NESTOR

MACHINE-AUGMENTED ANNOTATION FOR TECHNICAL TEXT

Thurston Sexton

Knowledge Extraction and Application for Smart Manufacturing Operations Management

Systems Integration Division
Engineering Laboratory

National Institute of
Standards and Technology
U.S. Department of Commerce

DISCLAIMER

The use of any products described in any presentation does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that products are necessarily the best available for the purpose.

Knowledge Extraction *and* ***Application***
for Smart Manufacturing Operations Management

- Much of manufacturing know-how is computationally inaccessible, within informally-written documents
- Create human-centric data pipelines to extract value from existing unstructured data at minimal labor cost
- Develop guidelines for using semi-structured data in KPI creation, functional taxonomy prediction, and customized worker training paths

MAINTENANCE WORK-ORDER DATA

"HP coolant pressure at 75 psi"

"Hyd leak at saw atachment"

"Major hydraulic leak at Sp#6 horseshoe"

"Clamping spool guard broken"

"Replaced seal in saw attachment but still leaking – Reapirs pending with ML"

"Bad Gauge / Low pressure lines cleaned ou"

"Replaced – Operator could have done this!"

"Repaired horseshoe seals"

CURRENT MWO DATA ENTRY

PHYSICAL PLANT
MAINTENANCE WORK ORDER

Date: _____

Requested by: _____

Building/Room: _____

Description of Needs: _____

Org. to be Charged:

_____

Estimated Cost Amount:

_____

Supervisor Approval: _____ Date: _____

VP of Administration Approval: _____ Date: _____

Work Completed by: _____ Date: _____

Return completed form to Administrative Services
Rev 5/01

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

Do “AI” to it!

But wait, we need to clean it first...

MANUAL CLEANING

Description	Resolution	Cause	Effect	Solutions
“Hyd leak at saw atachment”	“Replaced seal in saw attachment but still leaking – Reapirs pending with ML”			
“HP coolant pressure at 75 psi”	“Bad Gauge / Low pressure lines cleaned ou”			
“Major hydraulic leak at Sp#6 horseshoe”	“Repaired horseshoe seals”			
“Clamping spool guard broken”	“Replaced – Operator could have done this!”			

MANUAL CLEANING

Description	Resolution	Cause	Effect	Solutions
“Hyd leak at saw atachment”	“Replaced seal in saw attachment but still leaking – Reapirs pending with ML”		Hydraulic Leak at saw attachment	Replaced Seal; Repaired
“HP coolant pressure at 75 psi”	“Bad Gauge / Low pressure lines cleaned ou”	Bad Gauge	Low Coolant	Cleaned Out Low Pressure Lines
“Major hydraulic leak at Sp#6 horseshoe”	“Repaired horseshoe seals”		Major Hydraulic Leak at SP#6 Horseshoe	Repaired Horseshoe seals
“Clamping spool guard broken”	“Replaced – Operator could have done this!”	Operator error	Broken Clamping Spool Guard	Replaced Clamping Spool Guard

MANUAL CLEANING

Description	Resolution	Cause	Effect	Solutions
“Hyd leak atach				Seal; d
“HP c press 75				t Low ines
“Major h leak a horse				seshoe
“Clampin spool guard broken”	Operator could have done this!”	Operator error	Broken Clamping Spool Guard	Replaced Clamping Spool Guard

12 hours for 800 MWOs

PROBLEM

*Enter **Technical Language Processing***

- NLP Techniques do not *always* adapt well to engineering text
- Current NLP solutions need to be adapted ***correctly*** for use in manufacturing
- TLP is a methodology to tailor NLP solutions to engineering text and industry use cases in a scalable and reproducible way [1]

[1] Brundage, Michael P., et al. "Technical language processing: Unlocking maintenance knowledge." *Manufacturing Letters* 27 (2020): 42-46.

