Application of knowledge graphs in aerospace education

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June, 2020

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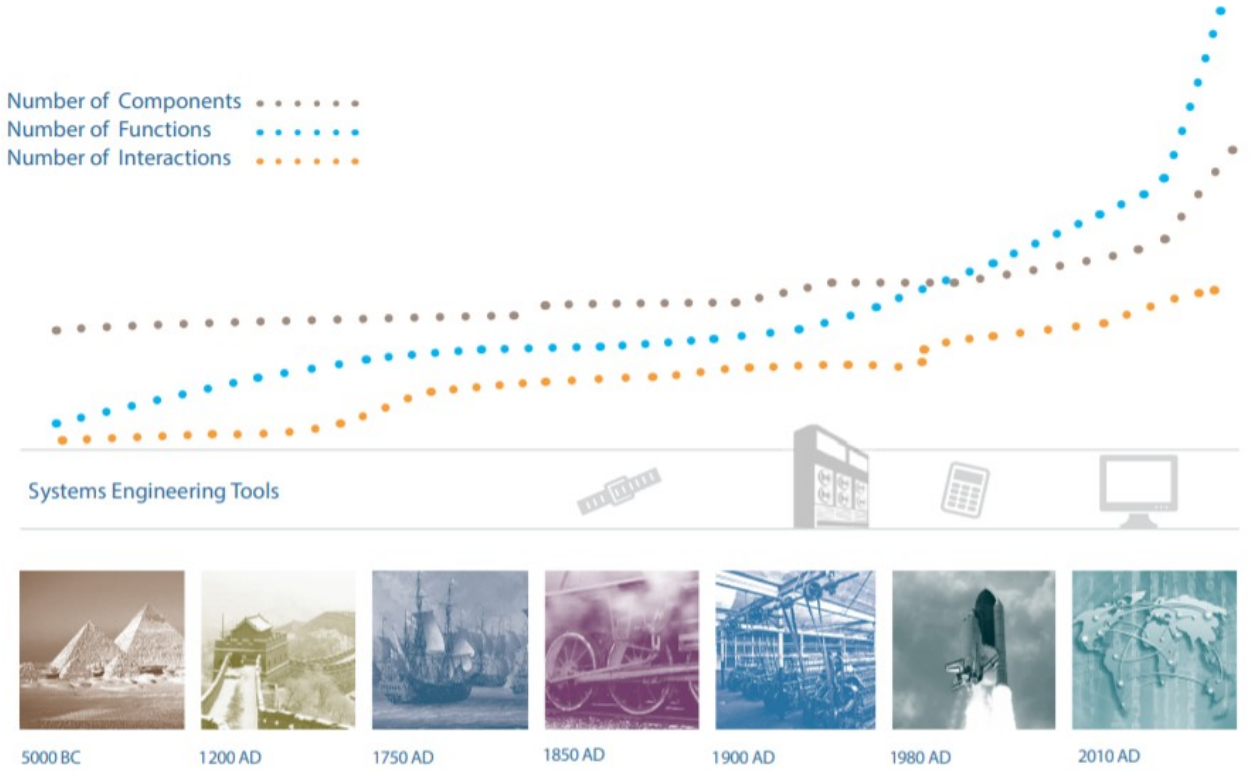
General problem / Introduction / Background

Complexity

“number of system functions, components, and interfaces and their non-linear
interactions and emergent properties”
INCOSE 2025



Complexity - INCOSE 2025 [1]

