Function-Oriented Software Design (continued)

Organization of this Lecture

- Brief review of previous lectures
- 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

- Last lecture we started discussion on **Structured Analysis/ Structured Design (SA/SD) technique:**
  - incorporates features from some important design methodologies.
- SA/SD consists of two important parts:
  - structured analysis
  - structured design.

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
  - number 7 is called the magic number.

Review of Last Lecture

- 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.
- We discussed two small examples:
  - RMS calculating software
  - tic-tac-toe computer game software

Review of Last Lecture

- Several CASE tools are available
  - help in design activities:
  - help maintain the data dictionary,
  - check whether DFDs are balanced, etc.
- DFD model:
  - difficult to implement using a programming language:
  - needs to be transformed to structured design.

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.

Example 3: Trading-House Automation System (TAS)

- 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.

Example: Trading-House Automation System (TAS)

- 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.

Example: Trading-House Automation System (TAS)

- 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

Example: Trading-House Automation System (TAS)

- 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.

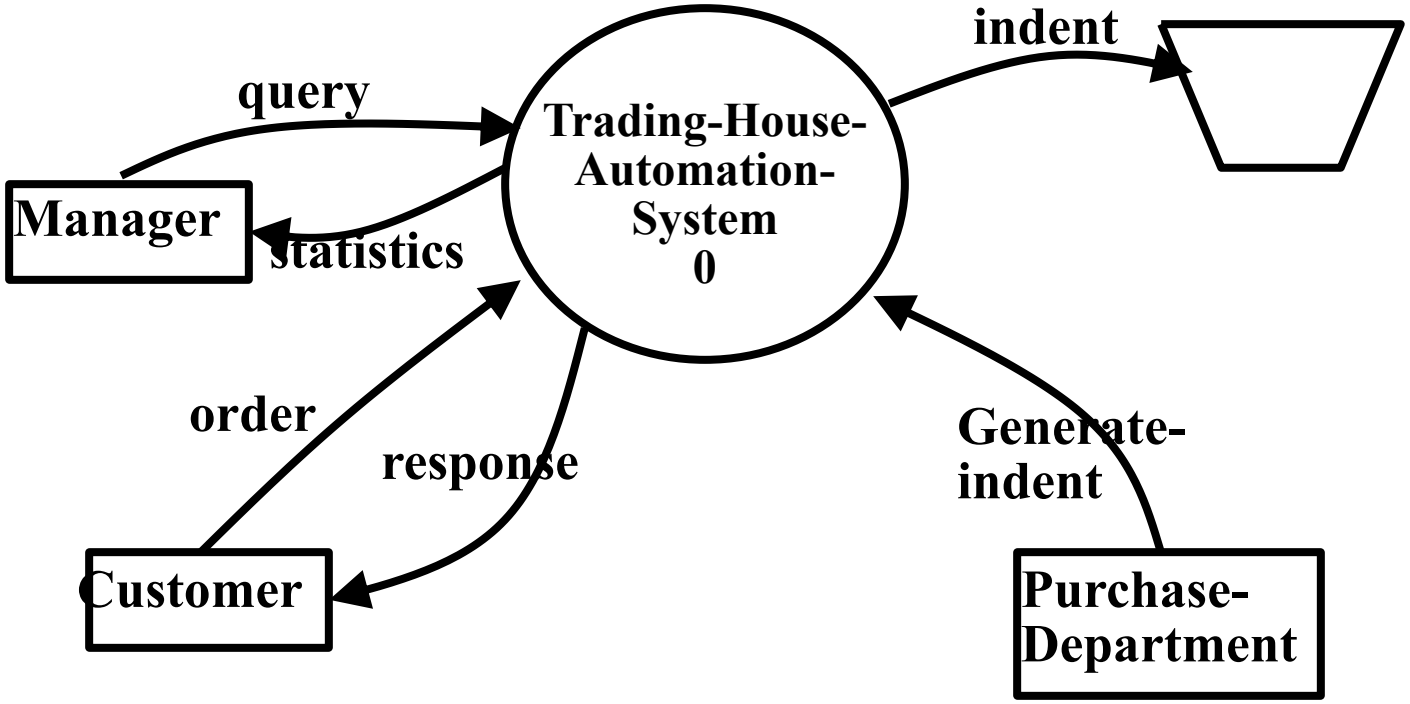
Example: Trading-House Automation System (TAS)

- 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.

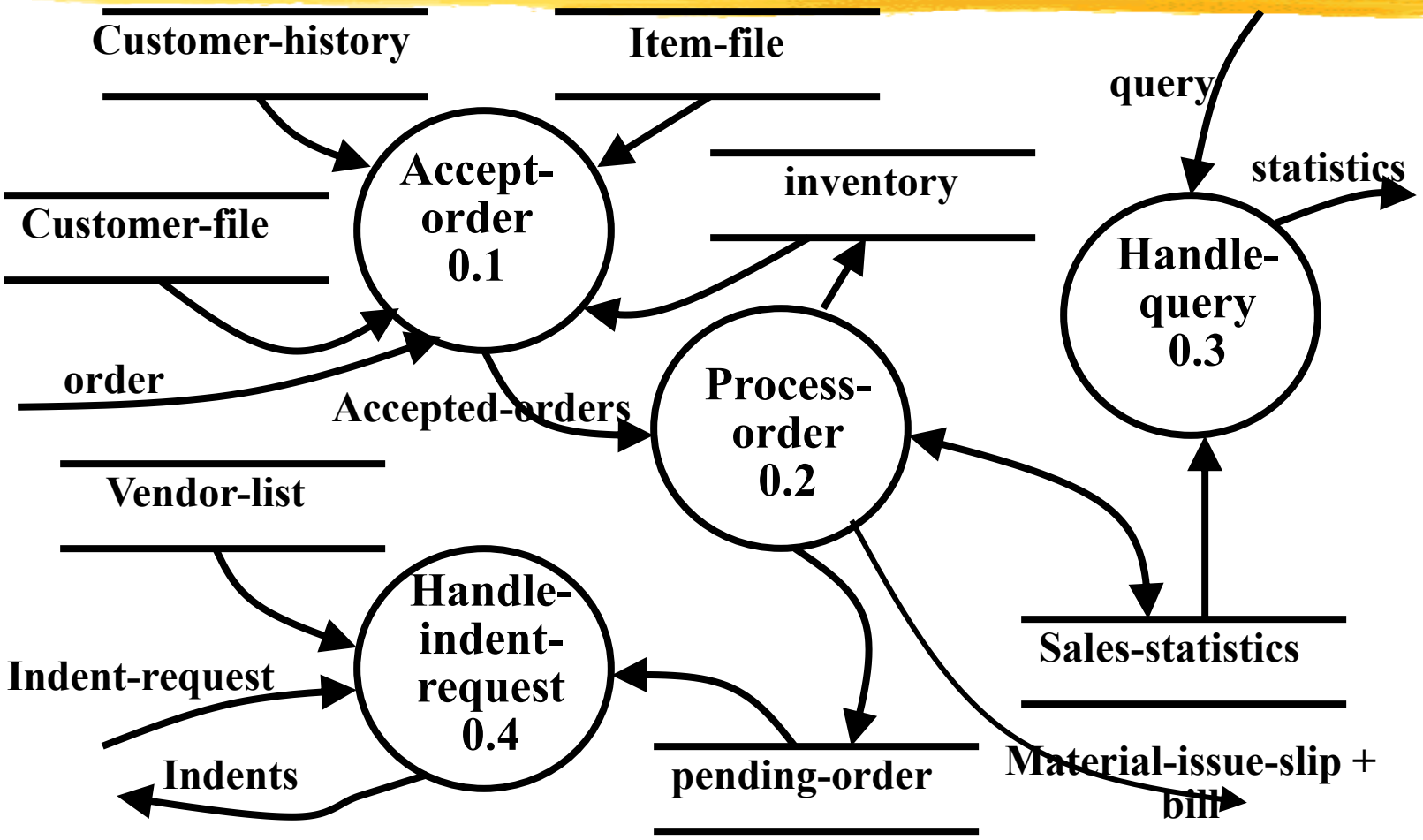
Example: Trading-House Automation System (TAS)

- 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
Accepted-orders
Process-order 0.2
Vendor-list
Handle-indent-request 0.4
Sales-statistics
Indent-request
Material-issue-slip + bill
Indents
pending-order

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

Observation

- 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.

