An approach to support I4.0 adoption in SMEs: a core-metamodel and applications

AUTHORS:

Michele Dassisti,
Antonio Giovannini,
Pasquale Merla,
Michela Chimienti,
Herve Panetto

Bergamo 11,June 2018

SMARTNESS IMPLEMENTATION IN MANUFACTURING SMEs

→ FEW SME'S ARE KEEN TO APPLY TRULY I4.0 SOLUTIONS

OBSTACLES:

1) Formalize of managerial and technological processes

2) Lack of deep ICT knowledge

3) Cost of smart systems (say sensor network, MES, etc) because of legacy HDW or SFTW

4) Overestimation of costs and underestimation of benefits

SMARTNESS IMPLEMENTATION IN MANUFACTURING SMEs

FACILITATOR

- **SIMPLIFICATION:** amazing simplification of the I4.0 system creation to extend their use to different knowledge domain

- **EXTENSIBILITY:** possibility of a gradual introduction of the new technologies without ask to the SMEs to have large investments

- **USER FRIENDLYNESS:** to make the use of the I4.0 solutions easy to use and apply

- **INTEROPERABILITY:** to provide a simple and total interoperability with the existing legacy systems

the core of smartness:
CYBER-PHYSICAL SYSTEMS

Combination of and coordination between the physical assets and their computational capabilities

NOT SATISFY UP TO NOW

KNOWLEDGE BASED: minimize the need of expert work to integrate the different interfaces that are intended to cover the I4.0

EXTENSIBILITY: SMEI4.0 solutions must be flexible to allow a gradual implementation

CYBER-PHYSICAL SYSTEMS: KNOWLEDGE-BASED

REUSABLE core-data model for all I4.0 applications

IN ORDER TO

ONE CORE- METAMODEL: different application gravitating around it with different aims

ADEQUATE REFERENCE MODEL: advanced knowledge representation mechanisms, supporting stakeholder communication and standardization across manufacturing

CYBER-PHYSICAL SYSTEMS: EXTENSIBILITY

Several approaches in literature

"vueOne" environment
- cooperative platform
(Harrison et al., 2016)

cloud-manufacturing model
- platform
(Tao et al., 2011)

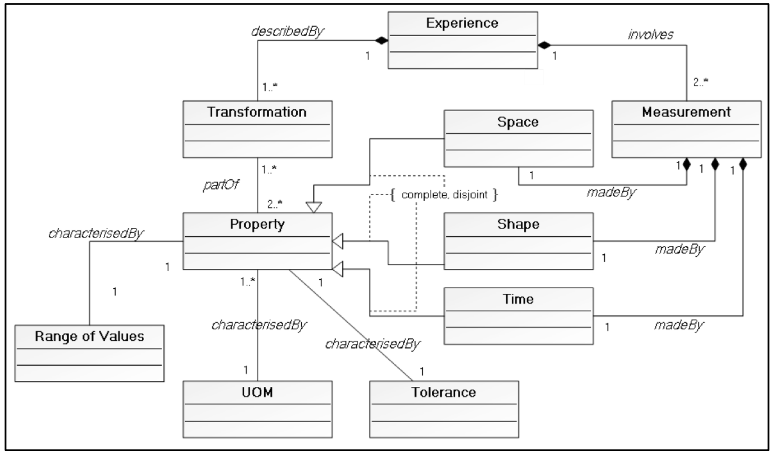
Linked factory
- Common hub
(Schlegel et al., 2017)

Cloud mftg
- service platform
(Huang et al., 2013)

collected data is mostly used and analyzed
only accordingly to the original reason of acquisition

→ MISSING KNOWLEDGE REPRESENTATION MECHANISM, SUPPORTING STAKEHOLDER COMMUNICATION AND STD.

CORE-METAMODEL: conceptual framework



“Anti-logicist framework for design-knowledge representation”

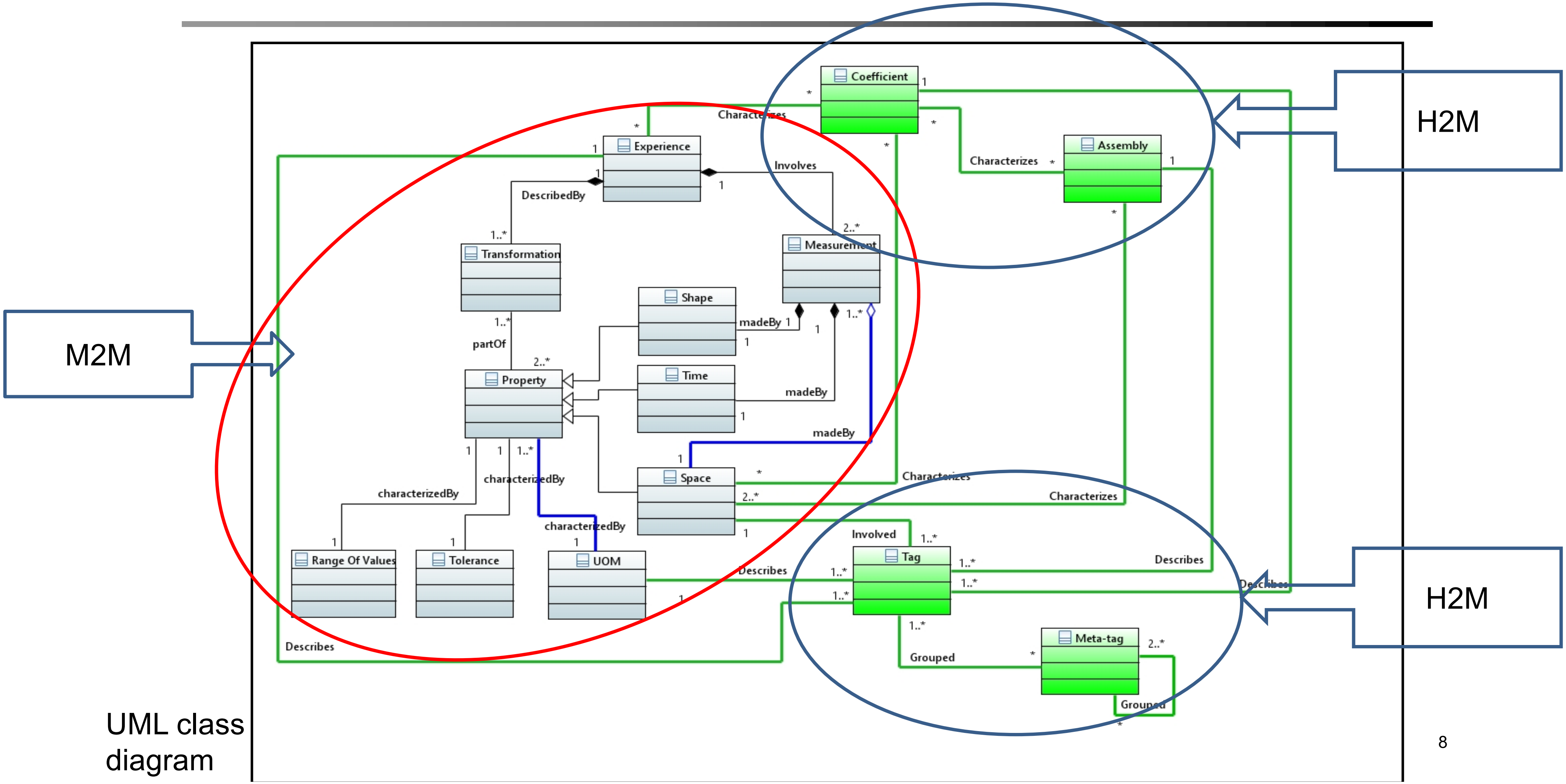
extension of a knowledge model based on the concept of <<measurement>>

