Debugging knowledge
by means of a spatial metaphor

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Bio

- Professor at the Department of Information Technology.
  - School of Engineering
  - University of Huelva. Spain
  - Head of Master of Economy, Finance and Computation.
- PhD in Computer Science and Artificial Intelligence.
  - University of Sevilla – Spain
  - Bachelor in Physics – University Complutense - Madrid

- My research interests include knowledge management, formal verification, logic, formal concept analysis, ontologies, …. multiagent systems, etc…

- Current projects include design and build cognitive tools to manage knowledge, extract information to transform into knowledge.

Aim of this talk

- The aim of this talk is to present a tool with 3 main goals:

  - Debug knowledge, preserving consistency and reasoning, using a graphical interface

  - Non-expert users should be able to use it.

  - Transformation applied to KB must be formally verified.

What means Debugging?

PAELLA
Framework

Jesús Valeo Fernández

Universidad de Huelva

Cargando módulo DUMMY...   30%

What is Paella?

- Its a…
  - FrameWork
    - It is designed to manage different kind of knowledge bases… and can be extended!

  - Visual editor for knowledge bases
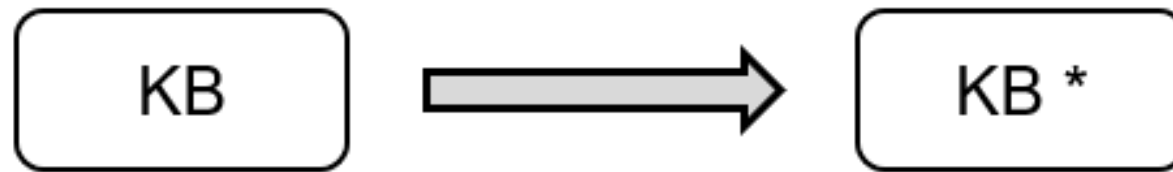
  - Based on relations about concepts (not on concepts)

G. A. Aranda-Corral, J. Borrego-Díaz and A. M. Chávez-González, "Repairing conceptual relations in ontologies by means of an interactive visual reasoning: Cognitive and design principles," *2012 IEEE 3rd International Conference on Cognitive Infocommunications (CogInfoCom)*, Kosice, Slovakia, 2012, pp. 739-744, doi: 10.1109/CogInfoCom.2012.6421949.
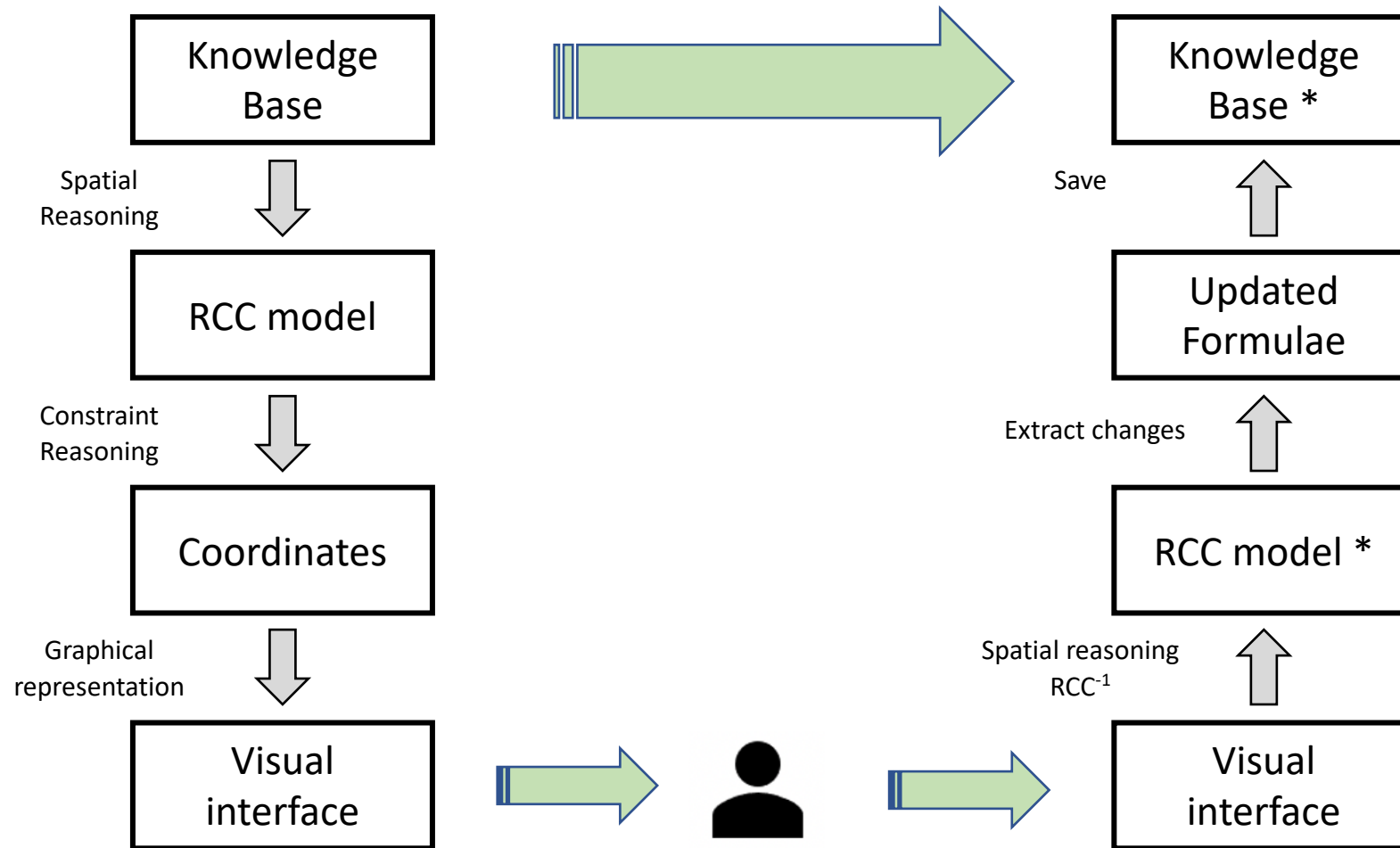
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Who is Paella?

- Researchers:
  - ***Joaquín Borrego-Díaz (US)***
  - Antonia M. Chávez-González (US)
  - ***Gonzalo A. Aranda Corral (UHU)****

- Developers:
  - Jesús Valeo Fernández (Student UHU)
  - Álvaro Martín Boza (Student UHU)
  - ***Gonzalo A. Aranda-Corral (UHU)****

How can we modify this "alignment"?

