SFWR ENG 3A04: Software Design II

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Term 2

Acknowledgments: Material based on *Software Architecture Design* by Tao et al. (Chapter 5)

Outline of Part I

1. Principle of Low Coupling and High Cohesion
2. Open-Closed Principle
3. Liskov substitution principle
4. Dependency Inversion Principle
5. Law of Demeter
6. Other Design Principles for Security
7. Questions???

Outline of Part II

8. Overview
9. Batch Sequential
10. Pipe and Filter Architecture
11. Process-Control Architecture
12. Data flow model to class model

Part I

Review of Previous Lecture

Part II

Today's Lecture

Data Flow Architecture Overview

- The data flow software architecture presents a system as a series of transformations on successive sets of data
- The software system is decomposed into functional process modules (sub-systems) where data directs and controls the order of data computation processing
- Each sub-system (module) component in this architecture transforms its input data to its output data
- The connection between the module components =
  - Input-output streams
  - Input-output files
  - buffers
  - piped streams
  - or other type connections

Data Flow Architecture Overview

- The focus in the data flow is the data availability
- The data can flow in a graph topology with cycles (linear, cyclic, tree, etc.)
- There is no interaction between the modules except the data connection between them
- The modifiability and reusability are the property attributes of the data flow architecture
  - The architectural elements are independent of each other (one element be substituted by another)
  - Each element does not need to know the identity of any other element

Data Flow Architecture Overview

There are many different ways to connect the output data of a module to the input of other module

- In terms of execution sequence between modules:
  - Batch Sequential
  - Pipes are stateless and serve as conduits for moving streams of data between multiple filters
  - Filters are stream modifiers, which process incoming data in some specialized way and send that modified data stream out over a pipe to another filter
- Pipes are special cases of filters; the modification function is the identity
- The close loop process control is another typical data flow architecture style

Data Flow Architecture Overview

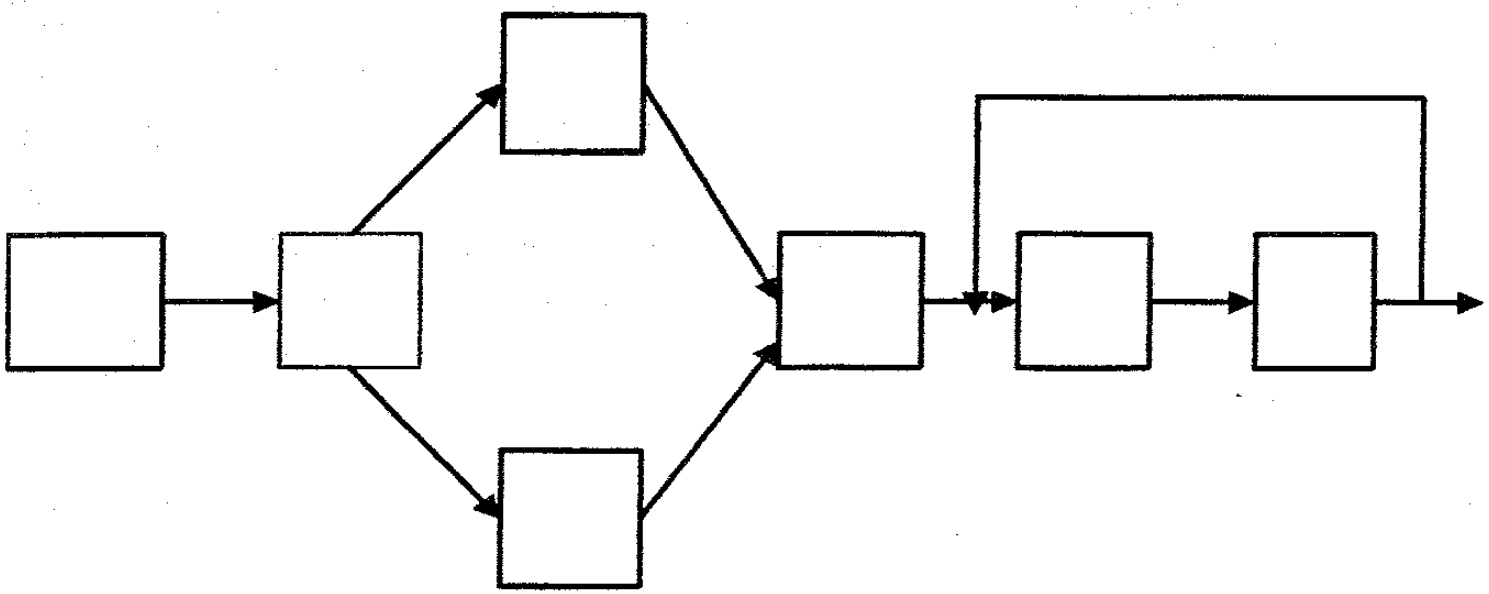


Figure: Block diagram of data flow architecture

Data Flow Architecture Batch Sequential

- An architectural style that was widely used in 1950' - 1970'
- RPG (Report Program Generator) and COBOL are two typical programming languages working on this model
- Each data transformation element cannot start its process until its previous element completes its computation
- Data flow carries a batch of data as a whole to move from one element to another

