



IOF Maintenance WG update

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IOF meeting

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Published outputs (page 1 of 2)



IOF Maintenance Reference Ontology

- provisional status – published on IOF web site
- <https://spec.industrialontologies.org/iof/ontology/maintenance/MaintenanceReferenceOntology/>
- Available on Ontocommons Portal with FAIR Score 271 (!)
- <https://industryportal.enit.fr/ontologies/IOF-MAINTENANCE>

Maintenance Activity Ontology

- Available on [Ontocommons Portal](#)
- This ontology is derived from a set of 800 000 real-world maintenance work orders. Published in [Semantic Web Journal](#)

Published outputs (page 2 of 2)



Maintenance Procedure Ontology

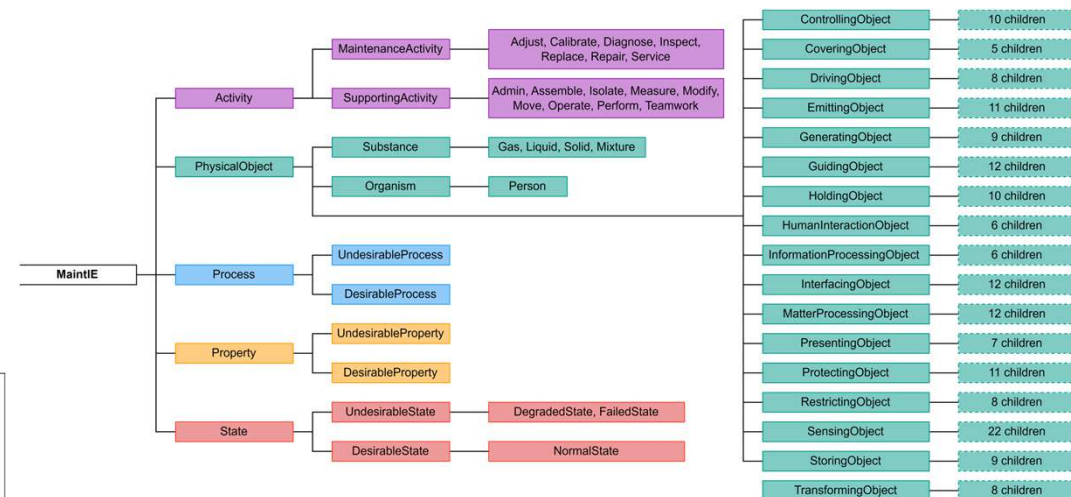
- This ontology captures information currently stored in maintenance procedure documentation in a generalizable way and supports its core users (maintenance technicians, maintenance engineers and maintenance schedulers) in their work
- 2 part modular ontology available on Ontocommons ([conditional task](#) and [static task](#))
- Published in [Applied Ontology](#)

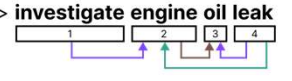
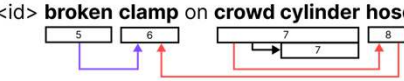
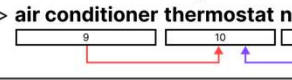
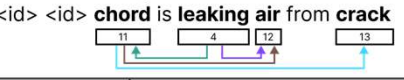

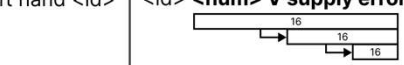
Influential uses

Foundation for entity and relation schemas for annotation schema in NLP pipelines and annotated data sets for corporate maintenance data

MaintIE: A Fine-Grained Annotation Schema and Benchmark for Information Extraction (entity AND relations) from Low-Quality Maintenance Short Texts <https://github.com/nlp-tlp/maintie>

- Gold standard fine grained annotations (3400 E & 2340 R)
- Silver annotated coarse grained (22,100 E + 15,200 R)
- 5 coarse-grained entity types
- 6 relations
- 224 fine grained entities (physical objects aligned to IEC 81346)



<p>ABC123 INVESTIGATE ENGINE OIL LEAK</p> <p><id> investigate engine oil leak</p> 	<p>CBA321 BROK CLAMP ON CROWD CYL HOSE TBC</p> <p><id> broken clamp on crowd cylinder hose TBC</p> 
<p>AB12 Air con thermostat not wking</p> <p><id> air conditioner thermostat not working</p> 	<p>123 'A' chord is leaking air from crack</p> <p><id> <id> chord is leaking air from crack</p> 
<p>1000H Mech Insp TRK CHN LH DR123</p> <p><num> hour mechanical inspection track chain left hand <id></p> 	<p>AB112 5v supply err</p> <p><id> <num> V supply error</p> 