(formalization of knowledge expertise & min integration issues)

The knowledge formalisation framework is able to represent the sensors capabilities and to perform actions on machine’s actuators

CORE-METAMODEL:

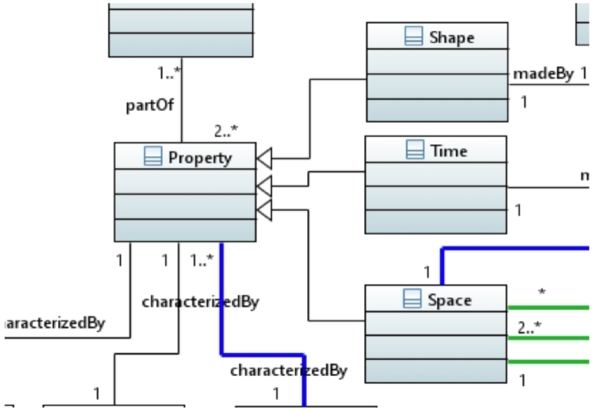
design knowledge formalization using «measurement» to minimize ambiguities



UML class diagram

M2M

CONCEPTUAL FRAMEWORK: MEASUREMENT



Measurement system

- **unit of measure**
- **range of measured values**
- **error,**
- **time**
- **place of measurement**

Measurement **is the characterisation of the act of perceiving the reality.**
(e.g. the temperature perceived in a sensor positioned in a volume of air at a time t identifies the sensor).

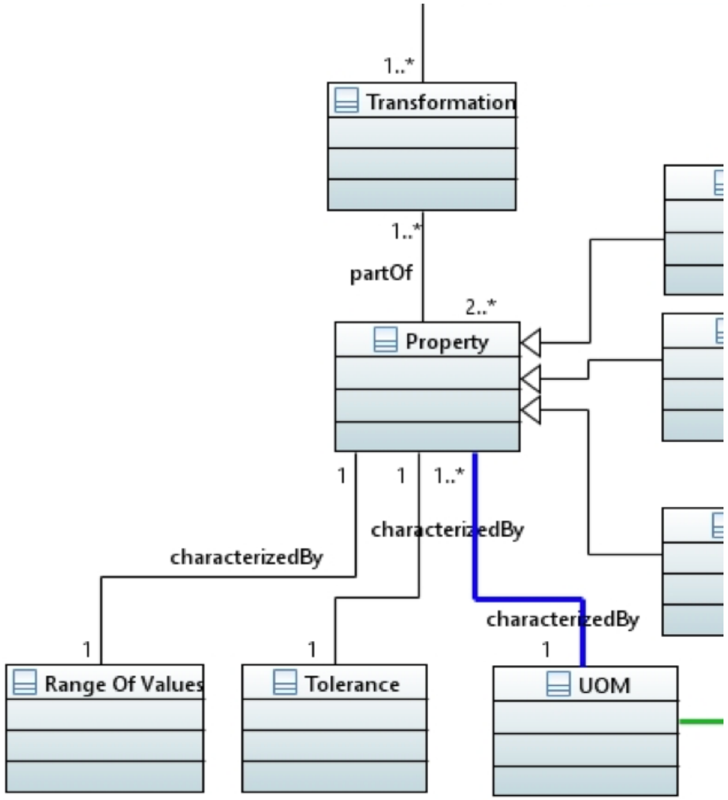
MEASUREMENT: ***A vector made of space, time and shape (S, T, S)***

→ *Temperature [UoM],/range/,[+/- T] : the shape of the measurement (i.e. what to measure)*
→ *Volume of air [UoM] /range/,[+/- T] : the space of the measurement (i.e. where to measure)*
→ *Time [UoM] /range/,[+/- T] : when the temperature is measured*