- We call the Paella's cycle…

How: Complete cycle

Knowledge Base

Spatial Reasoning

RCC model

Constraint Reasoning

Coordinates

Graphical representation

Visual interface

Knowledge Base *

Save

Updated Formulae

Extract changes

RCC model *

Spatial reasoning RCC^{-1}

Visual interface

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Where can be executed?

- Initially was born to be a Protégé plugin.

- In order to manage different kinds of Kb, evolves to Standalone

- Now, after a BIG restructure, we are considering to port some piece to Protégé, and be combined both versions.

Formal background

- Cognitive Principles

First Cognitive Principle (CP1): The concepts of a conceptualization associate to a clear ontology can be topologically represented by means of regular non-empty regions.
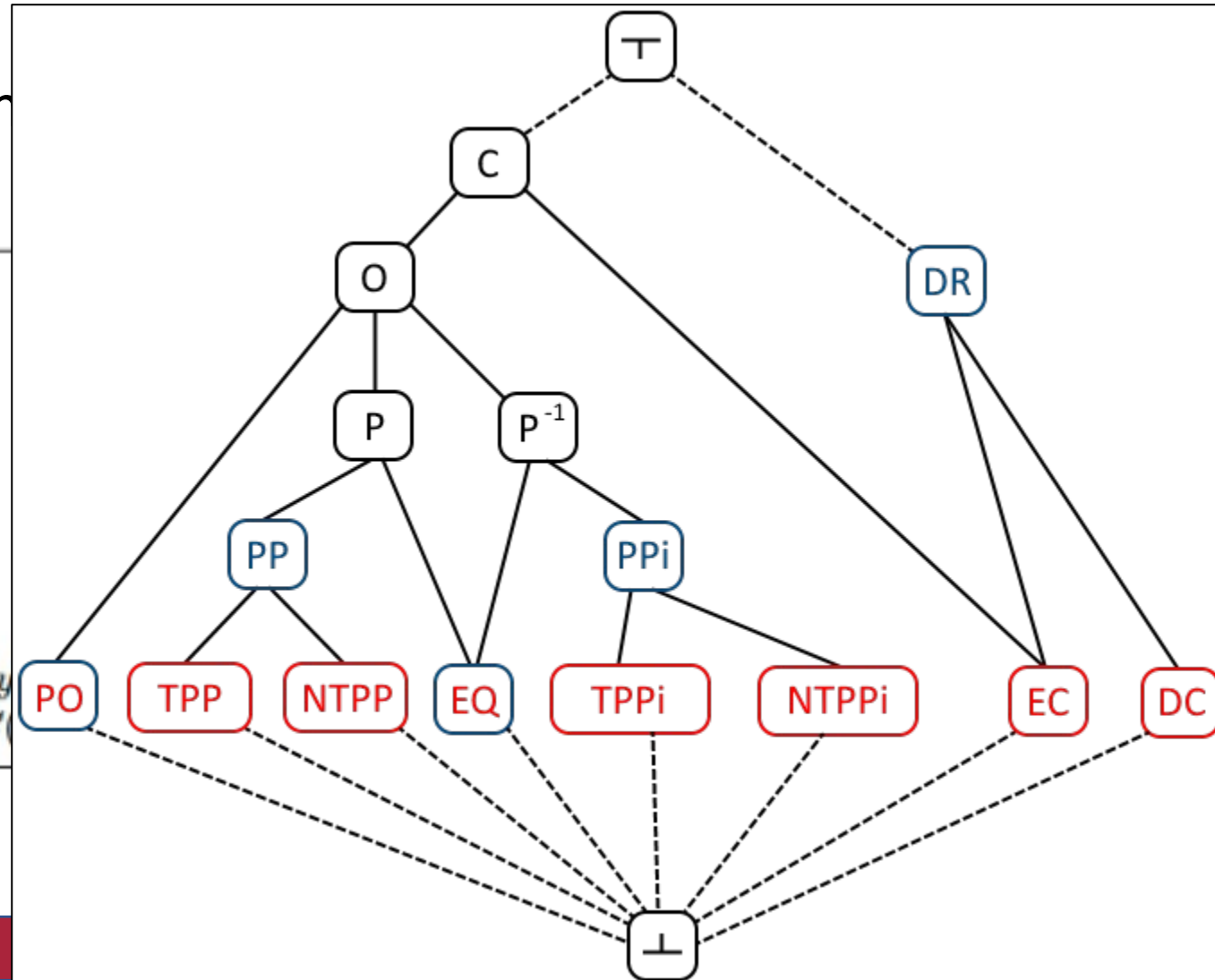
- For this, we use RCC (Region Connection Calculus) is a mereotopological approach to QSR (Qualitative Spatial Reasoning)

RCC

- In RCC, the spatial entities are non-empty regular sets.
- The ground relation is the connection, C(x,y),
  - with intended meaning:
    "the topological closures of x and y intersect".

- The basic properties that C(x,y) must holds are
  - Reflexive $\forall x[C(x,x)]$
  - Symmetric $\forall x, y[C(x,y) \rightarrow C(y,x)]$

RCC Theory
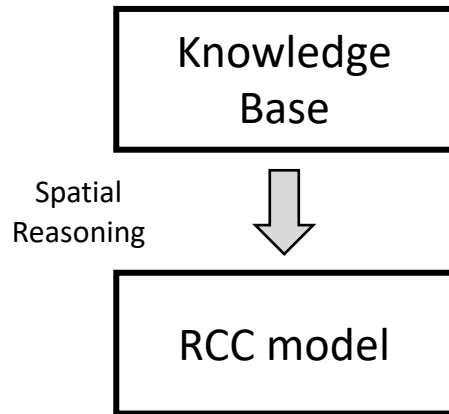
Knowledge Base

Spatial Reasoning

RCC model

First Cognitive Principle (CP1): The concepts of a conceptualization associate to a clear ontology can be topologically represented by means of regular non-empty regions.