- Corpus usable to fine-tuned (E&R) language models
- (e.g. SPERT/REBEL) for downstream use to annotate MWO's at scale and export annotations to a KG

*Paper submitted to LREC 2024

Schema used in MWO and FMEA to KG pipeline

NOTIFICATION_SHORT_TEXT
 PU311A leaking from between liners
 105,100 MWOs
 Sump well bogged
 Re-set PU0055 sump pump

Risk Name
 Low Pressure Filter - PP-316: Lubrication Cartridge Low Level due to usage
 103,000 FMEA's
 Terminal Strip - PP-315: Electric connections loose due to vibration
 Control Panel - PP-316: Control panel Short Circuit due to contamination

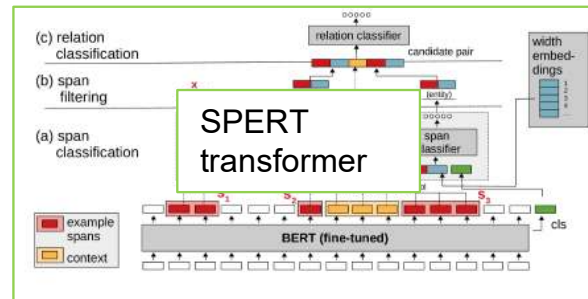
Sample & Pre-process
 (~500 from each data set)



Gold annotated strategy test set

Additional annotation to improve model performance

MaintIE – annotated MWO corpus



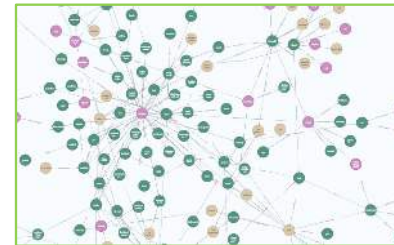
Fine-tuned maintenance-language model

Company annotated corpus

Annotation model performance

Uses all openly available tools. See end slide for links

Connect annotated KG – 105,100 MWOs + KG – 103,000 FMEAs in KG



Query on Neo4J Knowledge Graph (KG)

Puggle

Answering engineering questions using SPARQL and the ontology

Import MaintIE data set (annotated MWOs) into Protégé and answer the following types of questions using SPARQL

- Identify the types of pumps in the data set
- *Answer: 'water pump' 'implement pump' 'hydraulic pump' 'grease pump' etc.*
- Find all MWO's that contain parts of the air conditioner class
- Find all terms used to describe the 'failed state' of a part.
- *Answer includes: 'not working' 'unserviceable' 'plugged' 'disconnected' 'stuck on' 'failed' 'broken' 'blown' 'seized' etc.*
- Find all the different types of 'faults'
- *Answer includes: 'temperature fault' 'alarm fault' 'intermittent fault' 'ground fault' etc.*
- Find all parts of pumps that have experienced failed states
- *Answer includes: 'hose' 'oring' 'bolt' 'pressure gauge' etc.*

https://github.com/nlp-tlp/failure-mode-ontology/blob/main/maintie/ontology_query.ipynb

(Not public)

Current work - The Failure Ontology

Engineered Systems failures happen often – a rare few have significant consequences.

Most failures have ‘hidden’ costs – increased time to complete tasks, extra costs, more time a service is off-line, diversion of management attention.

Every organisation **identifies** failure events, **classifies** them and uses this data for continuous improvement and capital allocation **in their own way**.

There is **no agreement** on **how to describe** failures across organisations.

Hence **no pathway to machine readable** approaches to describing failures at an industry or inter-organisational level.



Examples of classification lists

Failure mode codes (ISO 142242)

Abnormal instrument reading	Insufficient heat transfer
Breakdown	Internal leakage
Delayed operation	Leakage in closed position
Erratic output	Load drop
External leakage - fuel	Loss of buoyancy
External leakage - process medium	Low oil supply pressure
External leakage - utility medium	Low output
Failure to connect	Loss of redundancy
Failure to disconnect	Minor in-service problems
Failure to rotate	Noise
Failure to close on demand	No output
Failure to function on demand	Overheating
Failure to function as intended	Other
Failure to open on demand	Parameter deviation
Failure to start on demand	Plugged / choked
Failure to stop on demand	Power / signal transmission failure
Faulty output frequency	Slippage
Faulty output voltage	Spurious high level alarm
High output	Spurious low level alarm
	Spurious operation
	Structural deficiency
	Unknown

Failure mechanisms (ISO 142242)