TAGGING AS ANNOTATION

“Tags” have many benefits for **users**:

- No Controlled Vocabulary
- Naturally reflect the user-base’s communication
- *Correct* abstraction level → 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
- Compare many user’s annotations for customizable validation

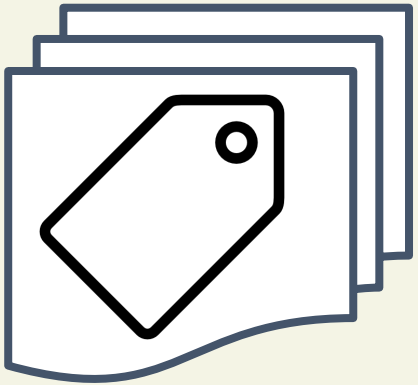
We sacrifice certainty about specific labels, and gain annotation quality & ease-of-use

BETTER, BUT WHAT NEXT?

Cause/Effects
By Hand

12 hrs
800 annotated (?)

Prob./Item/Soltn.
Tagging



12 hrs
1200 annotated

Ranked Concept Tagging

The Nestor Workflow

RANKED CONCEPT TAGGING

Description	Resolution
“Hyd leak at saw atachment”	“Replaced seal in saw attachment but still leaking – Reapirs pending with ML”
“HP coolant pressure at 75 psi”	“Bad Gauge / Low pressure lines cleaned ou”
“Major hydraulic leak at Sp#6 horseshoe”	“Repaired horseshoe seals”
“Clamping spool guard broken”	“Replaced – Operator could have done this!”

RANKED CONCEPT TAGGING

Description	Resolution
“Hyd leak at saw atachment”	“Replaced seal in saw attachment but still leaking – Reapirs pending with ML”
“HP coolant pressure at 75 psi”	“Bad Gauge / Low pressure lines cleaned ou”
“Major hydraulic leak at Sp#6 horseshoe”	“Repaired horseshoe seals”
“Clamping spool guard broken”	“Replaced – Operator could have done this!”

token	type	alias
repaired		
replaced		
leak		
seal		
hydraulic		
bad		
gauge		
low pressure		
reapirs		
hyd		

More Important

RANKED CONCEPT TAGGING

Description	Resolution
"Hyd leak at saw atachment"	"Replaced seal in saw attachment but still leaking – Reapirs pending with ML"
"HP coolant pressure at 75 psi"	"Bad Gauge / Low pressure lines cleaned ou"
"Major hydraulic leak at Sp#6 horseshoe"	"Repaired horseshoe seals"
"Clamping spool guard broken"	"Replaced – Operator could have done this!"

token	type	alias
repaired		
replaced		
leak		
seal		
hydraulic		
bad		
gauge		
low pressure		
reapirs		
hyd		

Similar Words	Same as Repaired? (Y/N)
Reapirs	
Repair	
Repir	
Rep	
Reparis	
Repaird	

RANKED CONCEPT TAGGING

Description	Resolution
"Hyd leak at saw atachment"	"Replaced seal in saw attachment but still leaking – Reapirs pending with ML"
"HP coolant pressure at 75 psi"	"Bad Gauge / Low pressure lines cleaned ou"
"Major hydraulic leak at Sp#6 horseshoe"	"Repaired horseshoe seals"
"Clamping spool guard broken"	"Replaced – Operator could have done this!"

token	type	alias
repaired		
replaced		
leak		
seal		
hydraulic		
bad		
gauge		
low pressure		
reapirs		
hyd		

Similar Words	Same as Repaired? (Y/N)
Reapirs	Y
Repair	Y
Repir	Y
Rep	N
Reparis	Y
Repaird	Y

RANKED CONCEPT TAGGING

Description	Resolution
"Hyd leak at saw atachment"	"Replaced seal in saw attachment but still leaking – Reapirs pending with ML"
"HP coolant pressure at 75 psi"	"Bad Gauge / Low pressure lines cleaned ou"
"Major hydraulic leak at Sp#6 horseshoe"	"Repaired horseshoe seals"
"Clamping spool guard broken"	"Replaced – Operator could have done this!"

