Semantic Space and History of Physics

E. Gasco[1]

[1]Zirak Software Department - www.zirak.it

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Outline

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Relativity of Inertia: Mach I

In the analysis of the newtonian concepts of Space and Time (during the exposition of the bucket experiment in the *Mechanics*) Mach seems to present a **causal mechanism** that explain inertial properties of the matter as produced by the presence of the other masses of the universe. This is the usual interpretation after Einstein work on relativity.
The reading of the causal mechanism is done by the fact that Mach uses:

- terms with evident causal meaning (like "produce")
- some type of thought experiment to reach the goal of his arguments (second example)

Relativity of Inertia: Mach II

For example look the following two sentences:

Example

"Newton's experiment with the rotating vessel of water simply informs us, that the relative rotation of water with respect to the sides of the vessel produce no noticeable centrifugal forces, but that such forces are produced by its relative rotation with respect to the mass of the earth and other celestial bodies".

Example

"No one is competent to say how the experiment would turn out if the sides of the vessel increased in thickness and mass till they were ultimately several leagues thick."

Outline

Relativity of Inertia: Einstein

Einstein and other German Physicists (Foppl and Friedlander) - on the other side - thought that really Mach suggested a new causal mechanism and worked in that way in order to group the inertia inside the concept of gravity.
For example during the construction of the new theory of general relativity (1907-15) Einstein wrote in a short article:

Example

"*...the presence of the inertial shell K increases the inertial mass of the material point P inside the shell. This suggests that the entire inertia of a mass point is an effect of the presence of all other masses, which is based on a kind of interaction with the latter*".

and cited Mach as his font of inspiration.

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Relativity of Inertia: the case study

We can ask if the concept of inertia in Mach view is the same as in Einstein's one.
To get the answer we can follow to ways:

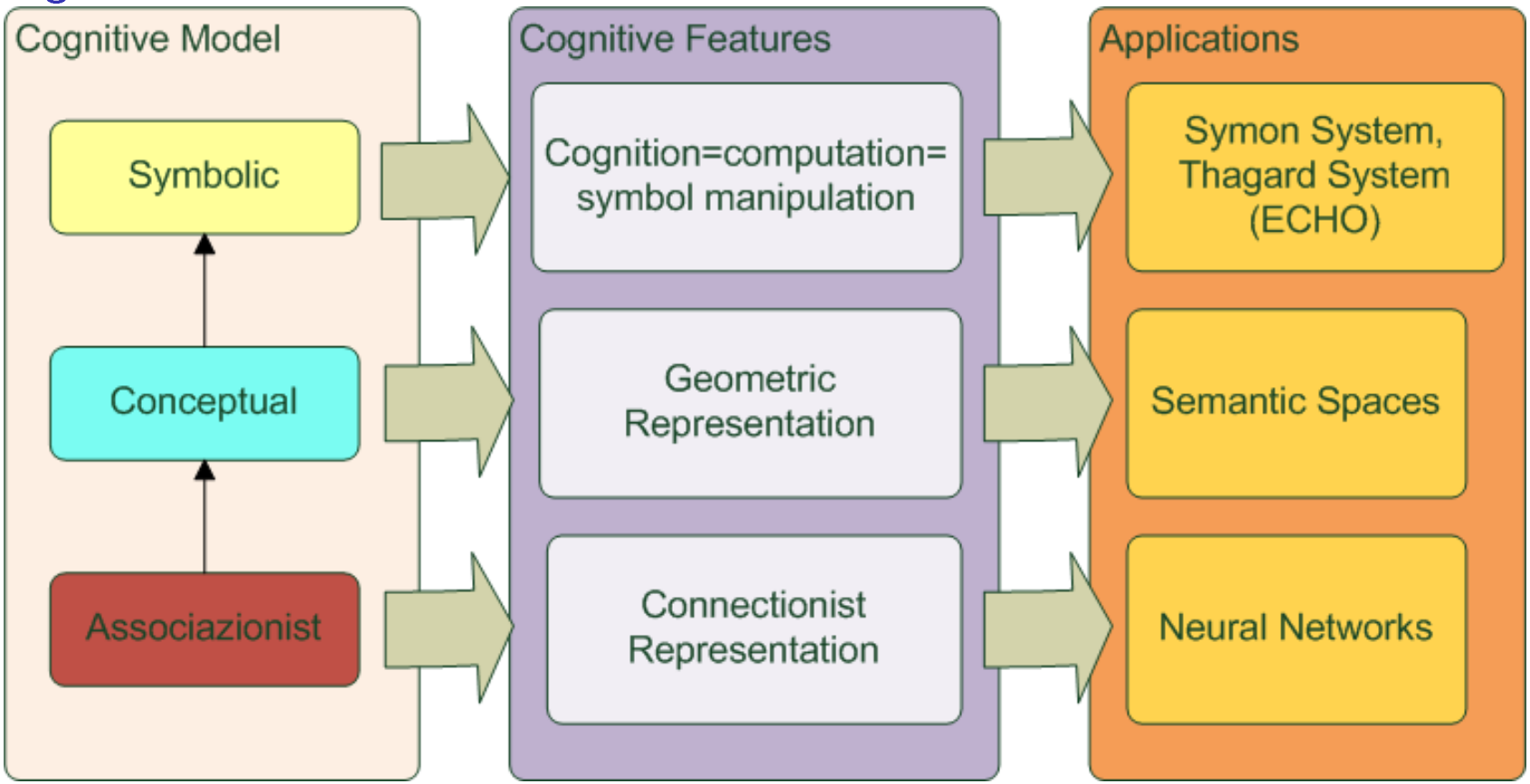
- Analyze the concept of inertia from a philosophical point of view: study the background philosophy of Mach and the evolving path that carry Einstein to propose the famous Mach's Principle and then draw the right conclusions (see **J.Renn**, **J.Norton**).
- Study the concepts used by Mach and Einstein from a new perspective: use **IR Tools** (like **Semantic Space**) to build an artefact of the inertia concept in Mach and Einstein and then compare them in some manner.

