# Structured Design

## Ideas Behind Structured Design

Structured design is a disciplined approach to design of
    Computer systems and software

Comprised of following 5 aspects

1. Used definition of problem to guide definition of solution
2. Seeks to attack complexity of contemporary problems by partitioning into modules and organizing modules into hierarchies
3. Uses variety of tools to render complex systems understandable
4. Offers set of strategies for developing design solution from well defined statement of problem
5. Offers set of criteria for evaluating quality of design

## Simplifying a System

### Partition into Modules

First step in controlling complexity
    Partitioning into modules
Goals

- Each module should solve one well defined piece of the problem
- System should be partitioned so that function of each module is easy to understand
- Partitioning should be done so that connections between modules only introduced because of connection between pieces of problem
- Partitioning should assure that connections between modules are as independent as possible

### Organize Modules into Hierarchies

Familiar approach
    Divide and conquer
Most natural systems divided into hierarchies of stable units

### Tools

*Graphical Tools*

Structured design uses tools
    Especially graphical ones to render systems more understandable
If structured analysis proceeds structured design
    Analyst will present designer with structured specification
    Such specification is
        Output from analysis
        Input to design

***Example***

Data and Control Flow diagrams
Decision Trees
Decision Tables
Data Dictionaries
Data Access Diagrams

*Pseudo Code*

Informal and flexible programming language
- Not intended to be executed on a machine

Used to organize designer's thoughts prior to implementation

Originally developed for structured programming
- Can be used in structured design as well
- Aides in clarifying internal
  - Procedures and flow of control in modules

***Example***

Serial Transmit Routine
What do we need to define?
- Beginning of the buffer
  - Where we enter the data
- Transmit index
  - Where we remove things

```
transmit
{
    save status  info
 // transmitt a character if there is a character in the buffer
    if (buffer not empty)
    {
        while(data)
            get character
            output character
        end while
        clear transmit status bit
    }
}
```

*Structure Chart*

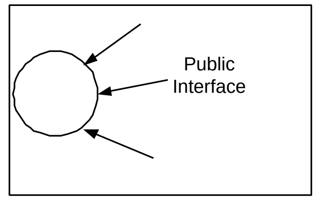
Structure chart
- Is static description of system
- Illustrates partitioning of system into modules

Gives overall functional architecture of system

  Expresses architecture as collection of functions

    Different from a block diagram

Implements our functional design step




Graphically illustrates

  Hierarchy

  Organization

  Communication

Structure chart is chief structured design tool

Has many advantages

- Graphic
- Partitionable
- Rigorous but flexible
- Valuable blueprint for implementing the system
- Helps to document system
- Aid in maintaining and modifying the system

Top level of structure chart

  Paints broad picture of the system

  Shows major functions of system and their interfaces

  Contains very little detailed information

  Once again not a block diagram

Bottom level contains more of detail

  May also hide such detail in descriptions of modules

Should not be something that is done once at start of design

  Should be a living document through lifetime of product

### Elaborating a Design Solution

Structured design offers set of strategies for

  Developing design solution

  From well-defined statement of problem

UML is extension of structured methodologies

We've developed overall static architecture of system

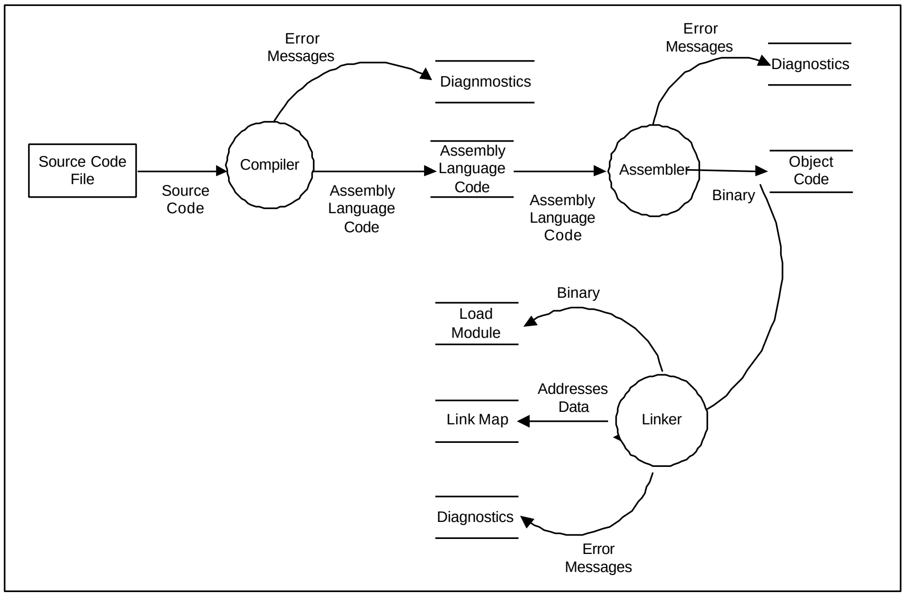
Now want to look at behaviour

  Data and control flow within system

If problem expressed in set of data / control flow diagrams

  Approach offers strategy for smoothly developing a good design

***Example***




Evaluating a Design Solution

Structured design offers set of effectively and empirically justified criteria for
Evaluating quality of design solution
With respect to problem being solved