Guidelines For Constructing DFDs

- 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

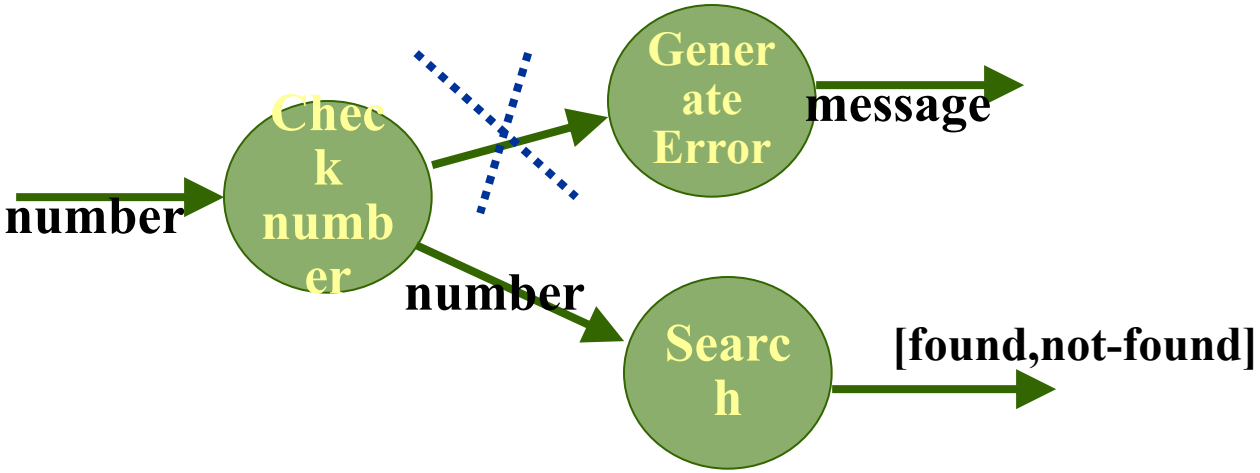
- A common mistake committed by many beginners:
  - attempting to represent control information in a DFD.
  - e.g. trying to represent the order in which different functions are executed.

Guidelines For Constructing DFDs

- 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.
  - Many beginners try to represent this aspect by drawing an arrow between the corresponding bubbles.

Example-1

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

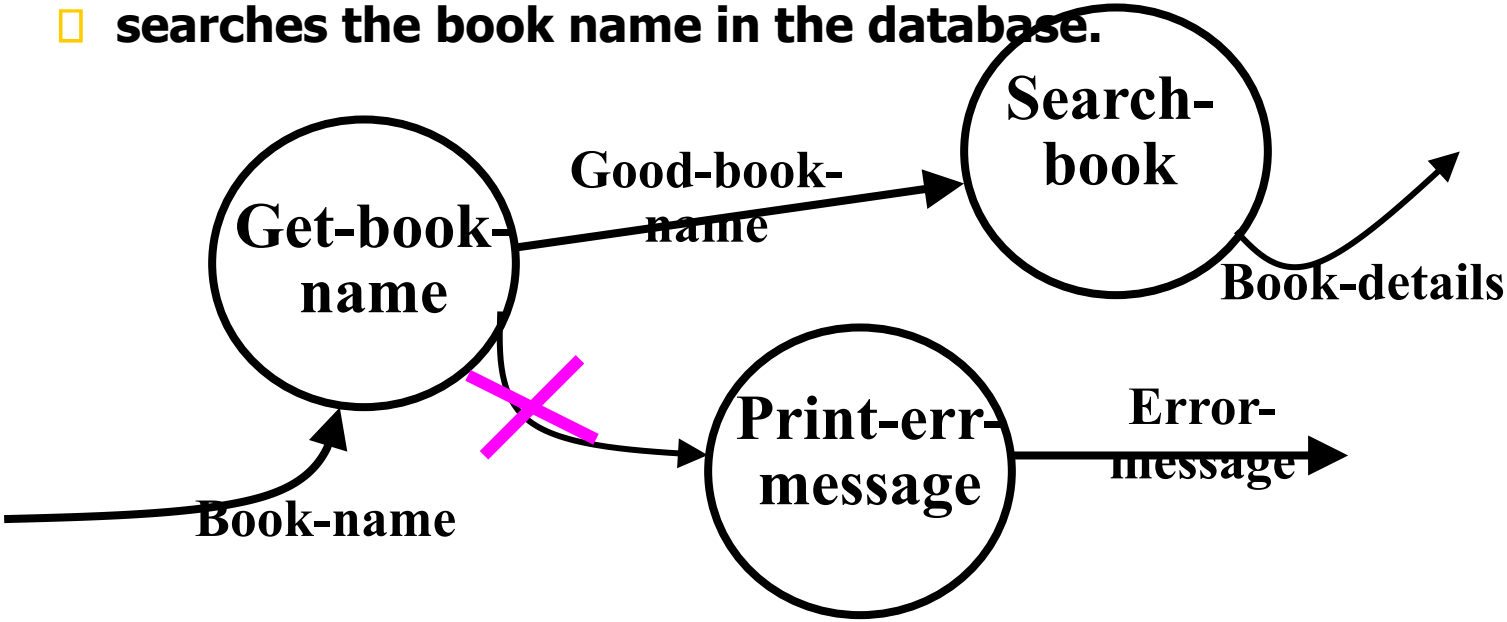


Guidelines For Constructing DFDs

- 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

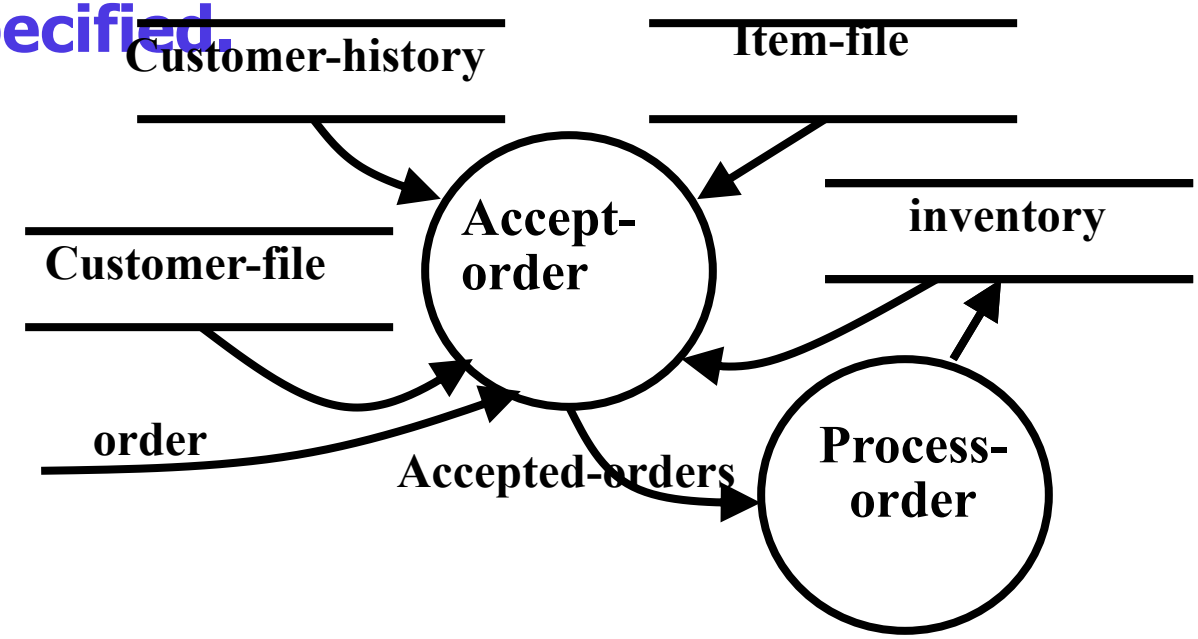
- DFD models suffer from several shortcomings:
- DFDs leave ample scope to be imprecise.
  - In a DFD model, we infer about the function performed by a bubble from its label.
  - A label may not capture all the functionality of a bubble.

