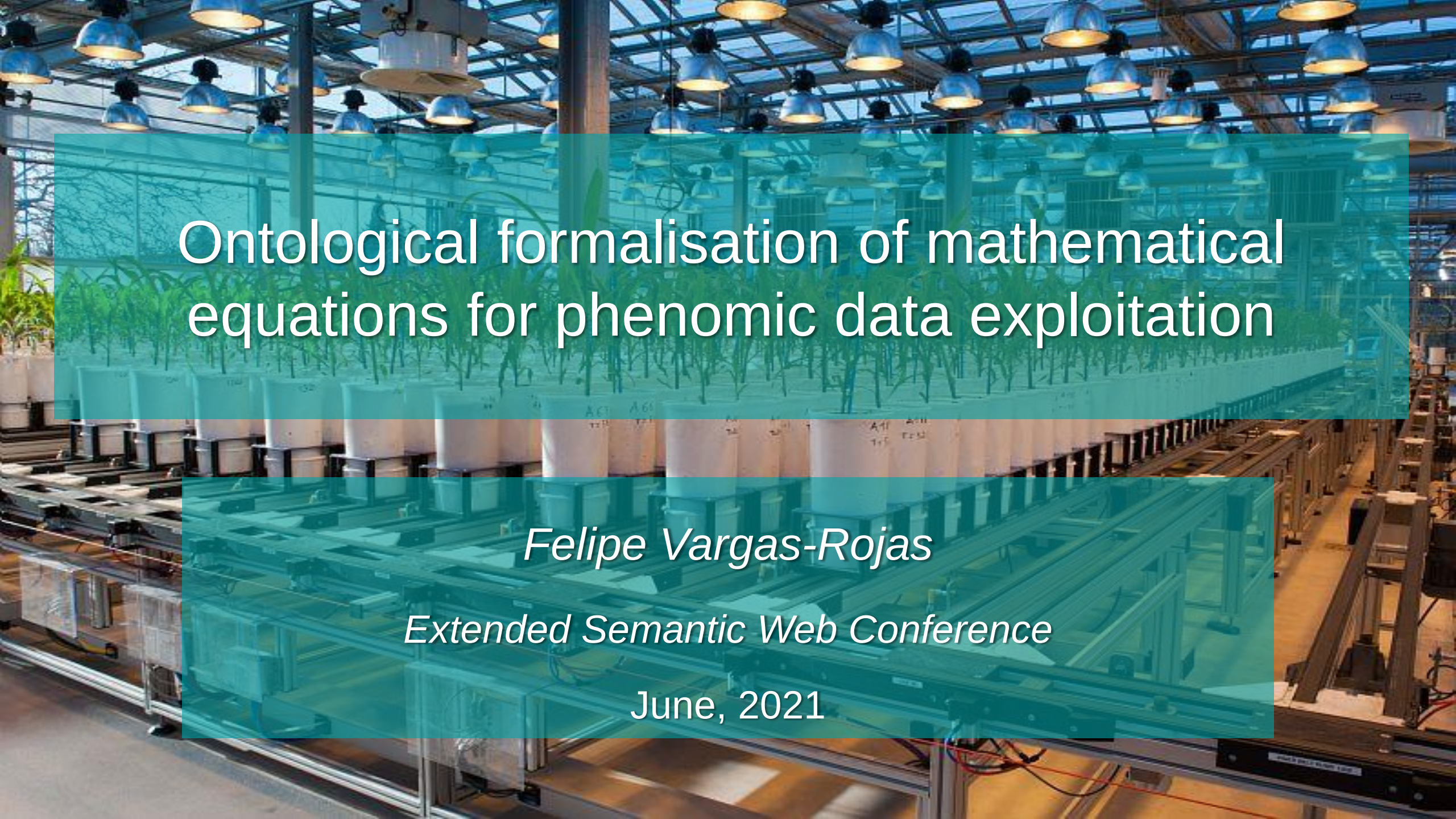

Ontological formalisation of mathematical equations for phenomic data exploitation

Felipe Vargas-Rojas

Extended Semantic Web Conference

June, 2021


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l'institut Agro
agriculture • alimentation • environnement
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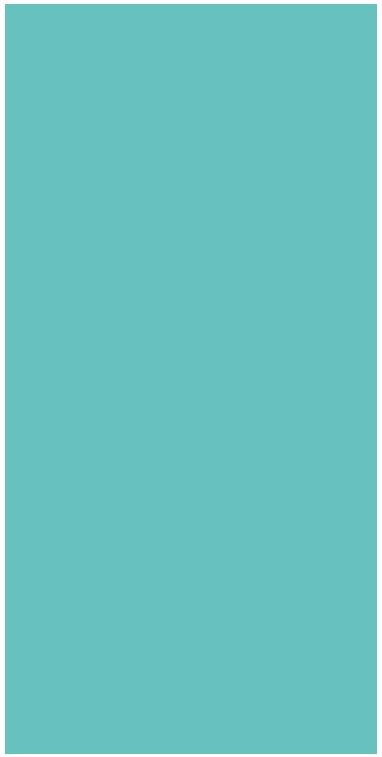
MOTIVATION

