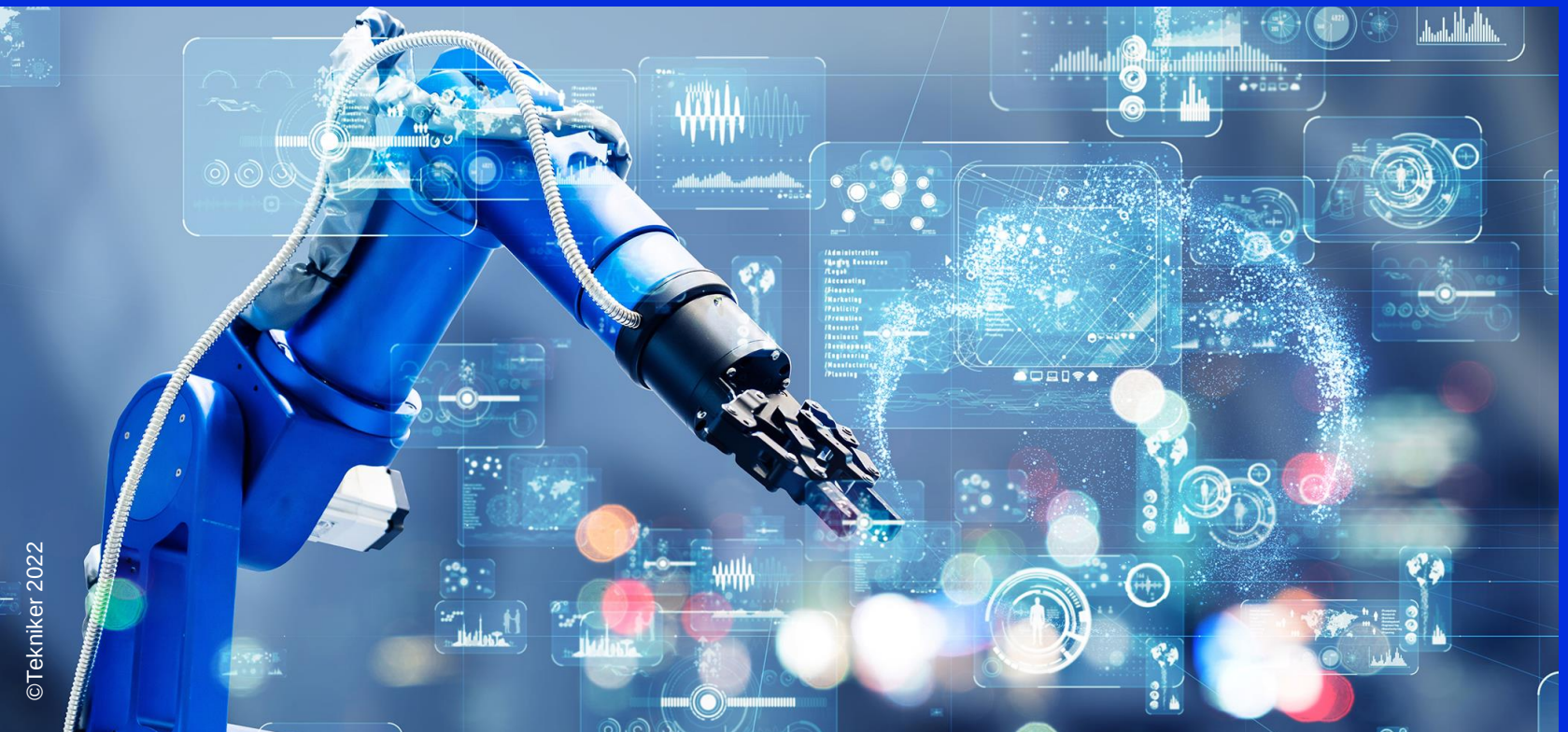
An Ontology-Driven Approach to Support Data Analysts with Thermal Comfort Problems in the Built Environment

Iker Esnaola-González | Jesús Bermúdez | **Cristina Aceta**

Chersonissos | 29/05/2022



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This presentation is supported by the REACT project, which has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 824395.

