Using Unstructured Work Order Data to Improve Maintenance Procedures in Manufacturing

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Outline

1. Current Paradigm with Maintenance Work Orders (MWOs)
2. Transforming the MWO Data
3. Investigatory Analysis with MWO Data
4. Future Work

Current Maintenance Paradigm

Date	Mach	Description	Issued By	Date Up	Maint Tech Assigned	Resolution
29-Jan-16	H15	St#14 tool detect INOP	JS	29-Nov-16	SA	Slug detector at station 14 not working. Would not recognize "Start" signal.
1-Jun-16	Mitsu FT	Brakes worn -Not stopping when in gear	AB	28-Jun-16	Steve A	Repaired
1-Jun-16	H8	St#7 rotator collet broken -wait for Bob B to show him how to remove	JS	8-Jun-16	John Smith	Machine went offline on 6/8 -Mark removed and instructed Bob B on removal/install process

Maintenance Work Order Data

"Turret removed, cleaned, reinstalled, and aligned"

"Hydraulic return line replaced"

"Marine door seal leaking / Leak from seal on basket shaft"

"Retrieved motor from spare automation and installed"

"Head removed and cleaned thoroughly. Found cam action spring binding on one tool station. Removed spring and cleaned up burring on spring; Reset and reinstalled"

"Bearings bad; removed spindle and replaced bearings"

"At 27bar; Charged to 30bar No issue"

Current Maintenance Paradigm

- Expertise Driven

- Sensors not always present

- Often unstructured MWOs
  - natural language; domain-specific abr. and jargon
  - "tribal" knowledge

- Proprietary maintenance software

Interactive Case Study
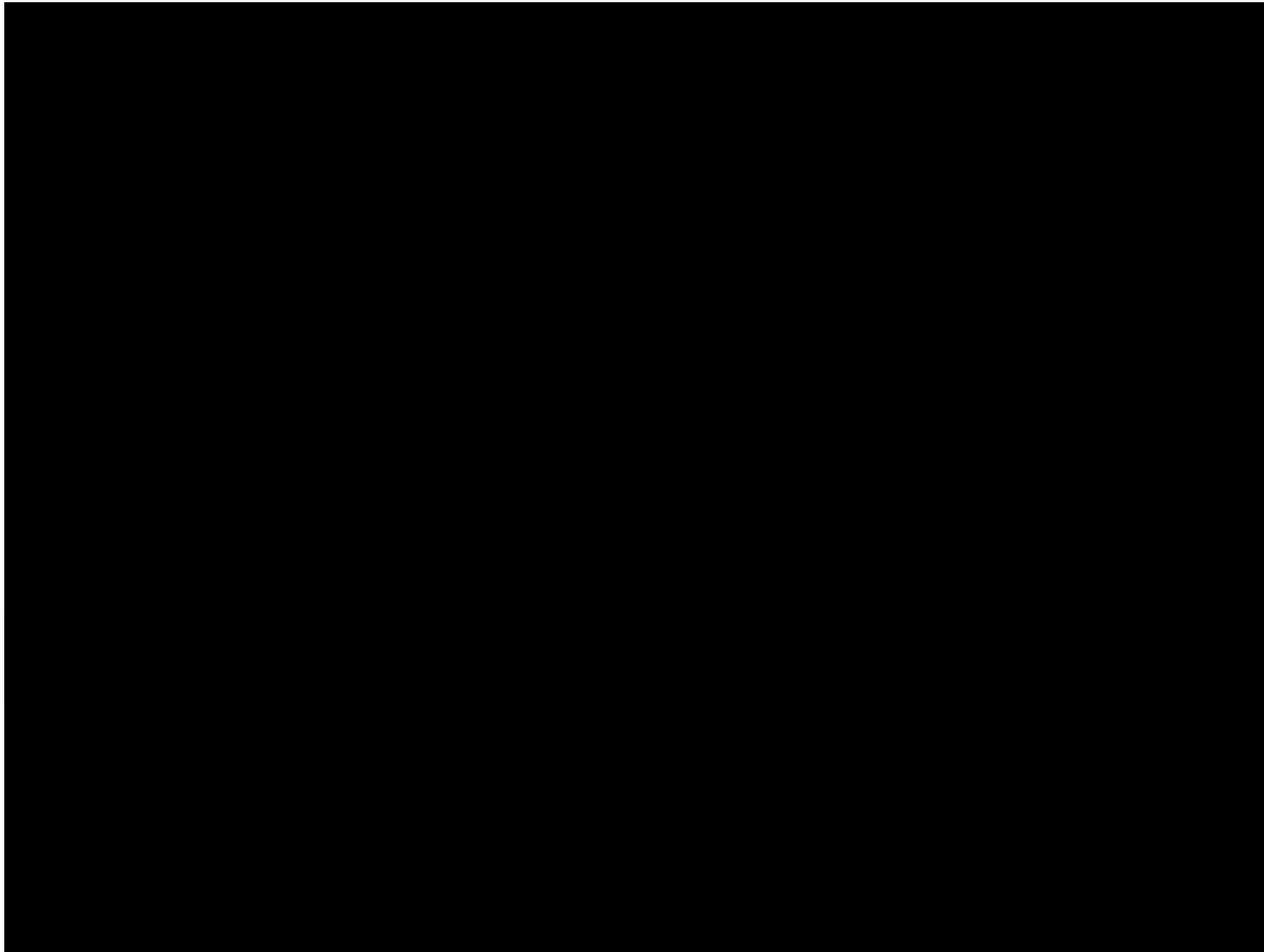
https://www.youtube.com/watch?v=jHbI_B2sPA0&feature=youtu.be&t=1m35s

Interactive Case Study

"The cutting tool snapped off. Need to replace tool and inspect spindle for damage. Looks like they were cutting too deep in one pass for the strength of the tool"

"All-around operator error. Looks to be too high a depth of cut at too high a feed-rate. Also looks like the move at the end put too high a stress on the tool. Operator should have retracted the tool before making that move if he/she wanted to keep that depth of cut."

"The DOC is too large and the feed too high for the slot such that the forces increase until tool breakage as the tool approaches the vice. It probably wasn't smart either to machine towards the vice as they have anyway. A typical approach to avoid this problem is to ramp into the slot."

"Too large of an engagement at tool high of a feed."