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

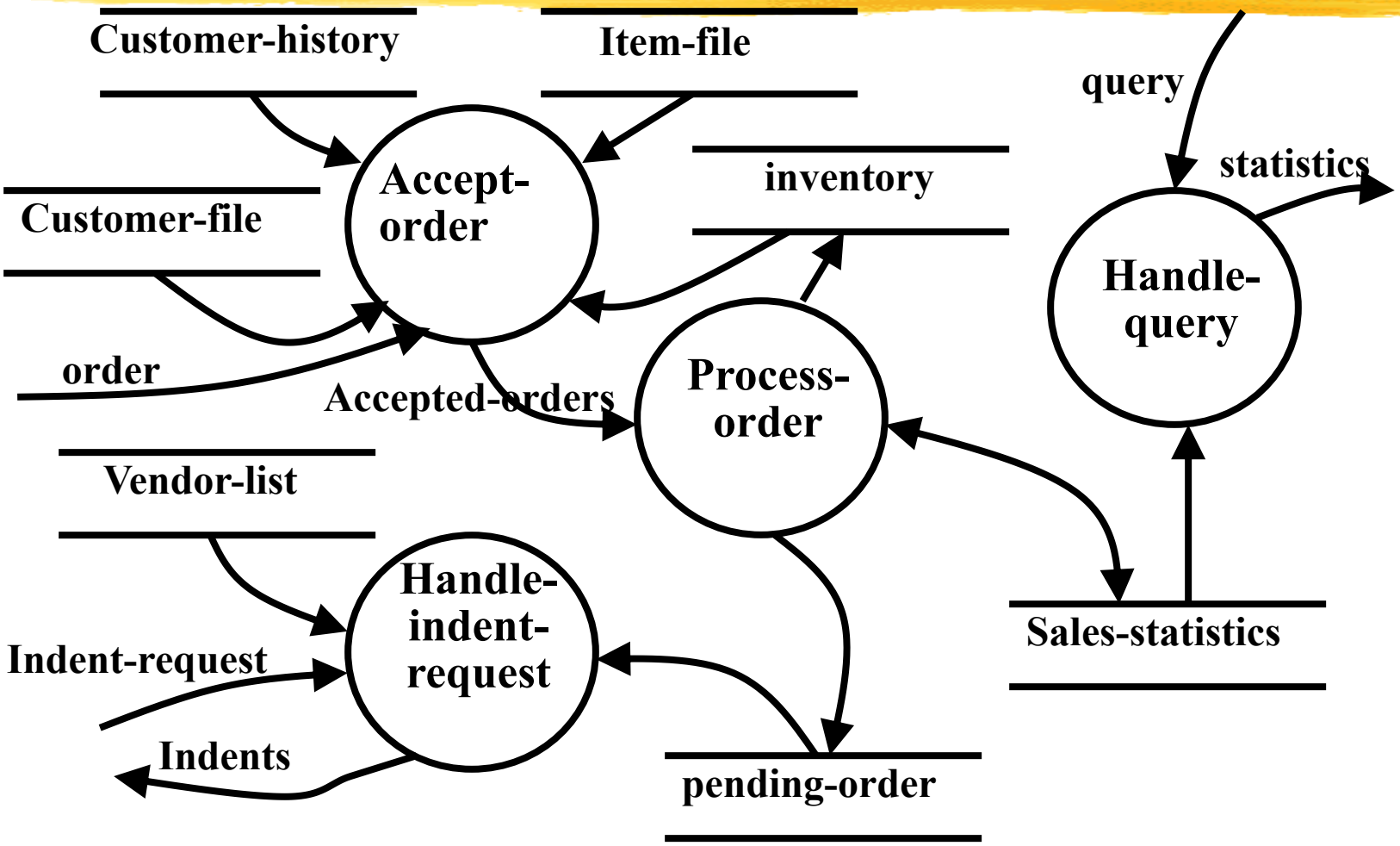
- Control information is not represented:
  - For instance, order in which inputs are consumed and outputs are produced is not specified.



Shortcomings of the DFD Model

- A DFD does not specify synchronization aspects:
  - For instance, the DFD in TAS example does not specify:
    - whether process-order may wait until the accept-order produces data
    - whether accept-order and handle-order may proceed simultaneously with some buffering mechanism between them.

TAS: Level 1 DFD



Shortcomings of the DFD Model

- The way decomposition is carried out to arrive at the successive levels of a DFD is subjective.
- The ultimate level to which decomposition is carried out is subjective:
  - depends on the choice and judgement of the analyst.
- Even for the same problem,
  - several alternative DFD representations are possible:
  - many times it is not possible to say which DFD representation is superior or preferable.

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 Chart

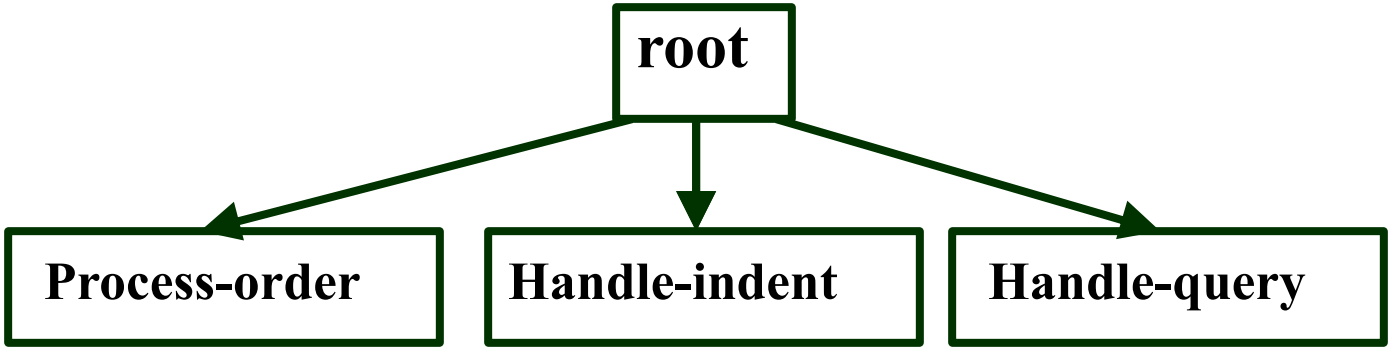
- Structure chart representation
  - easily implementable using programming languages.
- Main focus of a structure chart:
  - define the module structure of a software,
  - interaction among different modules,
  - procedural aspects (e.g, how a particular functionality is achieved) are not represented.