Data Flow Architecture Batch Sequential

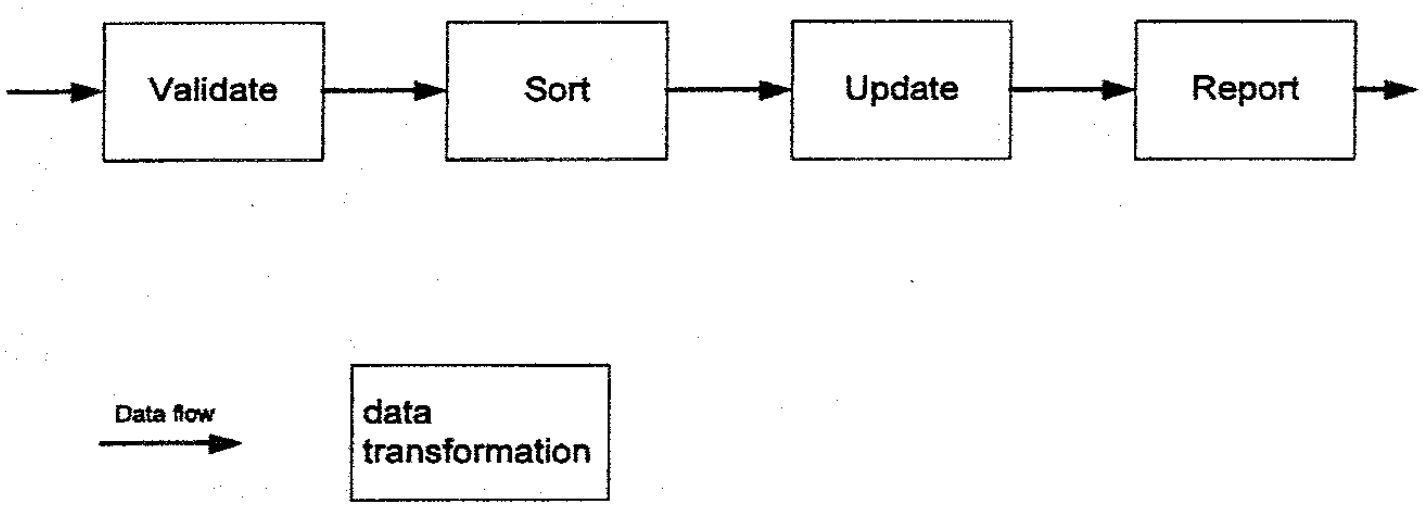


Figure: Batch sequential architecture

Data Flow Architecture Batch Sequential

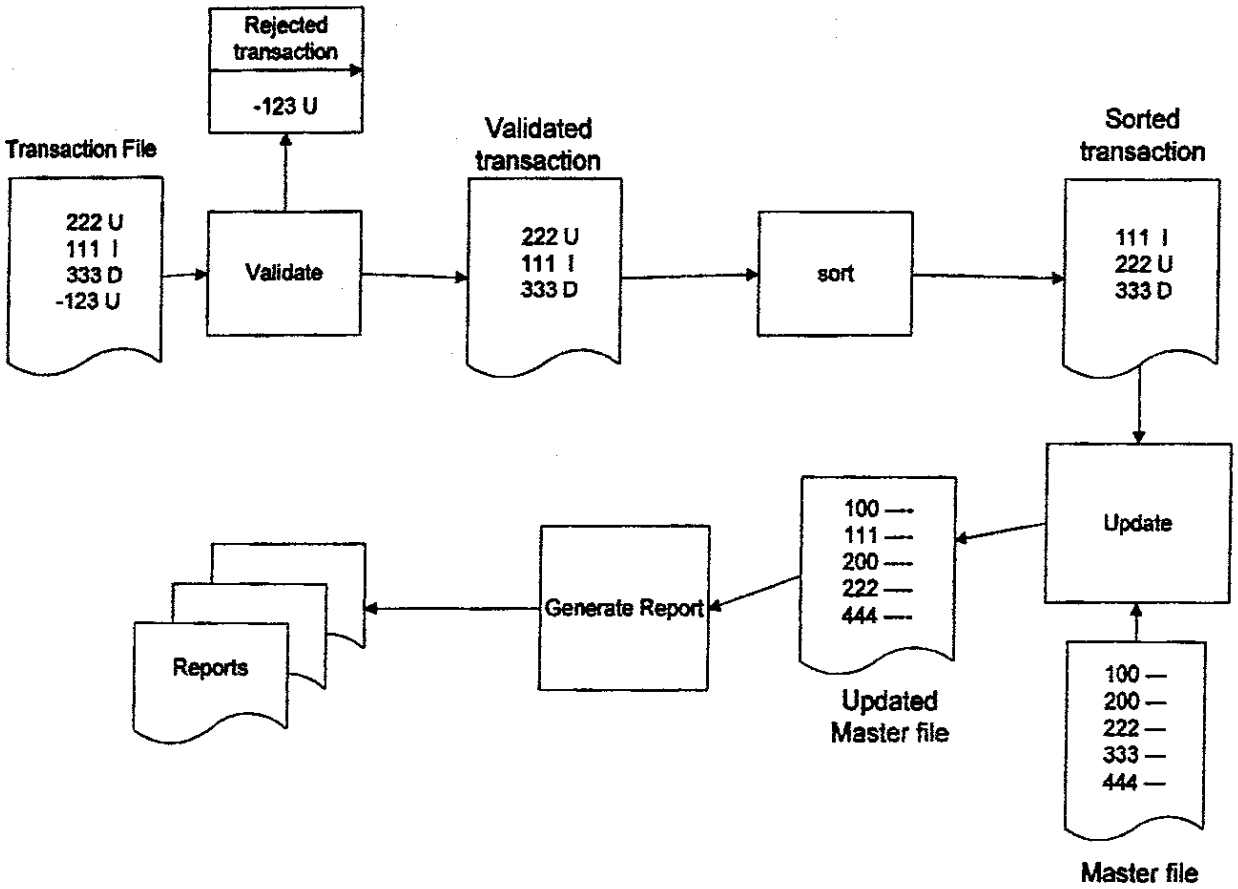


Figure: Batch sequential in business data processing

Data Flow Architecture Batch Sequential

- Connection links between elements are conducted through temporary files
- Business data processing are typical applications of this architecture
- A script is often used to make the batch sequence of the subsystems in the system

scriptExample.sh

```
ls *.pdf > toto1
grep -ir ".pdf" toto1
 ls *.tex > toto2
cat toto1 toto2 > toto
mail john.do@mcmaster.ca < toto
```

Data Flow Architecture Batch Sequential

myShell.sh

(exec) searching kwd <inputFile> matchedFile
(exec) counting <matchedFile> countedFile
(exec) sorting <countedFile> myReportfile

- We can also implement the batch sequential software architecture at Programming language level

Data Flow Architecture Batch Sequential