Interactive Case Study

"The ==cutting tool snapped off==. Need to replace tool and inspect spindle for damage. Looks like they were cutting too deep in one pass for the strength of the tool"

"All-around operator error. Looks to be too high a depth of cut at too high a feed-rate. Also looks like the move at the end put too high a stress on the tool. Operator should have retracted the tool before ~~...~~ e if he/she wanted to ~~...~~ depth of cut."

Tool is broken

"The DOC is too large and the feed too high for the slot such that the forces increase until ==tool breakage== as the tool approaches the vice. It probably wasn't smart either to machine towards the vice as they have anyway. A typical approach to avoid this problem is to ramp into the slot."

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Depth of cut too large

"The DOC is too large and the feed too high for the slot such that the forces increase until tool breakage as the tool approaches the vice. It probably wasn't smart either to machine towards the vice as they have anyway. A typical approach to avoid this problem is to ramp into the slot."

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"All-around operator error. Looks to be too high a depth of cut ==at too high a feed-rate==. Also looks like the move at the end put too high a stress on the tool. Operator should have retracted the tool before ... e if he/she wanted to ... depth of cut."

Feed rate too high

"The DOC is too large and the ==feed too high== for the slot such that the forces increase until tool breakage as the tool approaches the vice. It probably wasn't smart either to machine towards the vice as they have anyway. A typical approach to avoid this problem is to ramp into the slot."

"Too large of an engagement at ==tool high of a feed==."

Interactive Case Study

"The cutting tool snapped off. Need to replace tool and inspect spindle for damage. Looks like they were cutting too deep in one pass for the strength of the tool"

"All-around operator error. Looks to be too high a depth of cut at too high a feed-rate. Also looks like the move at the end put too high a stress on the tool. Operator should have retracted the tool before [...] ve if he/she wanted to [...] t depth of cut."

Bad process plan

"The DOC is too large and the feed too high for the slot such that the forces increase until tool breakage as the tool approaches the vice. It probably wasn't smart either to machine towards the vice as they have anyway. A typical approach to avoid this problem is to ramp into the slot."

"Too large of an engagement at tool high of a feed."

Interactive Case Study

"The cutting tool snapped off. Need to replace tool and inspect spindle for damage. Looks like they were cutting too deep in one pass for the strength of the tool"

"All-around ==operator error==. Looks to be too high a depth of cut at too high a feed-rate. Also looks like the move at the end put too high a stress on the tool. Operator should have retracted the tool before ~~changing~~ ~~the move~~ if he/she wanted to ~~increase~~ ~~the~~ depth of cut."

Operator error

"The DOC is too large and the feed too high for the slot such that the forces increase until tool breakage as the tool approaches the vice. It probably wasn't smart either to machine towards the vice as they have anyway. A typical approach to avoid this problem is to ramp into the slot."

"Too large of an engagement at tool high of a feed."

Maintenance Work Order Data

Raw Data

Effect	Average of Time to Complete (hrs)	Number of Instances	Total Time to Complete (hrs)
Accumulator check requested	1.4590	14	16.05
Vogel lube faults	1.5875	7	6.35
Base cleaning requested	13.575	4	27.15
Table index O/T faults	2.7	3	2.7
Iemca will not load in Auto	313.2	3	939.6
Chip conveyor INOP	1.075	3	2.15
Chip conveyor jammed	3.725	3	7.45
St#2 drill detector INOP	0.15	2	0.15
Table drifting at 1/2 table setting	47	2	94
Motor thermal overload fault -Hydraulic	24	2	24
Machine will not run in Auto		2	
Part not loading into collet		2	
St#8 Hyd flange not repeating	0.15	2	0.15
Power pack leak		2	
Table index O/T at 1/2 table -Turning off Hydraulics		2	

Clean Data

Effect	Average of Time to Complete (hrs)	Number of Instances	Total Time to Complete (hrs)
Hydraulic Leak	40.8775	39	817.55
Accumulator check requested	1.690	26	35.5
Coolant Leak	122.47	17	1347.2
Bearings check	16.835	16	168.35
Chip conveyor INOP	5.8	15	63.8
Broken screw	3.8722	14	34.85
Table index faults	24.08	13	120.4
Brush unit stuck forward	4.744	10	42.7
Vogel lube fault	2.27	9	11.35
Coolant Pressure Low	3.26	9	16.3
Oil leak	39.2375	8	156.95
Base cleaning requested	13.575	4	27.15
Iemca will not load in Auto	235.9	4	943.6
Bearings noise	79	4	79
Inverter failing to return	0.3	4	0.3

Total Time to Complete (hrs)		
Effect	Raw	Clean
Accumulator check requested	16.05	35.5

Raw Data

Hyd leak at Bar stop pre load position
Major Hydraulic leak at Bottom XD head
Hydraulic leak at cutoff unit
Hyd leak at St#2 chip breaker valve
Hyd leak reported
Hydraulic leak at bar loader -Rubber seal on vacuum
HP Hydraulic line ruptured
Multiple leaks at Iemca -25 Gallons in 48 hours
Hydraulic return line leak
Hyd leak from behind collet #6
Hydraulic leak turret 2
Hydraulic leak actuator or horseshoe
Hydraulic leak at chip breaker valve (? Valve station)
Hydraulic leaks -from collets??
Leak at High Pressure pump
Hyd leak St#2 valve
St#6 valve leaking hydraulic
Hydraulic leak
Hyd leak at locking pin assy
Iemca hydraulic pump leaking -Full tank per day
Hydraulic leak on Side A
Hydraulic leak from power pack
St#8 valve leaking Hyd fluid
Hyd leaks -C/O unit, St#11 Valve, Collet #10 (Internal)
Hydr pump? / Power pack leak / CNCs shuddering
Hydraulic leak at inverter st#8
Hyraulic leak at St#4
Hyd leaks at valve below #7 / Lid leaks at loader
St#8 valve spraying hydraulic fluid
Hyd leak at Iemca pumps tank
Hyd leak from dressing unit
Hydraulic leak at Cutoff valve
Hydraulic leak at power pack -per PM tix
Hydraulic leak found by Doug -3.1 quill
Hydraulic Leak reported -One tank per day
Hydraulics leaking from dressing unit
Major hydraulic leak
Major Hydraulic leak at rotator -Rotator rack is broken
Hydraulic oil getting into Vogel waste oil
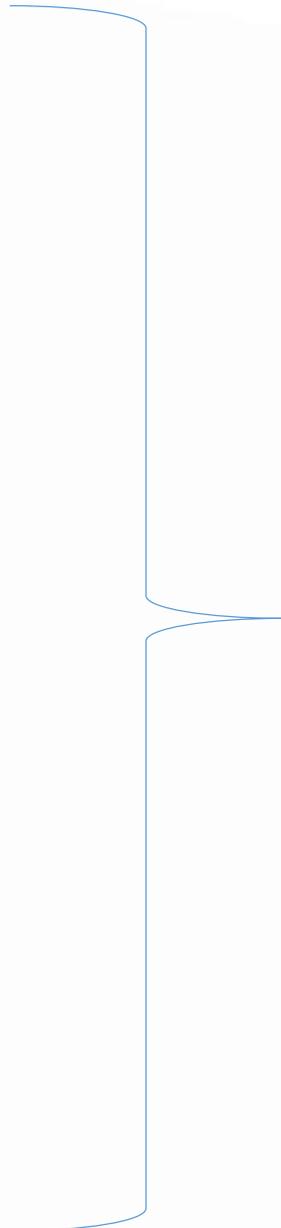
Clean Data

