A Thesaurus-guided Method for Smart Manufacturing Diagnostics

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Making AI Meaningful Again

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Landgrebe, J., & Smith, B. (2019). Making AI meaningful again. arXiv preprint arXiv:1901.02918.

#MakingAIMeaningfulAgain

General Limitations of Machine Learning

- Need for huge amount of data for training
- Need for stable environment
  - Unstable against variations in input
- Lack of transparency (blackbox operation mode)
- Output of all stochastic models is approximative

*"It is naïve to believe stochastic models **alone** can mimic human's decisions without benefiting form **prior knowledge**"*

"AI applications today can simulate only a small fragment of the semantics underlying human language use".

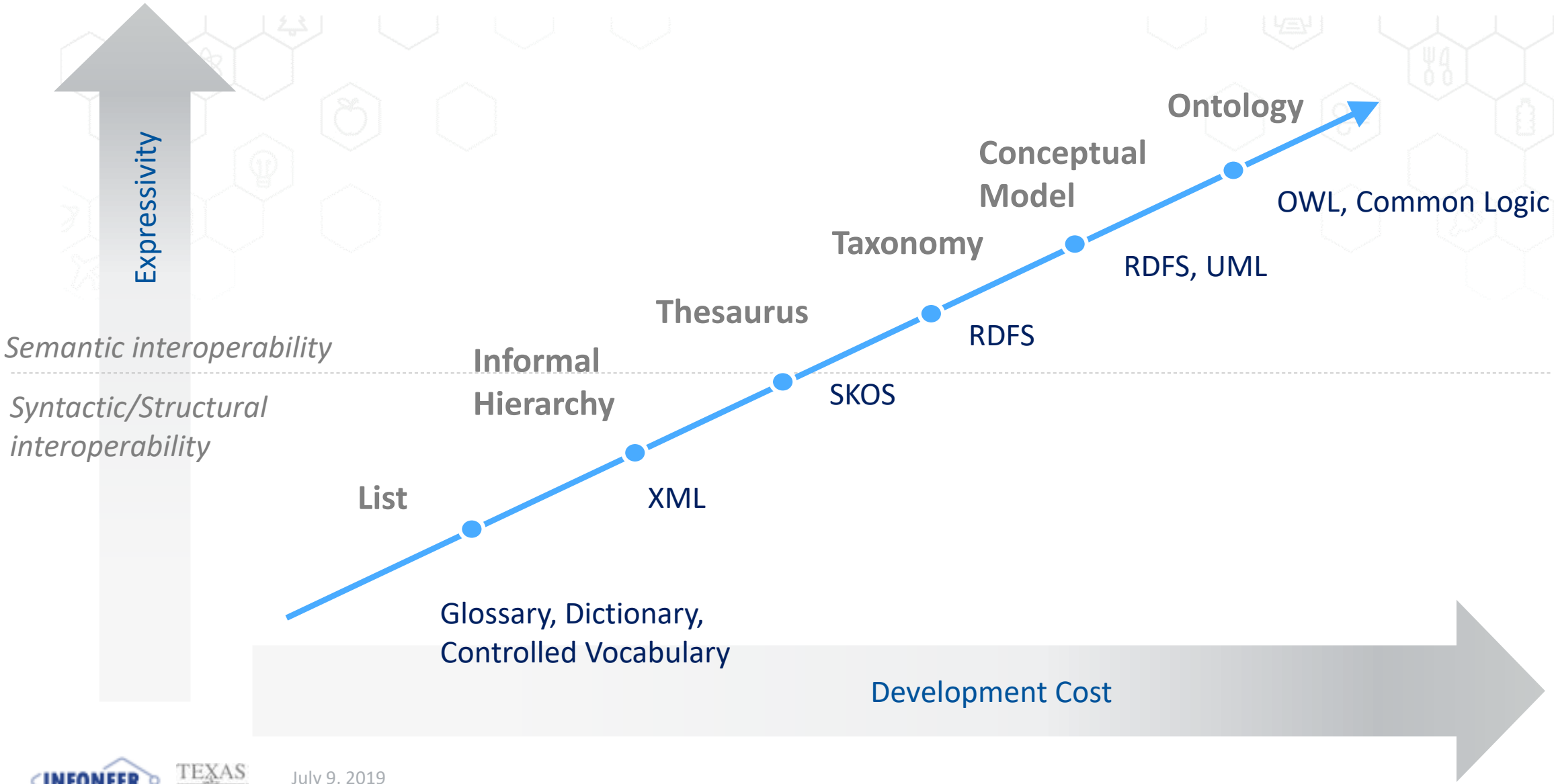
Proposed Solution

- Incorporating Prior Knowledge into AI Algorithms
- Combining formal logic (semantic representation) and stochastic models in AI applications.

Minimal Requirements for AI language processing systems

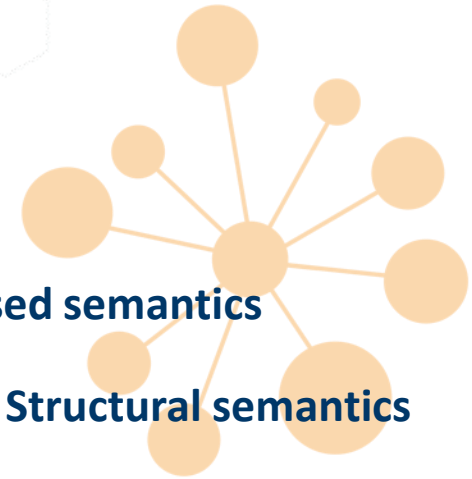
- Exactness
- Information security
- Robustness
- Data parsimony
- Semantic fidelity
- Inference
- Prior knowledge usage