```
public class batch_sequential
{
   . . .
   public static void main() {
       searching(kwd, inputFile, matchedFile);
       counting(matchedFile, countedFile);
       sorting (countedFile, reportFile);
   }

   public static void search(String kwd, String
       inFile, String outFile)
   { . . . }

   public static void counting(String inFile,
       String outFile)
   { . . . }

   public static void sorting(String inFile, String
       outFile)
   { . . . }
}
```

Data Flow Architecture Batch Sequential

Applicable Design Domains:

- Data are batched
- Each sub-system reads related input files and writes output files

Benefits:

- Simple divisions between sub-systems
- Each sub-system can be a stand-alone program working on input data and producing output data

Limitation:

- Requires an external control
- Low throughput
- No interactive interface

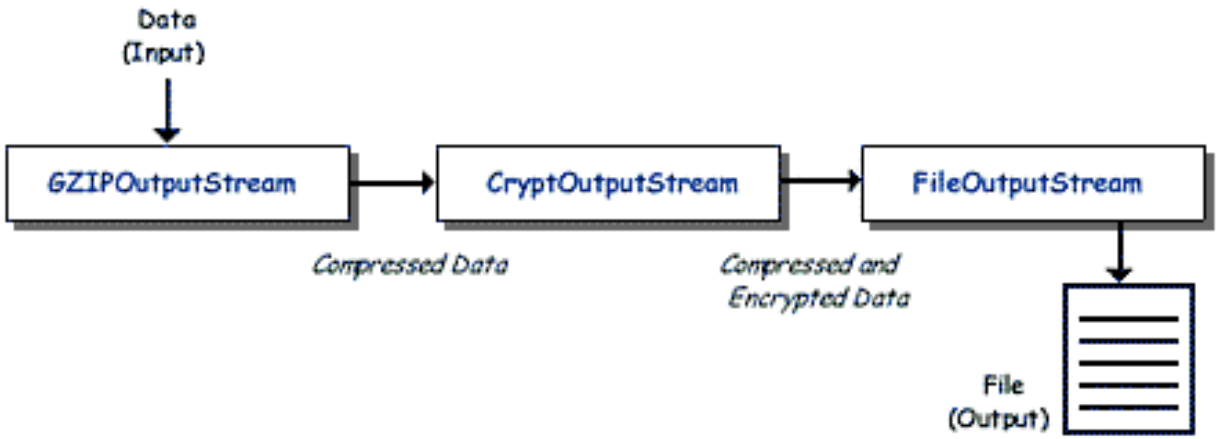
Data Flow Architecture Pipe and Filter Architecture

