Trabalho Final – Eng. De Ontologias

Rafael Schena

Disponível em:
https://github.com/BDI-UFRGS/CMP196/tree/master/Pred_Maintenance_Rafael_Schena

1 - Análise ontológica do domínio, com identificação das entidades que tem identidade rígida, e as entidades dependentes (moments e relações)

Continuants
Ocurrents
Particulars

Predictive Maintenance and Health Monitoring System

Let be a system responsible for predictive maintenance and health monitoring of a facility, such as an oil and gas extraction platform. This system may be considered as a part of the whole facility maintenance system and is composed by the equipment selected to be monitored, sensors that monitor the physical quantities and information necessary to predict the equipment's condition (pressure, flow, electric current, voltage, vibration, temperature, noise, rust, abrasion level, integrity of the parts, iron filing level in the bearing grease), a supervisory system that gathers these information and displays alerts whenever any of those measurements are out of the specified range, the technical maintenance team that install and uninstall the equipment, execute maintenance actions, collect samples (if needed) to detect any anomalous condition in the equipment, and a maintenance engineering team to decide wether and when is necessary any maintenance intervention.

In this example, there is 4 equipment selected to be monitored: pump B-01 installed in the bottom of the oil well, the electric motor M-01 that drives the pump B-01 and installed attached to it, and their respective spare equipment: the pump B-02 and the electric motor M-02. The technical maintenance team is composed by 4 technicians: Jerry, Moacir, Marcos and Jeferson. The maintenance engineering team is composed by 3 engineers: Rafael, Caldas and Ulysses. In this system there are real-time measurements in the supervisory system of the following physical quantities: the suction and discharge pressure of B-01, flow through B-01, B-01 and M-01 bearings vibration, propeled petroleum temperature, voltage and current of M-01. Once happens any alert in the supervisory system, the maintenance engineering team evaluates the necessity of stopping the operation or not so that the equipment can be brought to the platform for inspection and maintenance. Once the intervention is considered necessary, the maintenance engineering team opens an immediate maintenance work order in the Computerized Maintenance Management System (CMMS) and communicate the operation the need to stop the running equipment for maintenance. The stopped equipment are brought up to the platform, and the maintenance technician working in the current turn evaluates the equipment's general conditions (rust, abrasion, integrity of the parts of M-01 and B-01), collect samples from the bearings grease from B-01 and M-01 and send them to laboratory analysis. The out-of-order equipment can be fixed or replaced by its working spare so that they can be started and the production restablished. Then, the technician fill the maintenance work order data in the CMMS.

The maintenance engineering team have acess to the information gathered by the real-time sensors, as well as the reports generated by the maintenance technical team. They also use specific maintenance engineering softwares to make predictions. So, if needed, a maintenance notification is opened in the CMMS, and the discovered anomaly will be treated along other maintenance pendencies (either preventive or corrective).

Continuants:

- Facility: BFO:object aggregate
- Equipment: BFO:object
- Oil: BFO:object
- Gas: BFO:object
- Petroleum: BFO:object
- Sensor: BFO:object
- Physical quantity: IAO:physical_object_quality
- Condition: quality
- Pressure: IAO:physical_quality
- Flow: IAO:physical_quality
- Electric_current: IAO:physical_quality
- Voltage: IAO:physical_quality
- Vibration: IAO:physical_quality
- Temperature: IAO:physical_quality
- Noise: IAO:physical_quality
- Rust: IAO:physical_quality
- Abrasion_level: IAO:physical_quality
- Integrity: IAO:physical_object_quality

- Part: BFO:object
- Iron_filing_level: IAO:physical_quality
- Bearing: BFO:object
- Grease: BFO:object
- Supervisory_system: IAO:software_application
- Alert: IAO:software_method
- Range: IAO:'one dimensional cartesian spatial coordinate datum'
- Technical maintenance team: BFO:object_aggregate
- Sample: BFO:'fiat object part'
- Anomalous condition
- Maintenance engineering team: BFO:object_aggregate
- Pump: BFO:object
- Electric_motor: BFO:object
- In_service: quality
- Spare: quality
- Measurement: IAO: 'measurement datum'
- CMMS: IAO:software_application
- Running: quality
- Stopped: quality
- out-of-order: quality
- working: quality
- Normal: quality
- Maintenance_engineering_software: IAO:software_application
- Maintenance_work_order: IAO:document
- Maintenance_notification: IAO:document
- Anomaly: BFO:disposition

Considering:

Sortal: type of object that is able to carry a uniform principle of identity, persistence and counting for all its instances [1].