Theorem 3. [10] *The following conditions are equivalent:*

1. $C_\Sigma(C_1, C_2)$
2. *There is a spatial interpretation I of Σ such that $I \models C(C_1, C_2)$.*

RCC

• Based on this definition, we can

$$DC(x,y) \leftrightarrow \neg C(x,y)$$
$$P(x,y) \leftrightarrow \forall z[C(z,x) \rightarrow C(z,y)]$$
$$PP(x,y) \leftrightarrow P(x,y) \wedge \neg P(y,x)$$
$$EQ(x,y) \leftrightarrow P(x,y) \wedge P(y,x)$$
$$O(x,y) \leftrightarrow \exists z[P(z,x) \wedge P(z,y)]$$
$$DR(x,y) \leftrightarrow \neg O(x,y)$$
$$PO(x,y) \leftrightarrow O(x,y) \wedge \neg P(x,y) \wedge \neg P(y,x)$$
$$EC(x,y) \leftrightarrow C(x,y) \wedge \neg O(x,y)$$
$$TPP(x,y) \leftrightarrow PP(x,y) \wedge \exists z[EC(z,x) \wedge EC(z,y]$$
$$NTPP(x,y) \leftrightarrow PP(x,y) \wedge \neg \exists z[EC(z,x) \wedge EC$$

RCC

- Graphically:

- RCC5

PP(A,B)   PPi(A,B)   EQ(A,B)   PO(A,B)   DR(A,B)

JEPD

- RCC8

DC(A,B)   PO(A,B)   TPP(A,B)   NTPP(A,B)   EQ(A,B)

EC(A,B)   TPPi(A,B)   NTPPi(A,B)
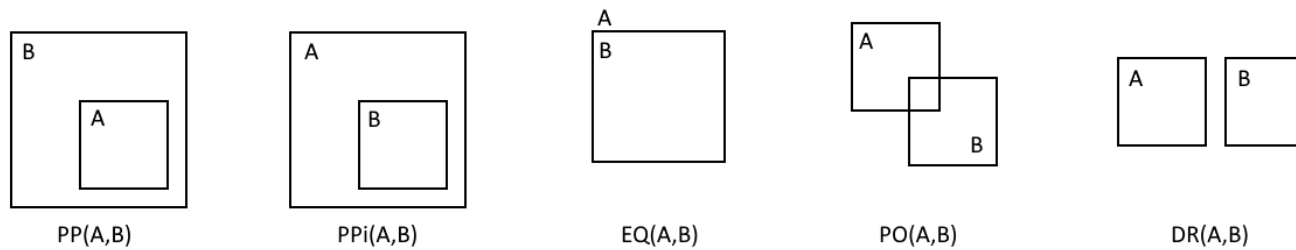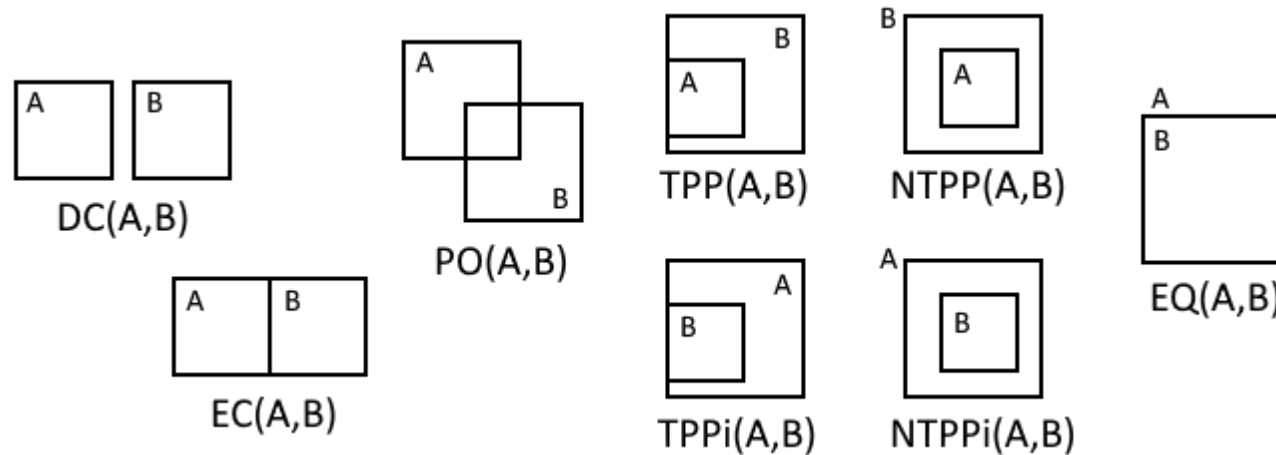
RCC

- It is not about CONCEPTS...

    It is about RELATIONS BETWEEN CONCEPTS

- We are not working with the definition of the concepts, just with their relations.

RCC (algorithm)

- RCC5
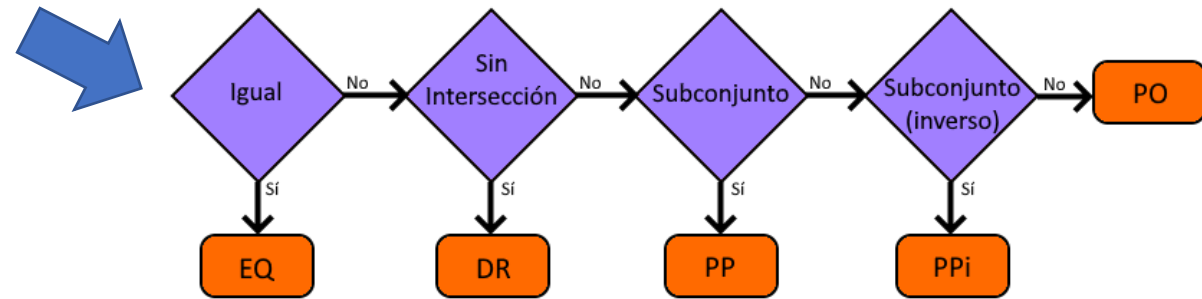
- RCC8
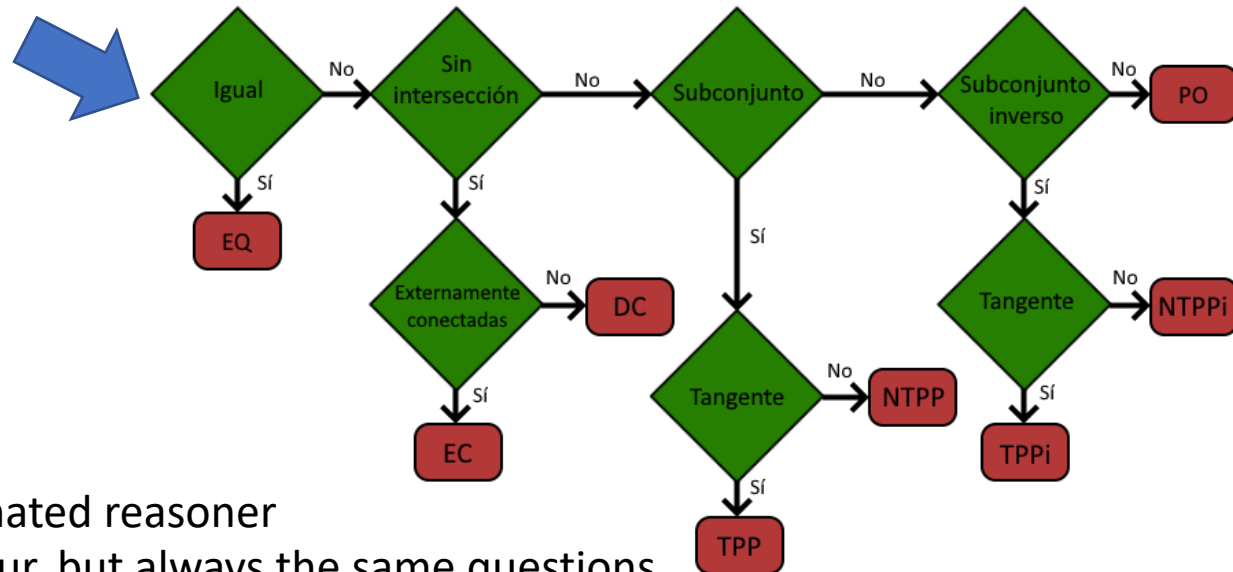
- Those questions are made to an automated reasoner
- The reasoner is different for each flavour, but always the same questions

