

# Flow-based AI Methods

## for Hoist Brake Health Monitoring

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# Background



**KONECRANES®**

# Brake Monitoring

AS IT IS TODAY

## Features

- Continuous remote condition monitoring of electromagnetic disc brakes
- Estimates friction material wear by measuring brake opening current
- Collects brake fault information

## Benefits

- Reduces risk of load drop
- Helps to avoid unnecessary inspections
- Aids maintenance planning



# Enriching Digital Twin Data

FOR DEEPER UNDERSTANDING OF BRAKE SYSTEM HEALTH

Digital Twin  
of Ilmatar



Understandable data for *operators, service personnel and crane owners*

- Proactive crane services
- Less maintenance breaks



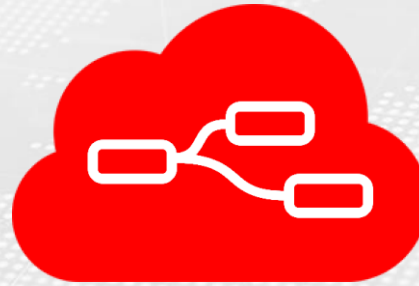
Ilmatar

TRUCONNECT® Remote Monitoring



Ilmatar

Brake Monitoring Unit (BMU)

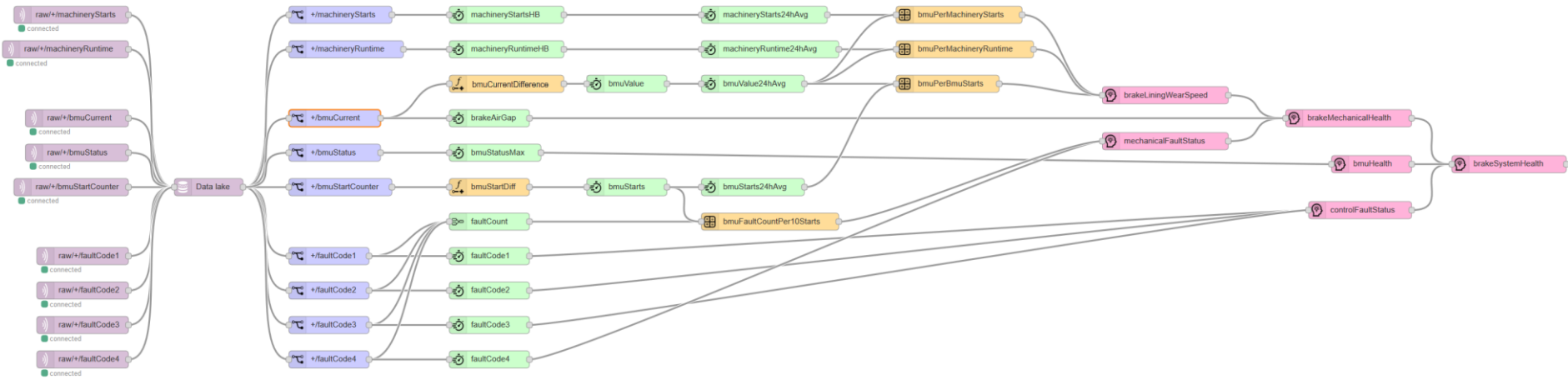


**REGATTA<sup>®</sup>** Flow

# Technical Solution



# Brake Monitoring Flow



Data  
ingestion

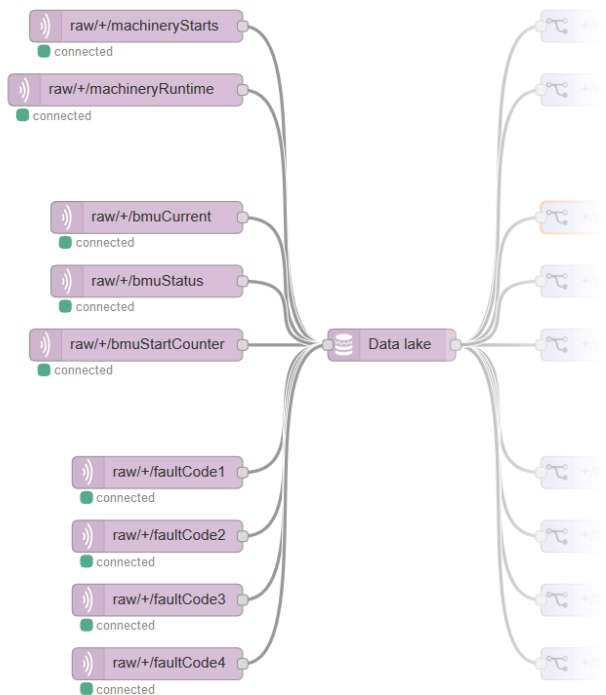
Data  
selection

Signal processing

Fuzzy inference (AI)



