RDFOX®
Oxford Semantic Technologies

# Reasoning rules the road: semantic reasoning on knowledge graphs deployed in vehicles

**Haonan Qiu**

Research Engineer, BMW Group

**Peter Crocker**

Co-founder and CEO, OST


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# Agenda

- An introduction to OST and semantic reasoning
- Reasoning onboard vehicle use cases
- Practical tips on how to get started with reasoning

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# Oxford Semantic Technologies (OST)

AI tech spun out from Oxford University in 2016

RDFox: Knowledge Graph & Semantic Reasoner

Co-founder Ian Horrocks Lovelace Medal Winner

Investment by Samsung Venture Capital

KRR

Knowledge Representation & Reasoning (KRR)

FTSE FORTUNE 500

Existing clients inc. Global FTSE 100 and Fortune 500

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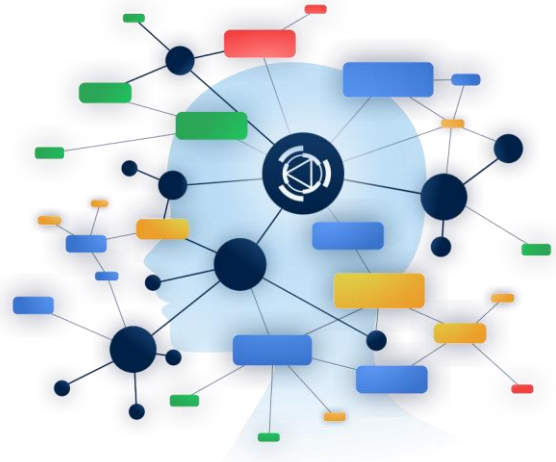
# What is our purpose

**We help organisations find accurate answers to complex questions in an instant.**



**We achieve this by combining human knowledge and data with rules-based artificial intelligence.**

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# What makes RDFox® different

## Our USPs

### Semantic Reasoning

### Speed & Scalability

### On Device

### Oxford University

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# Advanced Reasoning Functionality

RULE LANGUAGES SUPPORTED: OWL2-RL, SWRL, DATALOG

## Inferred & materialised relationships

## Calculations

## Aggregation

## Negation

## Explainable

## Incremental reasoning

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# Independent performance benchmark

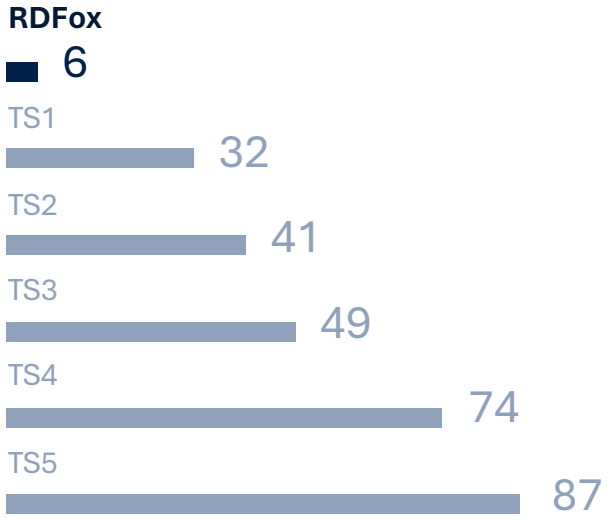
**An overview of the performance of five triple-stores and an experimental SPARQL query engine.**
This benchmark measured the import and query execution times by using Wikidata as a benchmark. Wikidata is one of the world's leading RDF data sources with over **15 billion triples.**

RDFox® was found to be the **only triple-store** that successfully **exported** the **entire Wikidata** data.

