Advanced Software Engineering (CS6401)

Autumn Semester (2022-2023)

Dr. Judhistir Mahapatro
Department of Computer Science and Engineering
National Institute of Technology Rourkela

Function-Oriented Software Design

Organization of this Lecture

- Introduction to function-oriented design
- Structured Analysis and Structured Design
- Data flow diagrams (DFDs)
- Examples
- Summary

Introduction

- Function-oriented design techniques are very popular:
  - currently in use in many software development organizations.
- Function-oriented design techniques:
  - start with the functional requirements specified in the SRS document.

Introduction

- During the design process:
  - high-level functions are successively decomposed:
    - into more detailed functions.
  - finally the detailed functions are mapped to a module structure.
- Successive decomposition of high-level functions:
  - into more detailed functions.
  - Technically known as top-down decomposition.

Introduction

- SA/SD methodology:
  - has essential features of several important function-oriented design methodologies ---
    - if you need to use any specific design methodology later on,
    - you can do so easily with small additional effort.

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
- SA/SD technique can be used to perform
  - high-level design.

Overview of SA/SD Methodology

- SA/SD methodology consists of two distinct activities:
  - Structured Analysis (SA)
  - Structured Design (SD)
- During structured analysis:
  - functional decomposition takes place
- During structured design:
  - module structure is formalized

Functional decomposition

- Each function is analysed
  - hierarchically decomposed into more detailed functions.
  - simultaneous decomposition of high-level data
    - into more detailed data.

Structured analysis

- Transforms a textual problem description into a graphic model.
  - done using data flow diagrams (DFDs).
  - DFDs graphically represent the results of structured analysis.

Structured design

- All the functions represented in the DFD
  - mapped to a module structure.
- The module structure:
  - also called as the software architecture

Detailed Design

- Software architecture:
  - refined through detailed design.
  - Detailed design can be directly implemented
    - using a conventional programming language

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 vs. Structured Design

- 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.
- The results of structured analysis can be reviewed by customers:
  - to check whether it captures all their requirements.

Structured Analysis

- 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 diagrams

- DFD is an elegant modelling technique:
  - useful not only to represent the results of structured analysis
  - applicable to other areas also:
    - e.g. for showing the flow of documents or items in an organization,
- DFD technique is very popular because
  - it is simple to understand and use.

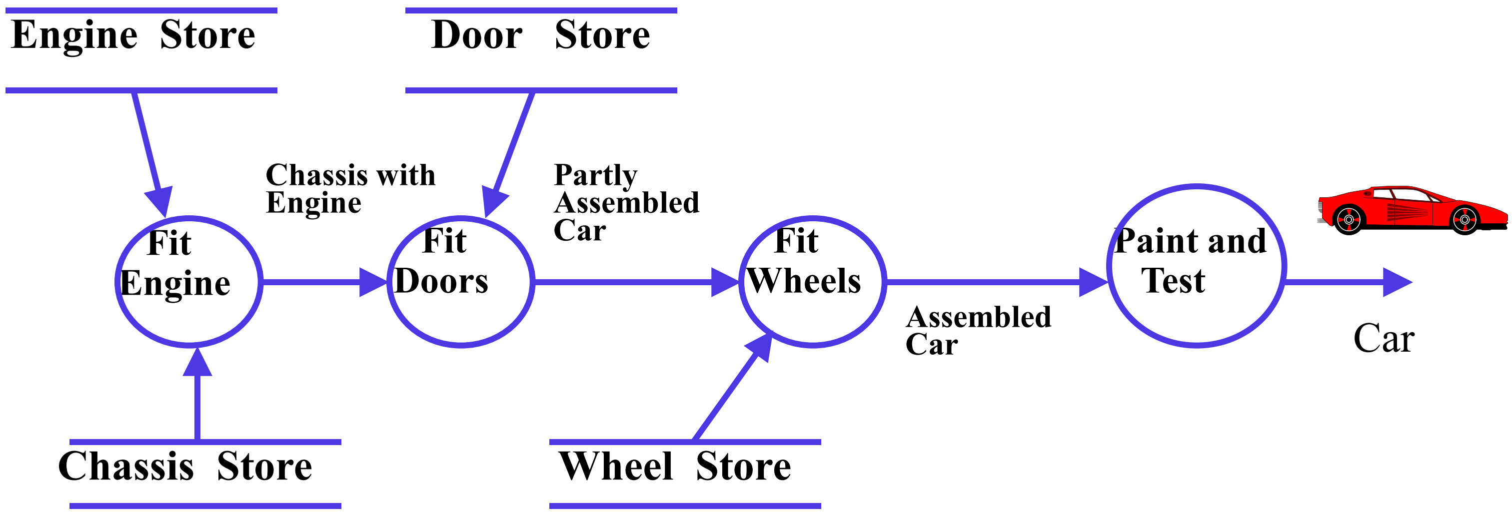
Data flow diagram

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

DFD Concepts

- It is useful to consider each function as a processing station:
  - each function consumes some input data and
  - produces some output data.

