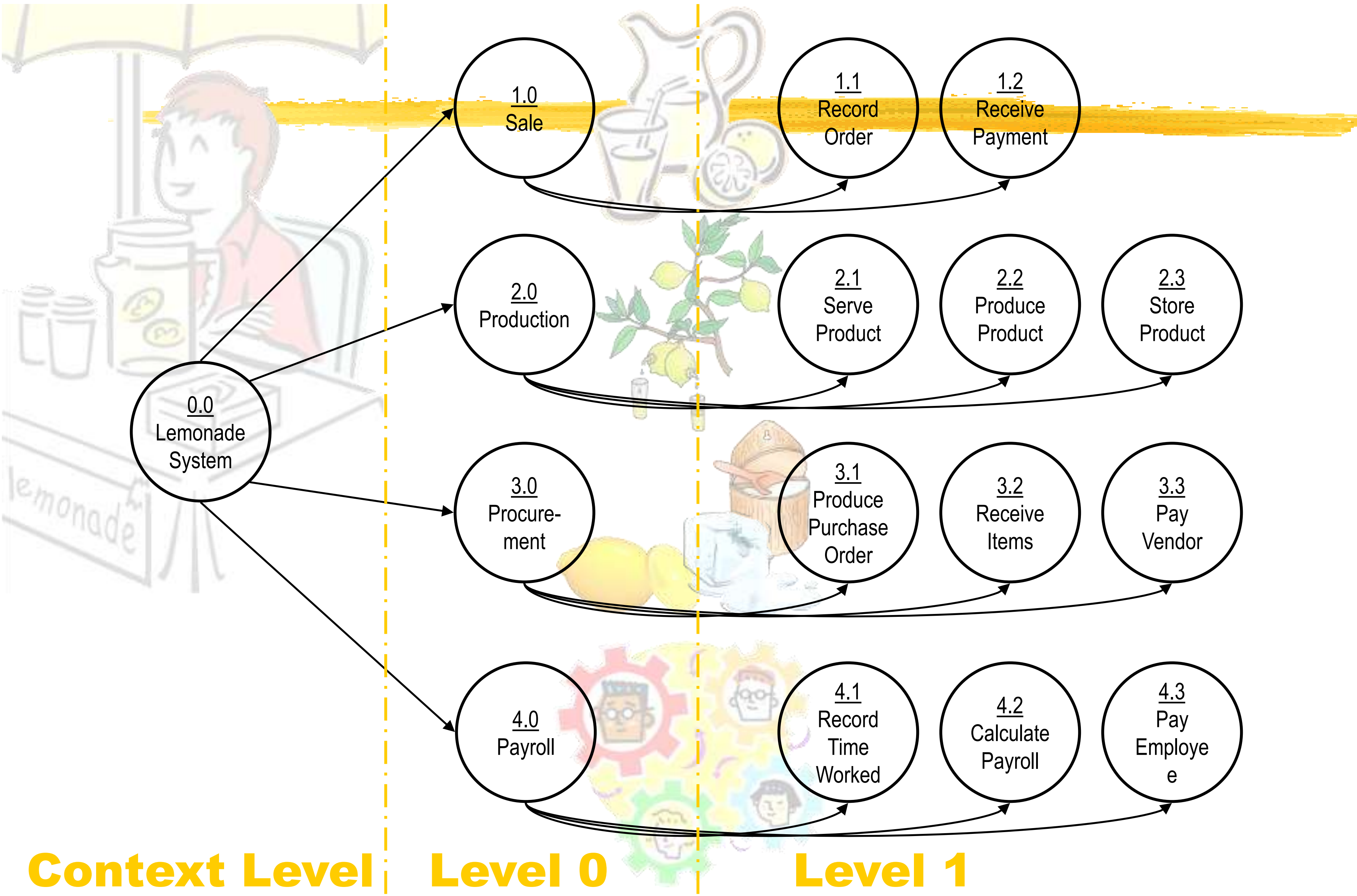
4. Construct Level 1 (continued)

Level 1 DFD



Process Decomposition



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- External entities appearing at higher level DFDs
- Trying to represent control aspects
- Context diagram having more than one bubble
- A bubble decomposed into too many bubbles in the next level
- Terminating decomposition too early
- Nouns used in naming bubbles

Shortcomings of the DFD Model

- DFD technique does not provide:
  - any clear guidance as to how exactly one should go about decomposing a function:
  - one has to use subjective judgement to carry out decomposition.
- Structured analysis techniques do not specify when to stop a decomposition process:
  - to what length decomposition needs to be carried out.

Extending DFD Technique to Real-Time Systems

- For real-time systems (systems having time bounds on their actions),
  - essential to model control flow and events.
  - Widely accepted technique: Ward and Mellor technique.
    - a type of process (bubbles) that handles only control flows is introduced.
    - These processes are represented using dashed circles.

Structured Design

- The aim of structured design
  - transform the results of structured analysis (i.e., a DFD representation) into a structure chart.
- A structure chart represents the software architecture:
  - various modules making up the system,
  - module dependency (i.e. which module calls which other modules),
  - parameters passed among different modules.

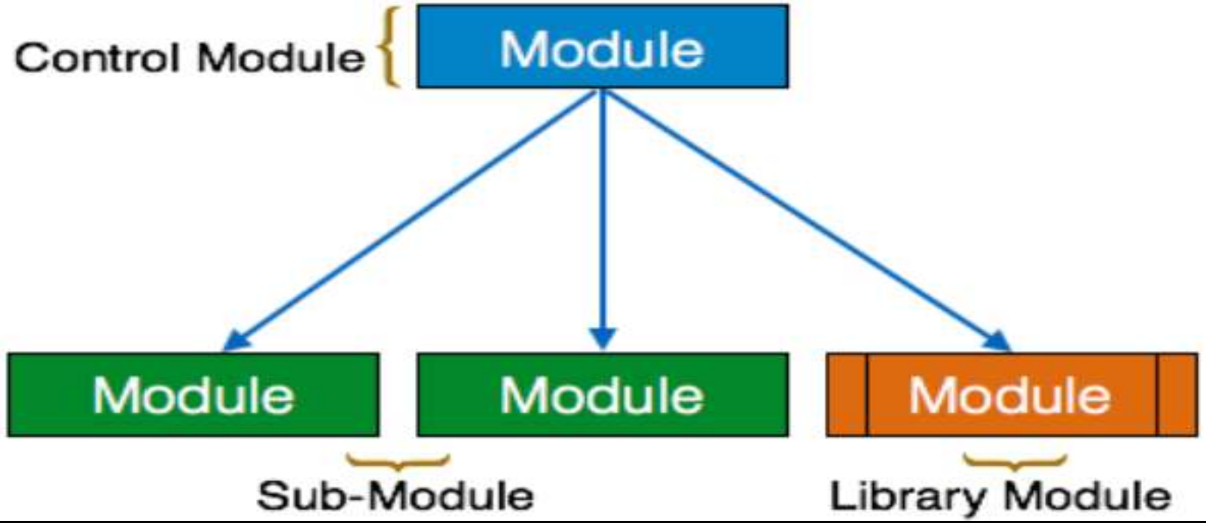
Structure Charts

Structure chart is a chart derived from Data Flow Diagram. It represents the system in more detail than DFD. It breaks down the entire system into lowest functional modules, describes functions and sub-functions of each module of the system to a greater detail than DFD.

Structure chart represents hierarchical structure of modules. At each layer a specific task is performed.

Here are the symbols used in construction of structure charts -

- **Module** - It represents process or subroutine or task. A control module branches to more than one sub-module. Library Modules are re-usable and invokable from any module.