Hydraulic Leak

Transforming the MWO Data

Initial Annotation Attempt

Method

- Find useful representations for common problems
- Unify terminology
- Preliminary Cause/Effects/Treatments

	Time Inv.	Result
Initial annotation	12 hours	800 labels

Transforming the MWO Data

Tagging as Annotation

- "Tags" have many benefits for **users**:
  - No Controlled Vocabulary
  - Naturally reflect the user-base's communication
  - Less ambiguous than strict classification → more usage

- Collections of tags on a domain form a "**Folksonomy**"
  - Relationships are encoded via tag co-occurrence — *like Bag of Words!*
  - Can be predicted via Multi-*label* classification

We sacrifice **certainty** about specific labels, and gain annotation quality & ease-of-use

Transforming the MWO Data

Description

Hydraulic Leak at cutoff unit

Resolution

Missing fitting replaced

Item   **Action**
      Problem

Action   **Item**
      Solution
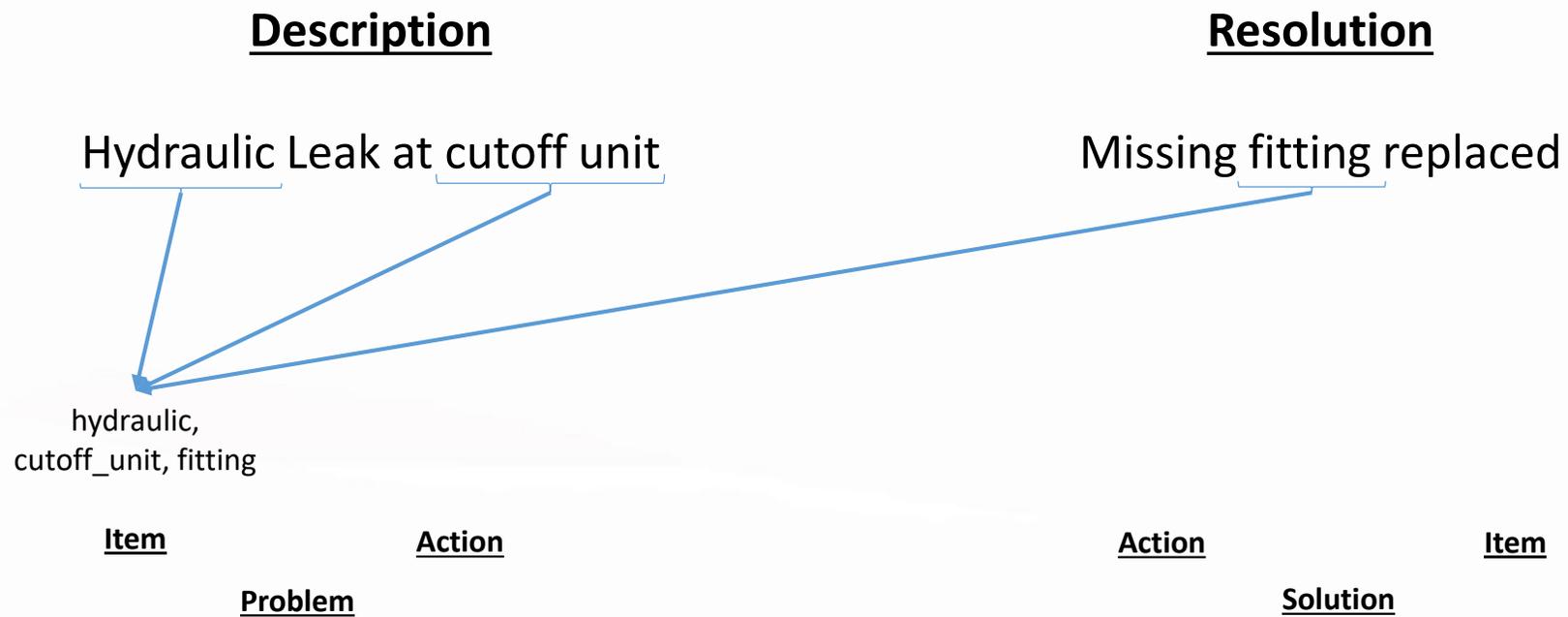
Transforming the MWO Data