# Data Ingestion

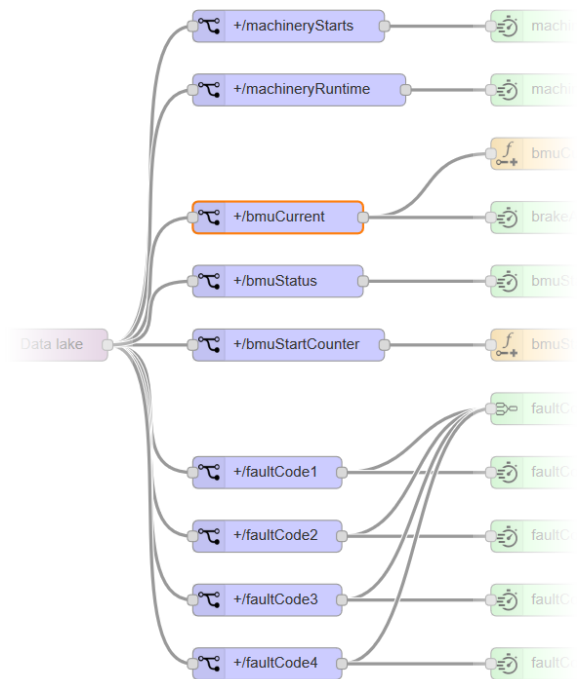


- **Flow nodes subscribe** to MQTT broker data channels
  - **Topic structure:**  
*< source / signal >*
  - **Payload:**  
*< timestamp, value >*
- Data is stored in an **time-series data lake**
- Data lake supports **direct SQL queries** for data analytics



# Data Selection

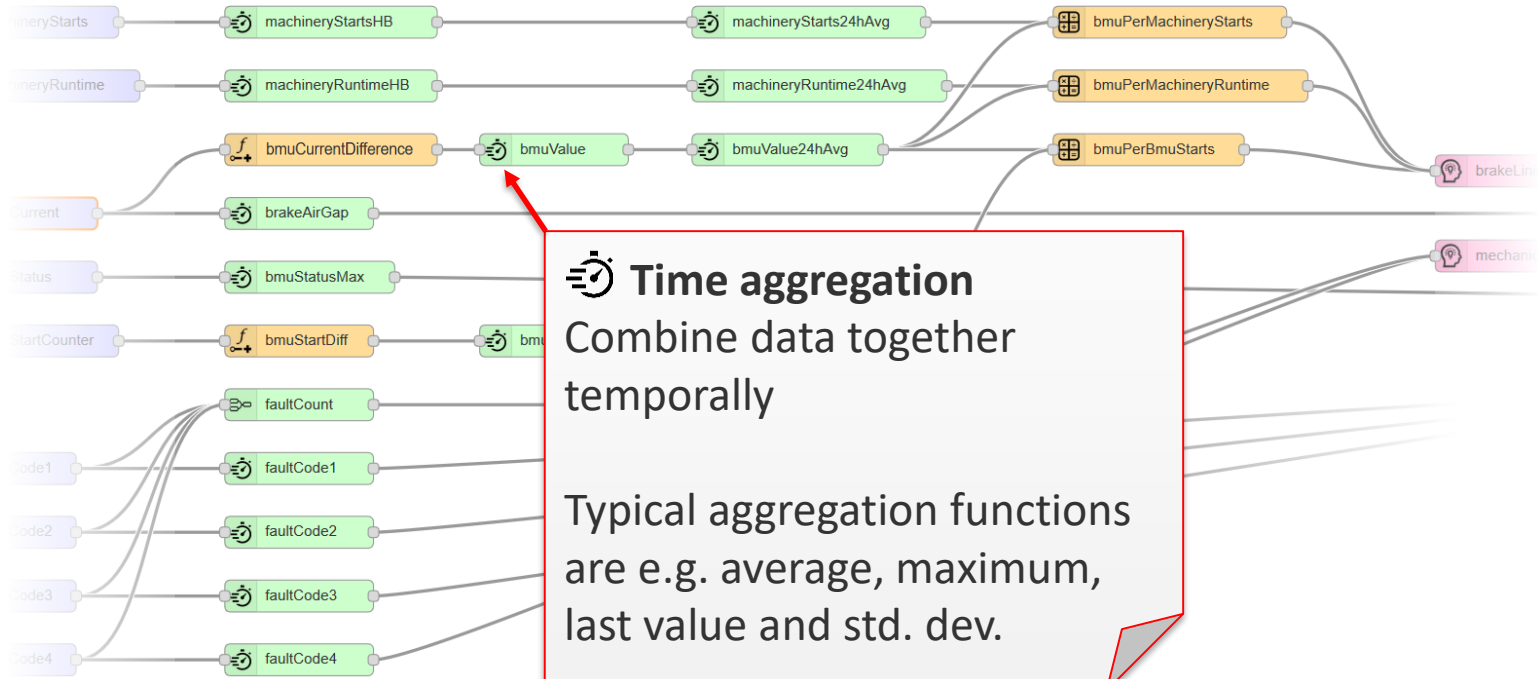
- **Selection nodes subscribe** to data lake updates
- **MQTT topic** is used for selecting data
- **Notifications of new data** are propagated to attached nodes