Failure mechanism	Notation	Failure mechanism	Notation	Failure mechanism	Notation
Mechanical	Leakage	Instrument	Control failure	External	Blockage/ plugged
	Vibration		No signal/ indication/ alarm		Contamination
	Clearance/ alignment		Faulty signal/ indication/ alarm		Miscellaneous external influences
	Deformation		Out of adjustment		
	Looseness		Software error		
Material	Sticking	Electrical	Common cause/ common mode		
	Cavitation		Short-circuiting		
	Corrosion		Open circuit		
	Erosion		No power/ voltage		
	Wear		Faulty power/ voltage		
	Breakage		Earth/ isolation fault		
	Fatigue				
	Overheating				
	Burst				

Failure Ontology project – goal



Being able to **capture asset failure information in a structured, semantically explicit way** for subsequent data use and **re-use** is vital for organisations as they manage internal and external stakeholder, regulatory and public views of failure and safety.

What do we mean by failure data?

Maintenance work orders

- **tank** has a **crack**
 - **transmission filter light** coming on
 - **power** tripped out
- (‘000’s created every month)

Maintenance notification

- **pump** is still **leaking** heavily from the **gland packing** after it has been **replaced** and **tensioned** all the way up over the last few weeks. The **shaft** is possibly **worn** from the **leak** and will **not seal up**. There is also **significant magnetic loss** starting to show from the production side.

Failure investigation reports

- The incident occurred during the **startup** of an **isomerization 1 (ISOM)** unit when a **raffinate splitter tower 2** was **overfilled**; **pressure relief devices** opened, resulting in a **flammable liquid geyser** from a **blowdown stack** that was **not equipped** with a flare. The **release of flammables** led to an **explosion and fire**.

Colour scheme

Item **activity** **state** **substance**

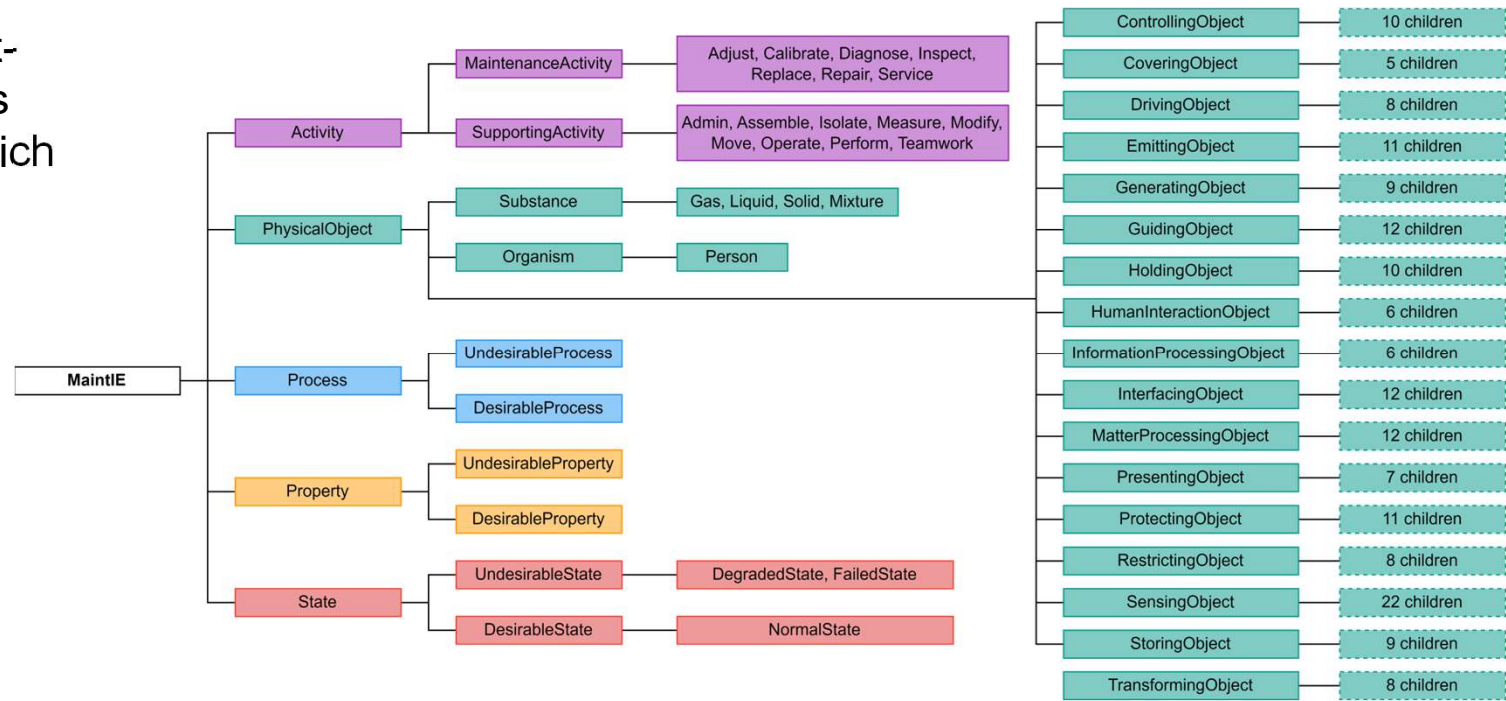
Note that relations between classes such as **hasPart**, **hasParticipant** etc are not shown here but used as are necessary for semantic meaning