- The Pipe and Filter architecture is another type of data flow architecture where the flow is directed by data
- It decomposes the whole system into components of
  - data source
  - filters
  - pipes
  - data sink
- The connections between components are data streams
- A data stream is a first-in-first-out buffer type data structure
- Almost all operating system and programming languages provide data stream mechanism

Data Flow Architecture Pipe and Filter Architecture

- A filter is an independent data stream transformer which
  - reads data from its input data stream
  - transforms and processes it
  - then writes the transformed data stream over a pipe to next filter
- A filter does not need to wait for batched data as a whole (can start working as soon as the data arrives)
- A filter does not even know the identity of data upstream or data downstream
- A filter is just working in a local incremental mode

Example of Pipe and Filter Architecture



Pipe and Filter Architecture

- A pipe is a stateless conduit that moves data stream from one filter to another filter
- A pipe can carry binary or character stream
- An object type data must be serialized to be able to go over a stream
- Serialization is the process of saving an object onto a storage medium or to transmit it across a network connection link in binary form

- When the resulting series of bytes is reread according to the serialization format, it can be used to create an accurate clone of the original object
- This process of serializing an object is also called deflating or marshalling an object
- The opposite operation, extracting a data structure from a series of bytes, is deserialization or unmarshalling

Serializing a structure (C language)

```
 #include "tpl.h"
struct ms_t {
    int i;
    char c[3];
    double f;
};
int main() {
    tpl_node *tn;
    struct ms_t ms = {1, {'a','b','c'}, 3.14};
    tn = tpl_map( "S(ic#f)", &ms, 3);
    tpl_pack( tn, 0 );
    tpl_dump( tn, TPL_FILE, "struct.tpl" );
    tpl_free( tn );
}
```

Deserializing a structure (C language)

```
#include "tpl.h"
struct ms_t {
    int i;
    char c[3];
    double f;
};
int main() {
    tpl_node *tn;
    struct ms_t ms;

    tn = tpl_map( "S(*)", &ms);
    tpl_load( tn, TPL_FILE, "struct.tpl" );
    tpl_unpack( tn, 0 );
    tpl_free( tn );
}
```

Pipe and Filter Architecture

There are 3 ways to make the data be flowed:

- Push only (Write only)
  - A data source may push data in a downstream
  - A filter may push data in a downstream
- Pull only (Read only)
  - A data sink may pull data from an upstream
  - A filter may pull data from an upstream
- Pull/Push (ReadIWrite)
  - A filter may pull data from an upstream and push transformed data in a downstream

There are 2 type filters:

- Active filter
  - It pulls in data and push out the transformed data (pull/push)
  - It works with a passive pipe which provides read/write mechanisms for pulling and pushing
- Passive filter
  - It lets connected pipe to push data in and pull data out
  - It works with active pipes that pull data out from a filter and push data into next filter

solid lines indicate the class connections; dash lines indicate an alternative configuration for pipes