Same criteria can be used when necessary to improve deficient design

**What Structured Design is Not**

- Structured Design is not structured programming
  - Generally agreed structured programming
    - Set of reasonable methods for developing
      - Understandable and reliable source code
  - Does not work well for large systems
    - Has no inherent strategy for addressing complexity in large systems

  Structured design and structured programming are not incompatible

- Structured design is not a means to a good problem specification
  - Structured takes as it input
    - Statement of what the system is supposed to accomplish
    - Without such a statement
      - Cannot move forward

- Structured design is not modular programming or top down design
  - Most of work is done with modules
  - Strong focus on top down organization

- Such ideas developed during early 70's
- Structured design is a logical extension of such ideas

- Structured design is not solution to all world's problems
  - There are no guarantees
  - All design has
    - Difficulties
    - Pitfalls
    - False starts
  - Structured design
    - Should help in recognizing such problems early
    - Offers set of tools to help correct such problems

- Structured design does not stifle creativity
  - Truly creative designers can use
    - Organization and discipline of structured design
      - To further creativity

  - Permits one to build on work of others
    - Rather than continually re-inventing the wheel

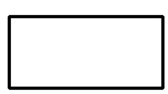
## Tools of Structured Design

### The Structure Chart

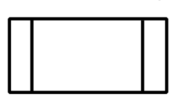
- Major tool used in structured design is *structure chart*
  - Used to depict overall structure of the system
- Once again remember
  - Working with architectural view

*Elements*

- Modules
  - Represent an encapsulation of a piece of functionality
    - Indicated by a box



- Pre-defined library routines identified by box with vertical lines



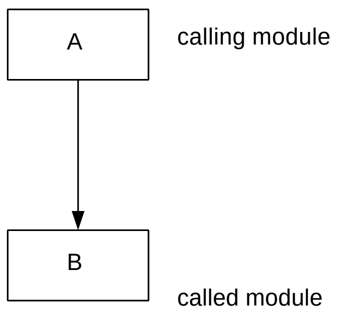
- Some modules may *call* other modules
  - Indicated by an arrow

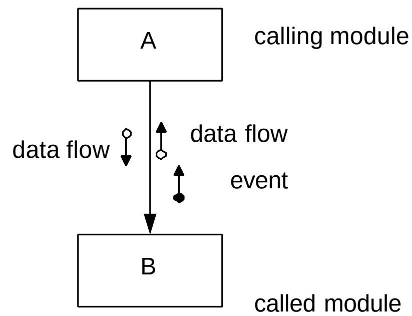
- Some modules may *send data* to other modules
  - Indicated by an open arrow

Some modules may *send flags* to other modules
Indicated by an closed arrow

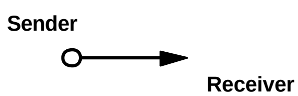
*Communication Between Modules*

We show communication between modules using such symbols




Open arrow is called data couple




Distinguished from flag because
- Data is processed
- Flag not really processed
  Signifies an event has happened

- Data relates to problem
- Flag one step removed

***Example***

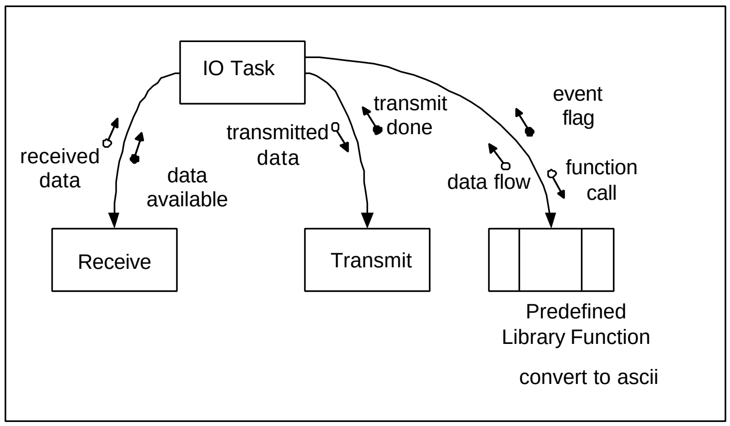
Consider simple input output task
At high level
Identify 4 modules
Top level task
Transmit module
Receive module
Code conversion library routine

