

# Bringing the Cloud to the 4th Industrial Revolution

---

Oden Technologies  
Devon Peticolas

# Who Am I?

Devon Peticolas

Sr. Data Engineer

My job is to prepare Oden's data and pipelines for Machine Learning and Data Science.

---

# Who Are We?

Oden Technologies

Founded in 2014

Pre-Series A

---

# Who Are Our Customers?

Manufacturers, people making things.

- Factories
- Multi-Factory Companies
- Focused Teams

---

# \$1.7 — 3.2T

Projected impact on global GDP from manufacturing IoT over by 2031  
~ McKinsey, 2016

# The Product

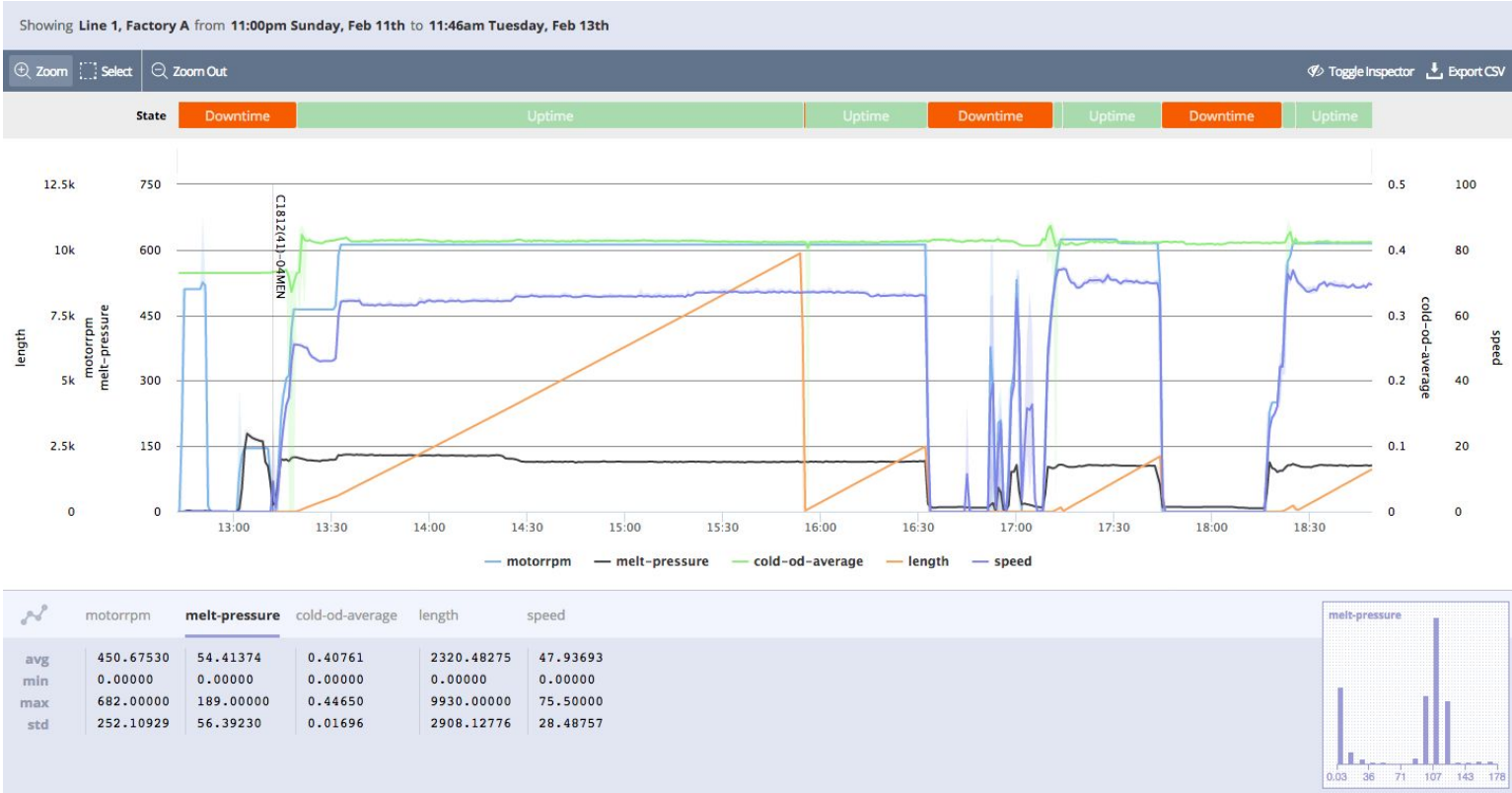
---

# Real Time Overview

Factory  
Demo Factory

Name	State	Product	Target	Actual
<div><div></div><div></div></div>	<div>Downtime</div> <div>18m 39s</div>	<div>V</div> <div>25d</div>	<div>130 ±3</div> <div>machine-speed</div>	<div>122 -8</div>
<div><div></div><div></div></div>	<div>Running</div> <div>1h 32m</div>	<div></div> <div>13d 13h</div>	<div>130 ±3</div> <div>machine-speed</div>	<div>128 -2</div>
<div><div></div><div></div></div>	<div>Running</div> <div>3h 45m</div>	<div></div> <div>27d 7h</div>	<div>154 ±4</div> <div>machine-speed</div>	<div>—</div>
<div><div></div><div></div></div>	<div>Downtime</div> <div>3h 56m</div>	<div></div> <div>41d 15h</div>	<div>—</div>	<div>—</div>

# Time Series View





# Spreadsheet View

Explore

Search

Run

Tue Jan 16th - Tue Feb 13th

All week • 12am - 12am

Hide Filters

Product

All Products

State




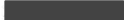









Annotations

Lines

Search

Product	Line	Annotations	States	From	To	Duration	1-machine-speed (average)	1-total-batch-part-counter-low-acc (deltasum)	
	Demo Factory	None	Insert Broken Uptime Downtime	Fri Jan 12th 11:44pm	Tue Jan 16th 3:06am	3d 3h	64.845 ⬆ 125 ± 3	159,779	
	Demo Factory	None	Uptime Downtime	Tue Jan 30th 10:19am	Still active	13d 13h	84.215 ⬆ 130 ± 3	1,005,754	
	Demo Factory	None	Uptime Downtime Setup/Changeover	Mon Jan 29th 12:59am	Tue Jan 30th 10:19am	33h 19m	62.959 ⬆ 130 ± 3	81,001	
	Demo Factory	None	Uptime Downtime Setup/Changeover Punch Pin	Thu Jan 18th 9:53pm	Mon Jan 22nd 11:07am	3d 13h	39.237 ⬆ 130 ± 3	122,604	
	Demo Factory	None	Setup/Changeover Uptime Downtime No Tubs Available	Mon Jan 22nd 11:07am	Wed Jan 24th 3:35am	40h 28m	118.844 ⬆ 120 ± 3	156,948	
	Demo Factory	None	Setup/Changeover Uptime	Tue Jan 16th 12:27pm	Thu Jan 18th 11:42pm	2d 11h	118.144 ⬆ 110 ± 3	247,145	