Each one of the three elements is a ***property***

CONCEPTUAL FRAMEWORK : transformation

M2M

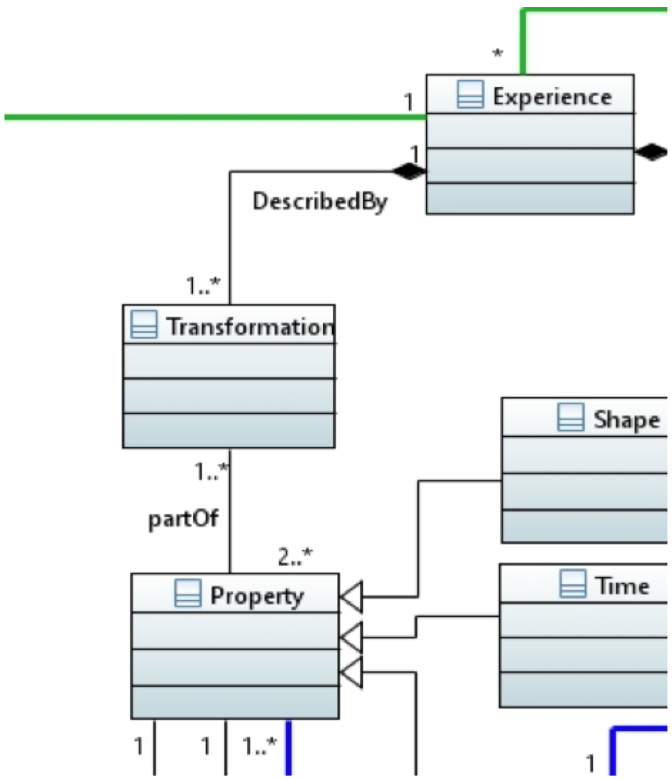


Mathematical relationship between different properties of several measures

/e.g. T=f(t)/

CONCEPTUAL FRAMEWORK :
<<experience>> ≅ system behaviour

M2M

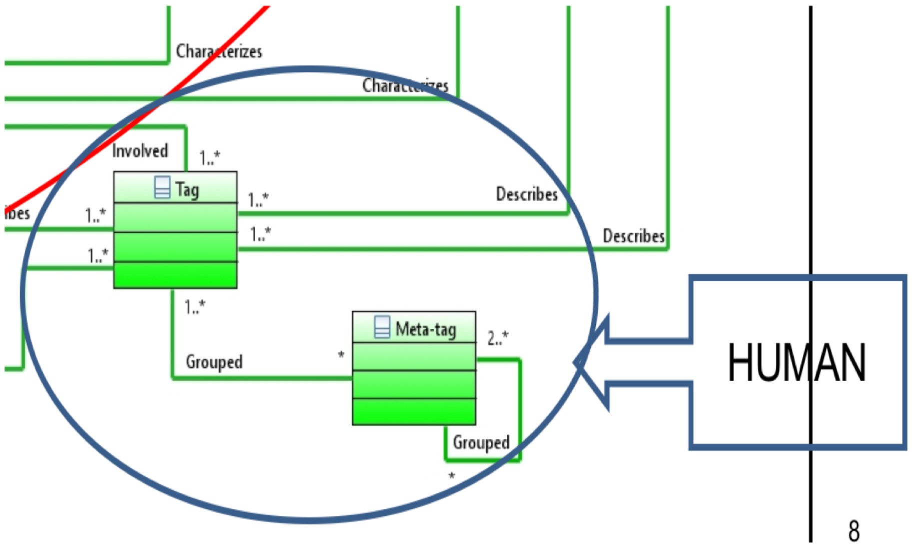


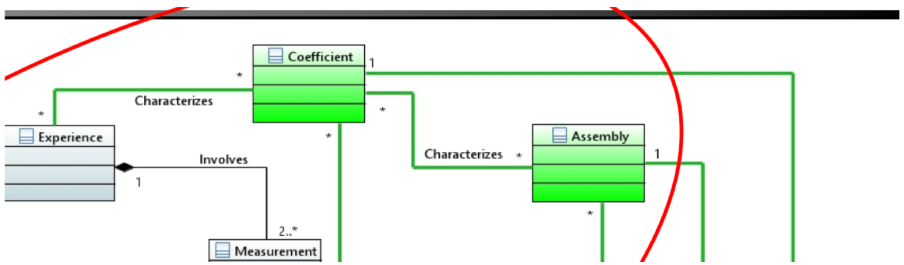
A set of mathematical relationships between properties of a set of measurements

test the validity of the ideal gas law *PV=nRT*
(an instance of *transformation*)
The instance of the *experience* has to capture
the mathematical relationships between all the (S, T, S)s
of the *measurements* (e.g. pressure, temperature,
volume of the gas considered)
that describe the environmental conditions
where the law holds

