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Structured Analysis and Design

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Introduction

- Structured analysis is a top-down decomposition technique:
  - DFD (Data Flow Diagram) is the modelling technique used
  - Functional requirements are modelled and decomposed.
- Why model functionalities?
  - **Functional requirements exploration and validation**
  - **Serves as the starting point for design.**

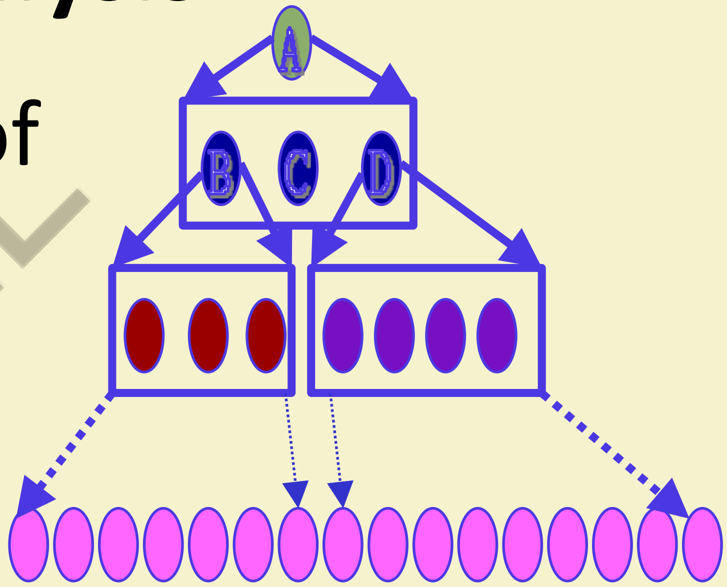
Function-oriented vs. Object-oriented Design

- Two distinct style of design:
  - **Function-oriented or Procedural**
    - Top-down approach
    - Carried out using Structured analysis and structured design
    - Coded using languages such as C
  - **Object-oriented**
    - Bottom-up approach
    - Carried out using UML
    - Coded using languages such as Java, C++, C#

Structured analysis and Structured Design

- During Structured analysis:
  - High-level functions are successively decomposed:
    - Into more detailed functions.
- During Structured design:
  - The detailed functions are mapped to a module structure.

Structured Analysis



- Successive decomposition of high-level functions:
  - Into more detailed functions.
  - Technically known as **top-down decomposition**.

SA/SD (Structured Analysis/Structured Design)

- SA/SD technique draws heavily from the following methodologies:
  - Constantine and Yourdon's methodology
  - Hatley and Pirbhai's methodology
  - Gane and Sarson's methodology
  - DeMarco and Yourdon's methodology

We largely use

- SA/SD technique results in:
  - high-level design.

Functional Decomposition

- Each function is analyzed:
  - Hierarchically decomposed into more detailed functions.
  - Simultaneous decomposition of high-level data
    - Into more detailed data.

Structured Analysis

- Textual problem description converted into a graphic model.
  - Done using **data flow diagrams (DFDs).**
  - DFD graphically represents the results of structured analysis.

Structured Analysis

- The results of structured analysis can be easily understood even by ordinary customers:
  - **Does not require computer knowledge.**
  - **Directly represents customer's perception of the problem.**
  - **Uses customer's 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 Design

- The functions represented in the DFD:
  - Mapped to a **module structure**.
- Module structure:
  - Also called **software architecture**

Structured Analysis vs. Structured Design

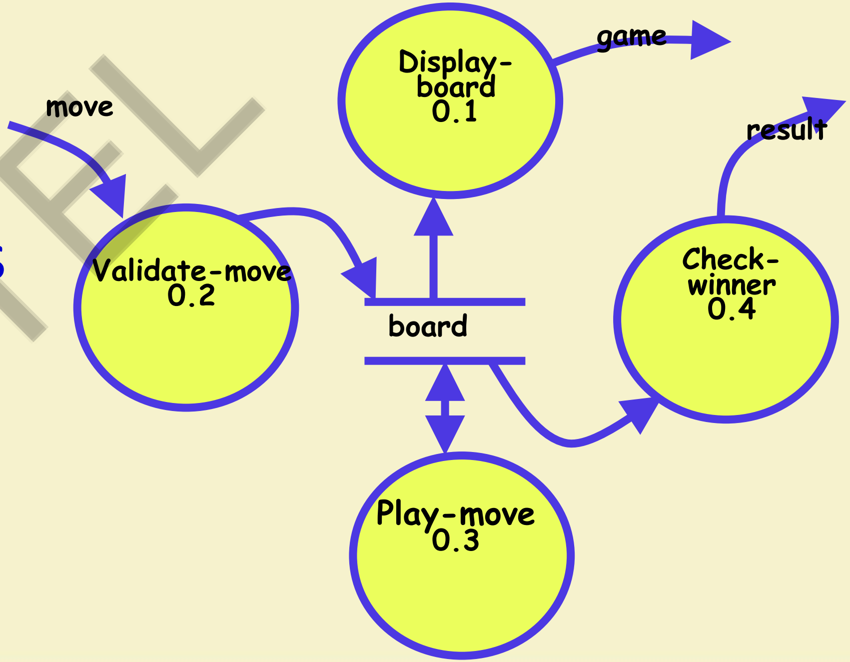
- Purpose of structured analysis:
  - Capture the detailed structure of the system as the user views it.
- Purpose of structured design:
  - Arrive at a form that is suitable for implementation in some programming language.

Structured Analysis: Recap

- Based on principles of:
  - **Top-down decomposition approach.**
  - **Divide and conquer principle:**
    - Each function is considered individually (i.e. isolated from other functions).
    - Decompose functions totally disregarding what happens in other functions.
  - Graphical representation of results using
    - **Data flow diagrams (or bubble charts).**

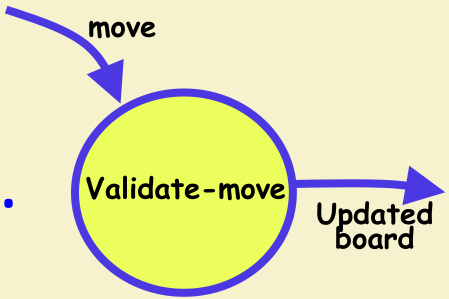
Data Flow Diagram

- DFD is a hierarchical graphical model:
  - Shows the different functions (or processes) of the system
  - Data interchange among the processes.

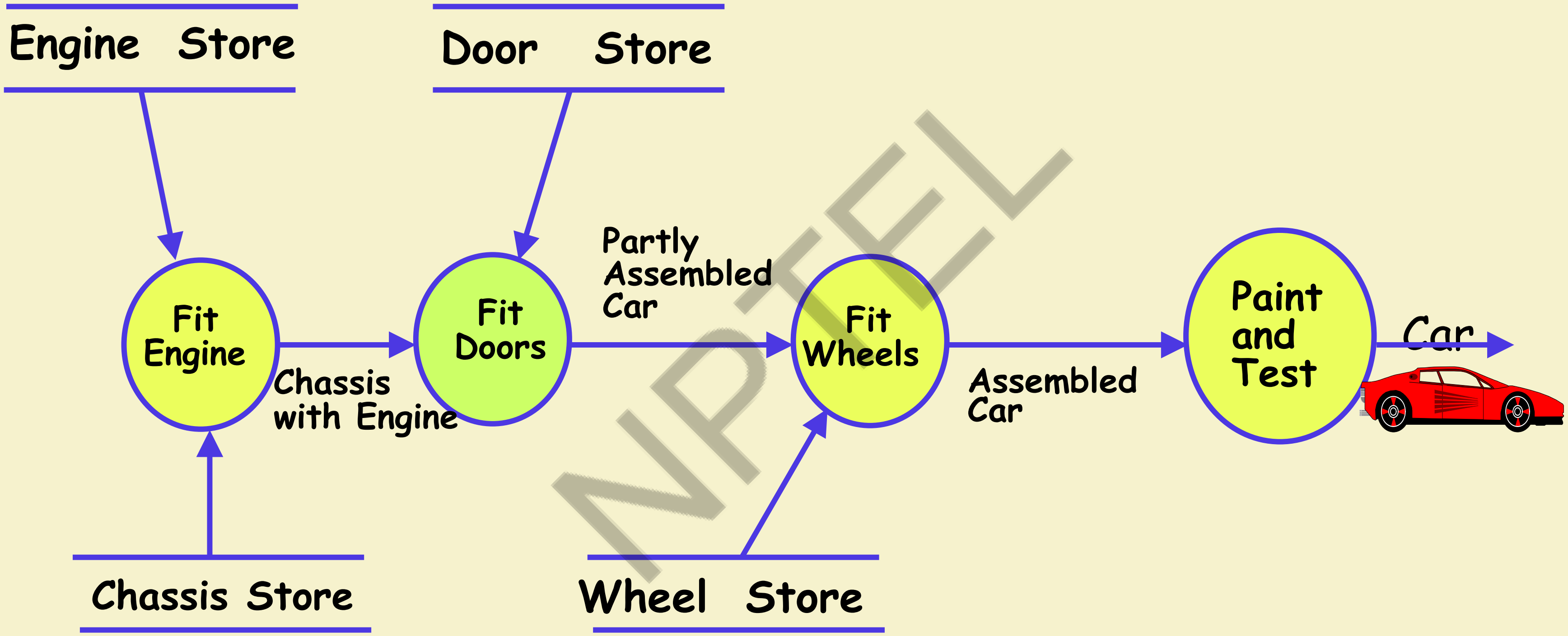


DFD Concepts

- 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



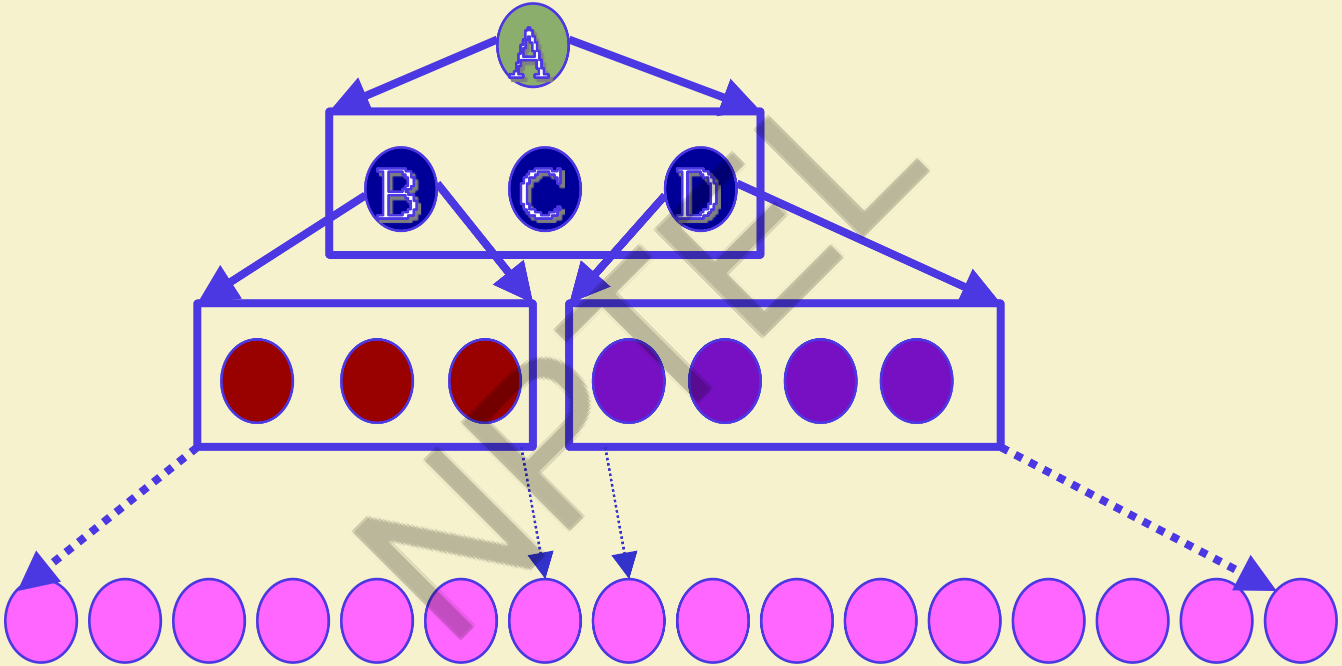
Pros of Data Flow Diagrams (DFDs)

- A DFD model:
  - Uses limited types of symbols.
  - Simple set of rules
  - Easy to understand --- a hierarchical model.

Hierarchical Model

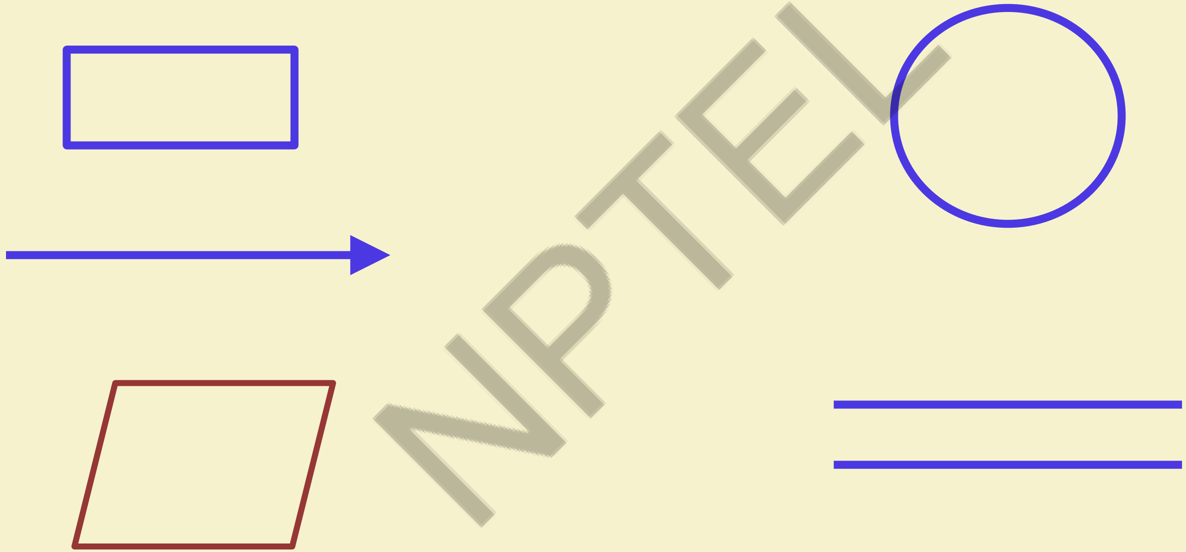
- As pointed out earlier:
  - Human cognitive restrictions are overcome through use of a hierarchical model:
  - In a hierarchical model:
    - We start with a very simple and abstract model of a system,
    - Details are slowly introduced through the hierarchies.

A Hierarchical Model



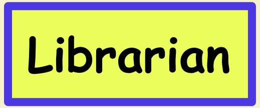
Data Flow Diagrams (DFDs)

- Basic Symbols Used for Constructing DFDs:



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 **terminator, source, or sink.**



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

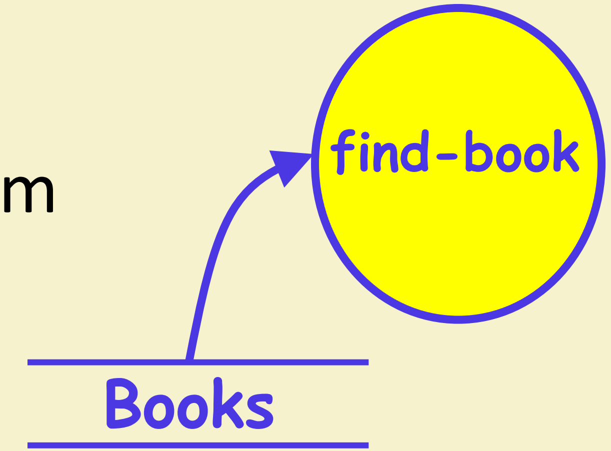
- A directed arc or line.
  - Represents data flow in the direction of the arrow.
  - Data flow symbols are annotated with names of data they carry.