# Reporting View

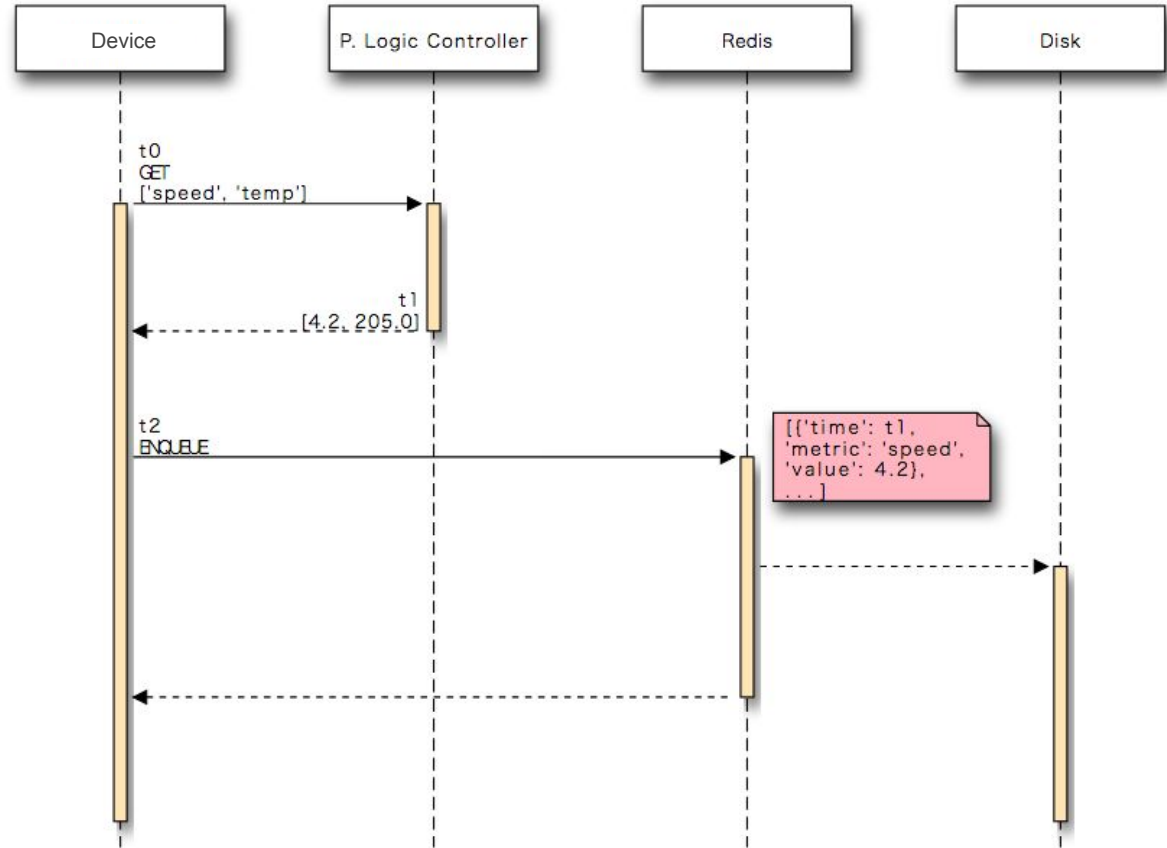
Quality Report  Tuesday, Sep 25				
Runs completed yesterday that deserve your attention				
Sorted lowest CPK to highest				
Run	Started	Uptime	CPK	Nonconforming
 Thermoformer 10	12:13am Yesterday	3h 37m	0.007	<b>6.59%</b> ↑ 0.11% ↓ 6.48% 
 Header 22	8:13am Sunday	32m	0.233	<b>3.20%</b> ↑ 3.13% ↓ 0.07% 
 Header 22	8:44pm Yesterday	1h 25m	0.557	<b>2.99%</b> ↑ 0.02% ↓ 2.97% 
⋮ 23 additional runs				
 Header 22	8:44pm Yesterday	1h 25m	1.033	<b>0.94%</b> ↑ 0.63% ↓ 0.31% 
 Header 6	11:29pm Friday	59h 35m	1.877	<b>0.37%</b> ↑ 0.37% ↓ 0.00% 
 Header 6	10:20pm Yesterday	6h 8m	2.096	<b>0.25%</b> ↑ 0.08% ↓ 0.17% 
<a href="#">See all runs from yesterday</a>				

# Data Acquisition

---

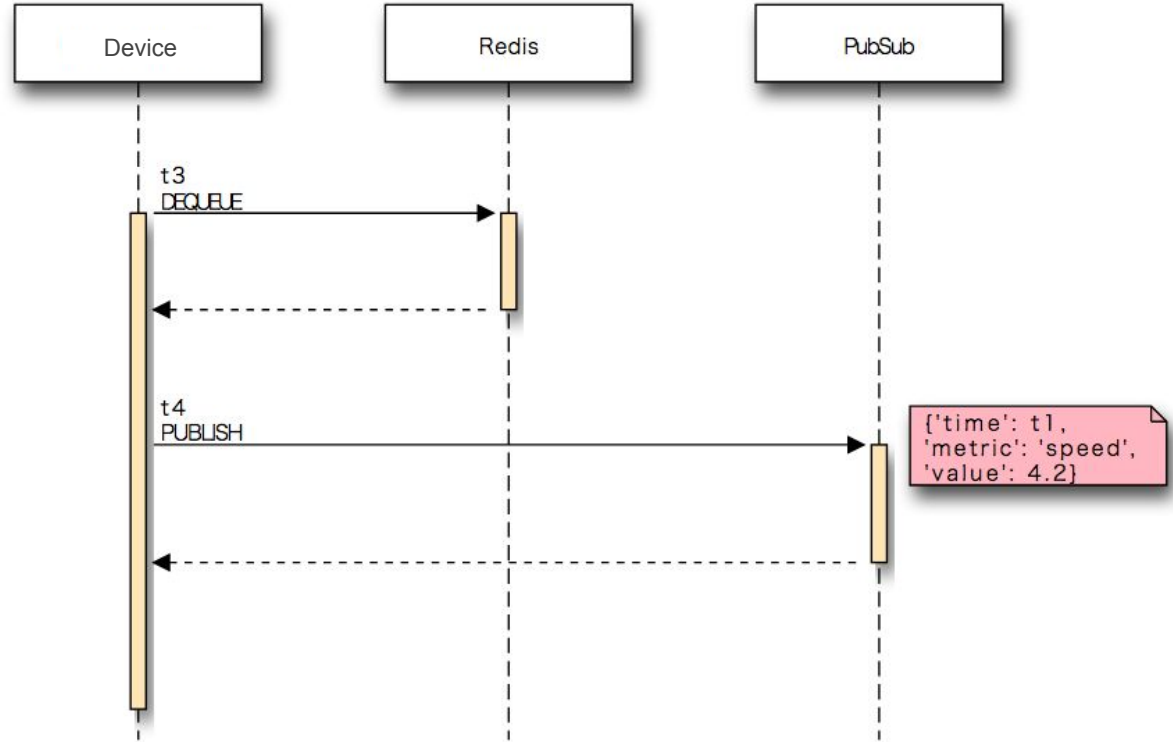
# Acquisition 1

- Requests metrics from PLC
- PLC returns values at t1
- Enqueues to disk-backed Redis w/ time t1