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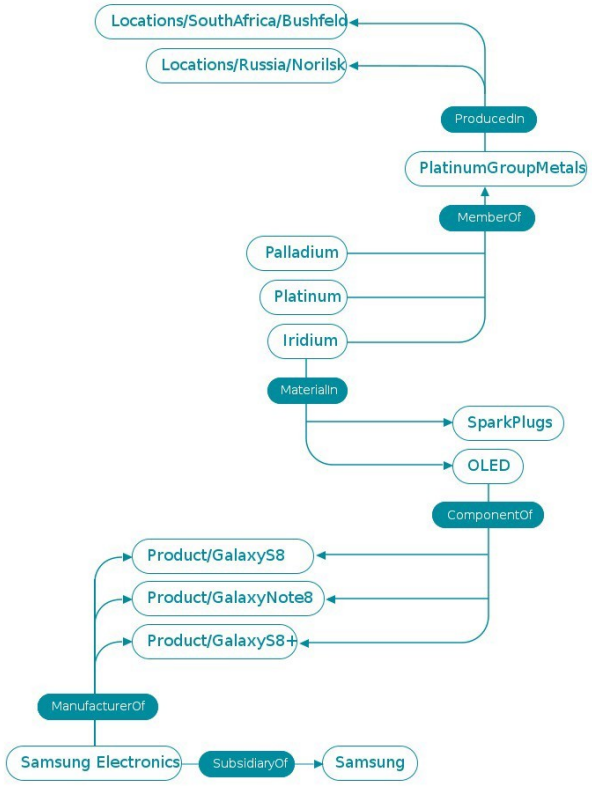
General problem / Introduction / Background – Knowledge Graphs

There is no clear definition of what is Knowledge graph.
KG technologies could be considered as a continuation of the semantic web, linked data, reasoning engines, data integration methods, etc.



An example of Knowledge graph with hyterogenous information (multiple domains, data sources) . c Forge.Ai [4]

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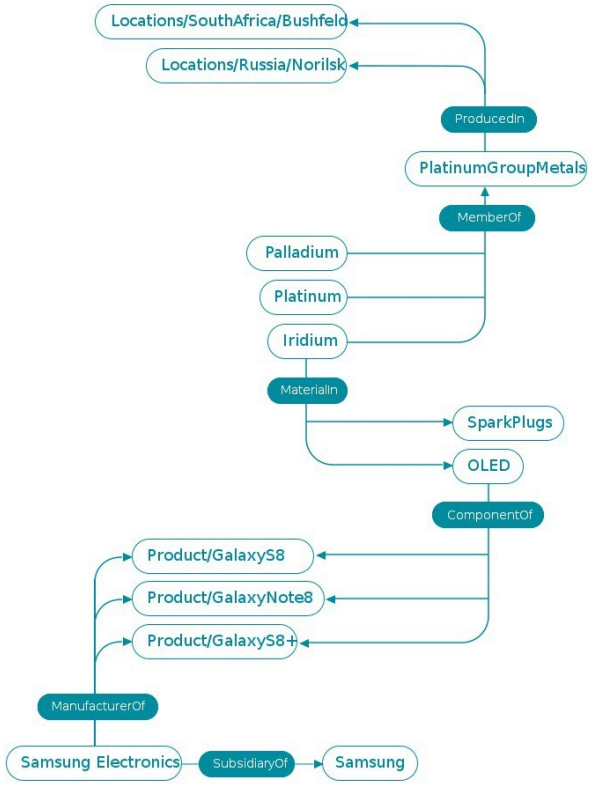
General problem / Introduction / Background – Knowledge Graphs

- KG in industry (basically on very competitive markets, like B2C CPS product-services, chemical, heavy industry, medicine) [2][3]
- KG is term closely related to Semantic Web, ontology, property graphs, etc.
- fundamentally based on cognitive science and linguistics



An example of Knowledge graph with hyterogenous information (multiple domains, data sources) . c Forge.Ai [4]

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- so I decided to research how to apply this to aerospace
- and make a prototype, but Knowledge Graph (KG) is not a very formal structure, but aerospace requires high formality and reliability

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General problem / Introduction / Background

- solution: make web-app for early stages of engineering research, it is still complex, cross-discipline and requires explainability, but requires a speed of obtaining a result more than the reliability of models.
- but software which collects data of early research models requires a high-quality app and strong security restrictions.
- solution: web-app for early research models and simulations of students in an education process.