H2M

CORE-METAMODEL: Extending for human-machine interface



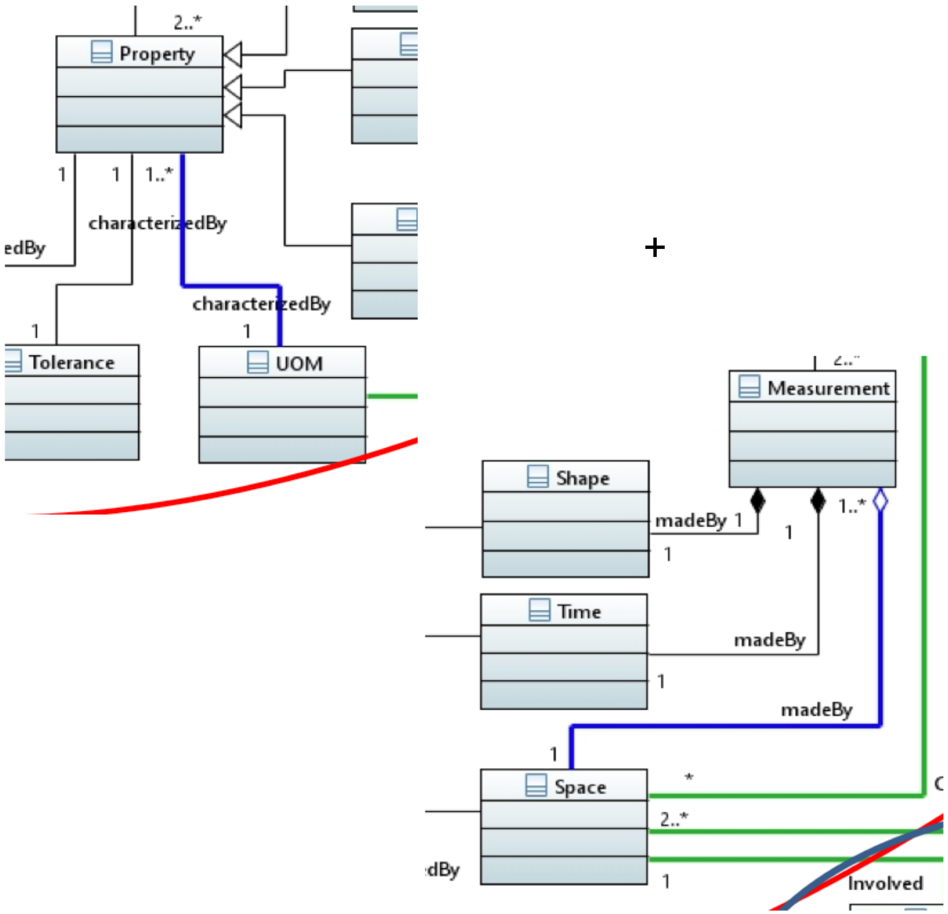


1) **USER FRIENDLINESS: new concepts to allow a non-expert user interaction and a multi-perspective descriptions**

2) **SYNTHESIS: concepts to improve the accessibility of the knowledge base content at multiple levels of detail**

H2M

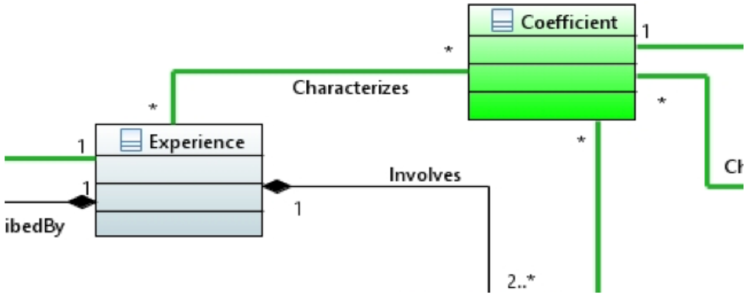
CORE-METAMODEL : Abstracting «UoM» and «space»



The abstraction of <<UoM>> and <<space>> allows to find two experiences that refer to the same space or UOM

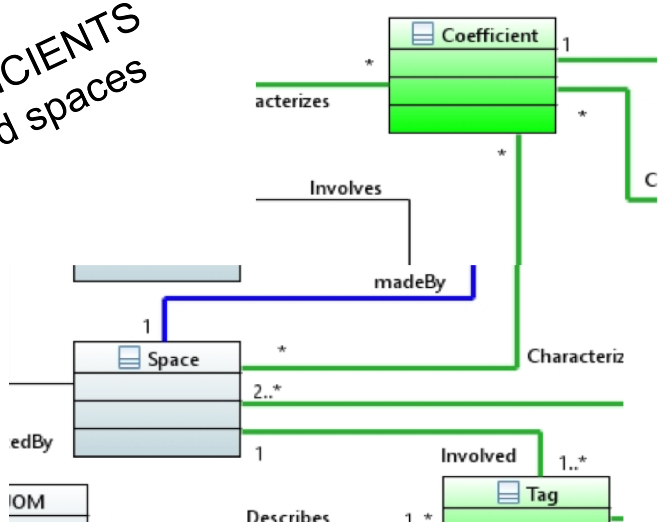
Two system behaviours:
1) the light diffusion in a room;
2) heat exchange in a room.
The concept of “window” is in both cases involved in the systems.
→ Without the abstraction of the concept of *space* there is no chance of finding the two experiences by querying the word “window”.

CORE-METAMODEL: COEFFICIENT



coefficients describe relationships between measurements but are not tied to direct measures

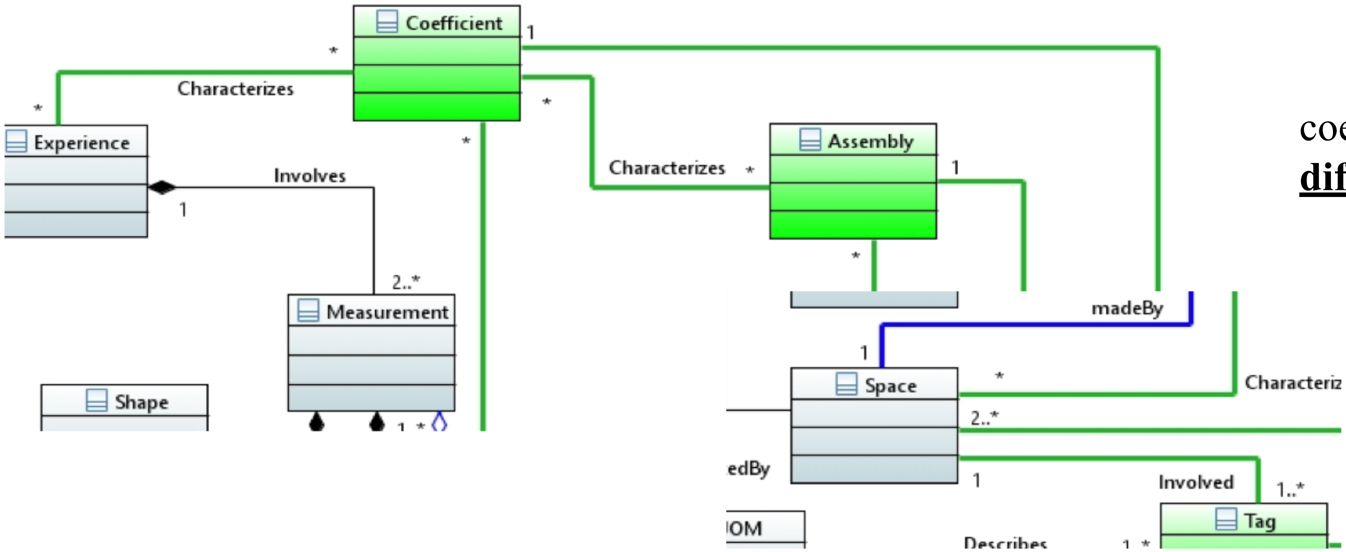
SEARCH FOR COEFFICIENTS
→ Find experience and spaces