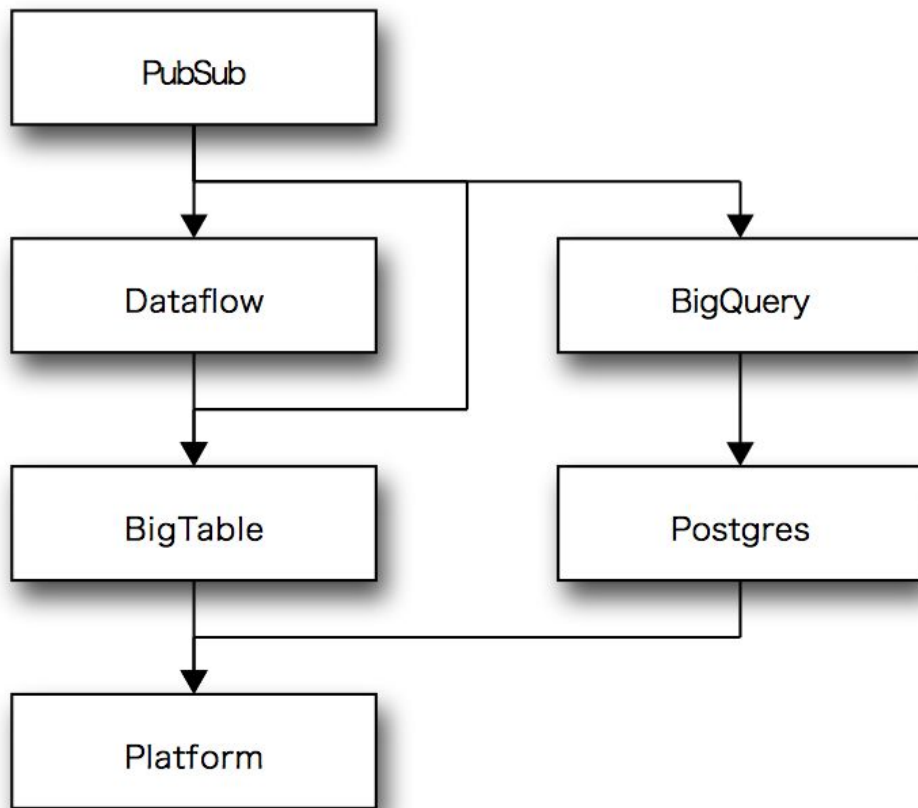
## Acquisition 2

- Dequeues from Redis
- Publishes to PubSub



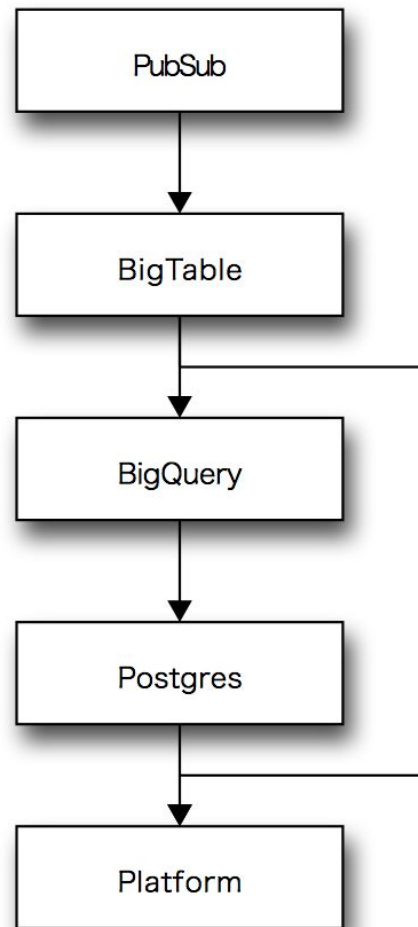
# Write And Transform 1

- PubSub fans out
  - BT for 1s-res “hot” data
  - BQ for “slow” data
  - Df to BT for 60s and 600s “roll-ups”
- ETLs run rollup BQ to PG
- PG and BT serve Platform



# Write And Transform (future)

- PubSub fans out
  - BT for 1s-res “hot” data
  - Df -> BT for 60s and 600s “roll-ups”
- BT feeds BQ
- ETLs run rollup BQ to PG
- PG and BT serve Platform