Identify data
Received from receive module

Transmitted by transmit routine
Sent to and received from library routine

Identify flags
Received data available
Transmit task done
Conversion task done

Can bring together in simple structure chart




Module Specification

Structure chart shows only high level details
Deliberately suppresses details

Ultimately must confront details
System must be built

Wide variety of ways to specify module

Will examine two ways
Module Interface Specification
Specification by pseudo code

Let's look at each

*Module Interface Specification*

Method permits one to specify
Function of module
Without getting into too much detail

Comprises several things
Specifies what inputs will be provided
Identifies what output is expected from module

Describes function to be carried out
  Should be stated in simple sentences
    Establish relationship between input and output
  May choose to supplement with
    Tables
    Drawings
    Graphs
    Formulas

***Example***

Let's examine the IO task diagrammed above
Remember we're viewing system from outside
  Similar to ADT
    Defining public interface

***Interface Specification for IO Task***

| | |
|---|---|
| Module: | System I/O Module |
| Purpose: | Receive data from and transmit data to outside world |
| Uses: | Measured Data |
| Returns: | Input Commands<br>Transmission complete |

Functional Details:

1. Accept measured data, translate to ASCII, transmit out.
2. When transmission complete signal done = 1.
3. Receive formatted measurement commands from outside world.
   Convert from ASCII to internal format 3.4A.
4. When command data is available, signal Input command = 1

*Specification by Pseudocode*

Pseudocode is much more detailed method to specify module
Begins to move toward how to do from what to do

Pseudocode
  Informal language
    Similar to structured English
  Is a tool of the designer rather than user
  Since no formal specification
    One can make it look as much like real code as desired

Much more detailed than interface specification
  Consequently much less margin for error

When translating into actual code

Allows flexibility but need to be careful
Not to turn pseudocoding into end goal

***Example***

***Pseudocode Specification for IO Task***

```
Module: System I/O Module
Purpose:    Receive data from and transmit data to outside world
Uses:       Measured Data
Returns:    Input Commands
            Transmission complete

if (transmit)
    begin transmit
        get measured data
        for each character c
            c <- ascii(c)
            transmit (c)
        end for
        complete <- 1
    end begin

else if receive
    while (not end of message)
        receive (c)
        c <- decimal (c)
    end while
    inputCommand <- 1
end if
```

Pseudocode works as excellent programming tool
Allows one to try out ideas at any level of detail
Don't need to be worried about constraints of programming language

Coupling

We've specified interface to module
Now examine interdependence between modules
We're still outside of the module
Called *coupling*
Objective
Minimize coupling

Want to make modules as independent as possible

Low coupling between modules
Indicates well partitioned system

Achieved in 3 ways

1. Eliminate unnecessary relationships
2. Reduce the number of necessary relationships
   Implement as 1 rather than 2 for example
3. Ease tightness of necessary relationships

Reducing coupling means reducing complexity of module interconnections
Approaches

1. Create narrow (as opposed to broad) connections
   Breadth is measure of number of interconnections between modules
   Reduce the number of pieces of data that must flow between modules

2. Create direct vs. indirect connections
   Don't require one module to go through second to get data from third

3. Create local rather than remote connections
   Have the connection with a second module
   Specified in parameter list
   Rather than through global data somewhere else in program

4. Create obvious rather than obscure connections
   Express information in natural and expected way

5. Create flexible rather than rigid connections
   Don't hard code parameters to
   Particular memory location
   Specific data value

## Cohesion

Idea related to *coupling* is *cohesion*

Coupling addresses partitioning a system
Cohesion addresses bringing things together

We stress modularity and encapsulation
Cohesion is measure of strength of functional relatedness
Elements in a module
Goal
Create strong highly cohesive modules
Whose elements are genuinely and strongly related to one another

Conversely
Elements should not be strongly related to elements in another module

Want to maximize cohesion and minimize coupling

Let's look at kinds of cohesion

*Functional cohesion*

Functionally cohesive module
Contains elements that all contribute to execution of
One and only one problem related task

*Sequential Cohesion*

Sequentially cohesive module
Contains elements that are involved in activity
Producing output data
That becomes input data to immediately successive task

***Example***

**module** formulate and cross validate data
uses raw data
format into raw record
cross validate fields in record
return formatted and cross validated record
**end module**

*Communicational Cohesion*

Communicational cohesive module
Contains elements that are involved in activity
Use the same input data

***Example***

**module** parse measurement command
uses raw data
find header field
find message length
find command
check parity
compute parity
return command or parity error
**end module**

*Procedural Cohesion*

Procedurally cohesive module
Contains elements that are involved in
Different and potentially unrelated activity

In which control flows from one activity to the next

***Example***

**module** read and modify record
uses output record
read input record
add parity to parity field
write output record
return
**end module**

*Temporal Cohesion*

Temporally cohesive module
Contains elements that are involved in activities
Related in time