[Click here to access full benchmark report]

## Time to import

(hours)




## Query speeds

**How much faster is RDFox compared to other triple-stores.**

| | |
|---|---|
| TS1 | 5x |
| TS2 | 11x |
| TS3 | 17x |
| TS4 | 82x |
| TS5 | 750x |

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# Our Customers

Global Banks

Global Data Publisher

Global News Publisher

Global Furniture Retailer

Global Automotive Manufacturers

Global Healthcare Manufacturer

Global Electronics

Global Industrial

Global Automation

SaaS Solution Providers

Global Energy Company

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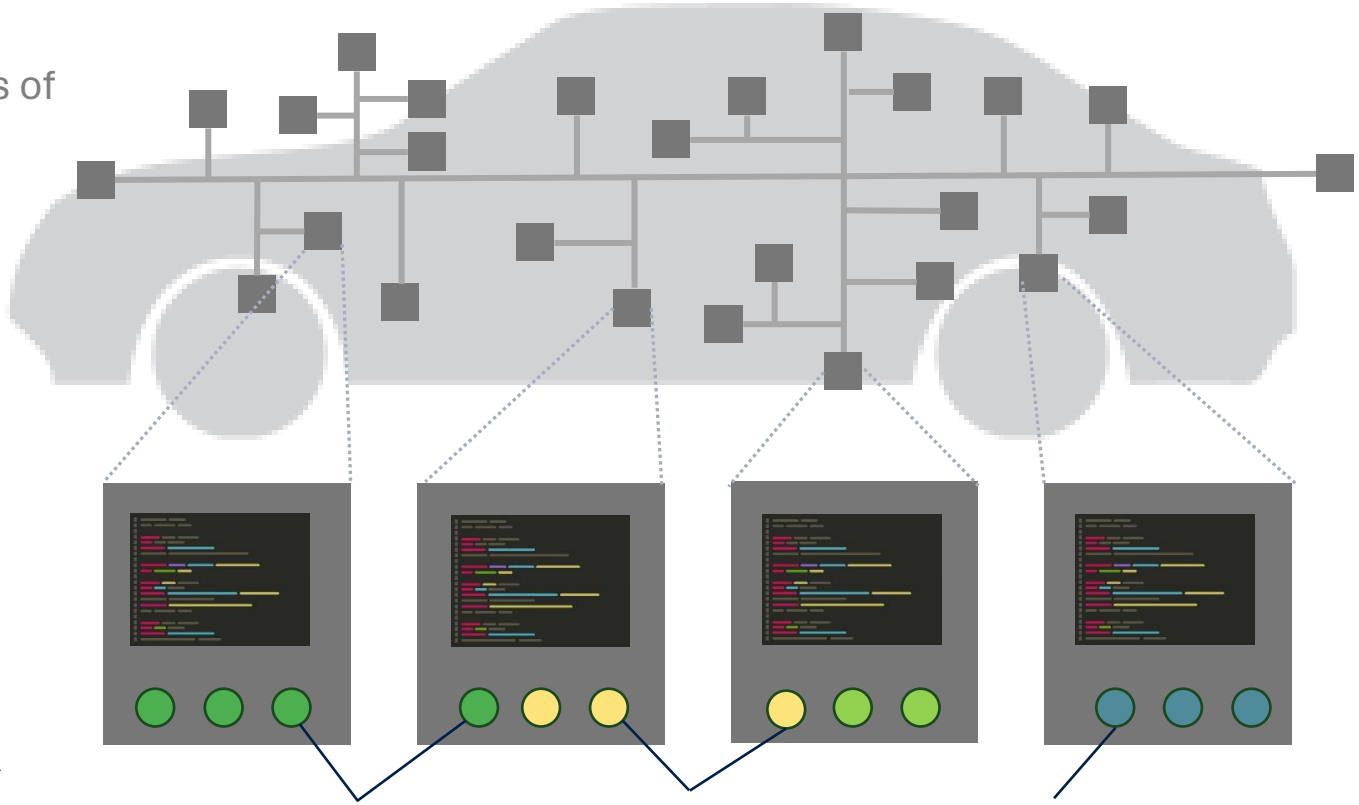
# The Pain

- Increased complexity:
  - Numerous ECUs (~100 ECUs) [1]
  - Sophisticated software (~100 million lines of code or more) [1]
  - Hard to **adapt** and **maintain** efficiently

- Isolated data processing:
  - **Duplicated** code
  - Process logic **coupled** with the data format and the application function
  - Difficult to **integrate** data

