Data Flow Architecture

- Batch sequential
- Pipe-and-filter

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Typical Database Applications

- Edit program: accept transaction input and perform validation without access to DB
- Transaction sort: get the transactions into the same order as the records on the sequential master file
- Update program (one for each master file): execute the transactions by
  - Moving sequentially through master files
  - Matching each type of transaction to its corresponding account
  - Updating the account records
- Print program: produce periodic reports

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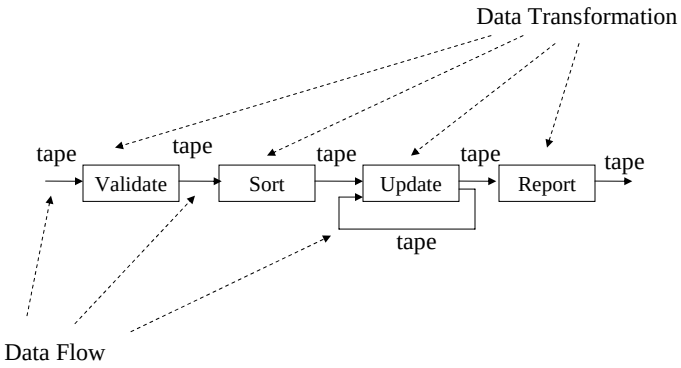
Batch Sequential Systems



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Batch Sequential systems

- Processing steps are independent programs
- Each step runs to completion before next step starts
- Data transmitted as a whole between steps
- Typical applications:
  - Classical data processing
  - Program development

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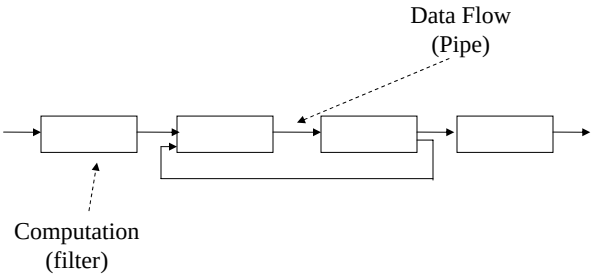
Pipes and Filters



Pipes and Filters

- Pipe
  - Move data from a filter output to a filter input
    - One-way flow; may be flow control upstream but not data
  - Pipes from data transmission graphs
- Filter
  - Incrementally transform some amount of the data at inputs to data at outputs
    - Enrich data by computing and adding information
    - Refine data by concentrating or extracting information
    - Transform data by changing its representation
  - Stream-to-stream transformations
  - Use little local context in processing stream
  - Preserve no state between instantiations
- Overall computation
  - Run pipes and filters (non-deterministically) until no more computations are possible
  - Action mediated by data delivery

Pipe-and-Filter Invariants

- Filters **do not share state** with other filters.
- Filters **do not know the identity** of their upstream or downstream filters.
- The **correctness** of the output of a pipe and filter network should not depend on the order in which their filters perform their incremental processing.

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Common Specializations

- Pipeline: the topology is restricted to linear
- Batch sequential: a special case of pipeline, when each filter processes all of its input data as a single entry
- Bounded pipe: the capacity of pipe is restricted
- Typed pipe: passing typed data

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Pipe-and-filter in Unix

- Unix processes that transform stdin to stdout are generally called filters
  - But when they consume all the input before starting the output, they violate the filter assumption (e.g., sort)
- Unix pipes can treat files as well as filters as data sources and sinks
  - But files are passive, so you can't make arbitrary combinations
- Unix assumes that the pipes carry ASCII character streams
  - The good news: anything can connect to anything else
  - The bad news: everything must be encoded in ASCII, then shipped, then decoded
  - The cloud on the good news: filters make assumptions about the syntax of the stream

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Data Pulling and Pushing

- What is the force that makes the data flow?
- Three choices, all with force emanating from filters:
  - Push: data source pushes data in downstream direction
  - Pull: data sink pulls data from upstream direction
  - Push/pull: a filter is actively pulling from upstream, computing, and pushing downstream
- Combinations may be complex: if more than one filter is pushing/pulling, synchronization is needed

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Pipe-and-Filter Advantages

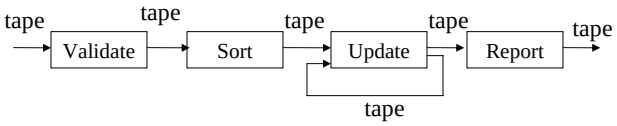
- Easy to understand the overall input/output behavior of a system as a simple composition of the behaviors of the individual filters.
- They support reuse, since any two filters can be hooked together, provided they agree on the data that is being transmitted between them.
- Systems can be easily maintained and enhanced, since new filters can be added to existing systems and old filters can be replaced by improved ones.
- They permit certain kinds of specialized analysis, such as throughput and deadlock analysis.
- They naturally support concurrent execution.

Pipe-and-Filter Disadvantages

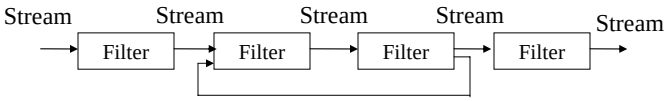
- Not good for handling interactive systems, because of their transformational character.
- Excessive parsing and unparsing leads to loss of performance and increased complexity in writing the filters themselves.