Outline

Knowledge Representation: Gärdenfors' Cognitive Model

In order to represent concept via a geometrical analogy we use the Cognitive Model developed by the cognitive scientist Gardenfors.

Figura:



Conceptual Space

A conceptual space is made by the following component:

- **Quality Dimensions**: are the building blocks of representations in Conceptual Space (ex: temperature and weight).
- **Quality Dimensions**: each quality dimension is endowed with certain geometrical structures (in some cases topological or ordering relations). For example consider the weight that is isomorphic to non negative reals.
- **Domains**: is a set of Quality Dimensions.
- **Conceptual Space**: is a set of Domains. You can have only a domain, so a domain is a conceptual space
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Conceptual Space: an example

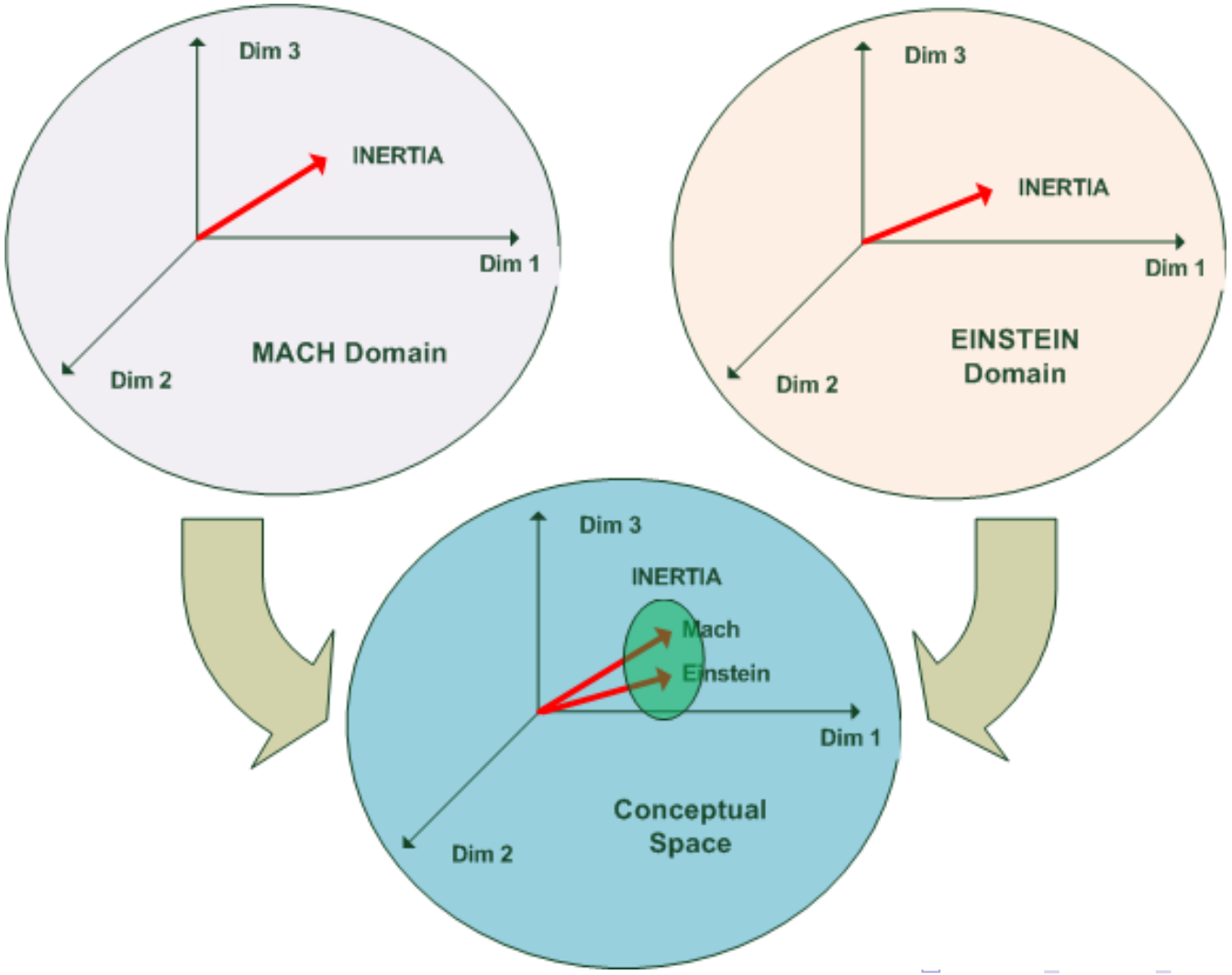

Figura:

Conceptual Space: similarity.

Conceptual Space with its geometrical structure has the ability to give us a notion of similarity for two concepts.

- **Similarity** is central to many aspects of cognition: concept formation (learning), memory and perceptual organization.
- **Similarity** is not an absolute notion but relative to a particular domain (or dimension)
  - "an apple and an orange are similar as they have the same shape"
- **Similarity** is a decreasing function of distance; so if we have a distance in the Conceptual Space we have also a notion of similarity.