Structure Chart

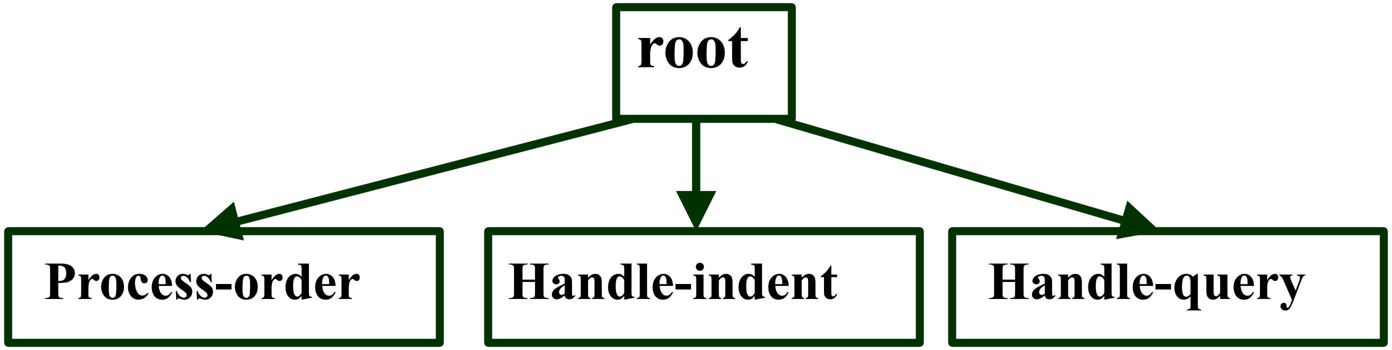
- Structure chart representation
  - easily implementable using programming languages.
- Main focus of a structure chart:
  - define the module structure of a software,
  - interaction among different modules,
  - procedural aspects (e.g, how a particular functionality is achieved) are not represented.

1. Basic building blocks of structure chart

- Rectangular box:
  - A rectangular box represents a module.
  - annotated with the name of the module it represents.

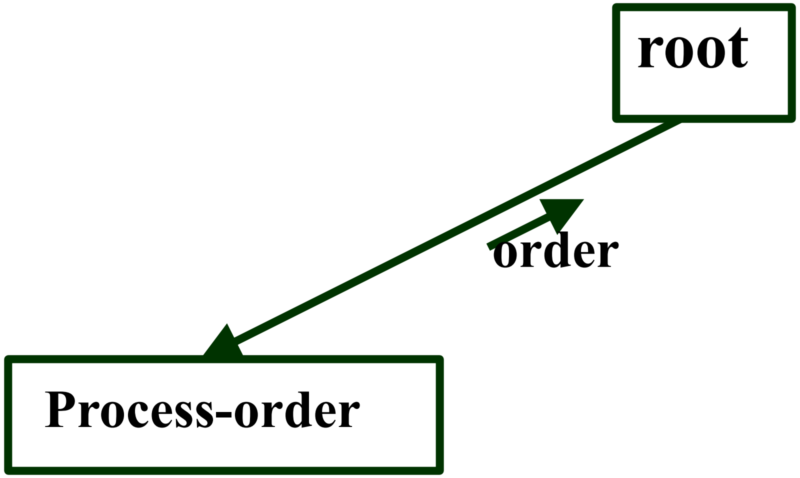
2. Arrows

- An arrow between two modules implies:
  - during execution control is passed from one module to the other in the direction of the arrow.

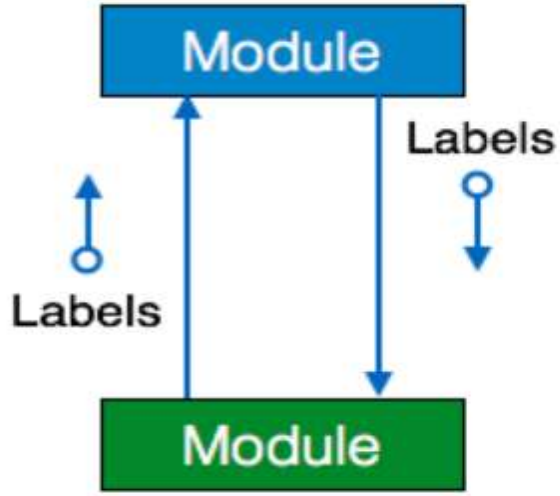


3. Data flow Arrows

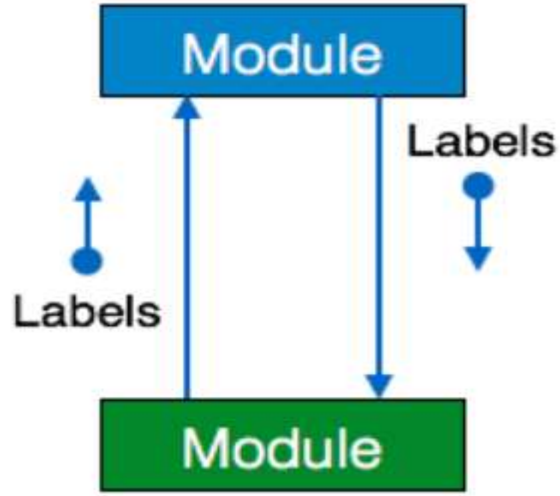
- Data flow arrows represent:
  - data passing from one module to another in the direction of the arrow.



- **Data flow** - A directed arrow with empty circle at the end represents data flow.



- **Control flow** - A directed arrow with filled circle at the end represents control flow.

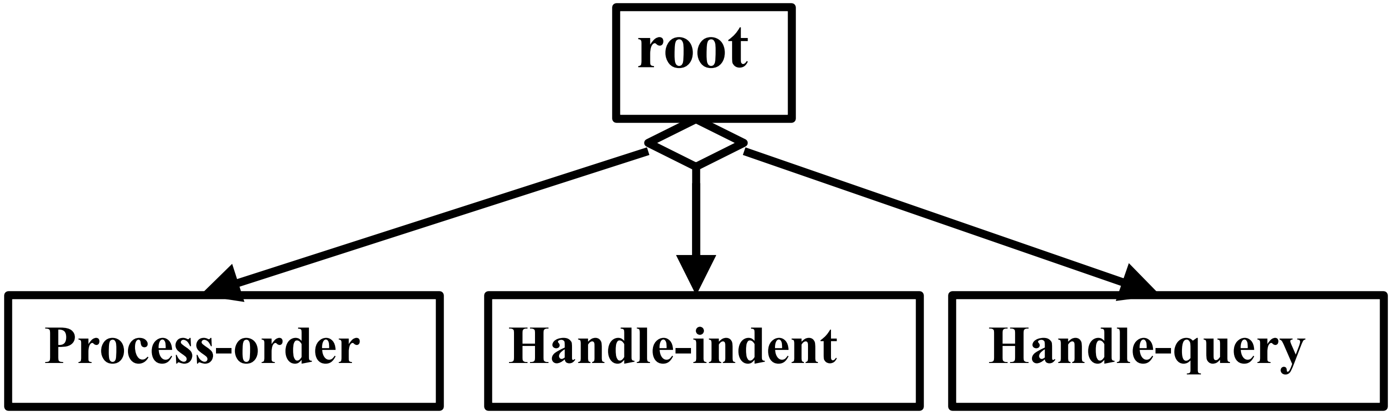


4. Library modules

- Library modules represent frequently called modules:
  - a rectangle with double side edges.
  - Simplifies drawing when a module is called by several modules.

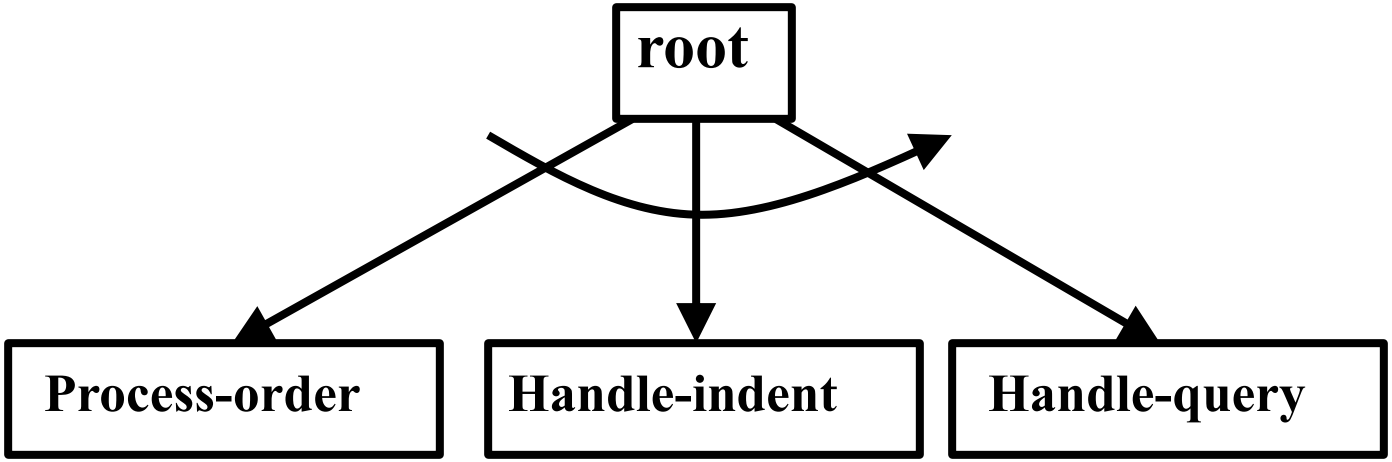
5. Selection

- The diamond symbol represents:
  - one module of several modules connected to the diamond symbol is invoked depending on some condition.