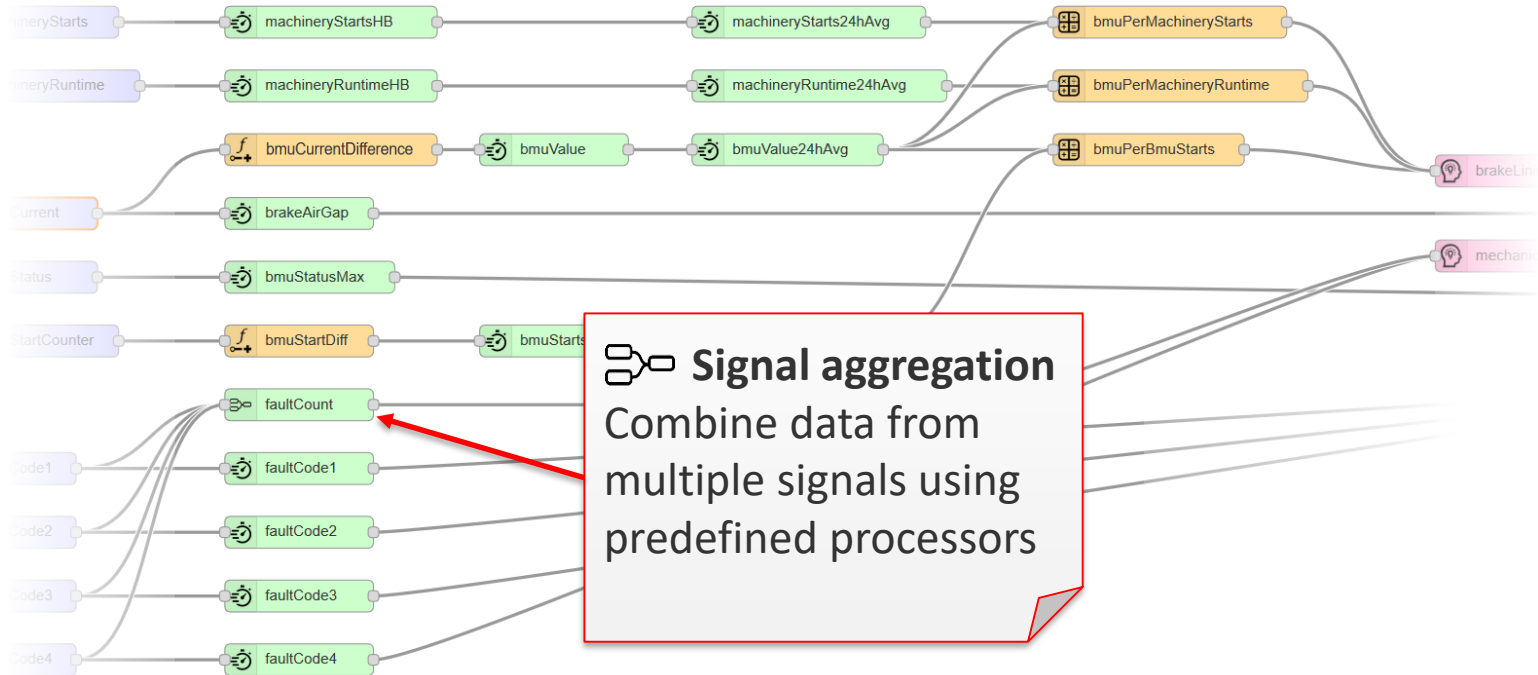


# Signal Processing



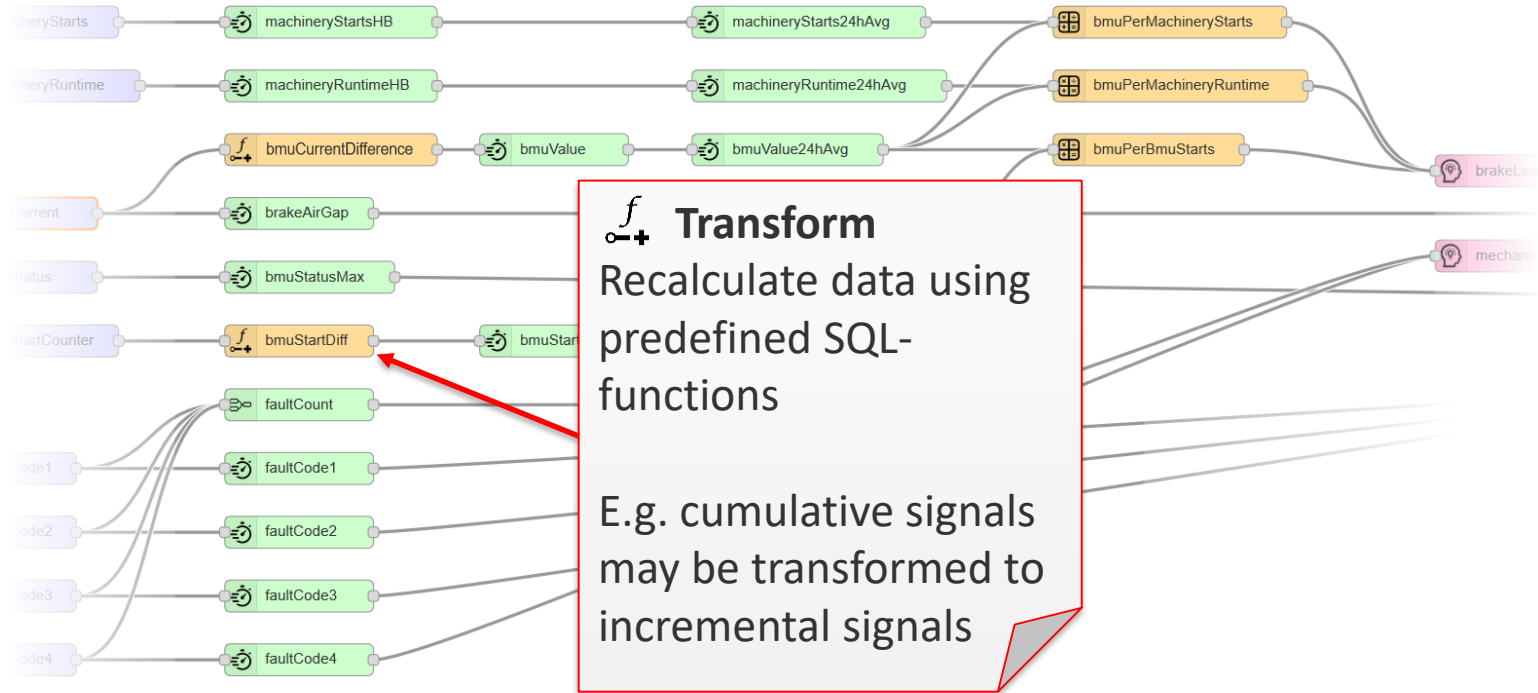


# Signal Processing



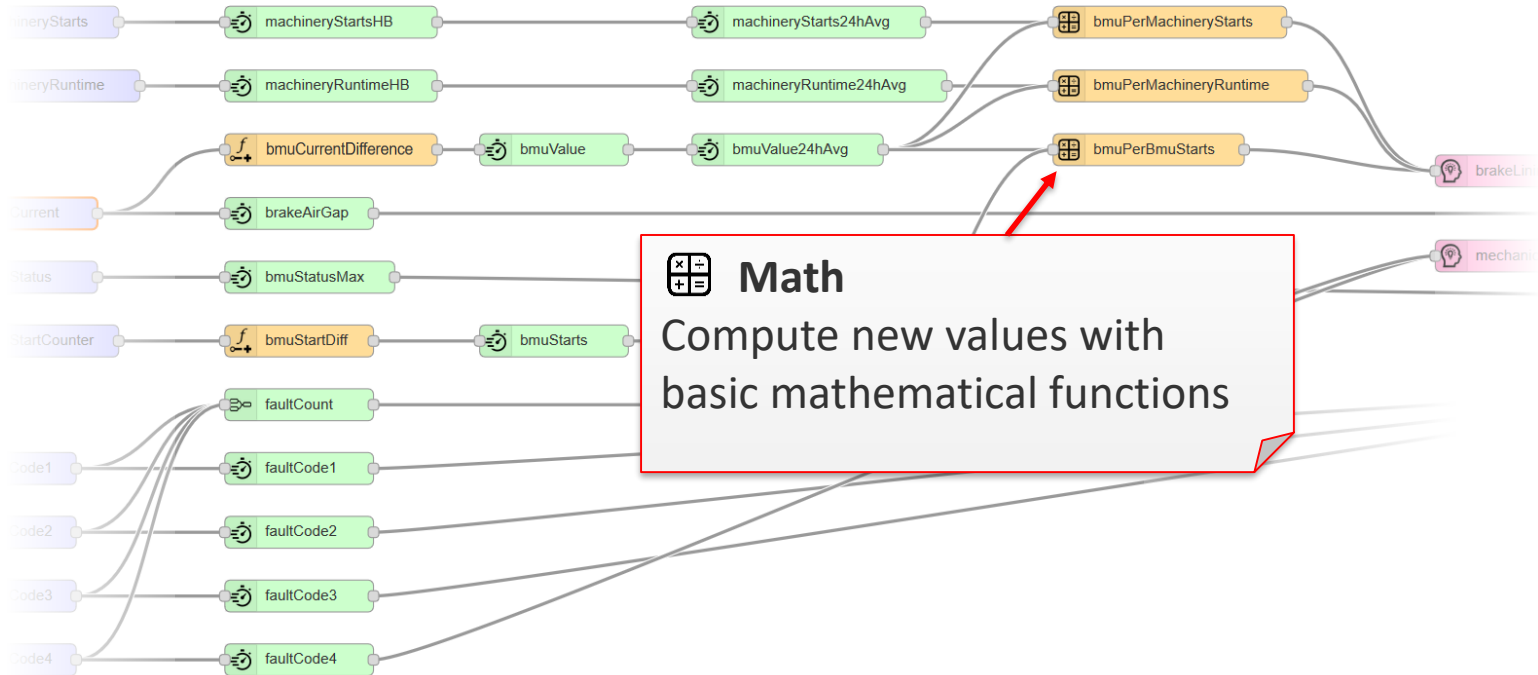


# Signal Processing



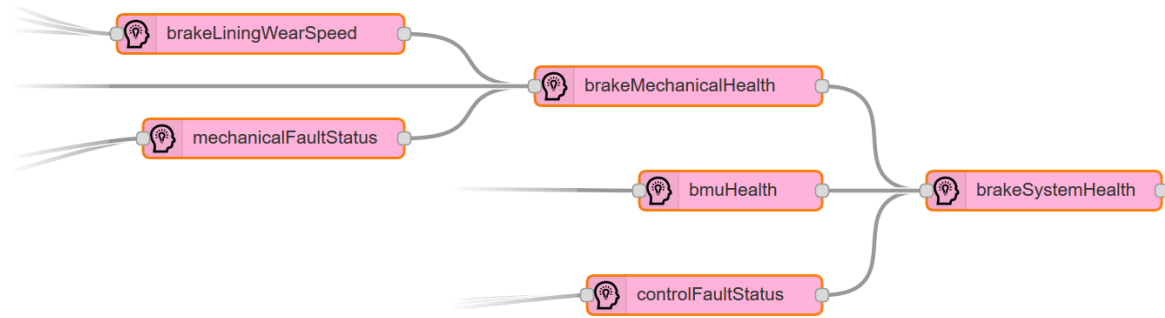


# Signal Processing



## Math

Compute new values with basic mathematical functions

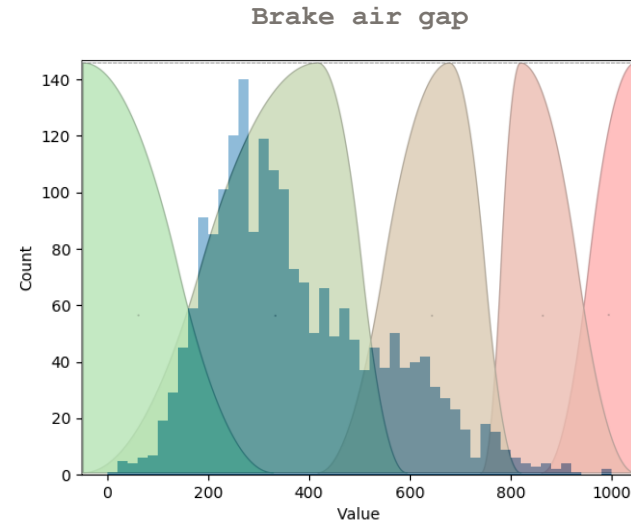


# Fuzzy Inference



# Linguistic Terms

- Data values are given **meaningful linguistic terms**