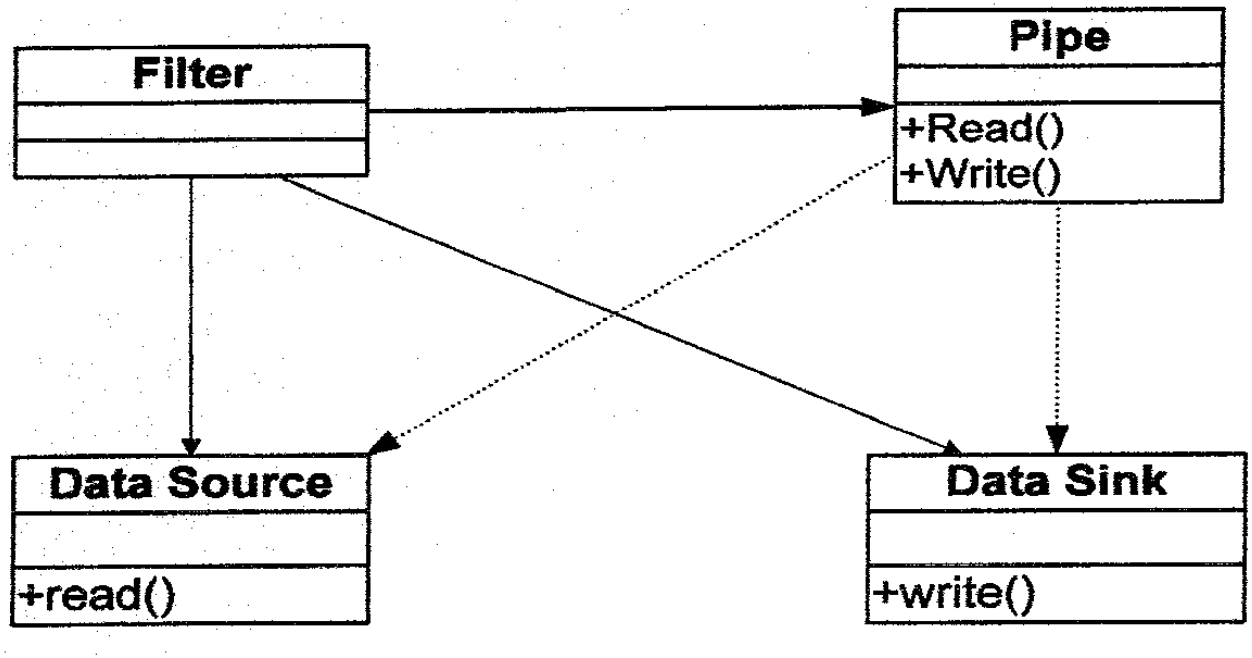


Figure: Pipe and active filter class diagram

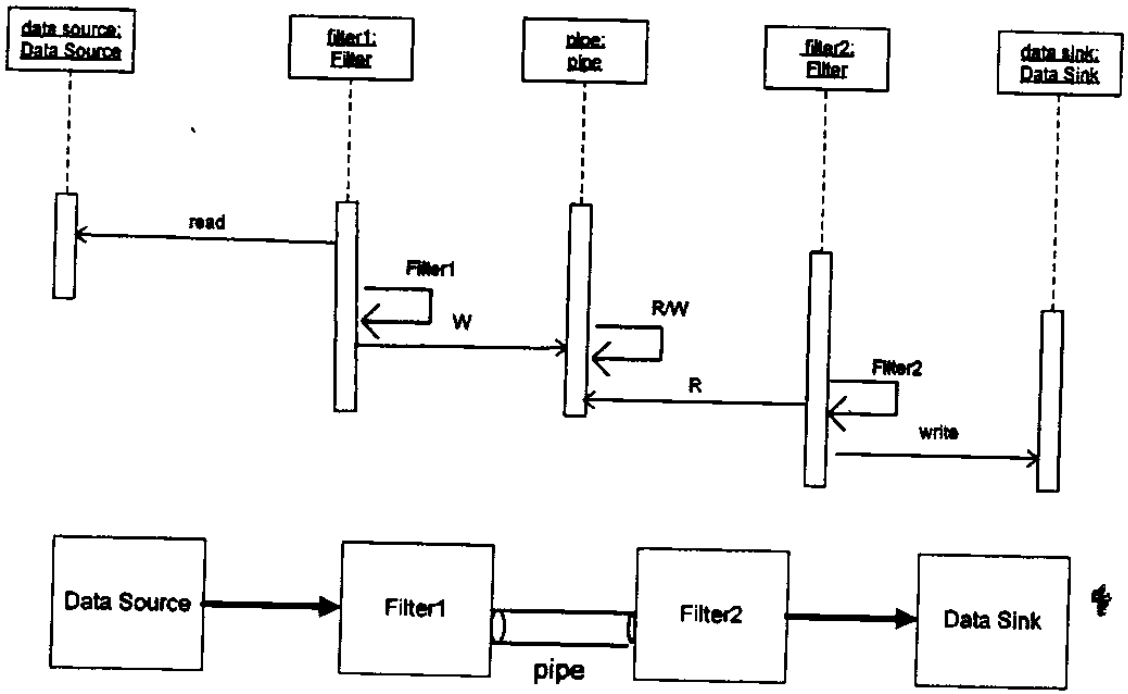


Figure: Pipe and filter block diagram and sequence diagram

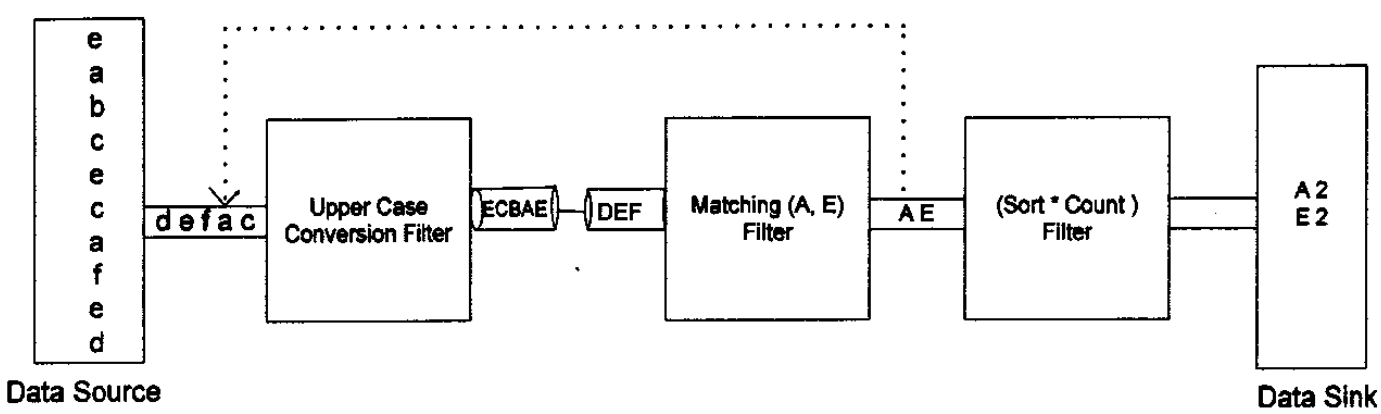


Figure: Pipelined pipe and filter

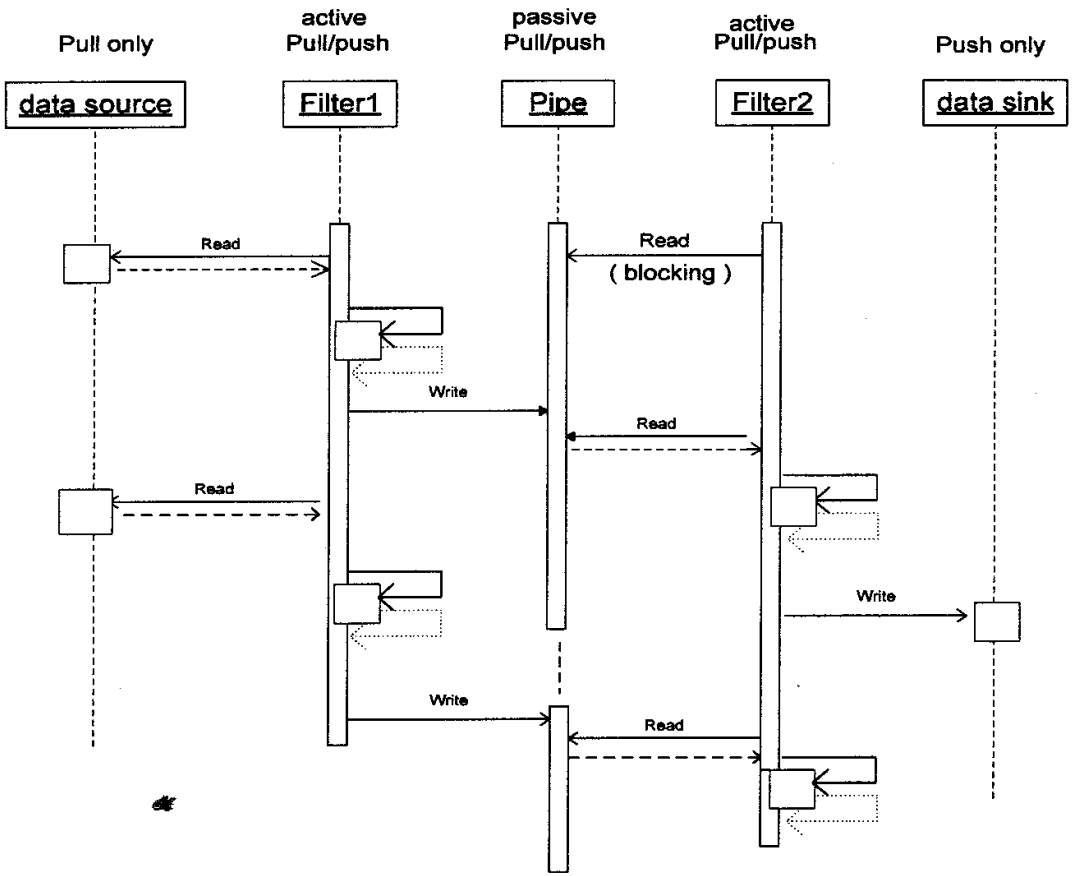


Figure: Pipe and filter sequence diagram

Pipe and Filter Architecture

- Applicable Design Domain of Pipe and Filter Architecture
  - Wherever the system can be broken into a series of processing steps over data stream
  - Data format on the data stream is simple and stable, and easy to be adapted if it is necessary
  - There are significant work which can be pipelined to gain the performance
  - Suitable for producer/consumer model