6. Repetition

- A loop around control flow arrows denotes that the concerned modules are invoked repeatedly.



Structure Chart

- There is only one module at the top:
  - the root module.
- There is at most one control relationship between any two modules:
  - if module A invokes module B,
  - module B cannot invoke module A.
- The main reason behind this restriction:
  - consider modules in a structure chart to be arranged in layers or levels.

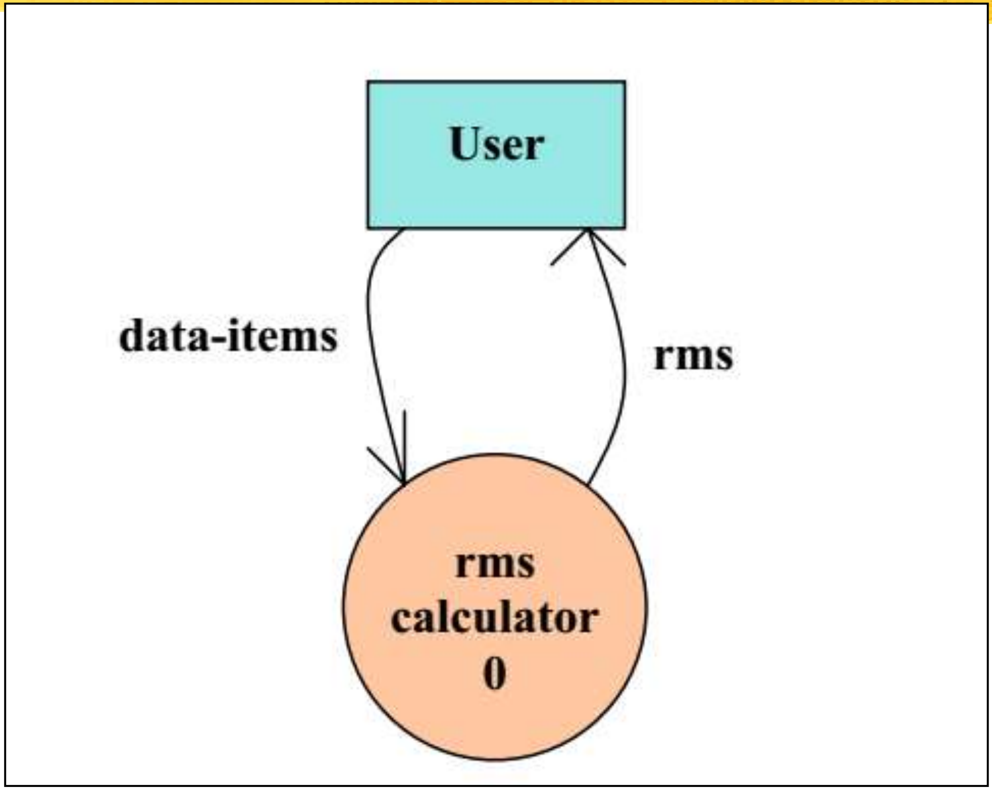
Structure Chart

- The principle of abstraction:
  - does not allow lower-level modules to invoke higher-level modules:
  - But, two higher-level modules can invoke the same lower-level module.

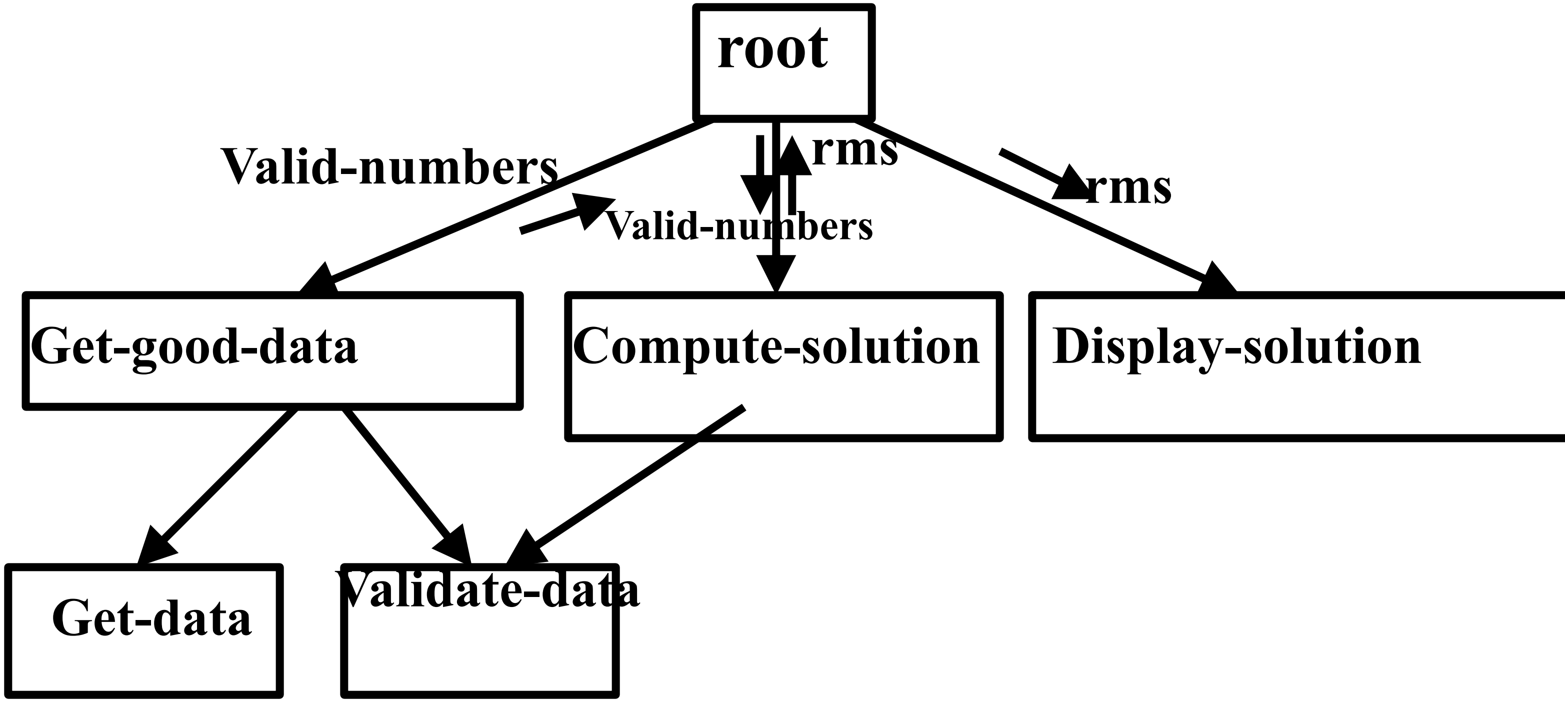
RMS calculator

RMS Calculator :