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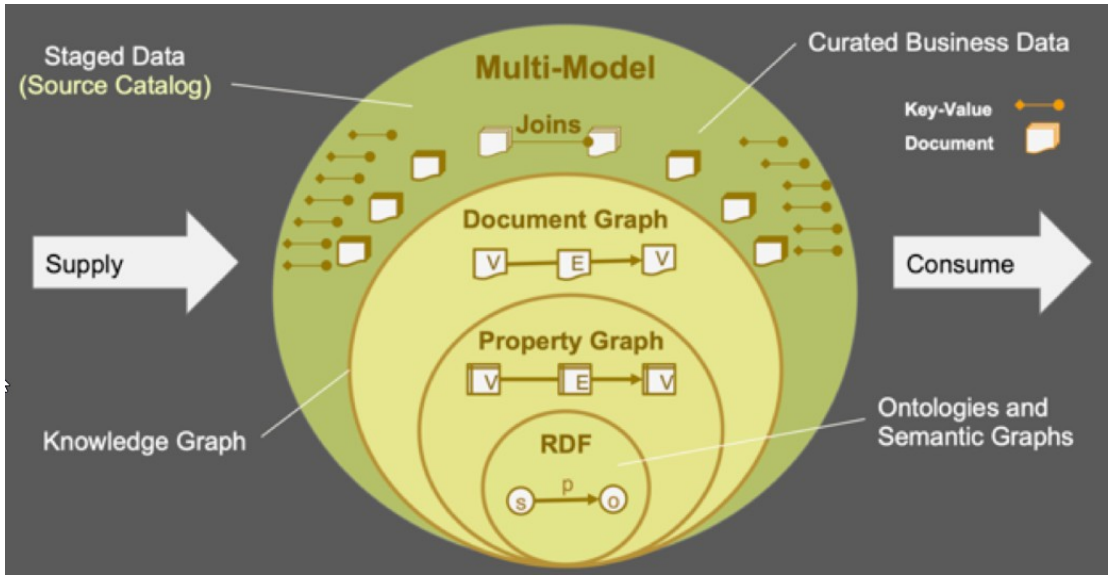
- articles about application semantic technologies and KGs in aerospace and other industries to understand the pros and cons [6.1-6.7].
- the articles basically based on ontologies, RDF triples, OWL, reasoners, rule engines, etc.
- and commercial applications based on a very complex bunch of products.



ArangoDB conceptual image of EKG [5]

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General problem / Introduction / Background

- a graph-based multi-model database instead of classical ontology engineering with triples and related classical products like Protege.
- it gives more control on data structure for a research without restrictions of “classic” technologies

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General problem / Introduction / Background – WEB

- to make prototype means create a user-friendly interface
- Web today is de facto standard for wide-usable applications
- in last years there are a few attempts to move engineering tools to the web (onshape, valispace, etc.)

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Aim and objectives

The aim is to find a way for easy development of engineering apps based on knowledge graphs to increase the work efficiency of an engineering community.

- check efficiency and developer-friendliness of an approach to development of web apps based on a graph-based multi-model database.
- create a web app with a combination of a few basic functions that combined based on one data structure.

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Methods

List the methods you've used – without much technical detail, but all of them (to show your proficiency)

- graph-based multi-model database 

- technologies for web: webgl, glTF libs. 