-> issues of application-centric architecture




[1] https://spectrum.ieee.org/software-eating-car

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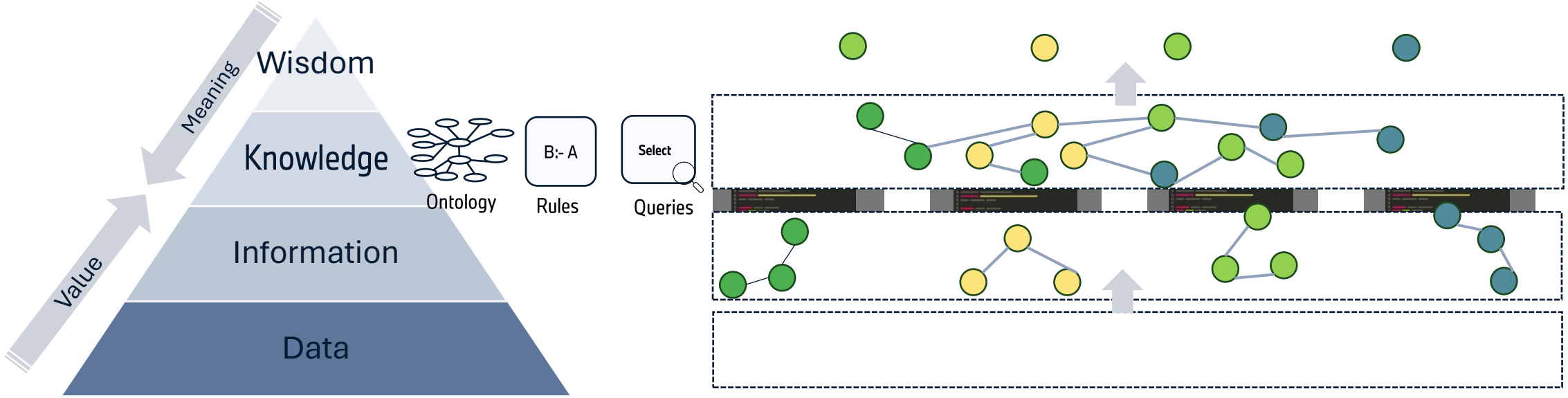
# A Knowledge Layer

- Shift to Data-Centric Architecture
  - Data is the centre
- Data, Information, Knowledge and Wisdom (DIKW)
  - A conceptual framework to utilize the data
  - Offers integration and insight




Qiu, H., Ayara, A., & Muehlbauer, C. (2023). *A Knowledge Layer in Data-Centric Architectures in the Automotive Industry*.

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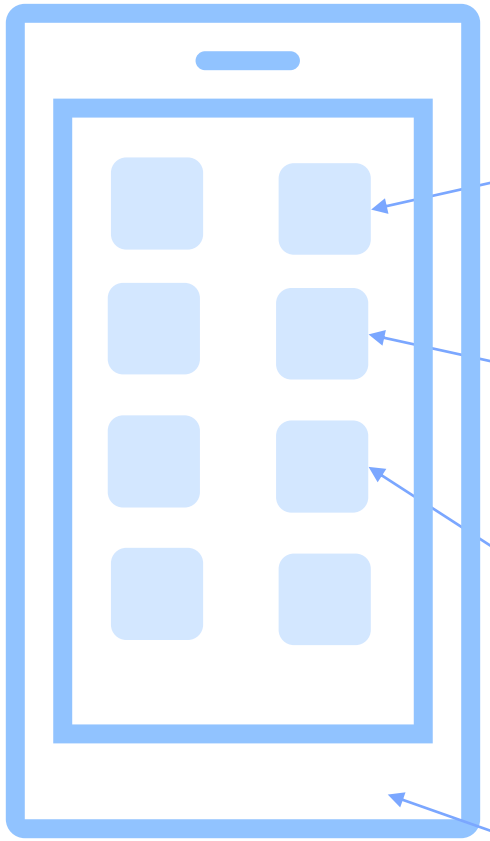
# Benefits?