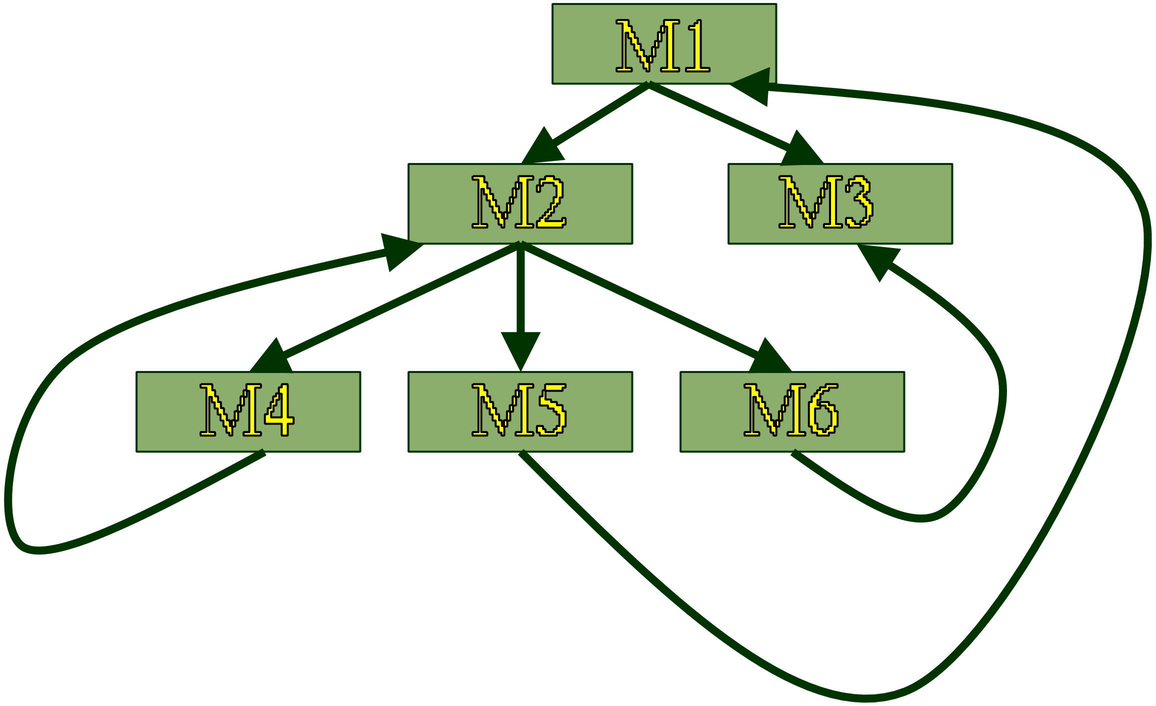
Reads three integers and determine Root Mean Square



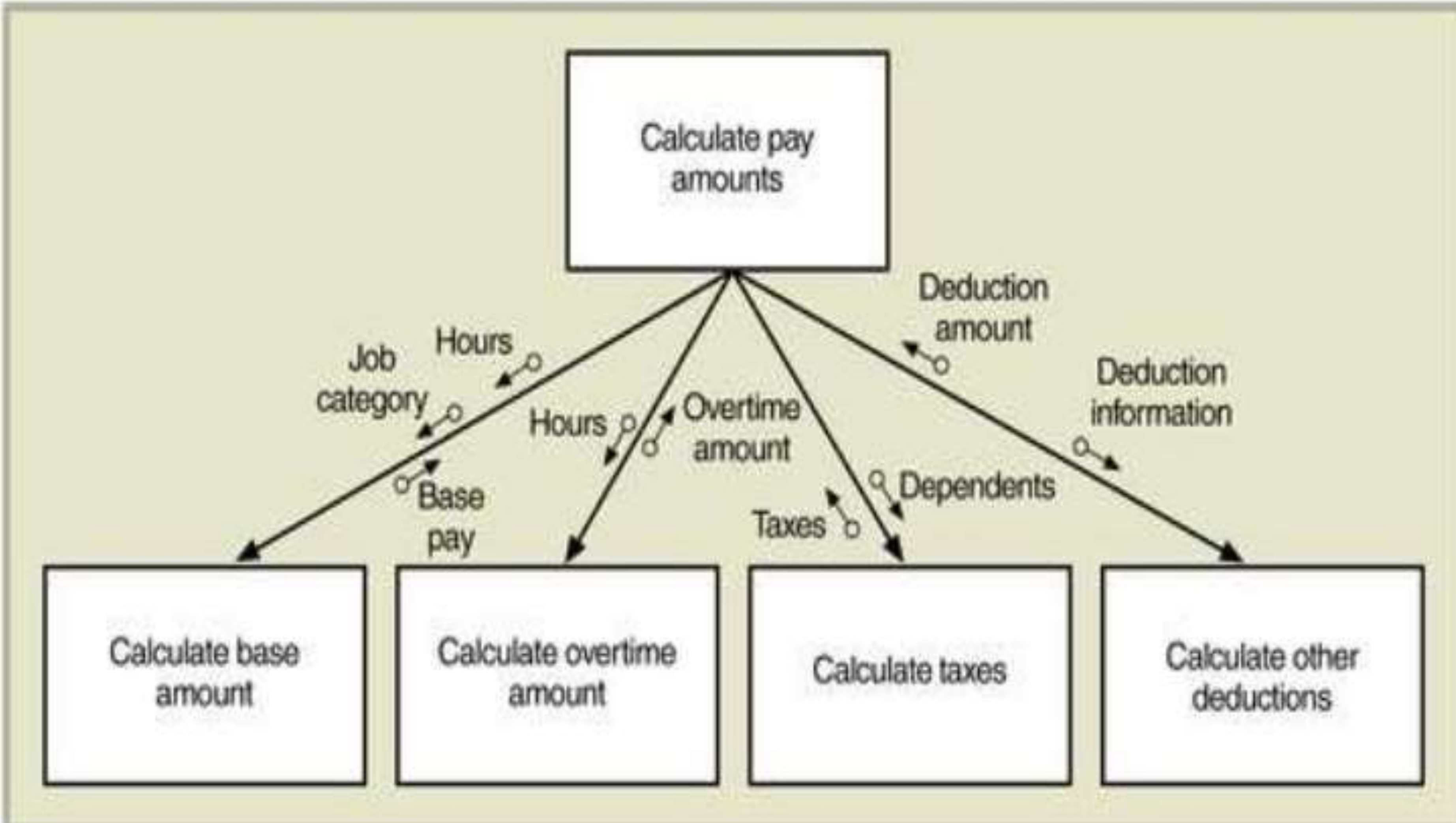
Example


root
Valid-numbers
rms
Valid-numbers
rms
Get-good-data
Compute-solution
Display-solution
Get-data
Validate-data

Bad Design



Structure Chart for Calculate Pay Amount Routine

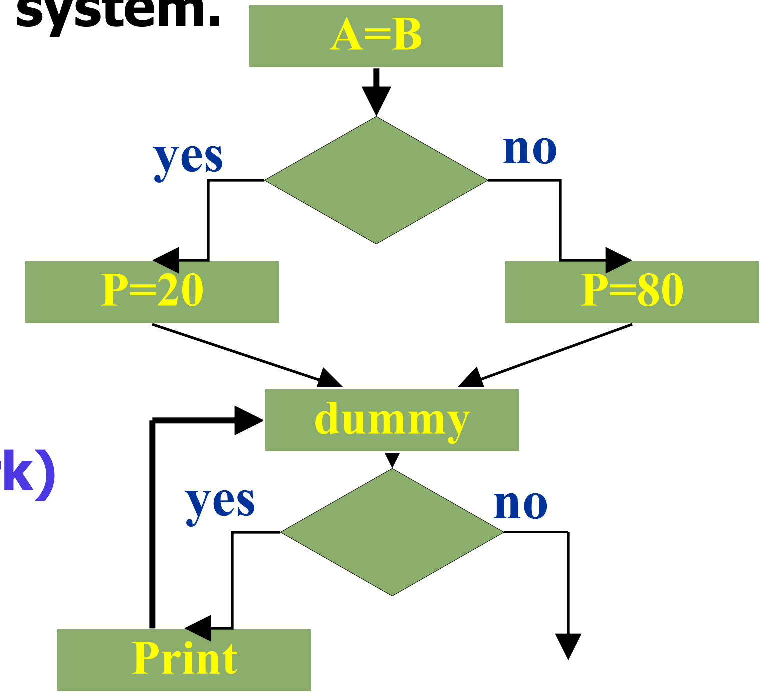


Shortcomings of Structure Chart

- By looking at a structure chart:
  - we can not say whether a module calls another module just once or many times.
- Also, by looking at a structure chart:
  - we can not tell the order in which the different modules are invoked.

Flow Chart (Aside)

- We are all familiar with the flow chart representations:
  - Flow chart is a convenient technique to represent the flow of control in a system.
- A=B
- if(c == 100)
-     P=20
- else p= 80
- while(p>20)
-     print(student mark)



Flow Chart versus Structure Chart

- A structure chart differs from a flow chart in three principal ways:
  - It is difficult to identify modules of a software from its flow chart representation.
  - Data interchange among the modules is not represented in a flow chart.
  - Sequential ordering of tasks inherent in a flow chart is suppressed in a structure chart.