token	type	alias
repaired	S	repaired
replaced		
leak		
seal		
hydraulic		
bad		
gauge		
low pressure		
reapirs	S	repaired
hyd		

Similar Words	Same as Repaired? (Y/N)
Reapirs	Y
Repair	Y
Repir	Y
Rep	N
Reparis	Y
Repaird	Y

RANKED CONCEPT TAGGING

Description	Resolution
“Hyd leak at saw atachment”	“Replaced seal in saw attachment but still leaking – Reapirs pending with ML”
“HP coolant pressure at 75 psi”	“Bad Gauge / Low pressure lines cleaned ou”
“Major hydraulic leak at Sp#6 horseshoe”	“Repaired horseshoe seals”
“Clamping spool guard broken”	“Replaced – Operator could have done this!”

token	type	alias
repaired	S	repaired
replaced	S	
leak	P	
seal	I	
hydraulic	I	
bad	P	
gauge	I	
low pressure	P	
reapirs	I	repaired
hyd	I	

RANKED TAGGING

Description	Resolution
"Hyd leak at saw atachment"	"Replaced seal in saw attachment but still leaking – Reapirs pending with ML"
"HP coolant pressure at 75 psi"	"Bad Gauge / Low pressure lines cleaned ou"
"Major hydraulic leak at Sp#6 horseshoe"	"Repaired horseshoe seals"
"Clamping spool guard broken"	"Replaced – Operator could have done this!"

token	type	alias
repaired	S	repaired
replaced	S	
leak	P	
seal	I	
hydraulic	I	
bad	P	broken
gauge	I	
low pressure	P	
reapirs	I	repaired
hyd	I	hydraulic

More Important

RANKED TAGGING

Description	Resolution	Item(s)	Problem(s)	Solution(s)
"Hyd leak at saw atachment"	"Replaced seal in saw attachment but still leaking – Reapirs pending with ML"	Hydraulic		
"HP coolant pressure at 75 psi"	"Bad Gauge / Low pressure lines cleaned ou"			
"Major hydraulic leak at Sp#6 horseshoe"	"Repaired horseshoe seals"	Hydraulic		
"Clamping spool guard broken"	"Replaced – Operator could have done this!"			

RANKED TAGGING

Description	Resolution	Item(s)	Problem(s)	Solution(s)
"Hyd leak at saw atachment"	"Replaced seal in saw attachment but still leaking – Reapirs pending with ML"	Hydraulic		Replaced
"HP coolant pressure at 75 psi"	"Bad Gauge / Low pressure lines cleaned ou"			
"Major hydraulic leak at Sp#6 horseshoe"	"Repaired horseshoe seals"	Hydraulic		
"Clamping spool guard broken"	"Replaced – Operator could have done this!"			Replaced

RANKED TAGGING

Description	Resolution	Item(s)	Problem(s)	Solution(s)
"Hyd leak at saw atachment"	"Replaced seal in saw attachment but still leaking – Reapirs pending with ML"	Hydraulic; Saw attachment; Seal	Leak	Replaced; Repaired
"HP coolant pressure at 75 psi"	"Bad Gauge / Low pressure lines cleaned ou"	High Pressure Coolant; Gauge; Low Pressure Line	Broken; Low Pressure	Cleaned
"Major hydraulic leak at Sp#6 horseshoe"	"Repaired horseshoe seals"	Hydraulic; SP#6 Horseshoe, Seal	Leak	Repaired
"Clamping spool guard broken"	"Replaced – Operator could have done this!"	Clamping Spool Guard; Operator	Broken	Replaced

Description	Resolution	Item(s)	Problem(s)	Solution(s)
“Hyd leak atach/				ced; ed
“HP c press 75				d
“Major h leak a horse				ed
“Clampi spool guard broken”	Operator could have done this!”	Clamping Spool Guard, Operator	Broken	Replaced