- Benefits of Pipe and Filter:
  - Concurrency
  - Reusability: Encapsulation of filters makes it easy to plug and play and to substitute
  - Modifiability: Low coupling between filters
  - Simplicity: Clear division between piped filters
  - Flexibility: It supports sequential + parallel execution

Limitations of Pipe and Filter:

- Not suitable for dynamic interactions
- Low Common Denominator is required for data transmission in the ASCII formats
- Overhead of data transformation among filters such as parsing overhead in two consecutive filters
- Difficult to configure a P&F system dynamically
- Error handling issue

Data Flow Architecture Process-Control Architecture

- The process-control software architecture is suitable for the embedded system software design
- The process-control architecture decomposes the whole system into two type sub-systems:
  - executor processor unit for changing process control variables
  - controller unit for calculating the amounts of the changes

Process-Control Architecture

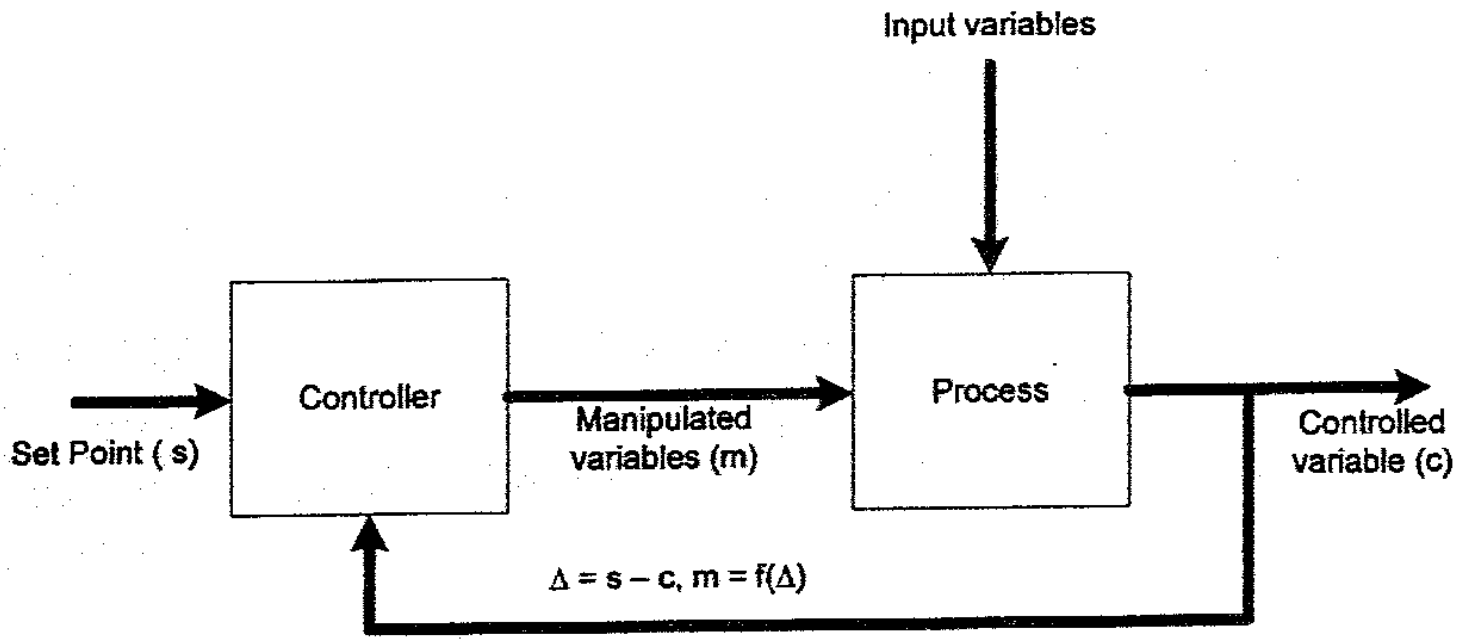


Figure: Data flow in the process control architecture

Data Flow Architecture Process-Control Architecture

A process control system must have the following process control data:

- Controlled variable:
  - Example: speed in a cruise control system
  - It has a set point which is the goal to reach
  - The controlled variable data should be measured by sensors
- Input variable:
  - Example: measured input data such as the temperature of return air in a temperature control system
- Manipulated variable: can be adjusted by the controller

Process-Control Architecture is subject of SFWR ENG 3DX3 Dynamic models and control of physical systems

Data Flow Architecture Process-Control Architecture

- Applicable domains
  - Embedded software system involving continuing actions
  - The system needs to maintain an output data at a stable level
  - The system can have a target point
- Benefits
  - Better solution to the control system where no precise formula can be used to decide the manipulated variable
  - The software can be completely embedded in the devices
- Limitations: Can be unstable and requires a thorough mathematical analysis

Data Flow Architecture

What class model would be appropriate to implement a given data flow?