RELATED WORKS

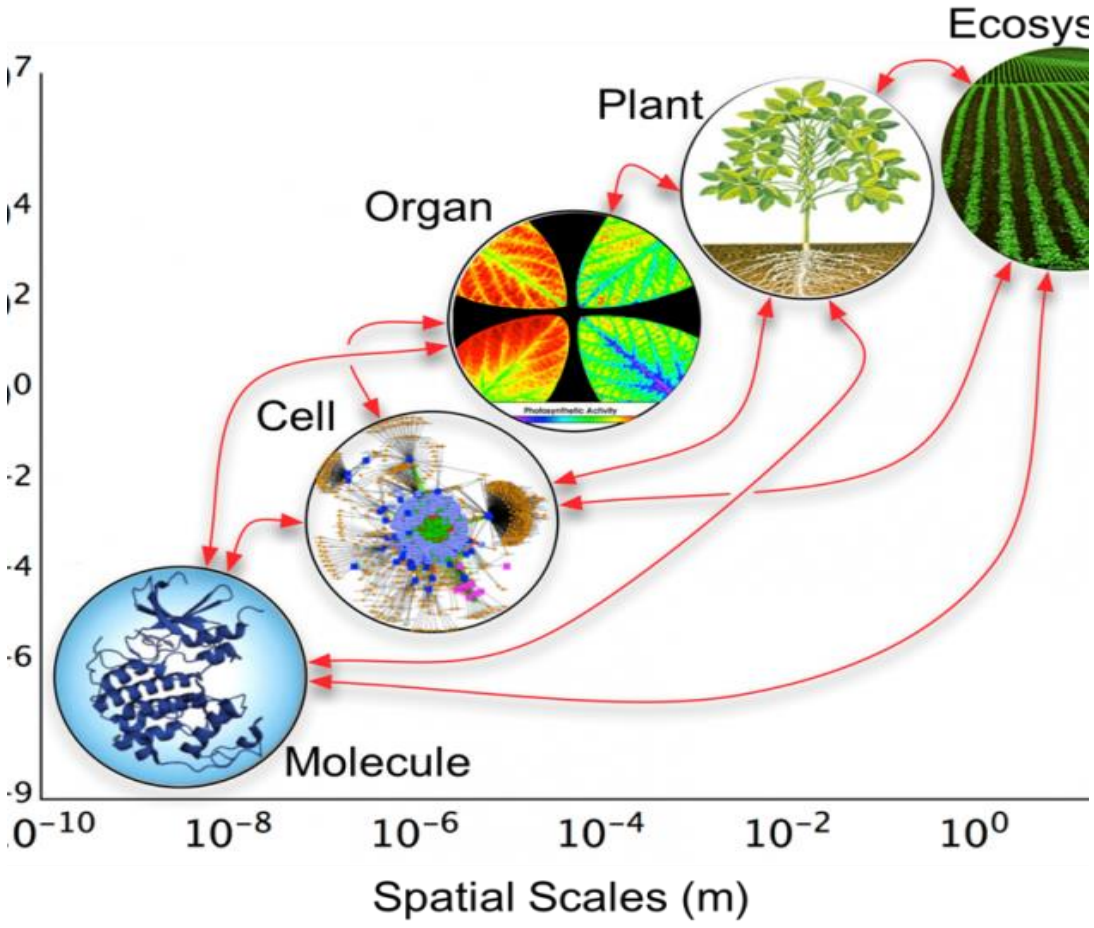
METHODOLOGY

EVALUATION PLAN

CONCLUSIONS



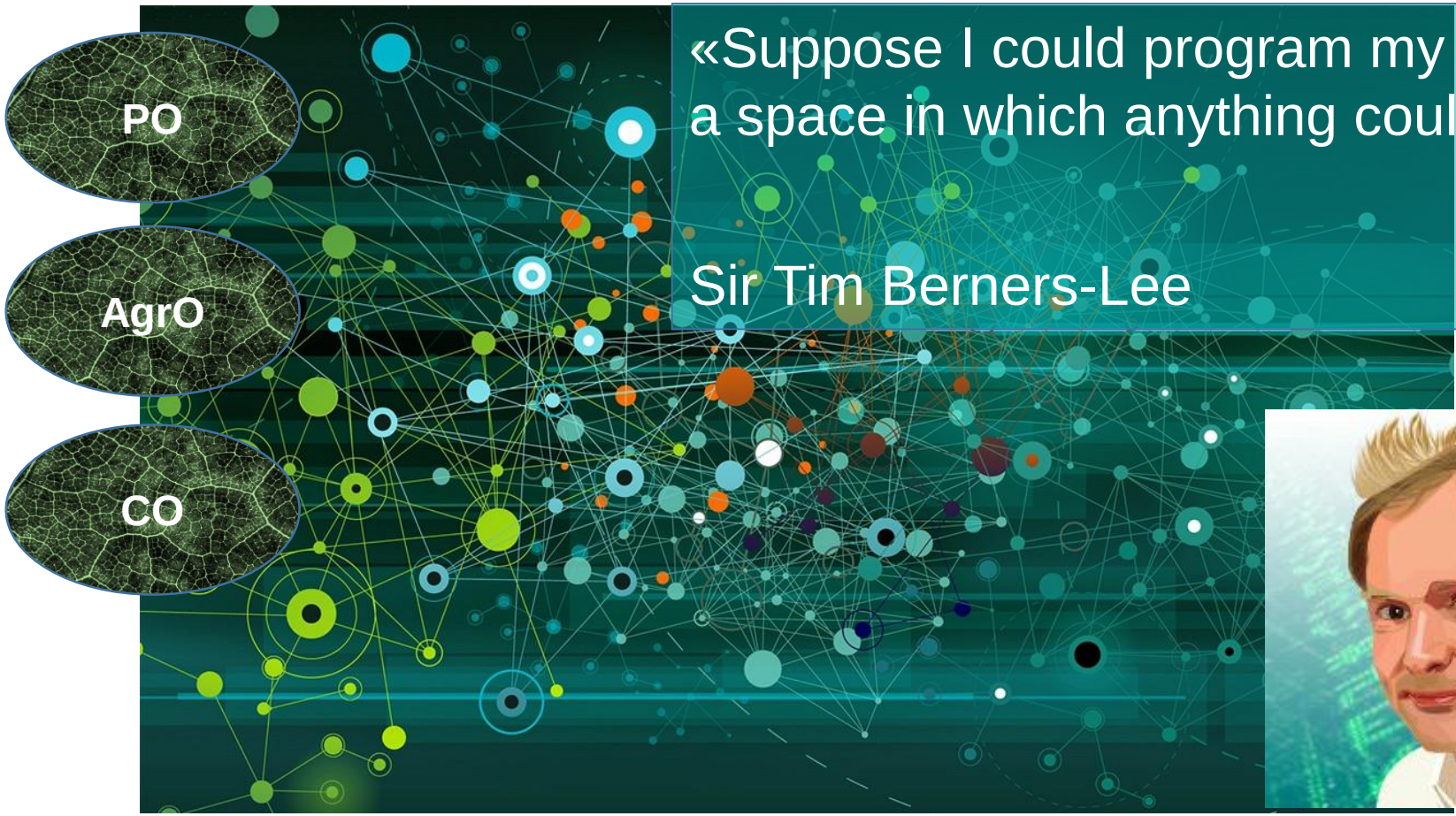
Multi-scale, multi-source, heterogeneous