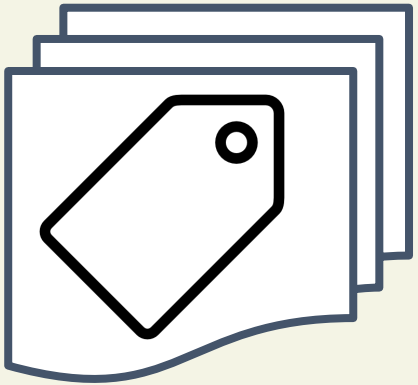
0.75 hours for *all* MWOs

RANKED CONCEPT TAGGING

Cause/Effects By Hand

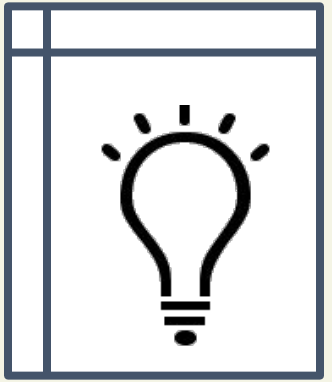
12 hrs
800 annotated (?)

Prob./Item/Soltn. Tagging



12 hrs
1200 annotated

Ranked Concept Tagging



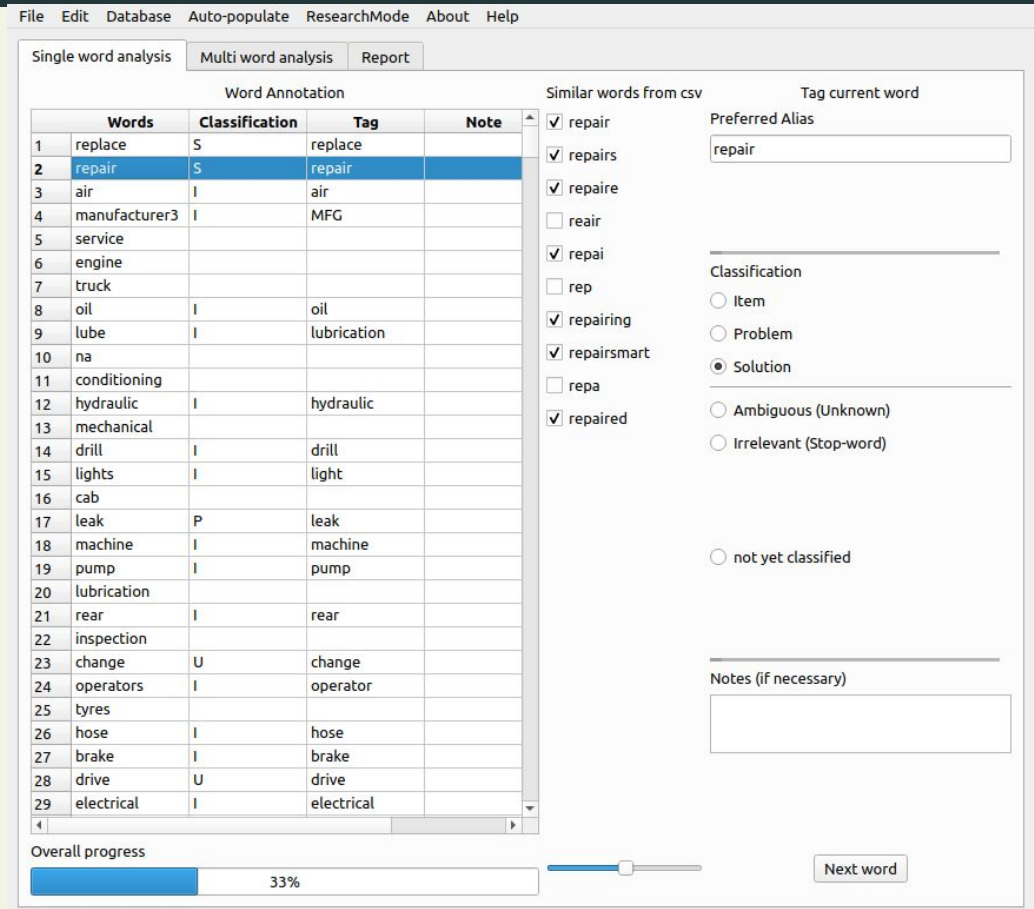
0.75 hrs
80% + (3k/3.5k)
99% partials

PUTTING IT TOGETHER

Nestor
reference implementation

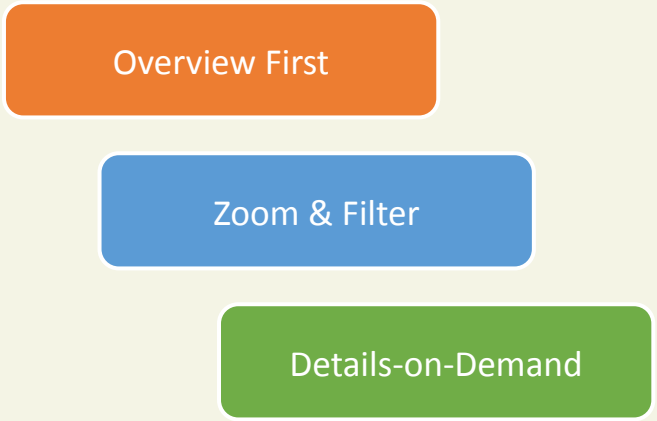
https://github.com/usnistgov/nestor

Next: When to use? How to properly treat tag-style data? Guidelines



GENERALIZE: LESSONS FROM INFO-VIZ

Mantra: *Visual Information Seeking*



Learn from Information Visualization!

Mantra: *Visual Information Seeking*

Overview First

Zoom & Filter

Details-on-Demand

Augmented Knowledge Extraction

Extract & Rank Concepts

- Unsupervised
- Fortuitous Data

Detect & Filter Relations

- “Domain” or “Stats”
- Defeat the “Hairball”