Data Flow Model of a Car Assembly Unit



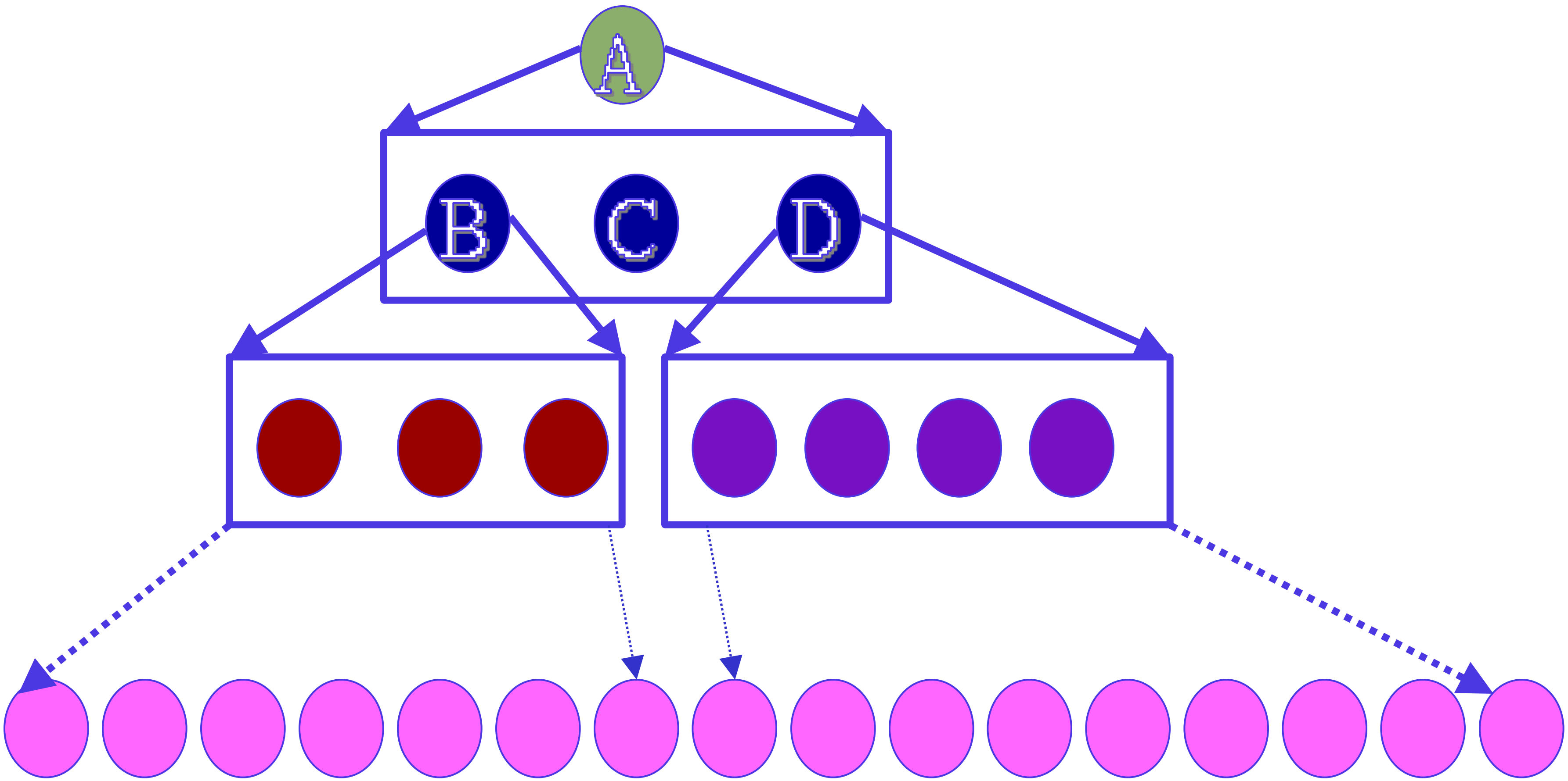
Data Flow Diagrams (DFDs)

- A DFD model:
  - uses limited types of symbols.
  - simple set of rules
  - easy to understand
    - it is a hierarchical model.

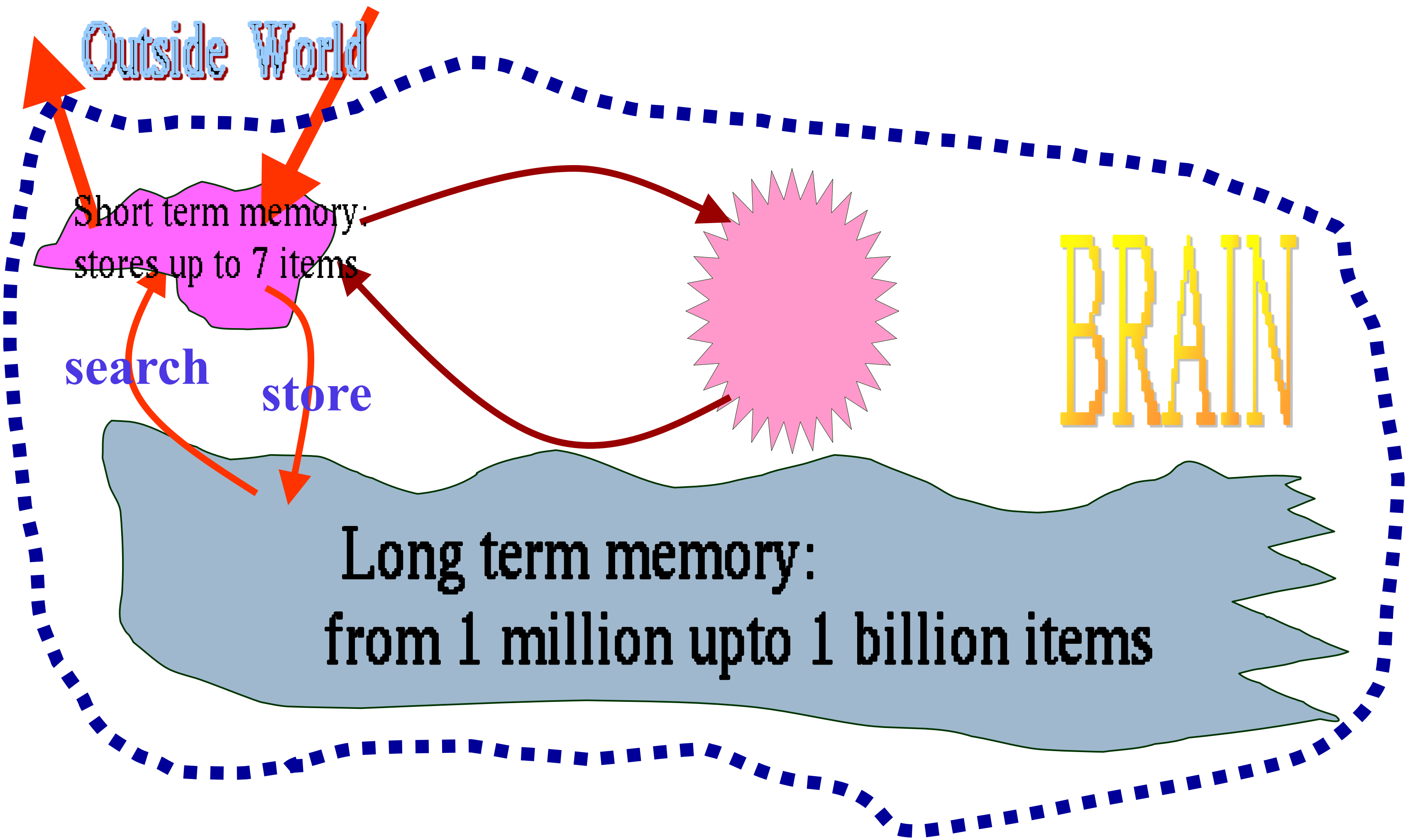
Hierarchical model

- Human mind can easily understand any 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.