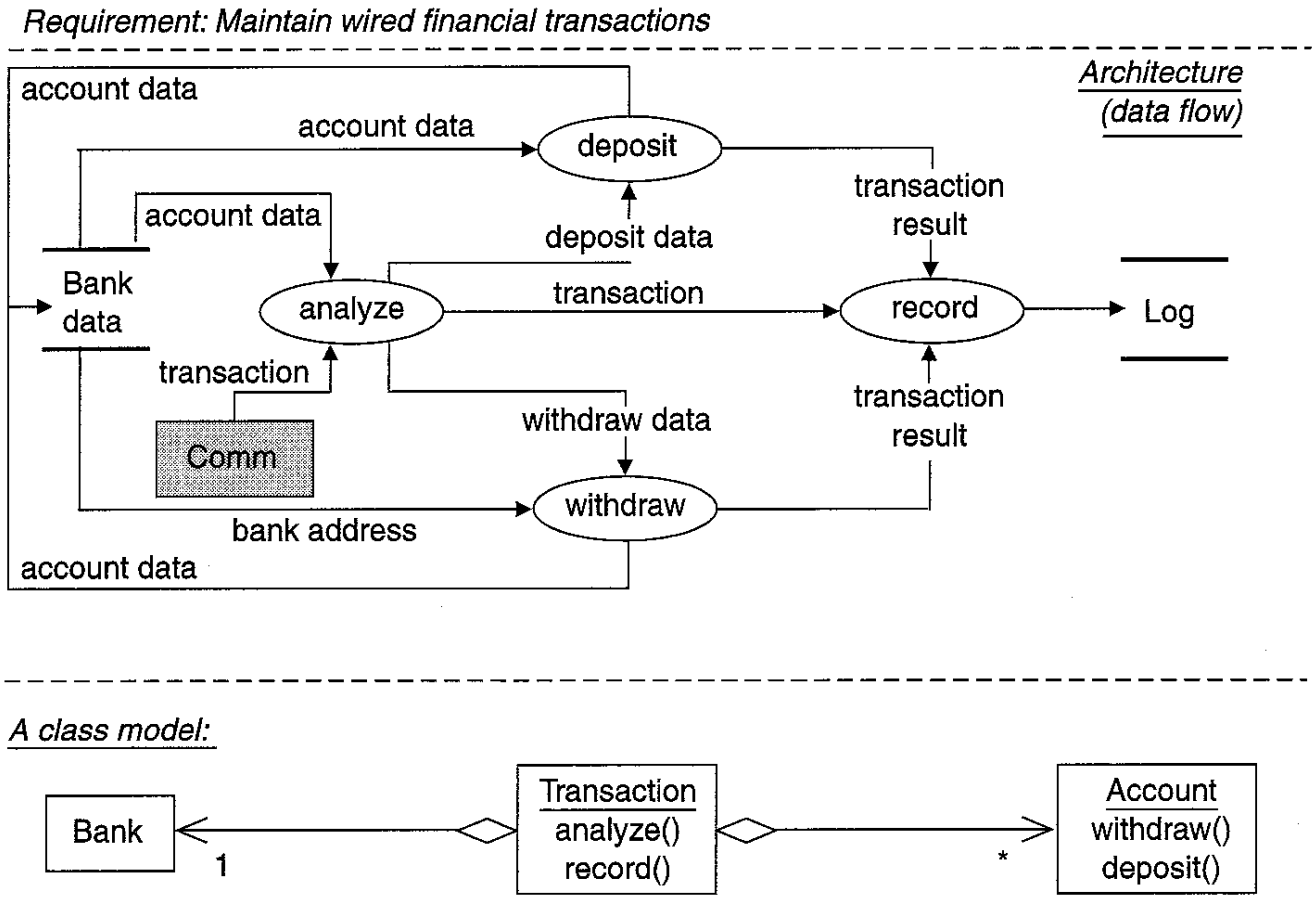


Figure: Example of Data Flow Architecture and Corresponding Class Model