Semantic Spectrum of Knowledge Organization Systems



Thesaurus vs. Ontology

Ontology

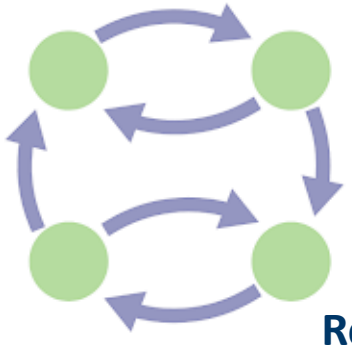


Logic-based semantics

Structural semantics

Text → Logic-based Formulae

Thesaurus



Relational semantics

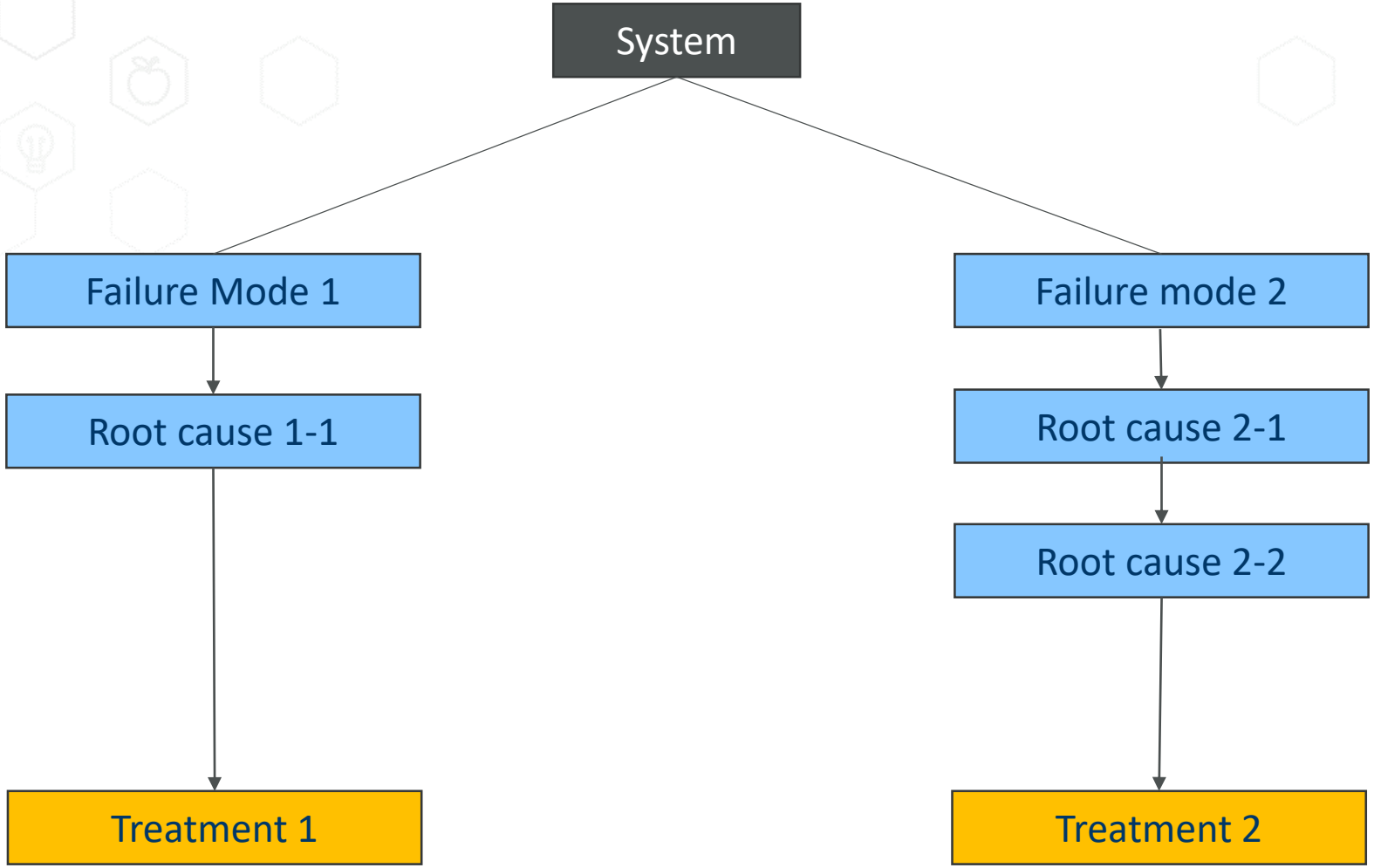
Lexical semantics

Text → Concept Vector

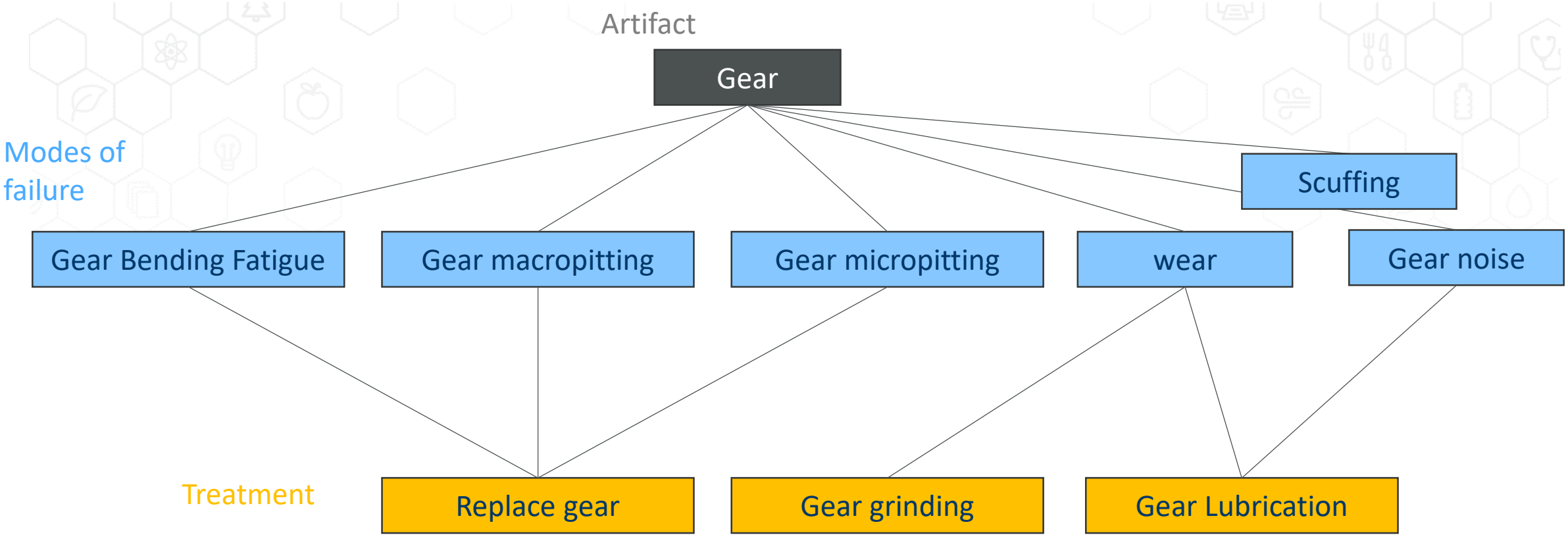
Research Objectives

- To develop a minimalistic knowledge graph (thesaurus) that can represent relational and lexical semantics in the domain of industrial maintenance.
- To develop models and tools for:
  - Text summarization and tagging
  - Maintenance diagnosis

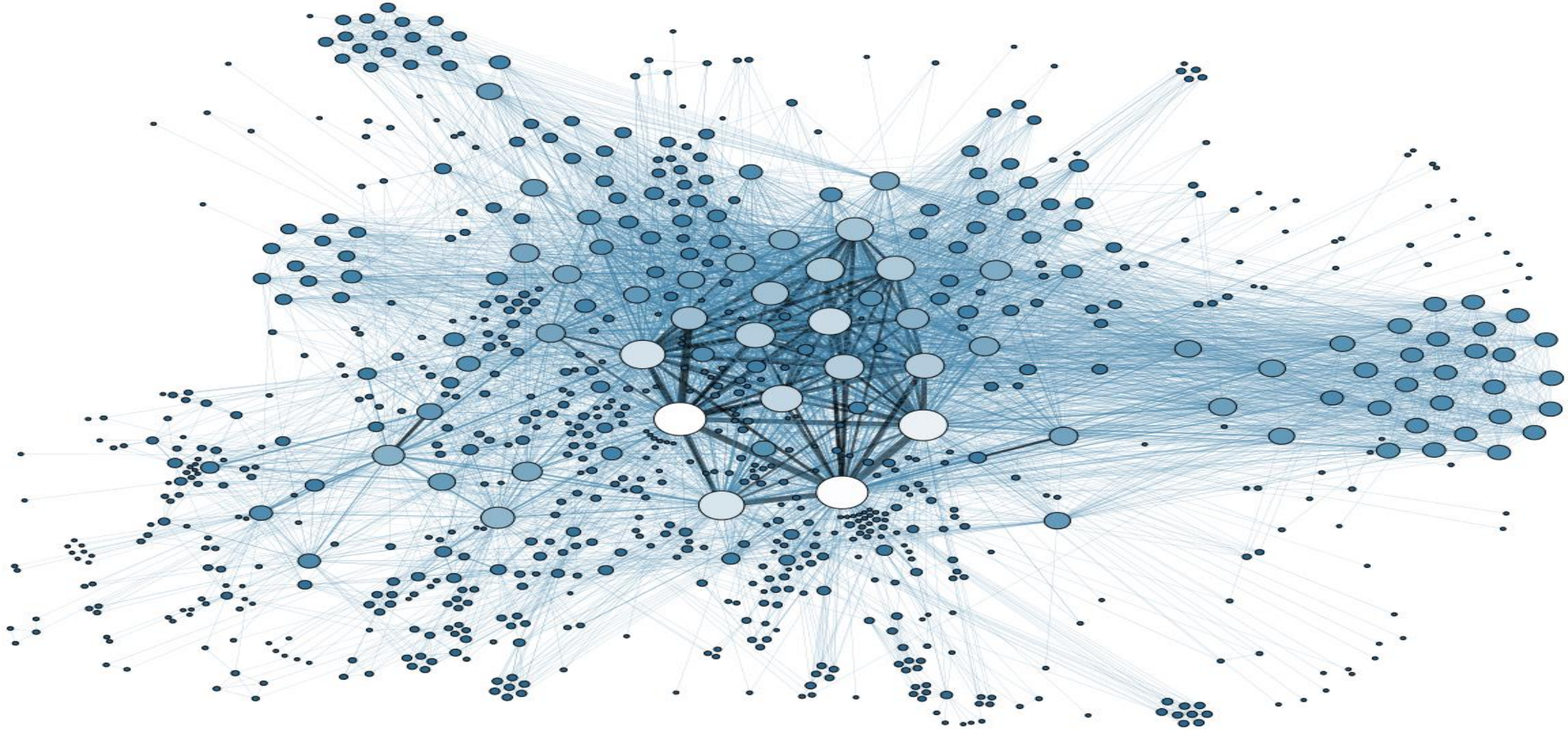
Prior Maintenance Knowledge (Relational Semantics)



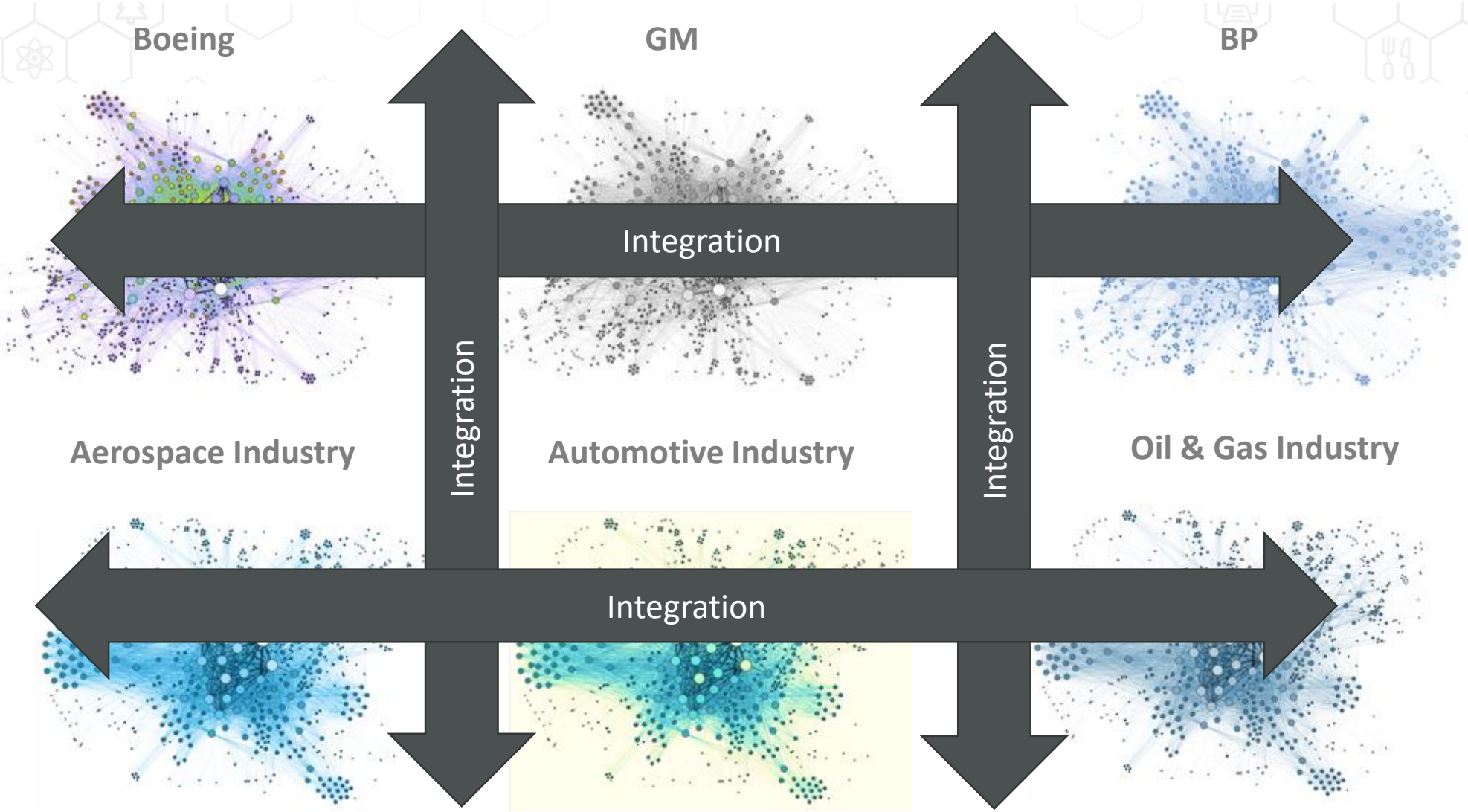
Gear Failure modes and Treatments



One knowledge graph for the entire maintenance domain



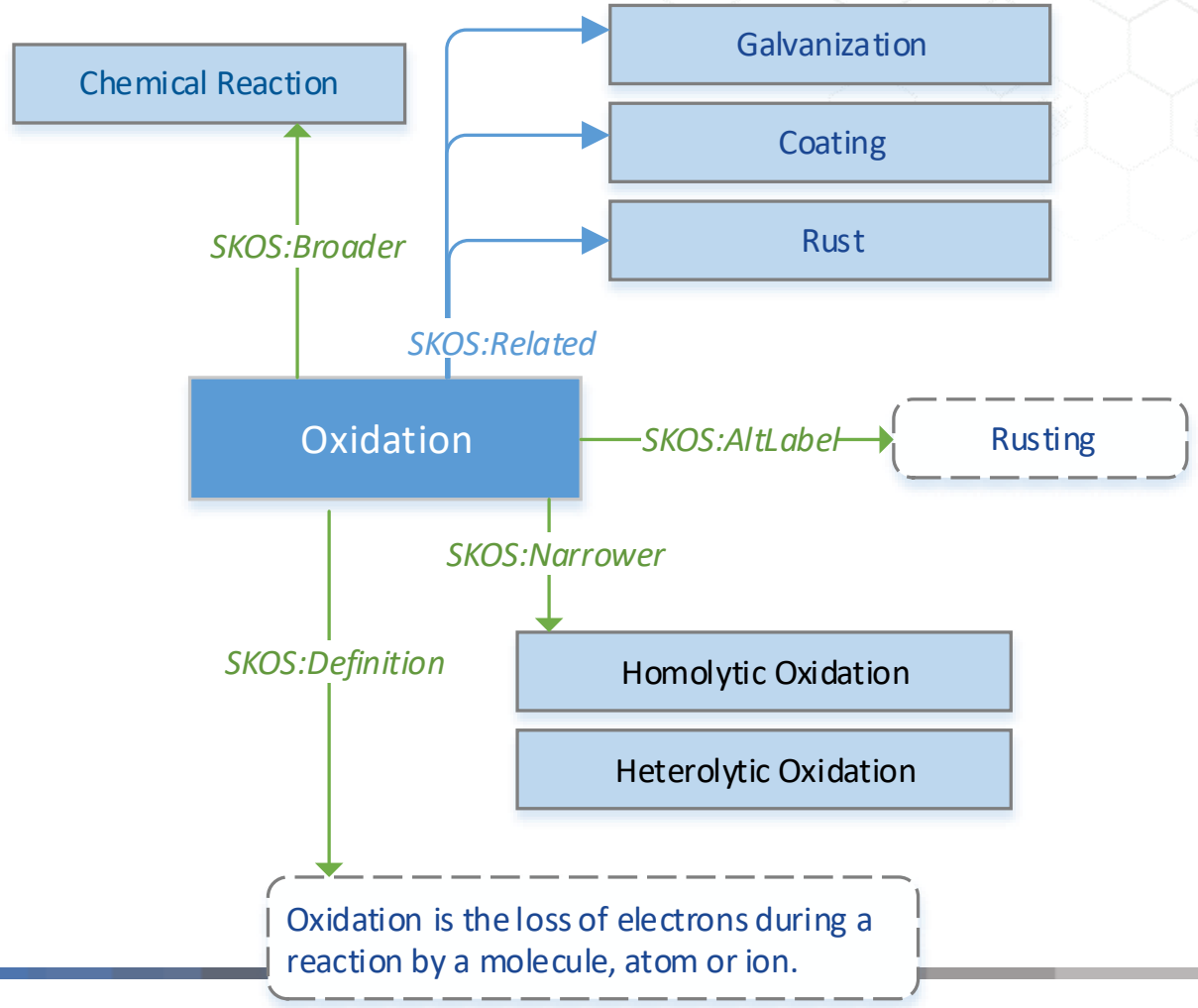
Company-specific or Industry-specific Knowledge Graphs