- **Historical data distributions** may be used for automatic creation of terms
- Linguistic terms enable **easy interpretation of reasoning outputs**

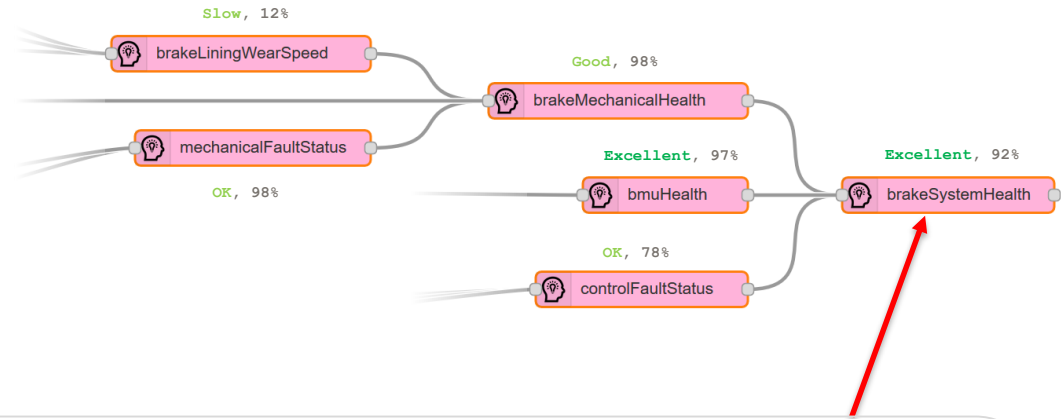


*excellent, good, degrading, worn, critical*



# Causal Reasoning

- Brake system health is described with **several indices (0-100%)** and associated **linguistic terms**
- Each fuzzy inference node calculates its output based on *if—then* rules



```
if brakeMechanicalHealth is nonFunctional then brakeSystemHealth is nonFunctional with 5
if brakeMechanicalHealth is critical then brakeSystemHealth is critical with 5
if brakeMechanicalHealth is warning then brakeSystemHealth is warning with 5
if brakeMechanicalHealth is good then brakeSystemHealth is good with 5
if brakeMechanicalHealth is excellent then brakeSystemHealth is excellent with 5
if bmuHealth is bad then brakeSystemHealth is nonFunctional
if bmuHealth is poor then brakeSystemHealth is critical
if bmuHealth is fair then brakeSystemHealth is warning
if bmuHealth is good then brakeSystemHealth is good
if bmuHealth is excellent then brakeSystemHealth is excellent
if controlFaultStatus is problematic then brakeSystemHealth is critical with 2
if controlFaultStatus is ok then brakeSystemHealth is good with 2
```