COEFFICIENT: to describe how the measurements relate in an experience

H2M

CORE-METAMODEL: ASSEMBLY

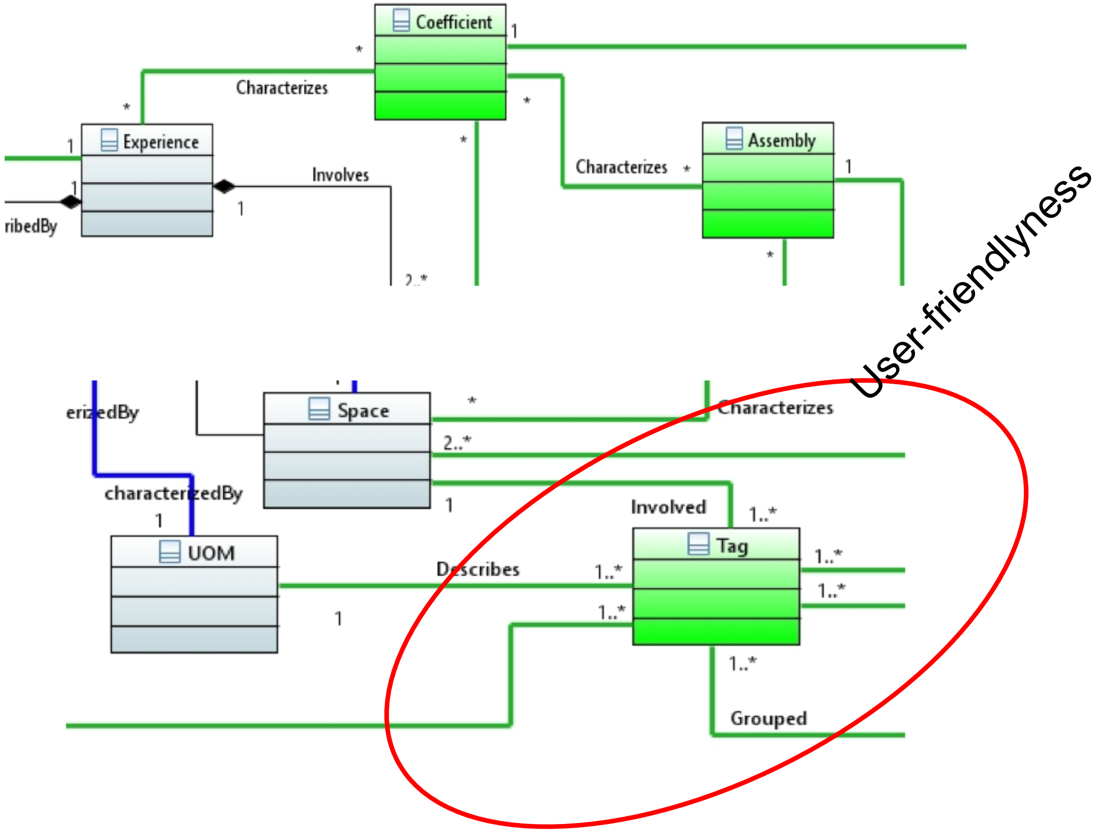


coefficient relates to measurements in **<u>different spaces</u>**➔ new concept

<u>ASSEMBLY: to represent different space (objects) aggregation</u>

CORE-METAMODEL : TAGS

H2M



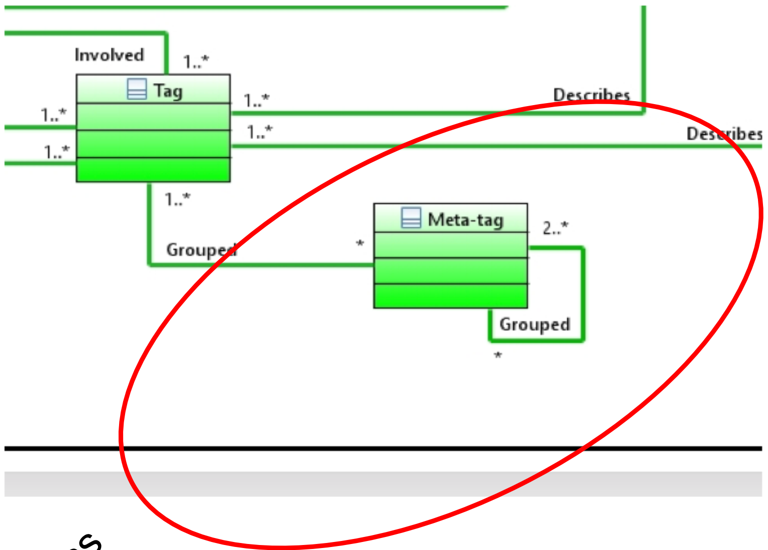
1 Tag = 1 DB content/
avoid multiple interpretation

One-word description associated with all the researchable concepts of the model, i.e. UOM, space, coefficient, assembly and experience.