(Marshall-Colon et al. 2017)

Plant phenomics datasets are in nature

Numerous equations relate plant phenomic traits



«Suppose I could program my computer to create a space in which anything could be linked to anything »

Sir Tim Berners-Lee

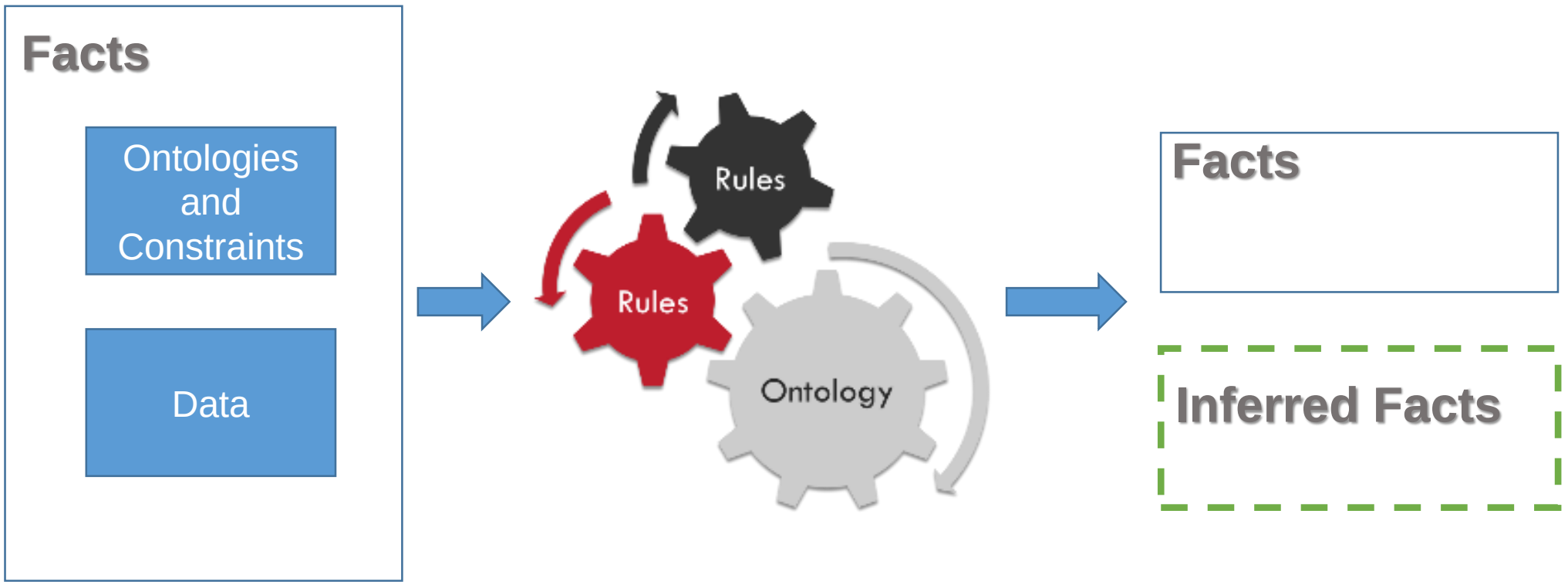
- PO: http://obofoundry.org/ontology/po
- AgrO: http://obofoundry.org/ontology/agro
- CO: https://www.cropontology.org

Plant phenomics community has adopted Semantic Web

- Facilitate data annotation and use of ontologies
- Exploit Semantic Web technologies
- Implement FAIR principles

(PHIS, www.phis.inra.fr, Neveu et al., 2019)

PHIS, an ontology-based information system



Reasoning services for harmonising data

Facts

$$ex:avgPrecipitation = \frac{\sum(ex:dailyPrecipitation)}{size(ex:dailyPrecipitation)}$$

dailyPrecipitation	units
3,9	inch
3,1	inch
2,4	inch

Facts

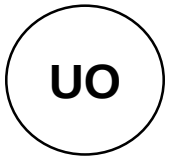
Inferred Facts:

avgPrecipitation = 3,13

Following the reasoning logic …..