Data Store Symbol

- Represents 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.

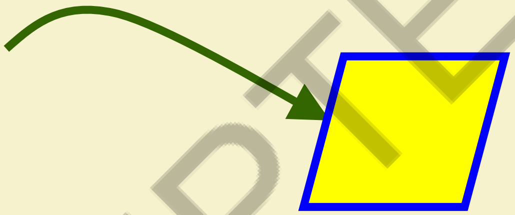
Data Store Symbol

- Direction of data flow arrow:
  - Shows whether data is being read from or written into it.
- An arrow into or out of a 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.



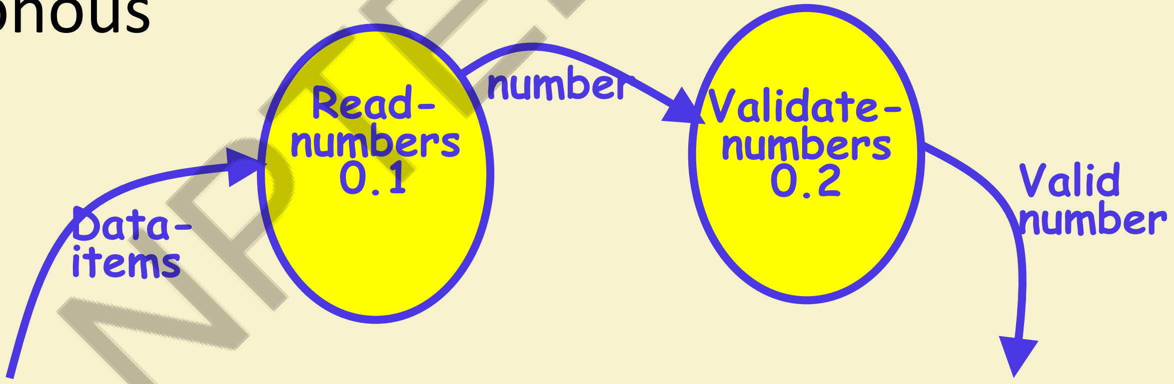
Output Symbol: Parallelogram

- Output produced by the system



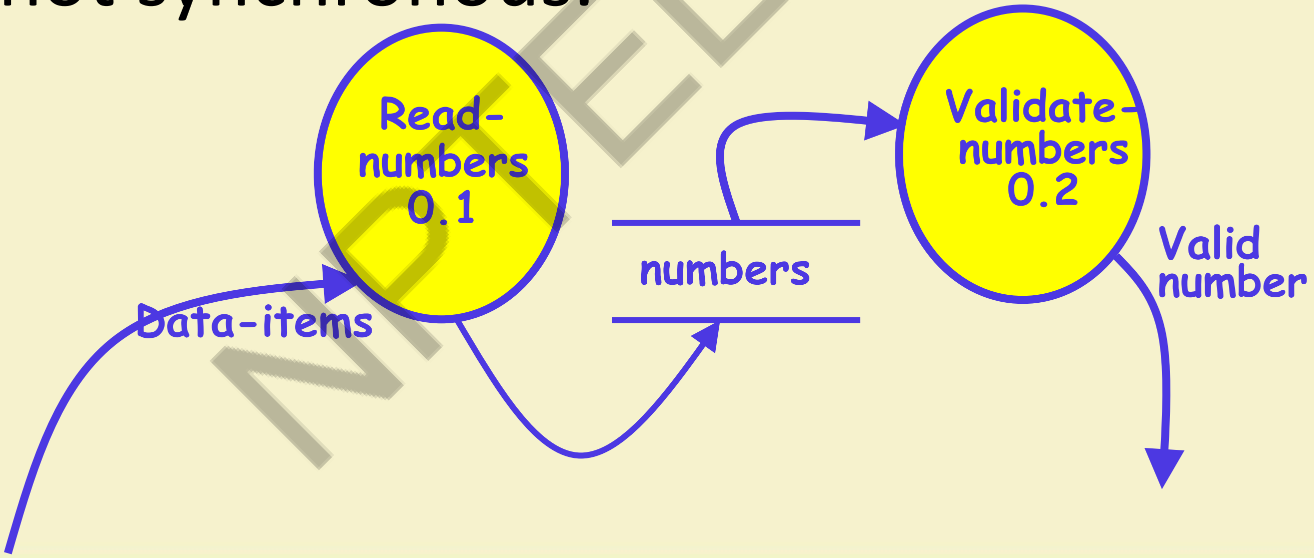
Synchronous Operation

- 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.

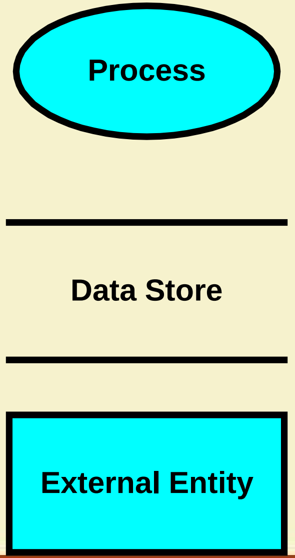


Yourdon's vs. Gane Sarson Notations

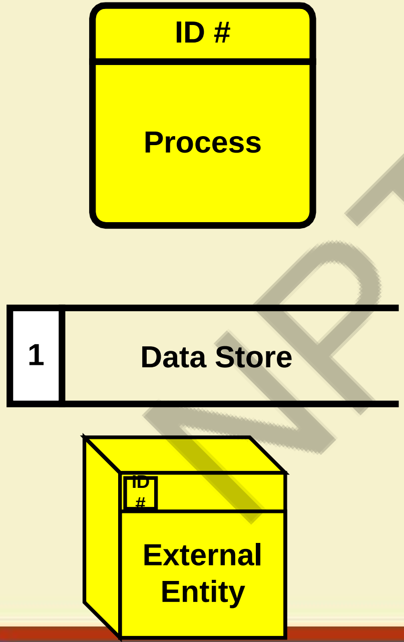
- The notations that we are following:
  - Are closer to the Yourdon's notations
- You may sometimes find notations in books and used in some tools that are slightly different:
  - For example, the data store may look like a box with one end closed

Visio 5.x

From Flow Chart /
Data Flow Diagram



From Software Diagram /
Gane-Sarson DFD



Visio 2000

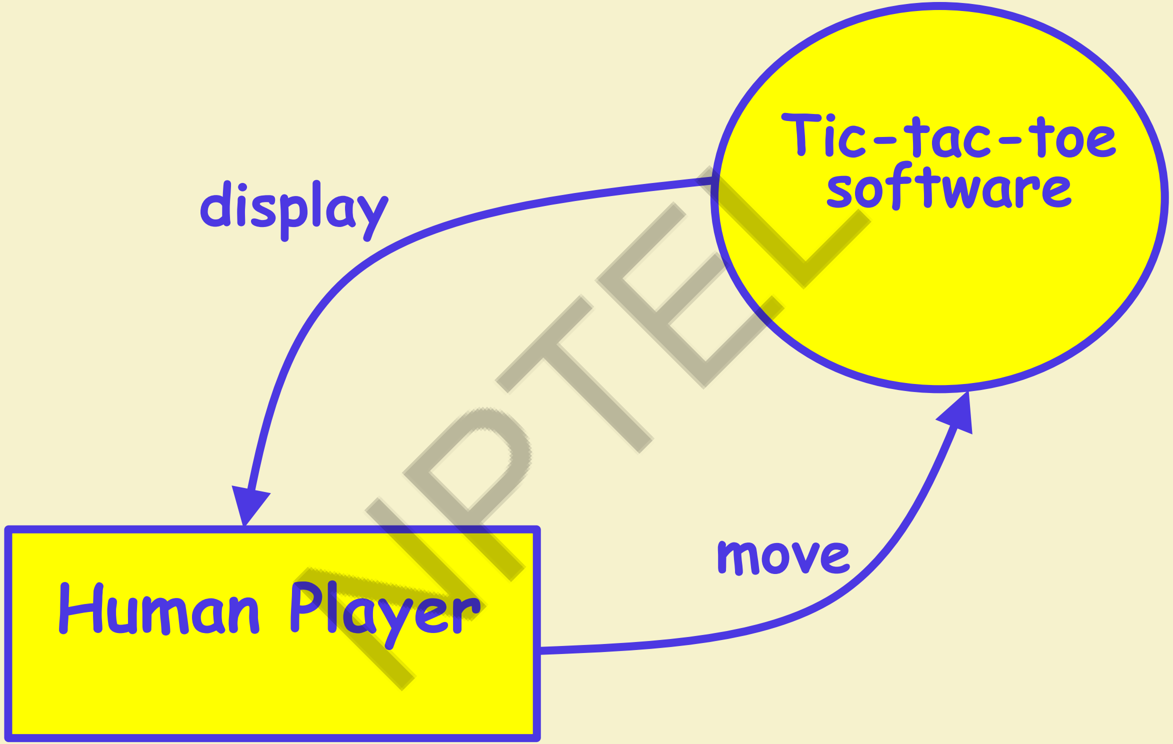
Data Flow Diagram

DFD Shapes from Visio

How is Structured Analysis Performed?

- Initially represent the software at the most abstract level:
  - Called the **context diagram**.
  - The entire system is represented as a single bubble,
  - This bubble is labelled according to the main function of the system.

Tic-tac-toe: Context Diagram



Context Diagram

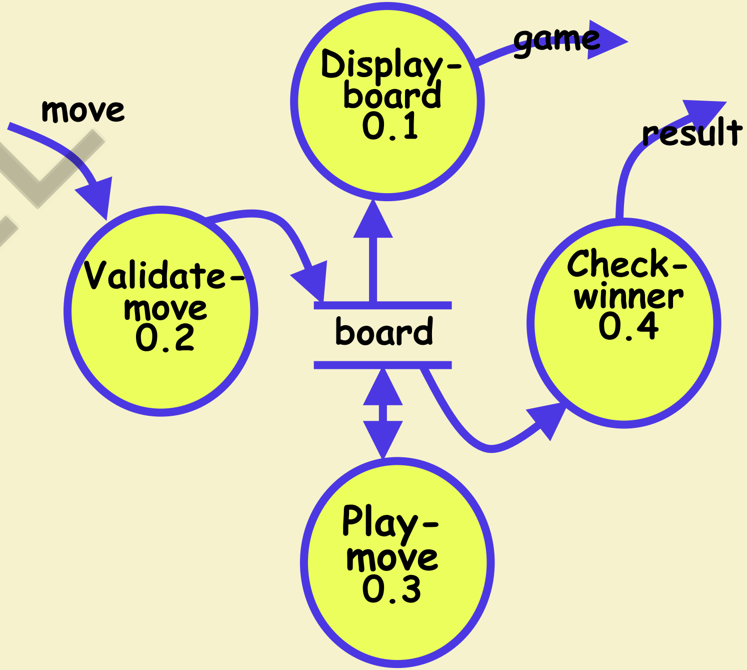
- A context diagram shows:
  - External entities.
  - Data input to the system by the external entities,
  - Output data generated by the system.
- The context diagram is also called the **level 0 DFD.**

Context Diagram

- Establishes the context of the system, i.e.
  - Represents the system level
    - **Data sources**
    - **Data sinks.**

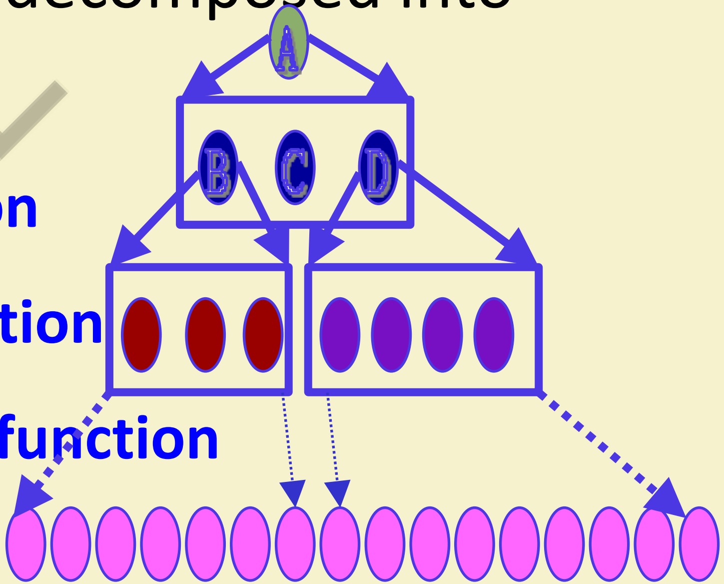
Level 1 DFD Construction

- Examine the SRS document:
  - Represent each high-level function as a bubble.
  - Represent data input to every high-level function.
  - Represent data output from every high-level function.



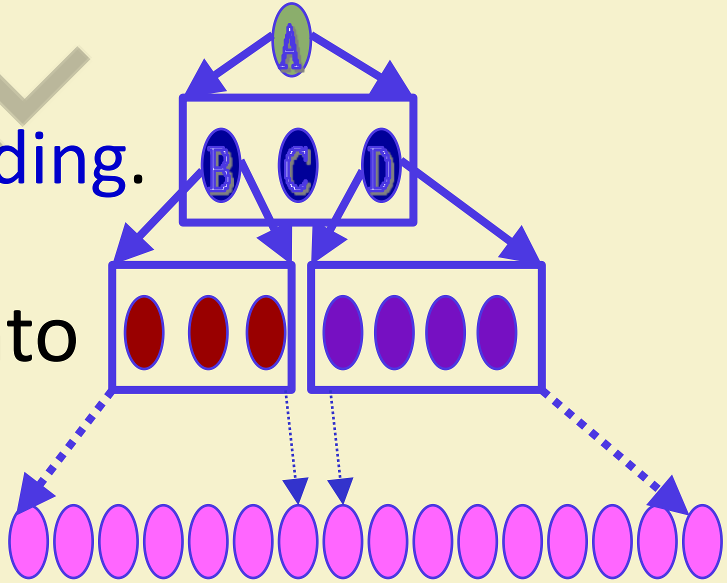
Higher Level DFDs

- Each high-level function is separately decomposed into subfunctions:
  - **Identify the subfunctions of the function**
  - **Identify the data input to each subfunction**
  - **Identify the data output from each subfunction**
- These are represented as DFDs.



Decomposition

- Decomposition of a bubble:
  - Also called factoring or exploding.
- Each bubble is decomposed into
  - Between 3 to 7 bubbles.



Decomposition

- Too few bubbles make decomposition superfluous:
  - If a bubble is decomposed to just one or two bubbles:
    - Then this decomposition is redundant.

Decomposition Pitfall

- Too many bubbles at a level, a sign of poor modelling:
  - **More than 7 bubbles at any level of a DFD.**
  - **Make the DFD model hard to understand.**

Decompose How Long?

- Decomposition of a bubble should be carried on until:
  - A level at which the function of the bubble can be described using a simple algorithm.

