An information analysis of the 'Celestial Object' concept in Copernican Revolution

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Outline

1. What is information
   - Definition of Information.
   - What are data.
   - Inductive Logic and Probability - Carnap
   - Semantic Information - Bar-Hillel and Carnap
2. Dynamic Frame
   - What is a Dynamic Frame
   - Formal definition of Dynamic Frame
   - Dynamic Frame and Semantic Information
3. The concept of Physical Object
   - The concept of 'Physical Object' before Copernicus
   - The concept of 'Physical Object' after Copernicus

Outline

what is information I

- Information is a concept whose meaning we have not recovered from ancient philosophy or Christian theology. Hence the difficulty of its definition and the multiple meanings that have been assigned to the concept.
- Shannon: "... *It is hardly to be expected that a single concept of information would satisfactorily account for the numerous possible applications of this general fields.*"
- Weaver (1949) find 3 aspect analyze:
  - The amount of information and how it is communicated (deepened by Shannon's mathematical theory).
  - The semantic content of information.
  - The use of information by the man in his social behavior.

what is information II

- Information is usually associated with something not dependent on the user, having a semantic (meaningful) content and being transmitted through multiple physical means (texts, websites, maps...).
- Information is usually conceived in terms of

$$\textit{information} = \textit{data} + \textit{meaning}.$$

- **General Definition of Information** (Floridi 2010). σ(infon) is an instance of semantic informationif and only if:
  - σ if formed by n data (n>1)
  - data is formatted correctly (e.g. in a language, but could also be a drawing)
  - data is meaningful.

Outline

what are data I

- An example to understand the role of data:
  - Consider the page of a book written in an unknown language:
    - data + no-meaning → no information
  - Delete what is written in half a page:
    - 1/2 data + no-meaning → no information
  - Consider the white page with ony 1 symbol:
    - 0.001 data + no-meaning → no information
  - Consider the page completely blank:
    - 0 data + meaning → information
- **MacKay** (1969): "... *Information is a distinction that makes a difference*"
- **Bateson** (1973) "*In fact, what we mean by information ... is a difference which makes a difference*".

what are data II

- the **datum** (1 data) is attributable to a lack of uniformity.
- Floridi (2010) distinguishes 3 levels of data:
    - Data as a difference (*diaphora*) de *re*: there is a lack of uniformity in the real world. The data are not yet 'epistemically interpreted'; they are something that is not accessible, but whose existence is empirically 'inferred'.
    - Data as a difference (*diaphora*) de *signo*: there is a lack of uniformity between two signals; e.g. "higher or lower charge in battery".
    - Data as difference (*diaphora*) de *dicto*: there is a lack of uniformity between two symbols; e.g. the letters A and B of the Latin alphabet.

Outline

Inductive Logic and Probability- Carnap I

- Carnap develops a theory of Inductive Logic that includes the concept of probability (1950)
- Probability (1): the statistical concept of probability, relative frequency in the long run.
- Probability (2): the logical concept of probability, degree of confirmation: a quantitative concept representing the degree to which the assumption of the hypothesis h is supported by the evidence e.
- Consider a class of simple languages formed by a finite series of monadic predicates ("naming properties"), applied to an equally finite number of individual constants ("naming individual") through the usual logical connectors.

Inductive Logic and Probability- Carnap II

- Formally the language is defined as a set $L^n_m = (\{c_1 \dots c_n\}, \{P_1 \dots P_m\})$ made up of n individual constants c_i and m predicates P_j. The atomic proposition $P_j c_i$ indicates that the constant c_i has the property P_j.
- **State Description**: conjunction of the application of predicates (negated or non-negated) to all individual constants such that each constant appears only once in the proposition.
- **Logical Space**: set of all the State Descriptions. It represents the set of all possible states of the logical universe that is being considered. Each State Description represents a possible state of the world.

Inductive Logic and Probability- Carnap III

- On the logical space we can define one or more **probability measures** $m(-)$ which carry with them the corresponding degree of **confirmation functions**:

$$c(h,e) = \frac{m(h \wedge e)}{m(e)}$$

- **Example**: Let's consider a language that has 3 individual constants (a,b,c) and a unique predicate F.

Inductive Logic and Probability- Carnap IV

- The set of State Descriptions and the related probability measures are reproduced in the following table:

State Description	Propositions	m(-)
w_1	$Fa \wedge Fb \wedge Fc$	1/8
w_2	$\neg Fa \wedge Fb \wedge Fc$	1/8
w_3	$Fa \wedge \neg Fb \wedge Fc$	1/8
w_4	$Fa \wedge Fb \wedge \neg Fc$	1/8
w_5	$\neg Fa \wedge \neg Fb \wedge Fc$	1/8
w_6	$\neg Fa \wedge Fb \wedge \neg Fc$	1/8
w_7	$Fa \wedge \neg Fb \wedge \neg Fc$	1/8
w_8	$\neg Fa \wedge \neg Fb \wedge \neg Fc$	1/8