Different units

dailyPrecipitation	units
3,9	inch
3,1	inch
60	mm

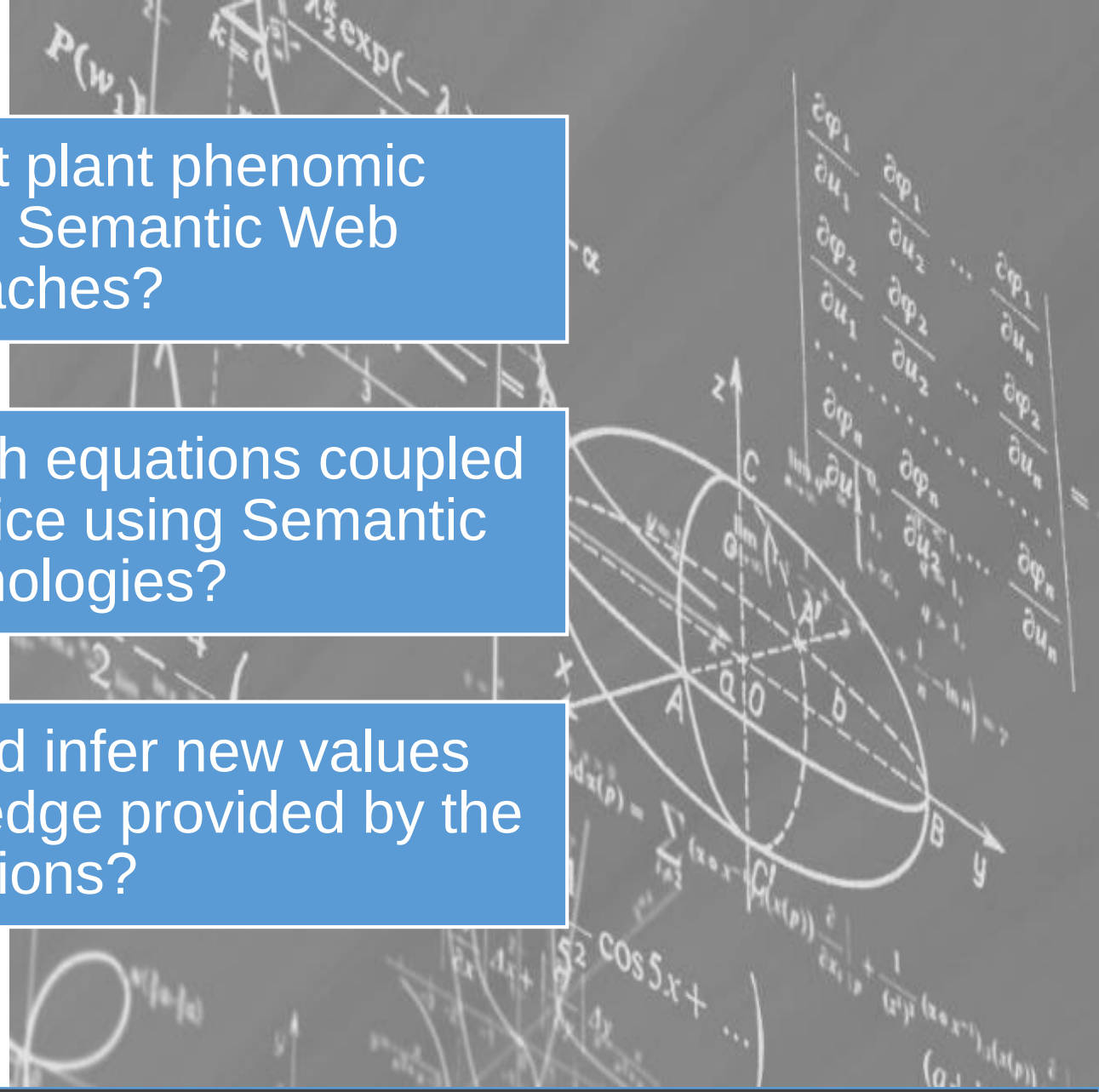


Different name conventions

dailyPrecipitation	dailyRaining	units
3,9	-	inch
3,1	-	inch
-	60	mm

dailyRaining rdfs:subPropertyOf dailyPrecipation

Increasing the complexity



- How to represent plant phenomic equations using Semantic Web approaches?
- How to compute such equations coupled with inference service using Semantic Web tecnologies?
- How to retrieve and infer new values based on the knowledge provided by the equations?

Research questions

Lack of studies exploiting inference services

MOTIVATION & PROBLEM

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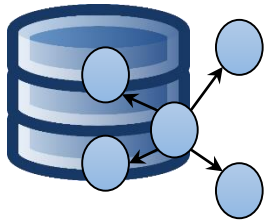
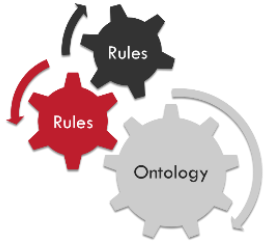
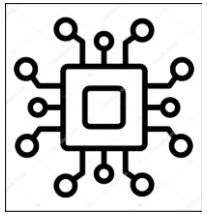


RDF/OWL data



Reasoning

Query



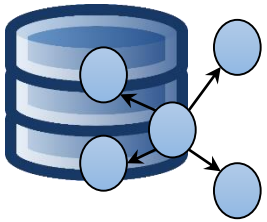
External computing

Computing and representing mathematical expressions

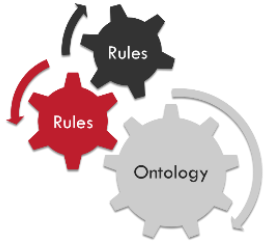
Ontology-based Information representation

- Function ontology *(Meester et al. 2016)*
- Unit ontologies *(OM, UO, QUDT)*
- OpenMath + RDF *(Wenzel & Reinhardt, 2012)*

- No info about how to perform the computation

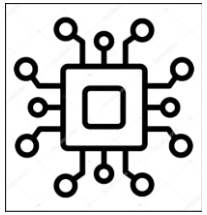


RDF/OWL data



Reasoning

Query

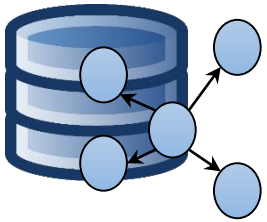


External computing

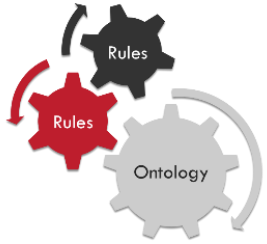
Ontological reasoning

- Extend a query rewriting algorithm *(Bischof et al, 2013),*
- New datatype *(Parsia et al., 2008)*

- No use of unit ontologies
- Equations structured as strings

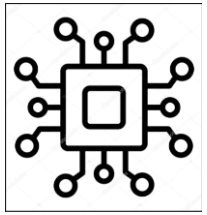


RDF/OWL data



Reasoning

Query

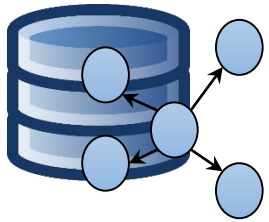


External computing

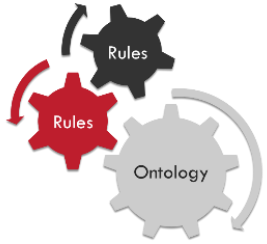
SPARQL extensions

- Query structure different from mathematical objects
- Equations calculated after reasoning