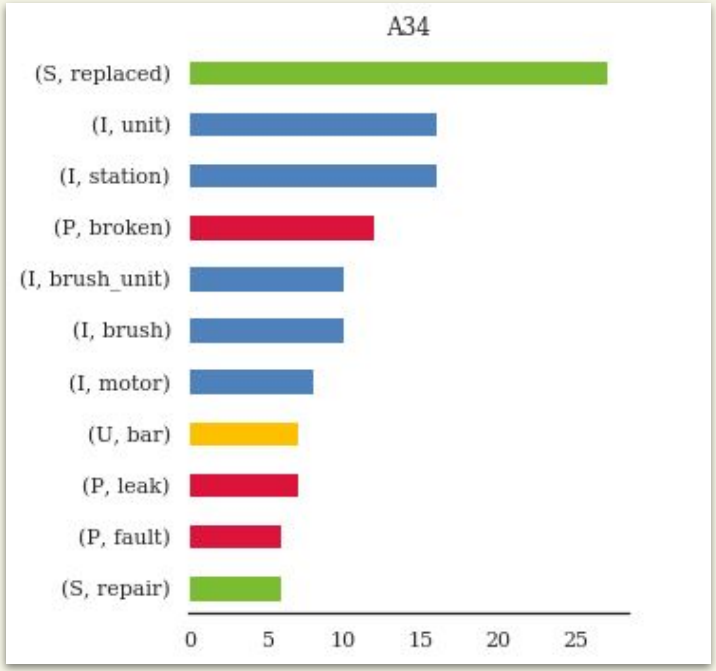
Context as Needed

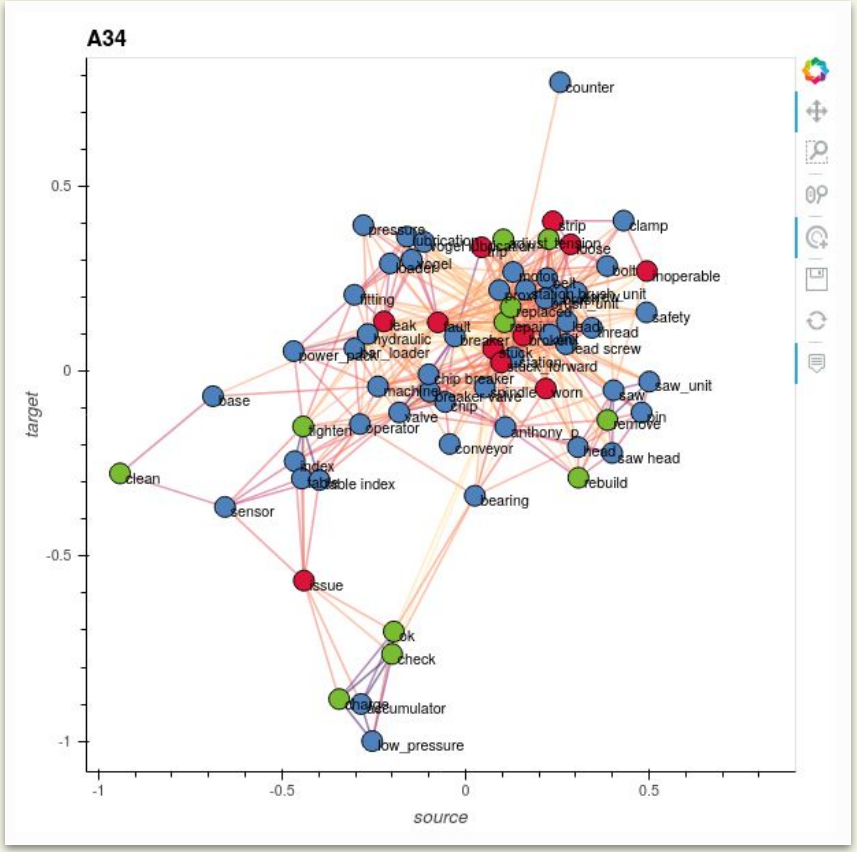
- Original?
- Abstractions?

What Now?

How do I use “tags”