SKOS model (Simple Knowledge Organization System)

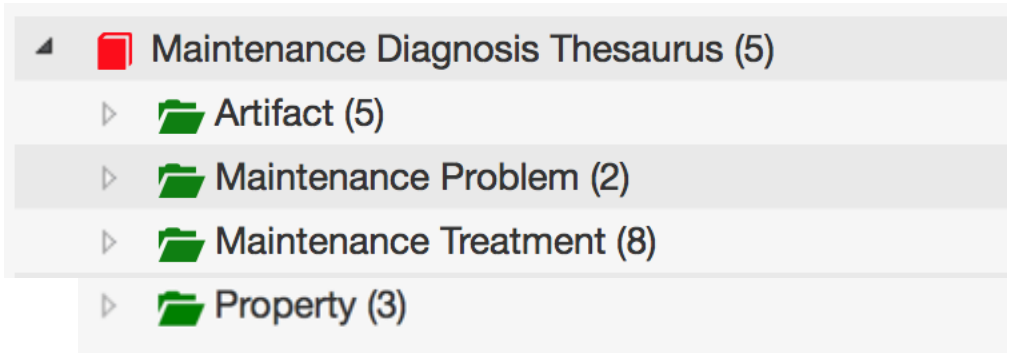
SKOS is a common data model for knowledge organization systems such as thesauri, classification schemes, subject heading systems, and taxonomies.

- W3C Standard
- Web-native syntax
- Machine-readable
- Simple semantics

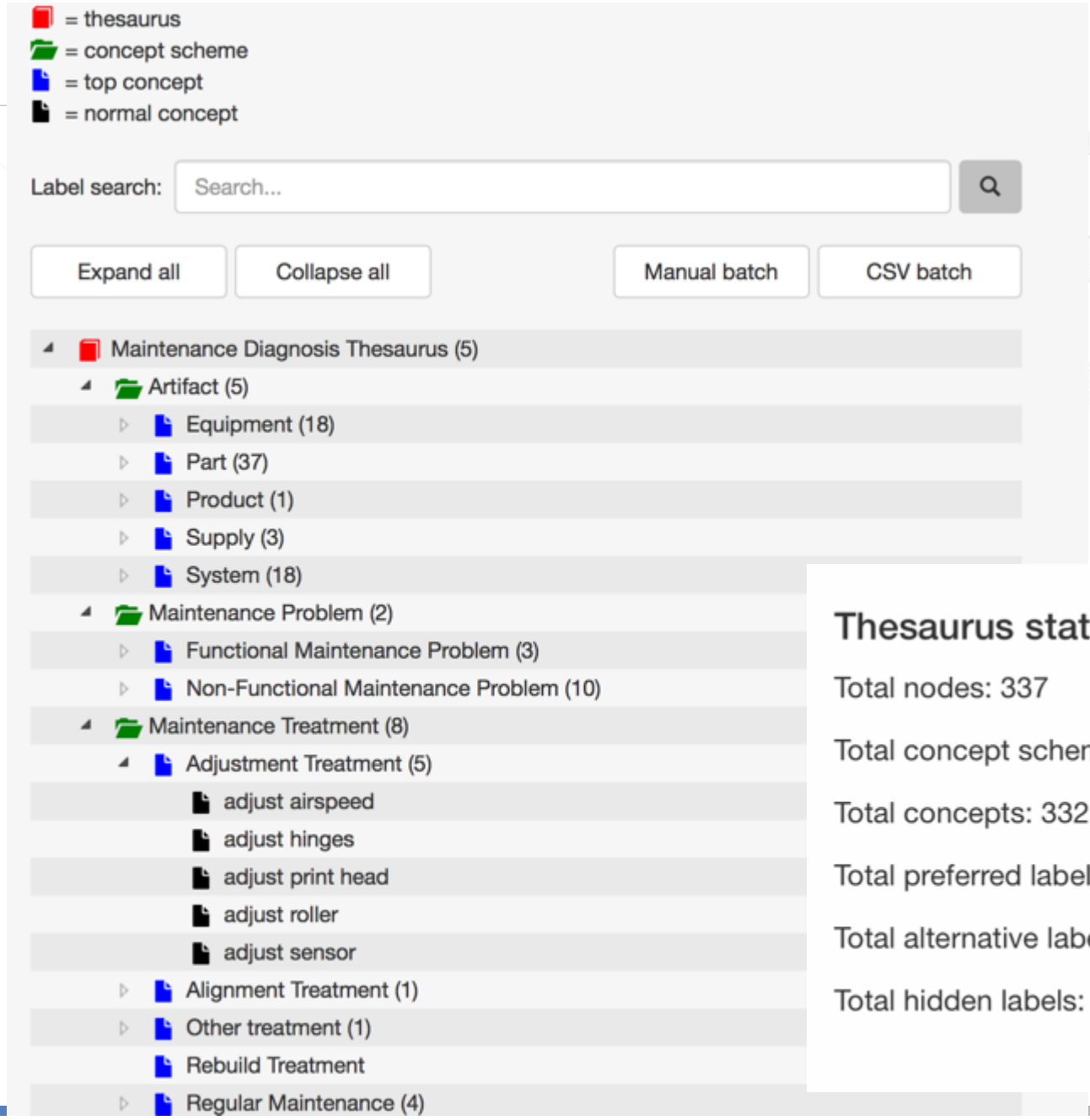



```
skos:semanticRelation
 |
 +— skos:related
 |
 +— skos:broaderTransitive
 |     |
 |     +— skos:broader
 |
 +— skos:narrowerTransitive
       |
       +— skos:narrower
```

Concept Schemes (types) in Maintenance Diagnosis Thesaurus



MD Thesaurus



Thesaurus statistics

Total nodes: 337

Total concept schemes: 5

Total concepts: 332

Total preferred labels: 332

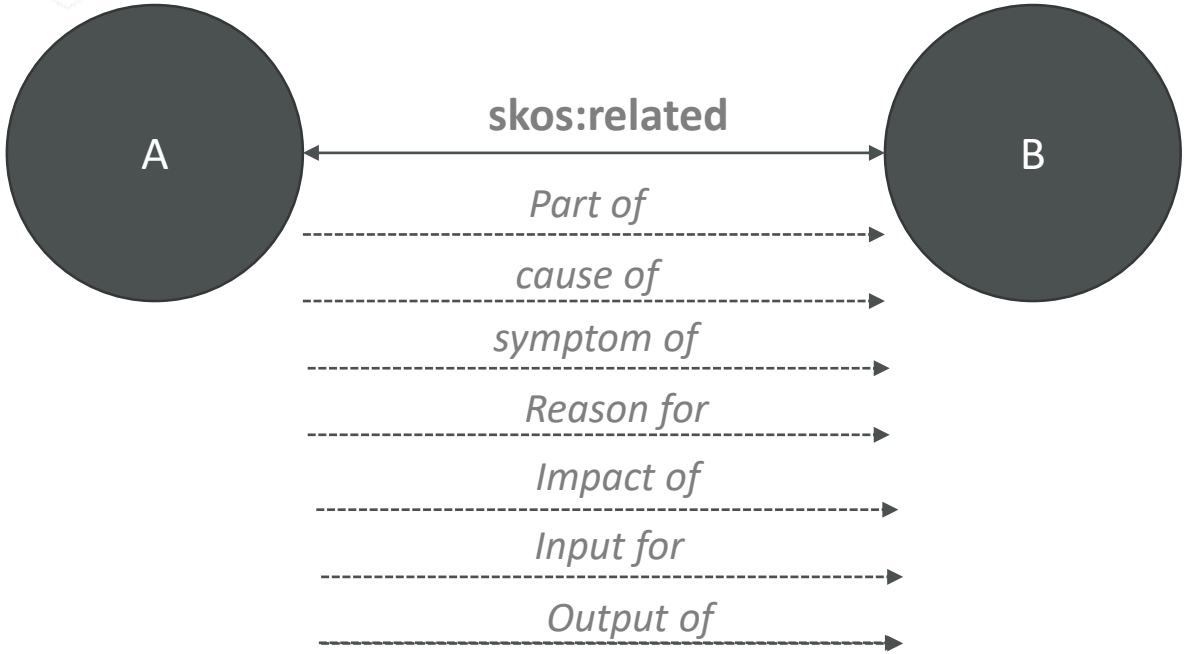
Total alternative labels: 99

Total hidden labels: 3

Alternative labels

concept	concept	concept	concept	altLabel@en
Functional Maintenance Problem				
	Incomplete Function			
		incomplete cleaning		
		incomplete pumping		pumping with low preasure
				Not pumping to desired level
				pumping with high preasure
	Undesirable Behavior			
		jamming		jammed
			conveyor jamming	conveyor jam
		erratic action		
		leaking oil		hyd leak
				hydraulic leak
		leaking water		water leak
		leaking air		air leak
		leaking coolant		coolant leak
	Missing Function			
		not stopping		will not stop
		not picking parts		Having problems picking up parts
		not indexing		will not index
		not openning		not open
				will not open
		not closing		