Resources

MaintIE is a fine-grained expert-annotated corpus of 8,076 texts containing 43,674 tokens of which 2,409 are unique.

Failure classification lists

- ISO 14224
- Many corporate lists
- Physics of failures literature



Technical challenges

- The **mix of verbs, verb tenses, nouns and adjectives** used to describe the problem. These words map to a variety of ontological classes such as **process, quality and function**.
- The vast range of regular expressions used.
- The **lack of any ontologically coherent, tested, and agreed class structure** to classify the [Problem] words. There are some engineering Standards that inform a taxonomy of equipment problems but they reflect the view of design engineers and not the messy reality to how equipment actually behaves and is described by those who operate and maintain it.
- The need for the annotator or reader to **infer what [Physical Object] in the MWO has the [Problem]** e.g. it is the clamp that is broken not the cylinder.
- The requirement to assign codes for failure modes and mechanisms which **require the failure mode to be assigned to the equipment level** and the **mechanism to the maintainable item level** necessitating an understanding (by the coder) of both equipment hierarchy and item functions.

Examples of what we want to represent

Undesirable State

AM/FM aerial bracket **broken off** [*past participle*]
power **tripped out** [*past participle*]
faults found on **break down** [*phrasal verb*]
replace **broken** pump [*adjective*]
header tank coolant hose **holed** [*past participle*]
park brake light **staying on** [*phrasal verb*]

Undesirable Process

doors **not opening** properly [*negative present participle*]
replace air compressor **bypassing** [*gerund*]
air conditioner fan **vibrating** [*gerund*]
transmission filter light **coming on** [*phrasal verb*]
pump is leaking [*present participle*]

Undesirable Characteristic

repair **crack** in body [*noun*]
replace the **cracked** tanks [*adjective*]
alarming high crankcase **pressure** [*noun*]
front muffler has a **hole** in it [*noun*]
check **noisy** bearings [*adjective*]

Formal concept analysis (WIP)

	change in shape (no change of mass)	change in mass	change in shape and surface condition	visible change in surface characteristics	change in metallurgical characteristics	involves a fluid (air, water, lubricant)	involves electrical current	can involve dust or product	valve or closing device related	desired action not occurring	drop in force, energy, power or torque transmission	unintended connection of power components	unintended break in electrical transmission	involves undesired motion	undesired movement from intended path	involves thermal or chemical energy or reaction	motion or flow restricted	involves mechanical force
arching							x					x						
blocked						x		x	x								x	
brittled					x													
buckled	x																	x
burnt		x			X											x		
capacitance drop					x		x				x							
chipped		x																x
contaminated				x		x												
corroded		x		x	x	x										x		
cracked	x																	X
deformed	x																	X
derailed														x	x			X
detached		x												x				
deteriorated																		
discoloured				x	x											x		
exploded			x		x											x		
failedToChange State										x								
failedToClose									x	x								

Thanks to all involved



Core team involved in **IOF Maintenance Reference Ontology**

- Caitlin Woods and Melinda Hodkiewicz (UWA)
- Markus Stumptner and Matt Selway (UniSA)

With support from: Will, Serm, Elisa, Chris, Evan, Barry, Arko, Milos, Todd, Farhad, Jim (IOF) and Emily Low (UWA) – thanks 😊

Core team involved in **NLP-to-KG-to-Ontology** work

- Tyler Bikaun, Michael Stewart, Wei Liu, Tim French, Caitlin Woods, Sirui Liu, Melinda Hodkiewicz (all UWA)

New recruits for the **Failure Ontology project** (2024)

- Allison Lau, Jadeyn Feng, Chayanika Gangopadhyay (all UWA Hons students)

Call out

Please make contact with me if you are interested in participating in a project to develop ontology patterns to model data containing failure information.

It would be good to have a working group on this in IOF – aligned to other's work to model qualities.

We can set up the maintenance working mailing list if there is interest.