Basic building blocks of structure chart

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

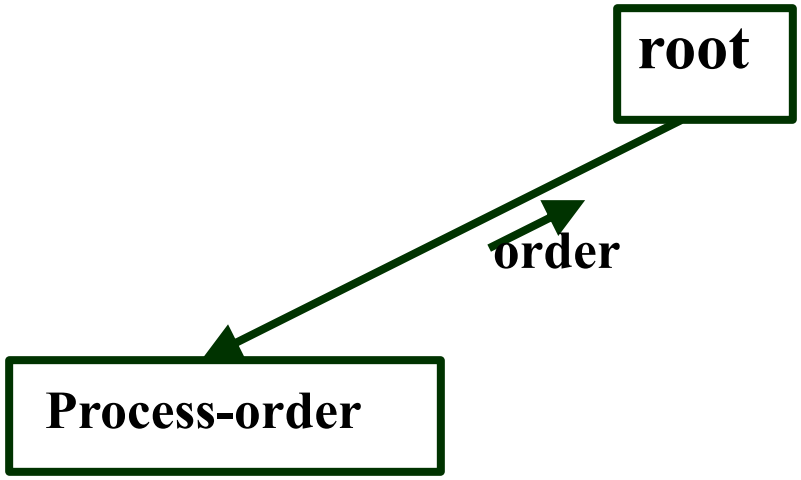
Arrows

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



Data flow Arrows

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

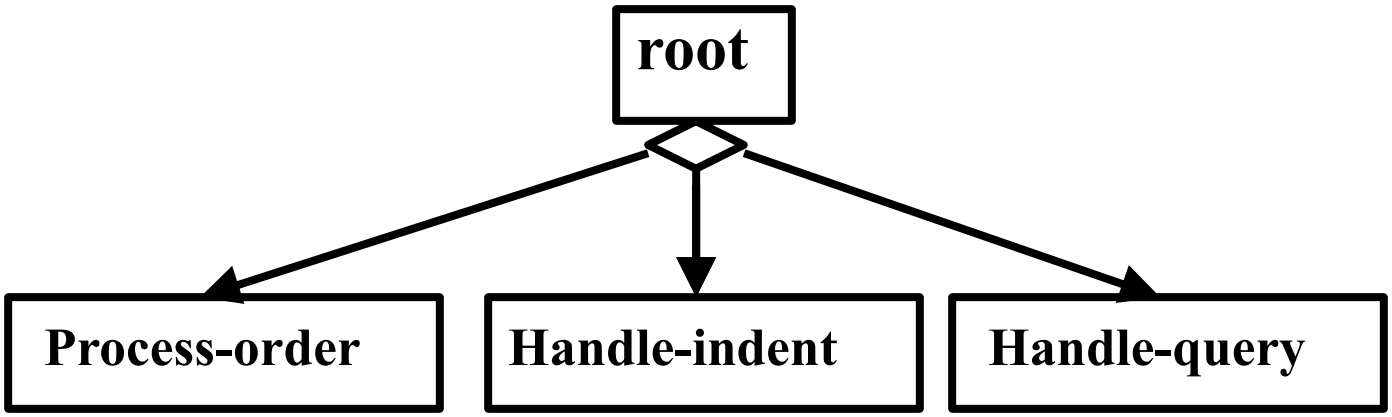


Library modules

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

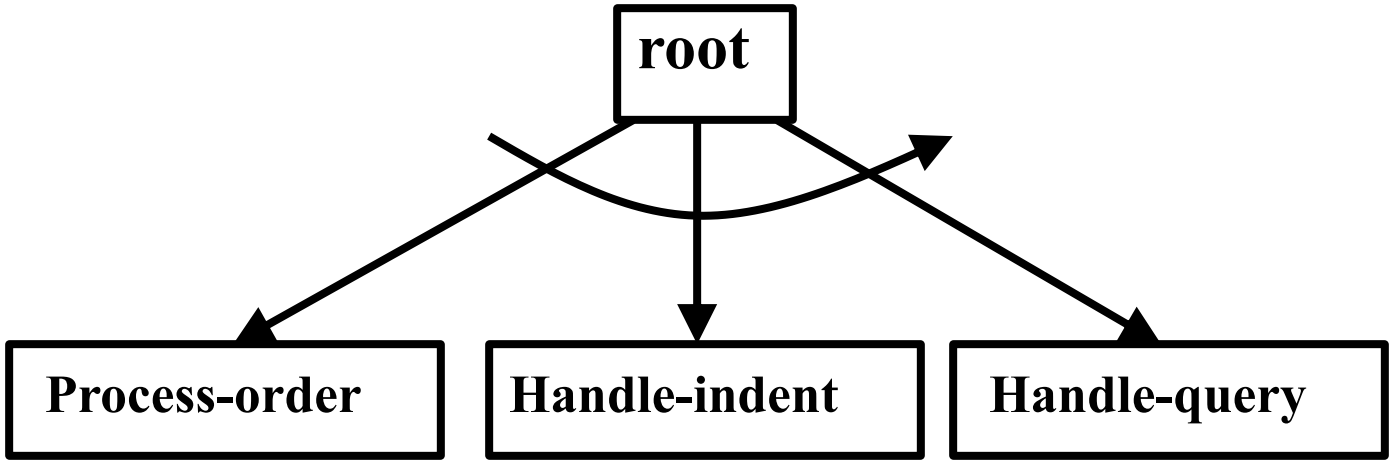
Selection

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



Repetition

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



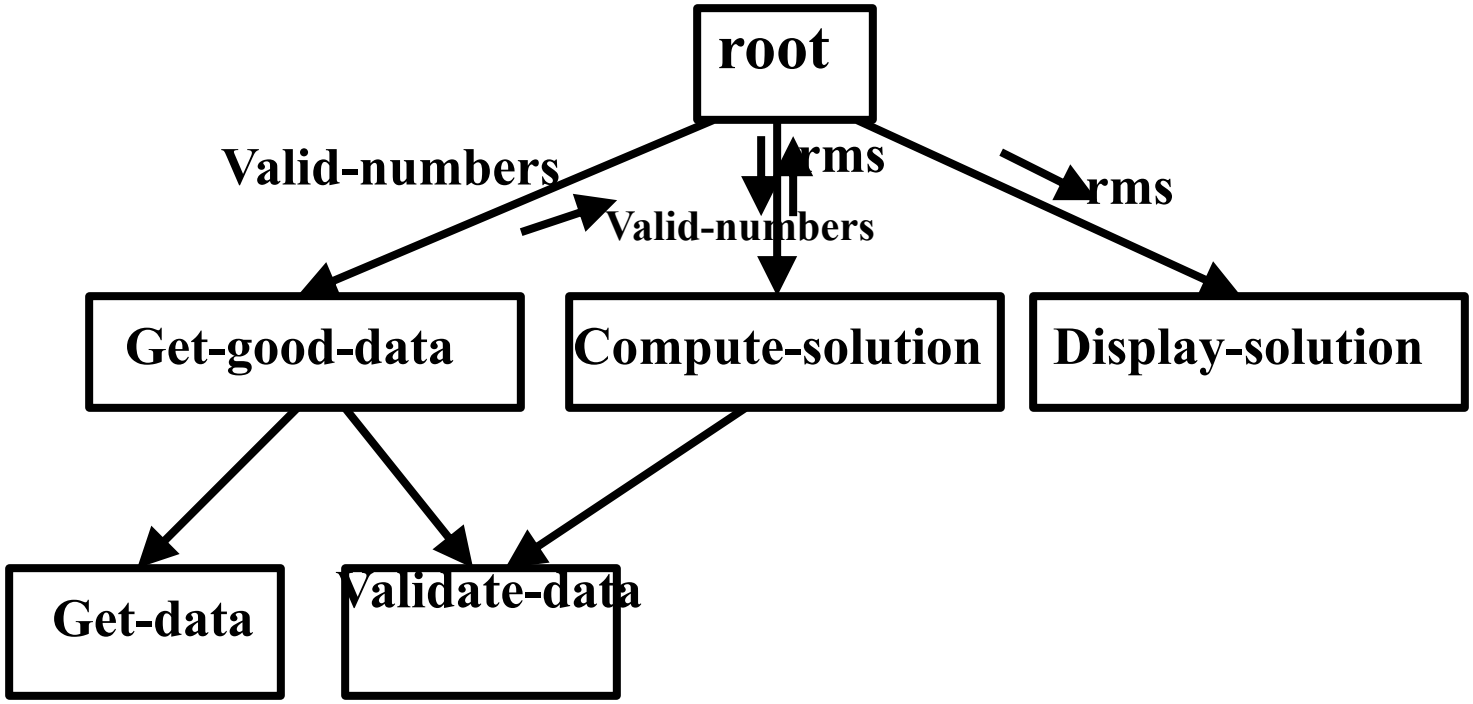
Structure Chart

- 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.