Relatedness



Relatedness

When an artifact is part of another artifact or share a common parent

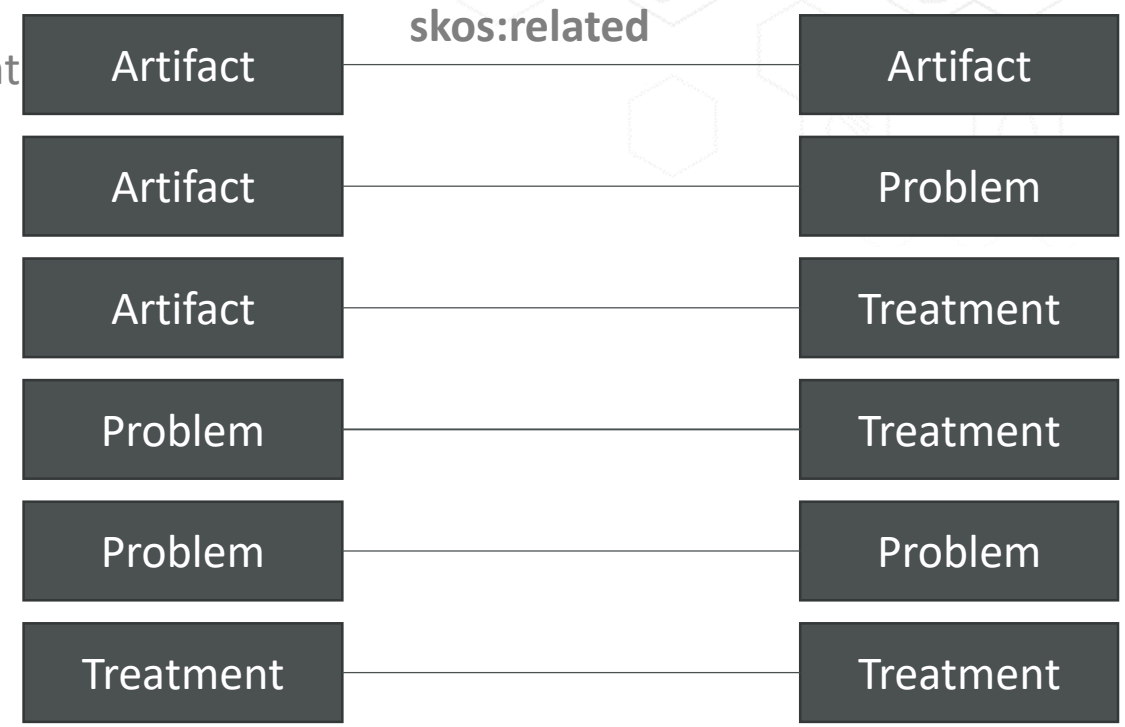
When certain artifacts are prone to certain problems (failures)

When certain treatments are effective for certain artifacts

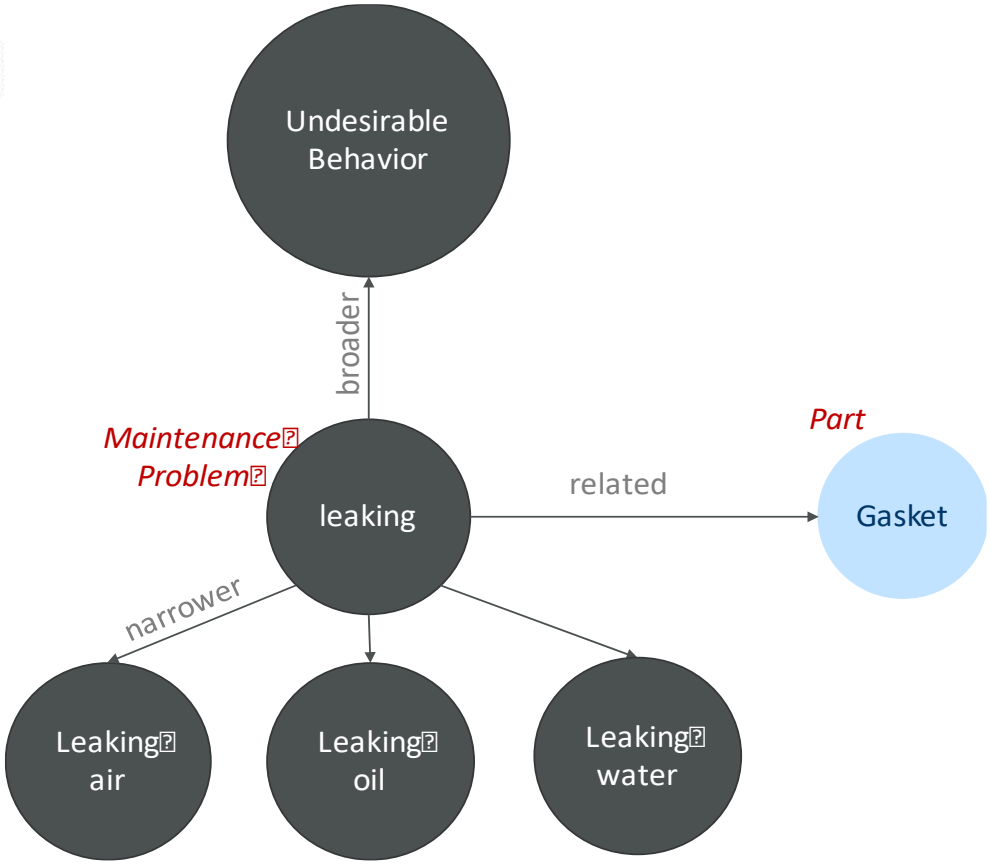
When problems have known treatments

When Certain problems are caused by other problems (causality)

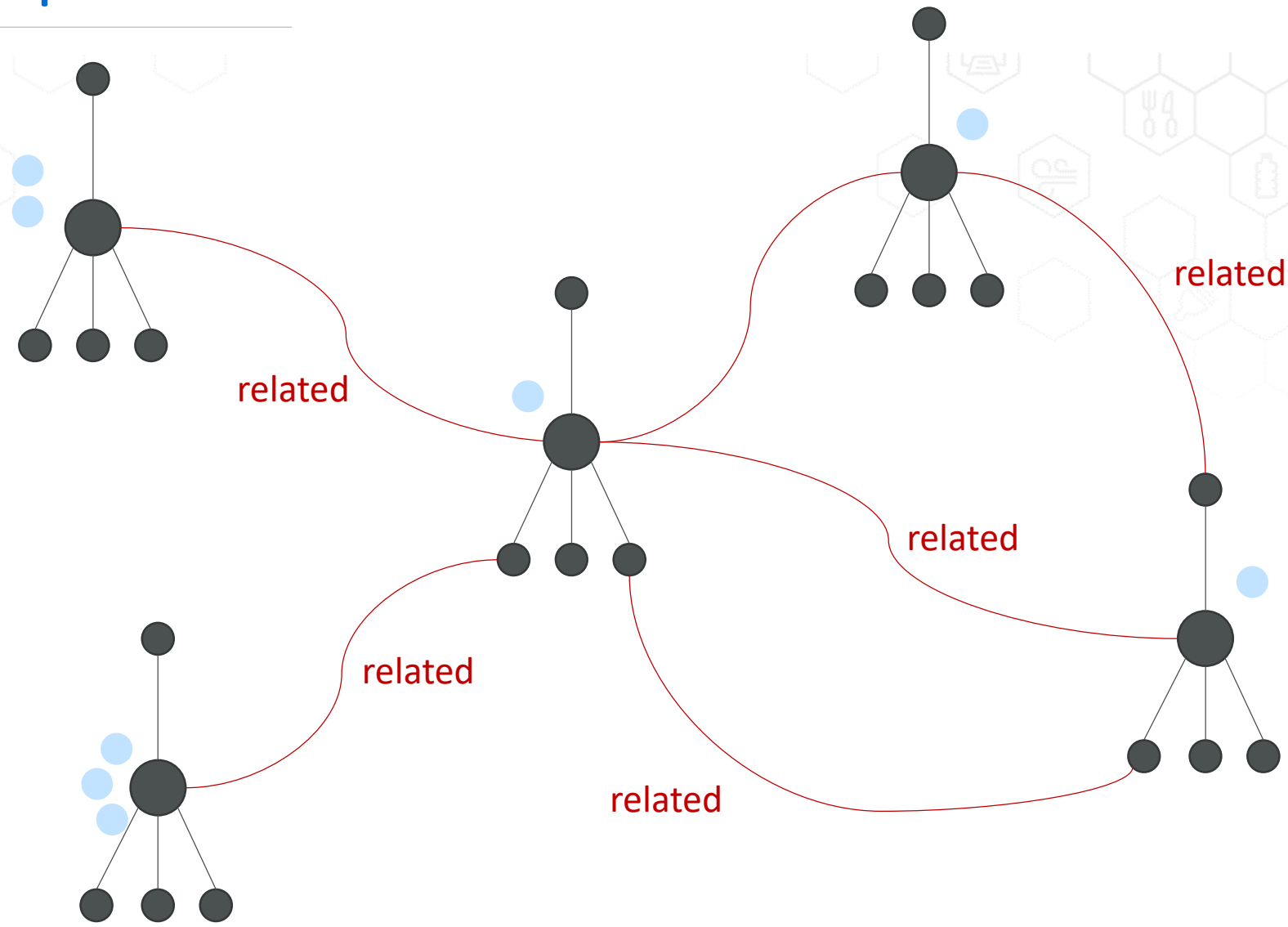
When certain treatments complement each other