When a user performs a tag-based research, the results are directly connected with the original concepts that are intended to disambiguate the knowledge on the basis of the measurement system.

H2M

CORE-METAMODEL : meta-tag



User-friendlyness

METATAG: aggregated tag

- To speed up a research based on descriptions and to associate related descriptions -

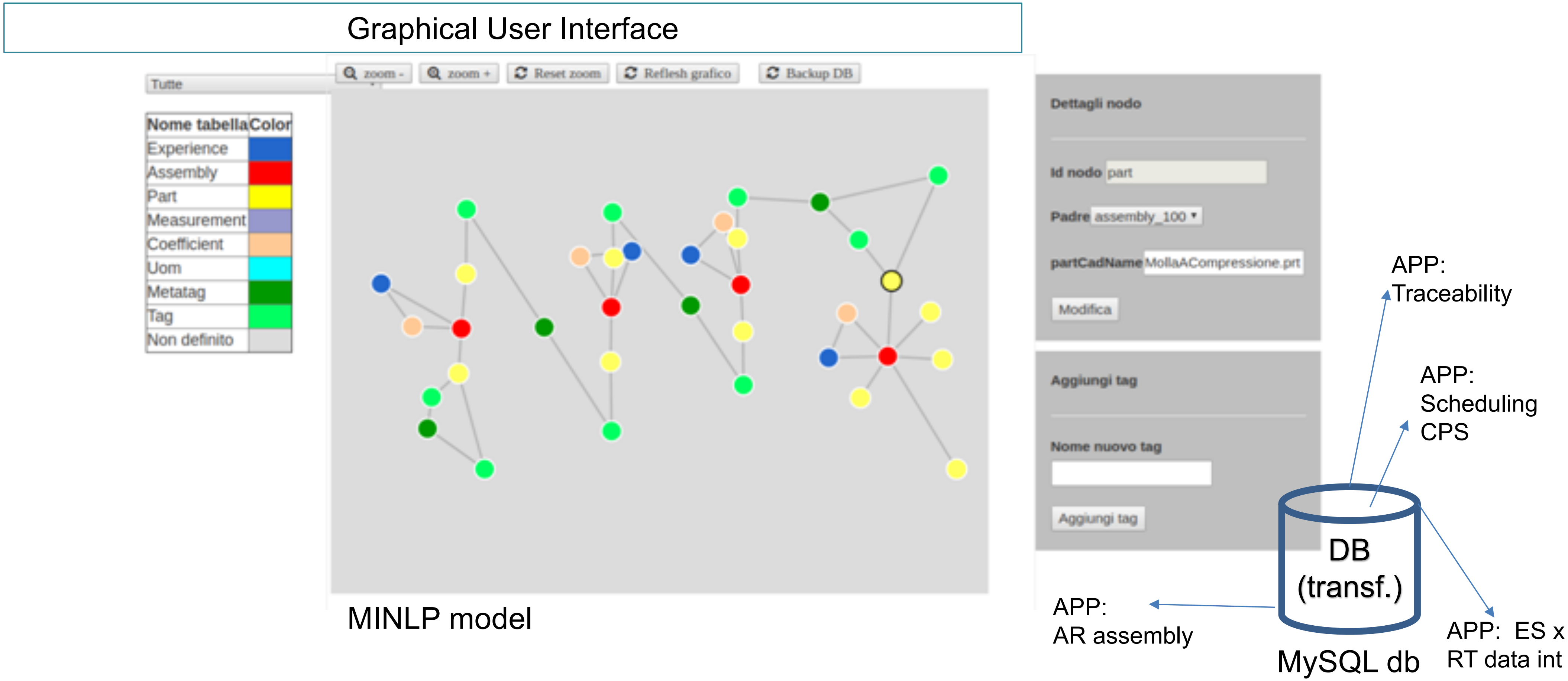
These relationships allow to build several levels of aggregations / MORE SYTHESIS LEVELS

CASE STUDY: METAMODEL IMPLEMENTATION

H0:
Core metamodel can be used indipendently by an interface (system traceability configuration)
M2M or even H2M (not experts)

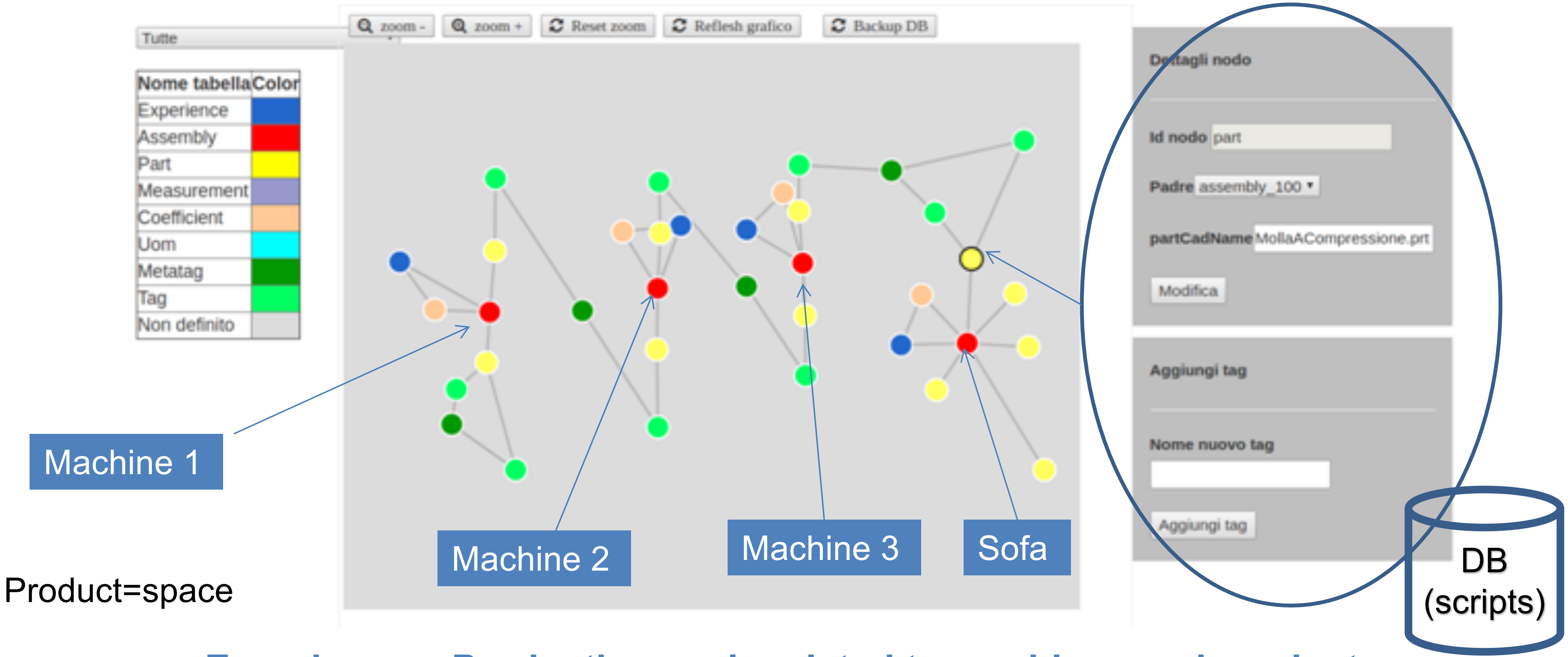
MollificioCentroItalia S.R.L.