Hierarchical Model



How does the human mind work? (Digression)



How does the human mind work? (Digression)

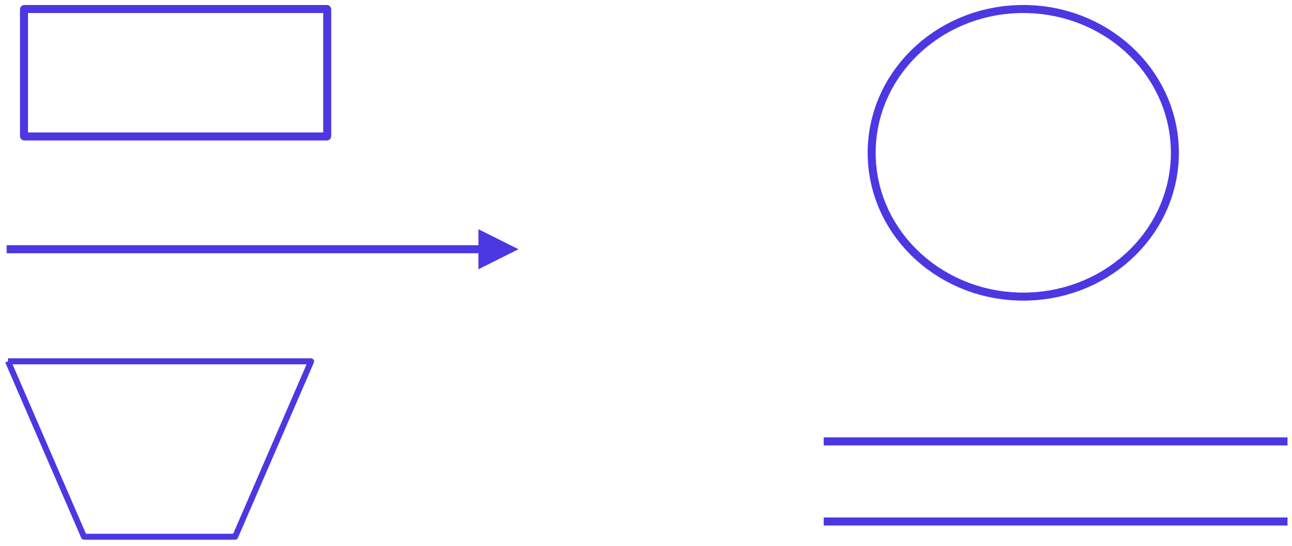
- Short term memory can hold upto 7 items:
  - In Software Engineering the number 7 is called as the magic number.
- An item is any set of related information (called a chunk):
  - an integer
  - a character
  - a word
  - a story
  - a picture, etc

How does the human mind work? (Digression)

- To store 1,9,6,5 requires 4 item spaces:
  - but requires only one storage space when I recognize it as my year of birth.
- It is not surprising that large numbers::
  - usually broken down into several 3 or 4 digit numbers
  - e.g. 61-9266-2948

Data Flow Diagrams (DFDs)

- **Primitive Symbols Used for Constructing DFDs:**



External Entity Symbol

- Represented by a rectangle
- External entities are real physical entities:
  - 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.
  - Functions represent some activity:
    - function names should be verbs.

Data Flow Symbol

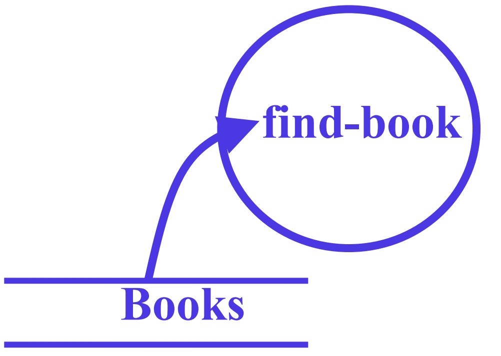
- A directed arc or line.
  - represents data flow in the direction of the arrow.
  - Data flow symbols are annotated with names of data they carry.

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.

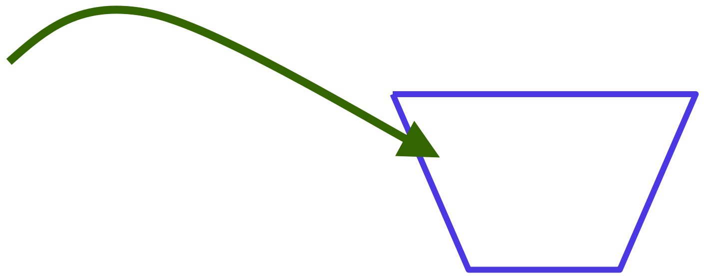
Data Store Symbol

- 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.