RCC

- Movements & neighbor's graph
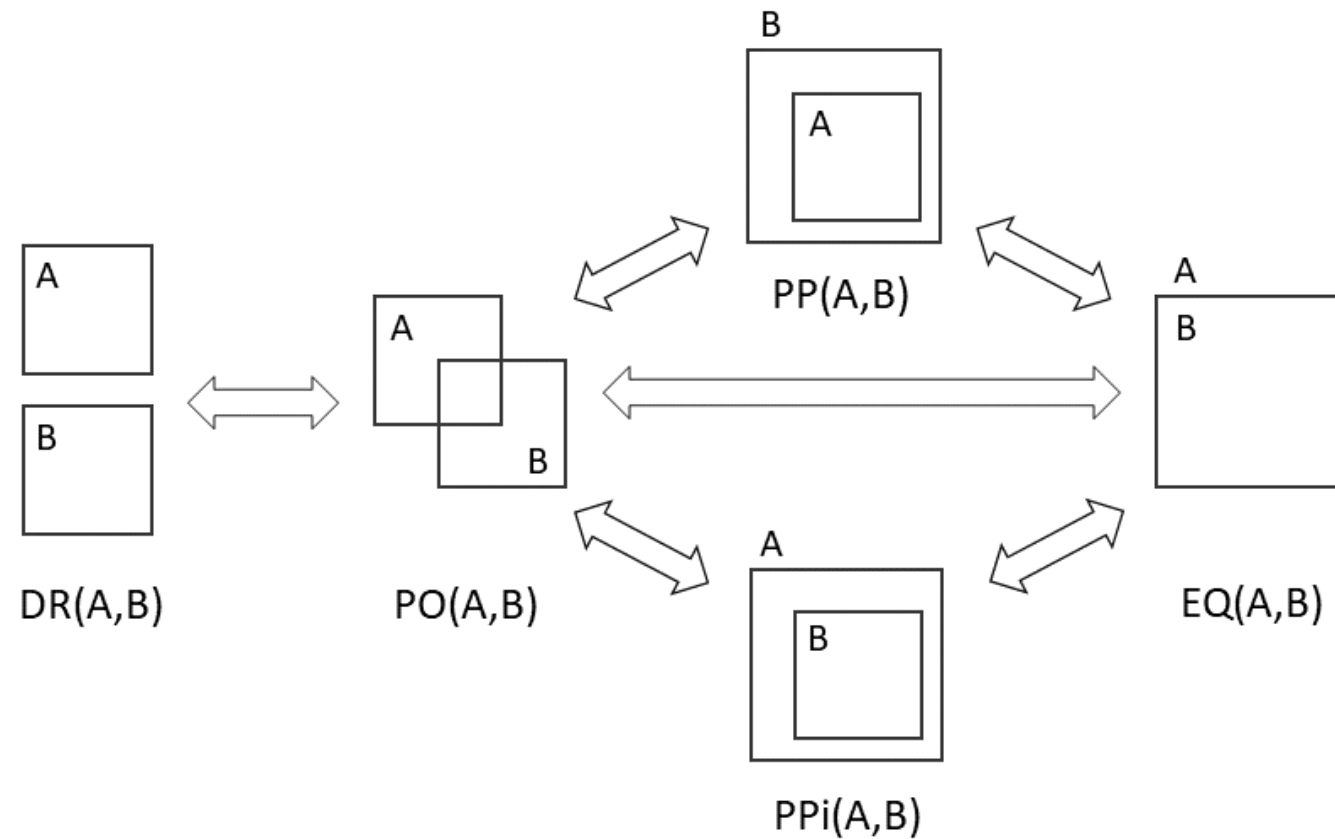
RCC

- Extension to "points"
  - We consider Individuals as "small" regions: Area>0 , but cannot contain elements (only itself)
  - Then, we can reduce the expressions:

IN(P,R) OUT(P,R)

RCC5*

IN(P,R) FRONT(P,R) OUT(P,R)
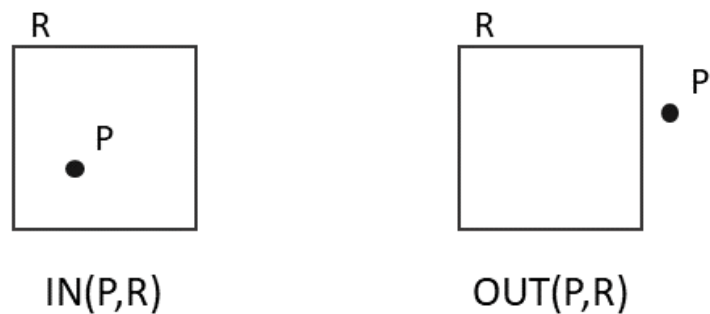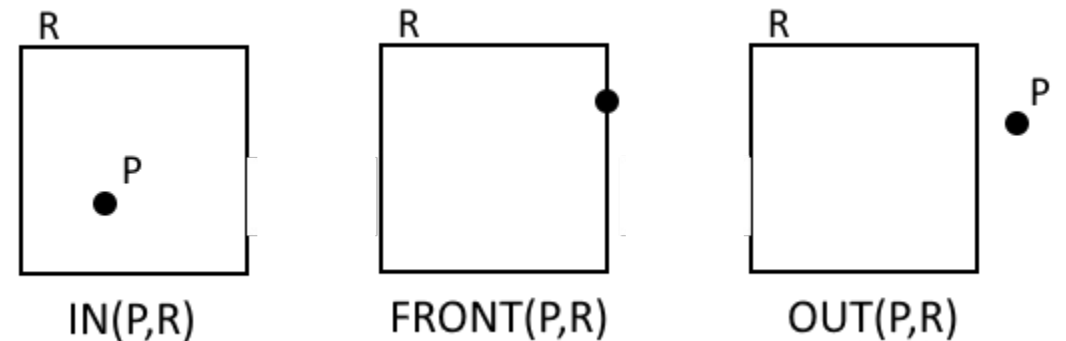
RCC8*

RCC

- To transform a Kb into a RCC representation, we have to calculate ALL pairs of relations:
  - #relations = HUGE NUMBER!!