Motivation

EEPSA: ontology-assisted thermal comfort in buildings

Use case: thermal comfort in restaurants

Conclusions

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- Comfortability while occupying buildings → very important

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- Different types of comfortability: acoustic, visual, **thermal**...

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- Thermal comfortability: "*that condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation*" (ANSI/ASHRAE Standard 55-2017)
- HVAC systems should ensure thermal comfort...
  - …BUT only 11% of buildings have a satisfaction level higher than 20%

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- Optimal HVAC activation strategy, ensuring:
  - Thermal comfort
  - Efficient use of energy
- Challenges:
  - Specific characteristics for each building
  - HVAC specific activation modes and times

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- **Predictive models to manage HVAC systems**

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- **Predictive models to manage HVAC systems**
  - Internet of Things (IoT): great amounts of data

Source: https://labs.sogeti.com/iot-or-interoperability-testing-in-the-age-of-cloud-things-devops/

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- **Predictive models to manage HVAC systems**
  - Internet of Things (IoT): great amounts of data
  - Knowledge Discovery in Databases (KDD): make sense of data

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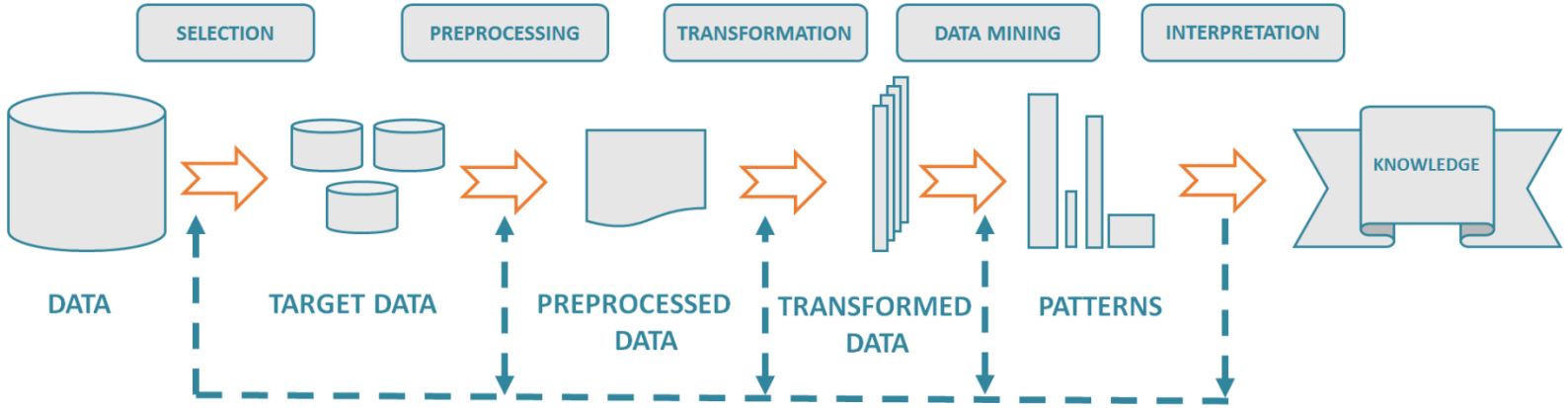