Description   **Resolution**

Hydraulic Leak at cutoff unit   Missing fitting replaced

hydraulic,
cutoff_unit, fitting

Item   **Action**   **Action**   **Item**

Problem   **Solution**

Transforming the MWO Data

Description   **Resolution**

Hydraulic Leak at cutoff unit   Missing fitting replaced

hydraulic,   leak, missing
cutoff_unit, fitting

Item   **Action**   **Action**   **Item**
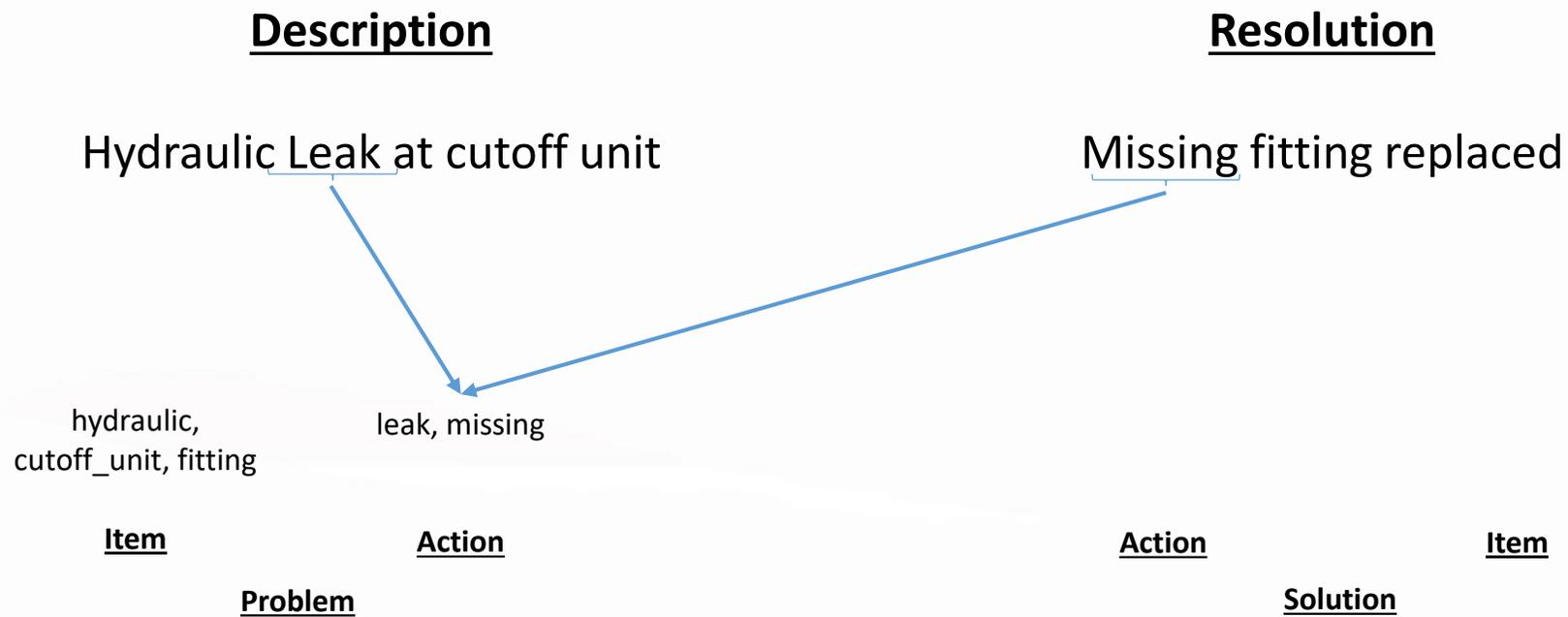
Problem   **Solution**

Transforming the MWO Data

Description

Hydraulic Leak at cutoff unit

hydraulic, cutoff_unit, fitting   leak, missing

Item   **Action**

Problem

Resolution

Missing fitting replaced

replace

Action   **Item**

Solution

Transforming the MWO Data

Description

Resolution

Hydraulic Leak at cutoff unit

Missing fitting replaced

hydraulic,
cutoff_unit, fitting

leak, missing

replace

fitting

Item

Action

Action

Item
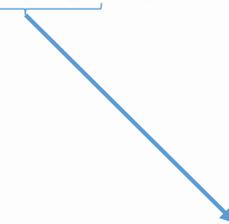
Problem

Solution

Transforming the MWO Data

Original Data

Description

Hydraulic Leak at cutoff unit

Resolution

Missing fitting replaced

Tagged Data

hydraulic, cutoff_unit, fitting   leak, missing   replace   fitting

Item   **Action**   **Action**   **Item**

Problem   **Solution**

Transforming the MWO Data

Issue

"Hydraulic Leak at cutoff unit; Missing fitting replaced"

Old classification

"Hydraulic Leak"/OR "Cutoff unit Leak"/OR "Missing Fitting"

"replace fitting"