CASE STUDY: METAMODEL IMPLEMENTATION



CASE STUDY: METAMODEL IMPLEMENTATION

Graphical User Interface



Experience = Production cycle related to machines and products

CASE STUDY: knowledge implemetation

UML-RT (Unified Modelling Language – Real-Time)

Different production cycles on the same machine based on available time

```
int main(int argc, char** argv)
{
    ofstream of("test.txt");
    tempo=atof(argv[1]);
    prod=argv[2];
    //acc0=atof(argv[3]);
    //tempo_acc0=atof(argv[4]);
    delta_temp=0;
    cout <<"tempo-->"<< tempo << endl;
    cout <<"prodotto-->"<< prod << endl;
    //cout <<"acc0-->"<< acc0 << endl;
    //cout <<"tempo_acc0-->"<< tempo_acc0 << endl;
    cout<<endl<<"------------------"<<endl;
//-----------------------------------AVVOLGIMENTO-----------------------------------
    if (prod==PROD1)
    {
        if (tempo<=TEMPO1_1)                                       //190Watt
        {
            cout<<"acc1=70"<<endl;      //16rpms
            cout<<"deltaT1=35"<<endl;   //17.5s
            cout<<"acc2=50"<<endl;      //0rpms          //w=280rpm  per 38s
            cout<<"delta2=76"<<endl;    //38s
            cout<<"acc3=5"<<endl;
            cout<<"delta3=30"<<endl;    //15s       //8s
            //tot=63.5
        }
        else if ((tempo>TEMPO1_1) && (tempo<=TEMPO1_2))            //165Watt
        {
            cout<<"acc1=60"<<endl;      //8rpms
            cout<<"deltaT1=60"<<endl;   //30s
            cout<<"acc2=50"<<endl;      //0rpms          //w=240rpm  per 34s
            cout<<"delta2=68"<<endl;    //34s
            cout<<"acc3=5"<<endl;
            cout<<"delta3=30"<<endl;    //15s       //8s
            //tot=30+34+(8)=72
        }
        else if (tempo>TEMPO1_2)                                   //144
        {
```

CASE STUDY: METAMODEL IMPLEMENTATION

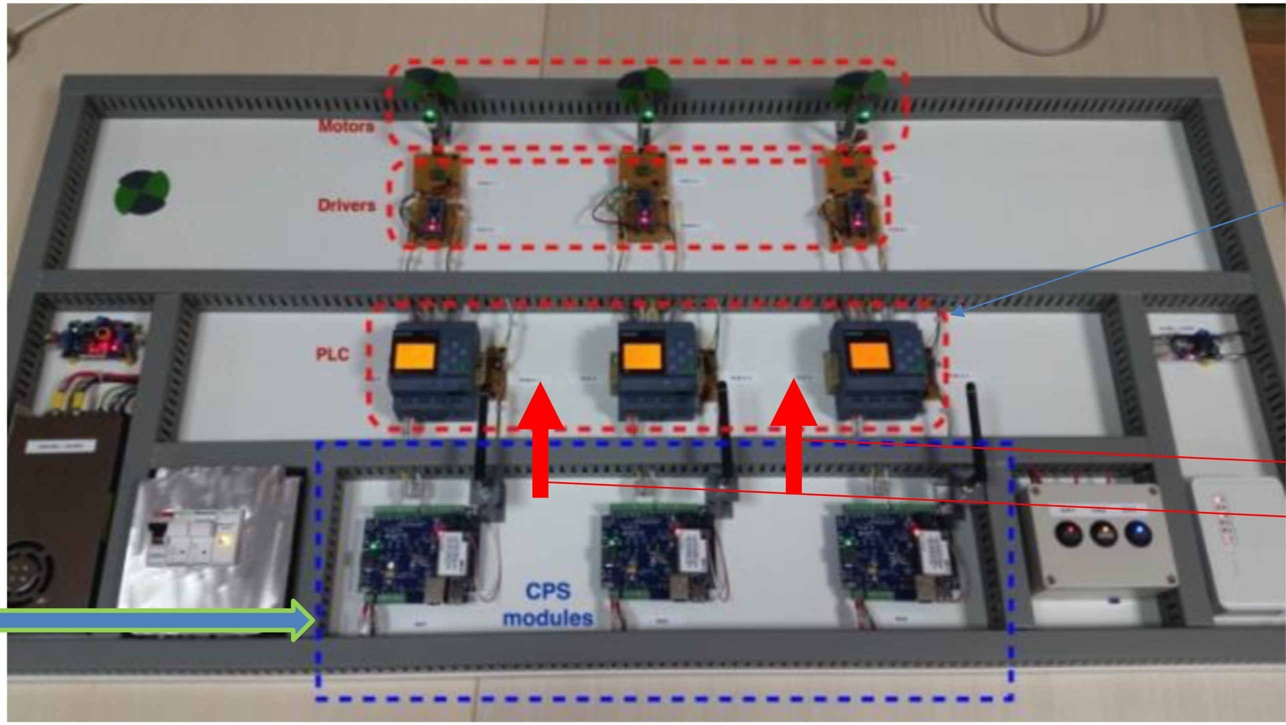
CPS app: optimise the scheduling in real-time to exploit energy saving opportunities /NO USER KNOWLEDGE/