Inductive Logic and Probability- Carnap V

- Each State Description is equally probable and therefore has a probability measure of 1/8.
- If $h = Fa$ and $e = Fb \wedge Fc$ we have
  - $m(h \wedge e) = m(Fa \wedge Fb \wedge Fc) = 1 \bullet 1/8 = 0.125$
  - $m(e) = m(Fb \wedge Fc) = 2 \bullet 1/8 = 0.25$
  - and we get the confirmation function:

$$c(h, e) = \frac{0.125}{0.25} = 0.5$$

- note that if $e = w_1 \vee \ldots \vee w_n$ we have $c(h, e) = m(h)$

Outline

Semantic Information - Bar Hillel e Carnap I

- Bar Hillel and Carnap (1953) propose a definition of semantic information based on the theory of Logical Probability developed by Carnap (1950)
- **Inverse Relationship Principle**: the ammount of information associated with a proposition is inversely related to the probability of thet proposition.
- Bar-Hillel and Carnap give a definition of **Semantic Content** of a proposition A:

$$cont(A) = 1 - m(A)$$

$$cont(h \mid e) = m(e) - m(h \wedge e)$$

Semantic Information - Bar Hillel e Carnap II

- Bar-Hillel and Carnap give a definition of the **Ammount of Semantic Information** of a proposition A

$$inf(A) = -\log_2(m(A))$$

$$inf(h \mid e) = \log(m(e)) - log(m(h \wedge e))$$

- where h represents an hypothesis and e the evidence that we have.

Semantic Information - Bar Hillel e Carnap III

- Bar-Hillel and Carnap also introduce the "**estimate of the ammount of information carried by H with rispect to e**" for cont and inf:

$$est(cont, H, e) = \sum_p c(h_p, e) \bullet cont(h_p \mid e)$$

$$est(inf, H, e) = \sum_p c(h_p, e) \bullet inf(h_p \mid e)$$

- where H is the set of hypotheses $\{h_1 \dots h_n\}$.

Semantic Information - Bar Hillel e Carnap IV

- If we have two groups of hypotheses $H = \{h_1 \dots h_n\}$ and $K = \{h_1 \dots h_m\}$ based on the same evidence e we have at the end:

$$est(cont, H \wedge K, e) = \sum_p \sum_r c(h_p \wedge k_r, e) \bullet cont(h_p \wedge k_r \mid e)$$

$$est(inf, H \wedge K, e) = \sum_p \sum_r c(h_p \wedge k_r, e) \bullet inf(h_p \wedge k_r \mid e)$$

Outline

What is a Dynamic Frame: base structure I

A frame is defined as an array that associates values with attributes; a typical example that is provided to illustrate what it consists of is the concept of '*bird*', whose frame can be represented as:

Example

bird = {beak:{round, pointed}; leg:{short, long}; foot:{webbed, clawed}}

where the bird concept takes the name of '*superodinate concept*', the attributes are the set {beak, leg, foot} and for each attribute there are the right values (e.g. the attribute beak has the values {round, pointed}).

What is a Dynamic Frame: subordinate concepts I

the '*subordinate concepts*' are 'secondary' concepts that activate only some values among those possible for the superordinate concept.
E.g. in the case of the superordinate concept 'bird' we have the subordinate concepts of 'water bird' and 'land bird' which can be represented as:

Example

water bird = {beak:round; leg:short; foot:webbed}
land bird = {beak:pointed; leg:long; foot:clawed}

The activation function of the values that determine the subordinate concept is called '*determination link*'.

What is a Dynamic Frame: constraints I

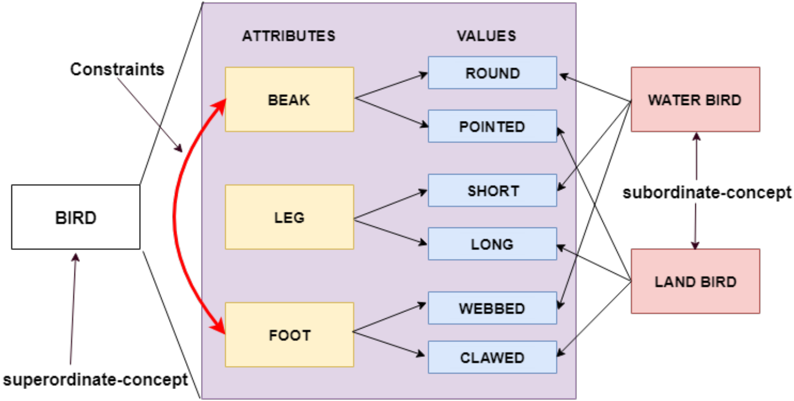
The 'constraints' are links that intervene between attributes or values. The most significant are the constraints that exist between values.
E.g. in the case of the subordinate concept 'water bird' there is the constraint that the webbed foots (foot = WEBBED) always correspond to the rounded beak (beak = ROUND).