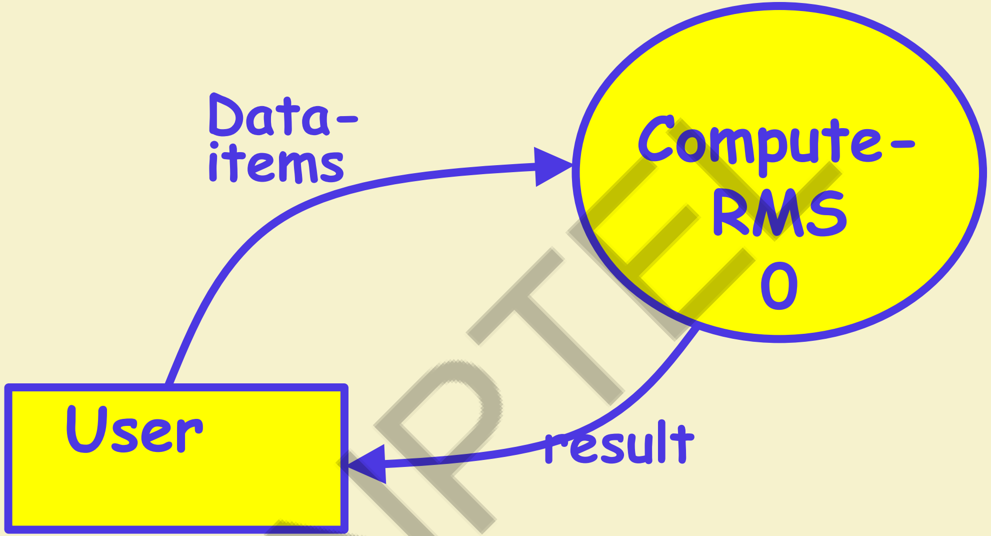
Example 1: RMS Calculating Software

- Consider a software called RMS calculating software:
  - Reads three integers in the range of -1000 and +1000
  - Finds out the root mean square (rms) of the three input numbers
  - Displays the result.

Example 1: RMS Calculating Software

- The context diagram is simple to develop:
  - The system accepts 3 integers from the user
  - Returns the result to him.

Example 1: RMS Calculating Software



Context Diagram (Level 0 DFD)

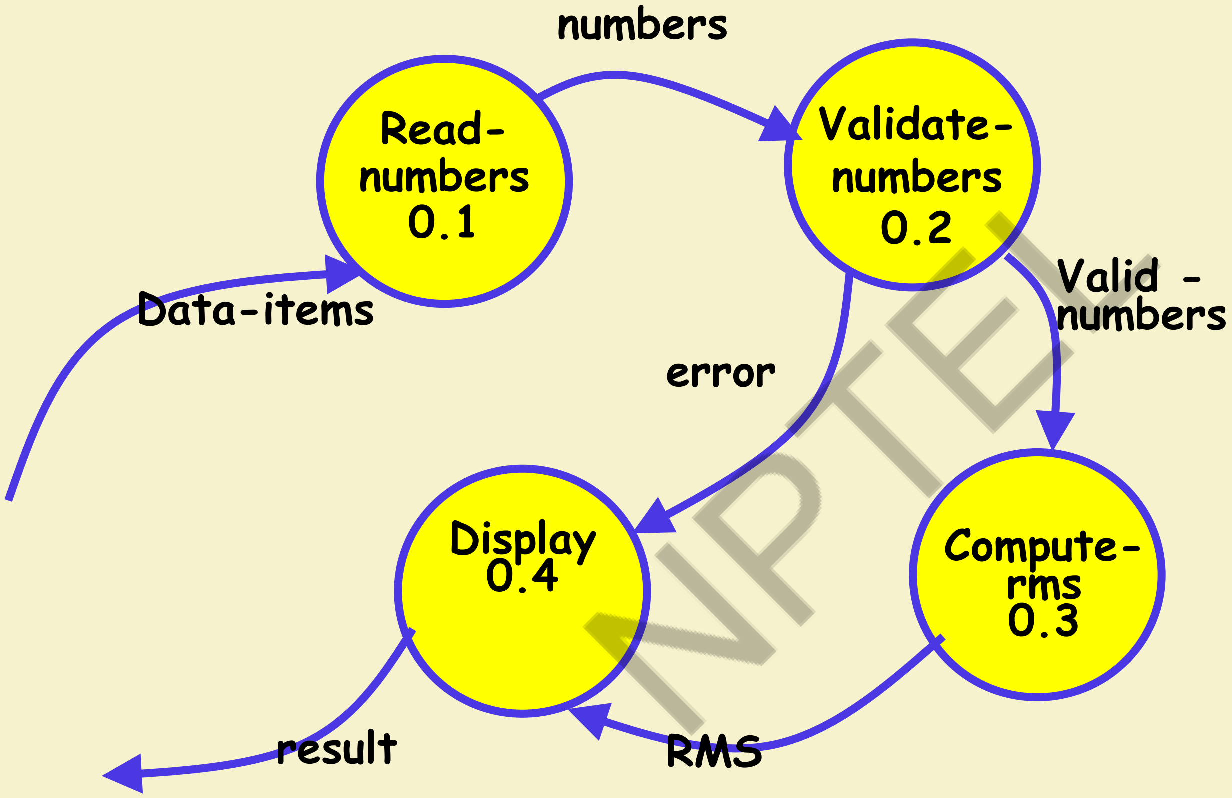
Example 1: RMS Calculating Software

- From a cursory analysis of the problem description:
  - We can see that the system needs to perform several things.

Example 1: RMS Calculating Software

- Accept input numbers from the user:
- Validate the numbers,
- Calculate the root mean square of the input numbers
- Display the result.

Example 1: Level 1 DFD RMS Calculating Software



Example: RMS Calculating Software

- Decomposition is never carried on up to basic instruction level:
  - A bubble is not decomposed any further:
    - If it can be represented by a simple set of instructions.

Data Dictionary

- A DFD is always accompanied by a data dictionary.
- A data dictionary lists all data items appearing in a DFD:
  - Definition of all composite data items in terms of their component data items.
  - All data names along with the purpose of the data items.
- For example, a data dictionary entry may be:
  - grossPay = regularPay+overtimePay

Importance of Data Dictionary

- Provides the team of developers with standard terminology for all data:
  - A consistent vocabulary for data is very important
- In the absence of a data dictionary, different developers tend to use different terms to refer to the same data,
  - Causes unnecessary confusion.

Importance of Data Dictionary

- Data dictionary provides the definition of different data:
  - In terms of their component elements.
- For large systems,
  - The data dictionary grows rapidly in size and complexity.
  - Typical projects can have thousands of data dictionary entries.
  - It is extremely difficult to maintain such a dictionary manually.

Data Dictionary

- CASE (Computer Aided Software Engineering) tools come handy:
  - CASE tools capture the data items appearing in a DFD automatically to generate the data dictionary.

Data Dictionary

- CASE tools support queries:
  - About definition and usage of data items.
- For example, queries may be made to find:
  - Which data item affects which processes,
  - A process affects which data items,
  - The definition and usage of specific data items, etc.
- Query handling is facilitated:
  - If data dictionary is stored in a relational database management system (RDBMS).

Data Definition

- Composite data are defined in terms of primitive data items using simple operators:
- **+:** denotes composition of data items, e.g
  - **a+b represents data a together with b.**
- **[,,,]:** represents selection,
  - Any one of the data items listed inside the square bracket can occur.
  - For example, **[a,b] represents either a occurs or b**

- **( ):** contents inside the bracket represent optional data
  - which may or may not appear.
  - **a+(b) represents either a or a+b**

Data Definition

- **{}:** represents iterative data definition,
  - **{name}5 represents five name data.**

Data Definition

- {name}* represents
  - zero or more instances of name data.
- = represents equivalence,
  - e.g. **a=b+c** means that a represents b and c.
- * *: Anything appearing within * * is considered as comment.

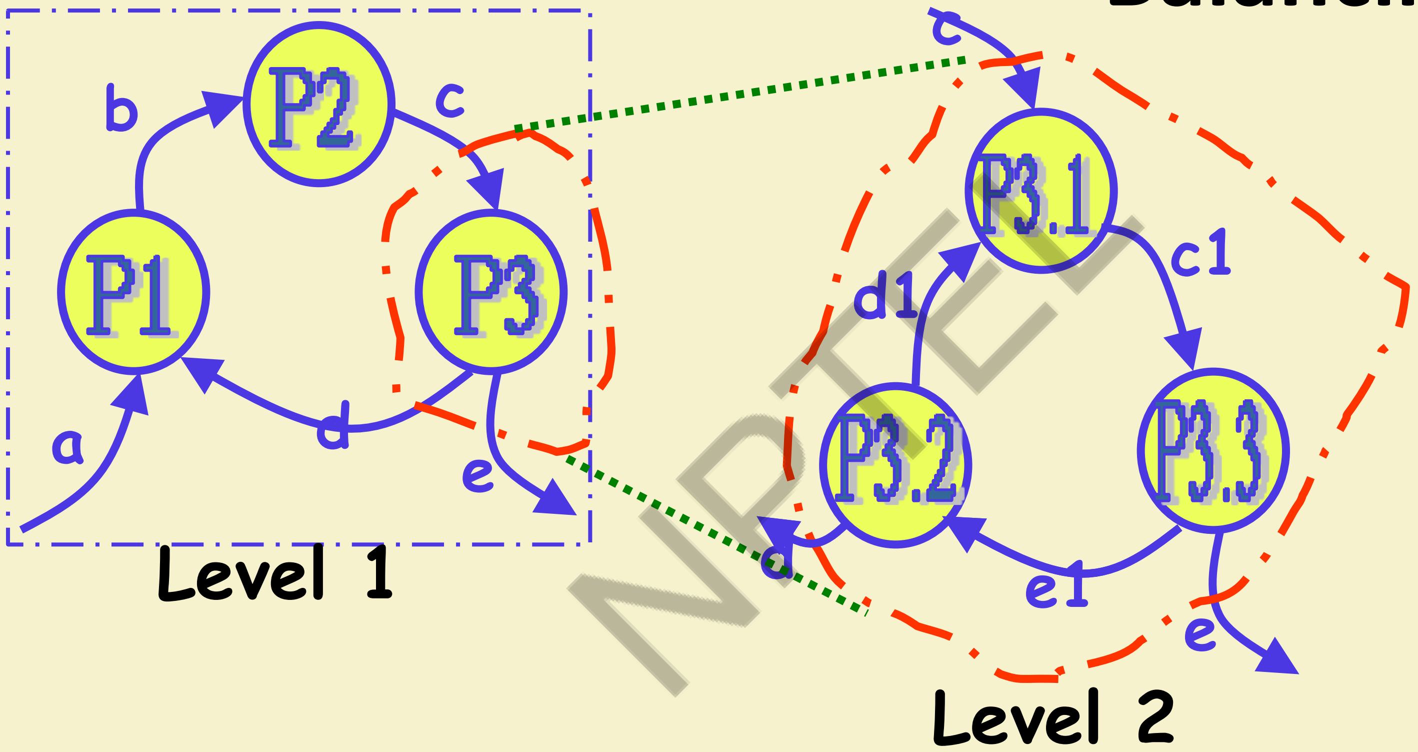
Data Dictionary for RMS Software

- numbers=valid-numbers=a+b+c
- a:integer * input number *
- b:integer * input number *
- c:integer * input number *
- asq:integer
- bsq:integer
- csq:integer
- squared-sum: integer
- Result=[RMS,error]
- RMS: integer * root mean square value*
- error:string * error message*

Balancing a DFD

- **Data flowing into or out of a bubble:**
  - **Must match the data flows at the next level of DFD.**
- In the level 1 of the DFD,
  - Data item c flows into the bubble P3 and the data item d and e flow out.
- In the next level, bubble P3 is decomposed.
  - The decomposition is balanced as data item c flows into the level 2 diagram and d and e flow out.

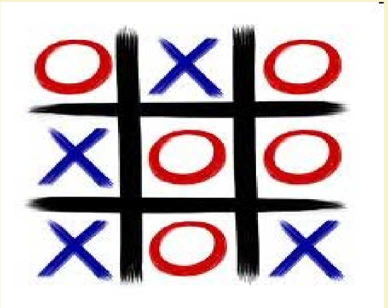
Balancing a DFD



- Number the bubbles in a DFD:
  - **Numbers help in uniquely identifying any bubble from its bubble number.**
- The bubble at context level:
  - Assigned number 0.
- Bubbles at level 1:
  - Numbered 0.1, 0.2, 0.3, etc
- When a bubble numbered x is decomposed,
  - Its children bubble are numbered x.1, x.2, x.3, etc.

Numbering of Bubbles

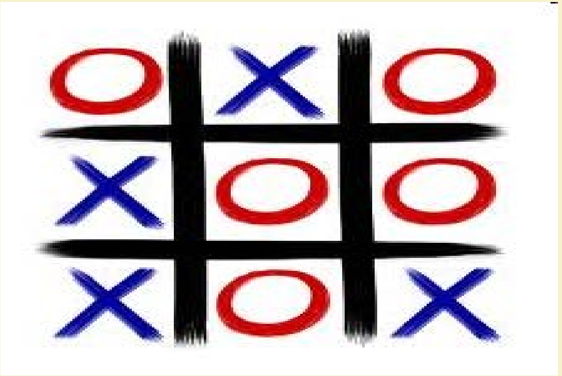
Example 2: Tic-Tac-Toe Computer Game

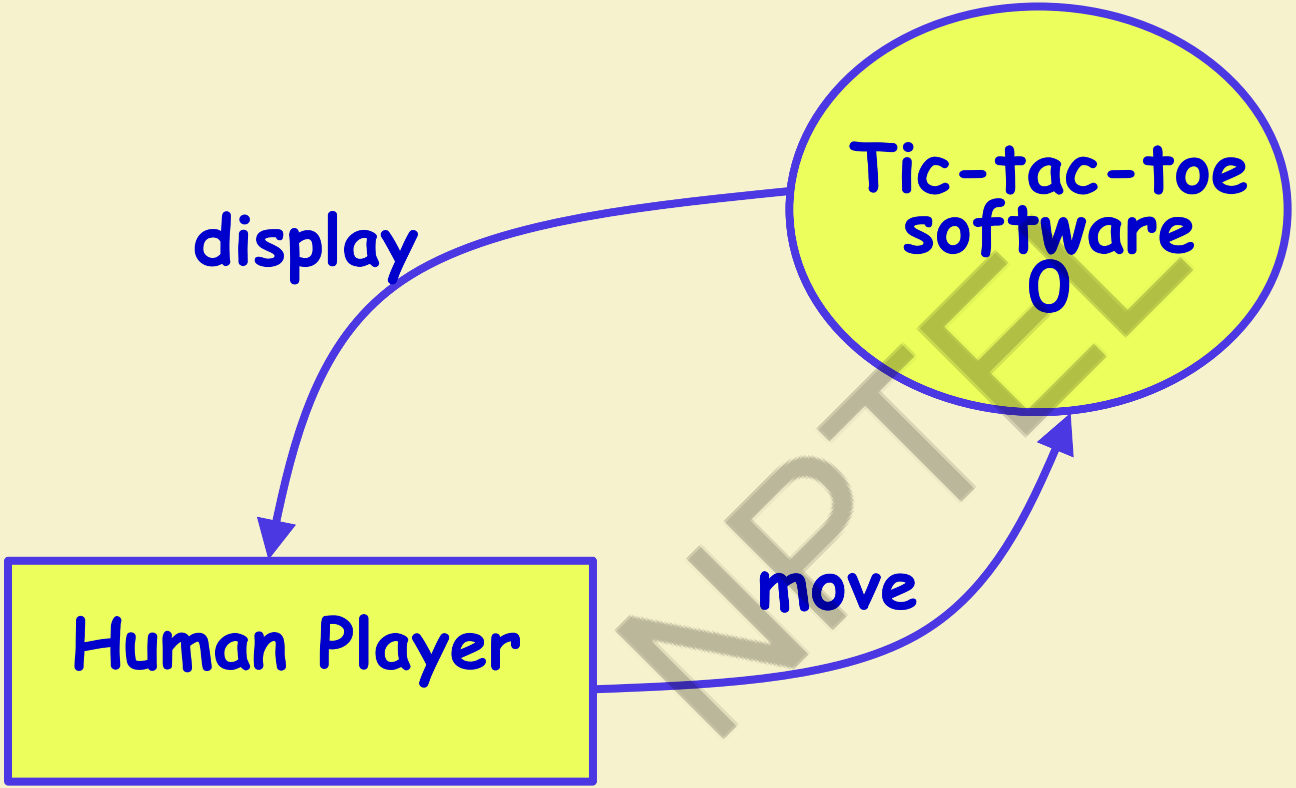


- A human player and the computer make alternate moves on a 3 X 3 square.
- A move consists of marking a previously unmarked square.
- The user inputs a number between 1 and 9 to mark a square
- Whoever is first to place three consecutive marks along a straight line (i.e., along a row, column, or diagonal) on the square wins.