- Optimize: Removing redundant relations.

R(a,b) \ R(b,c)	DR	PO	PP	PPi	EQ
DR	*	*	*	DR	DR
PO	*	*	*	*	DR
PP	DR	*	PP	*	PP
PPi	*	*	*	PPi	PPi
EQ	DR	PO	PP	PPi	EQ

From RCC to Graphical representation

- Transform RCC relations into a CSP problem.

- Areas are rectangles (mereotopology)

- Variables:
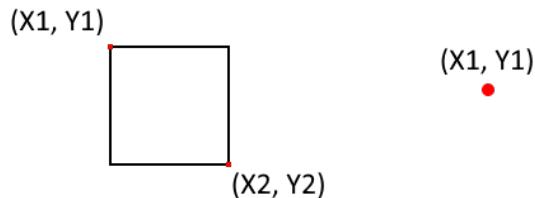
- Domains: Screen width and height (640*480)

- Constraints:
  - Area > 0 :   X2 #> X1 AND Y2 #> Y1
  - ALL related to RCC-relations

From RCC to Graphical representation

- Constraint

  - Ex: DR(A,B)
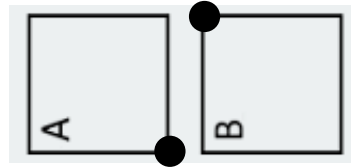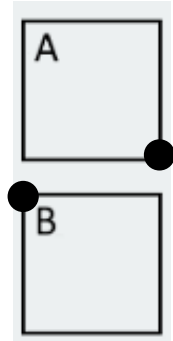
  - Constraint: Y2A #< Y1B   OR   X1B #> X2A. … OR ….

- Translate ALL relations… but 1!! (JEPD)

- With this… we obtain the coordinates to represent the relations.

From RCC to Graphical representation

Definition 2. *A **spatial interpretation** I of Σ is a interpretation in the language of Σ, such that $I : concepts(\Sigma) \cup indiv(\Sigma) \rightarrow \Omega$, where Ω is a T_3 connected topological space such that $I \models \Sigma$ and for each $C \in concepts(\Sigma), I(C)$ is an open regular set in Ω and for each $a \in indiv(\Sigma), I(a)$ is a point.*
A spatial model *of Σ is a spatial interpretation which is a model of Σ.*

Theorem 2. *[10] The CSP associate to Σ is spatially consistent if Σ is consistent.*

Moreover, it is possible to obtain a spatial model on the plane formed by polygonal regions [25].

From RCC to Graphical representation

- CSP is solved by an existing library… called CHOCO©

@article{Prud'homme2022, doi = {10.21105/joss.04708}, url = {https://doi.org/10.21105/joss.04708}, year = {2022}, publisher = {The Open Journal}, volume = {7}, number = {78}, pages = {4708}, author = {Charles Prud'homme and Jean-Guillaume Fages}, title = {Choco-solver: A Java library for constraint programming}, journal = {Journal of Open Source Software} }

User Interface

Movements

DRAG (left button)
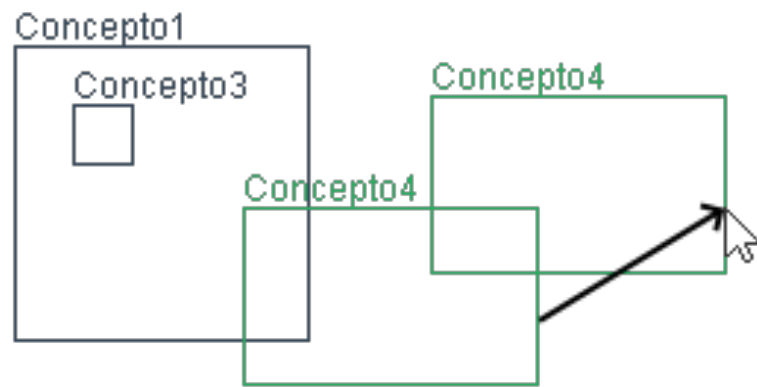
PO(C3,C4) → DR(C3,C4)

REDIM (right button)
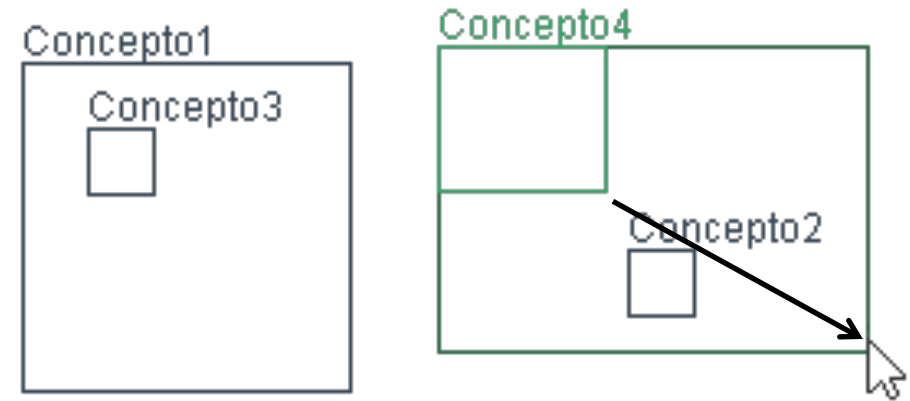
DR(C2,C4) → PP(C2,C4)

Movements

Visual Editor

From UI to RCC (we call: RCC^{-1})