Health

```
:close_to_goal[?user]:-
    :daily_steps[?user, ?steps],
    :step_goals[?user, ?goal],
    Filter(?steps > 0.9*?goal
    && ?steps < ?goal).
```

Right of Way

```
:has_right_of_way[?vehicle] :-
    :arrived_first[?vehicle, true],
    not EmergencyVehicle[?vehicle].
```

Map Processing

```
:hasRightLane[?lane2,?lane1]:-
    :hasLeftLane[?lane1, ?lane2].
```

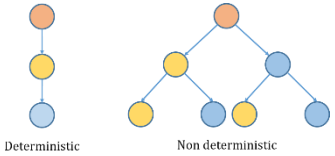
Rule Engine

**Common**

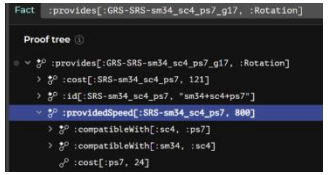
- Domain independence
- Rapid adaptation
- Scalability

**Rule Engine**

- Determinisim

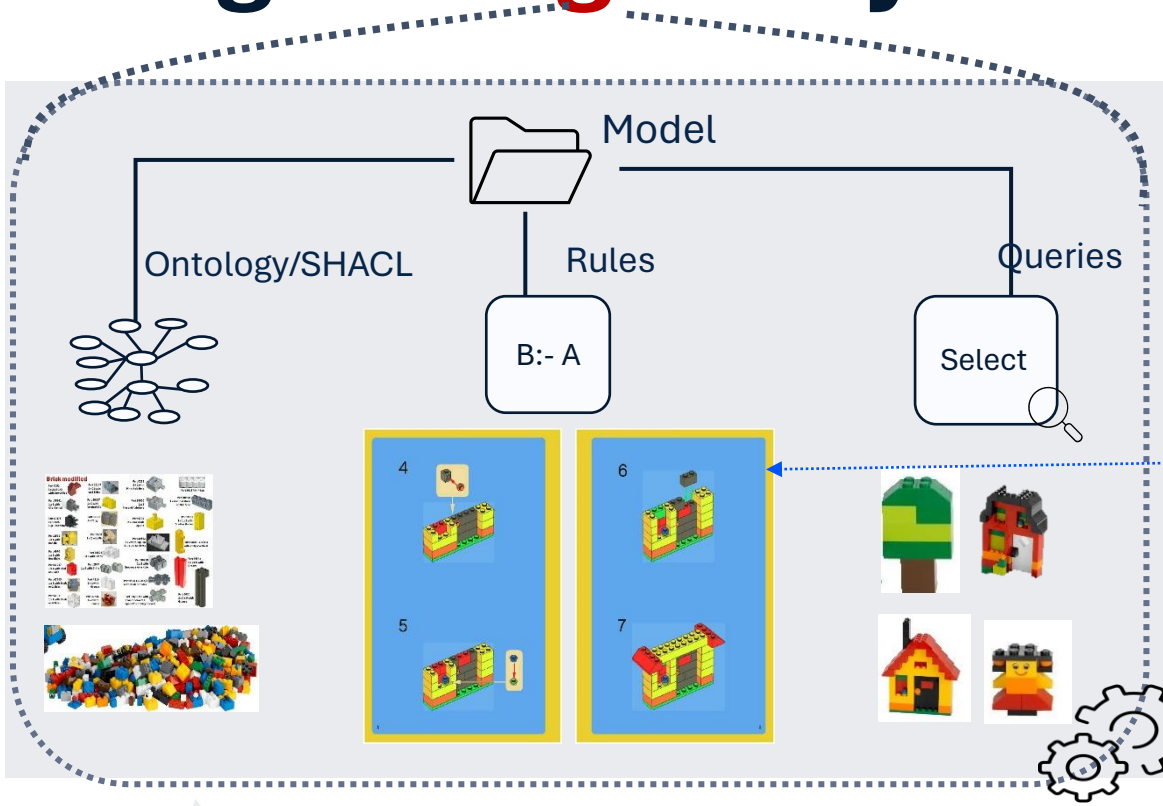



- Explainability




- Transparency

# Bring the logic only!




```
isExecutable[?s,true]:-
Service[?s],
serviceName[?s, "set_driver_ambient_light_off"],
hasRule[?s,?r],
ServiceRule[?r],
serviceRuleDescription[?r,?srd],
FILTER(contains(?srd,"Vehicle.Cabin.Light.AmbientLight.IsLightOn=true")
),
isTargetStateSet[?s,true],
CurrentAmbientLightRow1DriverIsLightOn[?x],
value[?x,?v],
FILTER(?v = true).
```