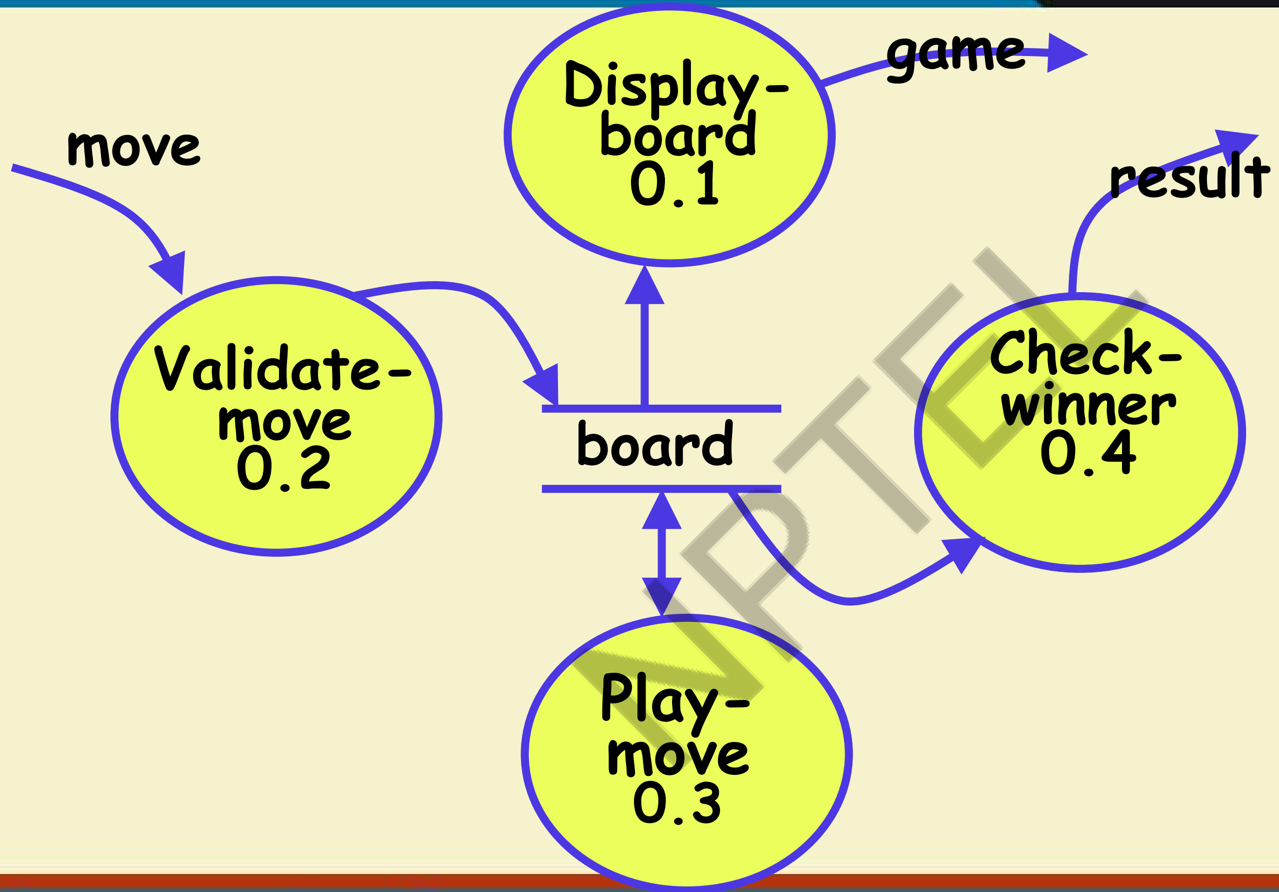
Example: Tic-Tac-Toe Computer Game

- As soon as either of the human player or the computer wins,
  - A message announcing 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


game
Display-board 0.1
move
result
Validate-move 0.2
board
Check-winner 0.4
Play-move 0.3

Level 1 DFD

Data Dictionary

Display=game + result

move = integer

board = {integer}9

game = {integer}9

result=string

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:
  - They 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 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 fulfil 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)

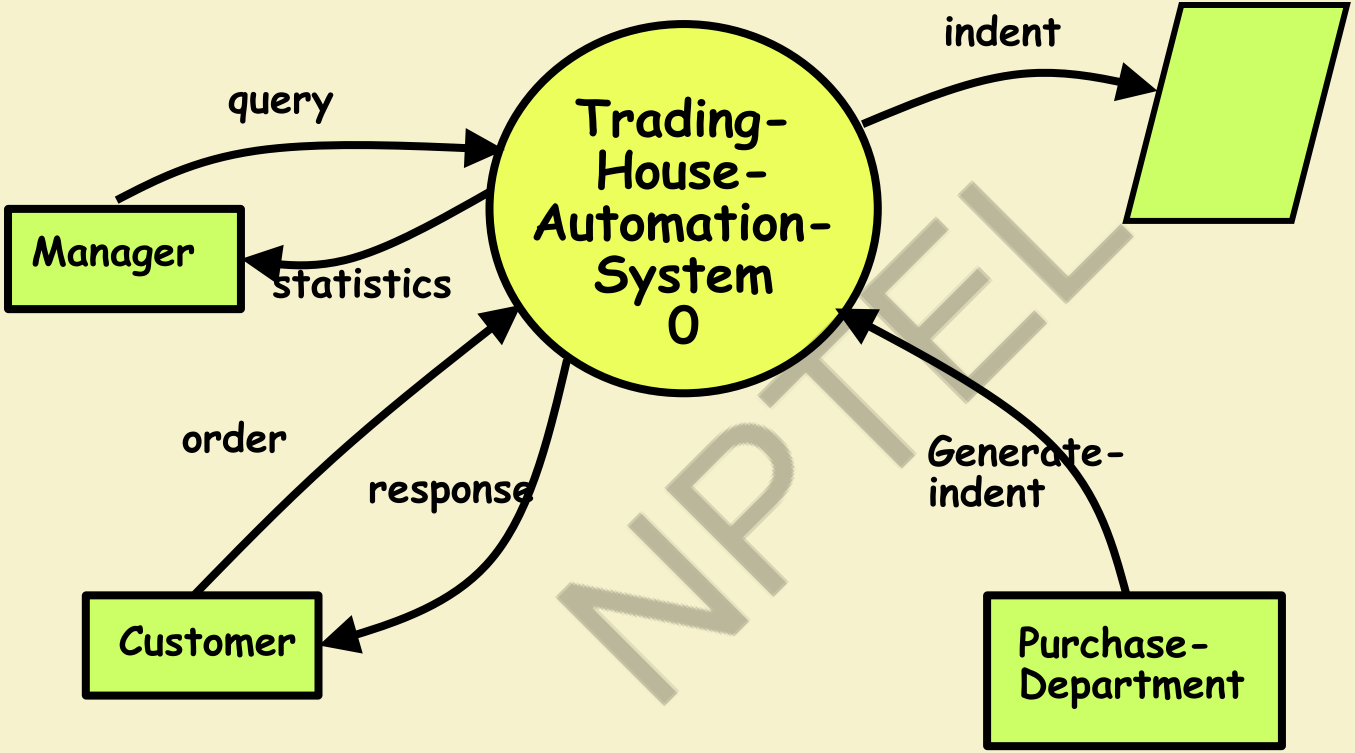
- The purchase department:
  - would periodically issue commands to generate indents.
- When **generate indents** command is issued:
  - The system should examine the "pending-order" file
  - Determine the orders that are pending
  - Total quantity required for each of the items.

Example: Trading-House Automation System (TAS)

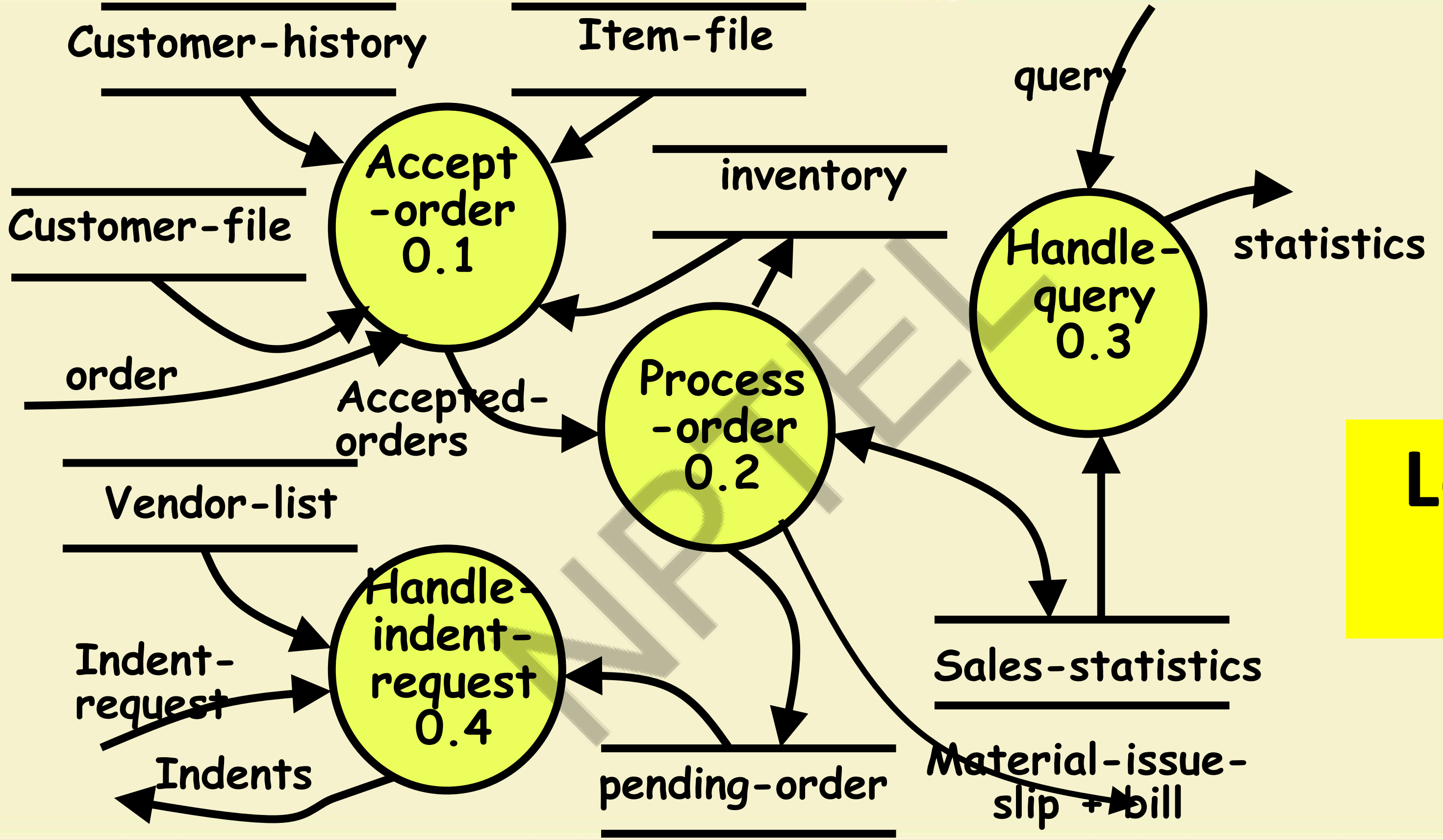
- TAS should find out the addresses of the vendors who supply the required items:
  - Examine the file containing vendor details (their address, items they supply etc.)
  - Print out indents to those vendors.

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



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

Level 1 DFD

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 discussed 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 DFD.
- Only 3 to 7 bubbles per diagram should be allowed:
  - Each bubble should be decomposed to between 3 and 7 bubbles.

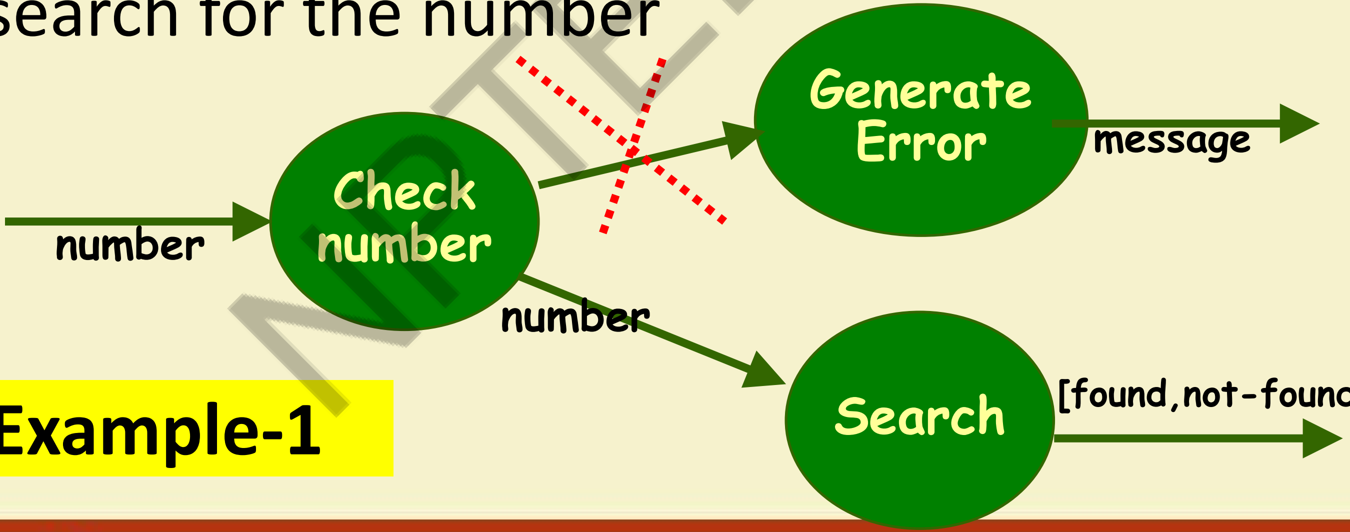
Guidelines For Constructing DFDs

- 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.