- Transformation from coordinates to RCC-relations
- Similar algorithm (same questions) with totally different implementation
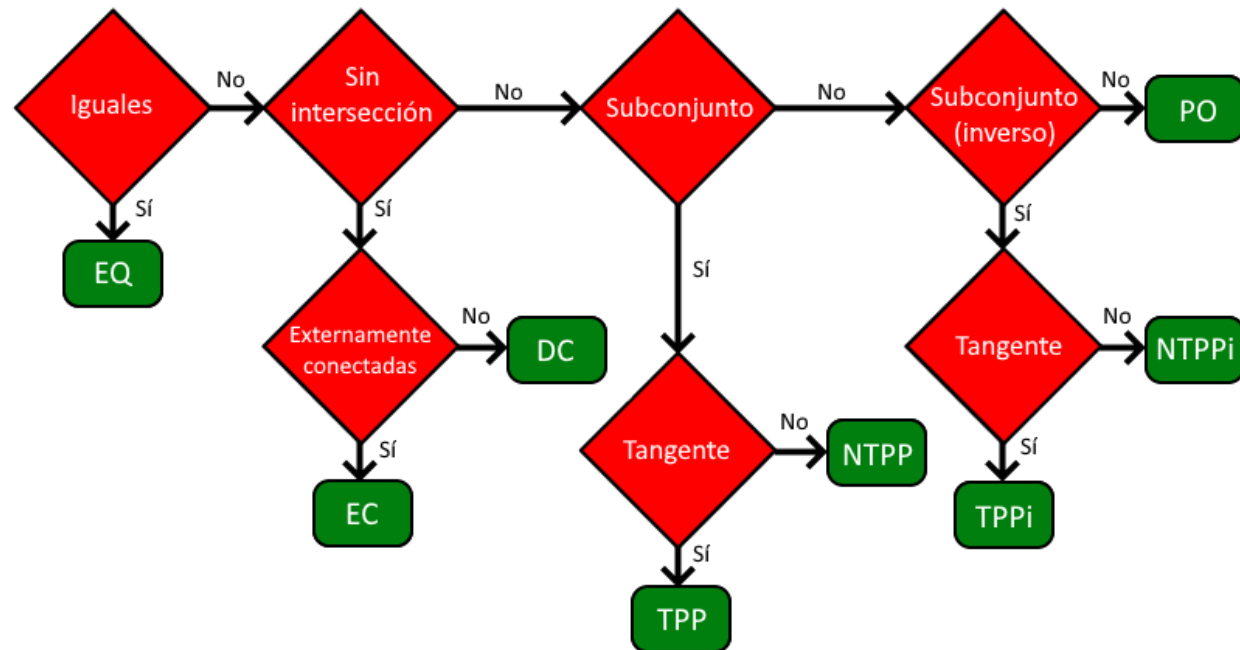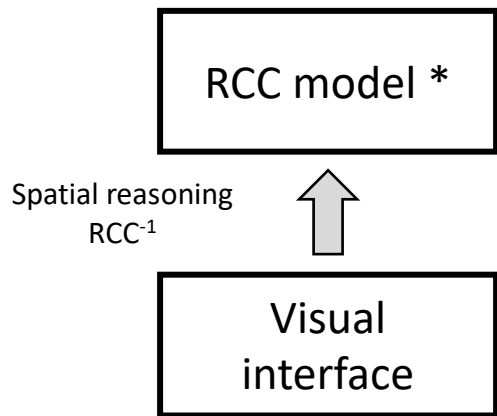
Applying changes

- This is the most difficult section.
- Depends a lot on what type of Kb we are working on.

  - Extensives: changes are only creation of new individuals or classes. Inconsistences cannot exists (Our diagram is a model)

  - Intensives: (as Ontologies) Changes mean introduce (or remove) individuals, concepts AND AXIOMS!
    - Sometimes, we need to add, pj ex, ALL_DISJOINT axiom, or remove it.
    - THIS CAN INTRODUCE INCONSISTENCES. (because the draw is a model of that part of the ontology, but not all the ontology)

Applying Movements

- A change can be seen as a path of basic steps in the graph.
  - This is a first approach for **an automated repairing** system.
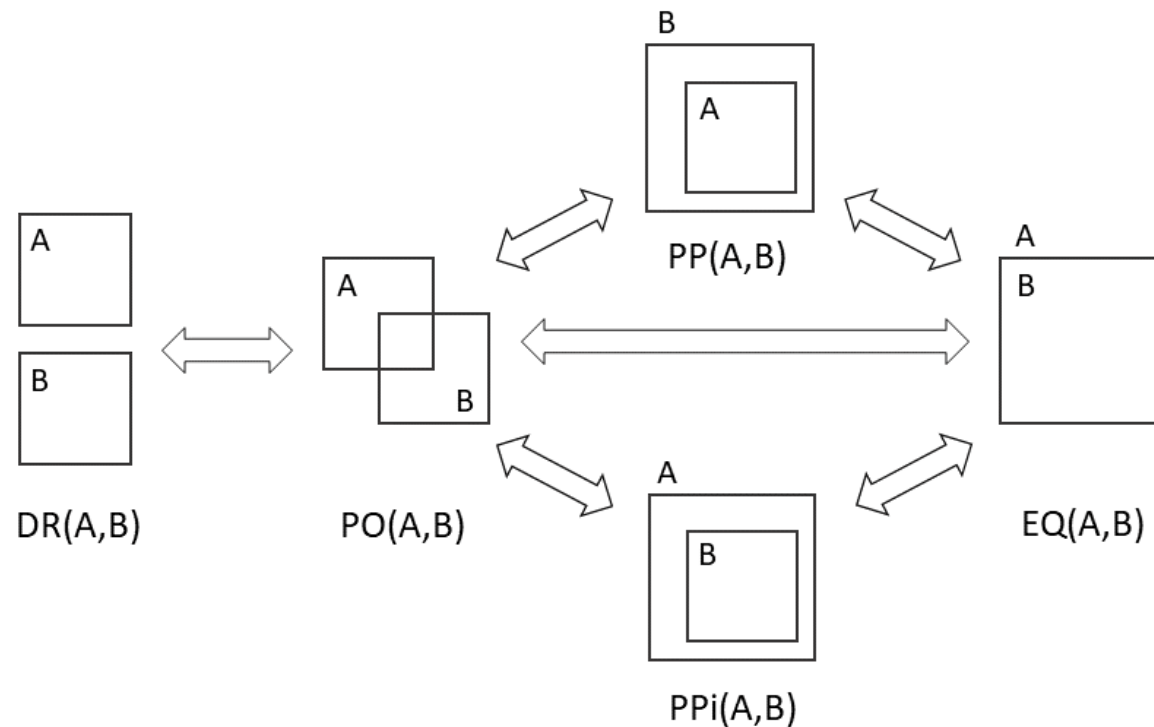
Applying changes (example)

$$\Sigma = \begin{cases} \text{Omnivorous} \sqsubseteq \text{Carnivorous} \sqcap \text{Herbivorous} \\ \text{Carnivorous} \sqsubseteq \text{Animal}, \quad \text{Herbivorous} \sqsubseteq \text{Animal} \\ \text{Omnivorous(Bear)} \end{cases}$$

We deduce that $PO_\Sigma(\text{Carnivorous, Herbivorous}) \wedge EQ_\Sigma^\sigma(\text{Carnivorous, Herbivorous})$.