Input

Ouput

```
{
 “service.Name”:"set_driver_ambient_ligh
 “service.RuleDescription”:
“Vehicle.Cabin.Light.AmbientLight.IsLightOn=true”
,…}
```

Step 1

```
{
 “service.isExecutable”:”true”
}
```

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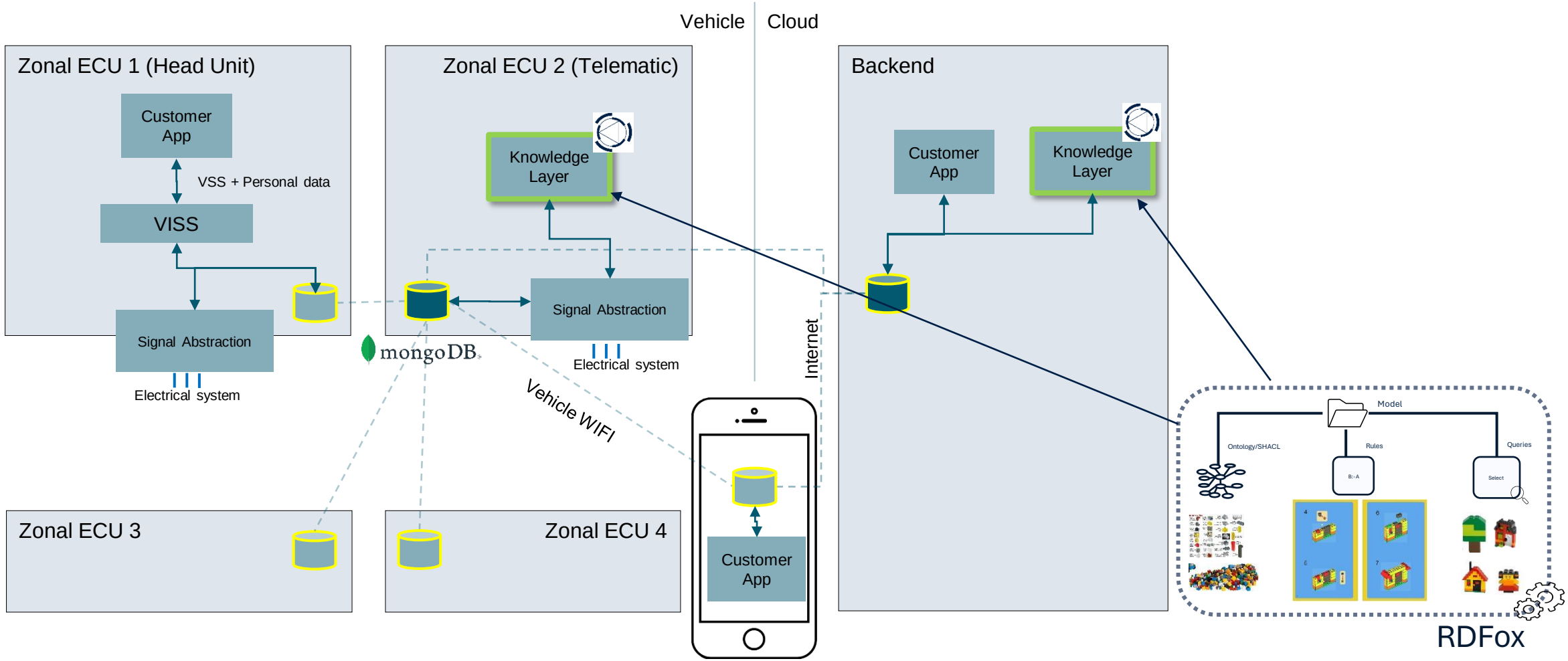
# Implementation