Problem

cutoff_unit

hydraulic

leak

fitting

missing

Solution

replace

fitting
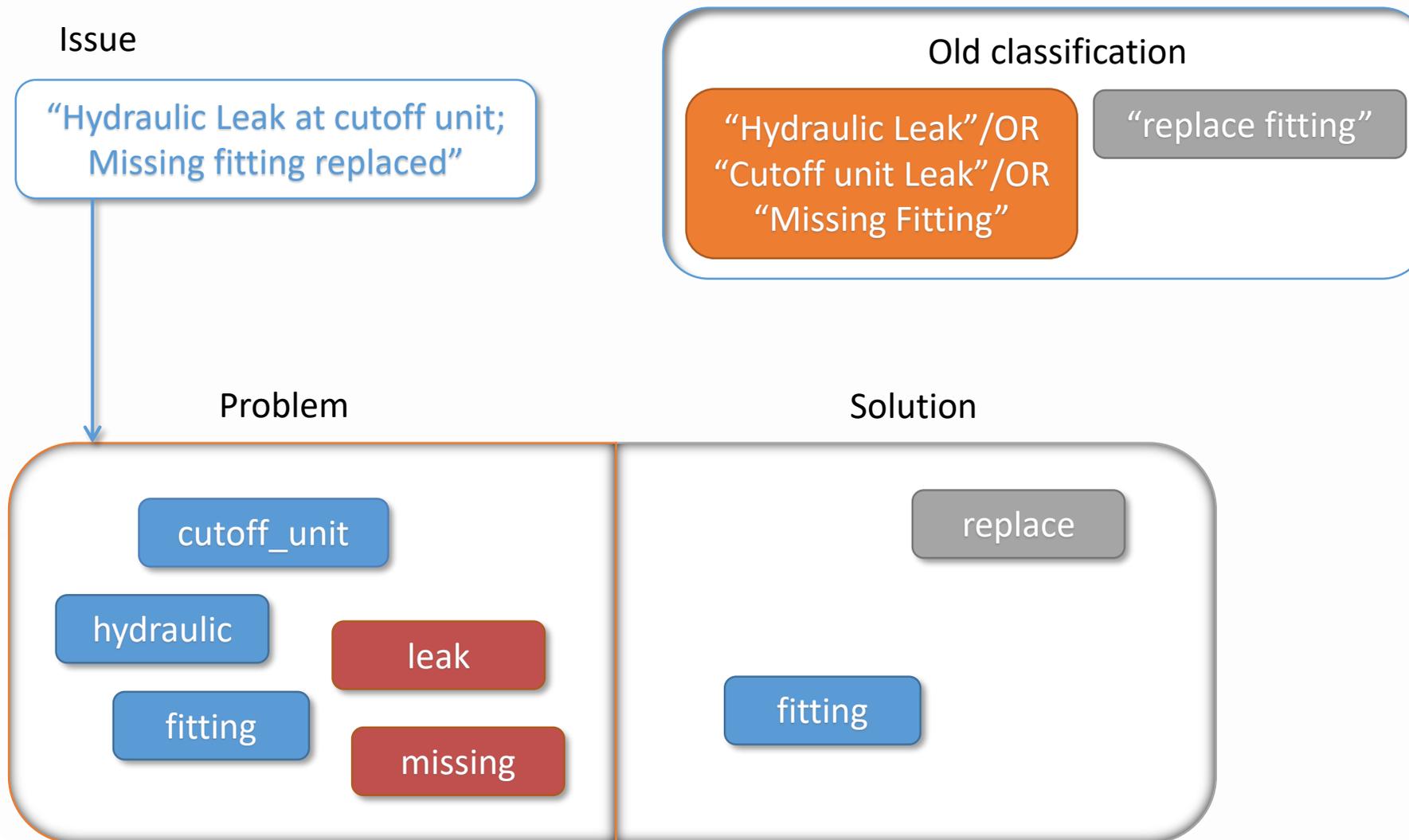
Transforming the MWO Data

	Time Inv.	Result
Previous annotation	12 hours	800 labels
Tagging method	12 hours	1200 tagged

Semi-Automated Tagging

Keyword-based Tagging Tool

Ordered Vocabulary Annotation

token	type	alias
replace	S	
unit	I	
motor	I	
spindle	I	
leak	P	
valve	I	
replaced	S	replace
fault	P	
bar	I	
inop	P	inoperable

More Important
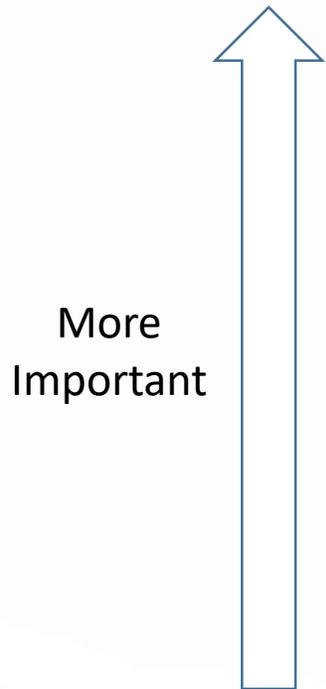
Keyword Extractor
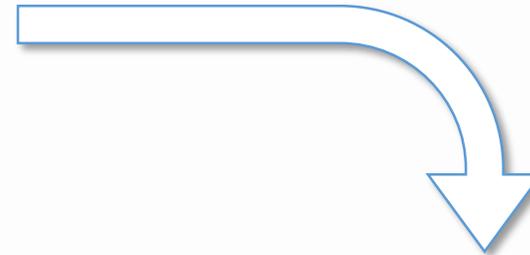
Tags Extracted from Work-order

"Hydraulic Leak at cutoff unit; Missing fitting replaced"

Semi-Automated Tagging

	Time Inv.	Result
Previous annotation	12 hours	800 labels
Tagging method	12 hours	1200 tagged
Ordered Keyword Tagger	0.75 hours	3100 tagged, 99.7% partials