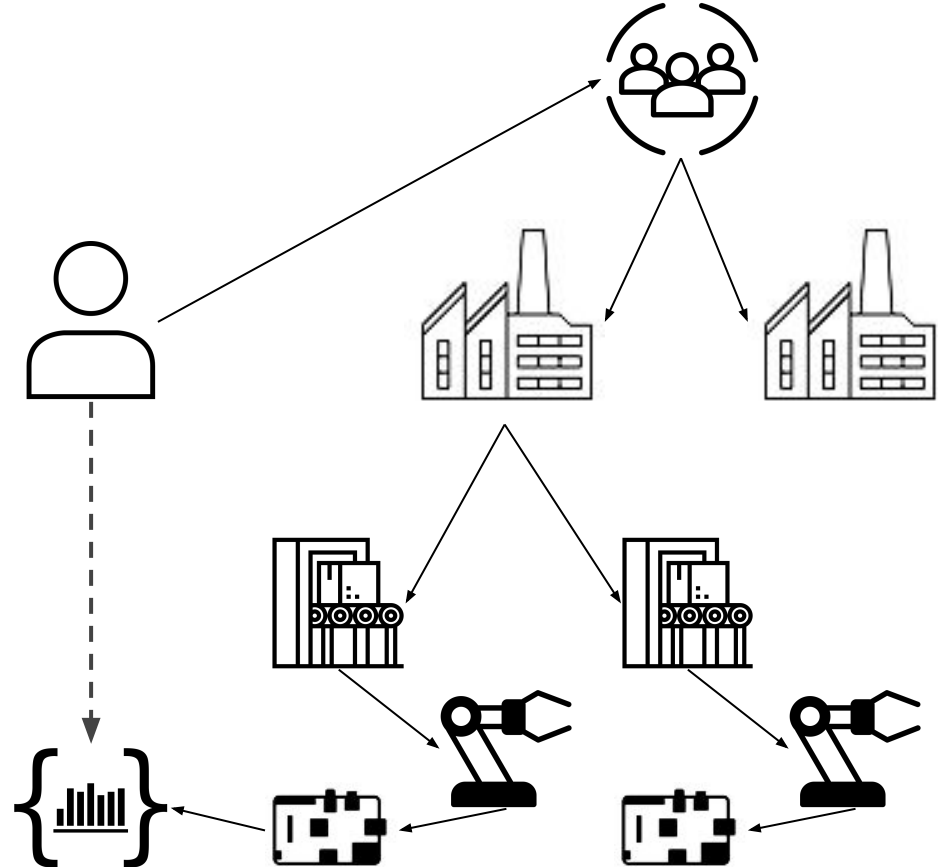
# Mapping the Factory

---



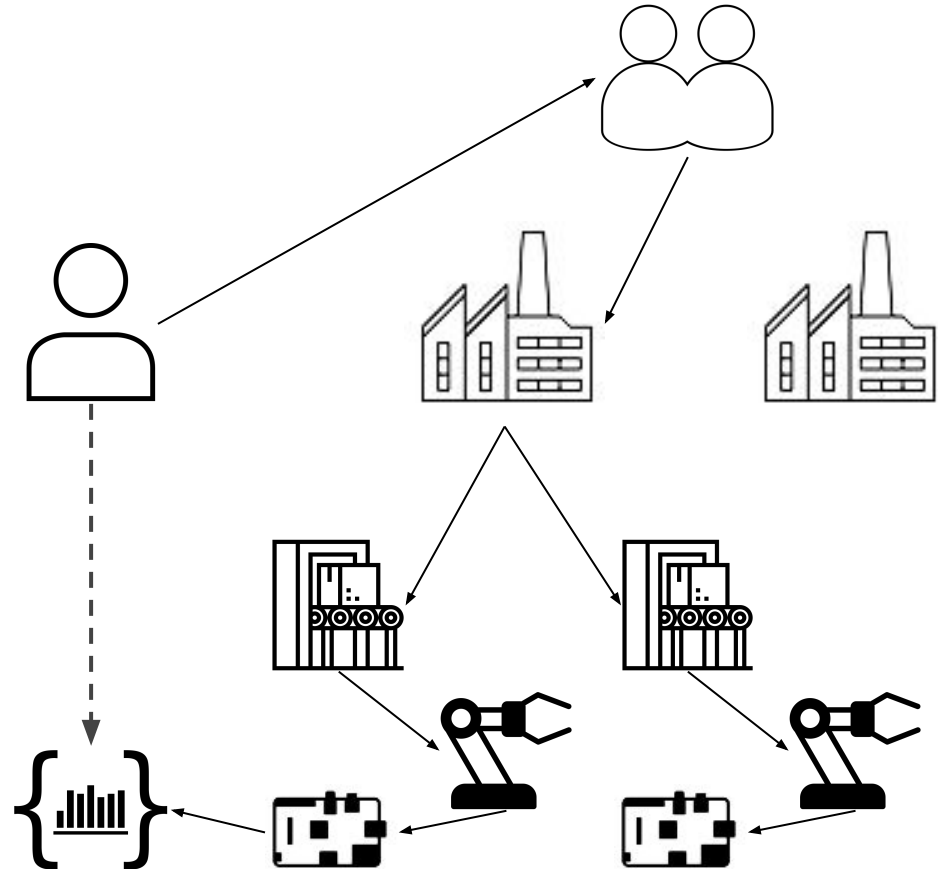
# Permissions 1

- User belongs to an Organization
- Organization owns factories
- Factories have lines
- Lines have machines
- Machines are connected to Oden devices
- Oden devices collect metrics