Ridigity: A property is rigid if it is essential to all its possible instances; an instance of a rigid property cannot stop being an Instance of that property in a different world [2].

Quality: a trope classified under a quality type, which is an intrinsic trope type that are directly associated with a quality structure.

Rigid Sortals:

- Equipment: BFO:object
- Oil: BFO:object
- Gas: BFO:object
- Petroleum: BFO:object
- Sensor: BFO:object
- Part: BFO:object
- Bearing: BFO:object
- Grease: BFO:object
- Pump: BFO:object
- Electric_motor: BFO:object
- Maintenance_work_order: IAO:document
- Maintenance_notification: IAO:document
- Supervisory_system: IAO:software_application
- Supervisory_system: IAO:software_application
- Maintenance_engineering_software: IAO:software_application
- Maintenance_work_order: IAO:document
- Maintenance_notification: IAO:document

Moments:

- Pressure: IAO:physical_quality – quality structure: 'scalar measurement datum' – inheres in: pump
- Flow: IAO:physical_quality – quality structure: 'scalar measurement datum' – inheres in: pump
- Electric_current: IAO:physical_quality – quality structure: 'scalar measurement datum' – inheres in: electric_motor
- Voltage: IAO:physical_quality – quality structure: 'scalar measurement datum' – inheres in: electric_motor
- Vibration: IAO:physical_quality – quality structure: 'scalar measurement datum' – inheres in: equipment
- Temperature: IAO:physical_quality – quality structure: 'scalar measurement datum' – inheres in: equipment
- Noise: IAO:physical_quality – inheres in: equipment
- Rust: IAO:physical_quality – inheres in: equipment
- Abrasion_level: IAO:physical_quality – inheres in: equipment
- Integrity: IAO:physical_object_quality – inheres in: equipment

- Iron_filing_level: IAO:physical_quality – inheres in: grease
- inventory_status: IAO: quality – inheres in: equipment
- maintenance_status: IAO: quality – inheres in: equipment
- operational_status: IAO: quality – inheres in: equipment

Relações estruturantes:

Subsumption:

- grease is an object;
- sensor is an object;
- person is an object;
- petroleum is an object;
- oil is an object;
- part is an object;
- gas is an object;
- equipment is an object;
- bearing is a part;
- pump is an equipment;
- electric_motor is an equipment;
- sample is a fiat_object_part;
- facility is an object_aggregate;
- team is an object_aggregate;
- technical_maintenance_team is a team;
- maintenance_engineering_team is a team;
- physical_object_quality is a quality;
- operational_status is a quality;
- installation_status is a quality;
- maintenance_status is a quality;
- physical_quality is a physical_quantity;
- physical_quantity is a physical_quality;
- physical_quality is a physical_object_quality;
- morphology is a physical_object_quality;
- pressure is a physical_quality;
- noise is a physical_quality;
- mass is physical_quality;
- flow is physical_quality;
- iron_filing_level is physical_quality;
- voltage is physical_quality;
- vibration is physical_quality;
- electric_current is physical_quality;
- temperature is physical_quality;
- abrasion_level is physical_quality;
- rust is physical_quality;
- integrity is physical_quality;
- discharge_pressure is a pressure;
- suction_pressure is a pressure;
- not-broken is a integrity;
- broken is a integrity;
- employee is a role;
- engineer is a employee;
- technician is a employee;
- fixing_equipment is a planned_process;
- measurement is a measurement_datum;
- measurement_datum is a measurement;
- measurement is a data_item;
- measurement_datum is a data_item;
- scalar_measurement_datum is a measurement_datum;
- vibration_measurement_datum is a scalar_measurement_datum;
- mass_measurement_datum is a scalar_measurement_datum;
- noise_measurement_datum is a scalar_measurement_datum;
- temperature_measurement_datum is a scalar_measurement_datum;
- electric_current_measurement_datum is a scalar_measurement_datum;
- flow_measurement_datum is a scalar_measurement_datum;
- voltage_measurement_datum is a scalar_measurement_datum;
- pressure_measurement_datum is a scalar_measurement_datum;
- iron_filing_measurement_datum is a scalar_measurement_datum;
- measurement_unit_label is a datum_label;
- vibration_unit is a measurement_unit_label;
- electric_current_unit is a measurement_unit_label;
- iron_filing_unit is a measurement_unit_label;

