Designing Resilient Data Pipelines

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About Two Sigma

TWO SIGMA
What are we going to cover today?

I. Pipelines Crash Course

II. Observability

III. Structure

IV. Pipelines as Code

V. Data Validation
What is a data pipeline?

A collection of data processors with directional dependencies and no cycles

What does a data pipeline do?

Automates the process of bringing data from its origins to data consumers in a usable form
Data Pipelines Crash Course

Simple Pipeline Example: ETL (Extract, Transform, Load)

Extract:
Retrieve data from one or more data sources and load it into a staging location for use by downstream processes.

Transform:
One or more transformations are applied to the extracted data to prepare it for loading into the data destination.

Load:
The process of writing the data into the targeted data destination.

Diagram:

- **Data** → **Extract** → **Transform** → **Load** → **Data**
## Real World Pipelines

<table>
<thead>
<tr>
<th>Business Purpose</th>
<th>Frequency</th>
<th>Depends on Previous Runs?</th>
<th>Example SLO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trading Day Analysis</td>
<td>Daily</td>
<td>Yes</td>
<td>Delivery X hours before market open</td>
</tr>
<tr>
<td>Research Environment Build</td>
<td>Weekly</td>
<td>No</td>
<td>New environment released biweekly</td>
</tr>
<tr>
<td>Trading Platform Integration Tests</td>
<td>On Demand</td>
<td>No</td>
<td>95% of pipelines complete within X hours</td>
</tr>
</tbody>
</table>
Common Concerns

How do I detect and understand failures in my pipelines?

How can I minimize the risk associated with changes to my pipelines?

How do I quickly recover from pipeline failures?

How do I know that the data I generate is good?
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Observability

Logging

Metrics Collection

Status Monitoring
What does logging give us?
- Logs provide a record of events
- Used to determine when and why something happened
  - Why did this pipeline task fail?
  - When was this pipeline scheduled?
  - Why was/wasn’t this task launched?

Pipeline Logging Checklist
- All of the processors in the data pipeline produce logs
- The pipeline scheduler or workflow manager produces logs
- Logs are available after batch pipelines have completed their execution
Metrics Collection

- What type of metrics to collect?
  - Latency
  - Queued time
  - Resource usage
- …and at what level to collect them?
  - Individual task level
  - Pipeline level
Status Monitoring

- Monitor statuses at both the task and pipeline level
- Monitor status over time and across pipeline instances
- Make use of states
  - Running
  - Failed
  - Queued
  - Blocked on Concurrency
  - Canceled
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Idempotent Tasks

- A task is idempotent if, given the same inputs, it can be rerun without producing different results.

<table>
<thead>
<tr>
<th>Idempotent</th>
<th>Not Idempotent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rounding db entries to nearest integer</td>
<td>Appending rows to a csv</td>
</tr>
</tbody>
</table>

**Idempotent**

<table>
<thead>
<tr>
<th>Data</th>
<th>1st Run</th>
<th>2nd Run</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.7</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>8.3</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>4.2</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

**Not Idempotent**

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
<th>1st Run</th>
<th>2nd Run</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>
Immutable Inputs

What is immutable data?
- Data is immutable if it cannot be modified after it is created

Why use immutable inputs?
- Ensures reproducibility when combined with idempotent tasks

Ways to ensure immutability?
- Version your data
- Use immutable data stores
Benefits of Idempotency and Immutability

- Simplifies testing of tasks and pipelines
- Allows tasks to be retried without unintended effects
  - Reduces instances of operator error
  - Facilitates automatic retries
  - Facilitates checkpointing
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Pipelines as Code

What does Pipelines as Code mean?
- Defining pipelines in configuration or code

How is that accomplished?
- Pipelines can be expressed as Directed Acyclic Graphs (DAGs)
- DAGs can be encoded in declarative configuration
- DAGs can be generated using a general purpose programming language
Declarative Pipeline Example

```yaml
# General
# General
name: 'Extract'
id: 1
description: 'Extract data from source db'

# Execution
hostGroup: batch
runAs: 'abolin'
maxRun: 1h
command: 'extract.py'
maxAutoRetry: 3
autoRetryOn: [error]

# Tasks
# Dependencies
prerequisites: []

# Alerting
e-mail: [abolin@twosigma.com]
warn: 30m
alertOn: [error, failure]

# Resources
cpus: 1
memory: 1024

warn: 4h
```
Benefits of Pipelines as Code

- Storing pipelines in source control
  - Code review of pipeline updates
  - History of changes
  - Possible to keep the pipeline alongside the code it executes
- Static analysis
- Supports automation of pipeline deployments
- Regenerating historical pipeline outputs is possible with versioned pipelines, idempotent tasks, and immutable inputs
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Usable Data

What is usable data?
- Data that can be used for its intended business purpose

What causes data to be unusable?
- Does not conform to the format required by consumers
- Is wrong or impossible
- Is incomplete

<table>
<thead>
<tr>
<th>Price</th>
<th>Currency</th>
</tr>
</thead>
<tbody>
<tr>
<td>One Hundred Forty</td>
<td>$</td>
</tr>
<tr>
<td>-140.01</td>
<td>$</td>
</tr>
<tr>
<td>140.01</td>
<td>-</td>
</tr>
</tbody>
</table>
Data Validation

What is data validation?
- The process of ensuring data is usable through the use of data validators

What are data validators?
- A data processor which verifies or tests the properties of its input data
  - Data type validation
  - Constraint validation
  - Quantitative validation

<table>
<thead>
<tr>
<th>Time</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:30</td>
<td>97.01</td>
</tr>
<tr>
<td>9:31</td>
<td>97.05</td>
</tr>
<tr>
<td>9:32</td>
<td>97.03</td>
</tr>
</tbody>
</table>

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<tr>
<td>9:30</td>
<td>97.01</td>
</tr>
<tr>
<td>9:31</td>
<td>45.03</td>
</tr>
<tr>
<td>9:32</td>
<td>180.43</td>
</tr>
</tbody>
</table>
Pros and Cons of Data Validation

Pros

- Provides guarantees on the usability of the data
- Can detect soft failures in data pipelines
- Can prevent execution of downstream tasks using invalid data

Cons

- Can increase pipeline latency
- Flaky validators introduce instability
Adding Validators to Data Pipelines

Quarantine Method

- New validators are always added as leaf nodes to the data pipeline
- After observing the validators over several execution cycles:
  - Continue running the validator outside of the critical path
  - Move the validator into the critical path of the pipeline
  - Remove the validator
Common Concerns

- How do I detect and understand failures in my pipelines?
- How can I minimize the risk associated with changes to my pipelines?
- How do I know that the data I generate is good?
- How do I quickly recover from pipeline failures?

Observability

Pipelines as Code

Data Validation

Structure
Thanks for Attending!

If you have any questions

- I’ll be available right outside the hall right after this talk
- Later you can find me at the Two Sigma booth