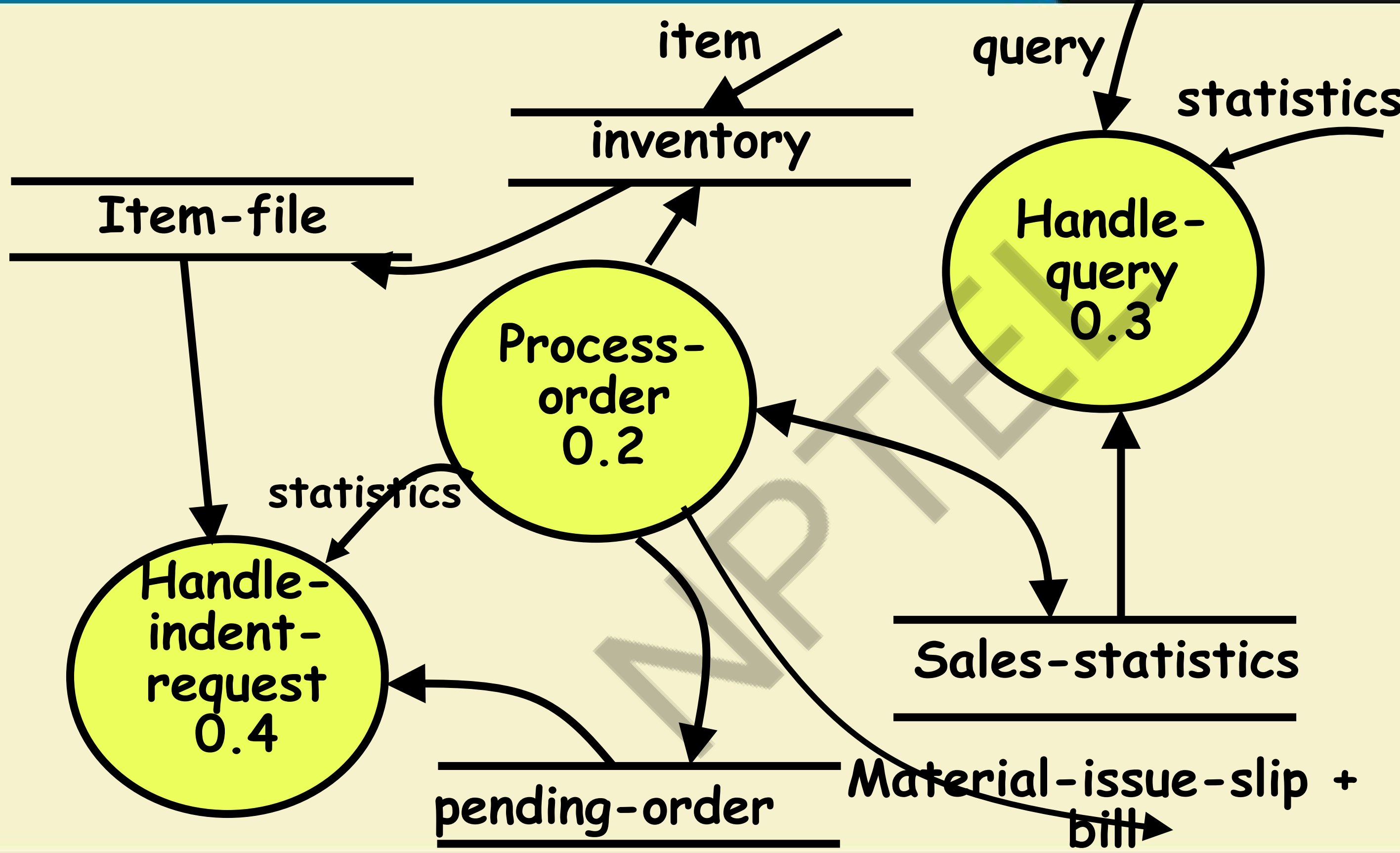
Guidelines For Constructing DFDs

- A DFD model 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.**

- Functionality: 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



Find Error Example-1



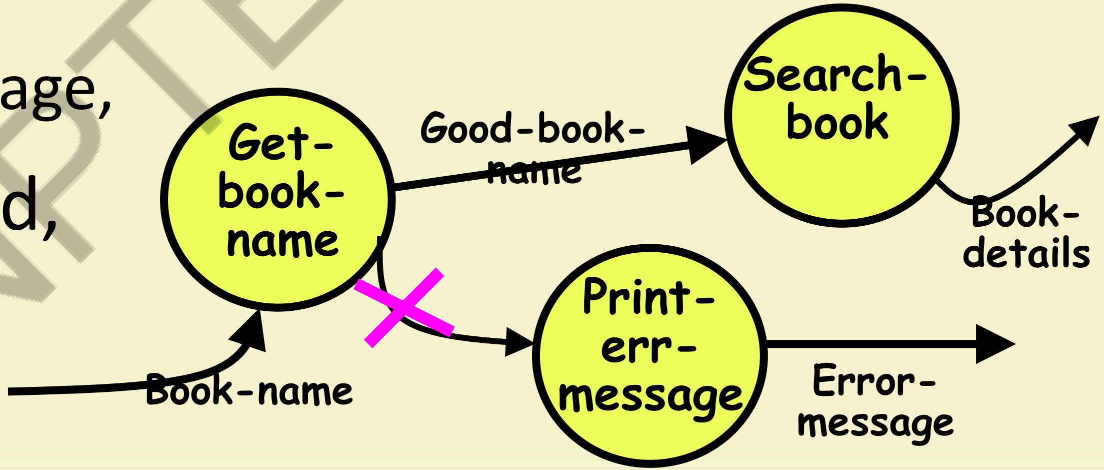
Find 4 Errors

Common Mistakes in 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.

Find Error 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 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 name 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 at next level
- Terminating decomposition too early
- Nouns used in naming bubbles

Shortcomings of the DFD Model

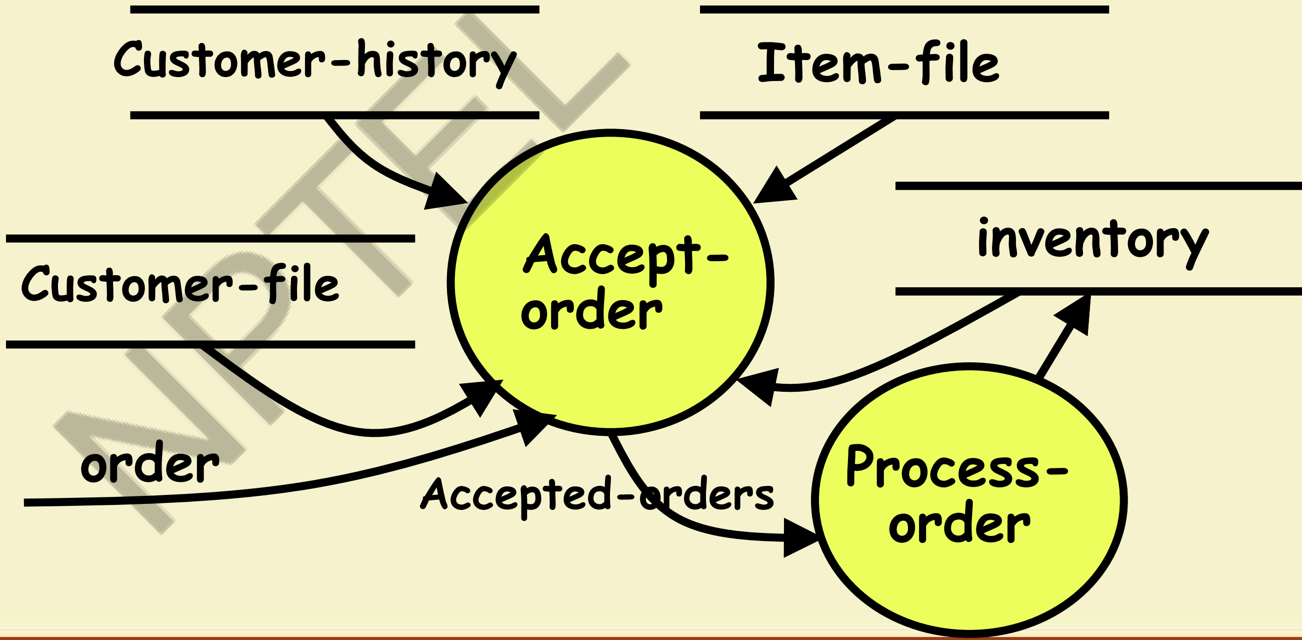
- DFD models suffer from several shortcomings:
- DFDs leave ample scope to be imprecise.
  - In a DFD model, we infer about the function performed by a bubble from its label.
  - A label may not capture all the functionality of a bubble.

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
    - 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

- 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 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.

- Several commercial and free tools available.
- **Commercial:**
  - Visio
  - Smartdraw (30 day free trial)
  - Edraw
  - Creately
  - Visual analyst
- **Free:**
  - Dia (GNU open source)

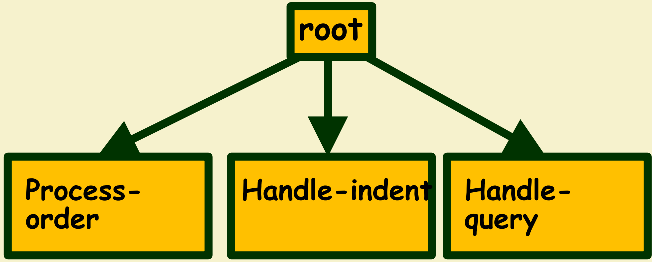
DFD Tools

Word of Caution

- Tools can be learnt and used with some effort.
- **But, too much focus on SA/SD case tools does not make you any more a good designer:**
  - **Than an expert knowledge of the Word Package making you a famous writer of thriller stories.**

Structured Design

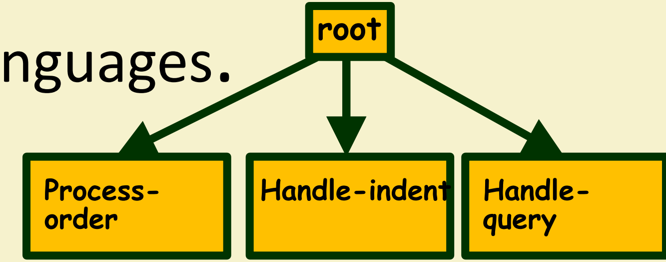
- The aim of structured design
  - **Transform the results of structured analysis (DFD representation) into a structure chart.**



- 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.



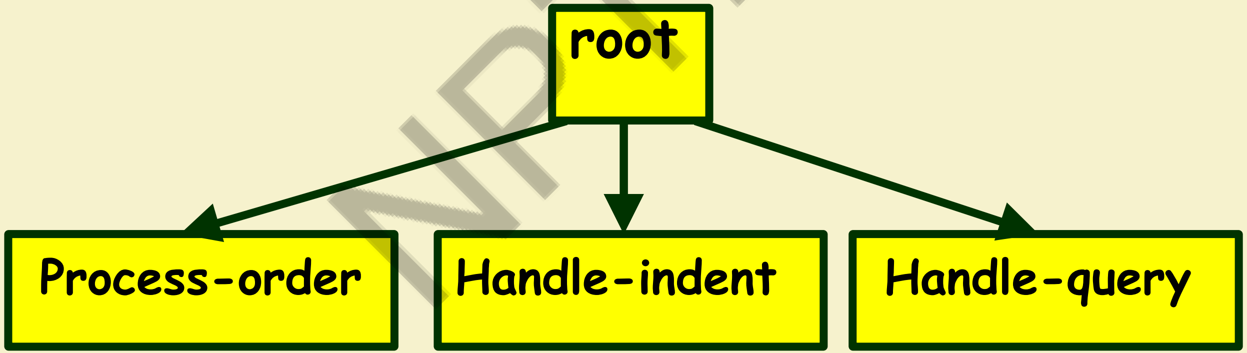
- Main focus of a structure chart:
  - Define the module structure of a software,
  - Interaction among different modules,
  - **Procedural aspects (e.g, how a particular functionality is achieved) are not represented.**

Basic Building Blocks of Structure Chart

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

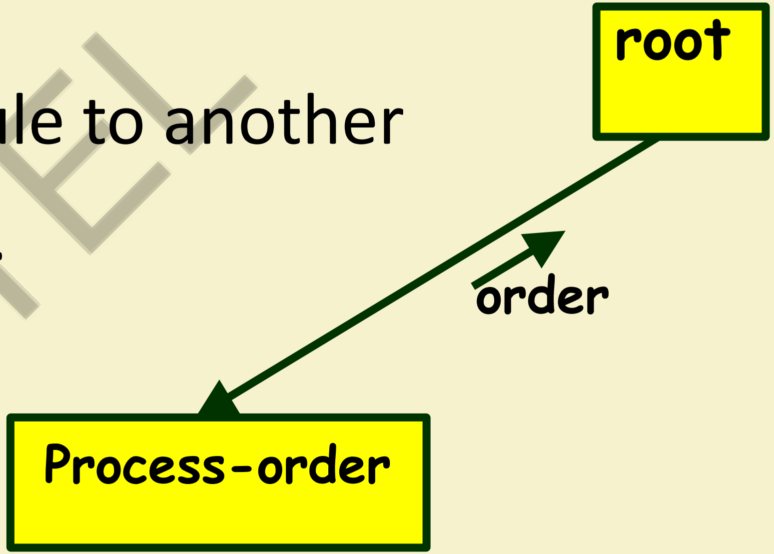
Arrows

- 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.

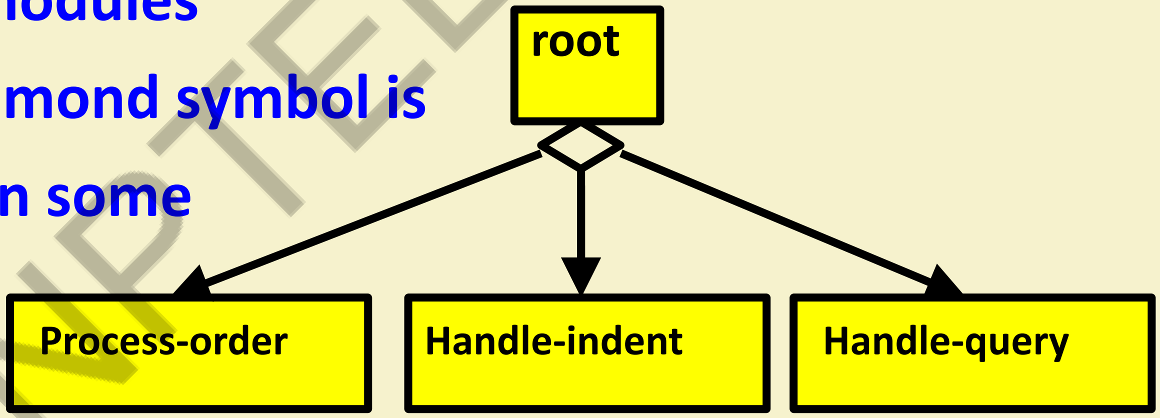


Library Modules

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

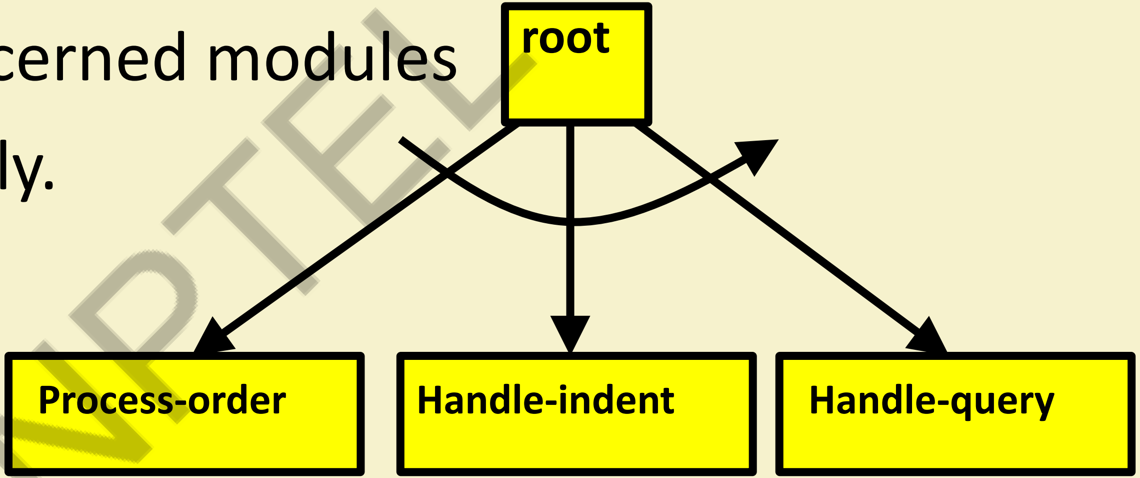
Selection

- The diamond symbol represents:
  - Each one 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.