Exploratory Data Analysis

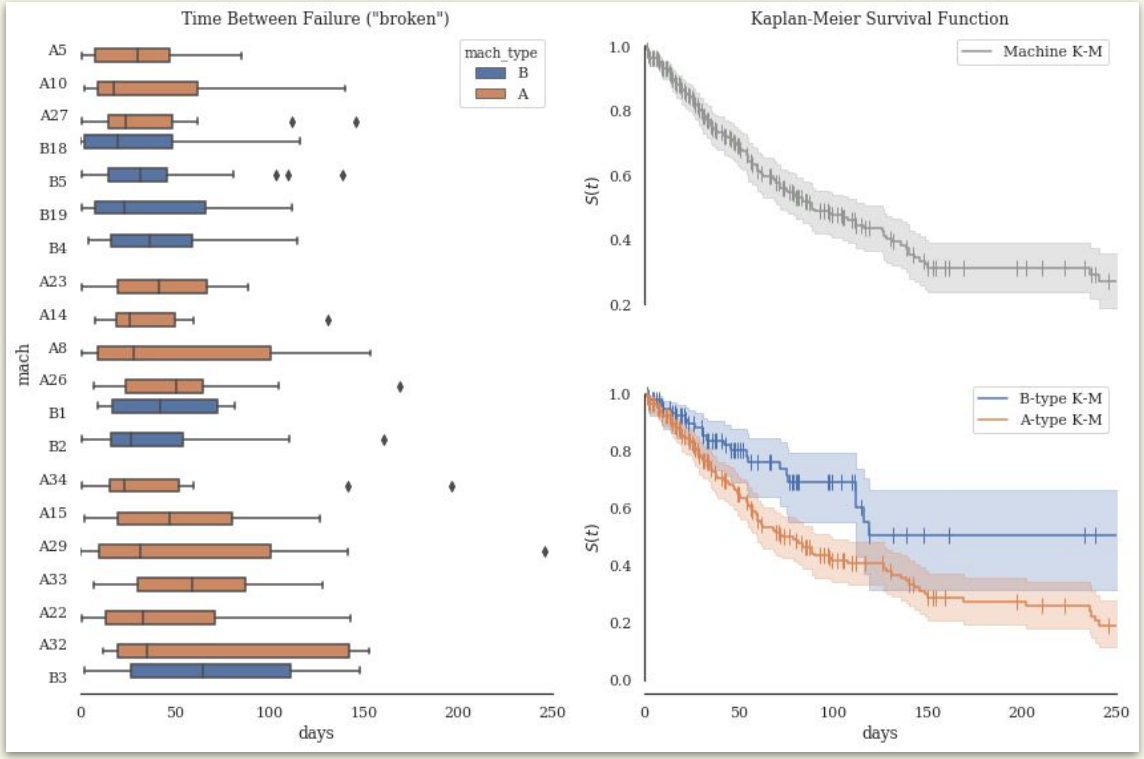




Survival Analysis

- MTBF Estimation:
  On-par with rules-based systems! [2]

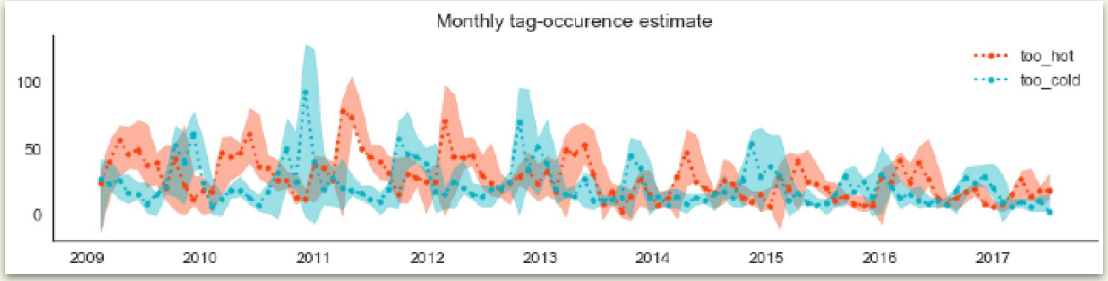
- *Coming soon:*
  Data quality benchmarking and Human-centric modeling
  [*Conte et al., under review*]