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Semantic Space as a proxy of Conceptual Space

Hyperspace Analogue to Language (HAL) is a computational model of a Conceptual Space.

- Given an n-word vocabulary, a HAL space is an n × n matrix constructed by moving a window of length L over the corpus.
- All words within the window are considered as co-occurring with the last word in the window with a strength inversely proportional to the distance between the words.
- Each row in the matrix represents accumulated weighted associations of word with respect to other words in a context window.
- Each **word** in the vocabulary is an example of **Quality Dimensions** in the Conceptual Space Framework.
- The **HAL space** (n × n matrix) is a set of Dimensions, so is a Domain and also a **Conceptual Space**

Semantic Space as a proxy of Conceptual Space: example

If we consider the second Mach's sentence we have the hal space:

	compet	exper	turn	side	vessel	increas	thick	mass	till	ultim	leagu
compet	0	5	4	3	1	0	0	0	0	0	0
exper	1	0	5	4	3	2	1	0	0	0	0
turn	1	2	0	5	4	3	2	1	0	0	0
side	1	2	3	0	5	4	3	2	1	0	0
vessel	1	2	3	4	0	5	4	3	2	1	0
increas	1	2	3	4	5	0	5	4	3	2	1
thick	0	1	2	3	4	5	0	6	5	4	3
mass	0	0	1	2	3	4	6	0	4	3	2
till	0	0	0	1	2	3	5	5	0	3	2
ultim	0	0	0	0	1	2	4	4	5	0	2
leagu	0	0	0	0	0	1	3	3	4	5	0

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zSSLib: a tool for Semantic Space

Zirak has developed a tools (**zSSLib**) to create and manipulate Semantic Space:

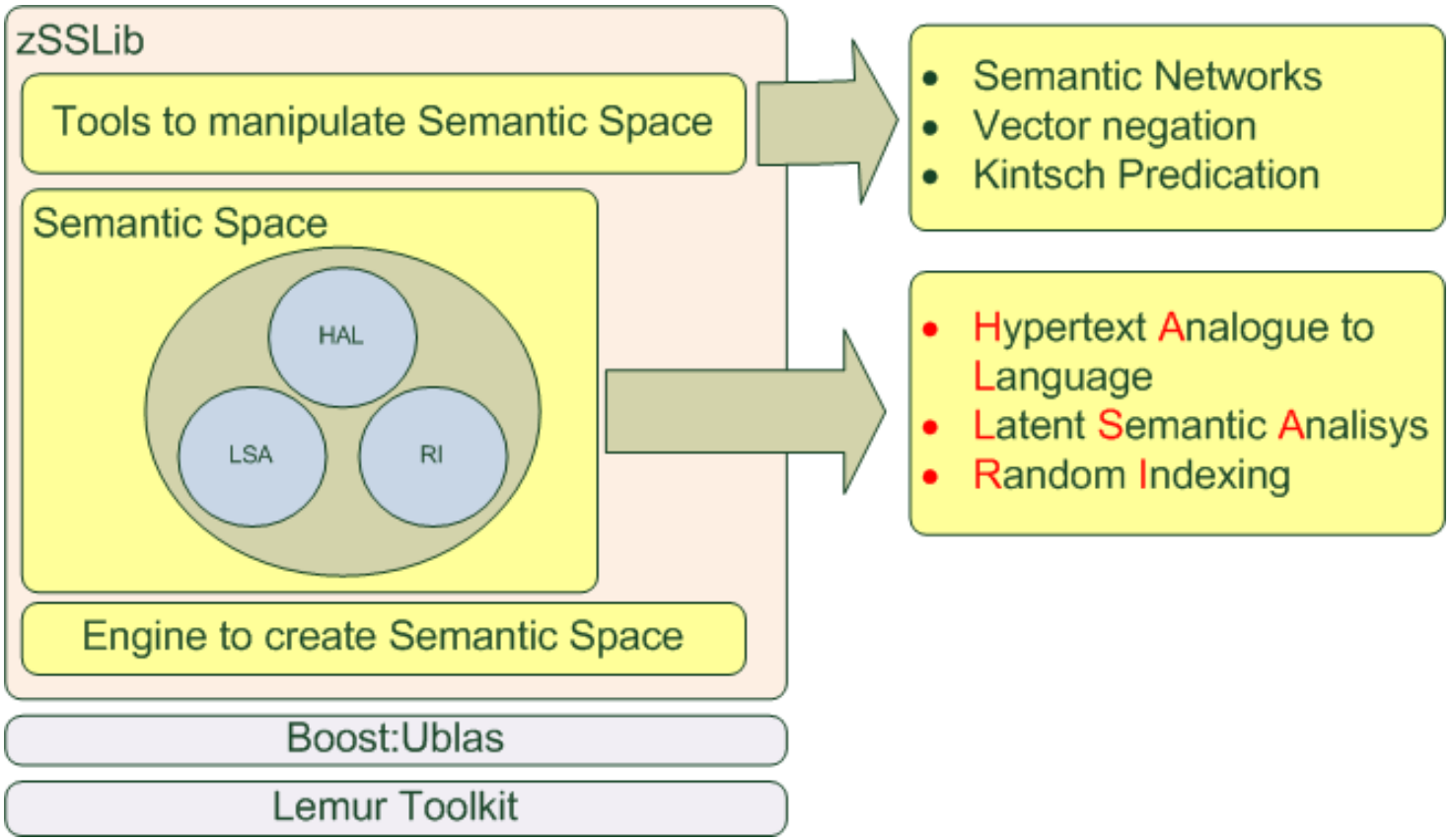

Figura:

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The Corpus and the Semantic Spaces

To build Semantic Space we need a Text Corpora. The features of our corpora are:

- We get the sentences of the Authors from "*Mach's Principle: from Newton bucket to Quantum Gravity*" of the Einstein Studies
- We made 4 Semantic Spaces for **Mach**, **Einstein**, **Friedlander** and **Foppl** (in order to have comparison among different authors)
- The index built with Lemur has 932 unique terms (a few little)
- Each Semantic Space has the vocabulary:

	Mach	Einstein	Friedlander	Foppl
Unique Terms	301	397	442	299

Outline

How To Compare Concepts in Semantic Spaces

To compare the similarity of concepts there are different methods:

- **Cosine Similarity**: we calculate the effective distance among concepts.
- **Conceptual Network**: for each concept we build its network and then compare the resulting nets.
- **Vector Negation**: to a concept we delete a definite meaning and then we see the new relations with the other concepts.
- **Kintsch Predication:** we construct a network of the neighbours of a concept and then use a background concept to view which neighbour is activated.

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Cosine Similarity

- To compare concepts in different Semantic Space we can use the Cosine Similarity:

$$sim(a,b) = \frac{\sum a_i b_i}{\sqrt{\sum a_i^2 \sum b_i^2}} = \frac{a \cdot b}{\| a \| \| b \|}$$

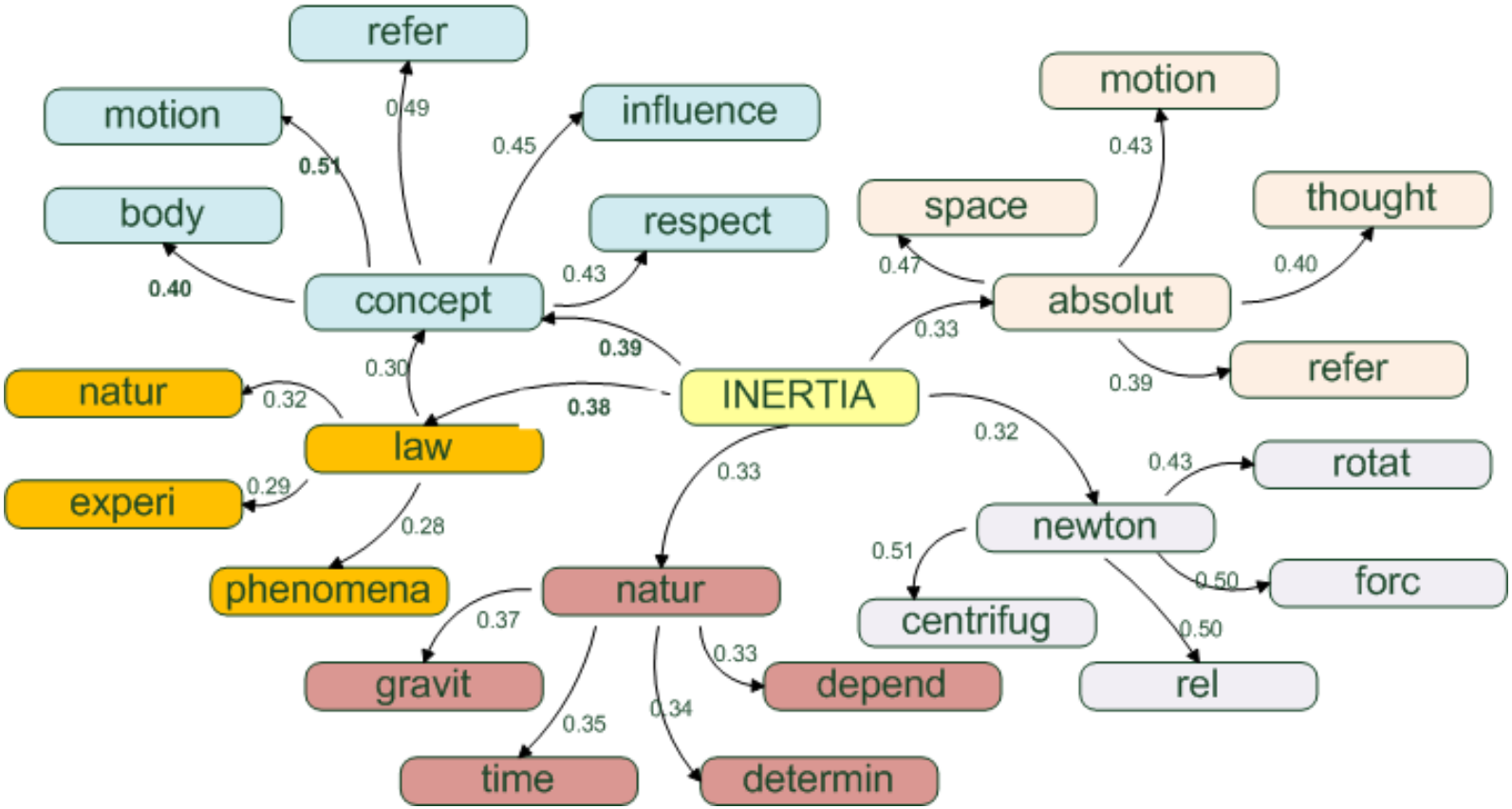
- In the following table some examples from the 4 semantic spaces:

	$d_{M,E.}$	$d_{M,Fr.}$	$d_{M,Fo}$	$d_{E,Fr.}$	$d_{E,Fo.}$	$d_{Fr,Fo.}$
inertia	0.03	0.59	0.53	0.13	0.32	0.51
mass	0.44	0.18	0.25	0.31	0.28	0.21
force	0.34	0.14	0.30	0.16	0.24	0.09
relativity	0.24	0.30	0.37	0.39	0.45	0.46
dependence	0.13	0.24	-	0.01	-	-

Conceptual Networks

A conceptual network is made by a set of concepts that are semantically correlated. Here there is the network for the Mach concept of inertia:

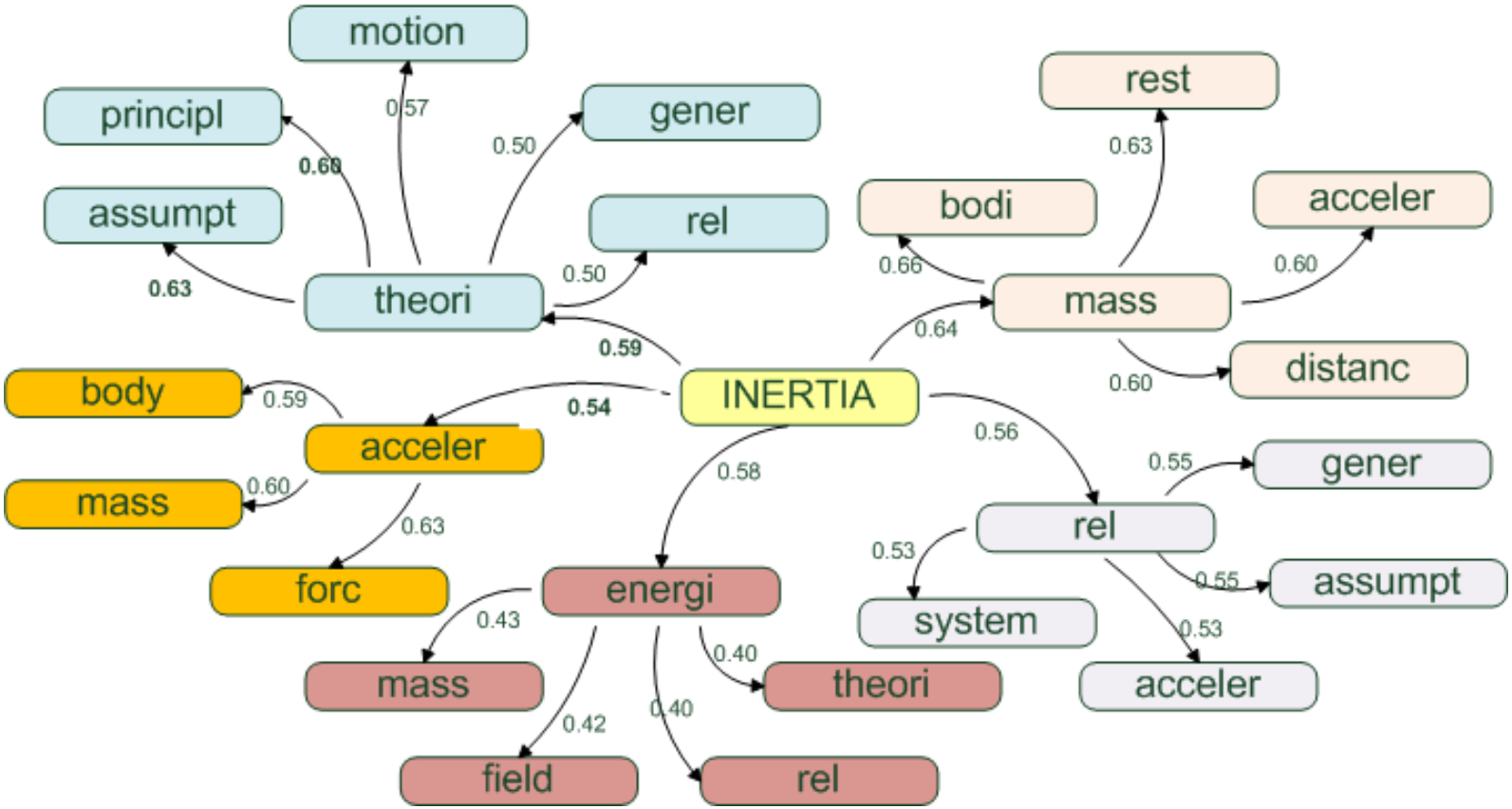
Figura:



Conceptual Network

Here there is the network for the Einstein concept of inertia:

Figura:



Conceptual Network: Results

What can we infer from these two networks?

- **Mach's** inertia concept is poorelly correlated with its adiacent concepts ($sim \leq 0.4$)
- In **Mach** network there are few cross-correlations.
- In **Mach** the concepts of **inertia** and **relativity** are linked only with a second order level.
- In **Einstein** inertia has neighbours linked to the concept with a high similarity ($sim \leq 0.6$)
- In **Einstein** network there are a lot of cross-correlations.
- In **Einstein** the concepts of **inertia** and **relativity** are linked with a first order level.

Vector Negation

We want to model the meaning of a statement like 'rock NOT band' in such a way that the result means we are interested in the geological, not the musical meaning of the word rock, and then apply this logical connectives to inertia and relativity.

- Two words a and b are considered irrelevant to one another if their vectors are orthogonal, i.e. a and b are mutually irrelevant if $a \cdot b = 0$
- The statement 'a NOT b' is interpreted as '*those features of a to which b is irrelevant*'.
- Let V be a vector space equipped with a scalar product. For a vector subspace $A \subseteq V$, define the orthogonal subspace $A^{\perp}$to be the subspace $A^{\perp} = \{v \in V : \forall a \in A, a \cdot v = 0\}$
- Let $a, b \in V$. Then $a\,NOT\,b$is represented by the vector

$$a\,NOT\,b = a - \frac{a \cdot b}{|b^2|}\,b$$

Vector Negation: Results

- We want to use the vector negation with the concept of inertia in Einstein.
- We delete the meaning of '**relativity**' from the concept of inertia in Einstein and then compare the new concept with the inertia concept in Mach
- If the similarity of the two inertia concepts increase, it means that the features of relativity is present in the Einstein concept but not in the Mach one.

Mach - Einstein	**Similarity**
inertia - inertia	**0.032**
inertia - inertia NOT rel	0.038
inertia - inertia NOT mass	0.011
inertia - inertia NOT forc	0.010

Outline

Semantic Space Distance

We can also consider the 4 semantic space as subspaces of a bigger semantic space, and then calculate the distance among the subspaces. The distance used is:

$$d(H_1, H_2) = \sqrt{max(p, r) - \sum_{i=1}^{p} \sum_{j=1}^{r} (u_i^T \, v_j)^2}$$

where p and r are the rank of H_i , u_i and v_j a vector basis of H_i. The similarities among the 4 subspaces are:

$dSS_{M,E.}$	$dSS_{M,Fr.}$	$dSS_{M,Fo}$	$dSS_{E,Fr.}$	$dSS_{E,Fo.}$	$dSS_{Fr,Fo.}$
0.72	0.74	0.61	0.66	0.70	0.73

where we see that they are very similar.

Summary

- We used the IR technics in a case study of the History of Physics.
- We have built a proxy (artefact) of the concept of inertia and relativity in Mach and Einstein and then compared them.
- We developed an open-source library for Semantic Space.

- Outlook
  - We have to build a bigger text corpora.
  - We must also use LSA and RI.