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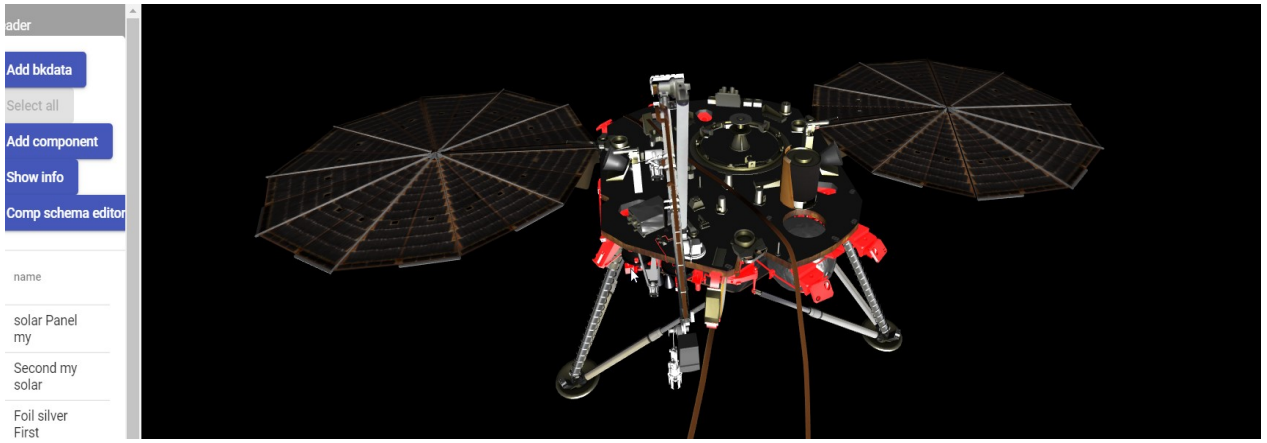
Results

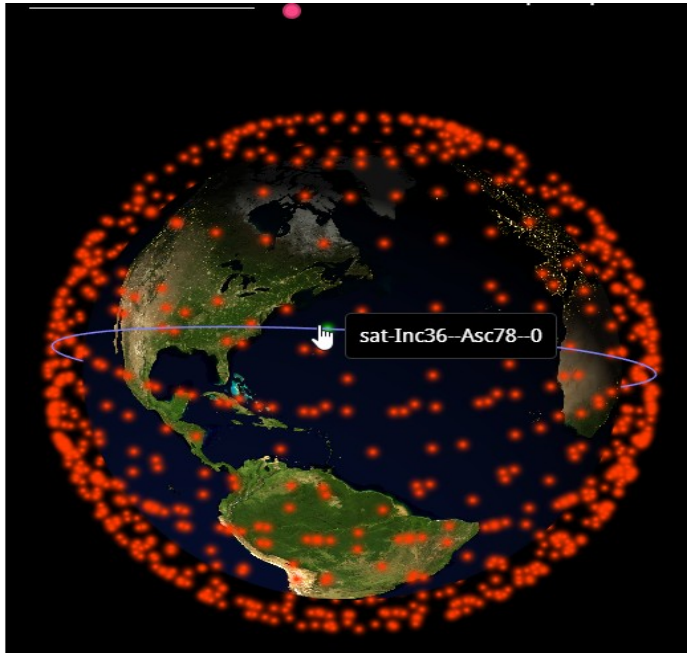
Primary and processed results of research in the form of graphs, tables, pictures, and charts.

- web-based app to create a hierarchy of components with editing parameter values online. Based on a graph-based structure in the backend.

Results

- app functions based on open web technologies and libraries: for 3d interactive models of satellite structure and the interactive orbits visualization