source:https://wiki.covesa.global/pages/viewpage.action?pageId=71074417

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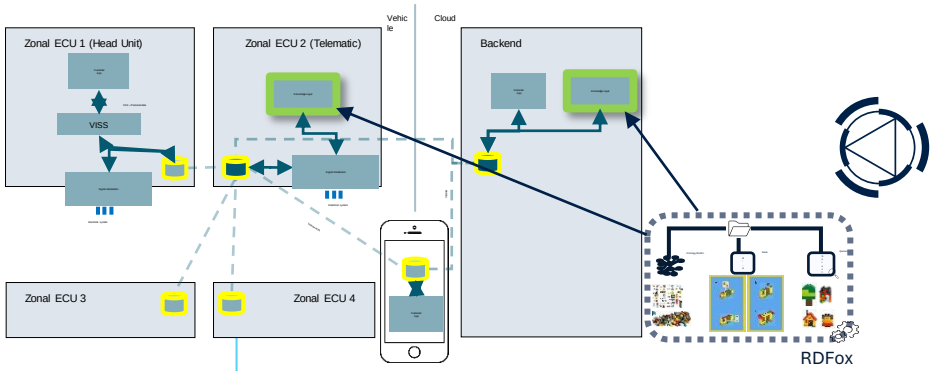
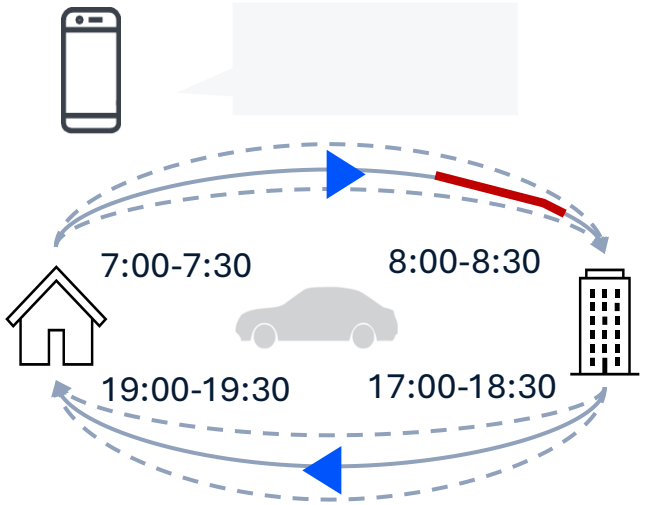
# Use cases




## Daily User Trip[1]

Input: GPS, Driving Status

Output: User Trips

## Vehicle Service

Service description, Vehicle Signals

Service isExecutable

## Radio Station Recommendation

Radio info, Person Preferences

Song URL

[1] Qiu, H., Ayara, A., & Muehlbauer, C. (2023). *A Knowledge Layer in Data-Centric Architectures in the Automotive Industry.*

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AMBIENTE
Ambientes Licht
Farbe
Hintergrundlicht
Akzentlicht
Reduziert bei Nachtfahrt
21.0
Services
set_driver_ambient_light_off
set_driver_ambient_light_off
Id
Change Driver Ambient Light from off
Description
WBY11CF080CH47081
Vin
false
isExecutable
EXECUTED
State
[Vehicle.Cabin.Light.AmbientLight.Row1.Driver.IsLightOn/set=false]
Function Description
[Vehicle.Cabin.Light.AmbientLight.Row1.Driver.IsLightOn=true]
Rule Description
[Vehicle.Cabin.Light.AmbientLight.Row1.Driver.IsLightOn=NULL]
Target State Description
testing
testing123
Id
testing
Description

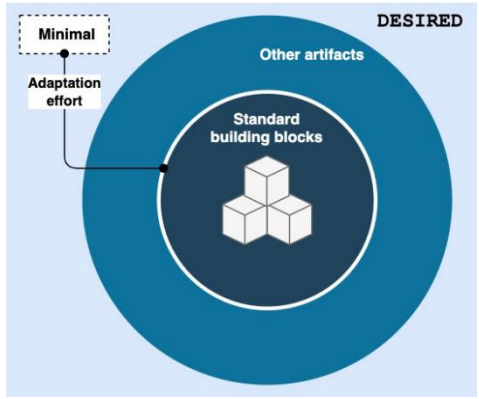
# What's next?