Transformation of a DFD Model into Structure Chart

- Two strategies exist to guide transformation of a DFD into a structure chart:
  - Transform Analysis
  - Transaction Analysis

Transform Analysis

- The first step in transform analysis:
  - divide the DFD into 3 types of parts:
    - input,
    - logical processing,
    - output.

Transform Analysis

- Input portion in the DFD:
  - processes which convert input data from physical to logical form.
  - e.g. read characters from the terminal and store in internal tables or lists.
- Each input portion:
  - called an afferent branch.
  - Possible to have more than one afferent branch in a DFD.

Transform Analysis

- Output portion of a DFD:
  - transforms output data from logical form to physical form.
    - e.g., from list or array into output characters.
  - Each output portion:
    - called an efferent branch.
- The remaining portions of a DFD
  - called central transform

Transform Analysis

- Derive structure chart by drawing one functional component for:
  - the central transform,
  - each afferent branch,
  - each efferent branch.

Transform Analysis

- Identifying the highest level input and output transforms:
  - requires experience and skill.
- Some guidelines:
  - trace the inputs until a bubble is found whose output cannot be deduced from the inputs alone.
  - Processes which validate input are not central transforms.
  - Processes which sort input or filter data from it are.

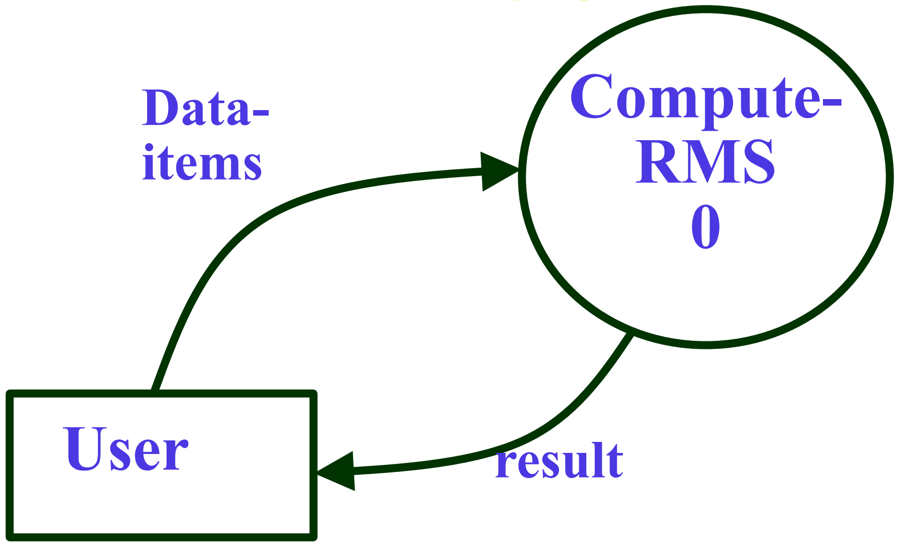
Transform Analysis

- First level of structure chart:
  - draw a box for each input and output units
  - a box for the central transform.
- Next, refine the structure chart:
  - add subfunctions required by each high-level module.
  - Many levels of modules may required to be added.

Factoring

- The process of breaking functional components into subcomponents.
- Factoring includes adding:
  - read and write modules,
  - error-handling modules,
  - initialization and termination modules, etc.
- Finally check:
  - whether all bubbles have been mapped to modules.

Example 1: RMS Calculating Software

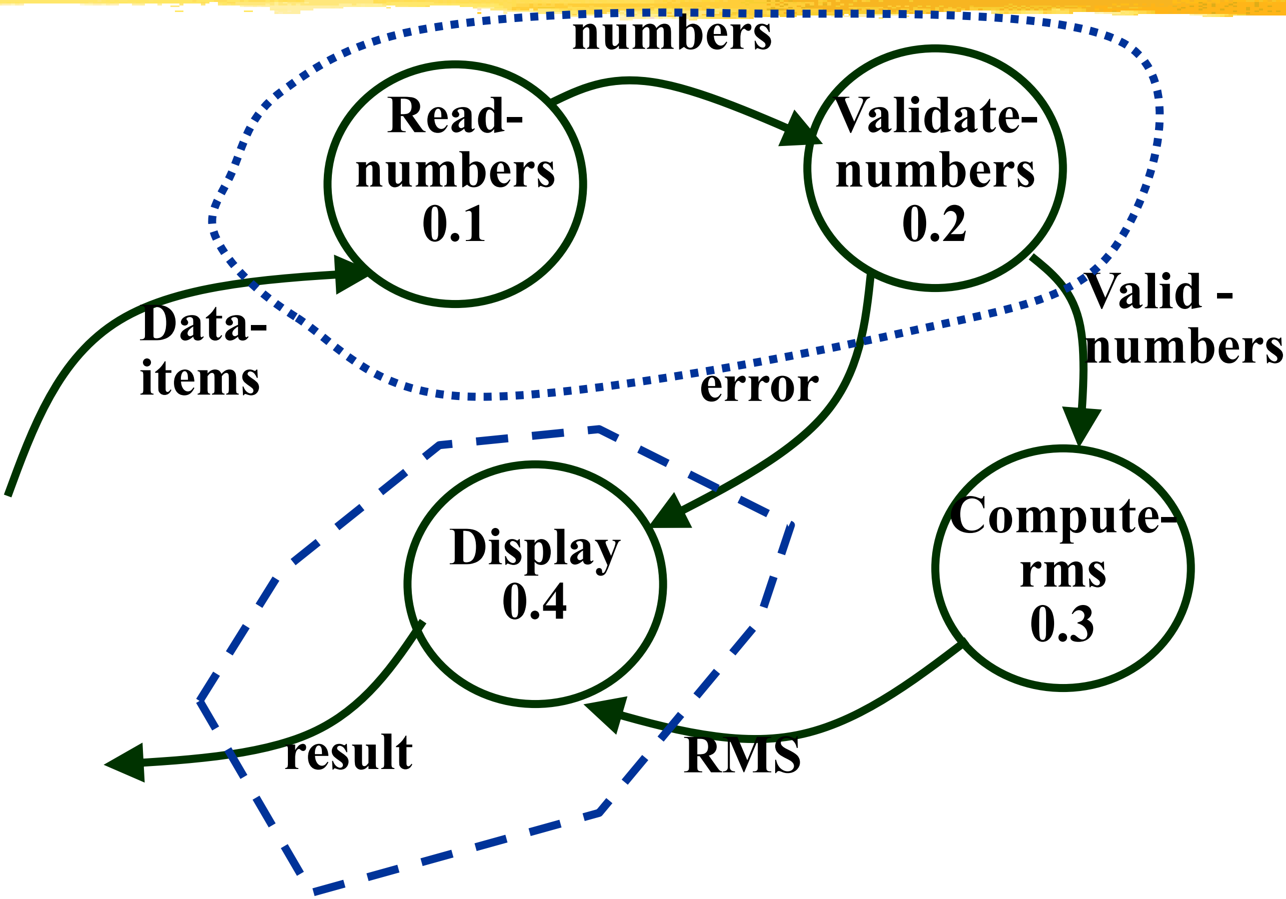


Context Diagram

Example 1: RMS Calculating Software

- From a cursory analysis of the problem description,
  - easy to see that the system needs to perform:
    - accept the input numbers from the user,
    - validate the numbers,
    - calculate the root mean square of the input numbers,
    - display the result.