Part-Problem subgraph

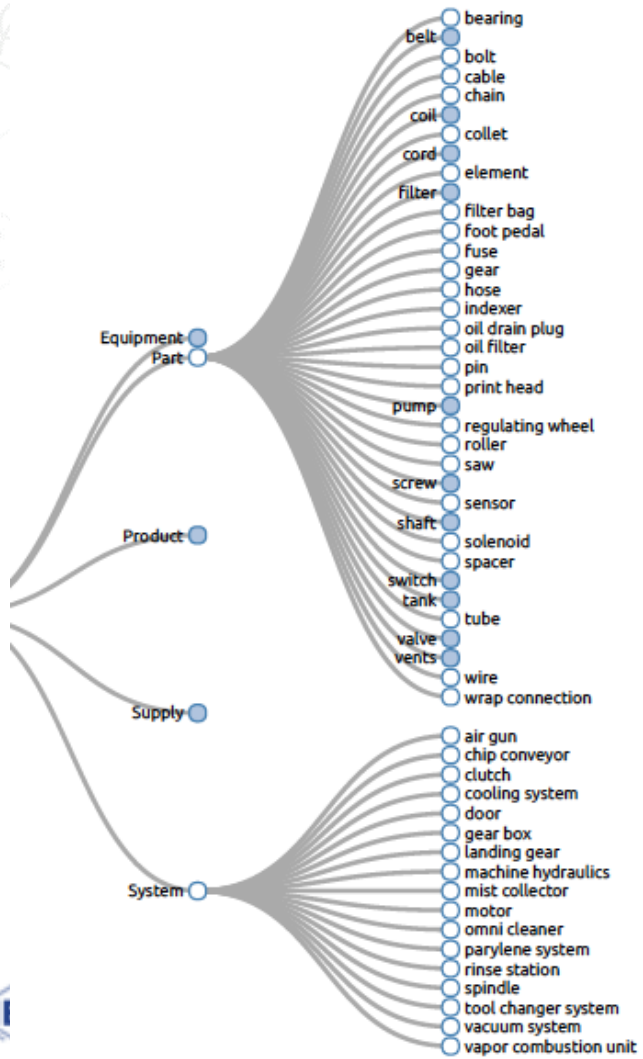


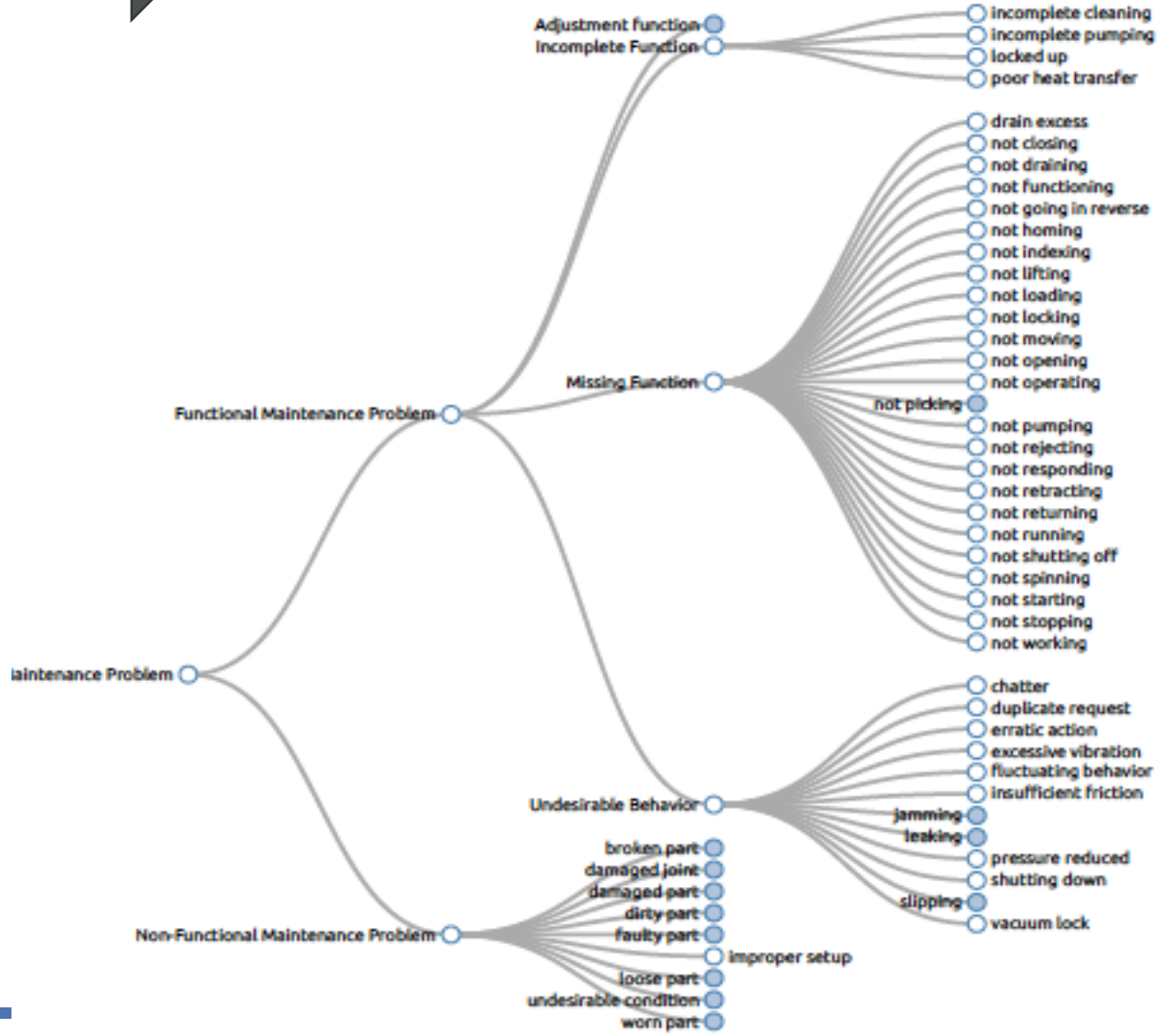
Graph of “related” problems



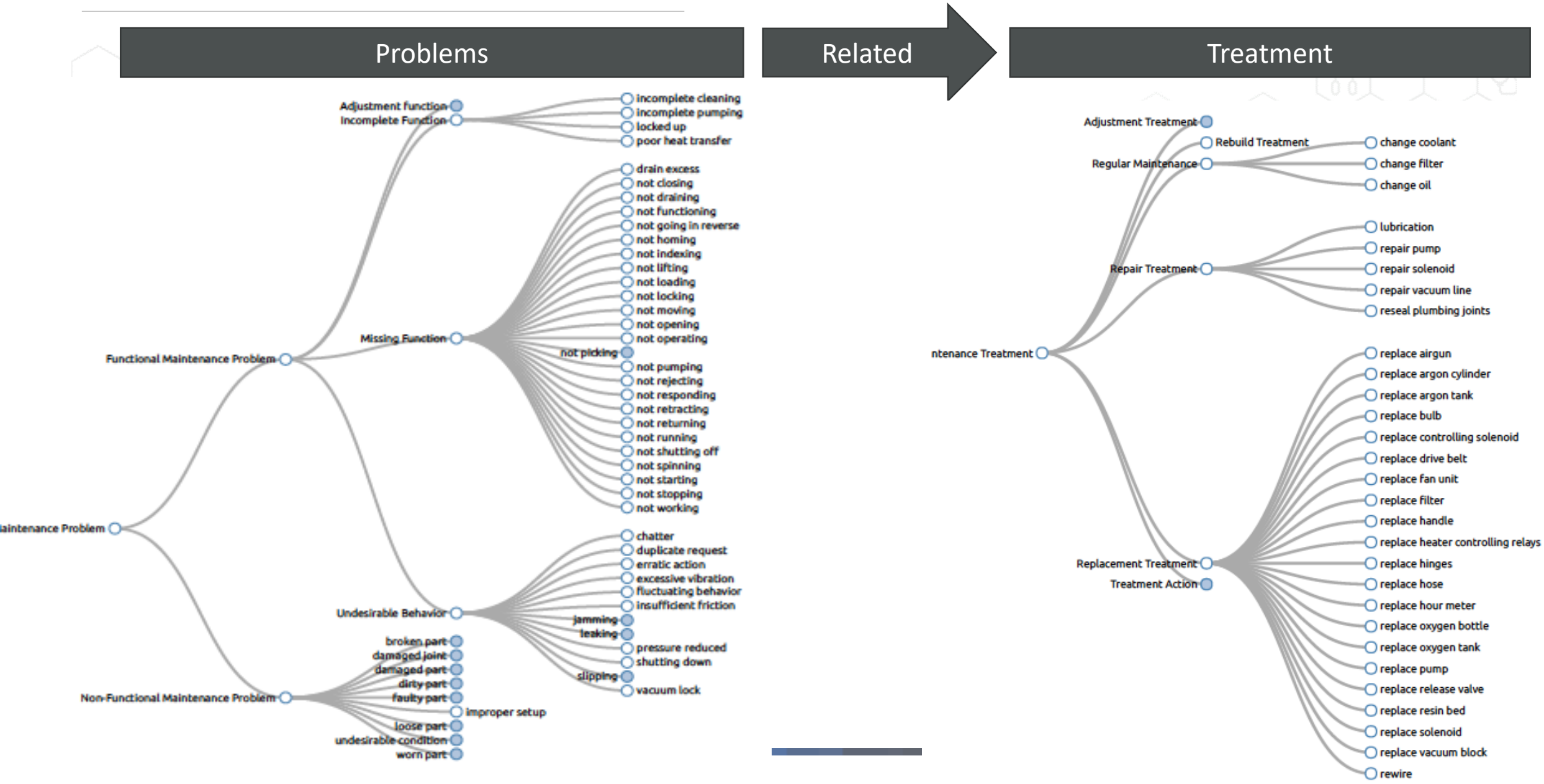
Artifacts *related to* Problems

Artifacts → Related → Problems





Problems related to Treatments

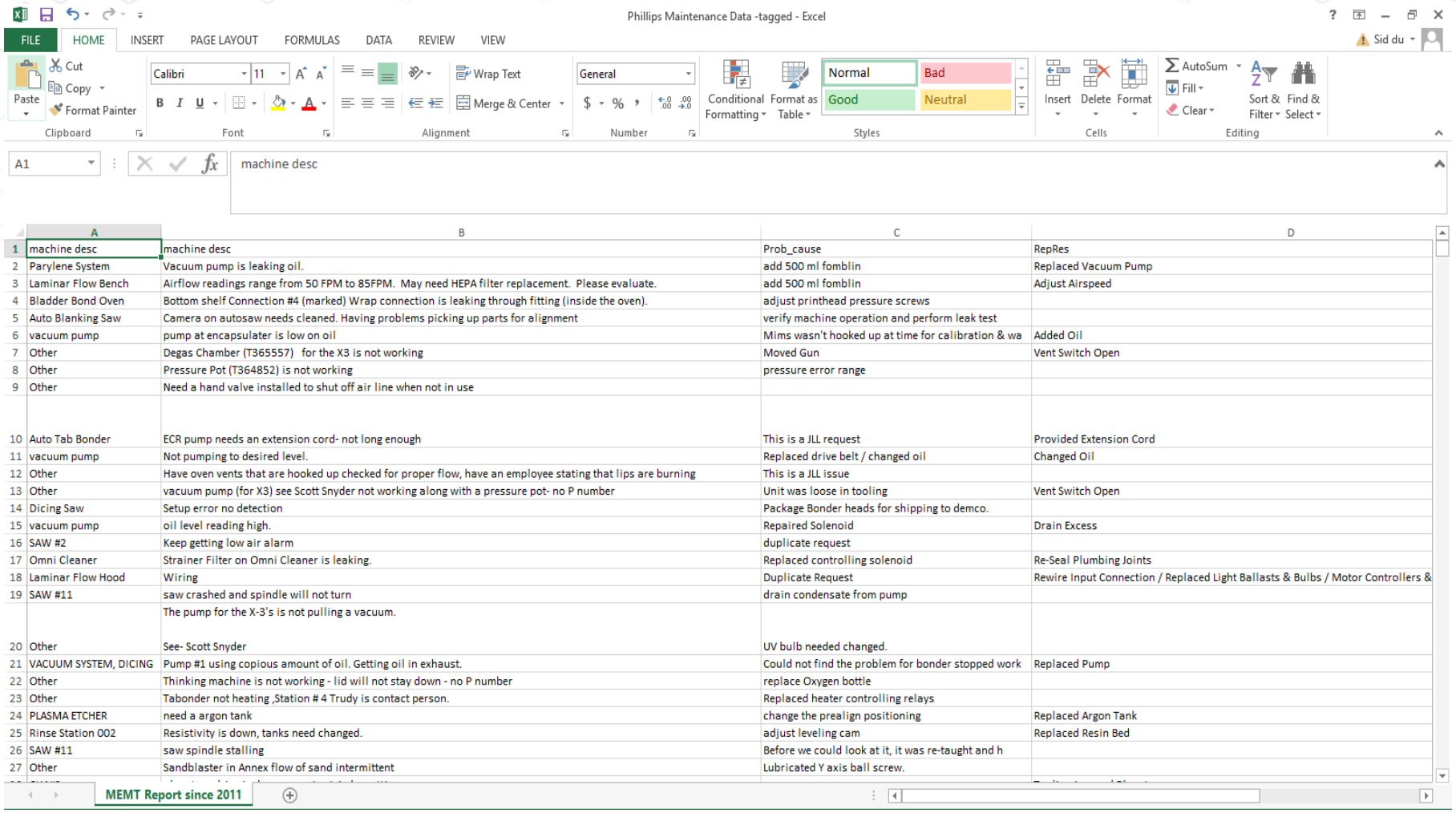


How MD Thesaurus Helps ?