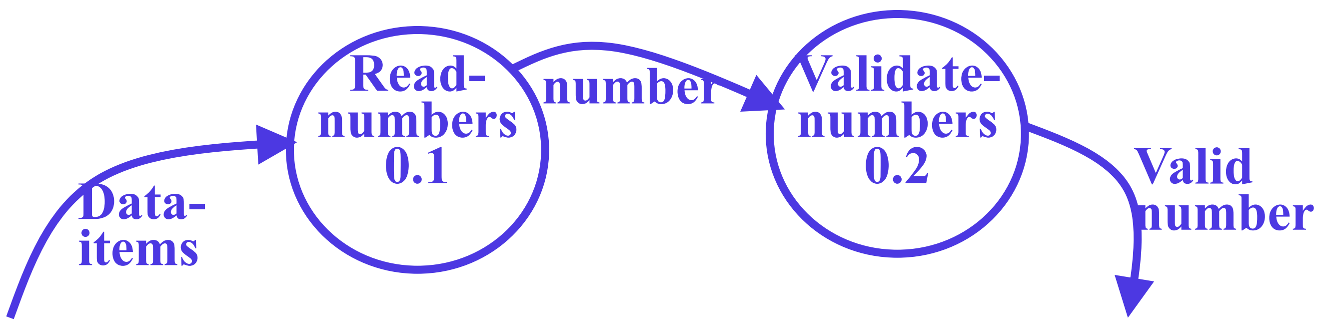
Output Symbol

- Output produced by the system



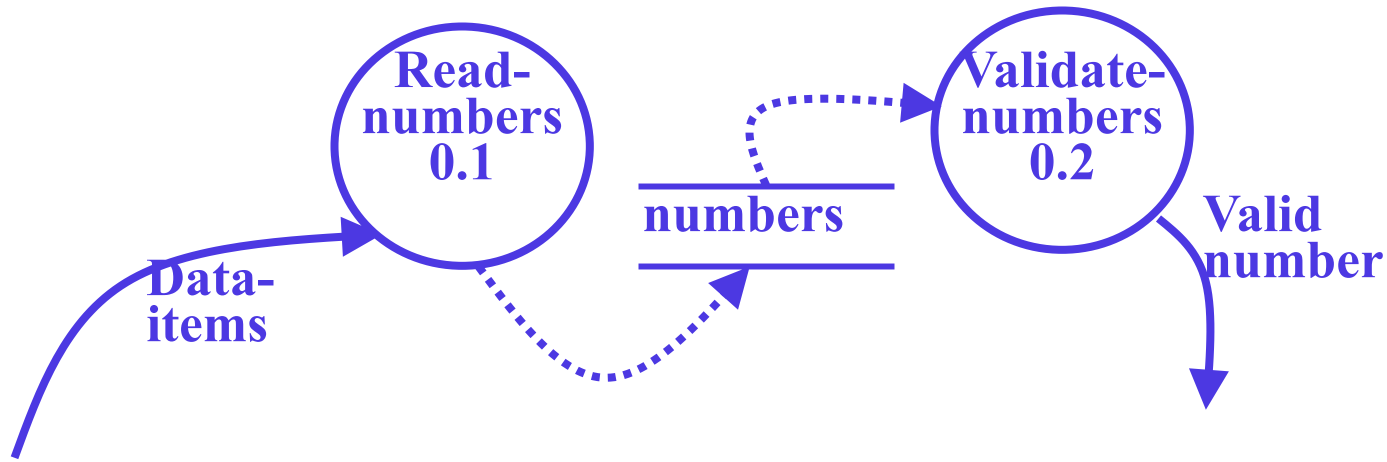
Synchronous operation

- **If two bubbles are directly connected by a data flow arrow:**
  - they are synchronous



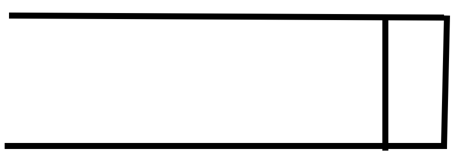
Asynchronous operation

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



Yourdon's vs. Gane Sarson Notations

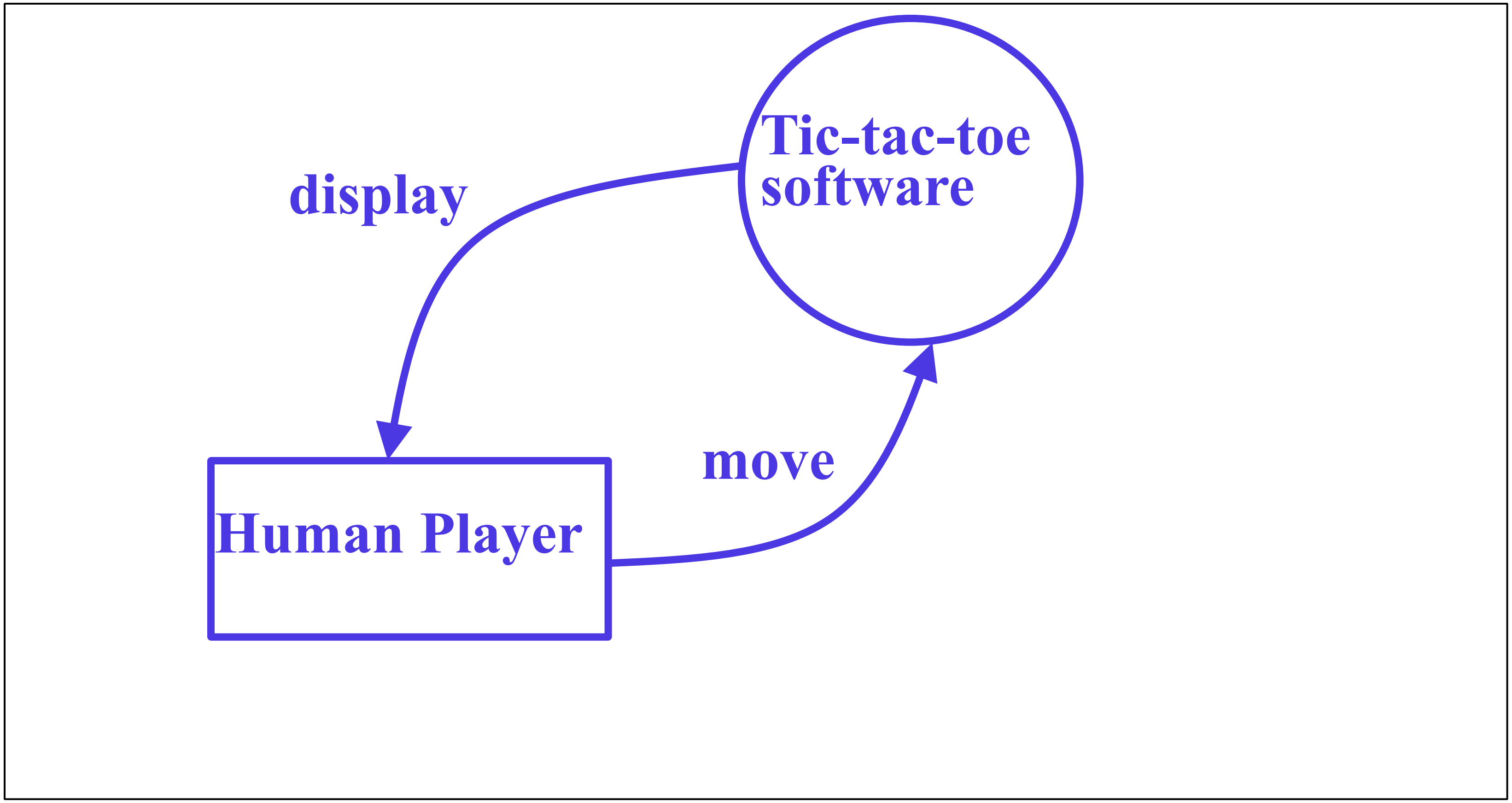
- The notations that we would be following are closer to the Yourdon's notations
- You may sometimes find notations in books that are slightly different
  - For example, the data store may look like a box with one end closed



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:
  - data input to the system,
  - output data generated by the system,
  - external entities.