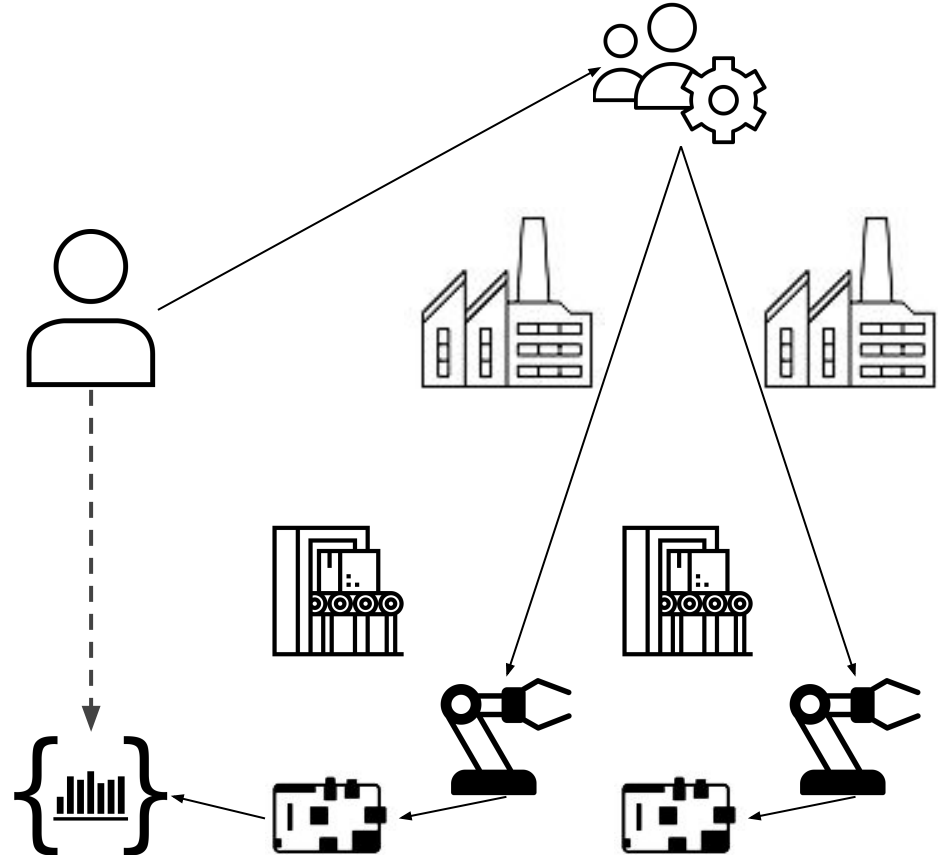
## Permissions 2

- User belongs to a team
- Organization can see single a factory



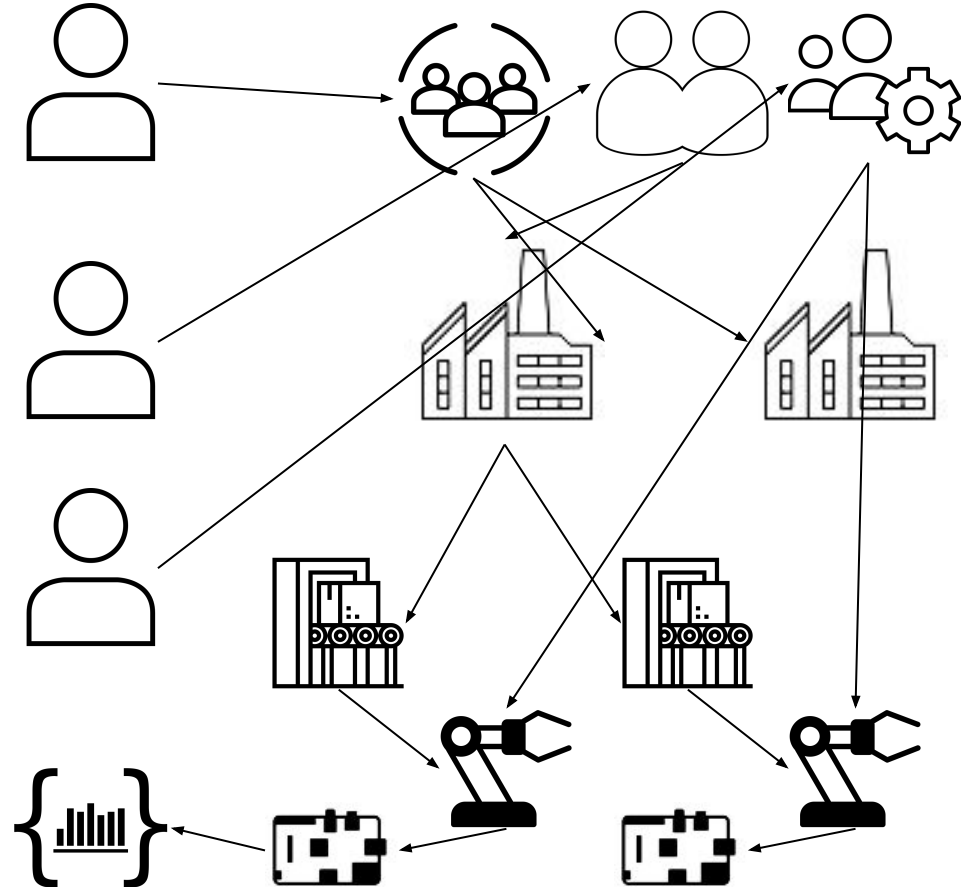
# Permissions 3

- User belongs to an Organization
- Organization maintains machines



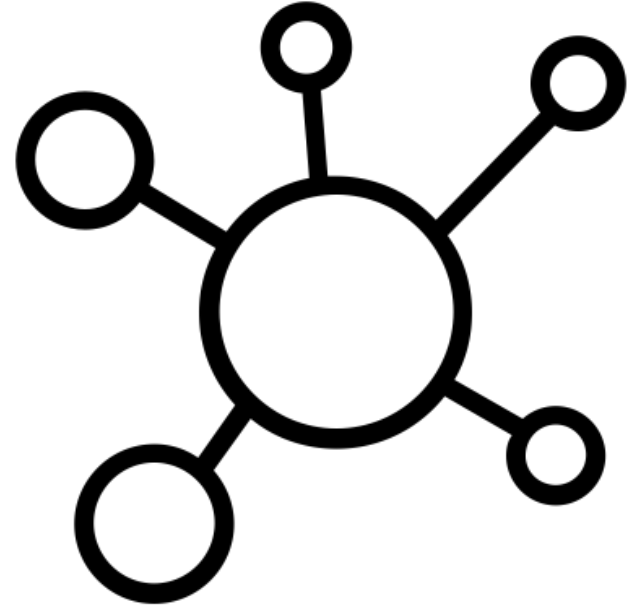
## Permissions 4

→ All of these relationships live side-by-side simultaneously



## Permissions - Neo4j

- Answers our arbitrary relationship questions quickly
- Allows for the currently known relationships between business entities
- Allows for the currently unknown relationships between business entities



# Defining Types of Data

---

# Metric

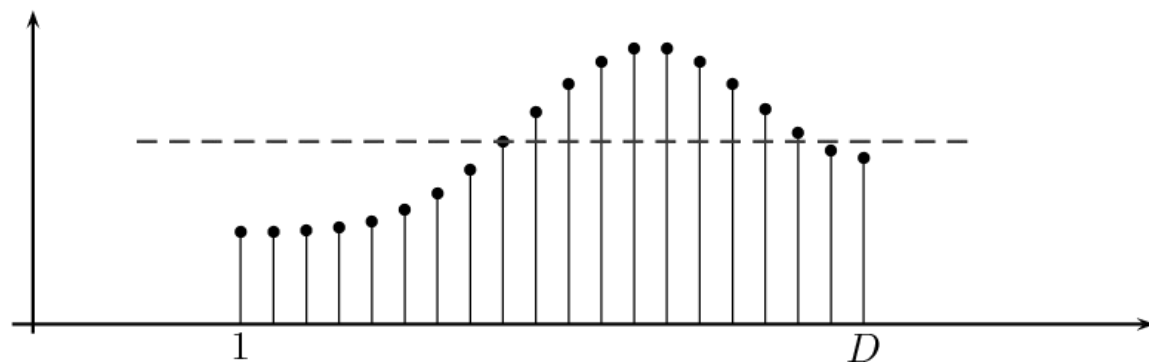
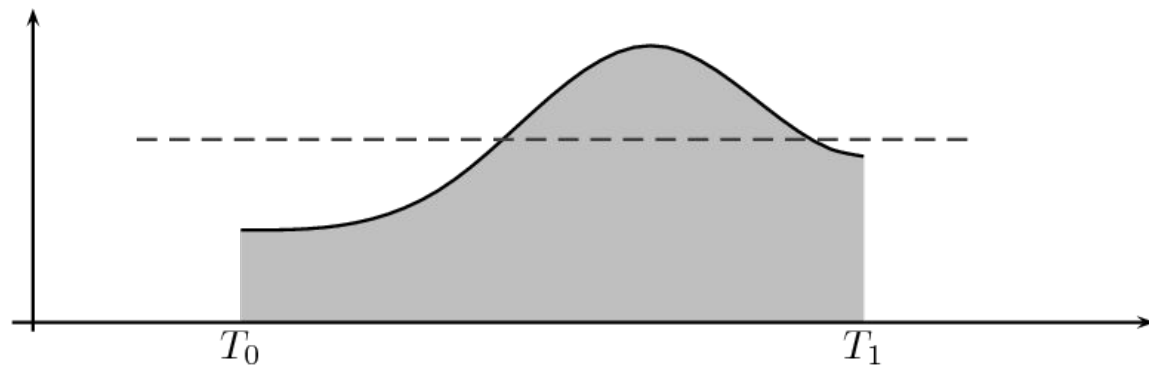
## Definition

A metric is an **immutable** floating point value **uniquely** describing the behavior of part of a manufacturing process for some machine, label, and second-resolution timestamp.

## Example

"The **melt-temp** on machine **12345** is **4.5** at **2017-12-11T13:30:45**."

# Metric





# Interval

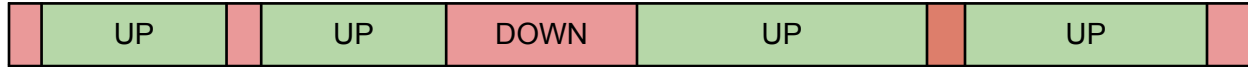
## Definition

An interval of some class is a **mutable** and **non-overlapping** time-range that reflects a **business context** for the metrics produced during that time.