- Summarizing and tagging maintenance logs.
- Decision support in maintenance diagnosis systems
  - From symptoms to root-causes to treatments
  - Document classification

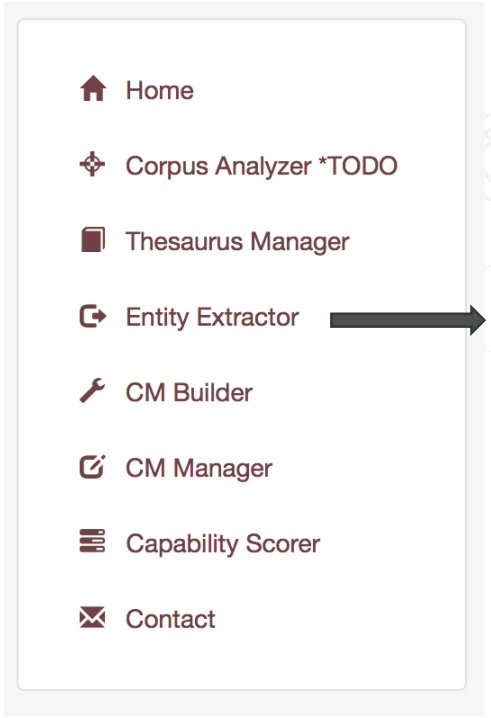
Data Tagging and Summarizing

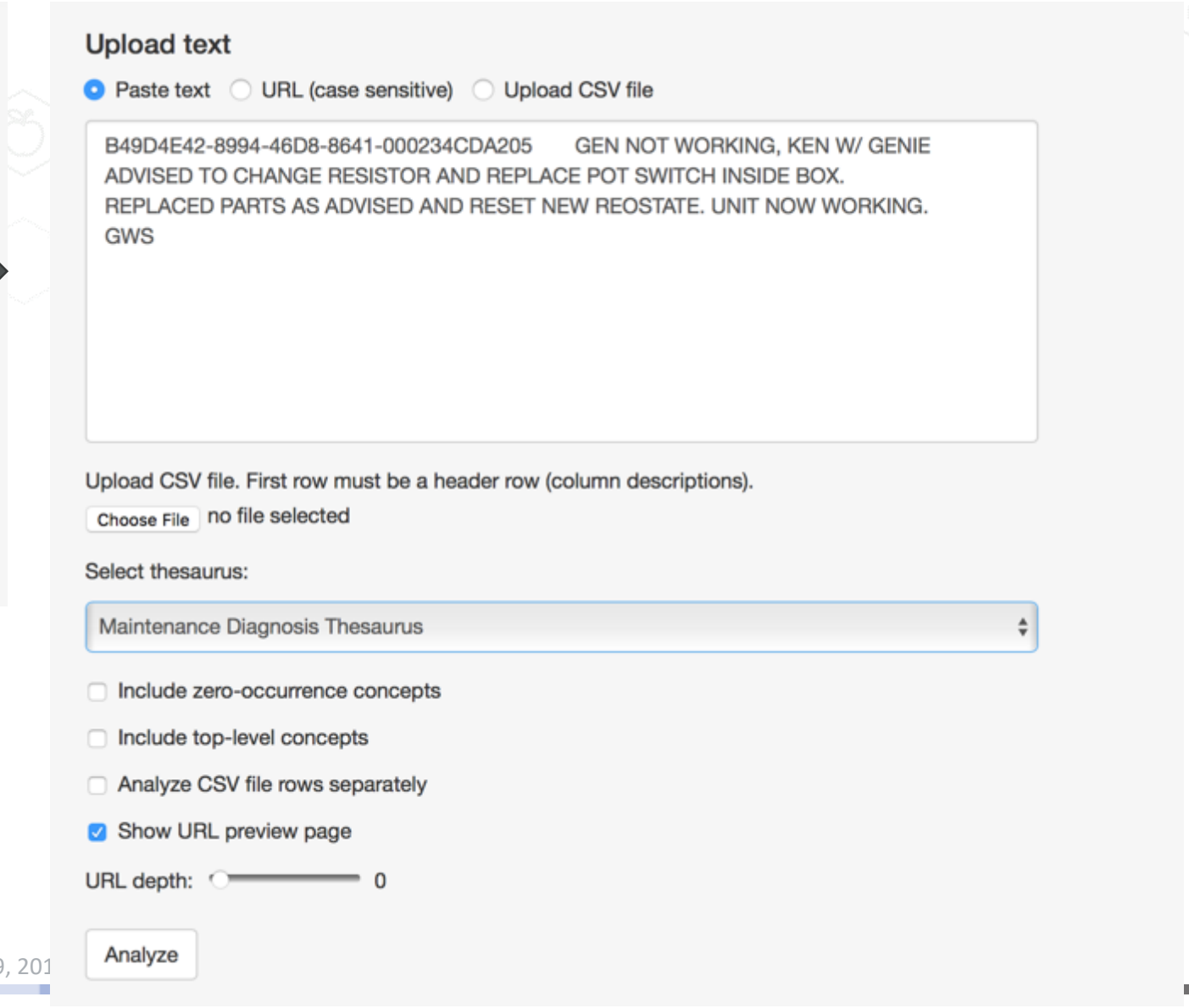
Maintenance Logs



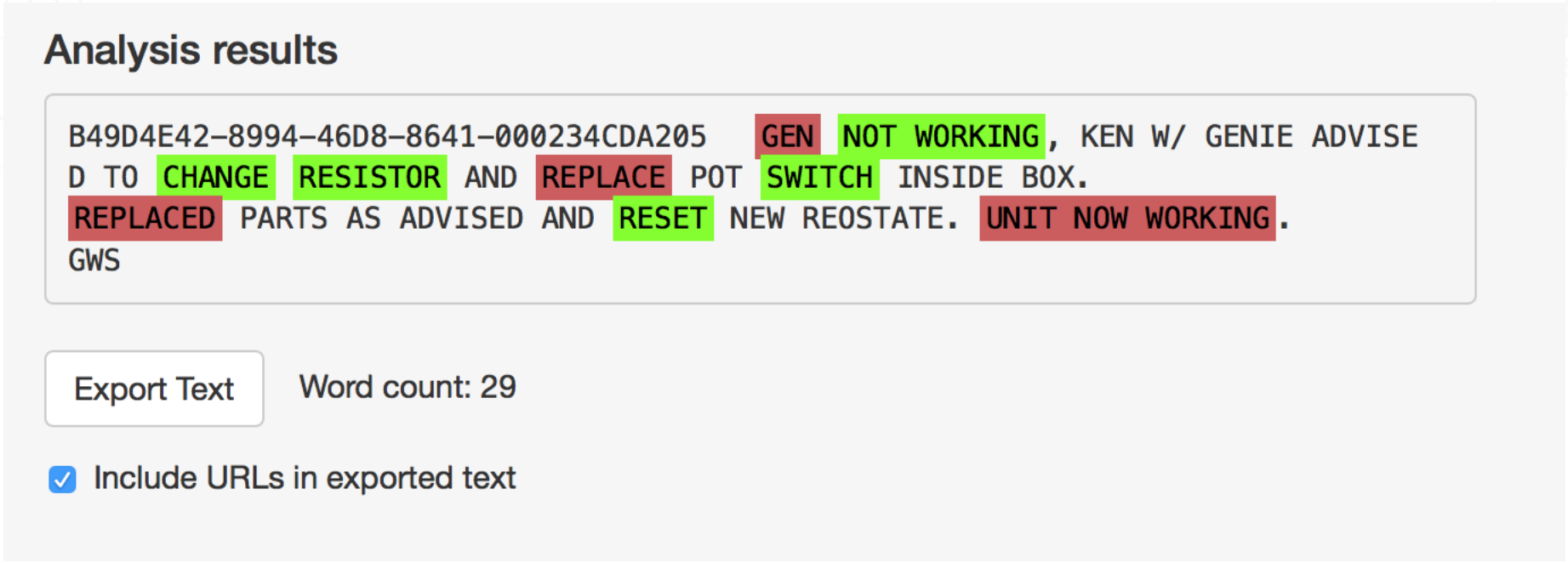
	A	B	C	D
1	machine desc	machine desc	Prob_cause	RepRes
2	Parylene System	Vacuum pump is leaking oil.	add 500 ml fomblin	Replaced Vacuum Pump
3	Laminar Flow Bench	Airflow readings range from 50 FPM to 85FPM. May need HEPA filter replacement. Please evaluate.	add 500 ml fomblin	Adjust Airspeed
4	Bladder Bond Oven	Bottom shelf Connection #4 (marked) Wrap connection is leaking through fitting (inside the oven).	adjust printhead pressure screws	
5	Auto Blanking Saw	Camera on autosaw needs cleaned. Having problems picking up parts for alignment	verify machine operation and perform leak test	
6	vacuum pump	pump at encapsulater is low on oil	Mims wasn't hooked up at time for calibration & wa	Added Oil
7	Other	Degas Chamber (T365557) for the X3 is not working	Moved Gun	Vent Switch Open
8	Other	Pressure Pot (T364852) is not working	pressure error range	
9	Other	Need a hand valve installed to shut off air line when not in use		
10	Auto Tab Bonder	ECR pump needs an extension cord- not long enough	This is a JLL request	Provided Extension Cord
11	vacuum pump	Not pumping to desired level.	Replaced drive belt / changed oil	Changed Oil
12	Other	Have oven vents that are hooked up checked for proper flow, have an employee stating that lips are burning	This is a JLL issue	
13	Other	vacuum pump (for X3) see Scott Snyder not working along with a pressure pot- no P number	Unit was loose in tooling	Vent Switch Open
14	Dicing Saw	Setup error no detection	Package Bonder heads for shipping to demco.	
15	vacuum pump	oil level reading high.	Repaired Solenoid	Drain Excess
16	SAW #2	Keep getting low air alarm	duplicate request	
17	Omni Cleaner	Strainer Filter on Omni Cleaner is leaking.	Replaced controlling solenoid	Re-Seal Plumbing Joints
18	Laminar Flow Hood	Wiring	Duplicate Request	Rewire Input Connection / Replaced Light Ballasts & Bulbs / Motor Controllers &
19	SAW #11	saw crashed and spindle will not turn	drain condensate from pump	
20	Other	The pump for the X-3's is not pulling a vacuum. See- Scott Snyder	UV bulb needed changed.	
21	VACUUM SYSTEM, DICING	Pump #1 using copious amount of oil. Getting oil in exhaust.	Could not find the problem for bonder stopped work	Replaced Pump
22	Other	Thinking machine is not working - lid will not stay down - no P number	replace Oxygen bottle	
23	Other	Tabonder not heating ,Station # 4 Trudy is contact person.	Replaced heater controlling relays	
24	PLASMA ETCHER	need a argon tank	change the prealign positioning	Replaced Argon Tank
25	Rinse Station 002	Resistivity is down, tanks need changed.	adjust leveling cam	Replaced Resin Bed
26	SAW #11	saw spindle stalling	Before we could look at it, it was re-taught and h	
27	Other	Sandblaster in Annex flow of sand intermittent	Lubricated Y axis ball screw.	