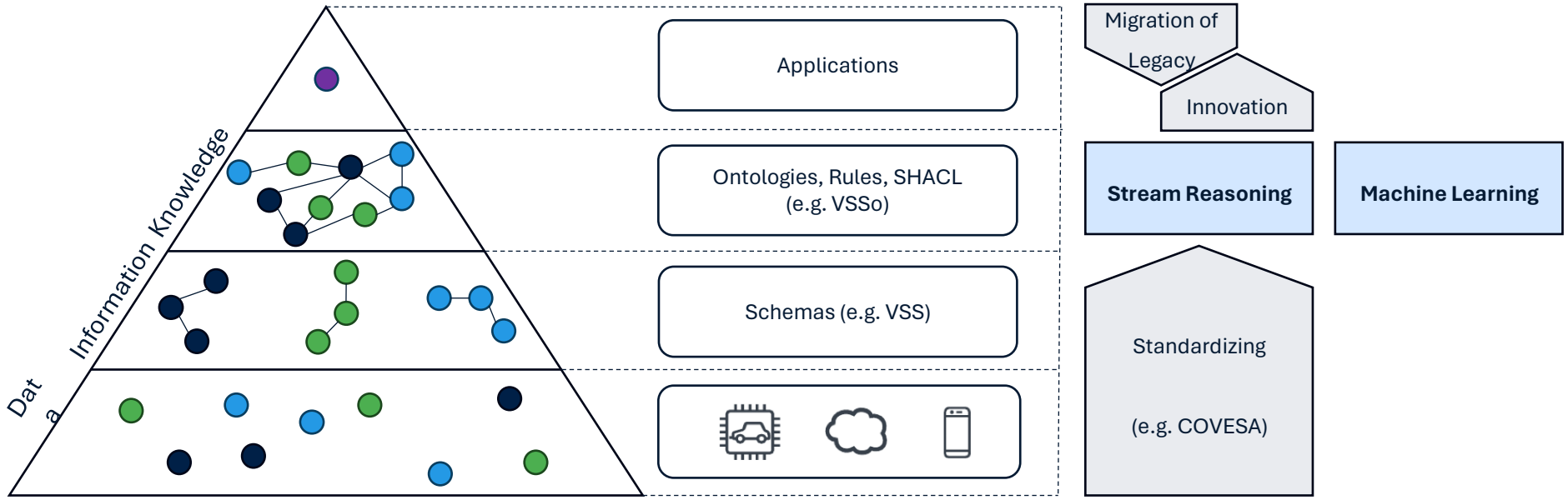
Standard Building Blocks [1]

- Reasoning mechanisms
- Common knowledge definition
- …

Expanding knowledge layer:

- Machine learning




[1] *Alvarez-Coello, D., Muehlbauer, C., & Qiu, H. (2024). On the Role of Stream Reasoning for a Data-Centric Architecture in Automotive.*

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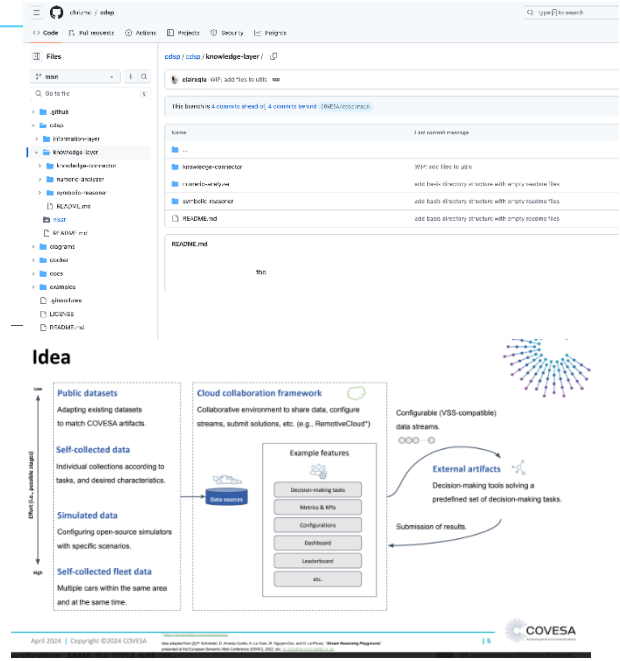
# Joined Efforts

## EU Project HAL4SDV [1]

- Hardware Abstraction Layer for Software Defined Vehicles

## COVESA

- Connected Vehicle System Alliance
  - -Data architecture group: Playground [2]
  - -Benchmark




Join us to bring semantics and reasoning into cars!