Applying changes (example)

$$\Sigma = \begin{cases} \text{Omnivorous} \sqsubseteq \text{Carnivorous} \sqcap \text{Herbivorous} \\ \text{Carnivorous} \sqsubseteq \text{Animal}, \quad \text{Herbivorous} \sqsubseteq \text{Animal} \\ \text{Omnivorous(Bear)} \end{cases}$$

$$\Sigma' = \begin{cases} \text{Omnivorous} \sqsubseteq \text{Carnivorous} \sqcap \text{Herbivorous} \\ \text{Carnivorous} \sqsubseteq \text{Animal} \sqcap \neg\{b_2\}, \quad \text{Herbivorous} \sqsubseteq \text{Animal} \sqcap \neg\{b_1\} \\ \text{Herbivorous}(b_2), \quad \text{Carnivorous}(b_1), \quad \text{Omnivorous(Bear)} \end{cases}$$

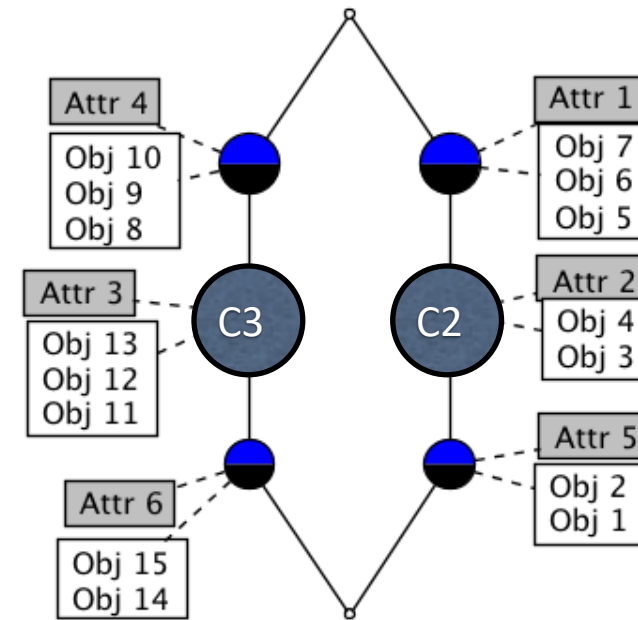Herbivorous
Carnivorous

PO(Carnivorous, Herbivorous)

EQ(Carnivorous, Herbivorous)

Herbivorous
Carnivorous

b1

b2
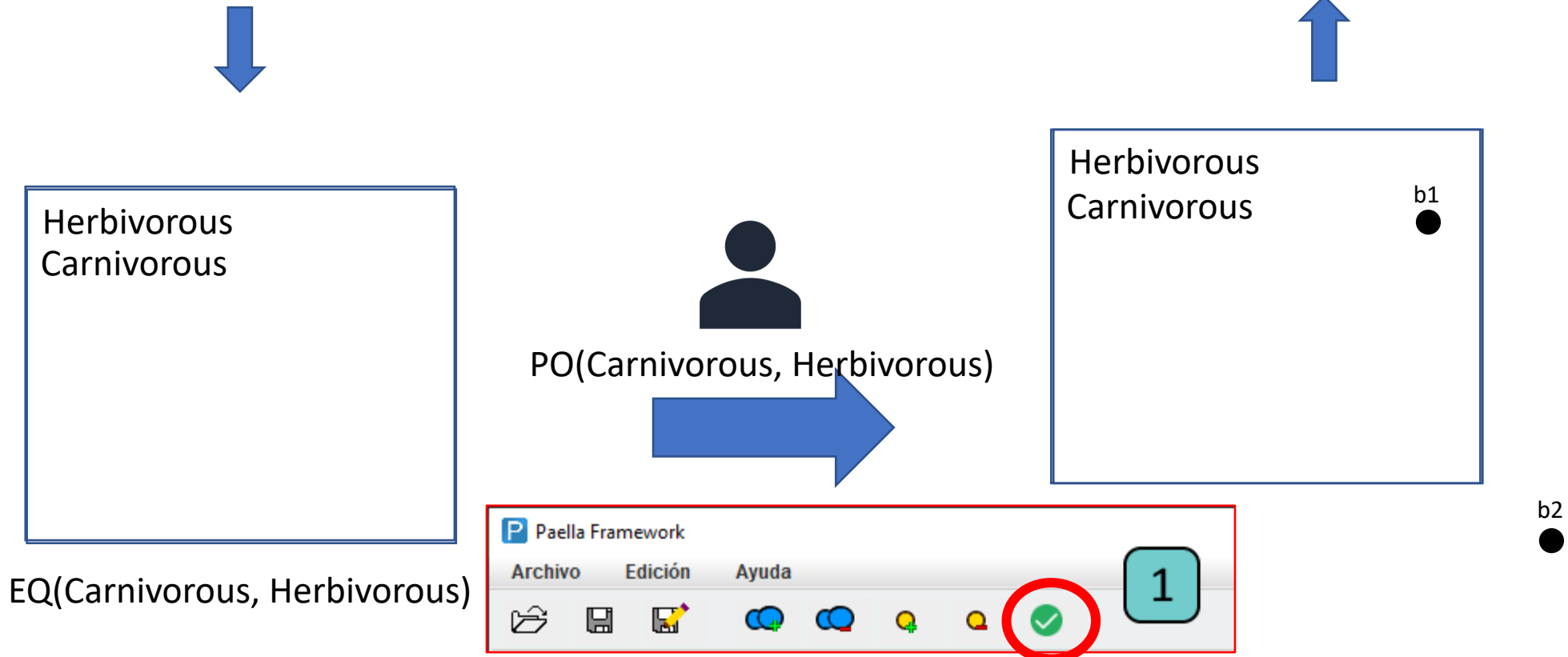
Cycle done!
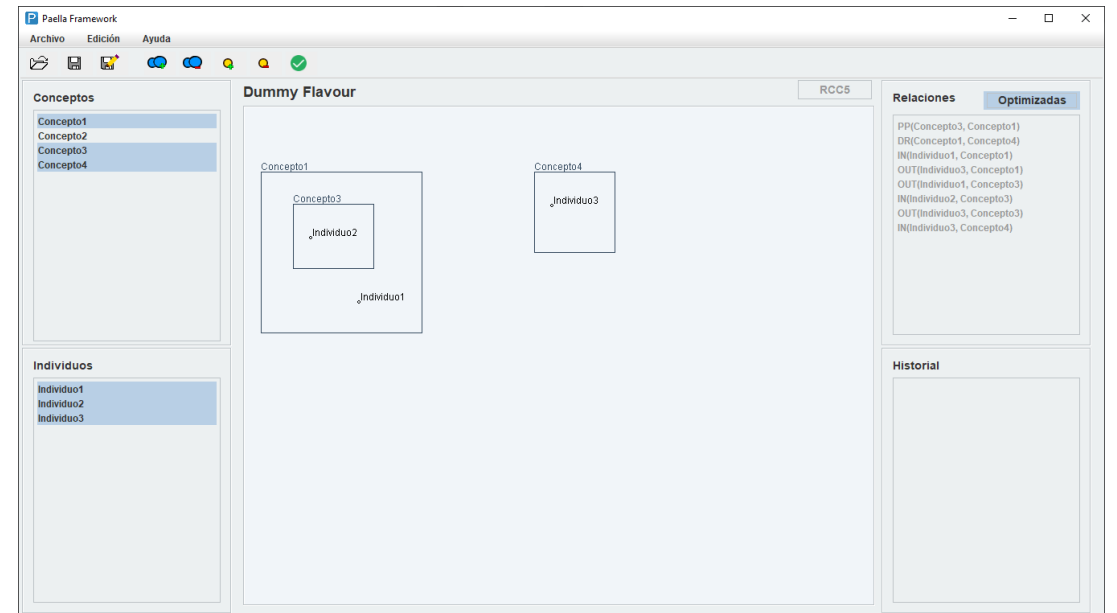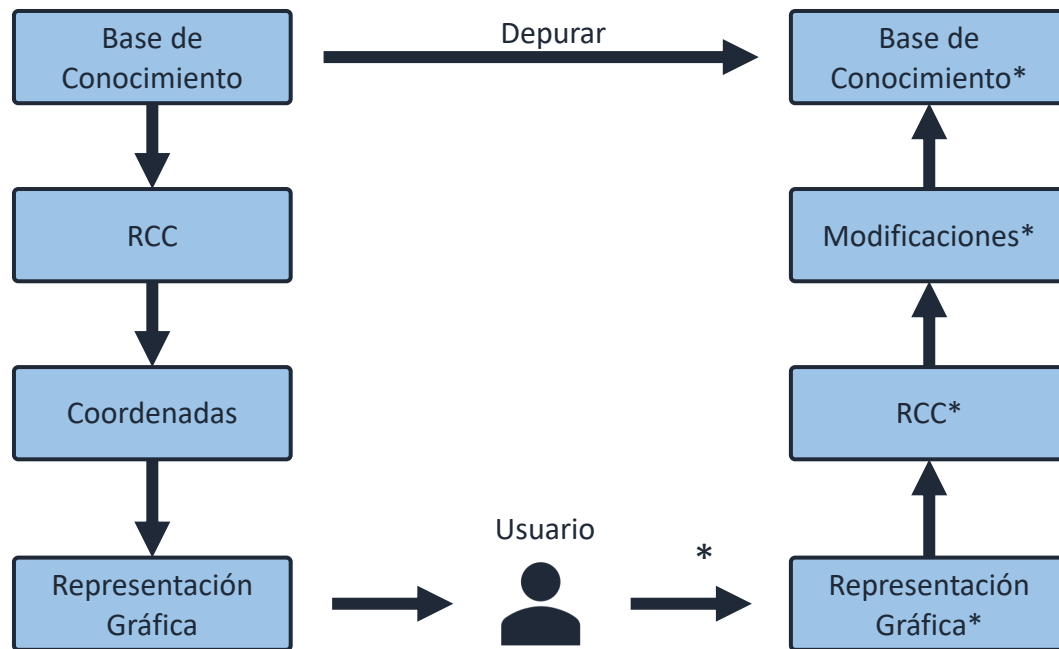
TinyPaella