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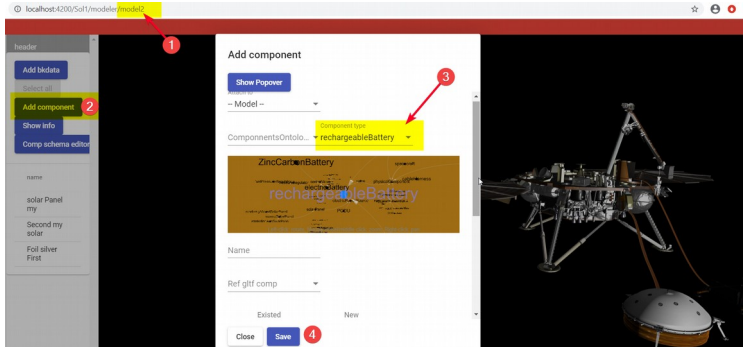
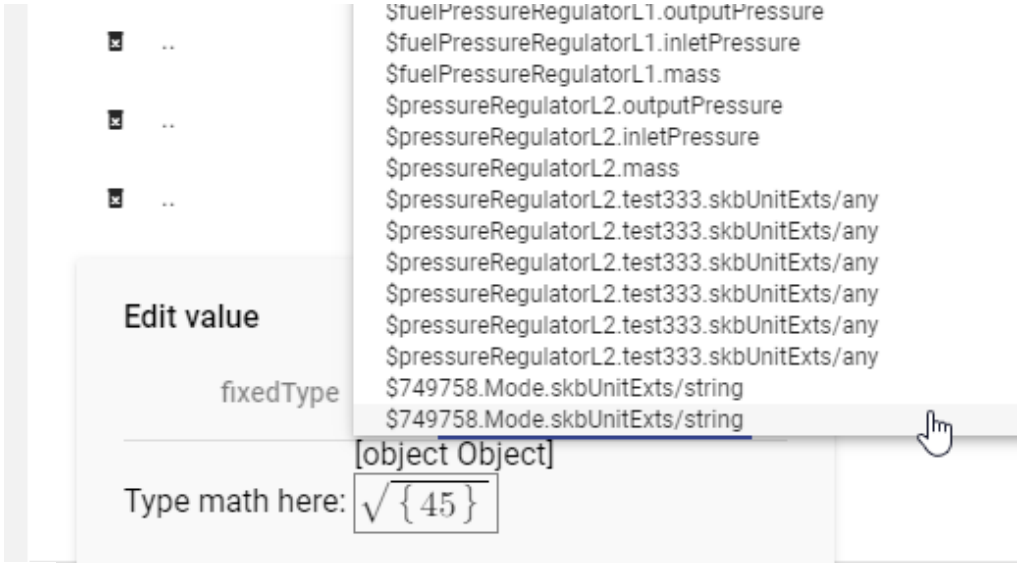
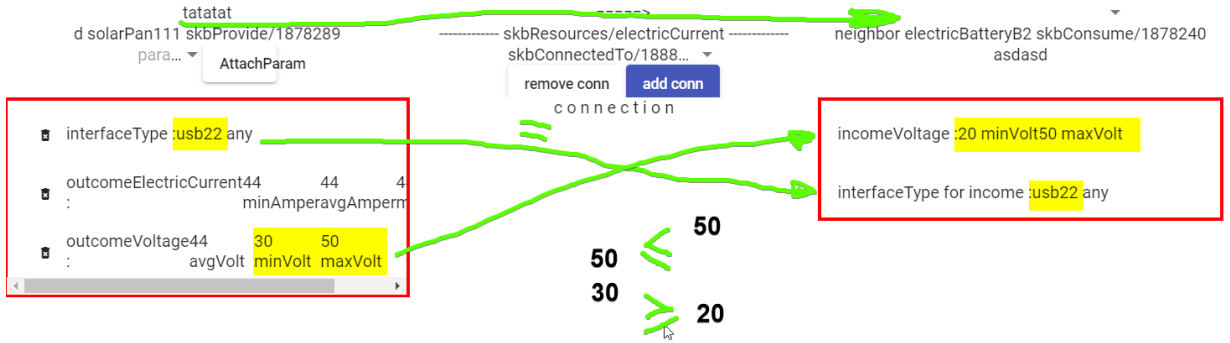
Results

- components hierarchy
- creating an editing parameters
- interface connections







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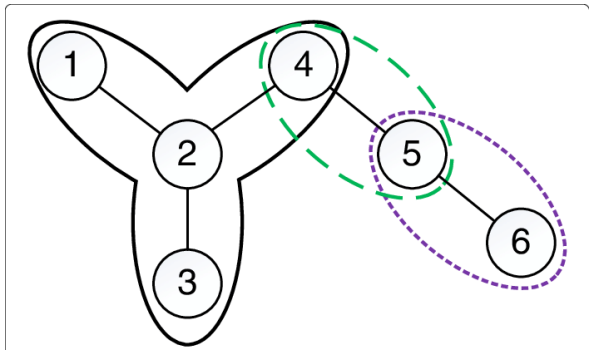
Results