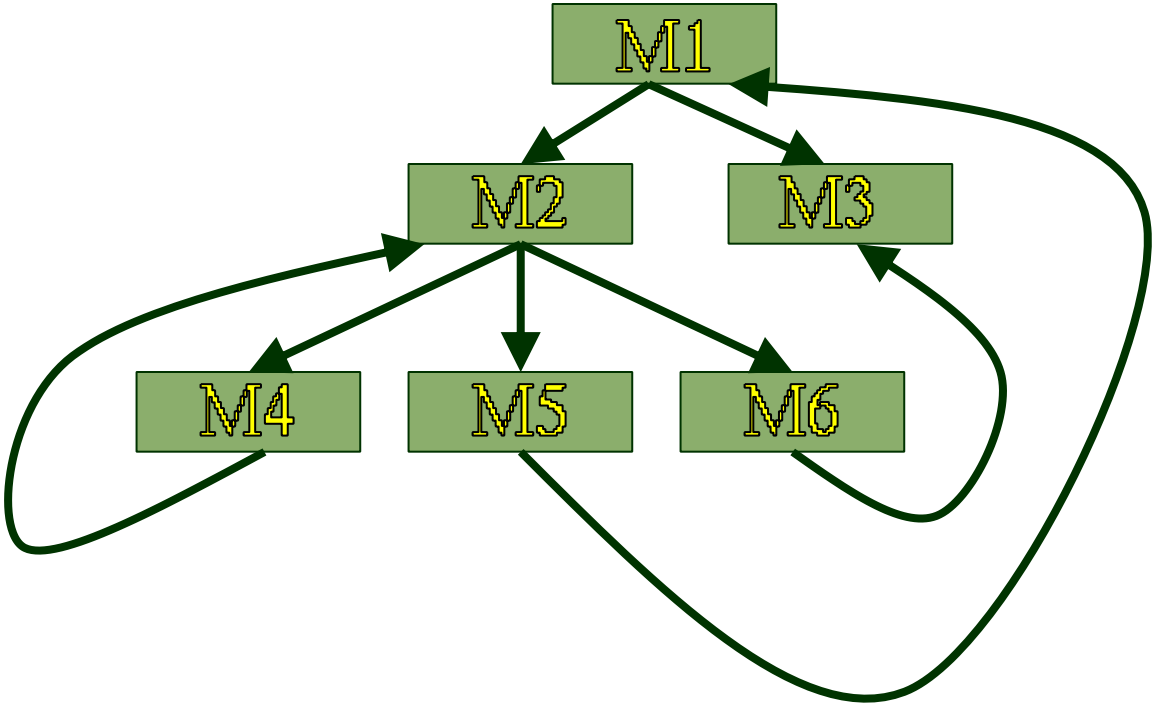
Structure Chart

- 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.

Example


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

Bad Design



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.

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.

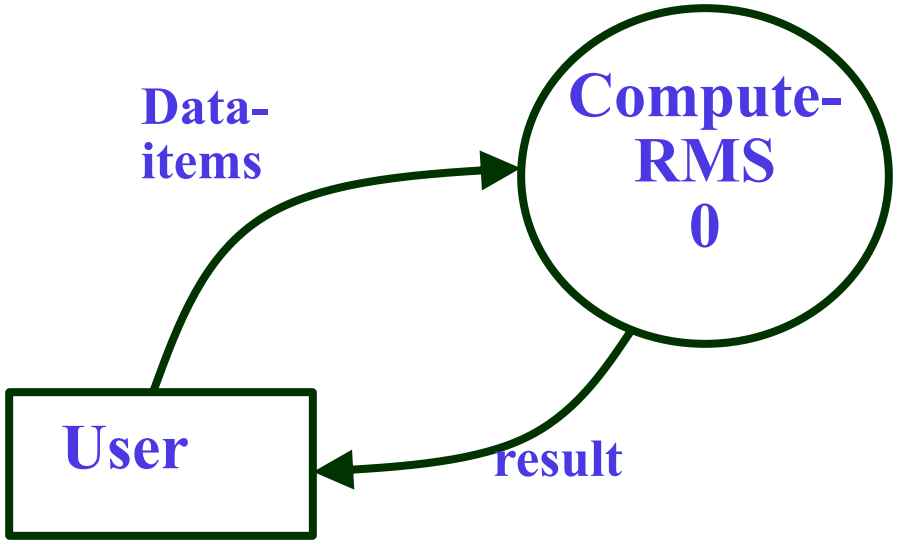
Transform Analysis

- 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

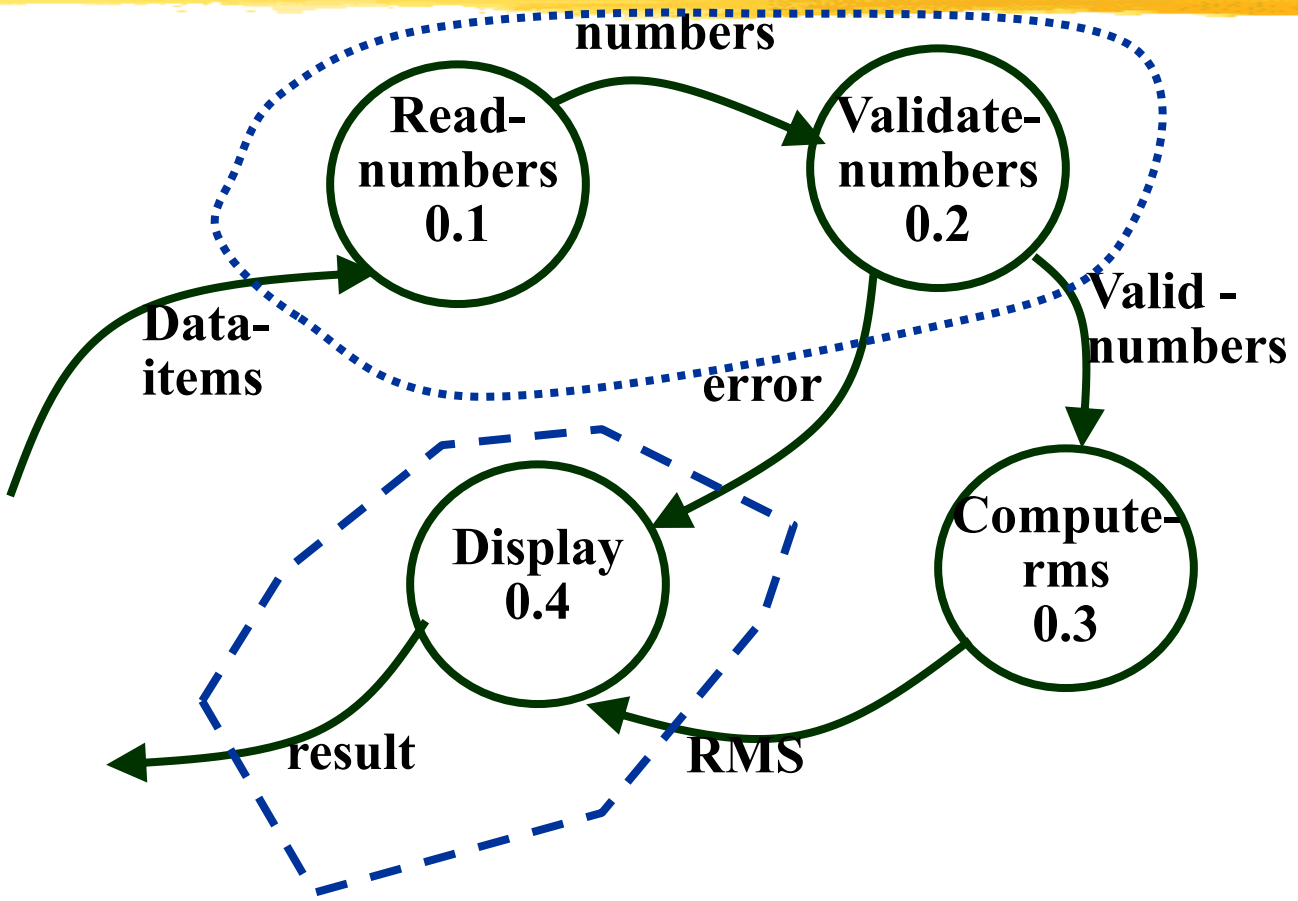


Context Diagram

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.