Semi-Automated Tagging

Case Studies: Machine Performance

Case Studies: Machine Performance

Top Tag occurences, by Machine
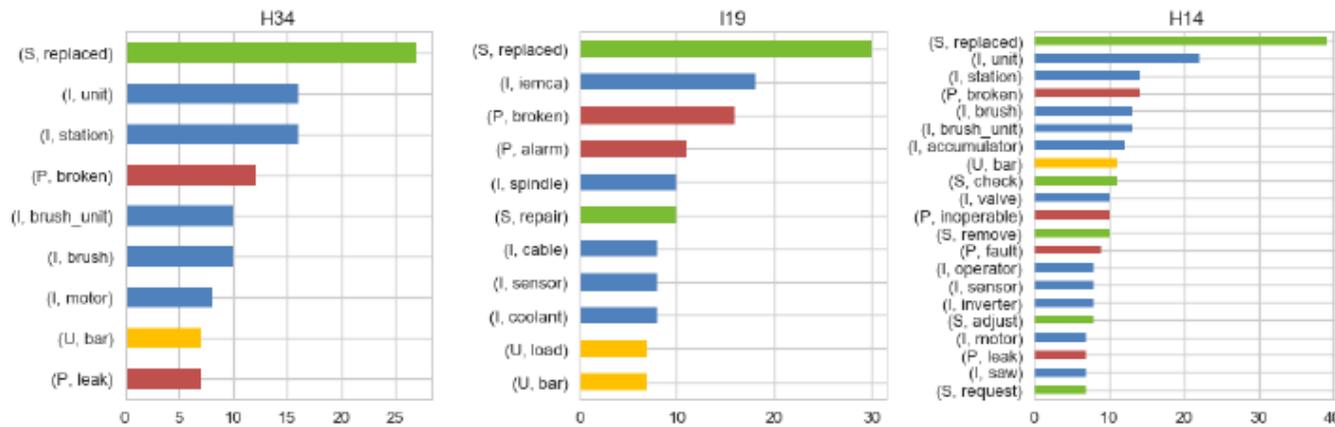
- H34 issues with `motor`, `brush_unit`
- I19 `alarms` and/or `sensors`, potentially coolant-related
- H14 wide array of issues, including `operator` (!?)
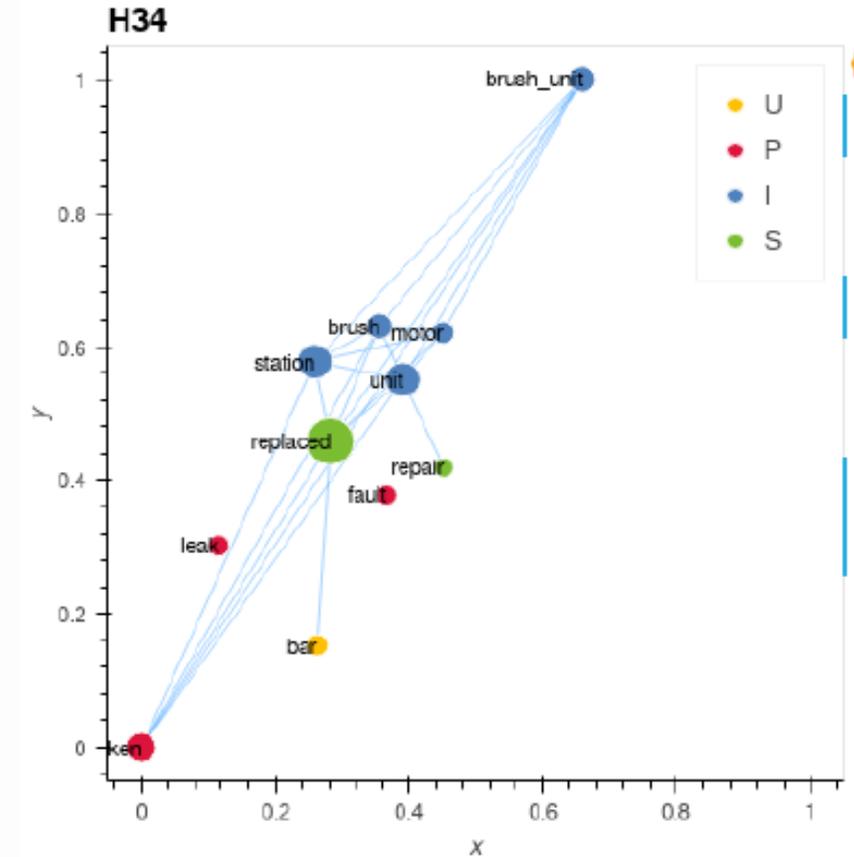