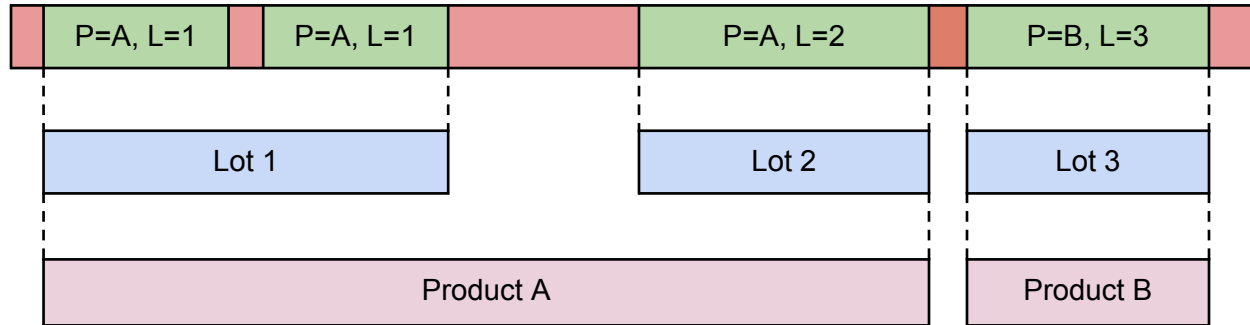
## Example

**“Line 13579** is producing **lot 6** of **product A10** during from **2017-12-11T11:00:00** until **2017-12-11T16:20:00”**

# Interval 2



# Interval 3



# Aggregate

## Definition

An aggregate is a function of the metrics within an interval that summarizes behavior of the system during that business context.

## Example

“When **Line 13579** produced **lot 6** of **product A10** 0.5% of the product produced was not within specification.”

# Associative Aggregate

## Formal Definition

$(x * y) * z = x * (y * z)$  for all  $x, y, z$  in  $S$

## Practical Definition

An aggregate function that can be reapplied to include other aggregates.

## Example

“Of all lots produced on **Line 13579** today, 0.5% of the product produced was not within specification.”

# Associative

Sum

Count

Sums of Squares

Min

Max

First

Last

# Non-Associative

Mean\*

Mode

Percent\*

KS-Statistic

Standard Deviation\*

Rate\*

$C_p$   $C_{pk}$   $C_{pm}$   $C_{pmk}$

# Associative

Sum

Count

Sums of Squares

$$\sigma^2 = \frac{\sum_{i=1}^N (X - \mu)^2}{N}$$

$$\sigma^2 = \frac{1}{n(n-1)} \left( n \sum_{i=1}^n x_i^2 - \left( \sum_{i=1}^n x_k \right)^2 \right)$$

# Non-Associative

Mean\*

Mode

Percent\*

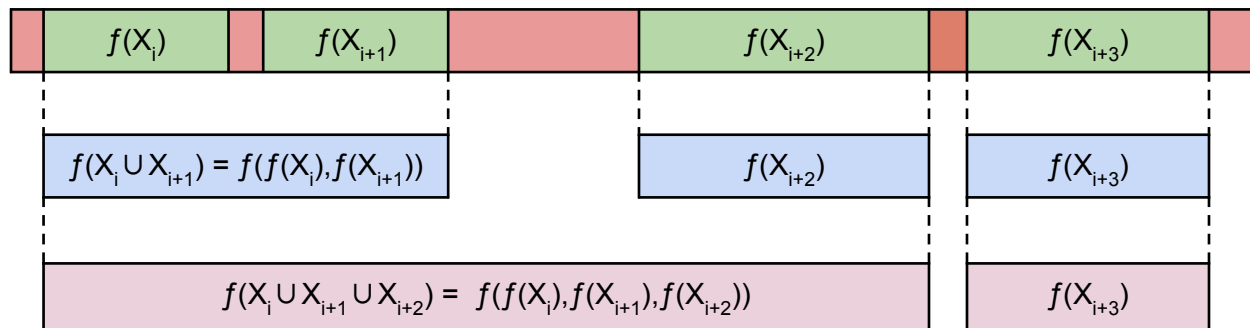
KS-Statistic

**Standard Deviation\***

Rate\*

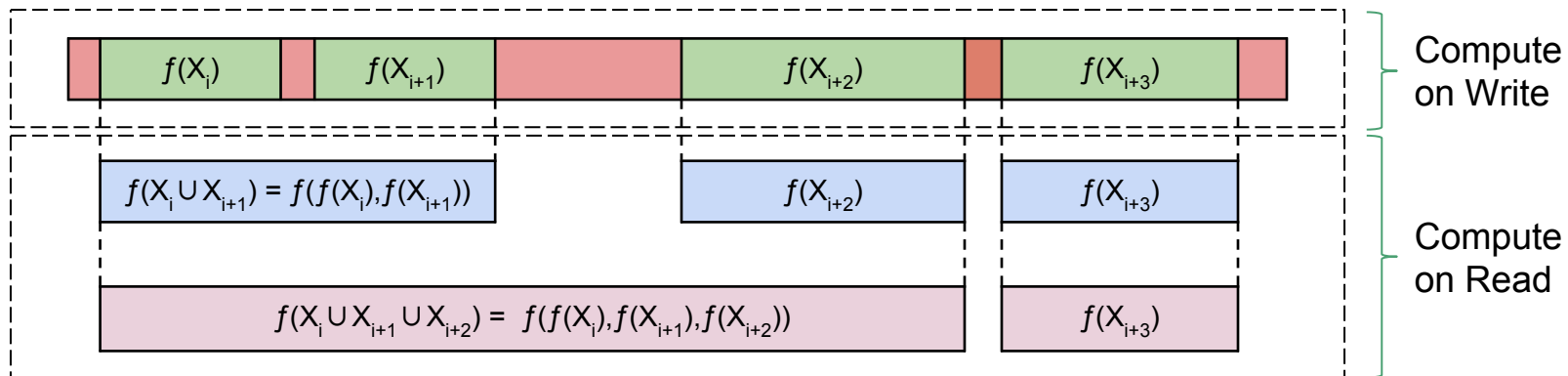
**C<sub>p</sub> C<sub>pk</sub> C<sub>pm</sub> C<sub>pmk</sub>**