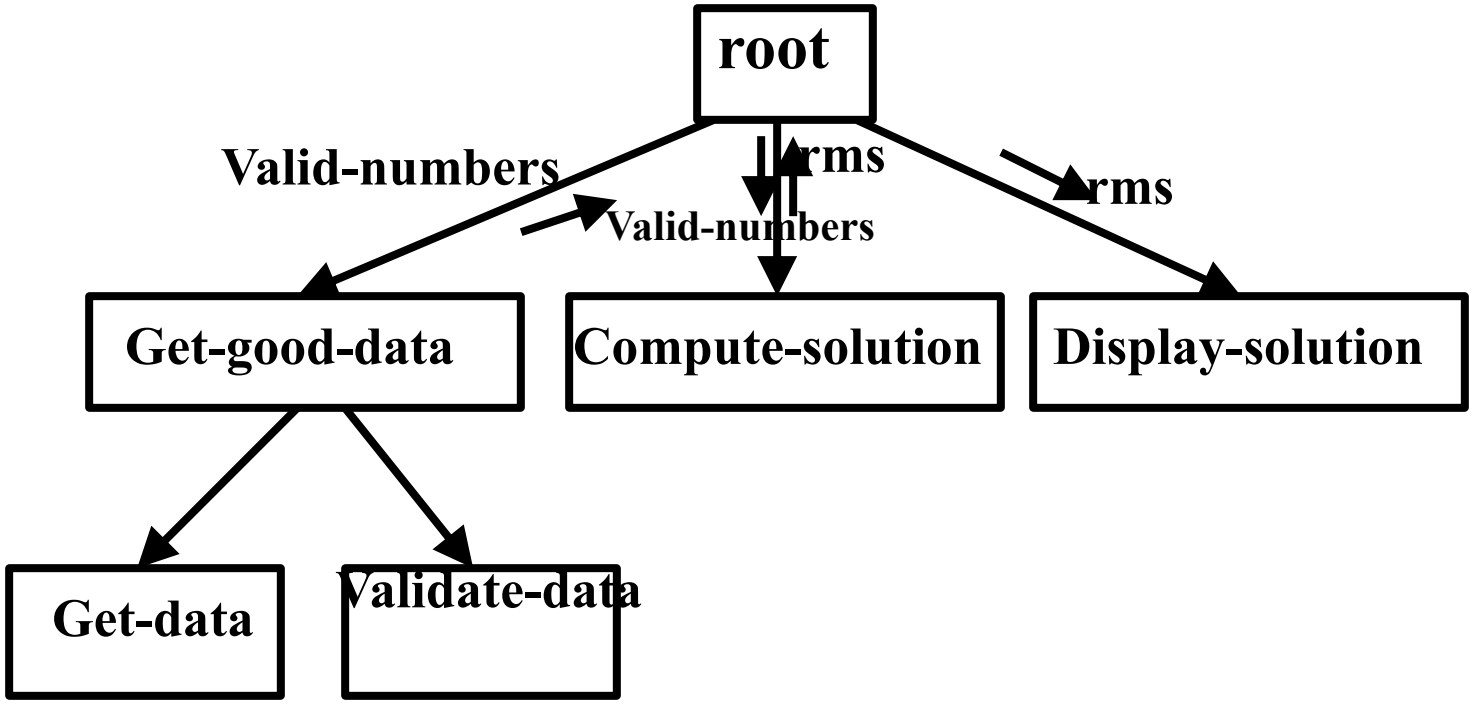
Example 1: RMS Calculating Software



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.