- Extend SPARQL functions
  (Hogan et al., 2020)

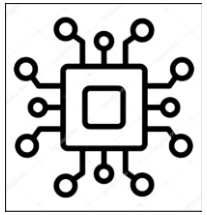


RDF/OWL data



Reasoning

Query



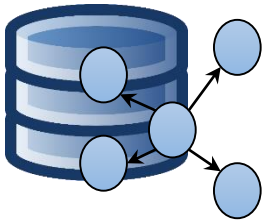
External computing

Delegated computing

Execution on external programs
(Python, Matlab, R)
mediated by ontologies

(Rijgersberg, et al. 2012)

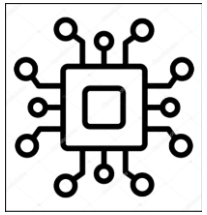
- Requires to install and external program
- Outside of the semantic web technologies



RDF/OWL data

Reasoning

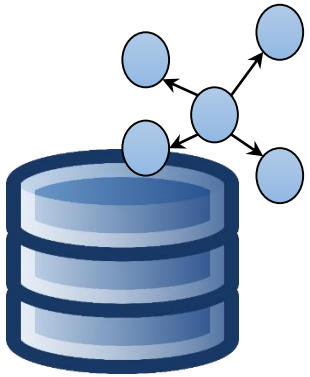
Query



External computing

Representation features

1. Mathematical equations compliant with symbolic mathematic
2. Based on ontology terms



Reasoning & computation features

1. Perform equations
2. Exploit unit ontologies
3. Nested equations

We propose an ontological framework

MOTIVATION & PROBLEM

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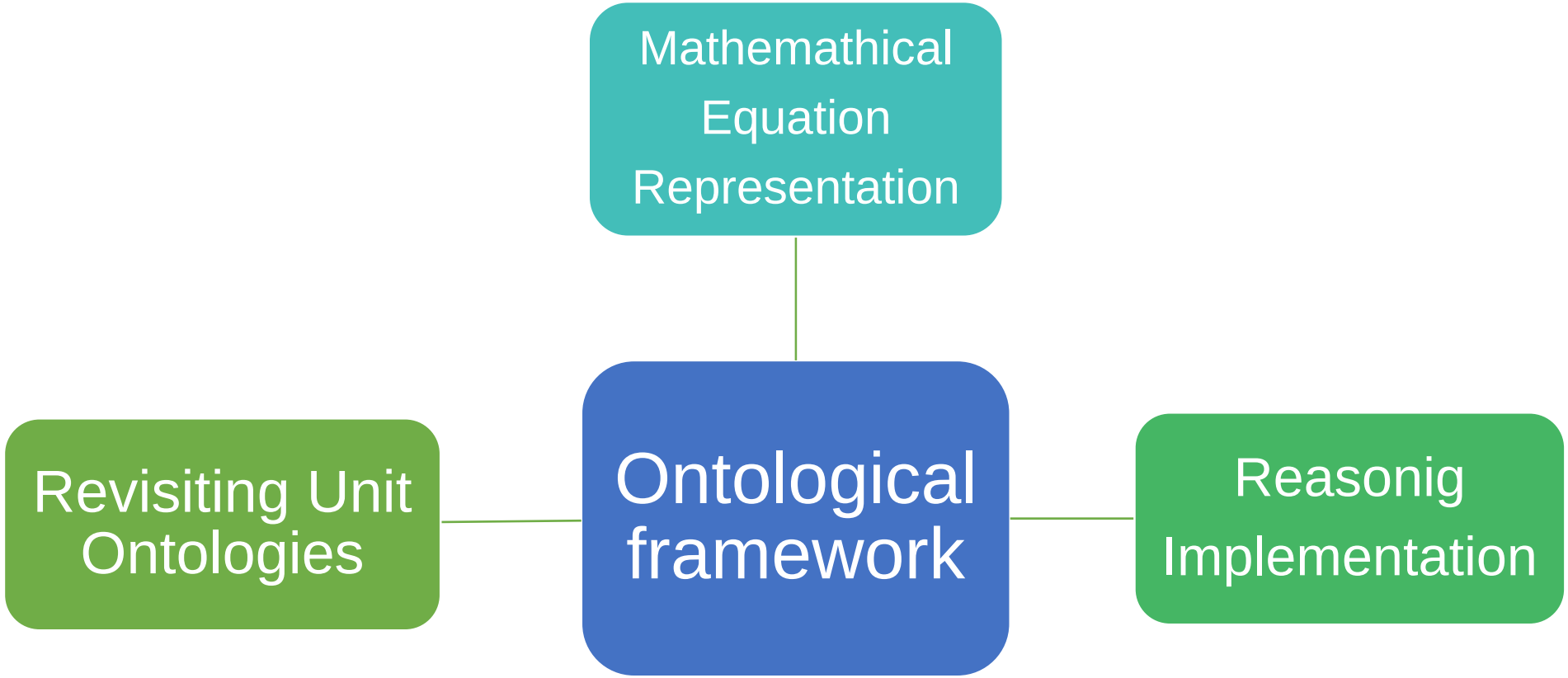