Case Studies: Technician Performance
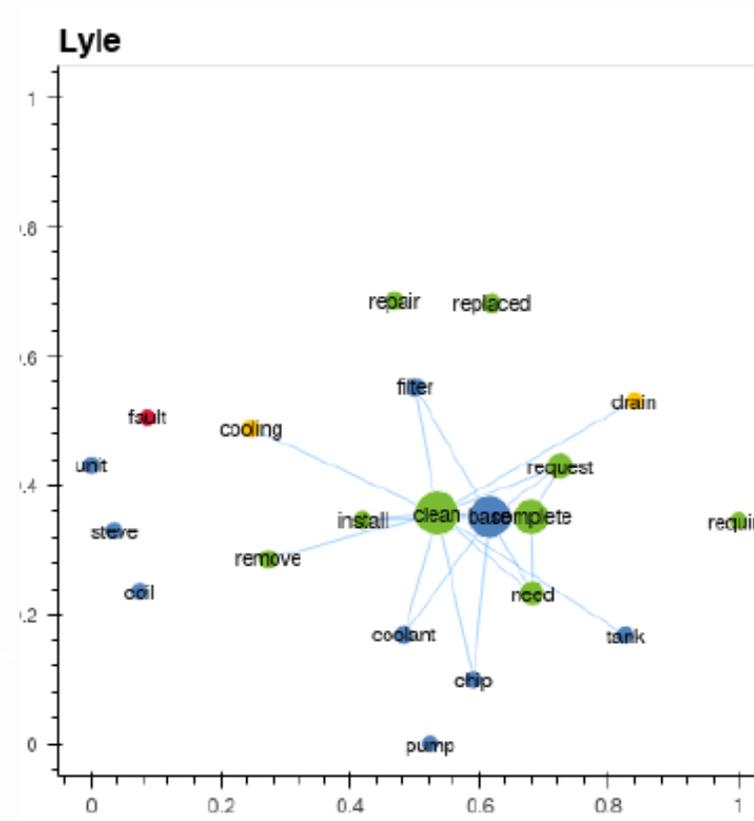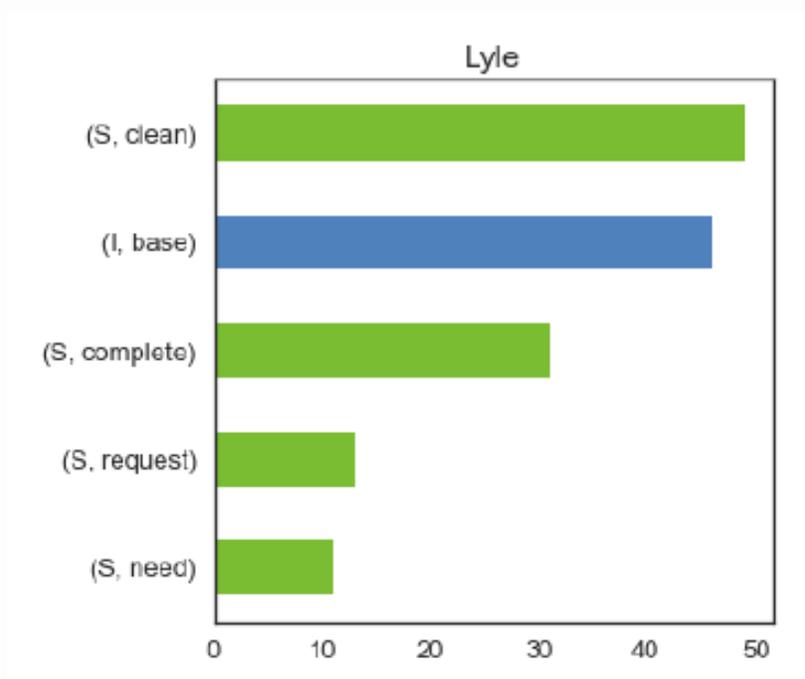
Case Studies: HVAC Hotspot Identification
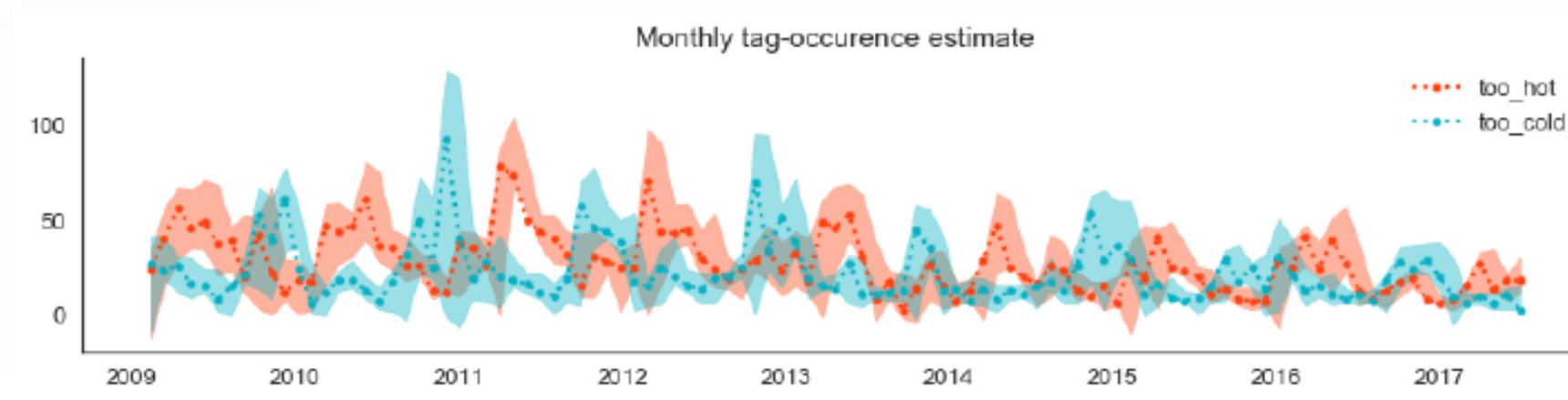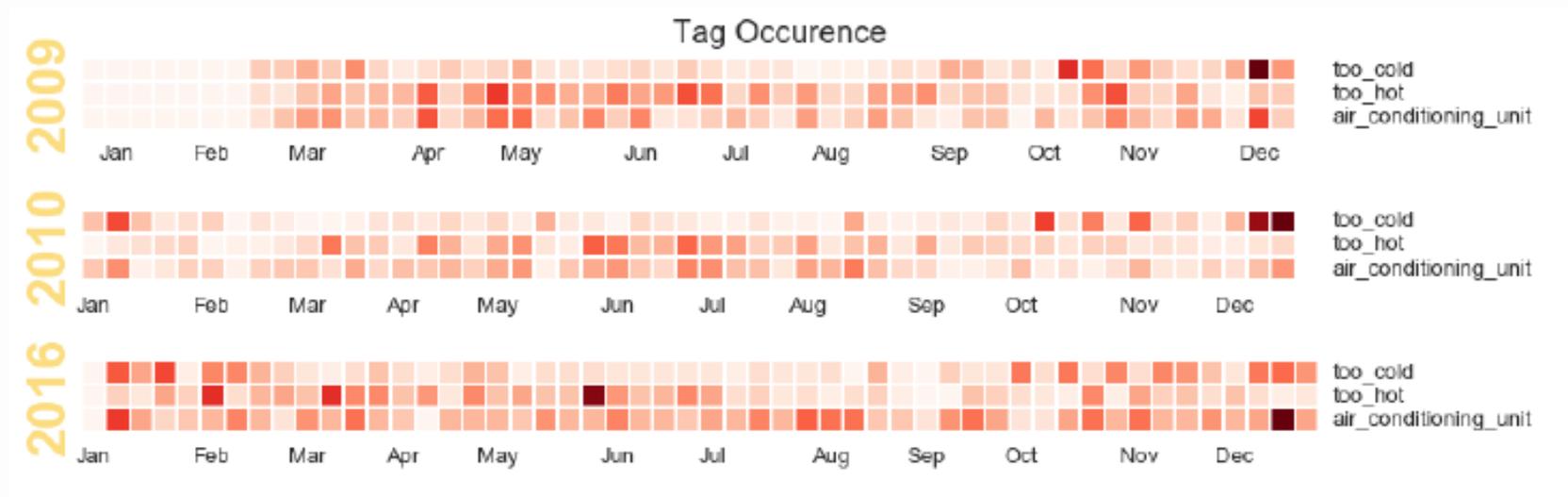
Case Studies: HVAC Hotspot Identification
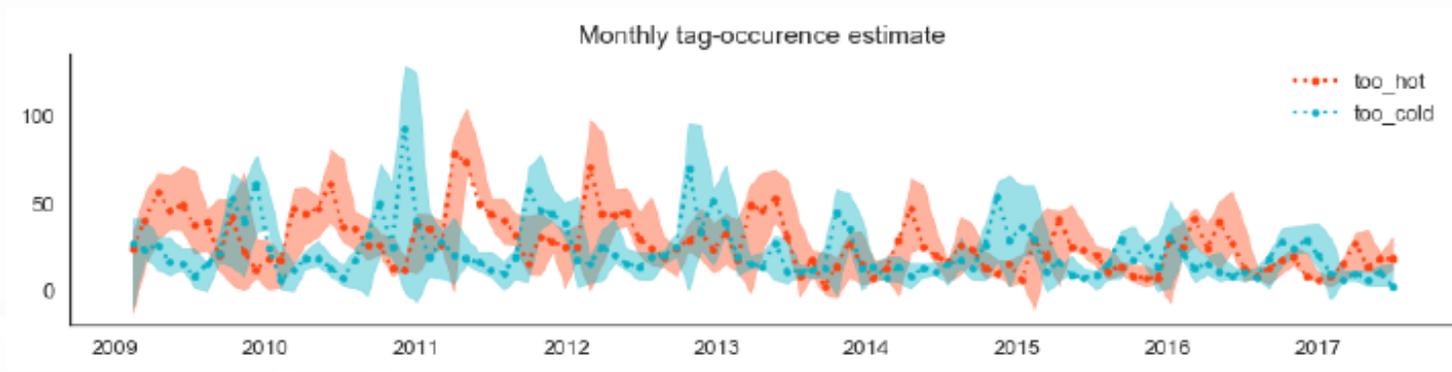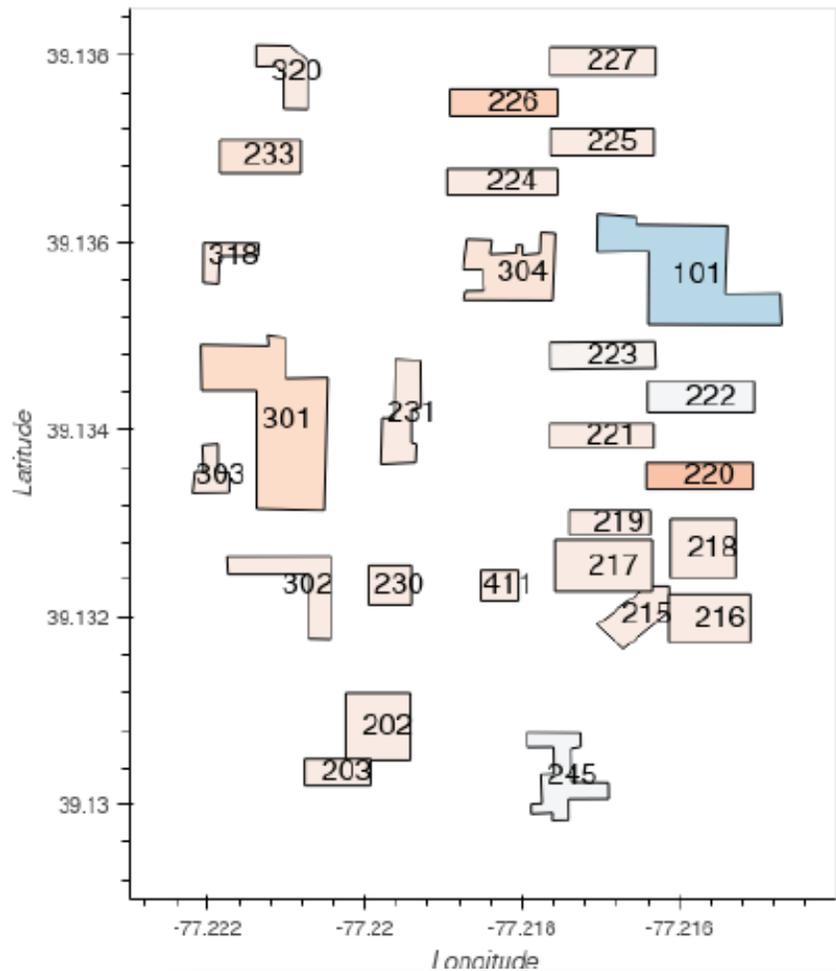
Comparing Manufacturers