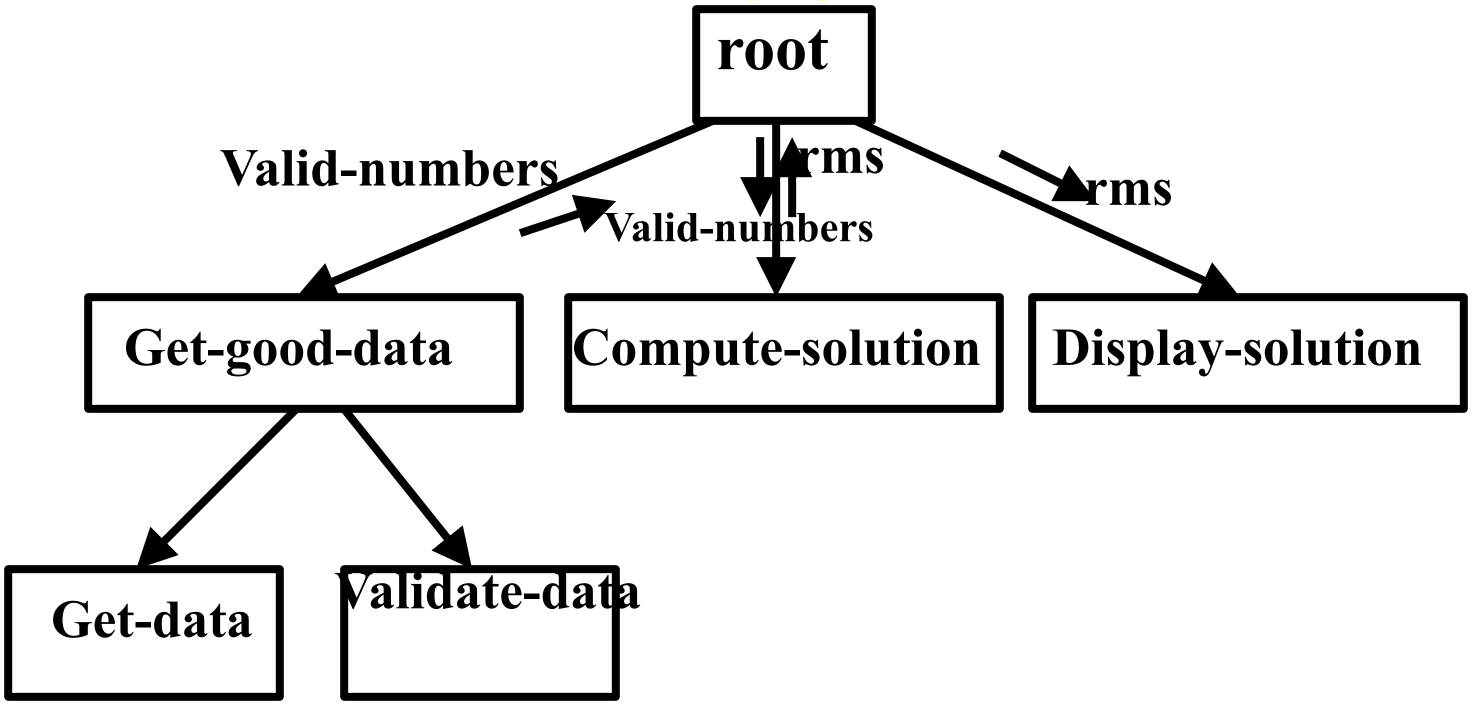
Example 1: RMS Calculating Software



Example 1: RMS Calculating Software

- By observing the level 1 DFD:
  - identify read-number and validate-number bubbles as the afferent branch
  - display as the efferent branch.