Research methodology and approach

Use metadata from unit ontologies to infer and unify heterogenoeus measurement

Perform Unit Conversion

$cm \rightarrow \mathrm{m}$

Normalise the temperature observation depending on contextual data from crops

Thermal time

$\boldsymbol{Temperature \rightarrow Thermal\ Time}$

Two case studies

Dimension units

$$1\,m^2 = 10000\,cm^2$$
$$1\,cm^2 = 1\,m^2 \times 10^{-4}$$

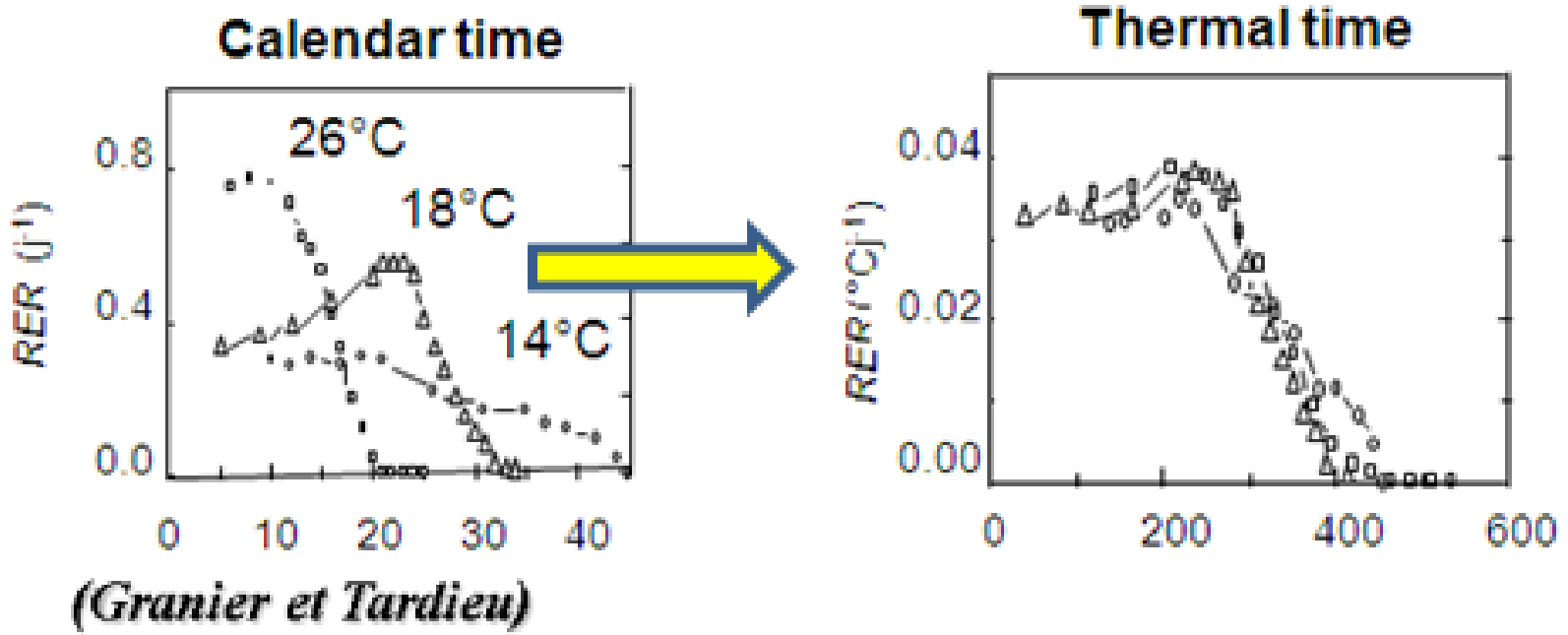
Light units

Global Solar Radiation (**Rs**)
Photosynthetically active radiation (**PAR**)

$$R_s(J \cdot cm^{-2}) \rightarrow PAR(\mu mol \cdot m^{-2}s^{-1})$$

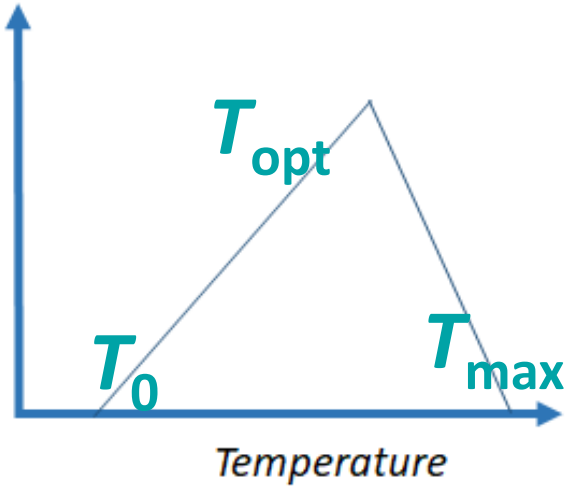
Perform unit conversion

(i.e. growing degree units) a process handled by biologists and agronomists used to normalise several temperature-dependent processes such as leaf-progression.



Thermal time definition

Bilinear Model



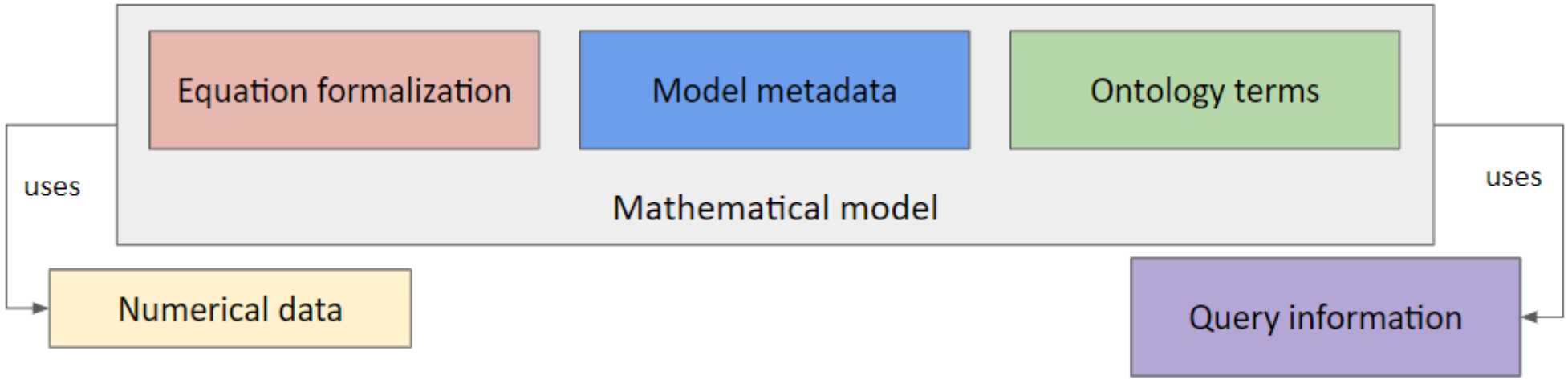
if $T > T_0 \leq T_{opt}$ then $T - T_0$