- flow_unit is a measurement_unit_label;
- noise_unit is a measurement_unit_label;
- voltage_unit is a measurement_unit_label;
- pressure_unit is a measurement_unit_label;
- temperature_unit is a measurement_unit_label;
- anomaly is a disposition;
- alert is a software_method;
- maintenance_engineering_software is a software_application;
- supervisory_system is a software_application;
- cmms is a software_application;
- range is an one_dimension_cartesian_spatial_coordinate_datum;
- maintenance_notification is a document;
- maintenance_work_order is a document;

Part-of:

- facility has_part equipment;
- facility has_part sensor;
- facility has_part part;
- team has_element person;
- petroleum has_subquantity gas;
- petroleum has_subquantity oil;
- part is component of equipment;
- engineer is element_of maintenance_engineering_team;
- technician is element_of technical_maintenance_team;

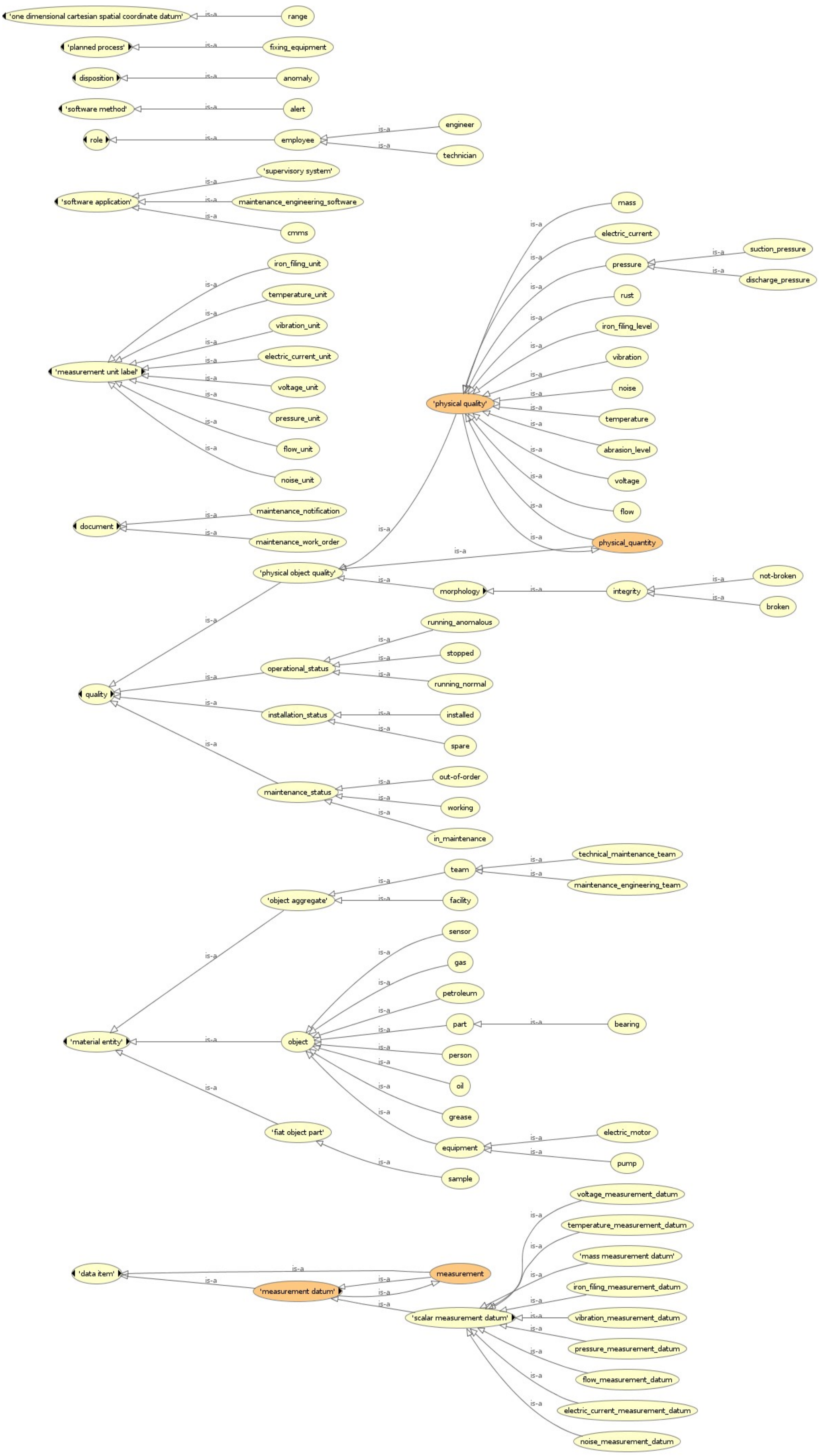
2- Defina um processo para ser modelado e de que forma afeta entidades continuantes (criando/destruindo entidades, alterando suas qualidades, modificando papéis). Lembrem-se que uma instancia de processo é identificada pela detecção da modificação que causam nas instancias dos continuantes.