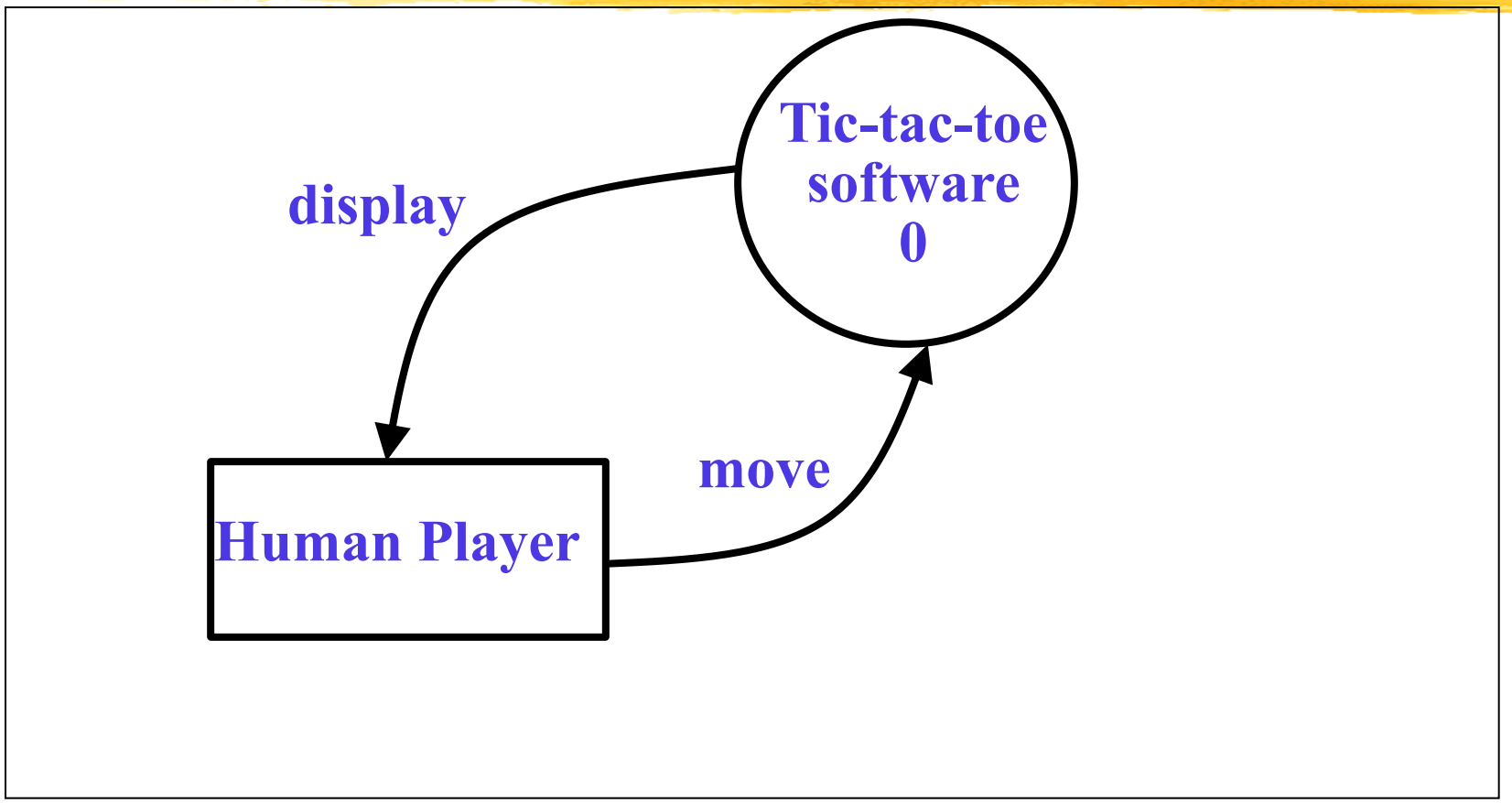
Example 1: RMS Calculating Software



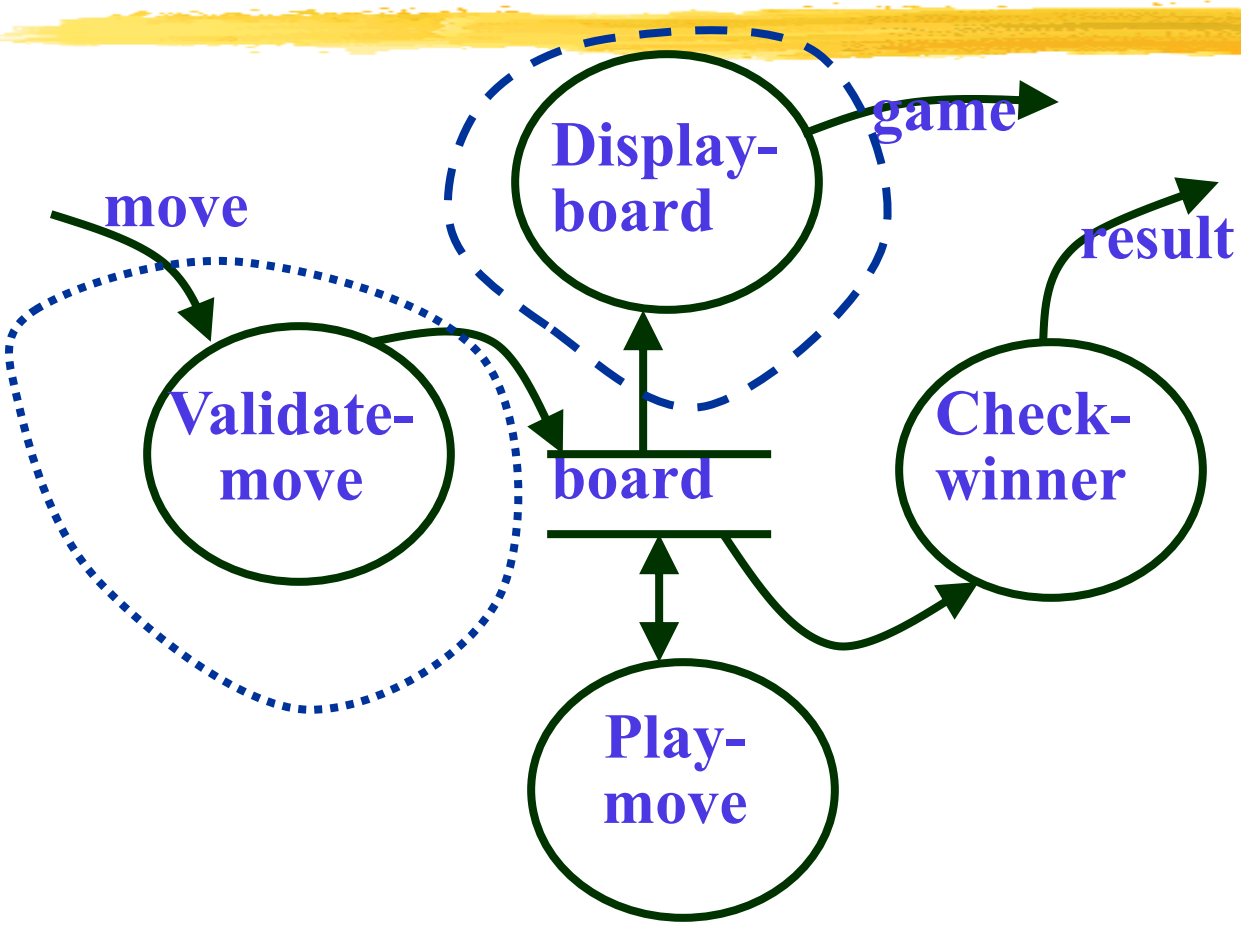
Example 2: Tic-Tac-Toe Computer Game

- 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.

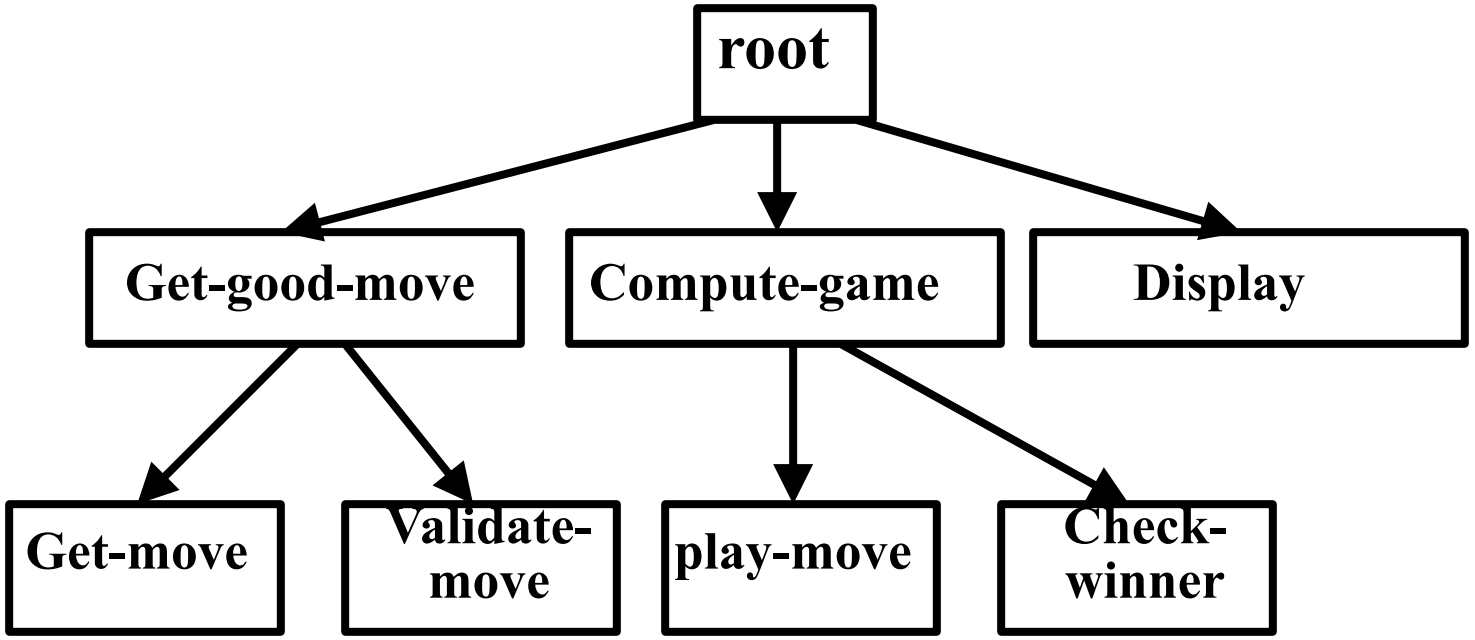
Context Diagram for Example 2



Level 1 DFD


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

Structure Chart



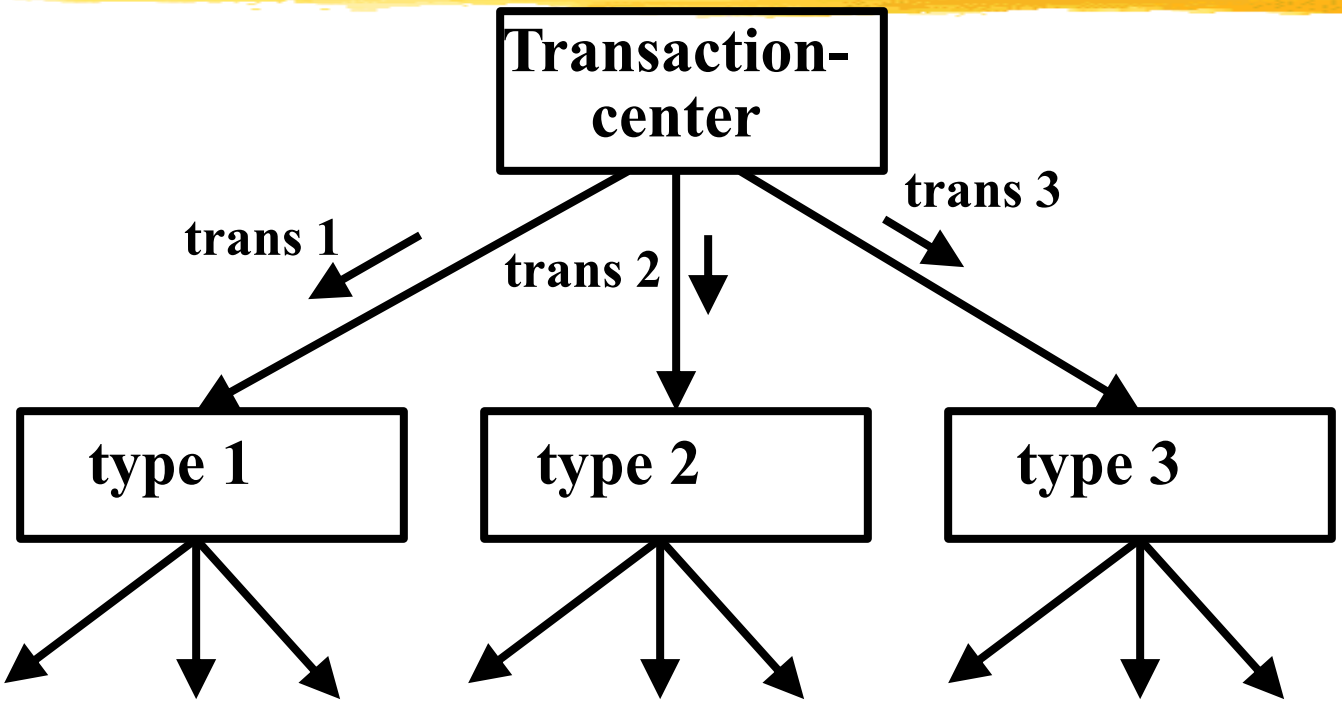
Transaction Analysis

- 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.