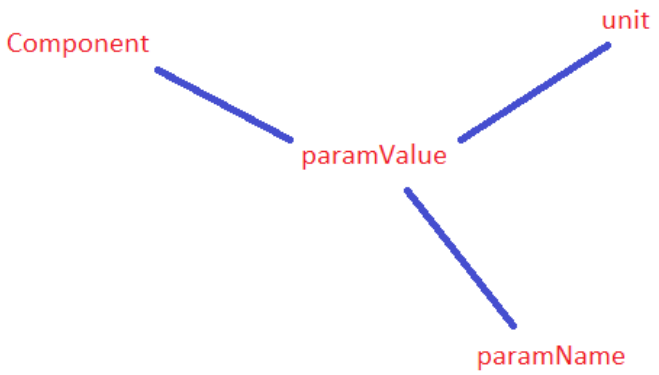
- back-end. Data structure, Graph-JSON

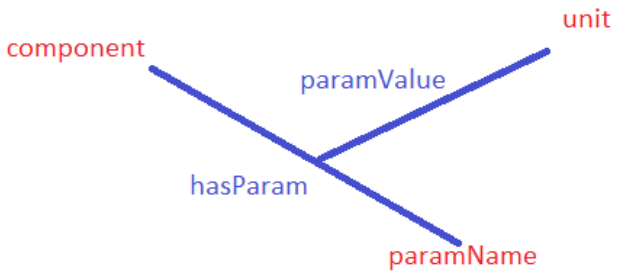
1) Flexibility (edge can be a start node for another edge)

2) App interpretation responsibility. Data is provided as it is.

3) Then data structure moved to hyperedges direction







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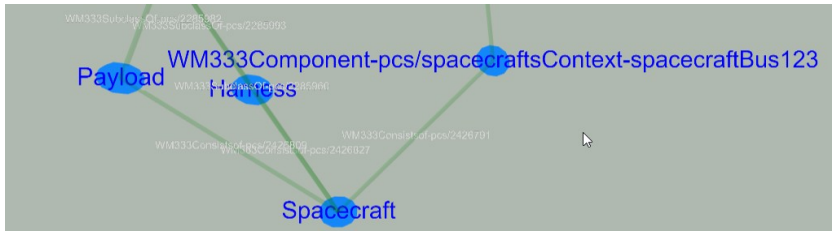
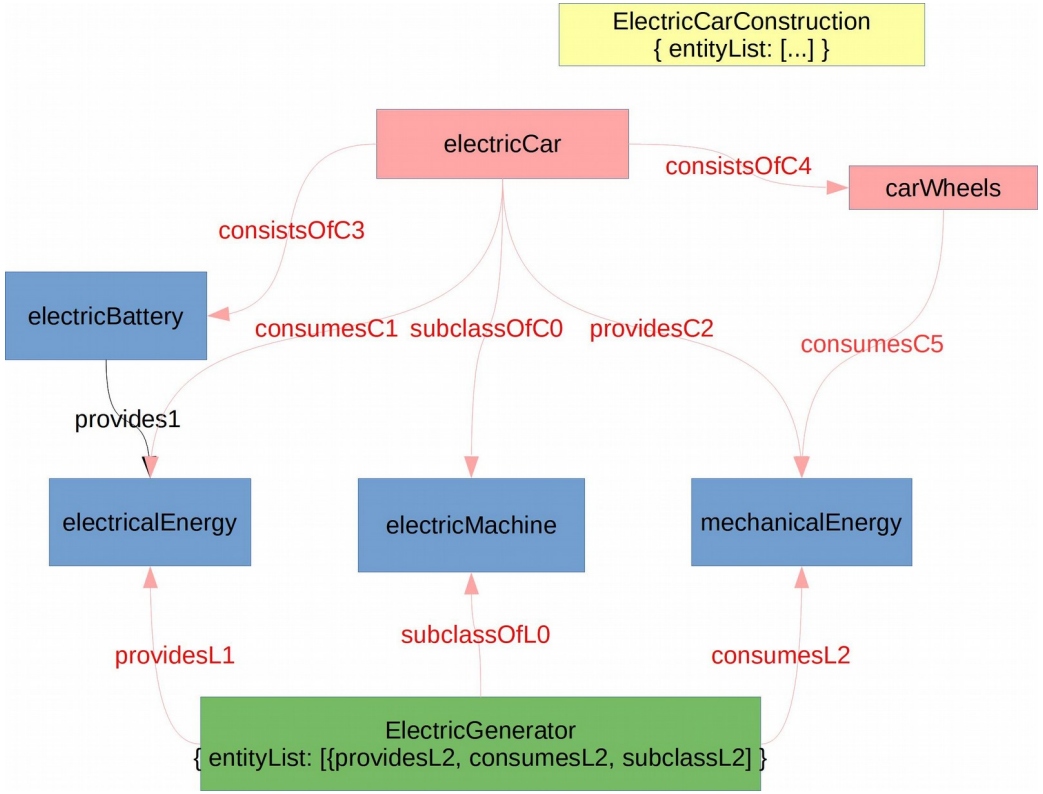
Results