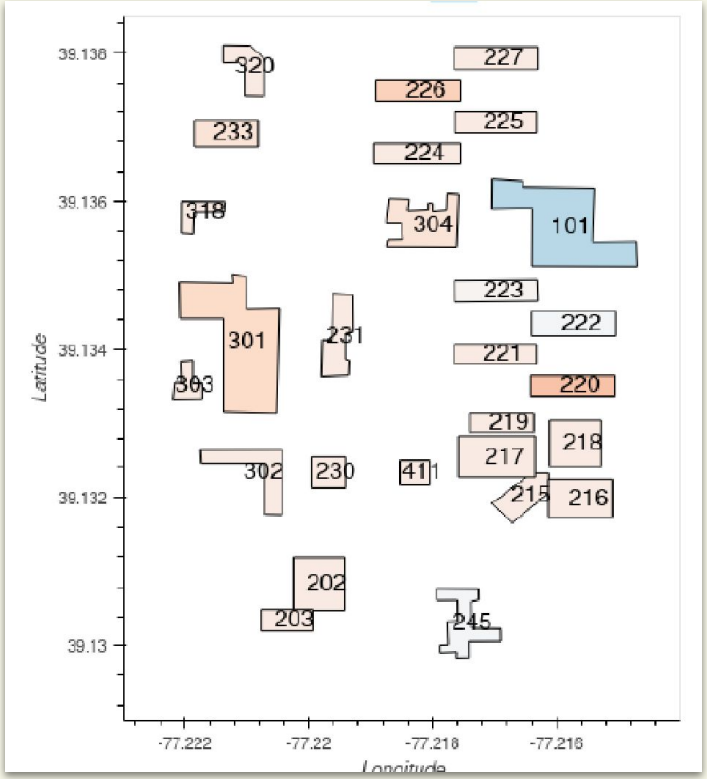


[2] Sexton, Thurston, et al. "Benchmarking for keyword extraction methodologies in maintenance work orders." *PHM society conference*. Vol. 10. 2018.

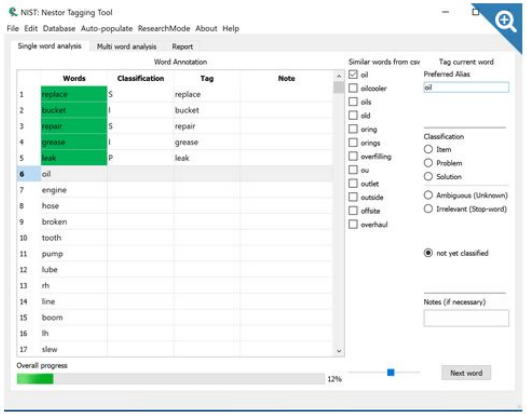
HVAC: Time Series and Impact Analyses

- Quantify intervention impacts with suitable tag combinations
- “Hackable”: easy to combine with various visualizations and query techniques.





Nestor



The Nestor Graphical User Interface (GUI) is a free toolkit that helps maintainers annotate their Maintenance Work Order (MWO) data through a process called "tagging". The MWOs are inputted as comma-separated variable (.csv) files with UTF-8 encoding into the Nestor GUI and the user goes through the tagging process to create an annotated, tagged MWO dataset. Nestor is a toolkit for using Natural Language Processing (NLP) with efficient user-interaction to perform structured data extraction from these MWOs with minimal annotation time-cost.

The user can follow the steps in the Nestor User's Guide to properly annotate the data. The source code is available on GitHub and the Installation Guide is available as well.

Once the data is annotated using the Nestor GUI, users can use this data for different analysis, such as major problem identification and skill assessment of technicians and operators. A complimentary Nestor dashboard is under development to help with pattern identification and can be tested by using this Dashboard Guide .

RELATED PUBLICATIONS

Where do we start? Guidance for technology implementation in maintenance management for manufacturing

Hybrid Datafication of Maintenance Logs from AI-Assisted Human Tags

Developing Maintenance Key Performance Indicators from Maintenance Work Order Data

Semi-Autonomous Labeling of Unstructured Maintenance Log Data for Diagnostic Root Cause Analysis

Smart manufacturing through a framework for a knowledge-based diagnosis system

Version
0.3

Type of Software
Cross-Platform GUI

Last Updated
2019-05-23

NIST Author
Thurston Sexton

Michael P. Brundage, Ph.D.

ORGANIZATIONS

Engineering Laboratory
Systems Integration Division
Information Modeling and Testing Group

SYSTEM/PLATFORM REQUIREMENTS

Windows Requirements

Windows 10 or greater

Mac Requirements

OSx v10.1 or greater

QUESTIONS?

Thurston Sexton
thurston.sexton@nist.gov

National Institute of
Standards and Technology
U.S. Department of Commerce

Copy and paste icon to desired slide. To change color, double click on icon, select color from drop down. For consistency, please use colors in the template. *Due to licensing restrictions, you can only use these icons for NIST PowerPoints.*