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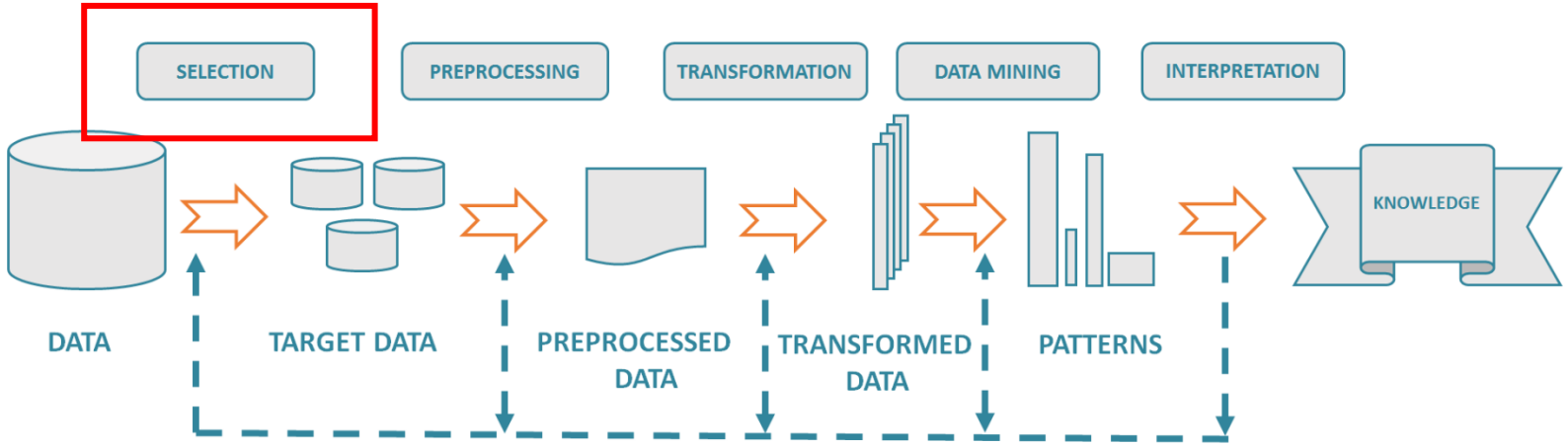

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- Expert knowledge is needed in the data selection phase to understand data
  - Some times, this knowledge may be insufficient →**trial-and-error**
- Approaches to data selection:
  - Visualization
  - Analysis and identification of relevant attributes
- Assistant to support data analysts would be an interesting asset
  - **Energy Efficiency Prediction Semantic Assistant (EEPSA)**

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- EEPSA: Assistant to support data analysts through the predictive model development process
- Use of Semantic Technologies
  - Ontologies
  - Ontology-driven rules
  - Ontology-driven data access
  - EEPSA Ontology

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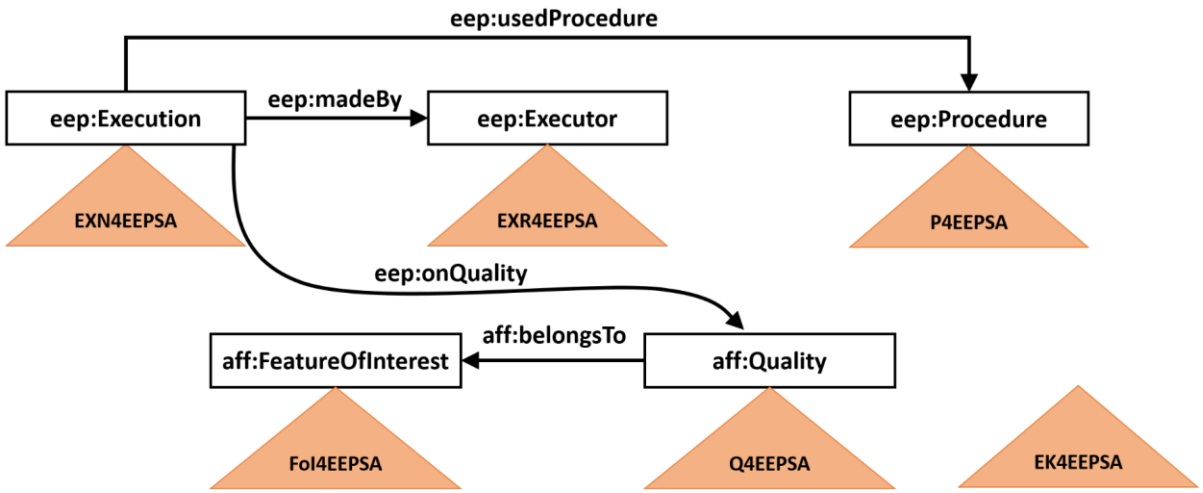
- EEPSA ontology:
  - 3 ODPs:
    - AffectedBy
    - Execution-Executor-Procedure (EEP)
    - Result-Context (RC)
  - ODPs overcome weaknesses in other ODPs: SOSA/SSN and SEAS FeatureOfInterest