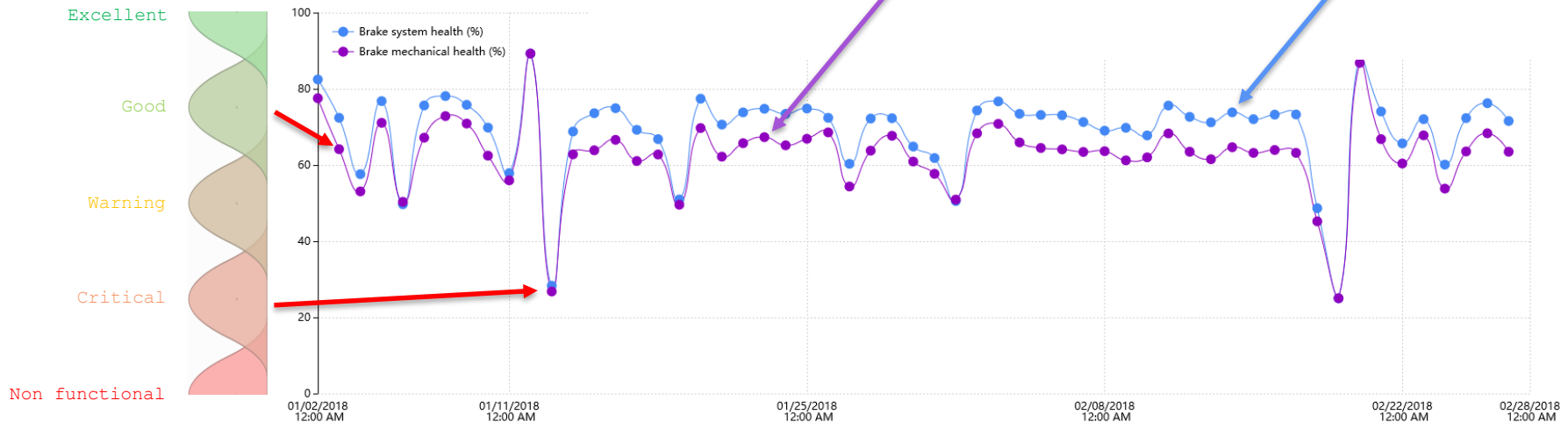
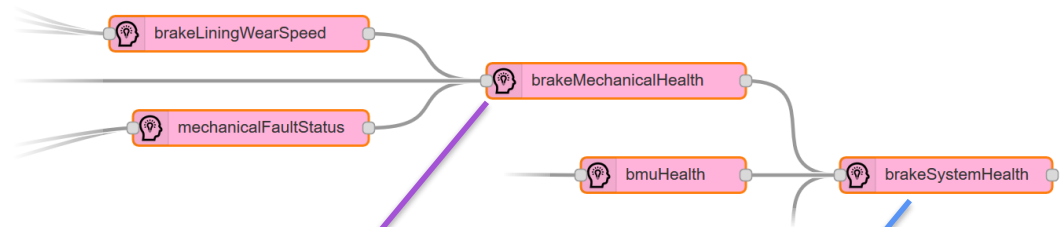
# Benefits