Processo a ser modelado: fixing_equipment, modelado no Protégé.

Definition: The process of repairing an equipment out-of-order so that it can be able to work normally. The installation status is changed from out-of-order to working after the process is complete.

3- Construa o modelo conceitual especializando a BFO (entidades materiais), a RO (relações), a IAO (artefatos de informação, se for o caso), e outras ontologias necessárias.
Feito no Protégé.

Figure 1: Print da árvore com a visão geral do modelo na BFO



4- Definição das entidades. Os itens a. até e. são definidos como annotations properties no Protege, enquanto o f. são object properties. Descreva as entidades com:
a. Label (nome que a entidade será referenciada)
b. Definição semi formal (pode ser descritiva, não precisa ser em Lógica, mas atentem para a precisão)
c. URL da fonte ou referência bibliográfica
d. Sinônimos (se houver)
e. Exemplo de uso
f. Relações de disjunção ou equivalência com outras entidades, se houver.

Feito no Protégé.

5- Definição dos moments das entidades definidas e, quando tiverem estruturas de valores, descrição dos quality domains.

Moments:

- Pressure: IAO:physical_quality – quality structure: 'scalar measurement datum' – inheres in: pump
- Flow: IAO:physical_quality – quality structure: 'scalar measurement datum' – inheres in: pump
- Electric_current: IAO:physical_quality – quality structure: 'scalar measurement datum' – inheres in: electric_motor
- Voltage: IAO:physical_quality – quality structure: 'scalar measurement datum' – inheres in: electric_motor
- Vibration: IAO:physical_quality – quality structure: 'scalar measurement datum' – inheres in: equipment
- Temperature: IAO:physical_quality – quality structure: 'scalar measurement datum' – inheres in: equipment
- Noise: IAO:physical_quality – inheres in: equipment
- Rust: IAO:physical_quality – inheres in: equipment
- Abrasion_level: IAO:physical_quality – inheres in: equipment
- Integrity: IAO:physical_object_quality – inheres in: equipment
- Iron_filing_level: IAO:physical_quality – inheres in: grease
- inventory_status: IAO: quality – inheres in: equipment
- maintenance_status: IAO: quality – inheres in: equipment
- operational_status: IAO: quality – inheres in: equipment

6- Definição das relações. Inclua no seu modelo pelo menos uma relação do tipo descritiva interna, descritiva externa, não-descritiva interna, não-descritiva externa. Para cada uma descreva:
a. Label (nome que a entidade será referenciada)
b. Definição semi formal
c. URL da fonte ou referência bibliográfica
d. Características da relação
e. Exemplo de uso
f. Relações de disjunção ou equivalência, se houver.

Descritiva interna: heavier_than
Descritiva externa: driven_by
Não-descritive interna: higher_than
Não-descritiva externa: component_of

7- Definição de relações mereológicas. Inclua no seu modelo pelo menos uma relação do tipo component-of, subquantity-of e element-of.
Relações e suas inversas:
element_of / has_element
subquantity_of /has_subquantity
composed_of / composed_by

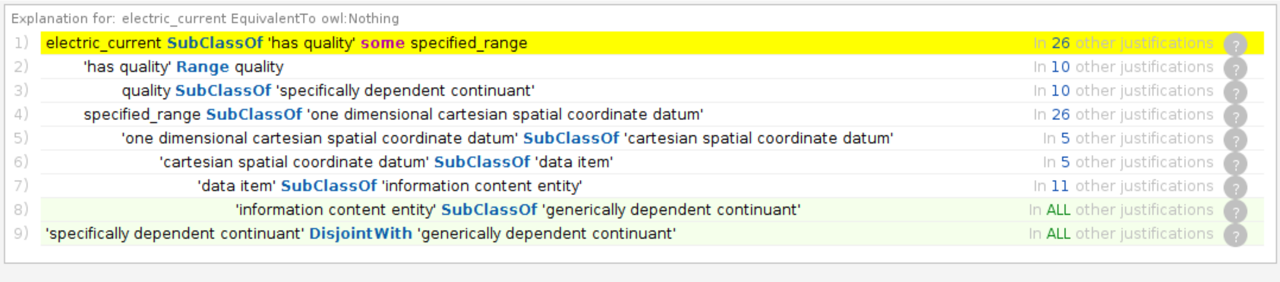
8- Definição de instâncias suficientes para validar o modelo.