***Example***

**module** initialize serial interface
**updates** wordCount, rBaudRate, tBaudRate, direction, parity
**reset** wordCount
**set** rBaudRate 9600
**set** tBaudRate 9600
**set** direction receive
**set** parity even
return
**end module**

*Co-incidental Cohesion*

Coincidentally cohesive module
Contains elements that are involved in activities
No meaningful relation to one another

Such cohesion – or lack of cohesion should not be used

*Comparison*

| Cohesion | Coupling | Cleanliness | Ease of Modification | Ease of Understanding | Ease of Maintenance |
|---|---|---|---|---|---|
| Functional | Good | Good | Good | Good | Good |
| Sequential | Good | Good | Good | Good | Fairly |
| Communicational | Medium | Medium | Medium | Medium | Medium |
| Procedural | Variable | Poor | Variable | Variable | Bad |
| Temporal | Poor | Medium | Medium | Medium | Bad |
| Logical | Bad | Bad | Bad | Poor | Bad |
| Co-incidental | Bad | Poor | Bad | Bad | Bad |

## The Data / Control Diagram

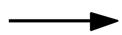
- Data / Control flow (DFD) diagram used to partition system
- Shows
  - Active components of system
  - Data and control interfaces between them
- Sometimes known as bubble chart

### *Elements*

- DFD comprises four graphic elements
  - Data or Control flow
  - The Processes
  - Data Source / Sink
  - Data Store

#### Data or Control Flow

- Similar to function call notation for structure chart
  - Indicated by an solid arrow for data flow



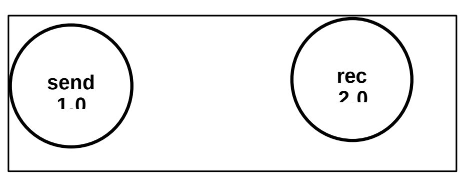
  - Indicated by an dashed arrow for control flow

- As notation indicates
  - Data or control flow in direction of arrow

#### Processes

- Processes modules or functions or tasks
  - Where the work is getting done

  - Indicated by labeled circles
    - Label identifies
      - The name of the process
      - The level in the hierarchy at which the process resides
        - Level 0 - 1.0, 2.0, 3.0 etc.
        - Level 1 - 1.1, 1.2, 1.3;  2.1, 2.2, 2.3;  3.1, 3.2 etc.
        - Level 2 - 1.1.1, 1.1.2;  1.2.1, 1.2.2; etc.

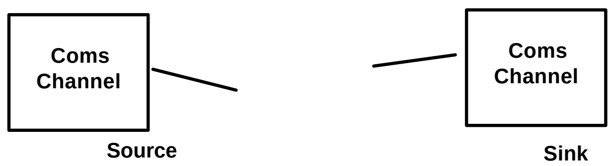


## Data Source / Sink

- As name implies
  - Source identifies where data originates
    - For example file or input port

  - Sink indicates where data goes
    - For example file or output port

- Drawn as labeled box with arrow to indicate direction of data flow




- Usually expresses entity outside system

## Data Store

- Final piece is data storage
- Indicates temporary store of data
  - Time delayed repository of data

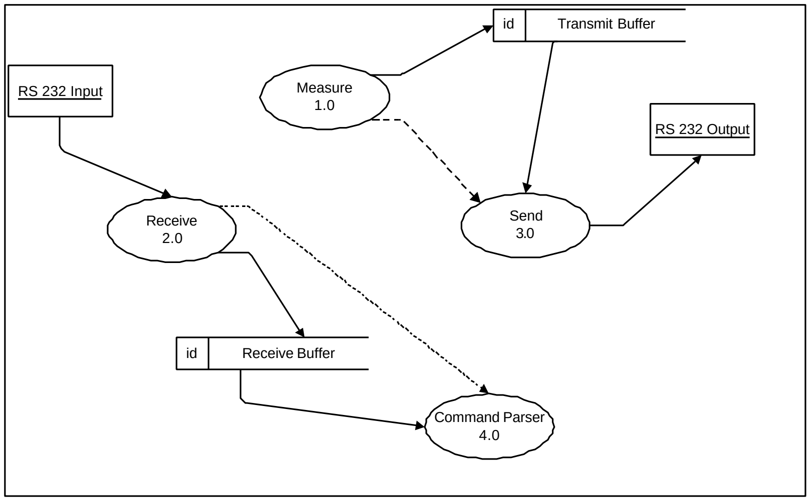
- Represented by
  - Two parallel lines (Yordon) or
  - Two parallel lines closed on left-hand end (Gane – Sarson)

  - Accompanied by labeled arrow to indicate direction of data flow

*Level 0 Communications System*

Let's look at a simple example

Will draw Level 0 - top level - data flow diagram




Level 1 DFD

Would expand each of processes or tasks

In similar way