- Working memory analogy, and “dislcose-close”, context of inner structures.

web diclose of two differenst spacecraft schemes





Example of two schemes. Red edges were diclosed

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Results

- checked usability to write queries to db with AQL (language for all data-models)
- and checked ability to write simplified logic queries to graph with flexible structure (high-order graphs), like SWRL.

```
var conn = ConnectedTo(Provide($c1, $res), Consume($c2, $res)) ^
        var f1 = xFroms($conn) ^
        var f2 = xTos($conn) ^
        var th1 = Through($f1,  HasParam($c1, skbGeneralParams/outcomeVoltage) ) ^
        var th2 = Through($f2,  HasParam($c2, skbGeneralParams/incomeVoltage) ) ^
        var outputVol = xTos($th1) ^
        var inputVol = xTos($th2) ->
        xGreaterOrEqual1to1Pair(ParamValue($outputVol, skbExtUnits/minVolt).xParamValueValue, ParamValue($inputVol,
skbExtUnits/minVolt).xParamValueValue) ^
        xLowerOrEqual1to1Pair(ParamValue($outputVol, skbExtUnits/maxVolt).xParamValueValue, ParamValue($inputVol,
skbExtUnits/maxVolt).xParamValueValue)
```

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Results

- not finished attempts to interlink existed KG entities with SPOON database (market spacecrafts components) and Hypothesis notes of research activity.

Discussion of results - 1

- the current approach is not very developer-friendly with existed developer instruments.
- not simple to translate a rule language to AQL to manage multi-model data.

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Discussion of results - 2

Research limitations

- basic functions include only a few entity relations, which basically relates to only one domain (components structure and interactions)
- the research doesn’t touch questions about the computational performance of this approach
- no any metrics

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Innovation

Innovation component of your research
- before: standards for data interoperability between PLMs etc, a lot of researches about ontologies, models for design, manufacturing, etc., semantic data models, standarts, etc. like JSON-LD.
- innovation: application of these ideas to make decentralized tissue of engineering tools.

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Application

Application of results
- the current result is not very applicable.
Because it’s an incoherent prototype web app.
- a potential application is as a basis for creation of open “tissue” of simple engineering web-based tools

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Conclusions

Conclusions should summarize the main results of the work and be consistent with the Aim and Objectives!

- graph-based multi-model database is not enough to efficiently work with knowledge representations.

- KG structures based on classic semantic technologies described in academic researches are not the only way to develop KG and maybe not very efficient.

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Acknowledgements

- Petr Mukhachev – PhD, discussions about engineering approaches, PLMs, CADs, etc.

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Thanks

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