Context Diagram

- Context diagram captures:
  - various entities external to the system and interacting with it.
  - data flow occurring between the system and the external entities.
- The context diagram is also called as the level 0 DFD.

Context Diagram

- Context diagram
  - establishes the context of the system, i.e.
  - represents:
    - Data sources
    - Data sinks.

Level 1 DFD

- 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 to
  - 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

- Too many bubbles:
  - 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.

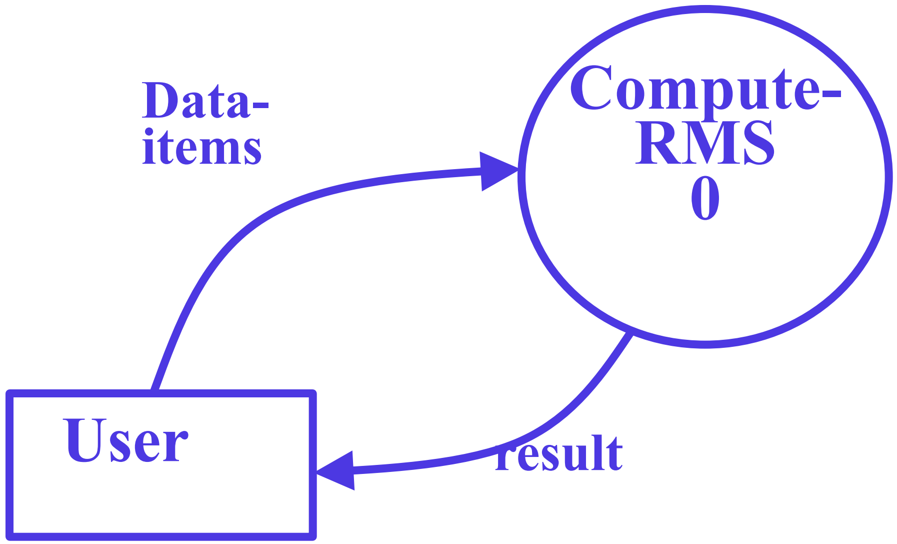
Example 1: RMS Calculating Software

- 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

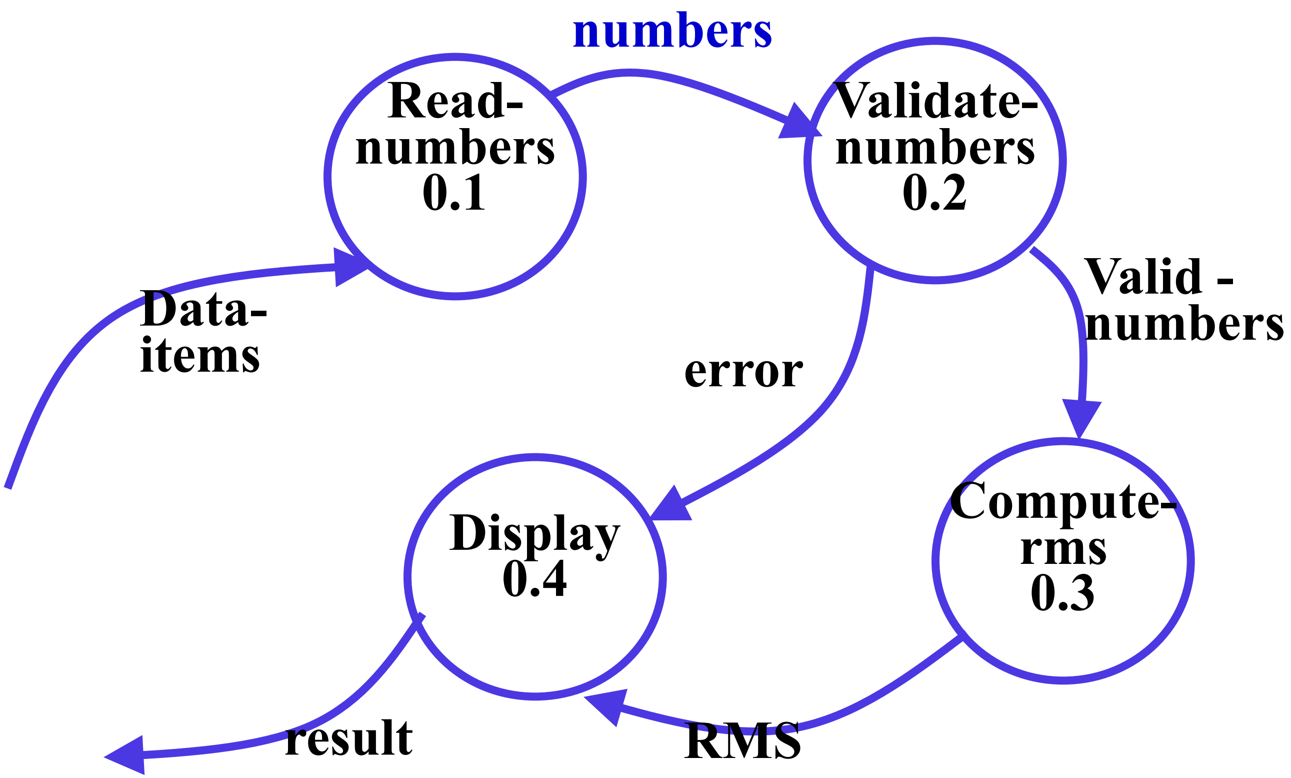
Example 1: RMS Calculating Software

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

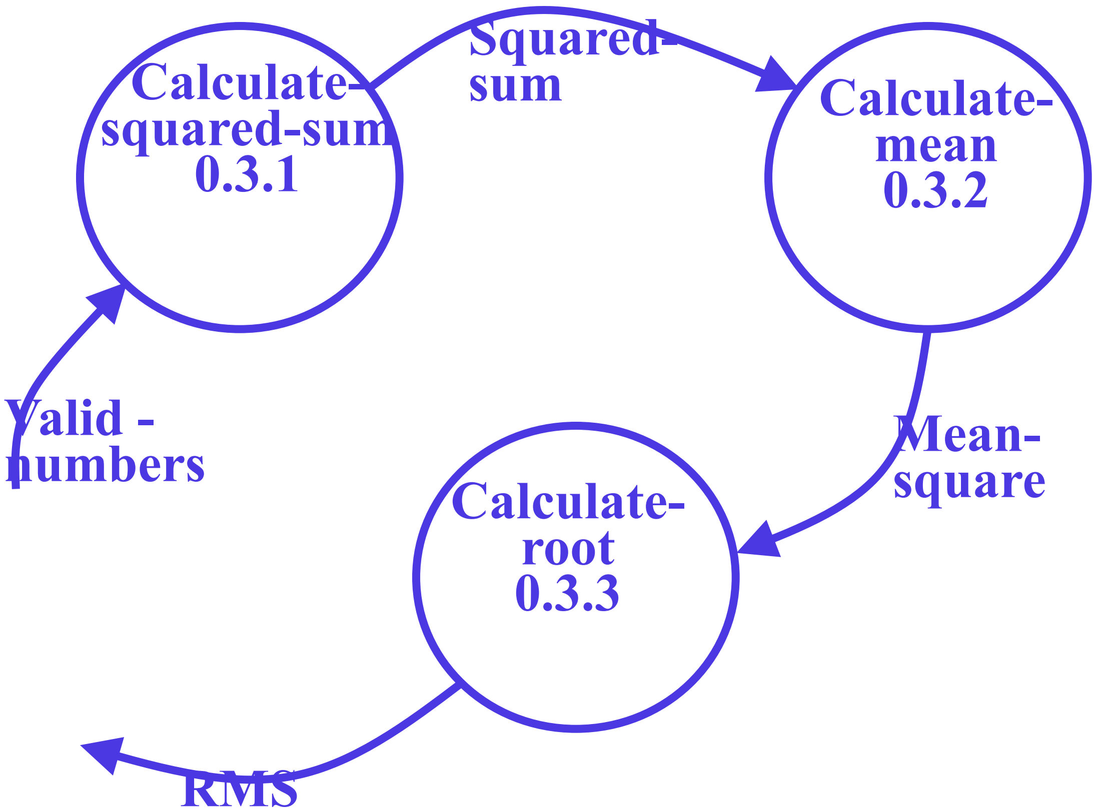
Example 1: RMS Calculating Software