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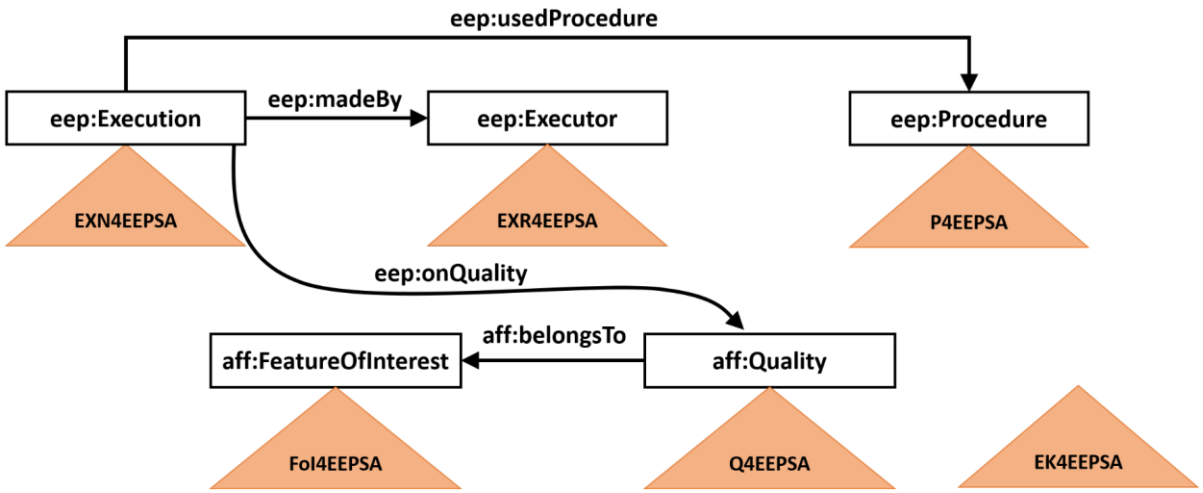
- EEPSA ontology:
  - 6 modules:
    - EXN4EEPSA: executions (e.g. observations, actuations)
    - EXR4EEPSA: executors (e.g. sensors)
    - P4EEPSA: plans or methods
    - FoI4EEPSA: buildings and spaces
    - Q4EEPSA: space qualities
    - EK4EEPSA: expert knowledge



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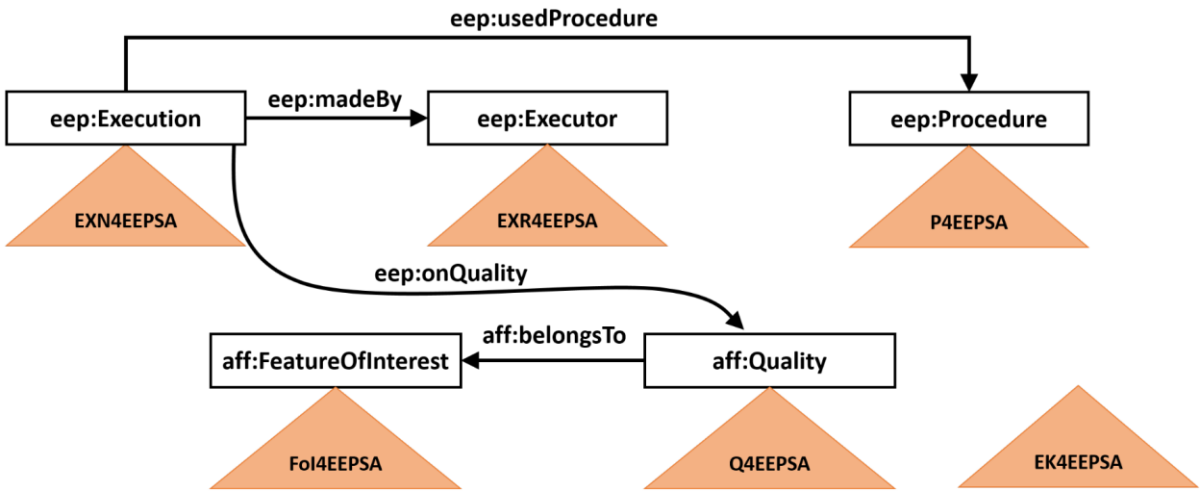
Specialization of ODP classes