# Associative Aggregate 2



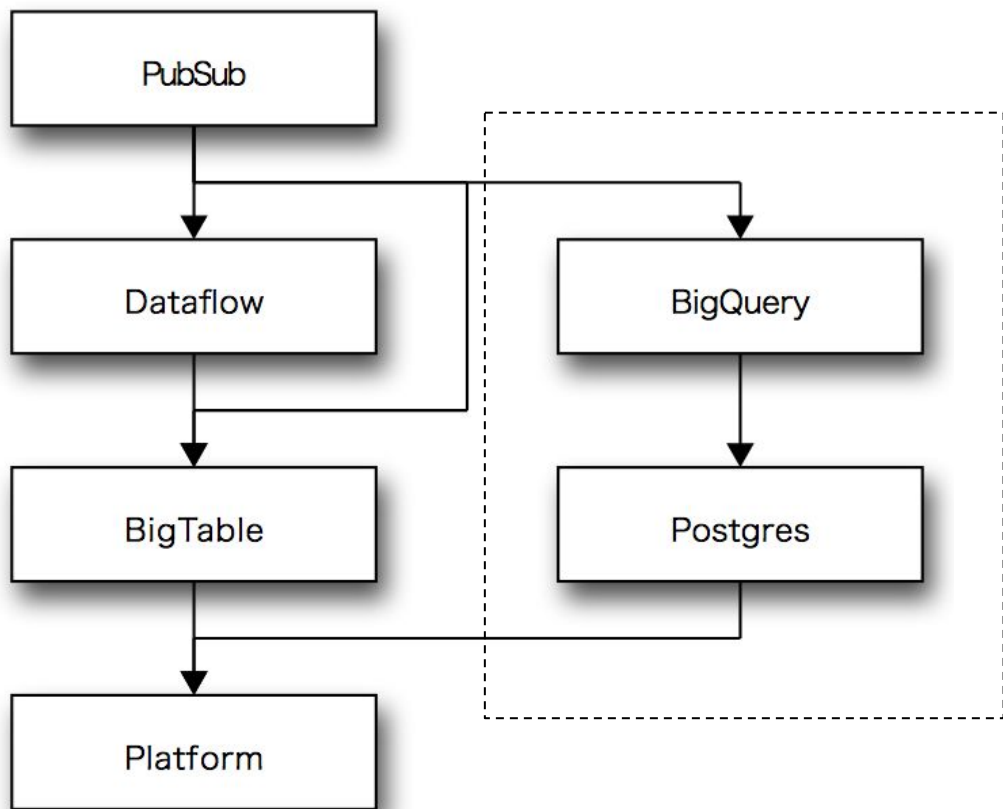


# Associative Aggregate 3



# Write And Transform (Revisit)

- Every k minutes visit the last k minutes of “changes”
- Compute necessary associative aggregates and cache these in Postgres



# Spreadsheet View (revisited)

Explore

Search

Run

Tue Jan 16th - Tue Feb 13th

All week • 12am - 12am

Hide Filters

Product

All Products

State

Annotations

Lines

Search

Product	Line	Annotations	States	From	To	Duration	1-machine-speed (average)	1-total-batch-part-counter-low-acc (deltasum)	
	Demo Factory	None	Insert Broken Uptime Downtime	Fri Jan 12th 11:44pm	Tue Jan 16th 3:06am	3d 3h	64.845 ⬆ 125 ± 3	159,779	
	Demo Factory	None	Uptime Downtime	Tue Jan 30th 10:19am	Still active	13d 13h	84.215 ⬆ 130 ± 3	1,005,754	
	Demo Factory	None	Uptime Downtime Setup/Changeover	Mon Jan 29th 12:59am	Tue Jan 30th 10:19am	33h 19m	62.959 ⬆ 130 ± 3	81,001	
	Demo Factory	None	Uptime Downtime Setup/Changeover Punch Pin	Thu Jan 18th 9:53pm	Mon Jan 22nd 11:07am	3d 13h	39.237 ⬆ 130 ± 3	122,604	
	Demo Factory	None	Setup/Changeover Uptime Downtime No Tubs Available	Mon Jan 22nd 11:07am	Wed Jan 24th 3:35am	40h 28m	118.844 ⬆ 120 ± 3	156,948	
	Demo Factory	None	Setup/Changeover Uptime	Tue Jan 16th 12:27pm	Thu Jan 18th 11:42pm	2d 11h	118.144 ⬆ 110 ± 3	247,145	

# Queries

→ “Which days did I produce the most product in January?”

```
SELECT SUM(rate_produced)
FROM metrics
JOIN days
```

→ “Which products do I produce at the highest quality in terms of being in specification?”

...

Naively From a Traditional  
Time Series Database

$O(k \times \log(t1 - t0))$

With Precomputed Interval  
Associative Aggregates

$O(\log(k \times (t1 - t0)))$

# How to be “Smart” in Manufacturing

---

# Machine Learning

## Formal Definition

"A computer program is said to learn from experience  $E$  with respect to some class of tasks  $T$  and performance measure  $P$ , if its performance at tasks in  $T$ , as measured by  $P$ , improves with experience  $E$ ." - Tom Mitchell

## Informal Definition

"A function with behavior that adapts over time."

# THE DATA SCIENCE HIERARCHY OF NEEDS

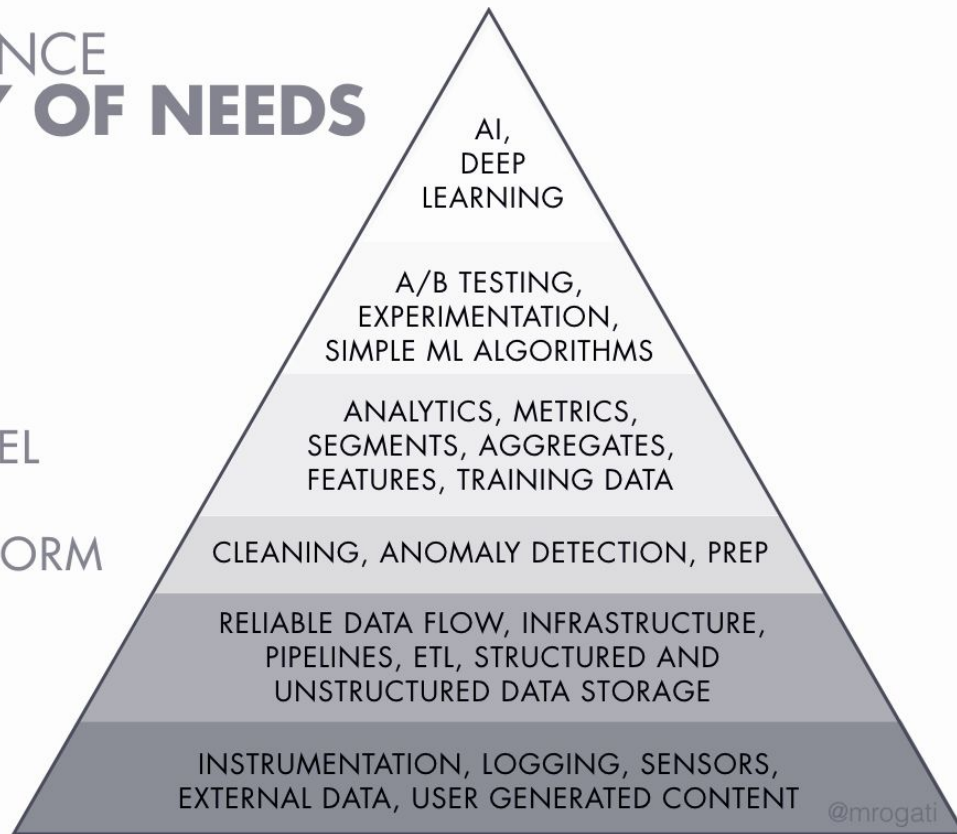
LEARN/OPTIMIZE

AGGREGATE/LABEL

EXPLORE/TRANSFORM

MOVE/STORE

COLLECT



Monica Rogati

<https://hackernoon.com/the-ai-hierarchy-of-needs-18f111fcc007>

Where in a  
factory do we  
benefit from  
learning?