- Accept input numbers from the user:
  - validate the numbers,
  - calculate the root mean square of the input numbers
  - display the result.

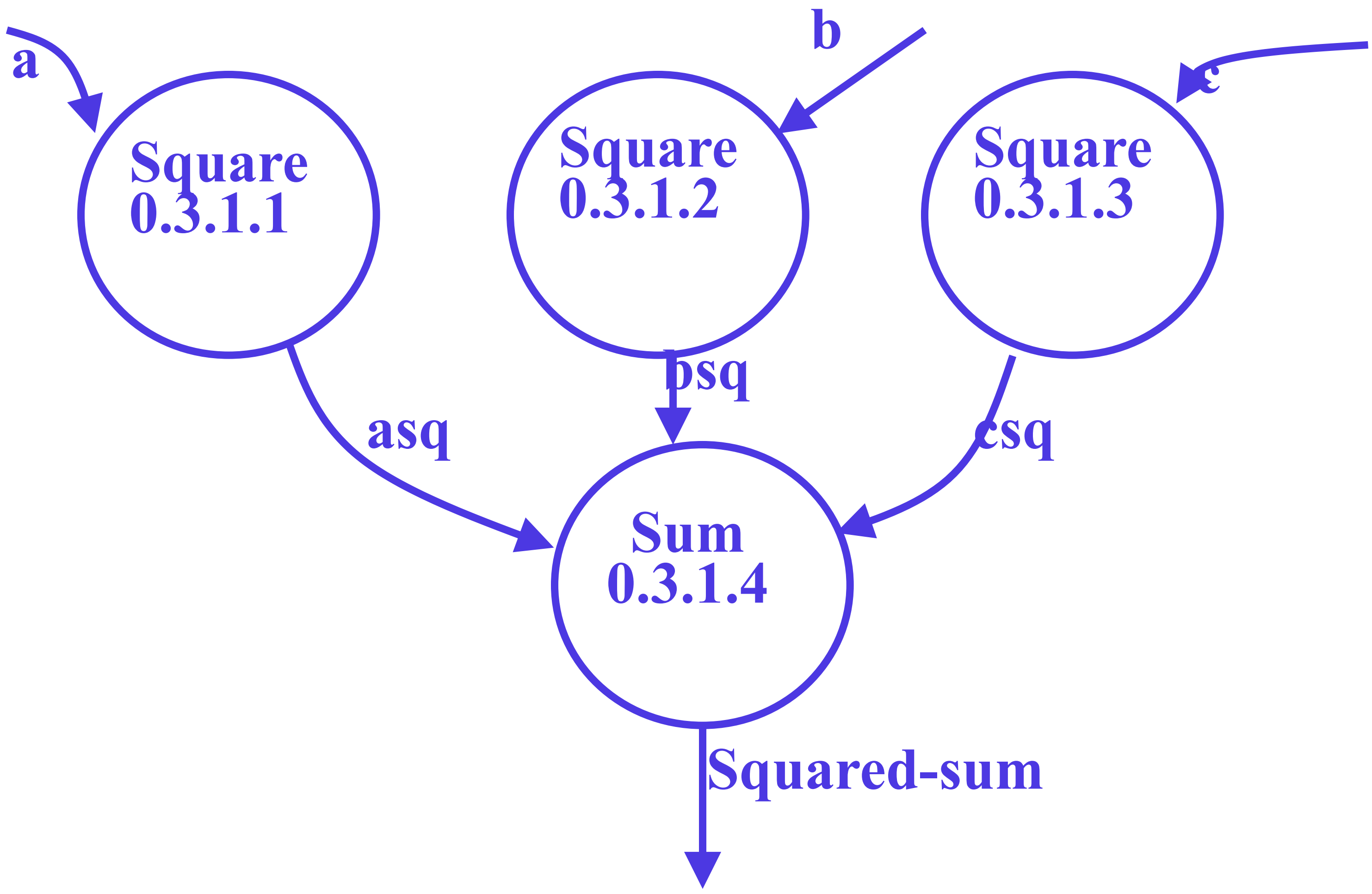
Example 1: RMS Calculating Software



Example 1: RMS Calculating Software



Example: 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 data items.
- For example, a data dictionary entry may be:
  - grossPay = regularPay+overtimePay

Importance of Data Dictionary

- Provides all engineers in a project with standard terminology for all data:
  - A consistent vocabulary for data is very important
  - different engineers 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 following operators:
- +: denotes composition of data items, e.g
  - a+b represents data a and b.
- [,,,]: represents selection,
  - i.e. any one of the data items listed inside the square bracket can occur.
  - For example, [a,b] represents either a occurs or b occurs.