Batch Sequential vs Pipe-and-Filter (Unix)

Batch Sequential



Pipe-and-Filter (Unix)



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Batch Sequential vs Pipe-and-Filter (Unix)

- Coarse-grained
- Total
- High latency
- Random access to input ok
- No concurrency

- Fine-grained
- Incremental
- Results start immediately
- Processing localized in input
- Feedback loops possible

•Decompose task into fixed sequence of computations
•Interact only through data passed from one to another

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Key Word In Context (KWIC)

- Problem description:
  - The KWIC index system accepts an ordered set of lines,
    - each line is an ordered set of words
    - each word is an ordered set of characters
  - Any line may be “circularly shifted” by repeatedly
    - removing the first word
    - appending it at the end of the line
  - The KWIC index system outputs a listing of all circular shifts of all lines in alphabetical order

Example

Pipe and Filter
Software Architecture in Practice

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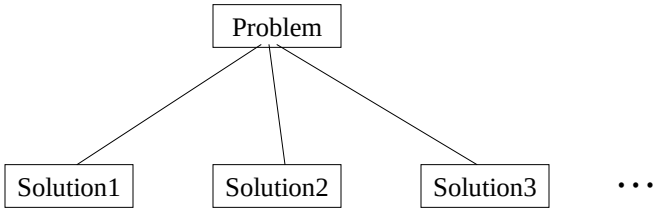
Solutions (Design Alternatives)

- There can be many solutions to this problem



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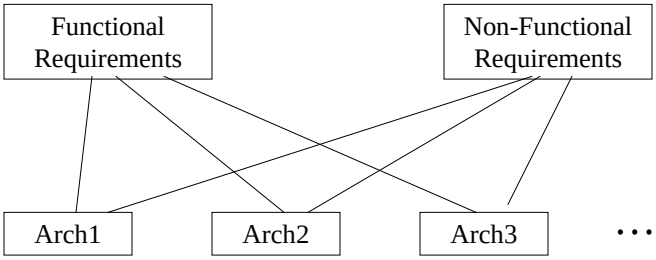
How to Choose



Basis for tradeoff analysis & design rationale

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Non-Functional Requirements

- Modifiability
  - Changes in processing algorithms, e.g.
    - Line shifting
      - One at a time as it is read
      - All after they are read
      - On demand when the alphabetization requires a new set of shifted lines
    - batch alphabetizer vs incremental alphabetizer
  - Changes in data representation, e.g.
    - Storing characters, words and lines
      - in 1-D/2-D array/linked list, compressed/uncompressed
      - Explicitly/implicitly (as pairs of index and offset)
      - Core storage/secondary storage
- Enhanceability
  - Enhancement to system function, e.g.,
    - eliminate noise words (a, an, the, and, etc.)
    - The user deletes lines from the original or shifted lines
- Performance
  - Space and time
- Reusability
  - To what extent can the components serve as reusable entities

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Solution 1: Pipe and Filter

- Decompose the overall processing into a sequence of processing steps:
  - Read input
  - Make shifts
  - Alphabetize
  - Print results
- Each step transforms the data completely

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Solution 1: Modularization

- Module 1: Input
  - Reads data lines
  - Passes it to Circular Shift
- Module 2: Circular Shift
  - Called after Input is done
  - Reads lines
  - Makes shifts
  - Passes the results to Alphabetize
- Module 3: Alphabetize
  - Called after Circular Shift
  - Reads lines
  - Arrays the lines in alphabetical order
- Module 4: Output
  - Called after alphabetization
  - Prints nicely formatted output of shifts

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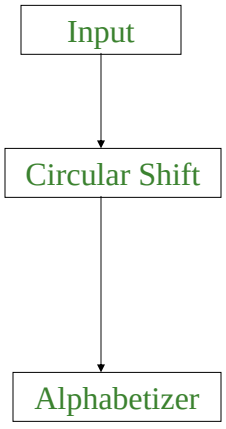
Solution 1: Pipe and Filter



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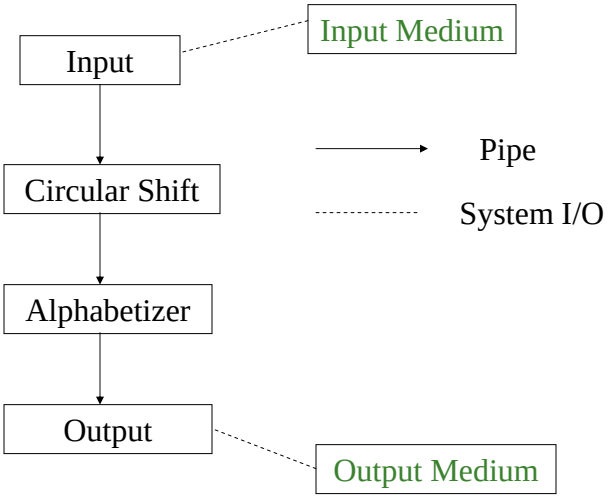
KWIC: Pipe and Filter

Filter:
Input
Circular Shift
Alphabetizer
Output



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Advantages

- Maintain the intuitive flow of processing
- Support reuse:
  - Each filter is independent
  - New filters can be added for new functions
- Easy to modify:
  - The change of the function of one filter will not affect other filter since they are independent

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Drawbacks

- Hard for interactive system, e.g. deleting a line requires some persistent shared storage
- Space inefficiency:
  - Each filter must copy all data

Non-Functional Requirements

- Modifiability
  - Changes in processing algorithms, e.g.
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Filter Independency

- Enhanceability
  - Enhancement to system function, e.g.,
    - eliminate noise words (a, an, the, and, etc.), by inserting filters at the appropriate points
    - The user deletes lines from the original or shifted lines – hard for interactive system
- Performance
  - Space and time – inefficient due to data replication
- Reusability
  - To what extent can the components serve as reusable entities – high due to filter independency

Pipe and Filter

- Components: Filters
- Connectors: Pipes
- Styles: Pipe-and-Filter
- Rationale: Non-Functional Requirements (NFRs)

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