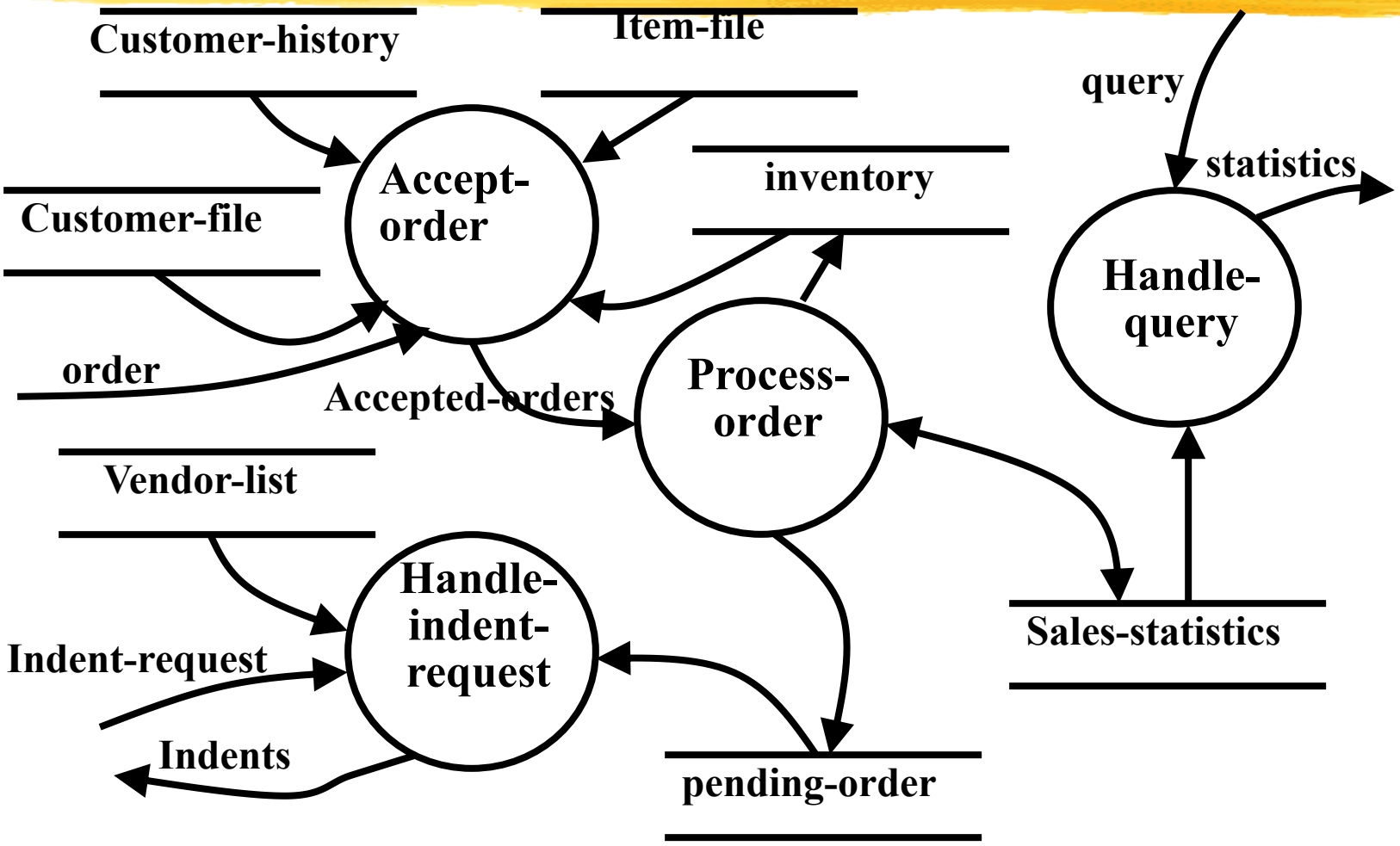
Transaction Analysis

- 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.

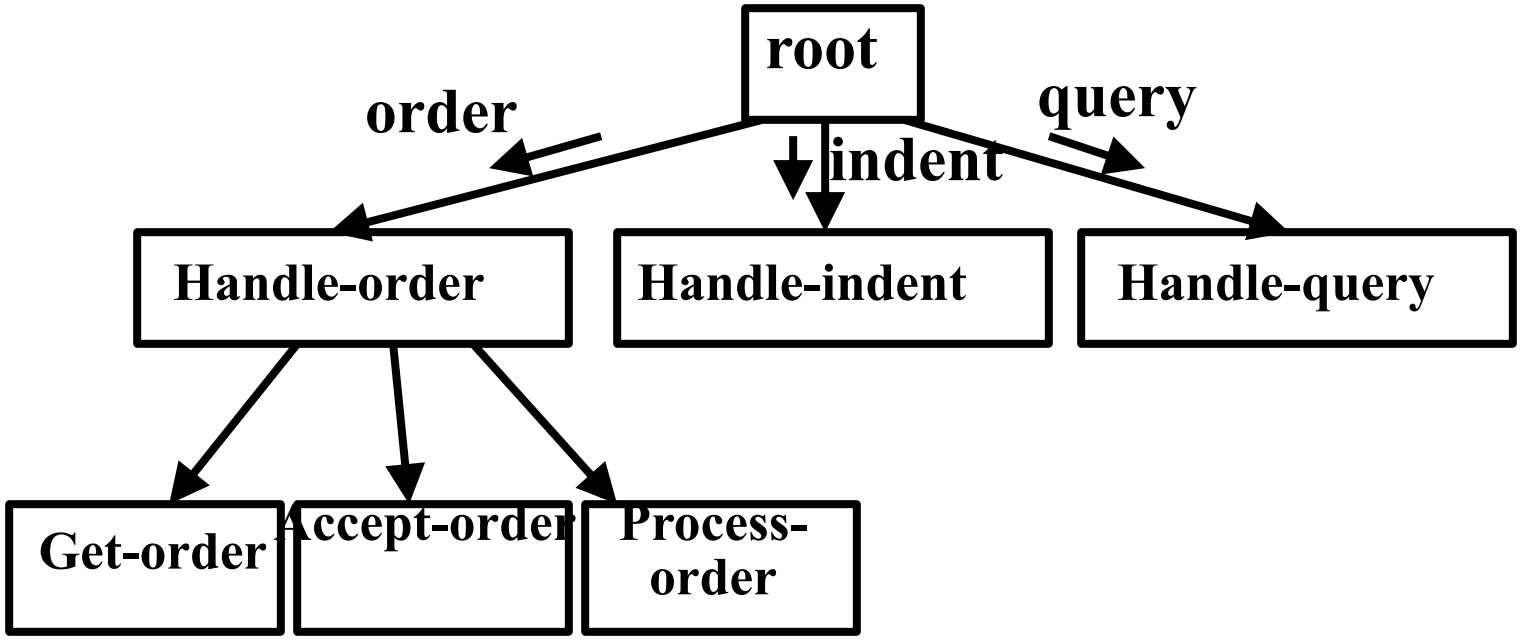
Transaction analysis



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.