Data Definition

- ( ): contents inside the bracket represent optional data
  - which may or may not appear.
  - a+(b) represents either a or a+b occurs.
- {}: represents iterative data definition,
  - e.g. {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.

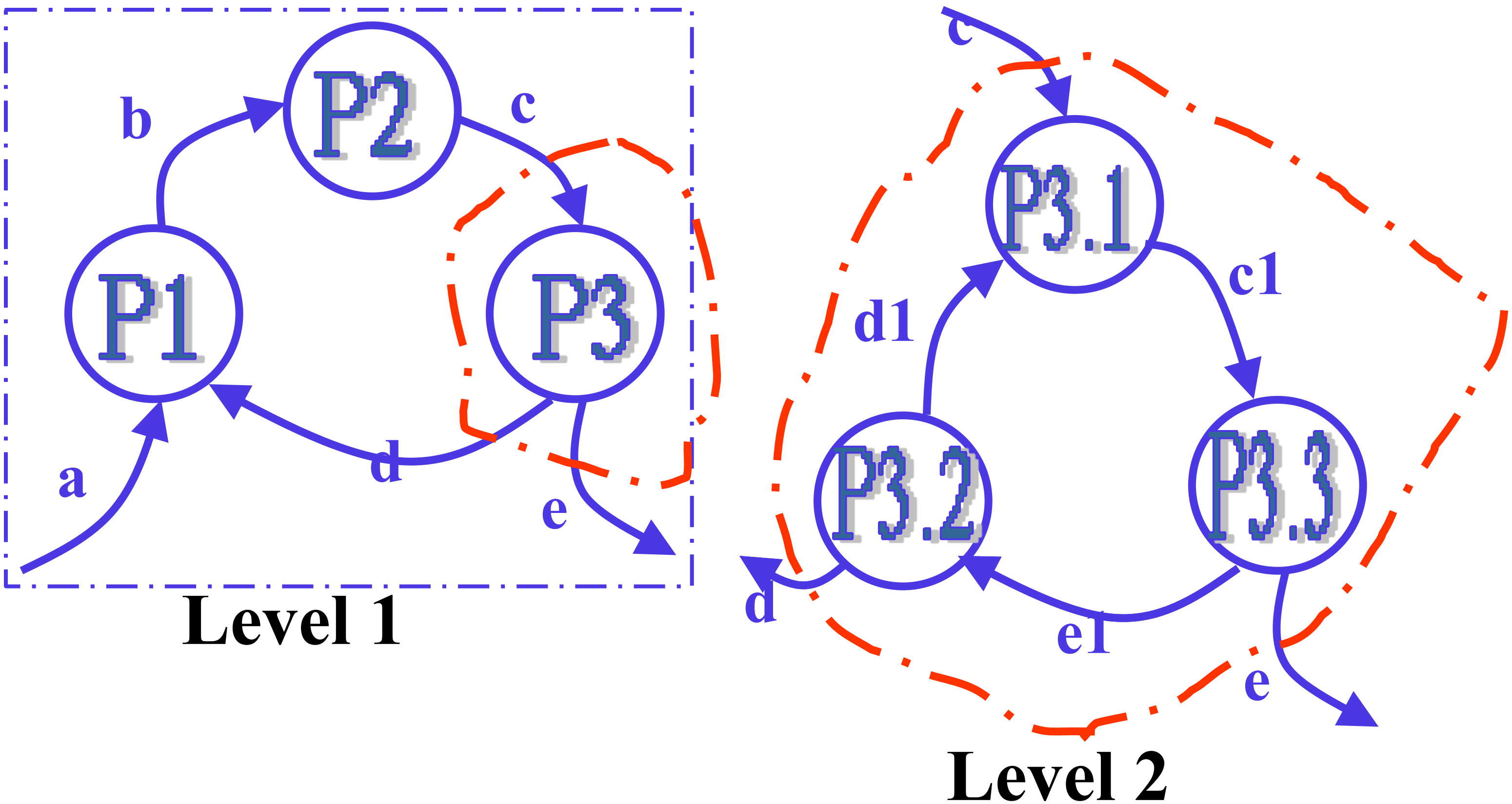
Data dictionary for RMS Software

- 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.
  - This is known as <u>balancing a DFD</u>
- 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



Numbering of Bubbles:

- 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.