Situaciones RCC5 y movimientos

Initial knowledge base

- Contexto y retículo inicial

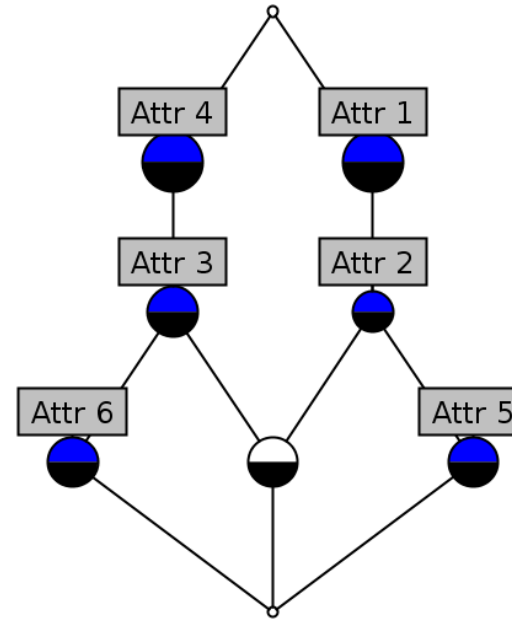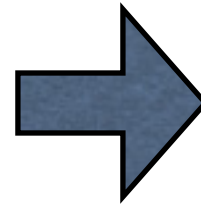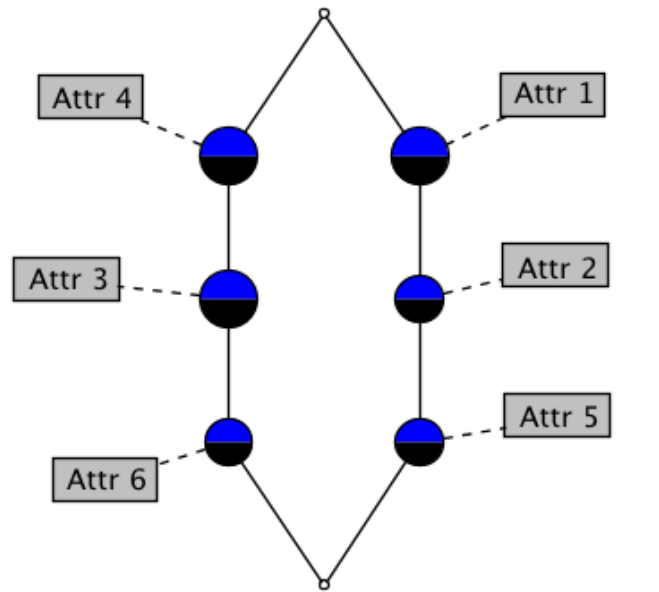# DR(C2,C3) -> PO(C2,C3)

- DR means they are not related: no individuals in common.

- PO means that:

    - ,at least, 1 common object

    - ,at least, 1 object that only holds C2

    - and, at least, 1 object that only holds C3

DR(C2,C3) -> PO(C2,C3)

DR(C2,C3) -> PO(C2,C3)

- Automatic repairing:

  - Insert a new "object" which holds all the attributes of both concepts.

  - Optional: we can suggest a new tag, only for this object.

  - Disadvatages: BIG POPULATION of individuals

Conclusions

- We have a **framework** to **DEBUG** knowledge
  - Extendable

- It is intended for **non-expert** users.
  - Spatial reasoning
  - Visual interface

- It is (somehow) **formal**

- It is a first step to **automatic** repairing theories.

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by means of a spatial metaphor

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