# Probably Should Not Learn

Metric

Interval

Associative Aggregate

# Could Benefit From Learning

Non-Associative Aggregate

Configuration

Attention Gating

# Probably Should Not Learn

Metric

Interval

Associative Aggregate

# Could Benefit From Learning

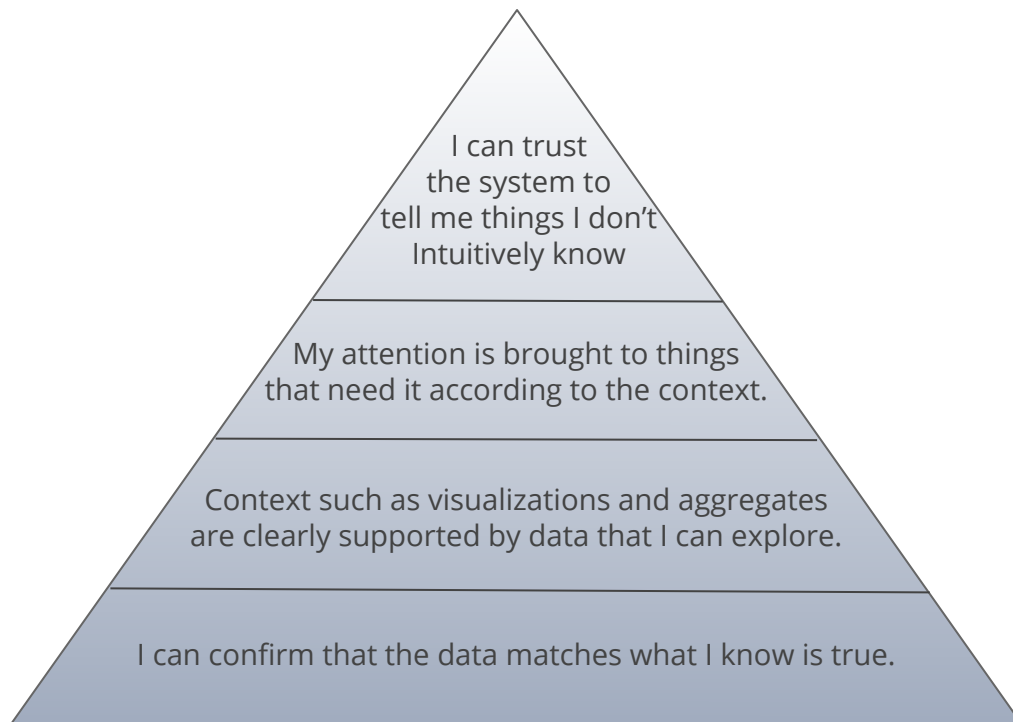
Non-Associative Aggregate

Configuration

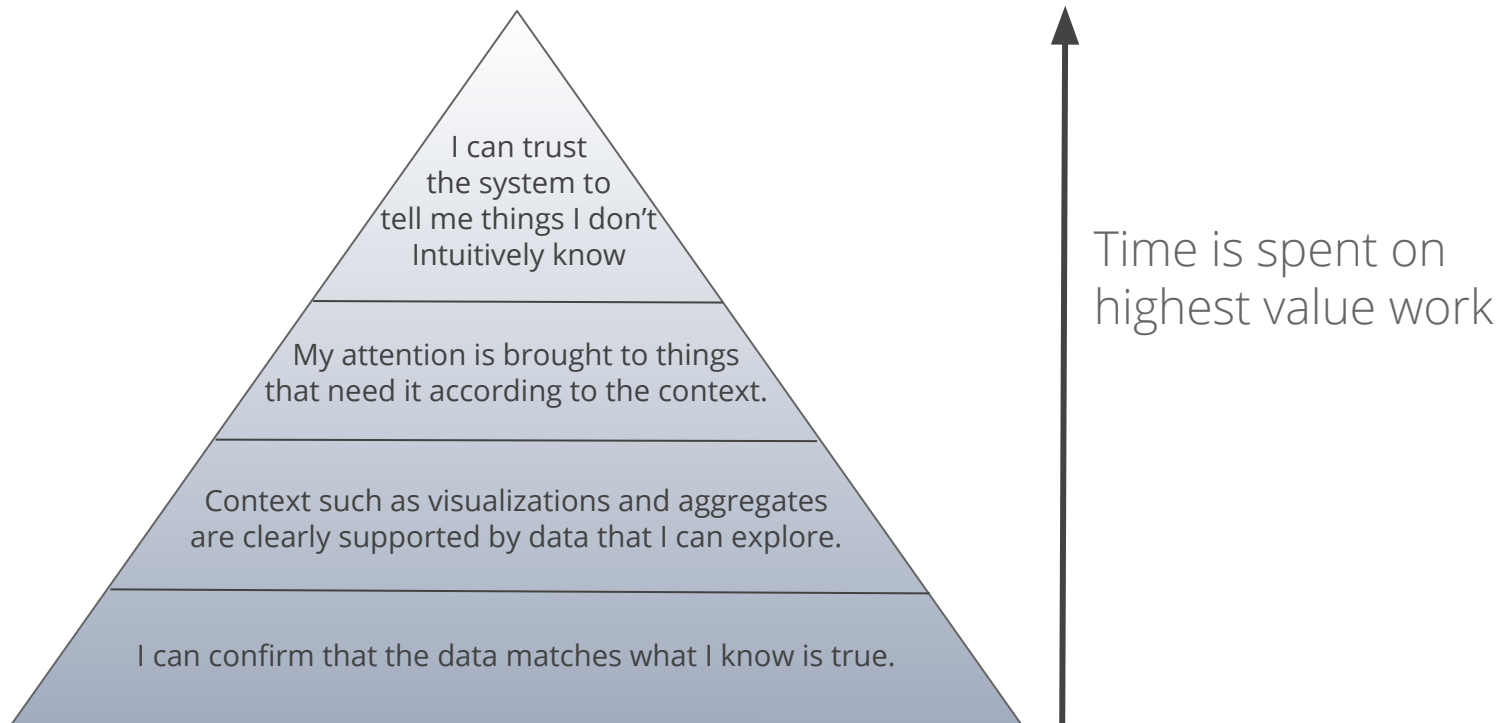
Attention Gating

*How should I, as a worker, most  
optimally spend my time today?*

# The Manufacturing Analytics Hierarchy of Trust



# The Manufacturing Analytics Hierarchy of Trust



Devon Peticolas  
devon@oden.io  
@dproi