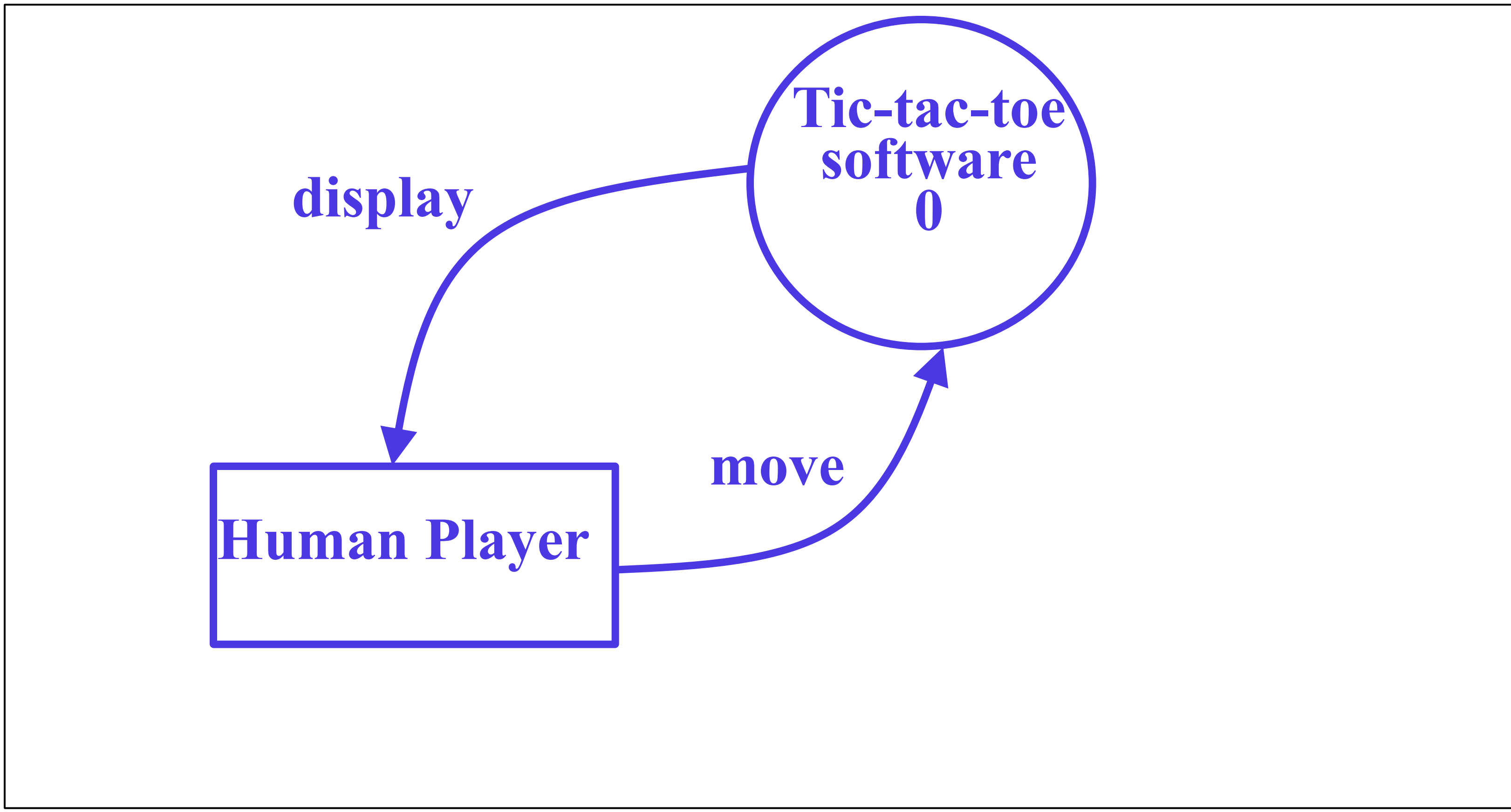
Example 2: Tic-Tac-Toe Computer Game

- A human player and the computer make alternate moves on a 3 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.

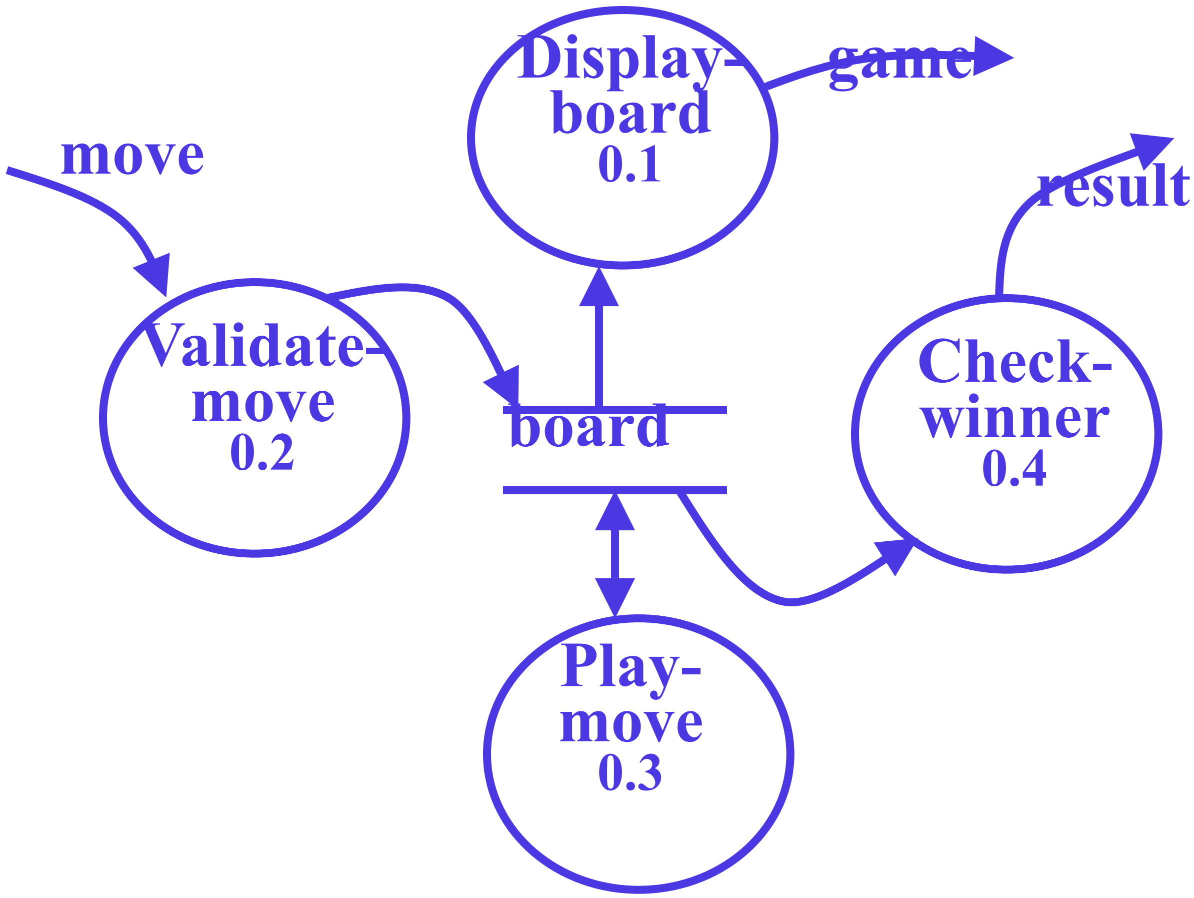
Example: Tic-Tac-Toe Computer Game

- 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



Level 1 DFD


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

Data dictionary

- Display=game + result
- move = integer
- board = {integer}9
- game = {integer}9
- result=string

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.

Summary

- The goal of structured analysis:
  - functional decomposition of the system.
- Results of structured analysis:
  - represented using Data Flow Diagrams (DFDs).
- We examined why any hierarchical model is easy to understand.
  - Number 7 is called the magic number.

Summary

- During structured design,
  - the DFD representation is transformed to a structure chart representation.
- DFDs are very popular:
  - because it is a very simple technique.

Summary

- A DFD model:
  - difficult to implement using a programming language:
  - structure chart representation can be easily implemented using a programming language.

Summary

- We discussed structured analysis of two small examples:
  - RMS calculating software
  - tic-tac-toe computer game software

Summary

- Several CASE tools are available:
  - support structured analysis and design.
  - maintain the data dictionary,
  - check whether DFDs are balanced or not.