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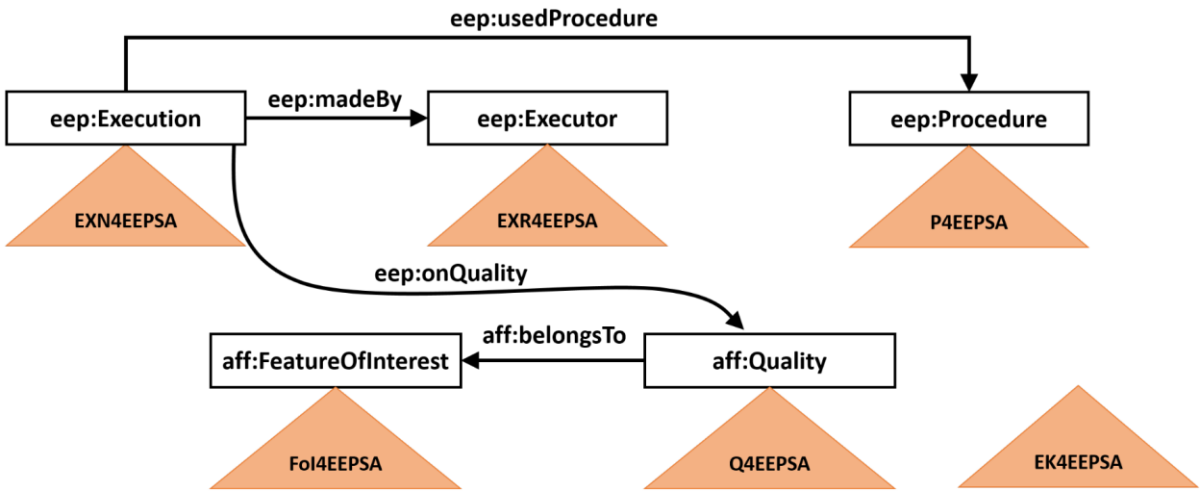
Expert knowledge

- EK4EEPSA: expert knowledge



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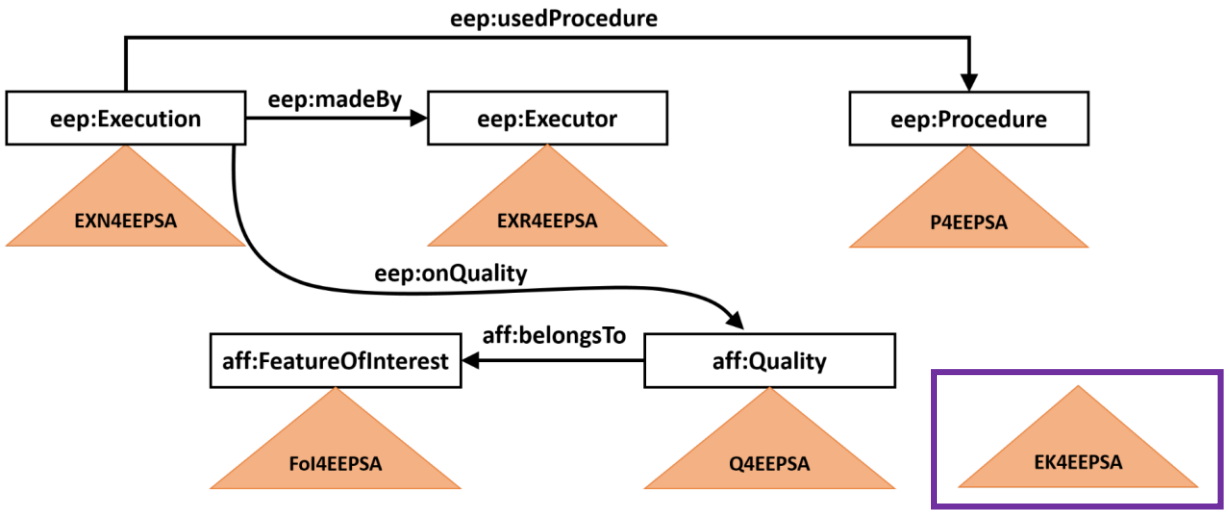
- EK4EEPSA
  - Expert knowledge that allows the necessary inferencing to assist data analysts in the KDD data selection phase