SKOS Tool


Home
Corpus Analyzer *TODO
Thesaurus Manager
Entity Extractor
CM Builder
CM Manager
Capability Scorer
Contact


Upload text
Paste text
URL (case sensitive)
Upload CSV file
B49D4E42-8994-46D8-8641-000234CDA205 GEN NOT WORKING, KEN W/ GENIE
ADVISED TO CHANGE RESISTOR AND REPLACE POT SWITCH INSIDE BOX.
REPLACED PARTS AS ADVISED AND RESET NEW REOSTATE. UNIT NOW WORKING.
GWS
Upload CSV file. First row must be a header row (column descriptions).
Choose File
no file selected
Select thesaurus:
Maintenance Diagnosis Thesaurus
Include zero-occurrence concepts
Include top-level concepts
Analyze CSV file rows separately
Show URL preview page
URL depth:
0
Analyze

Tagged Text


Analysis results
B49D4E42-8994-46D8-8641-000234CDA205 GEN NOT WORKING, KEN W/ GENIE ADVISE
D TO CHANGE RESISTOR AND REPLACE POT SWITCH INSIDE BOX.
REPLACED PARTS AS ADVISED AND RESET NEW REOSTATE. UNIT NOW WORKING.
GWS
Export Text
Word count: 29
Include URLs in exported text

Extracted Concepts

Sort table:

(•) Alphabetical ( ) Occurrences

Concept (preferred label)	Occurrences
change	2
generator	1
not working	1
replace	2
reset	1
resistor	1
switch	1
unit working	1

Export type:

(•) 2-column ( ) 4-column

Export Table

Exported Table

Concept Schema	Top Concept	Concept (preferred label)	Occurrences
Artifact	System	generator	1
Maintenance Problem	Functional Maintena	not working	1
Maintenance Treatment	Treatment Action	change	2
Artifact	Part	resistor	1
Maintenance Treatment	Treatment Action	replace	2
Artifact	Part	switch	1
Maintenance Treatment	Treatment Action	reset	1
Problem Resolved	Resolution Term	unit working	1

Sufficient Tagging

Problem Description: Table will not index.
Resolution: Table indexing valve coil found bad and replaced

Concept Schema	Top Concept	Concept (preferred label)	Freq.
Artifact	Part	coil	1
Artifact	Part	indexing valve	1
Maintenance Problem	Functional Maintenance Problem	not indexing	1
Maintenance Treatment	Treatment Action	replace	1
Artifact	Part	valve	1

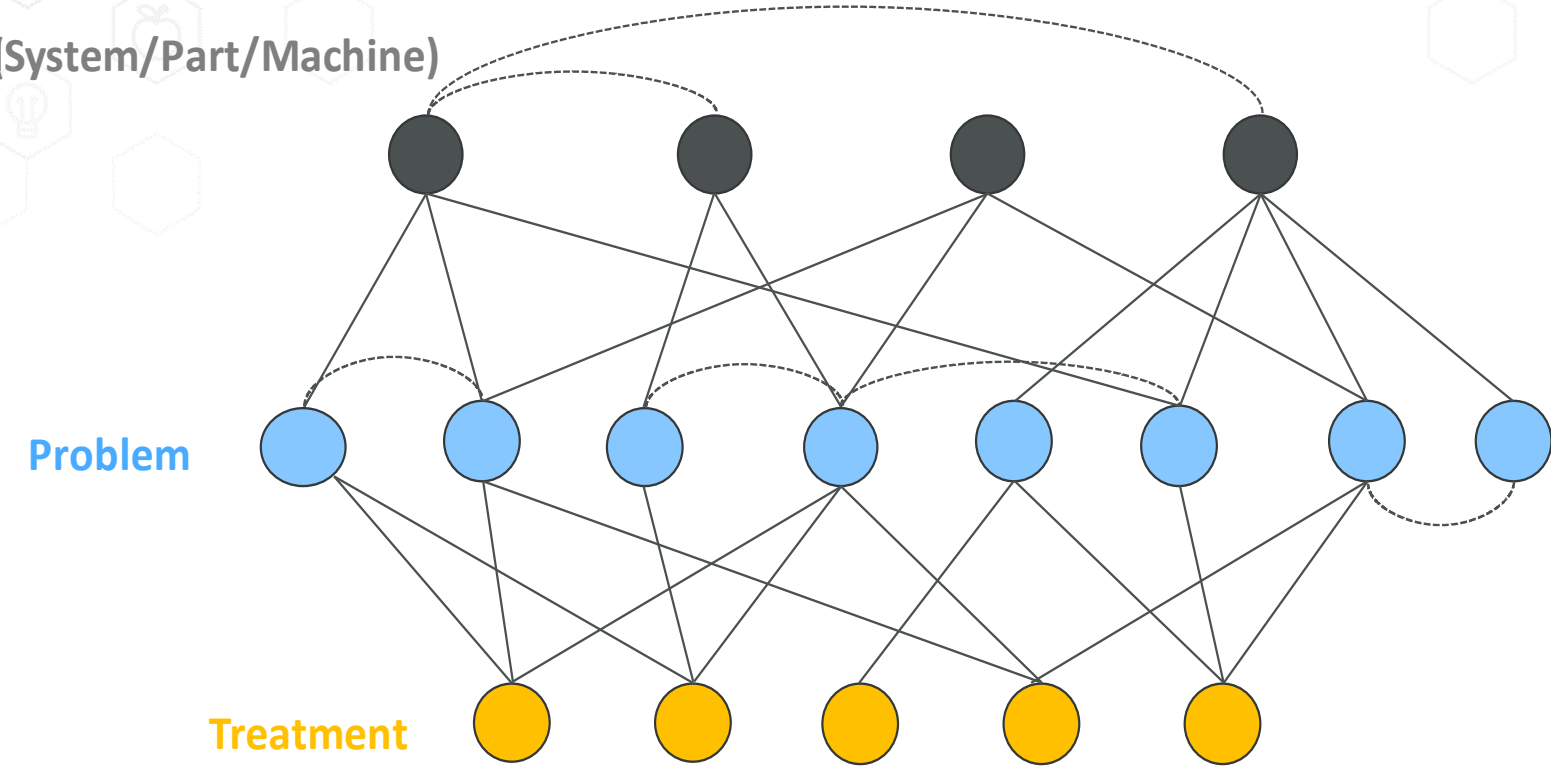
Insufficient Tagging

Problem Description: Damaged stock tubes (x3)
Resolution: New Hush Tubes ordered 9/8 -Installed 9/27 x3

Concept Schema	Top Concept	Concept (preferred label)	Freq.
Maintenance Problem	Non-Functional Maintenance Problem	damaged part	1
Artifact	Part	tube	2