# Data Interpretation

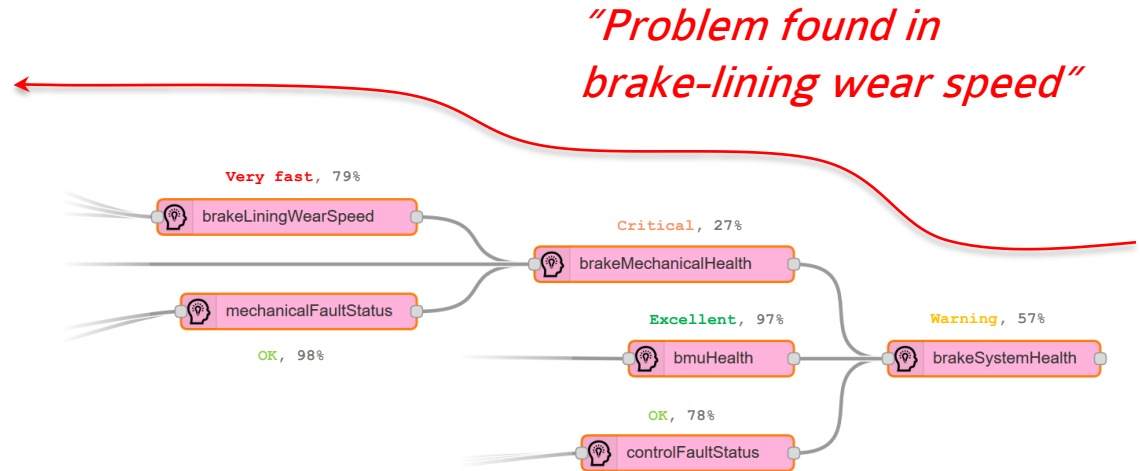
- A test crane was used to supply 2 months of data
- Linguistic terms are used to interpret data meaning





# Root-Cause Identification

- Higher-level nodes may show **health degradations**
- **Root-causes** may be detected from the flow tree



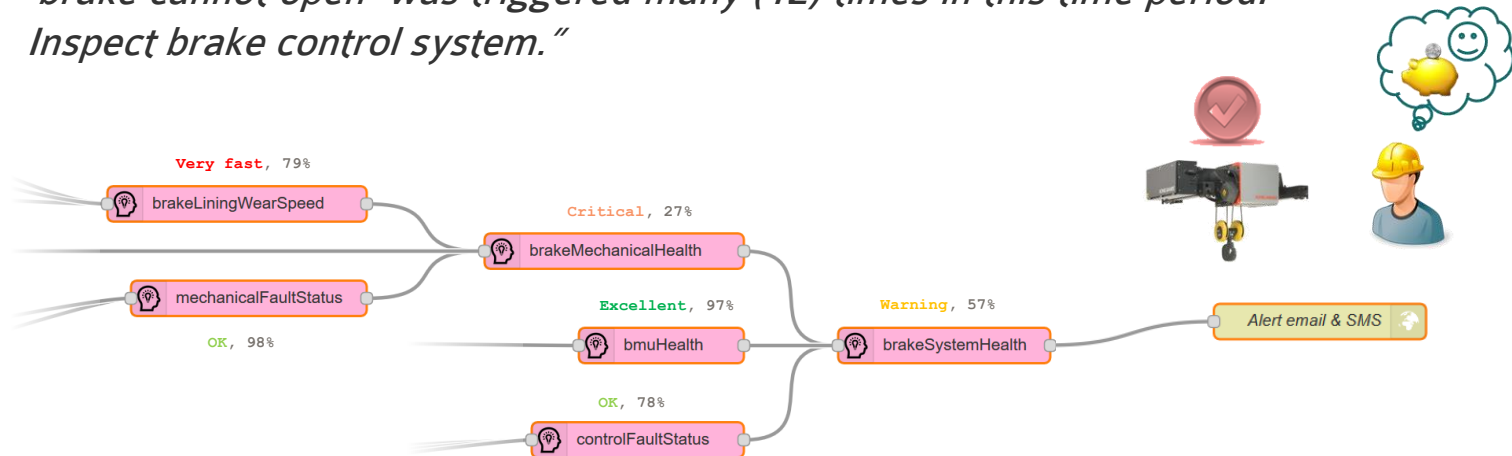


# Predictive Maintenance

- Easily interpretable notices, warnings and alerts may be automatically sent to operators, service personnel and crane owners

*"Brake system health in Ilmatar has degraded to warning level (57%). Root-cause of the problem is in very fast brake-lining wear speed. Service brake soon."*

*"Multiple faults have occurred over the last 24 hour period. Fault signal 'brake cannot open' was triggered many (12) times in this time period. Inspect brake control system."*



# REMION

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# KONECRANES<sup>®</sup>

**Lifting Businesses<sup>™</sup>**