[1] https://wiki.covesa.global/display/WIK4/COVESA+Work+Package+Mapping+to+HAL4SDV
[2] https://wiki.covesa.global/display/WIK4/Central+Data+Service+Playground

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# Practical tips on how to get started

1. Start!
2. Demonstrations and showcases
3. Placement of the rule-based engine, such as RDFox
   - Input/out
   - The data process flow
   - begin with ontologies, grow relationships with the rules

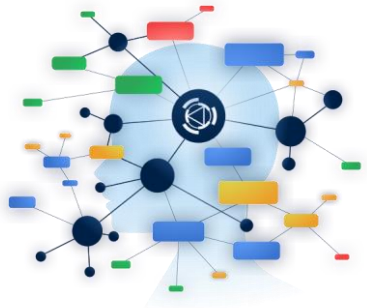
**Download RDFox Free Edition**

- Be descriptive with rule names
- Keep rules simple and focused
- Use consistent formatting
- Document your rules
- Optimize rule ordering
- Avoid redundancy
- Test your rules incrementally

# Power up your knowledge graph

## Why Knowledge Graphs?

Enables applications that are best served by the modelling of relationships.



## Why Reasoning and Rules?

Enables accurate AI decision systems by inferring new facts based on expert knowledge and data.

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## Why RDFox®?

Advanced reasoning, high performance and on-device support, backed by OU research.

## What Next?

Where can you see the applications to use rules-based AI in your business area?

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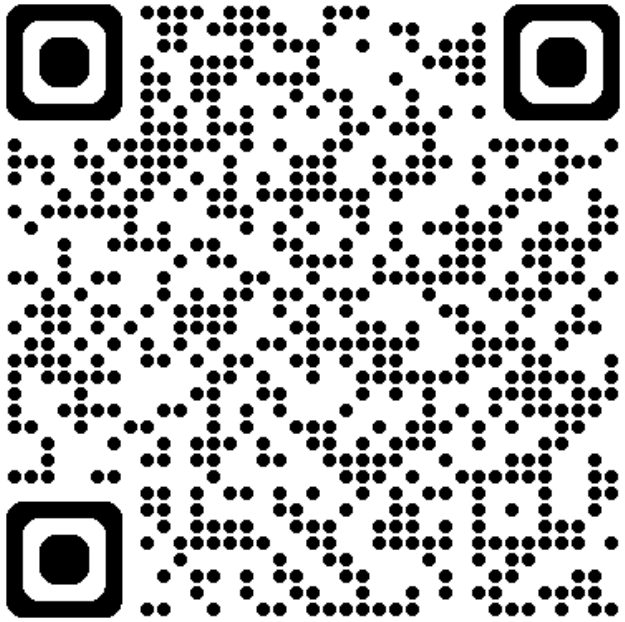
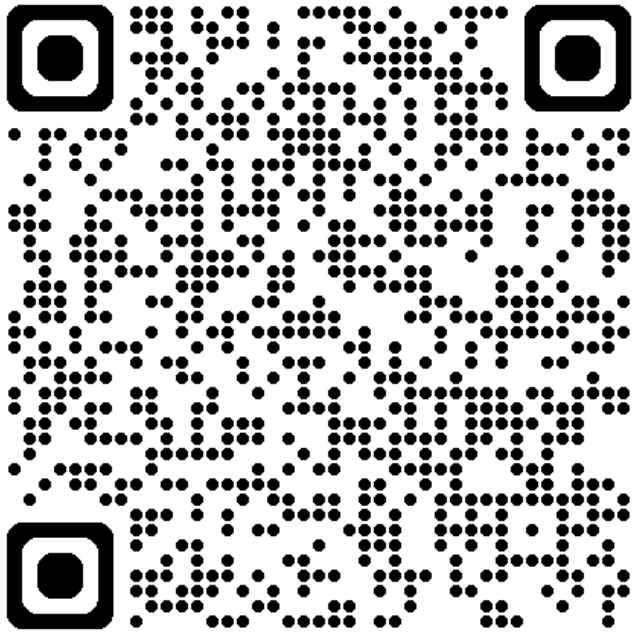


# Request a reasoning demo

See how it can transform your semantic projects.



# Join a free reasoning workshop!

Learn how to use reasoning with RDFox free edition.

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# For further information or a demo please contact:

**Philip Foster**
philip.foster@oxfordsemantic.tech

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