Decision Support Tool for Maintenance Diagnosis

APT Graph

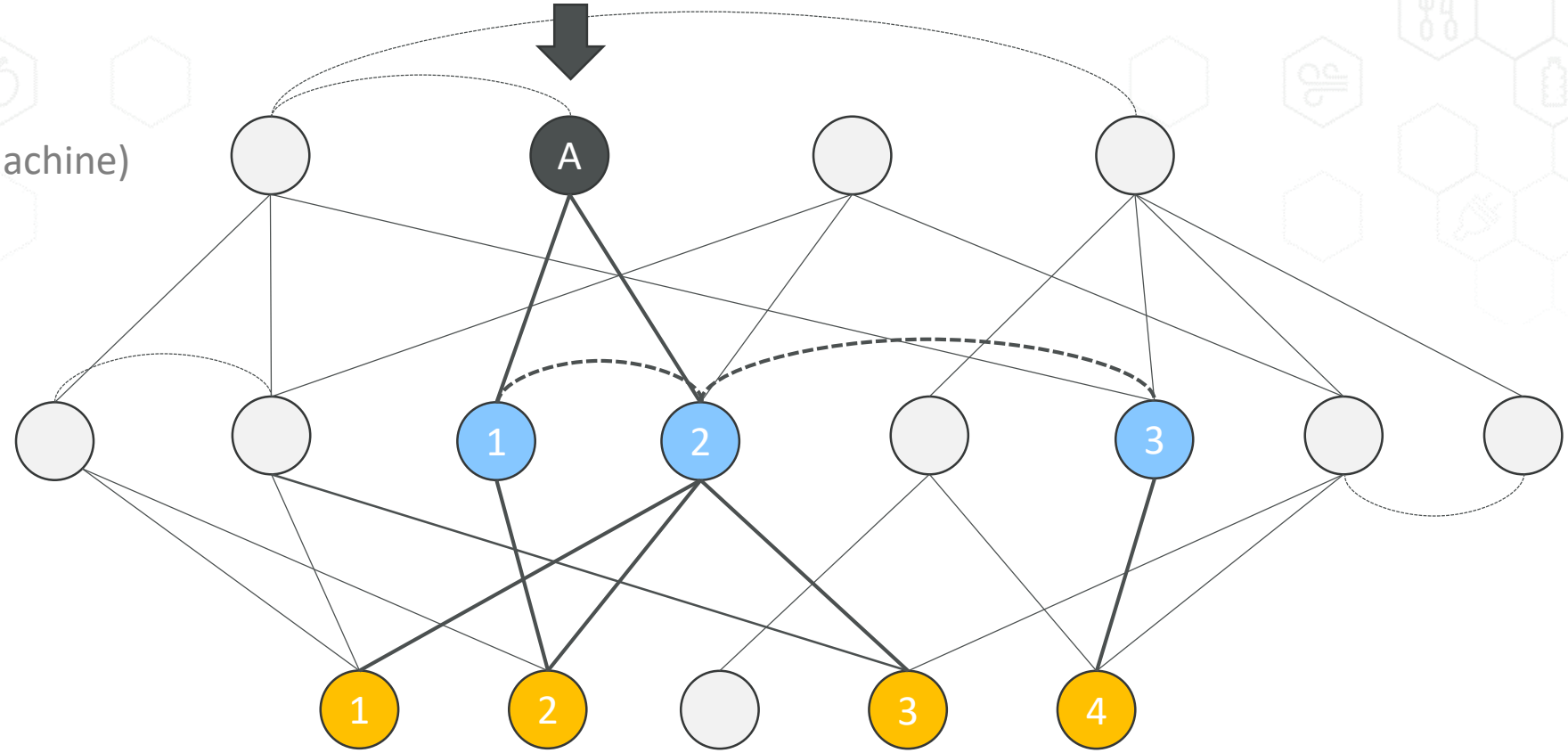


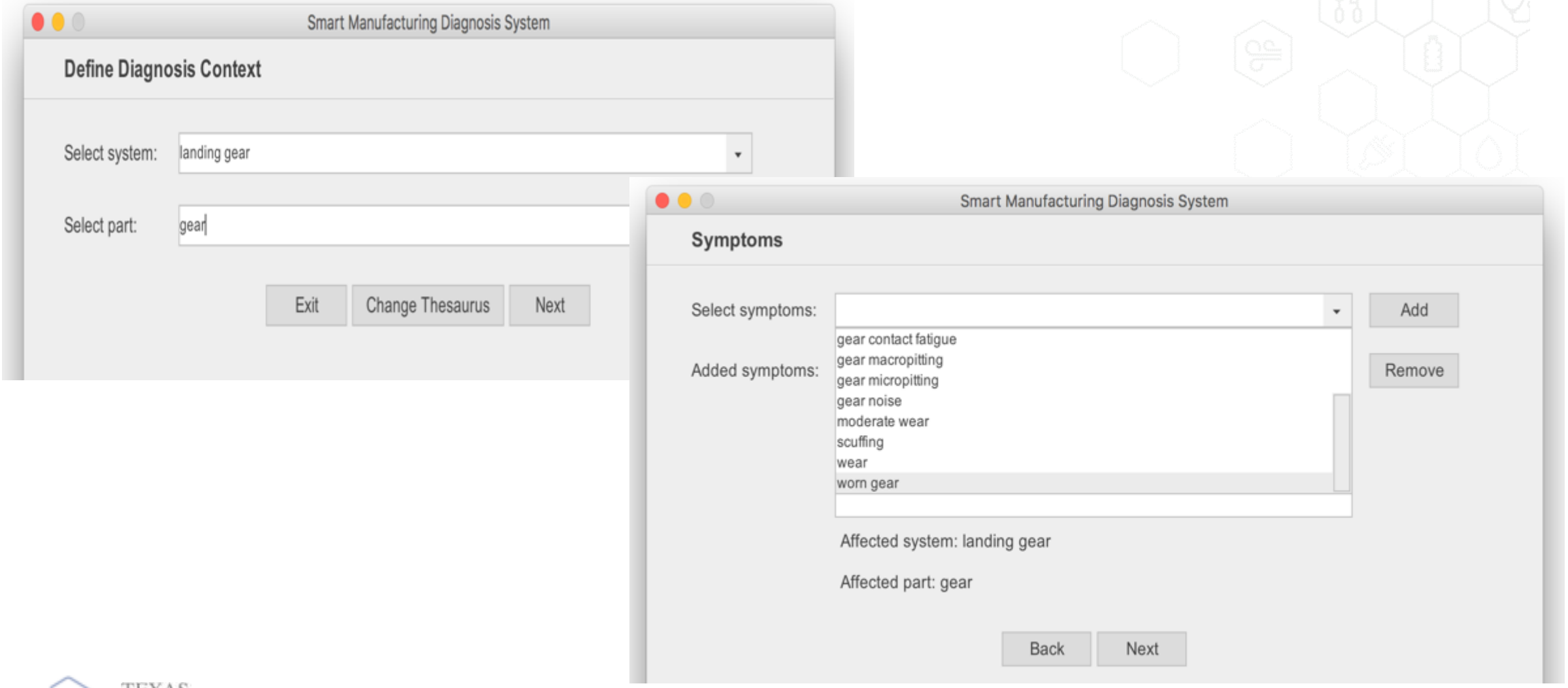
ATP Graph

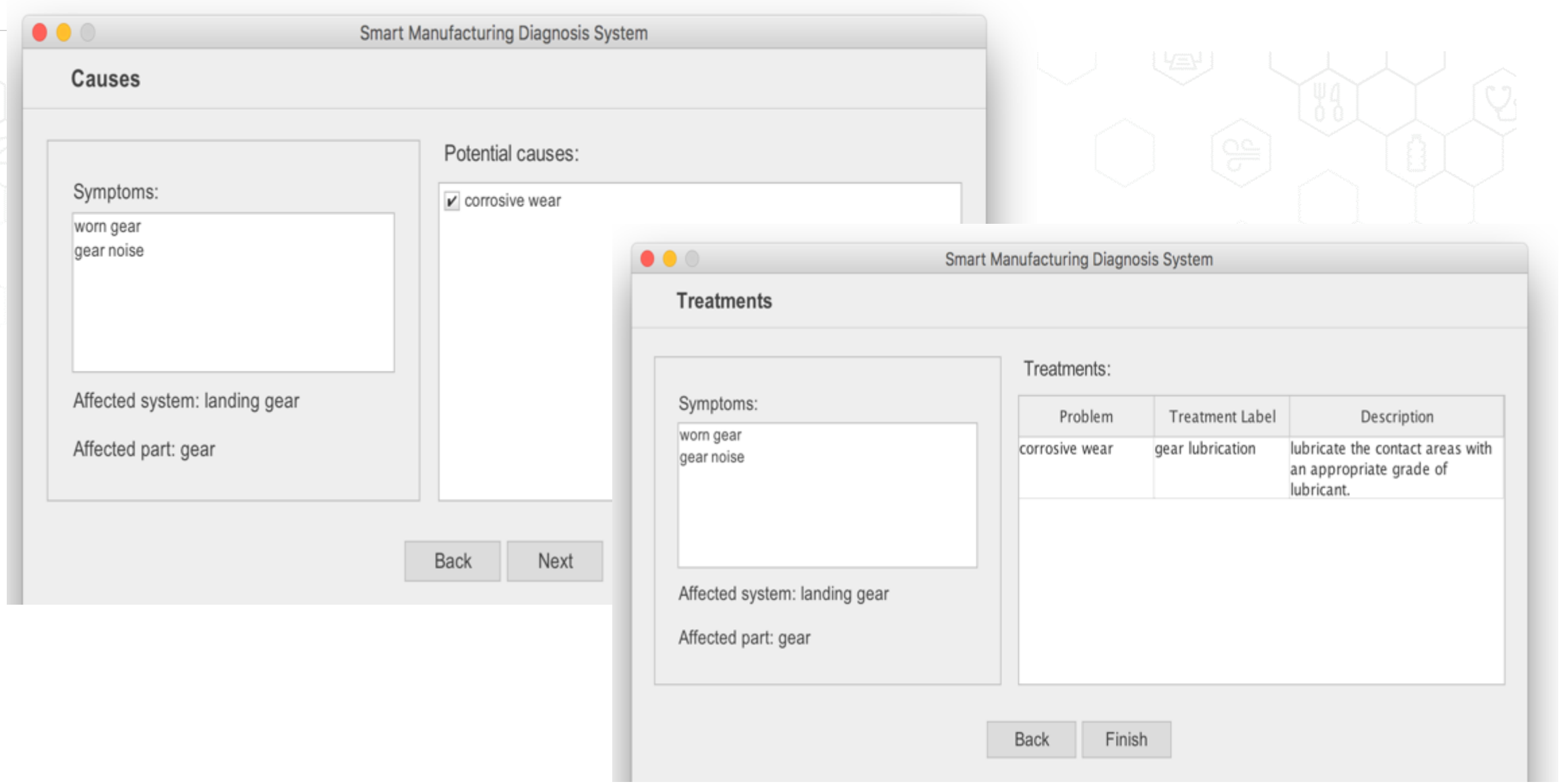
Artifact (System/Part/Machine)

Problem

Treatment

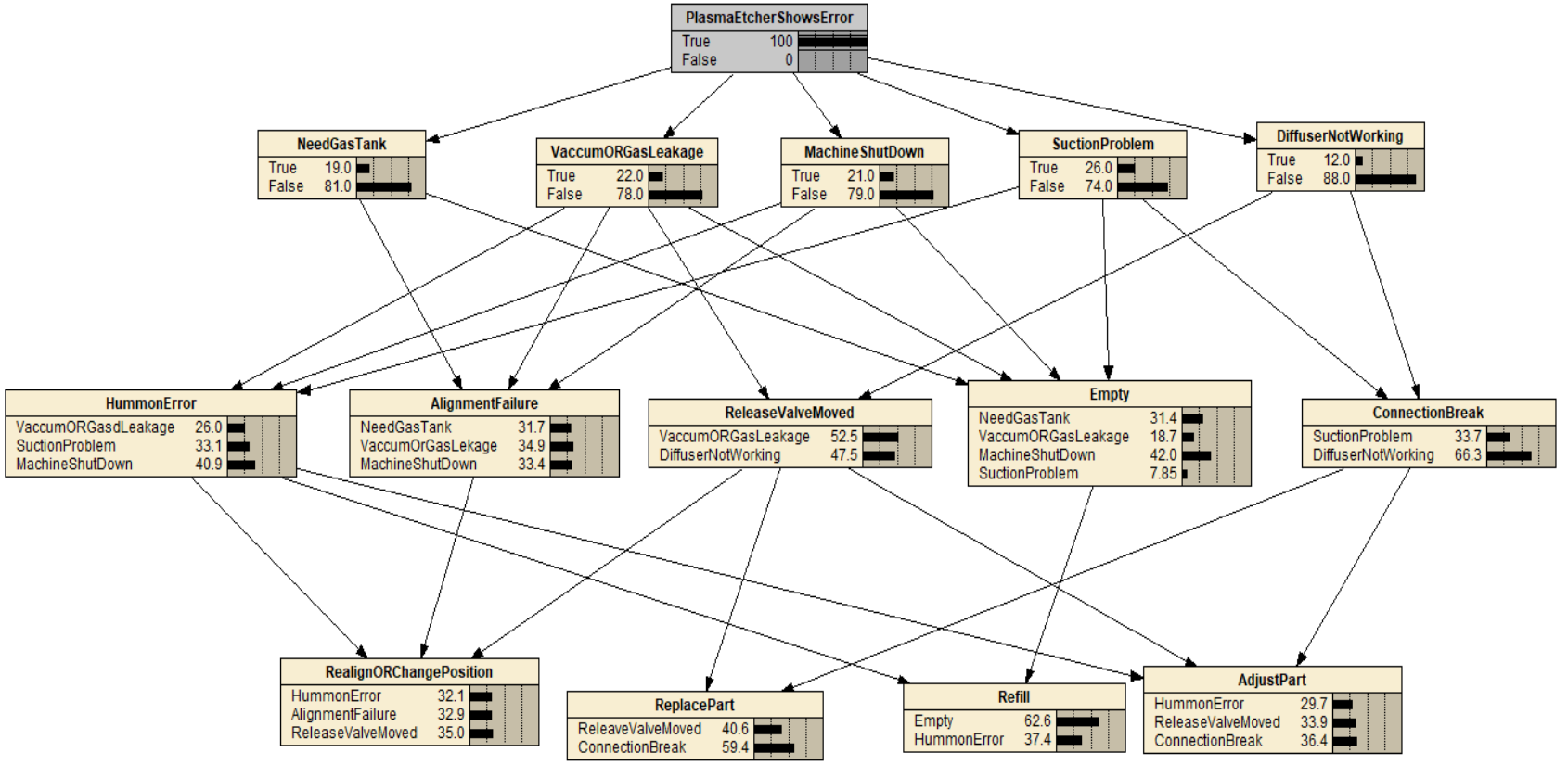



Smart Manufacturing Diagnosis System
Define Diagnosis Context
Select system:
landing gear
Select part:
gear
Exit
Change Thesaurus
Next
Smart Manufacturing Diagnosis System
Symptoms
Select symptoms:
Add
Added symptoms:
gear contact fatigue
gear macropitting
gear micropitting
gear noise
moderate wear
scuffing
wear
worn gear
Remove
Affected system: landing gear
Affected part: gear
Back
Next


Smart Manufacturing Diagnosis System
Causes
Symptoms:
worn gear
gear noise
Affected system: landing gear
Affected part: gear
Potential causes:
corrosive wear
Back
Next
Smart Manufacturing Diagnosis System
Treatments
Symptoms:
worn gear
gear noise
Affected system: landing gear
Affected part: gear
Treatments:
Problem
Treatment Label
Description
corrosive wear
gear lubrication
lubricate the contact areas with an appropriate grade of lubricant.
Back
Finish

Future Directions

- Automated creation of Bayesian Network
- Improving the expressivity of the knowledge graph
- Expanding the graph



Questions ?