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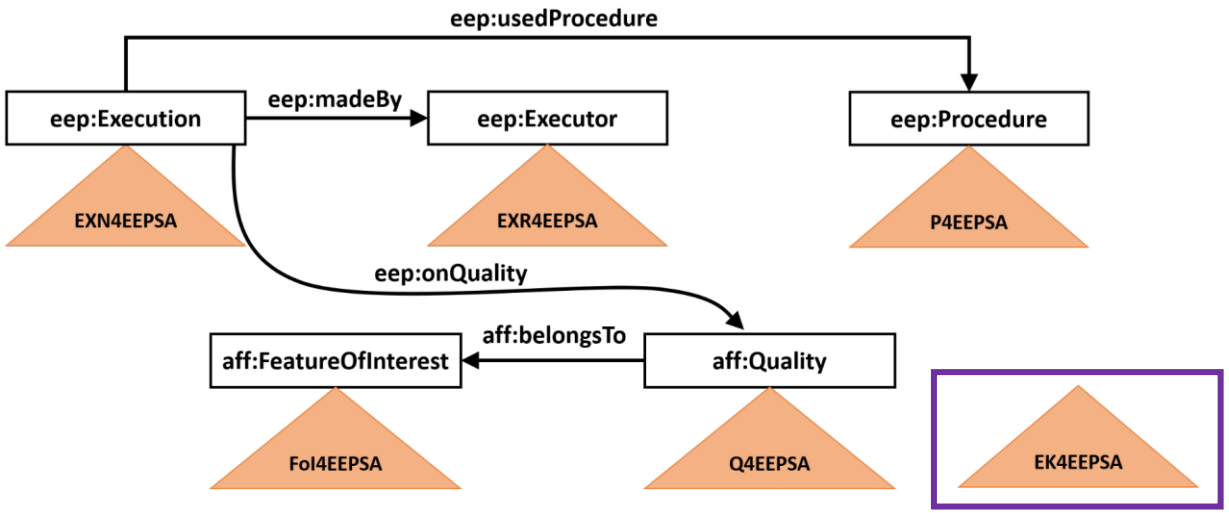
- EK4EEPSA
  - **Types of spaces** based on <u>structural features</u>
    - *ek4eepsa:BelowGroundLevelSpace*
    - *ek4eepsa:BadInsulatedSpace*
  - **Types of spaces** based on <u>building elements contained</u>
    - *hbc:SpaceWithAirTerminal*
    - *hbc:SpaceWithoutShadingSpace*



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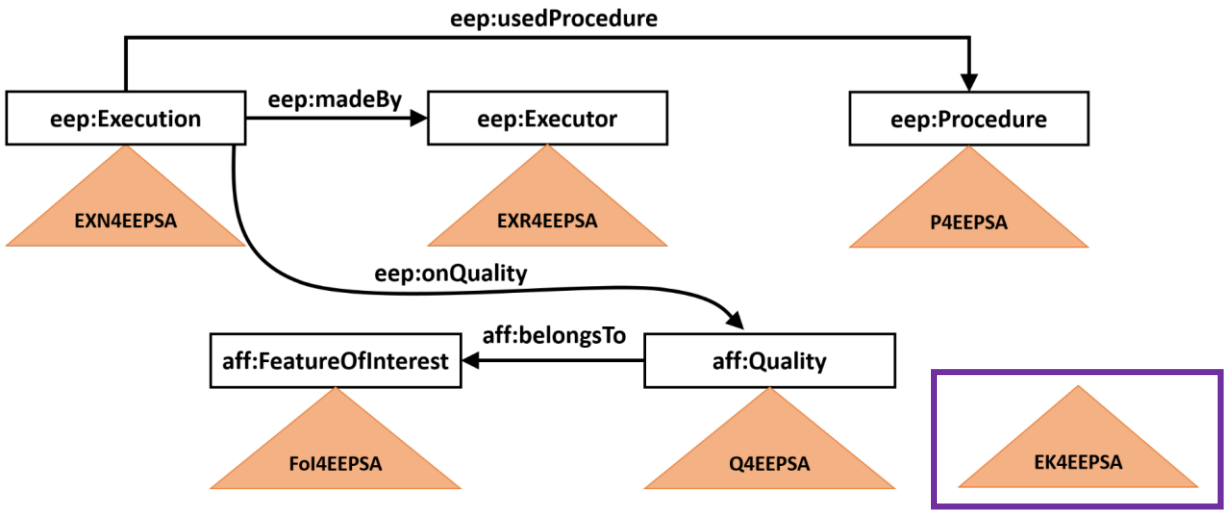
- EK4EEPSA
  - **Qualities** that affect the thermal conditions for each space type
    - Relies on other EEPSA modules (e.g. Q4EEPSA, AffectedBy ODP)