Words described in
MWOs

2846

Automotive

648

327

1169

Lighting

2679

484

1358

SME
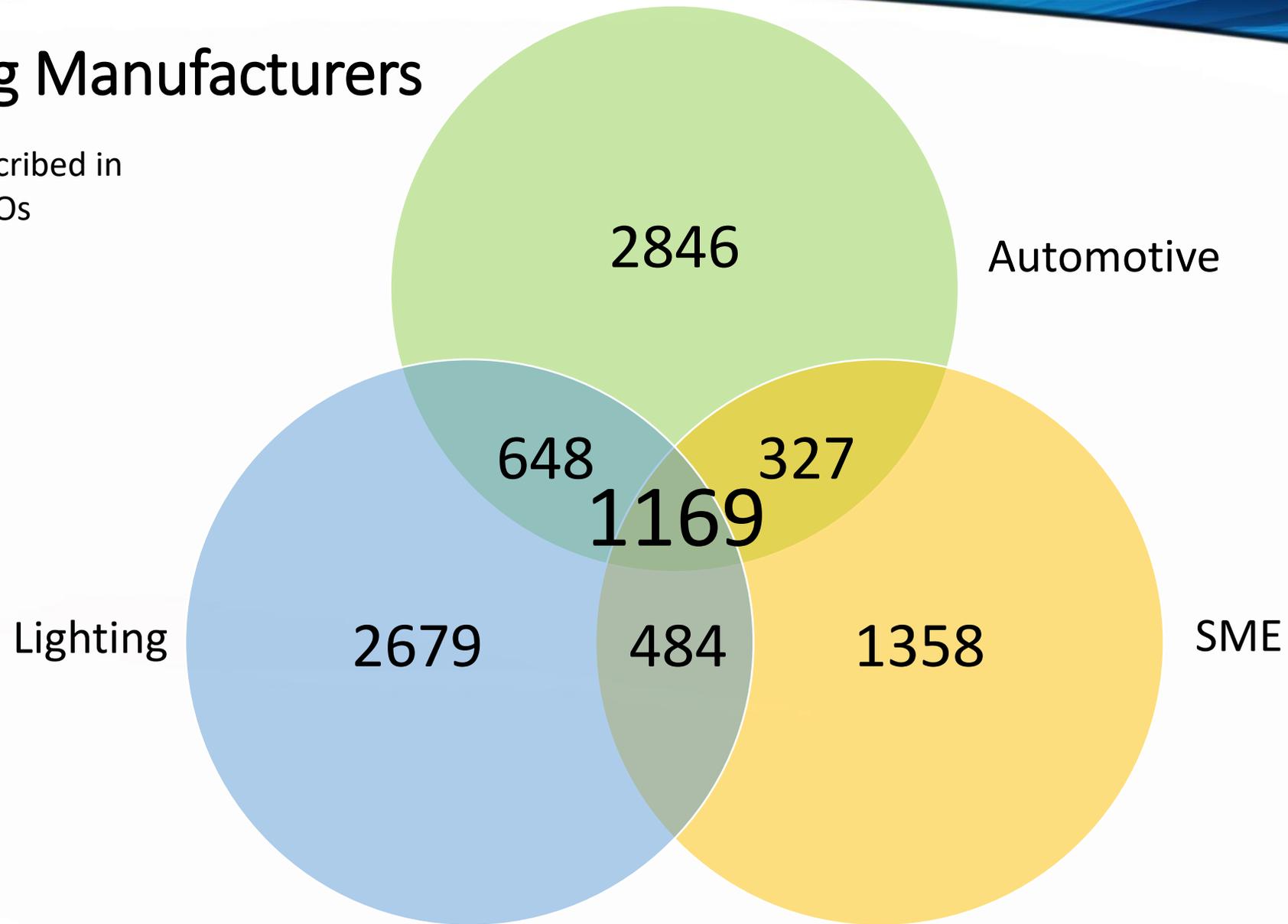
Future Work

- Tagging UI refinement and industry user studies
- Visualization UI
  - Explore alternative visualizations
- Incorporate other data sources
- More use cases
- Automated hierarchy generation and V&V
- Develop standard guidelines through ASME PHM Subcommittee

Thank you!!

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