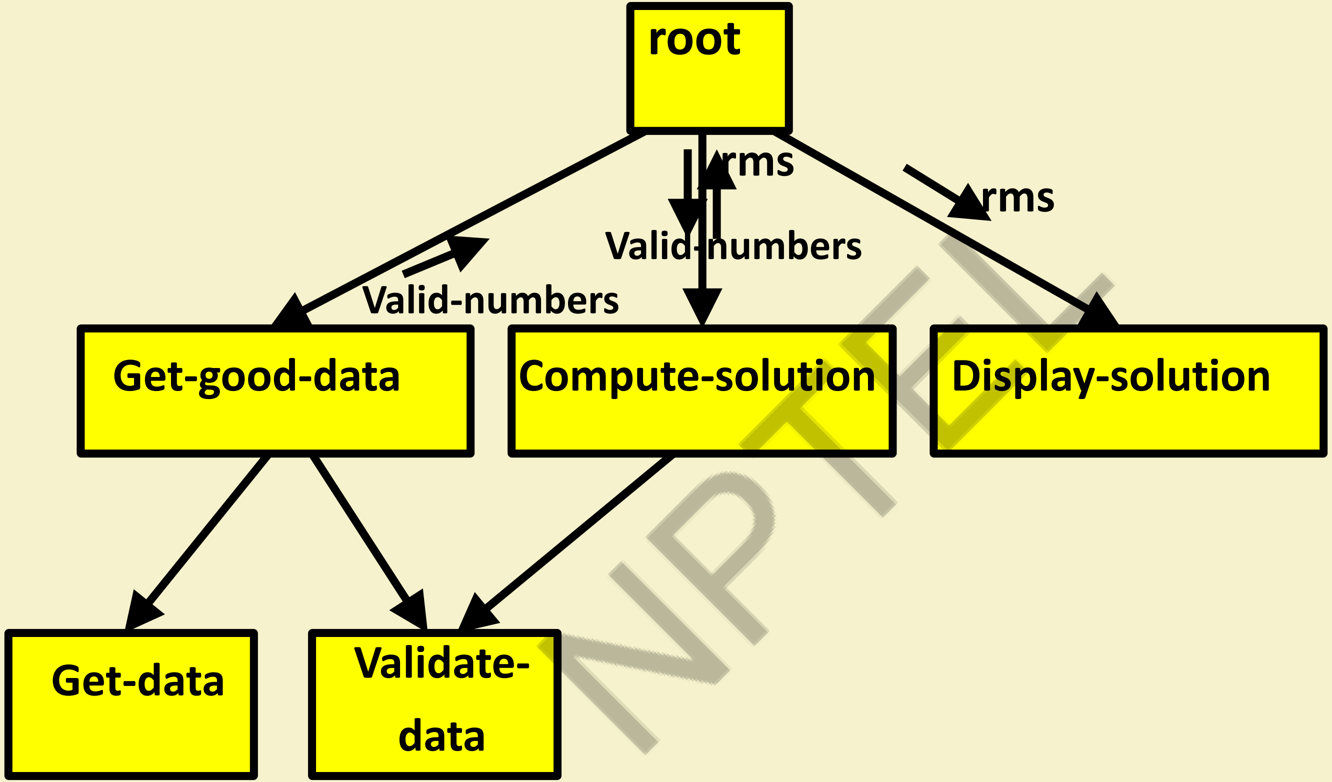
Structure Chart

- 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:
  - **Modules in a structure chart should be arranged in layers or levels.**

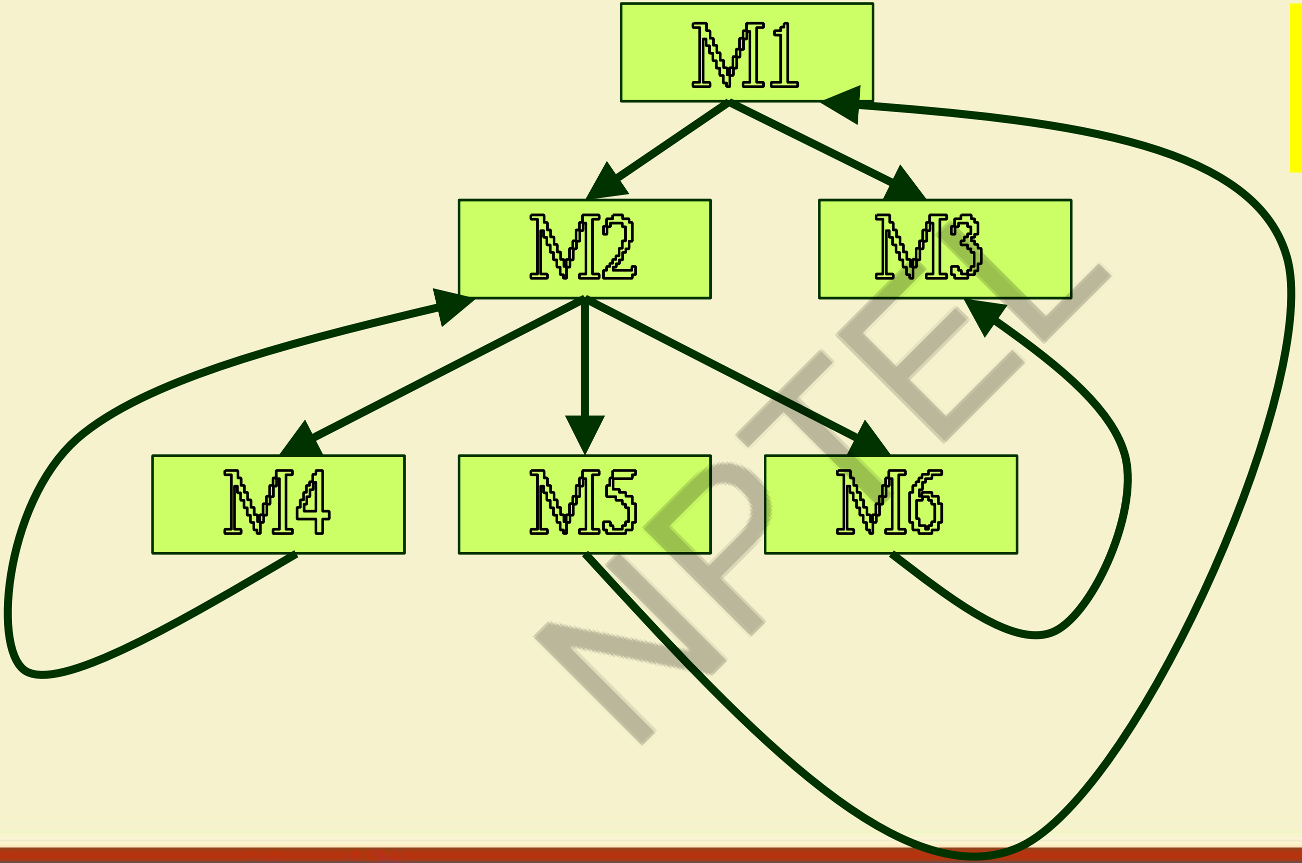
Structure Chart

- Makes use of 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: Good Design



Example: Bad Design



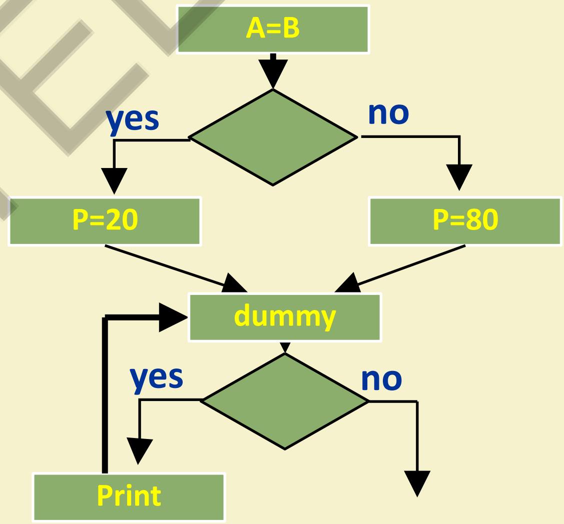
Shortcomings of Structure Chart

- By examining 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

1. It is difficult to identify modules of a software from its flow chart representation.

2. Data interchange among the modules is not represented in a flow chart.

3. **Sequential ordering of tasks inherent in a flow chart is suppressed in a structure chart.**

Transformation of a DFD Model into Structure Chart

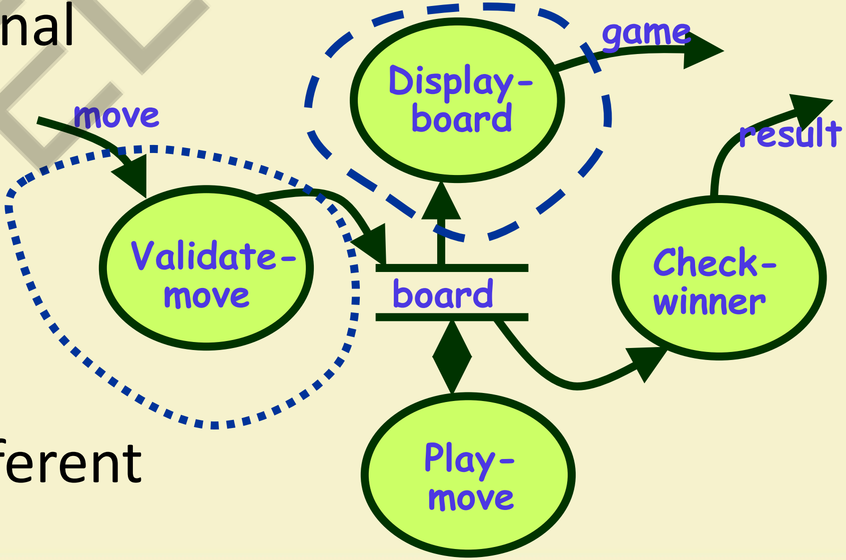
- Two strategies exist to guide transformation of a DFD into a structure chart:
  - **Transform Analysis**
  - **Transaction Analysis**

Transform Analysis

- The first step in transform analysis:
  - Divide the DFD into 3 parts:
    - **input,**
    - **logical processing,**
    - **output.**

Transform Analysis

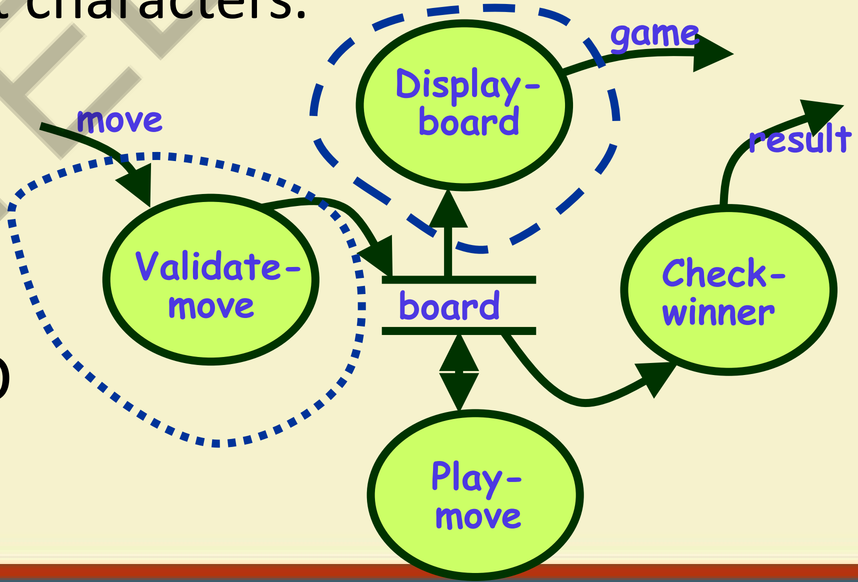
- Input portion in the DFD:
  – processes which convert input data from physical to logical form.
  – e.g. read characters from the terminal and store in internal tables or lists.



- Each input portion:
  – called an **afferent branch.**
  – Possible to have more than one afferent branch in a DFD.

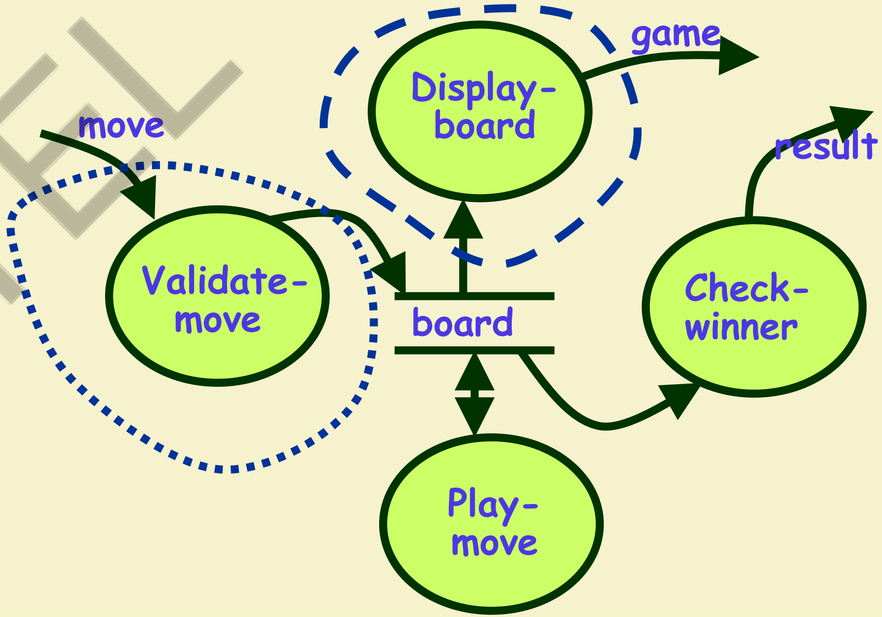
Transform Analysis

- 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:
  - **afferent branch,**
  - **central transform,**
  - **efferent branch.**

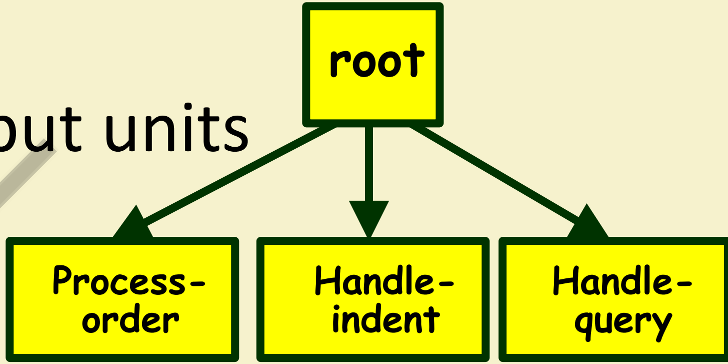


Transform Analysis

- Identifying input and output transforms:
  - requires experience and skill.
- Some guidelines for identifying central transforms:
  - **Trace 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.