Feito no Protégé.

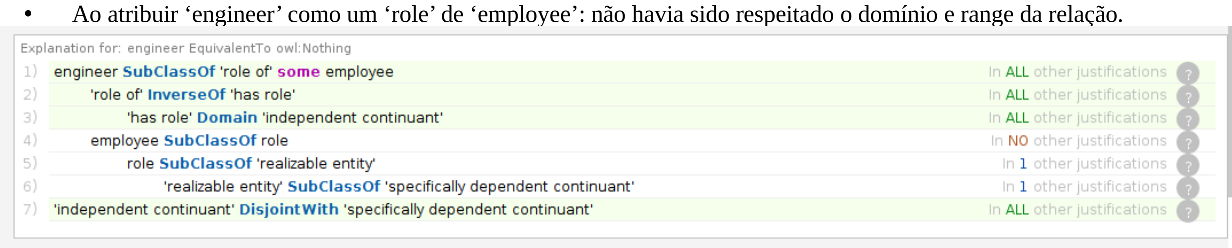
9- Descrição das informações ou inconsistências que podem ser extraídas com os raciocinadores do Protege. Em modelos pequenos, as inferências podem não mostrar muita informação útil, mas anotem inconsistências encontradas no processo de criação da ontologia.

Inconsistências:

- Ao tentar atribuir 'specified_range' como uma qualidade de 'physical_quality': não havia sido respeitado o domínio e range da relação.



- Ao atribuir 'engineer' como um 'role' de 'employee': não havia sido respeitado o domínio e range da relação.



10- (Não obrigatório) Verifique se existem ontologias no mesmo domínio e derivadas da BFO, com código OWL, que possam ser reusadas no seu trabalho.

Sim, existem 2 ontologias de manutenção encontradas e que poderiam ser utilizadas, porém não sem prejuízo da descrição anteriormente feita.

Uma delas é a ontologia de manutenção da **IOF** (https://www.industrialontologies.org/maintenance-wg/) (https://github.com/uwasystemhealth/IOF_Maintenance_Working_Group_Public), porém muito focada no processo de gestão da manutenção. Ainda está claramente em construção, com muitos termos ainda não classificados (existe um grupo de trabalho discutindo isto periodicamente) e algumas definições que parecem incompatíveis com a IAO (por ex.: CMMS). Como eram poucos termos que poderiam ser facilmente reaproveitados, optou-se por não utilizá-la neste momento.

A outra trata-se da ontologia do projeto **Z-BRE4K**, específica para manutenção preditiva. Especializa a ontologia da IOF, detalhando o processo de manutenção preditiva. Trata-se de uma ontologia bastante desenvolvida, que traz a abordagem gerencial (inclusive descrevendo prestadores de serviço e fornecedores de peças). A descrição do processo de manutenção preditiva é feita com base em modos de falha, suas causas e efeitos e criticidade das falhas, associando cada modo de falha a um componente, de acordo com a metodologia de manutenção centrada em confiabilidade. Não foi encontrado até o momento o arquivo .owl da ontologia, apenas a descrição da mesma em pdf. Não entra em detalhes de equipamentos, ficando a cargo de cada empresa participante do consórcio especializar para cada caso. São apresentados casos de 2 empresas (https://www.z-bre4k.eu/wp-content/uploads/2020/12/Z-BRE4K-semantic-modelling.pdf). Por esta razão e pela incompatibilidade entre a abordagem que já vinha sendo utilizada no estudo de caso do TF optou-se por não utilizá-la neste momento. No entanto, trata-se de uma boa alternativa para ser reutilizada no restante do projeto de mestrado, bastando para isto ter os estudos de manutenção centrada em confiabilidade dos sistemas selecionados.

References:

[1] - Guizzardi, G. and Zamborlini, V., 2014. Using a trope-based foundational ontology for bridging different areas of concern in ontology-driven conceptual modeling. Science of Computer Programming, 96, pp.417-443.

[2] - Guarino, N. and Welty, C.A., 2004. An overview of OntoClean. *Handbook on ontologies*, pp.151-171.

[3] - Fonseca, C.M., Porello, D., Guizzardi, G., Almeida, J.P.A. and Guarino, N., 2019, November. Relations in ontology-driven conceptual modeling. In *International Conference on Conceptual Modeling* (pp. 28-42). Springer, Cham.