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- Semantic representation of the restaurant:
  - Space
  - Structural elements
  - Equipment

```
:building35 rdf:type bot:Building ;
            (...)
            bot:hasStorey :level1 .
:level1 rdf:type bot:Storey ;
            bot:hasSpace :restaurant ;
            bot:hasSpace :kitchen ;
            (...)
            bot:hasSpace :bathroom .
: restaurant rdf:type bot:Space ;
            bot:hasElement :door01 ;
            bot:hasElement :window01 ;
            (...)
            bot:hasElement :tempSensor01 ;
:window01 rdf:type foi4eepsa:ExternalWindow .
(...)
:tempSensor01 rdf:type exr4eepsa:TemperatureSensor .
:obs_tempSensor01_2589 rdf:type exn4eepsa:Observation ;
            eep:madeBy :tempSensor01 ;
            eep:usedProcedure :sensingProcedure01;
            eep:onQuality :restaurantTemp .
:sensingProcedure01 rdf:type p4eepsa:SensingProcedure .
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```

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```

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- Space type:

```
SELECT ?spaceType
WHERE {
    :restaurant rdf:type ?spaceType . }
```

→

```
ek4eepsa:AdjacentToOutdoorSpace
ek4eepsa:NaturallyEnlightenedSpace
```

- Inference axioms:

ek4eepsa:AdjacentToOutdoorSpace ≡

bot:Space ⊓ ∃bot:hasElement.foi4eepsa:ExternalBuildingElement

ek4eepsa:NaturallyEnlightenedSpace ≡

bot:Space ⊓

(∃bot:hasElement.foi4eepsa:ExternalWindow ⊔ ∃bot:hasElement.foi4eepsa:Skylight)

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- Relevant variables:

```
PREFIX aff: <https://w3id.org/affectedBy#>
SELECT ?relevantVariable
WHERE {
    :restaurant rdf:type ?spaceType .
    ?spaceType aff:influencedBy ?relevantVariable}
```

→

```
q4eepsa:IndoorHumidity
q4eepsa:Occupancy
q4eepsa:SolarRadiation
q4eepsa:WindSpeed
q4eepsa:CloudCover
q4eepsa:SunPositionDirection
q4eepsa:SunPositionElevation
```

- Inference axioms:

ek4eepsa:AdjacentToOutdoorSpace ⊑ ∃aff:influencedBy.ek4eepsa:AdjacentToOutdoorSpaceIndoorTemperature

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ek4eepsa:NaturallyEnlightenedSpace ⊑ ∃aff:influencedBy.ek4eepsa:NaturallyEnlightenedSpaceIndoorTemperature

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- Variables not present in data set may be covered by other methods:
  - Occupancy → reservation list
  - Weather conditions (e.g. sun position/elevation, cloud coverage) →Linked Data resources

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- To develop predictive models to ensure thermal comfort is a complex task that requires expert knowledge
- EEPSA is proposed to assist data analysts in the KDD process to obtain predictive models by using Semantic Technologies
  - Data selection: suggestion of relevant features depending on the building/space characteristics

  →**These variables may not be included in the data set**
- EEPSA ontology: backbone of EEPSA
  - ODPs
  - Modular
  - Easily customizable

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Thank you for your attention

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