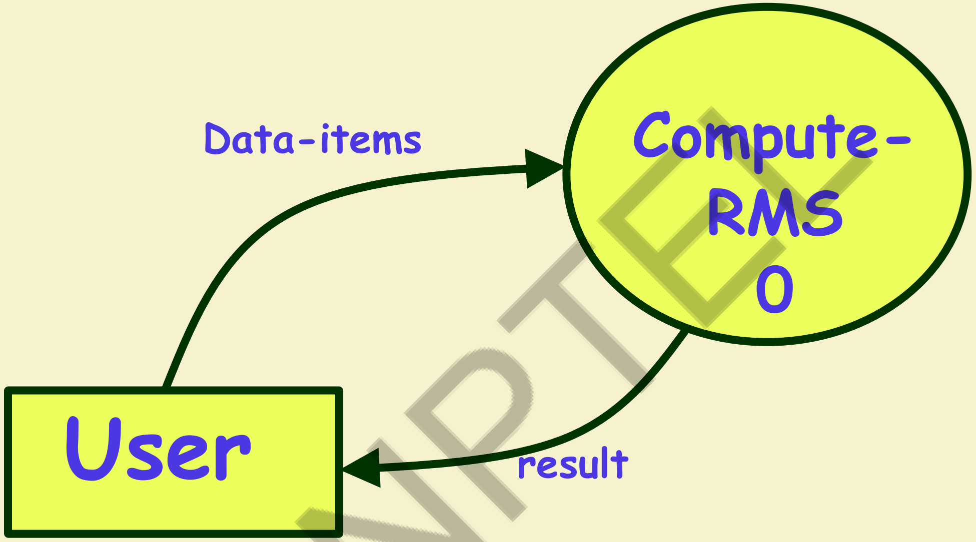


- Next, refine the structure chart:
  - Add subfunctions required by each high-level module.
  - Many levels of modules may required to be added.

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.

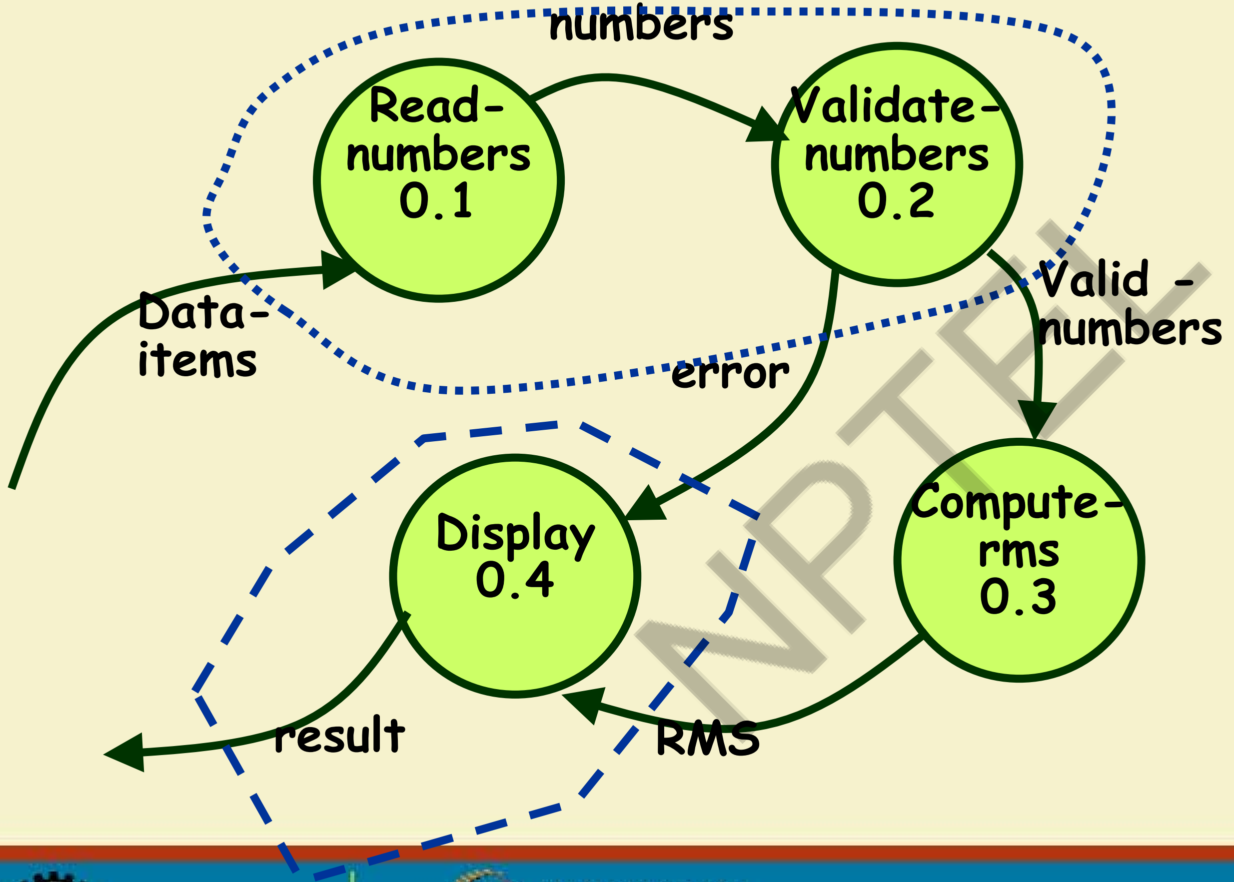
Example 1: RMS Calculating Software



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.

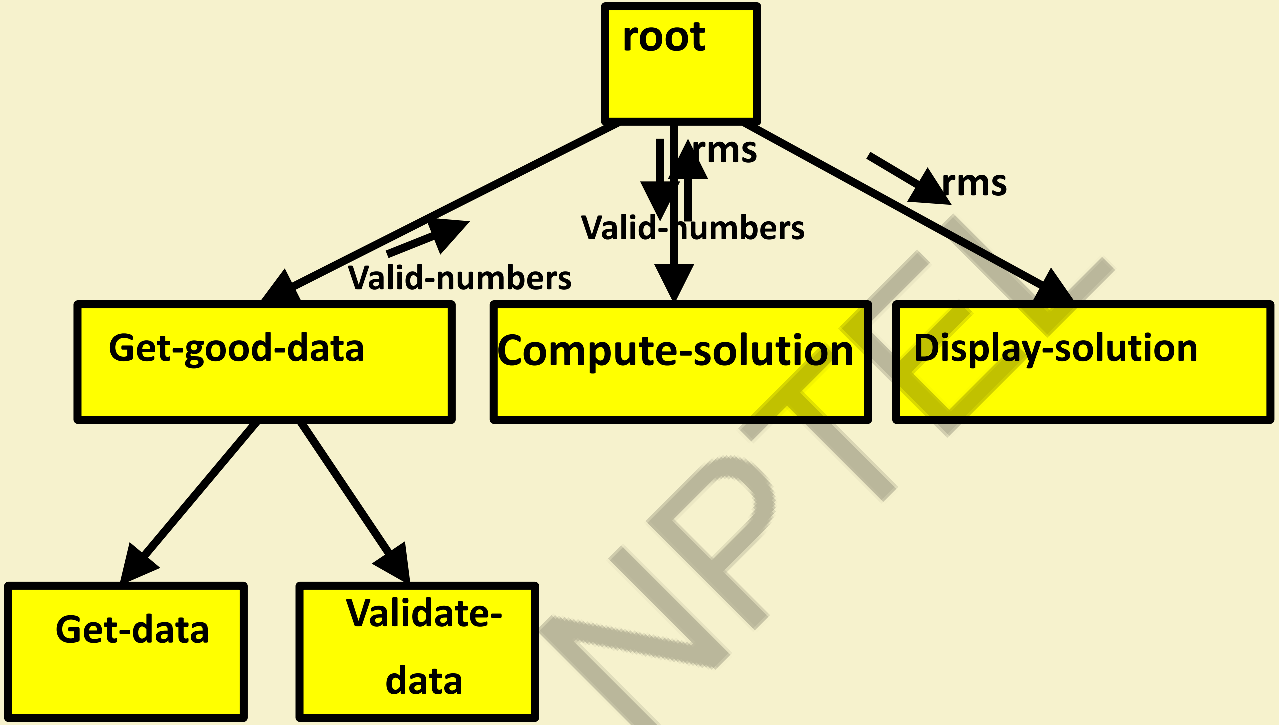


Example 1: RMS Calculating Software

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.

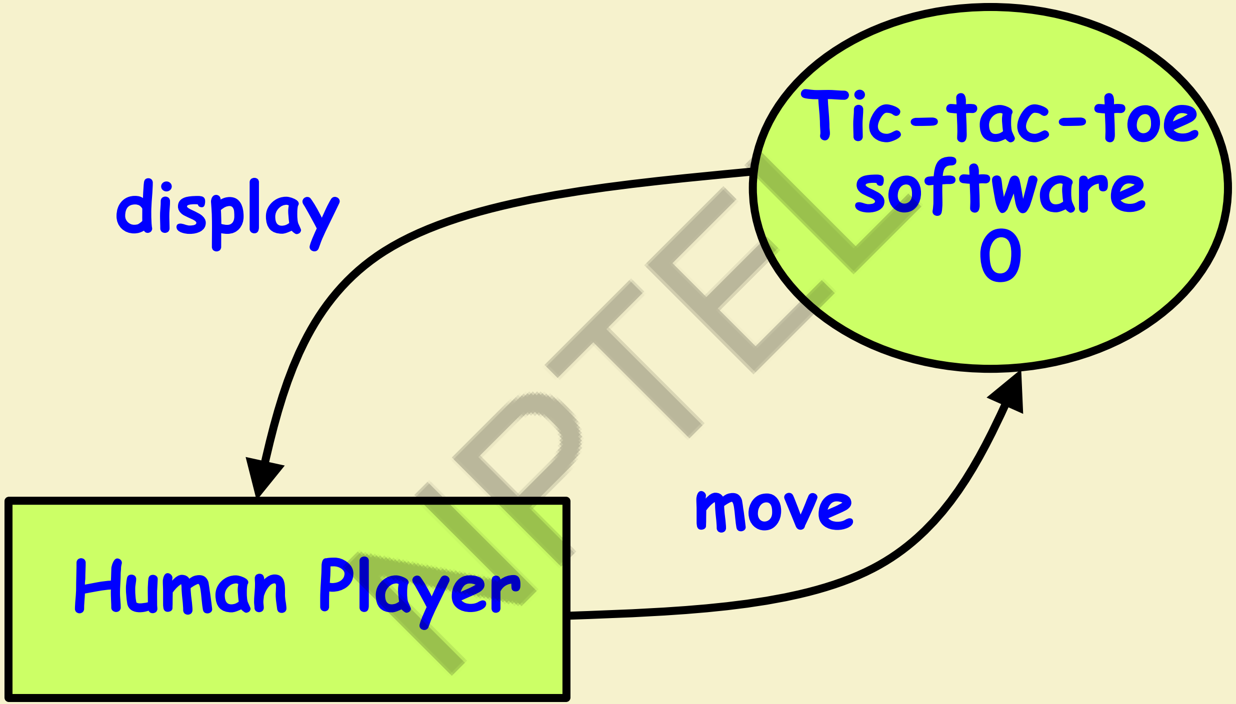
Example 1: RMS Calculating Software

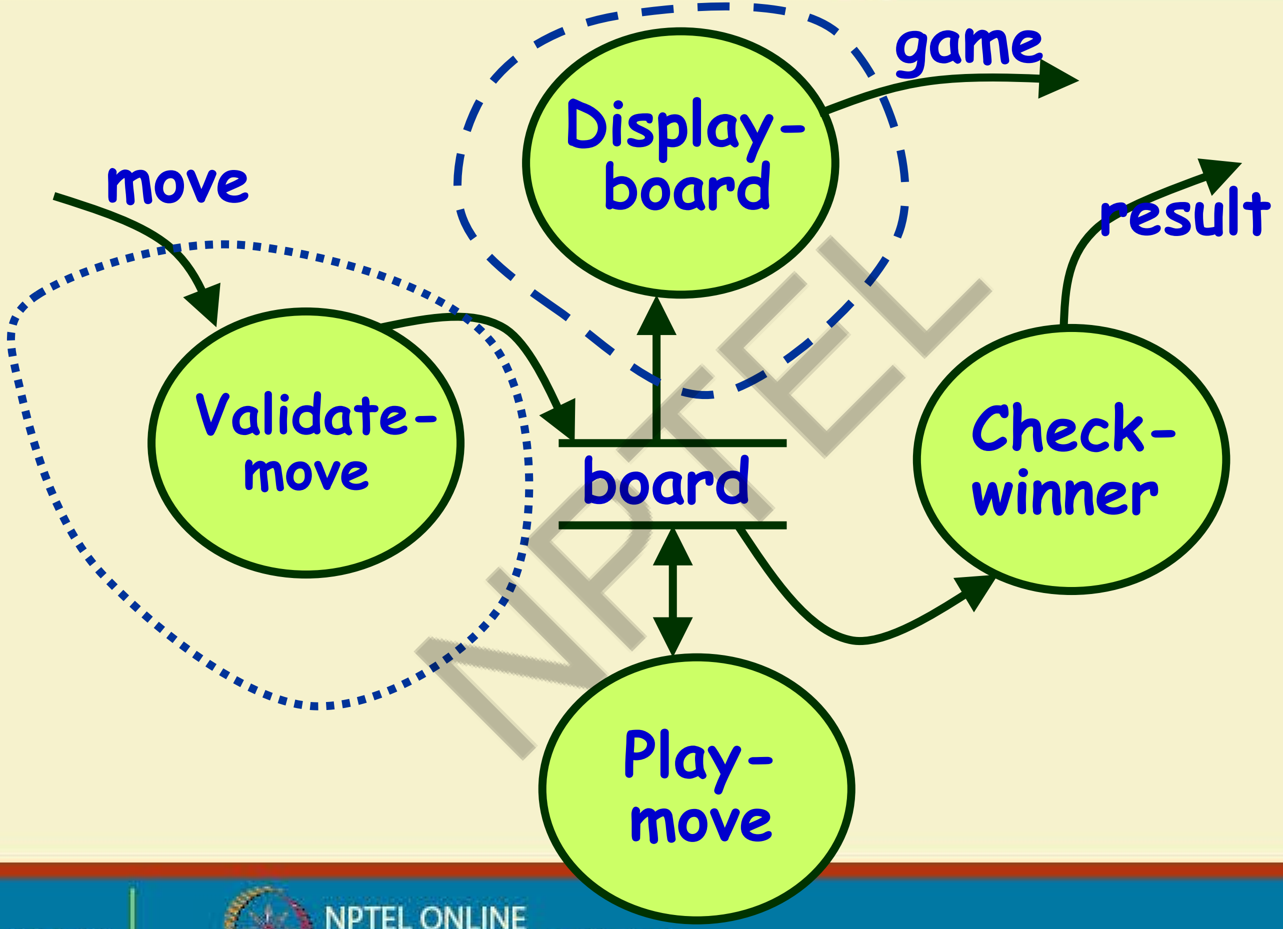


Example 2: Tic-Tac-Toe Computer Game

- 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.