if $T > T_{opt} \leq T_{max}$ then $T - T_{max}$

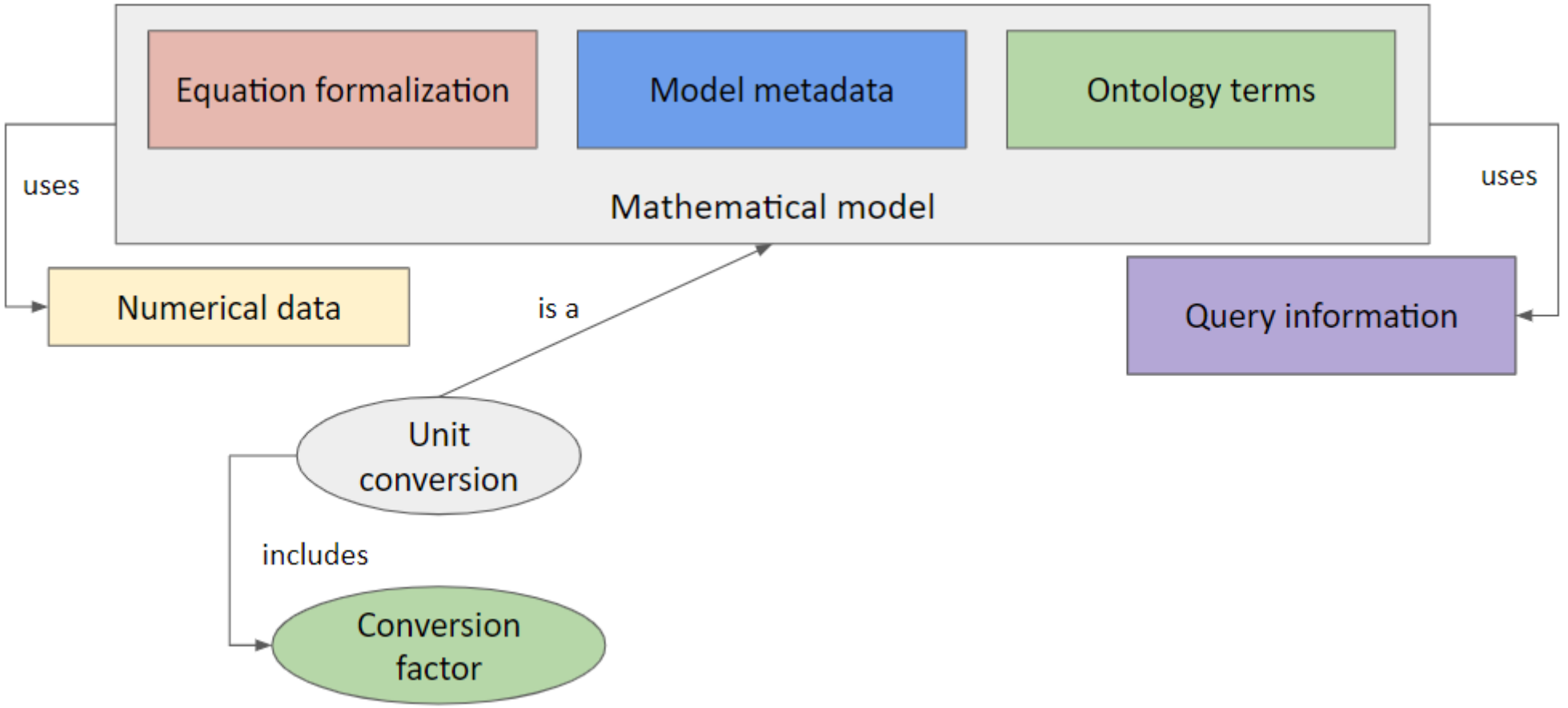
T_{opt}	30.9 °C
T_{max}	37.8 °C
T_0	7 °C