Order entry

Central Unit Simulation

synch

DB* (scripts)



Industrial Controller Simulation

*TRANSFORMATION→ Best motor speed ramp

Simulation of the 3 machines.
Each machine is composed by a PLC, a driver and a motor

CONCLUSIONS

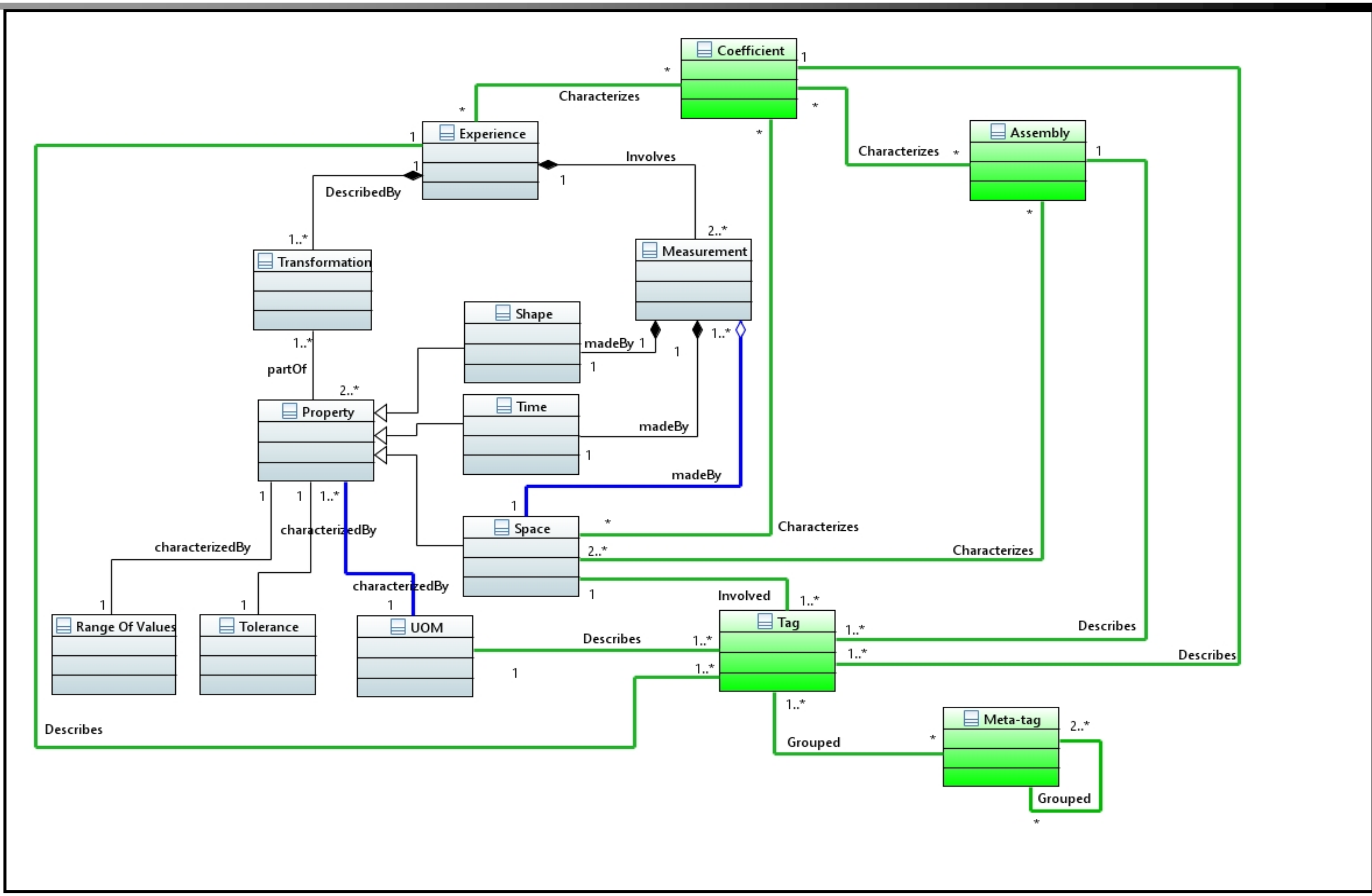
THE CORE METAMODEL:

- NO deep knowledge about the application domain (knowledge formalized with the proposed metamodel is able to properly support the users).

- The same DB can structure knowledge for different domains that can be used for different applications.

limits of the proposal are still related to the knowledge mapping in the DB.

By permission of MCI Srl, In. Tech. Srl, RG Impianti Srl, and Technoacque Srl companies, which committed research projects to InResLab scarl.



Coefficient
Experience
Assembly
Transformation
Measurement
Shape
Time
Property
Space
Range Of Values
Tolerance
UOM
Tag
Meta-tag
Characterizes
Involves
DescribedBy
partOf
madeBy
characterizedBy
Involved
Describes
Grouped