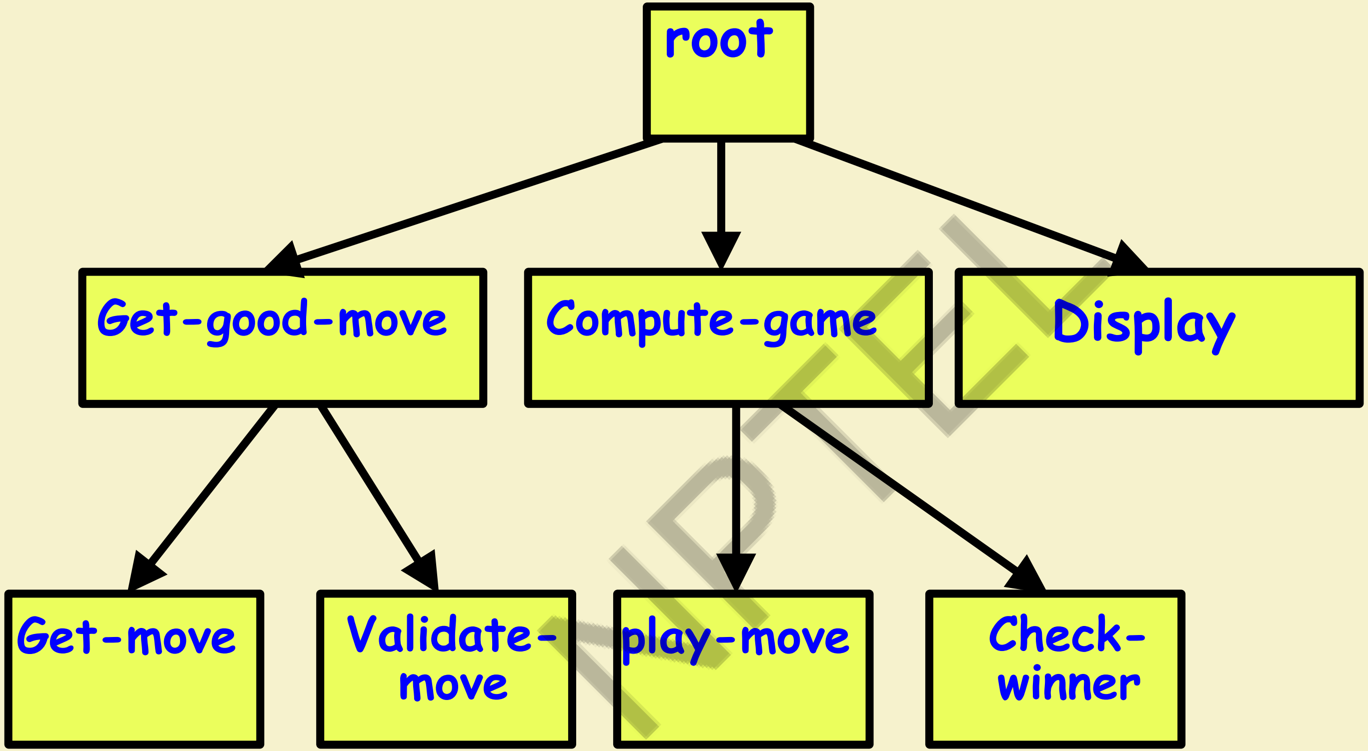
Context Diagram for Example 2





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

Level 1
DFD



Structure Chart

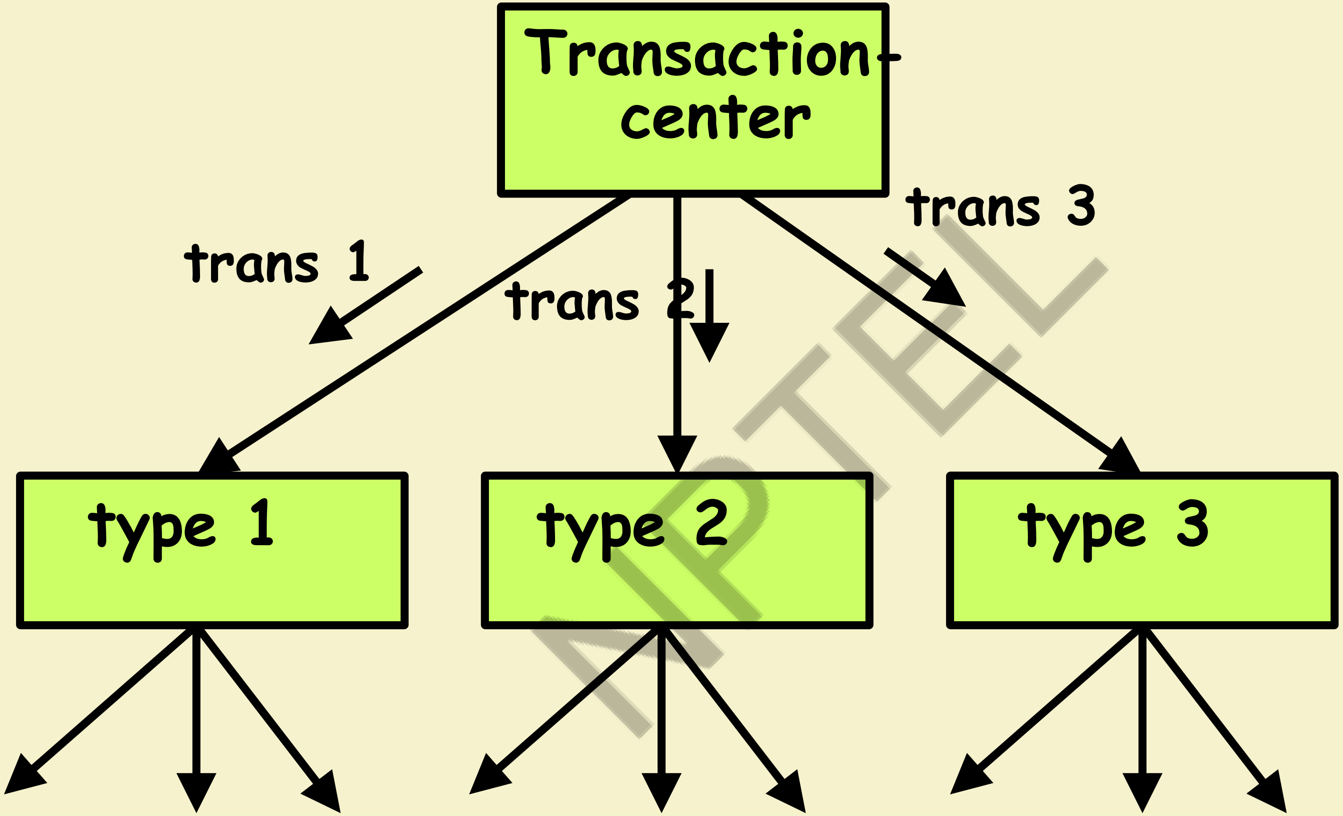
Transaction Analysis

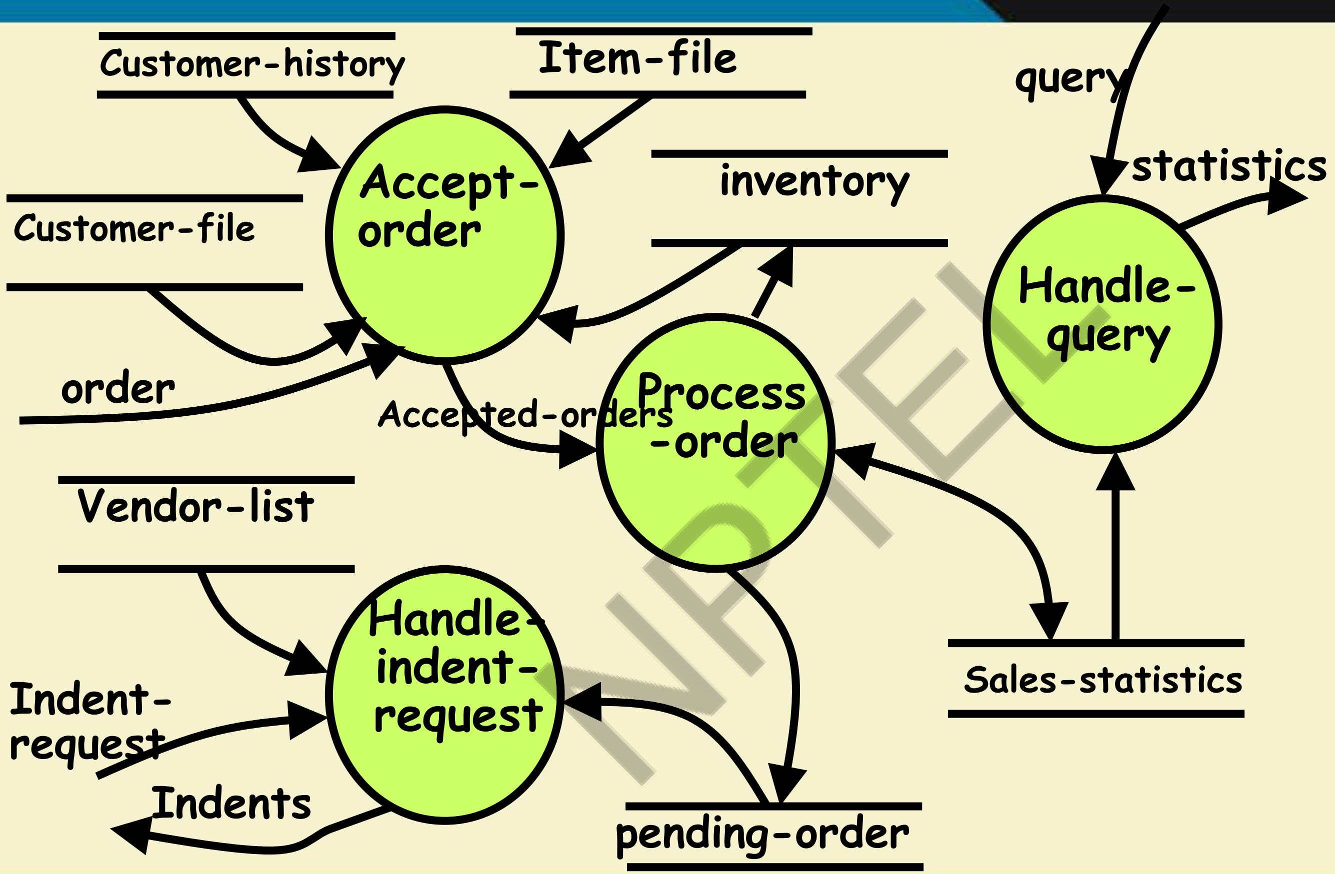
- Useful for designing transaction processing programs.
  - **Transform-centered systems:**
    - Characterized **by similar processing steps for every data item** processed by input, process, and output bubbles.
  - **Transaction-driven systems,**
    - **One of several possible paths** through the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

Transaction Analysis

- **Transaction: Any input data value that triggers an action:**
  - **For example, different 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.**

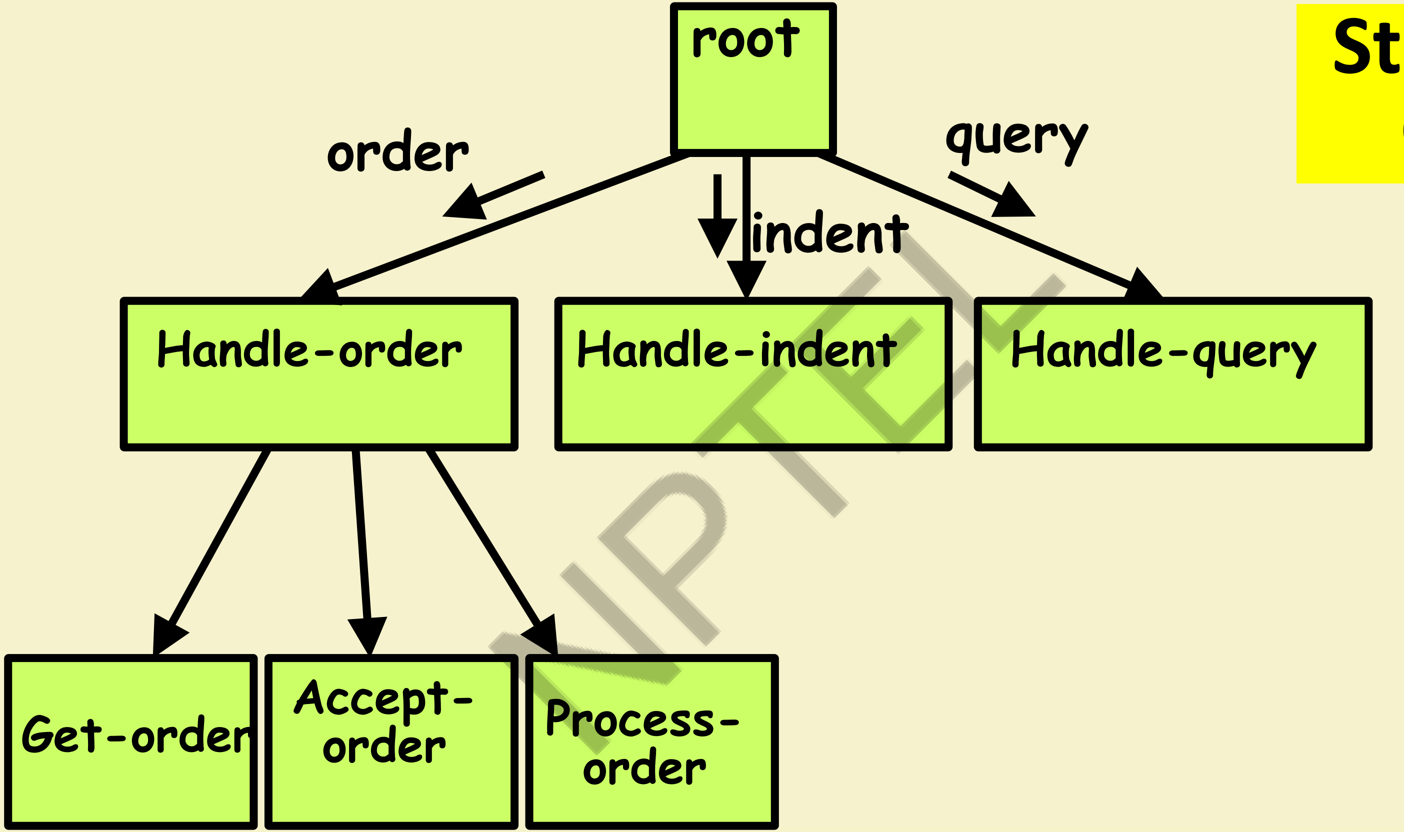
Transaction analysis





Level 1 DFD for TAS

Structure Chart



Summary

- We discussed a sample function-oriented software design methodology:
  - Structured Analysis/Structured Design(SA/SD)
  - Incorporates features from some important design methodologies.
- SA/SD consists of two parts:
  - Structured analysis
  - Structured design.

Thank You!!