T_{opt}	31.6 °C
T_{max}	38.9 °C
T_0	12 °C

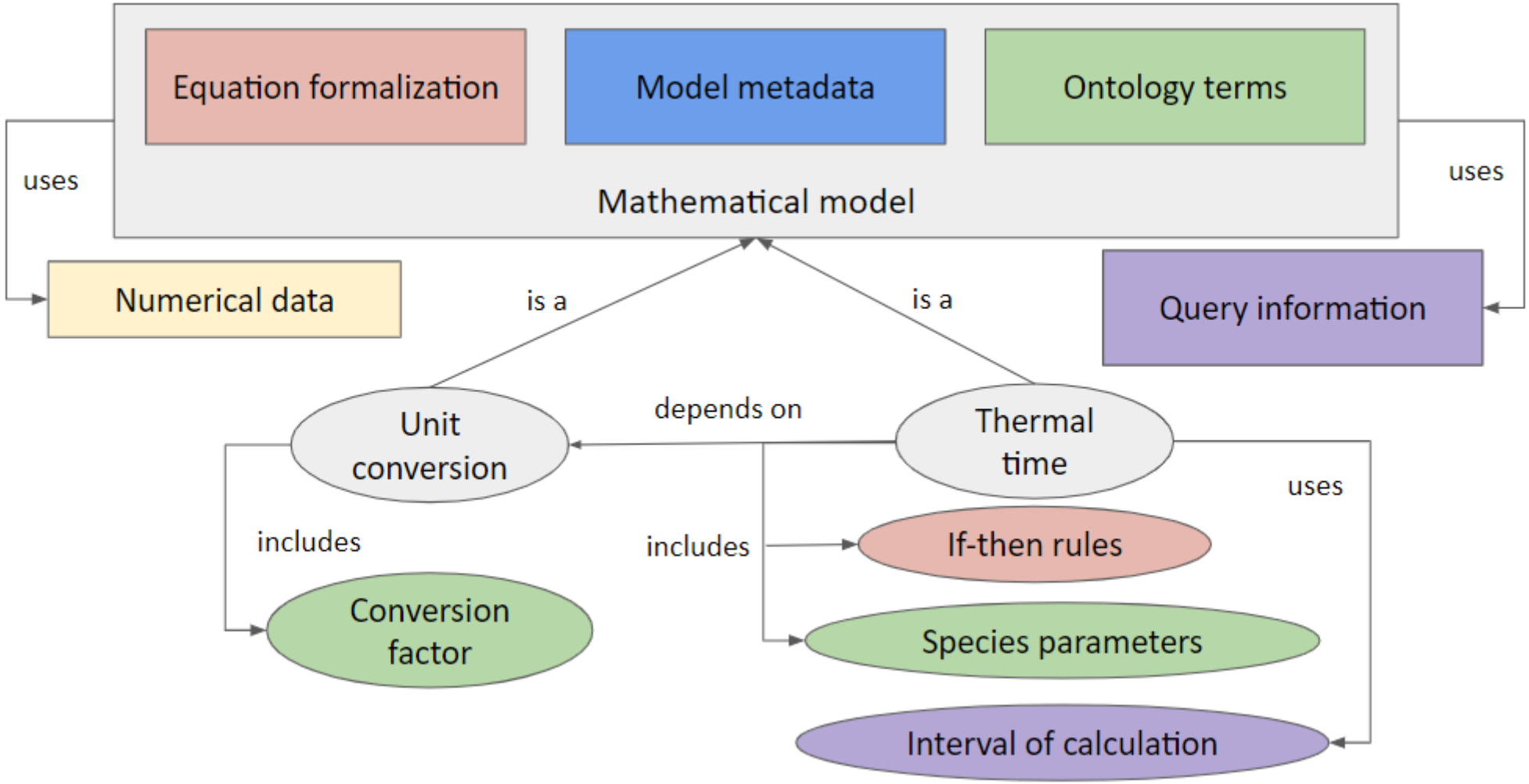
Thermal time equation



General components for mathematical equations



Components for unit conversion case study



Components for thermal time case study

MOTIVATION & PROBLEM

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Datasets

Unit ontologies

UO

OM

QUDT

Domain ontologies

PO

AgrO

CO

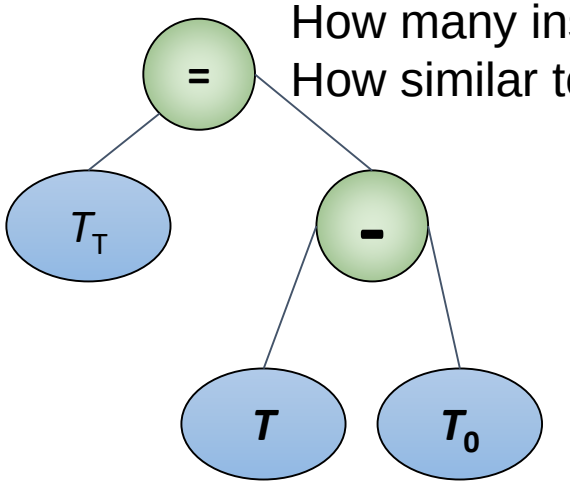
PHIS

GraphDB

16 GB RAM
1,8 GHz, 8-cores

Resources for the evaluation plan

Assessing the equation representation



How many instructions?
How similar to math notations?

Assessing the nested equation.

Thermal time

$$°F \rightarrow °C$$

Assessing the unit conversion modulo

Which one is better for unit conversion?

UO **OM** **QUDT**

Assesing the framework

MOTIVATION & PROBLEM

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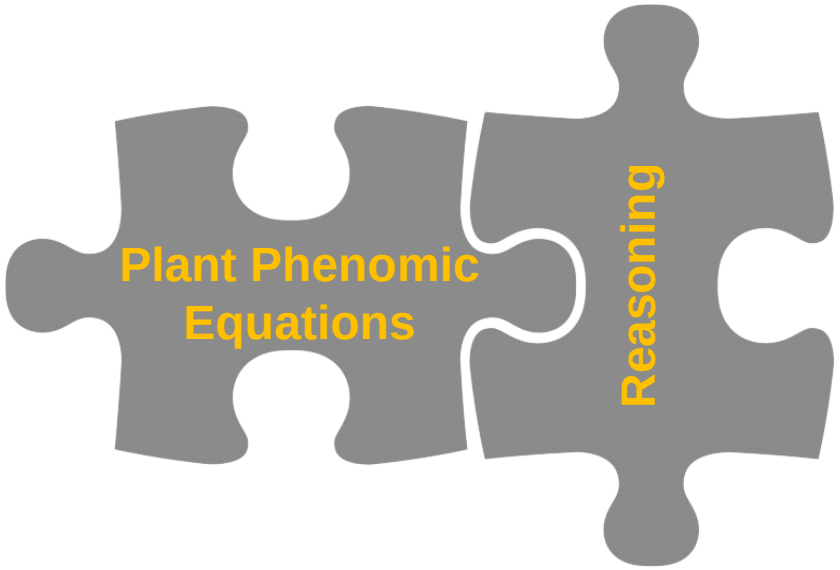

+ Linked models
+ Explainable equations
+ Effective use of unit ontologies

Therefore, the neglected numerical relationships will be easier to express

The framework can be used for another domains dealing with numerical attributes and mathematical equations.

Conclusions

THANK YOU

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