Pipeline Pattern

Also known as the **Chain of Responsibility Pattern**

Data flows through multiple stages, with each stage processed by different threads.

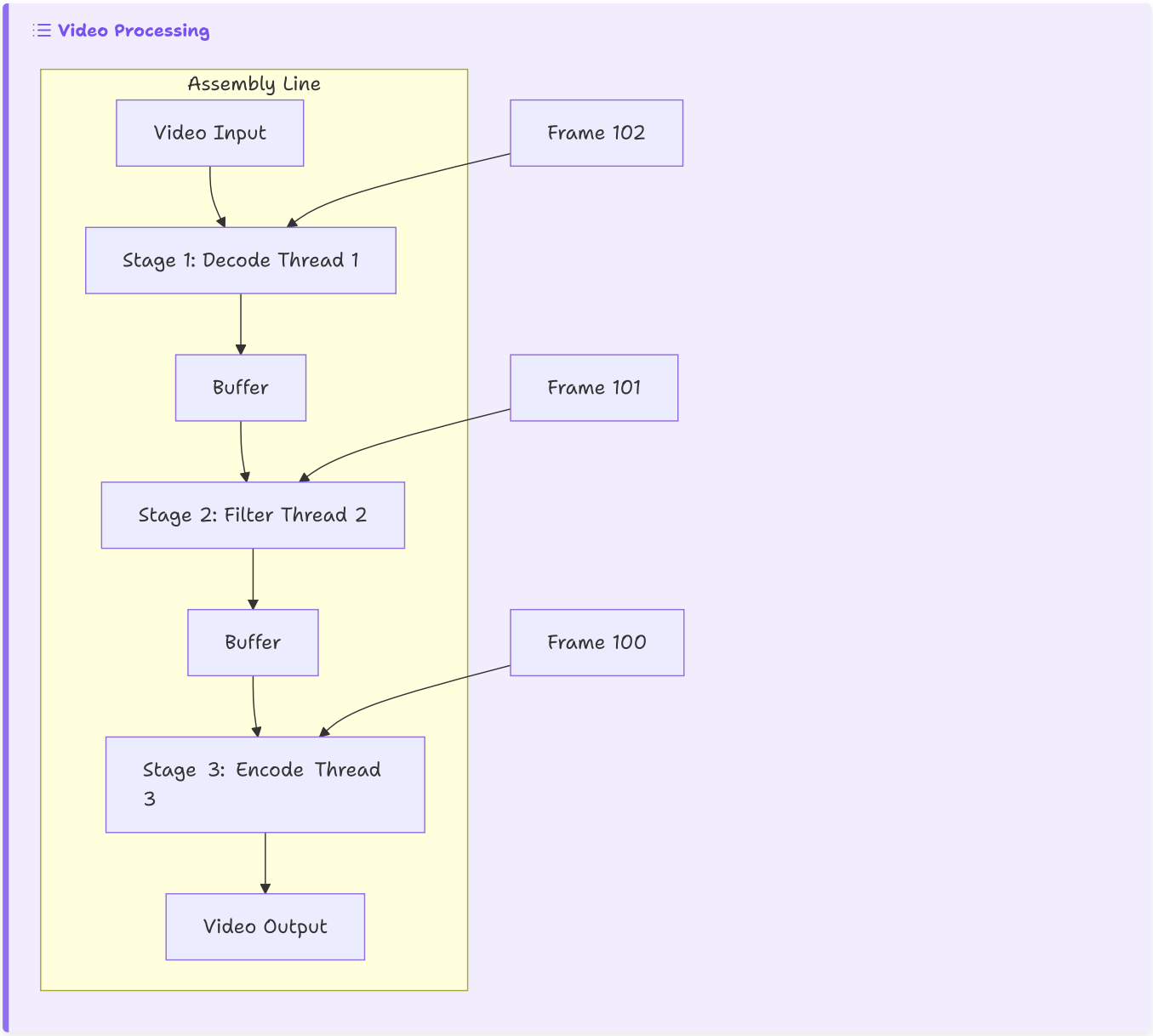
- Each stage can run in parallel on different data
- Like an assembly line

Each stage is **dependent** on the previous for input, but are complete **independent** in terms of process execution.

Benefits: High throughput, natural parallelism, easy to reason about.

Real-world example

An example would be video processing, data modelling pipelines.



- Video processing pipeline where:
  - Stage 1 decodes frames,
  - Stage 2 applies filters,
  - Stage 3 encodes output.
  While Stage 3 encodes frame 100, Stage 2 filters frame 101, and Stage 1 decodes frame 102.

Design Considerations

Choosing

Ask yourself this when choosing the design pattern

- Can your processing be broken into distinct, sequential stages?
- Do different stages have different processing times or resource requirements?
- Can stages process different items concurrently?
- Do you need high throughput for stream processing?
- Are the processing stages naturally independent?

Building Outline

Stage Design:

- How do you divide processing into stages?
- What's the optimal granularity for each stage?
- Can stages be reordered or parallelized?
- How do you handle stages with different processing speeds?

Buffer Management:

- What's the buffer size between stages?
- How do you handle back pressure when downstream stages are slow?
- Do you need flow control between stages?
- What's your strategy for handling buffer overflows?

Error Handling:

- What happens when one stage fails?
- Do you need to process items in strict order?
- How do you handle partial processing failures?
- What's your retry and recovery strategy?

Scaling:

- Can you run multiple instances of the same stage in parallel?
- How do you dynamically scale stages based on load?
- What's your strategy for handling varying stage complexities?
- How do you re-balance processing when adding/removing stage instances?

Monitoring:

- How do you measure throughput at each stage?
- What metrics indicate bottlenecks?
- How do you detect and handle stalled pipelines?