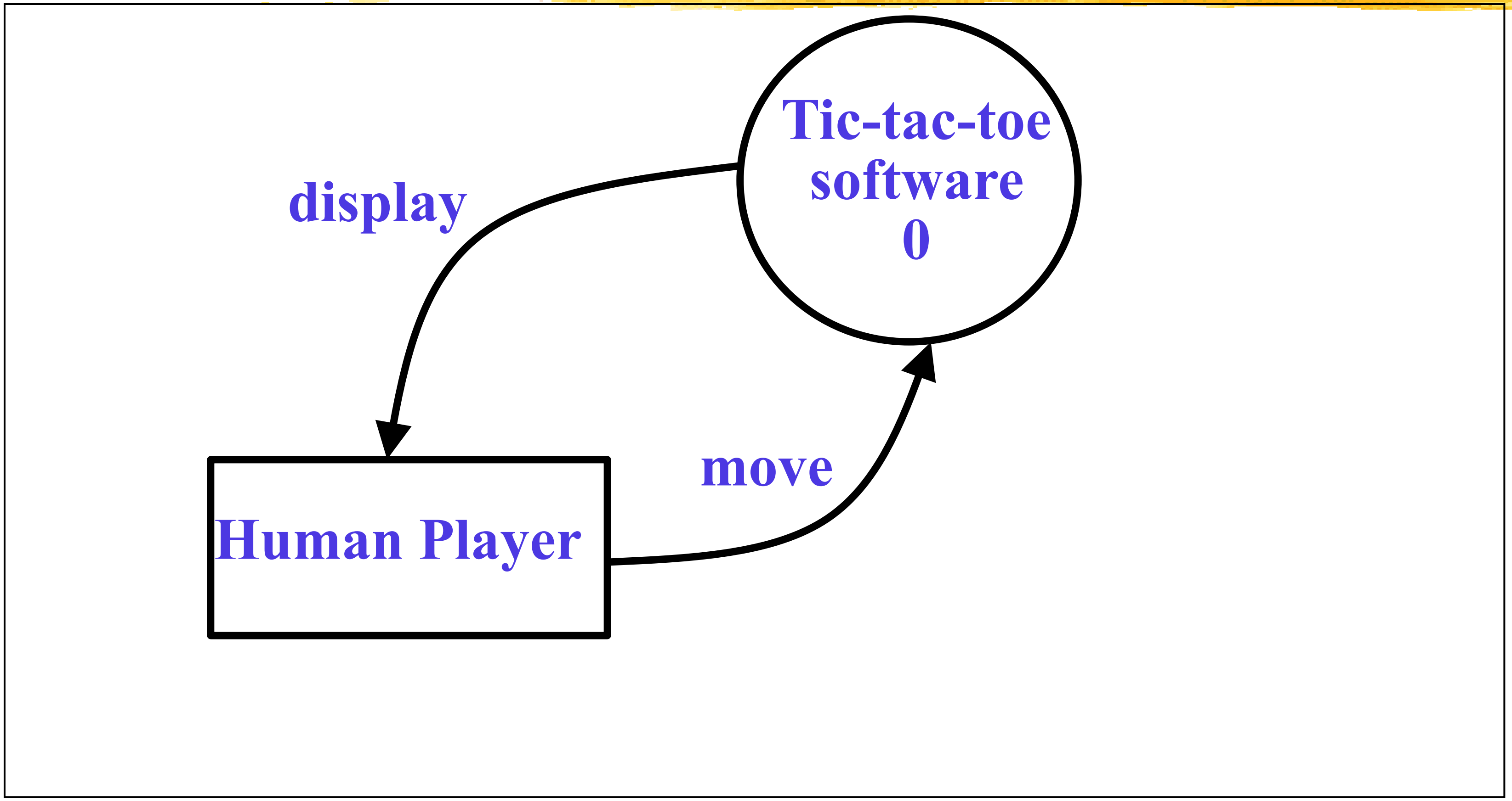
Example 1: RMS Calculating Software



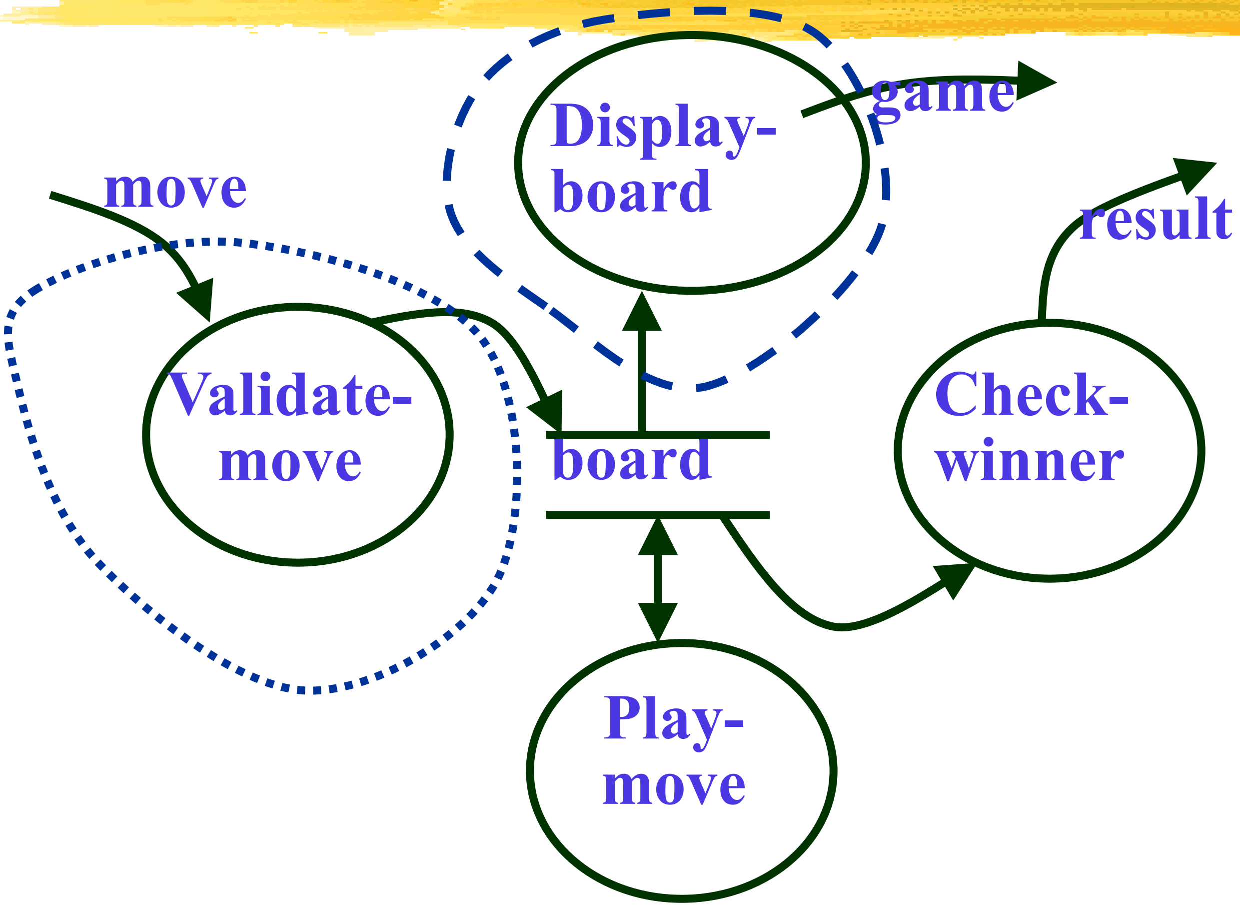
Example 2: Tic-Tac-Toe Computer Game

- As soon as either of the human player or the computer wins,
  - a message congratulating the winner should be displayed.
- If neither player manages to get three consecutive marks along a straight line,
  - and all the squares on the board are filled up,
  - then the game is drawn.
- The computer always tries to win a game.

Context Diagram for Example 2

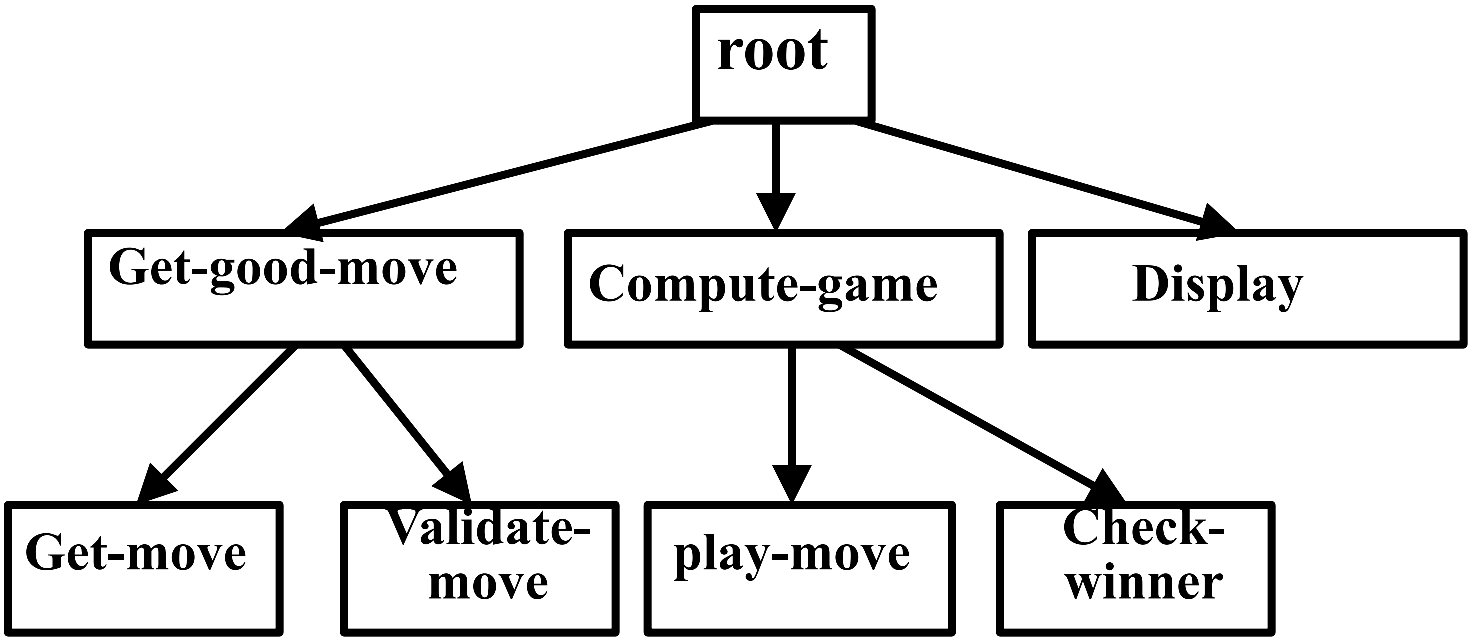


Level 1 DFD



move
Validate-
move
Display-
board
game
board
result
Check-
winner
Play-
move

Structure Chart



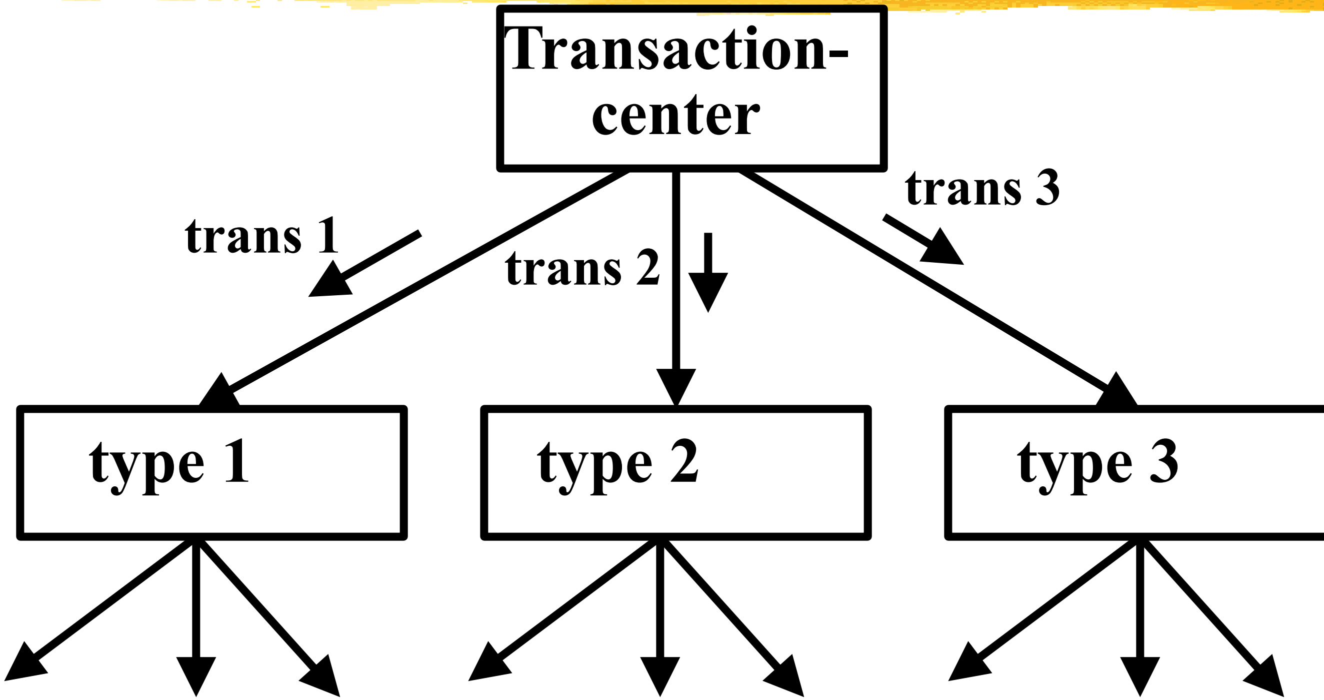
Transaction Analysis

- Useful for designing transaction processing programs.
  - Transform-centered systems:
    - characterized by similar processing steps for every data item processed by input, process, and output bubbles.
  - Transaction-driven systems,
    - one of several possible paths through the DFD is traversed depending upon the input data value.

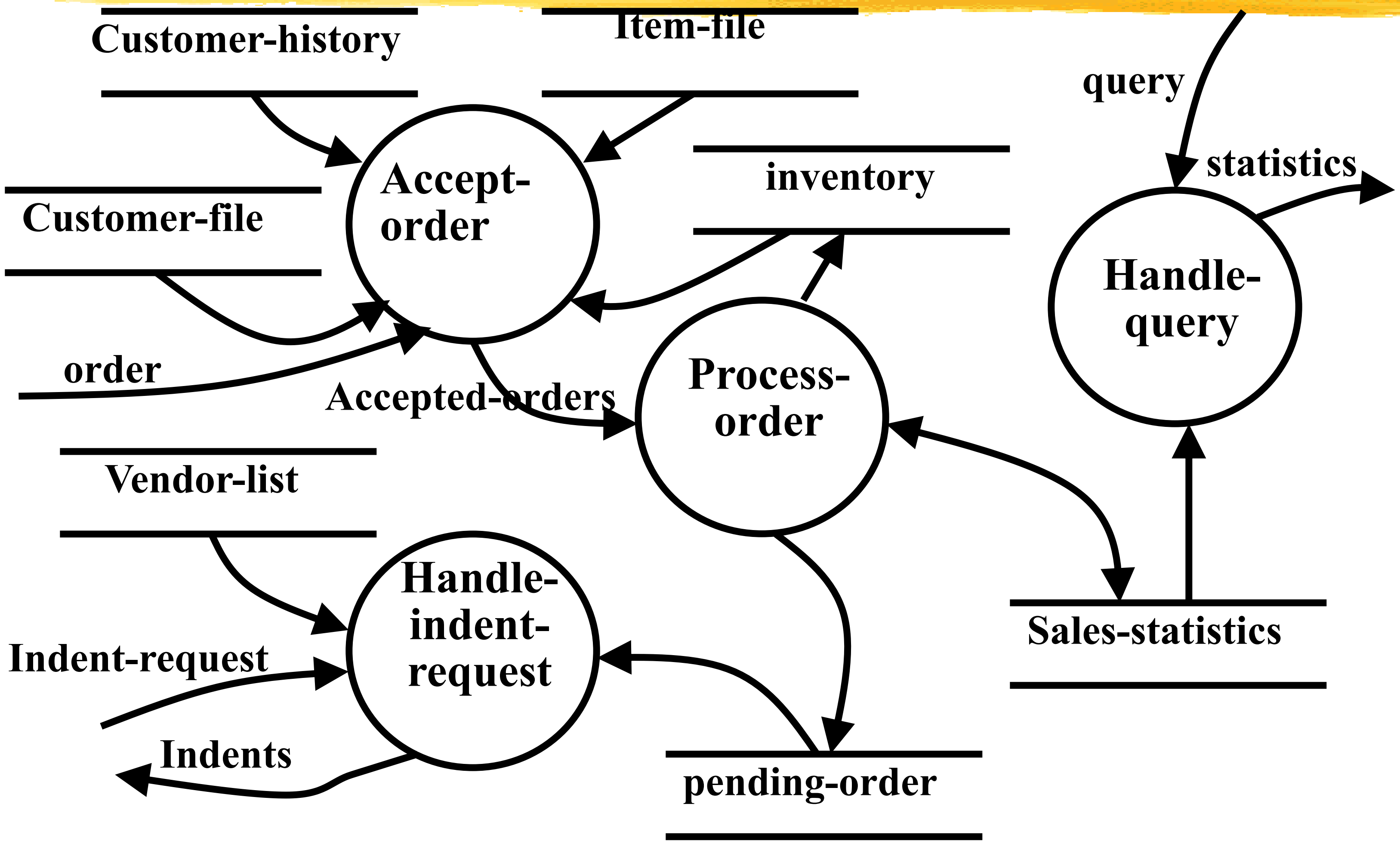
Transaction Analysis

- Transaction:
  - any input data value that triggers an action:
  - For example, selected menu options might trigger different functions.
  - Represented by a tag identifying its type.
- Transaction analysis uses this tag to divide the system into:
  - several transaction modules
  - one transaction-center module.

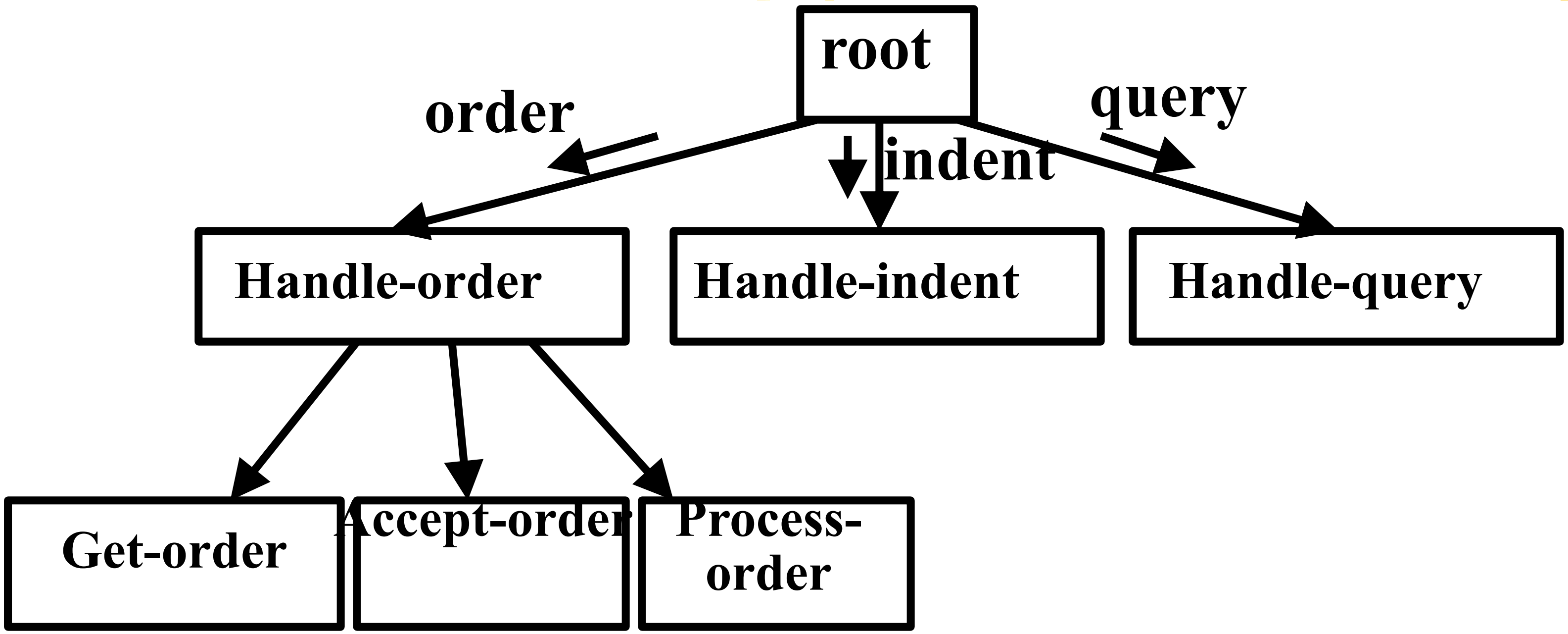
Transaction analysis



Level 1 DFD for TAS



Structure Chart



Summary

- We first discussed structured analysis of a larger problem.
- We defined some general guidelines
  - for constructing a satisfactory DFD model.
- The DFD model though simple and useful
  - does have several short comings.
- We then started discussing structured design.

Summary

- Aim of structured design:
  - transform a DFD representation into a structure chart.
- Structure chart represents:
  - module structure
  - interaction among different modules,
  - procedural aspects are not represented.

Summary

- Structured design provides two strategies to transform a DFD into a structure chart:
  - Transform Analysis
  - Transaction Analysis

Summary

- We Discussed three examples of structured design.
- It takes a lot of practice to become a good software designer:
  - Please try to solve all the problems listed in your assignment sheet,
  - not only the ones you are expected to submit.