Example

constraints on water bird = {beak:round; foot:webbed}
constraints on land bird = {beak:pointed; foot:clawed}

What is a Dynamic Frame: Diagram I

The concept of Bird is represented by the following diagram



Outline

Formal Definition of Dynamic Frame I

A frame *F(c)* is a structure formed by a set of subordinate concepts $S = \{s\}$ defined in relation with a superordinate concept *c*, a set of attributes $A = \{a\}$, a set of values $V = \{v\}$, a set of determination link $D = \{d\}$, that can be represented as **F(c) = <c, A, V, S, D>** and which satisfies the following properties:

1. Each attribute a ∈ A maps a value v ∈ V to the superodinate concept c: a = A(c, v). It is important to note that the value v itself can be thought of as a superodinate concept for which a frame can be provided. In this way the frame structure is recursive.
2. Each determination link d ∈ D establishes a link between a subordinate concepts s ∈ S and a v ∈ V: d = D(s, c)

Formal Definition of Dynamic Frame II

A Frame F(c) it can be specialized by introducing constraints. Indicating with CS = {cs} the set of constraints between the values of a frame, a Constraint Frame CF(c) meets the conditions:

1. CF(c) is a Frame
2. For each cs $\in$ CS: cs(v1, v2) with v1,v2 $\in$ V. The expression indicates that the constraints cs establishes a correlation link between the values v1 and v2.

Outline

Dynamic Frame and Semantic Information - Attribute I

It is possible to establish a corrispondence from an Attribute and its Values $(a, \{V_1^a \dots V_m^a\})$ of a Dynamic Frame and a language L_m^1 consisting of a single individual constant that corresponds to the attribute a and m predicates that correspond to the values V_m^a

- Consider 'foot' attribute of the concept 'bird', represented as $F : (f, \{V_1^f, V_2^f\}) = (f, \{webbed, clawed\})$.
- The corresponding language is L_2^1 where there is the individual constant f (foot) and two predicates $\{V_1^f, V_2^f\} = \{W, C\}$. E.g. the proposition Wf means 'foot' attribute has value 'webbed'.

Dynamic Frame and Semantic Information - Attribute II

- From a language L_m^n we can get a logical space made by $2^{n \bullet m}$ state desriptions w: $L_m^n \Longrightarrow \{w_i\}$
- Consider the logical space of 'foot' attribute:

State Descriptions	**Propositions**
w_1	$(W \wedge C)f$
w_2	$(W \wedge \neg C)f$
w_3	$(\neg W \wedge C)f$
w_4	$(\neg W \wedge \neg C)f$

Dynamic Frame and Semantic Information - Attribute III

- The Dynamic Frame imposes constraints on the language logical space. The only admitted states are those in which a single predicate is applied, while the others are all denied.
- So we can define a **Base State Description** w_b:

$$w^c_{b,i} = (V^c_i \wedge_{j \neq i} \neg V^c_j)$$

- For an Attribute of a Dynamic Frame at the end we have the correlation:

$$A = (a, \{V^a_1 \dots V^a_m\}) \Longrightarrow L^1_m \Longrightarrow \{w^a_{b,1} \dots w^a_{b,m}\}$$

Dynamic Frame and Semantic Information - Frame I

A Dynamic Frame is a set of attributes (and values), each attribute corresponds to a Language and so it is valid the following relation:

$$F = (A_1 \ldots A_n) = ([a_1, \{V_1^{a_1} \ldots V_m^{a_1}\}] \ldots [a_n, \{V_1^{a_n} \ldots V_r^{a_n}\}]) \Longrightarrow (L_m^{a_1} \ldots L_r^{a_n})$$

A Dynamic Frame corresponds to the union of multiple languages.

$$F = (A_1 \ldots A_n) \Longrightarrow (L_m^{a_1} \ldots L_r^{a_n})$$

Dynamic Frame and Semantic Information - Frame II

We therefore also have a **logical space** associated with Dynamic Frame:

$$F = (A_1 \dots A_n) \Longrightarrow \bigcup_{i=1}^{m} \bigcup_{j=1}^{k} w_{b,j}^{a_i} \bigwedge_{s \neq i} \bigcup_{v=1}^{t} w_{b,v}^{a_s}$$

which indicates how the logical space is the set of combinations of all the base state descriptions of attributes that define a Frame.

Dynamic Frame and Semantic Information - Frame III

Example: determine the logical space associated with the Dynamic Frame 'bird'.

- We have two languages associated with the two attributes:

$$bird = (beak, foot) \Rightarrow (L_2^{beak}, L_2^{foot}) = (L_2^b, L_2^f)$$

- and so:

$$bird \Rightarrow ((beak, \{Round, Pointed\}), (foot, \{Webbed, Clawed\}))$$

$$bird \Rightarrow ((b, \{R, P\}), (f, \{W, C\}))$$

Dynamic Frame and Semantic Information - Frame IV

- To attribute 'beak' we have the following base state descriptions:

State Descriptions	Propositions
w_1^b	$(R \wedge \neg P)b$
w_2^b	$(\neg R \wedge P)b$

- To attribute 'foot' we have the following base state descriptions:

State Descriptions	Propositions
w_1^f	$(W \wedge \neg C)f$
w_2^f	$(\neg W \wedge C)f$

Dynamic Frame and Semantic Information - Frame V

- If we consider the combination of the base state descriptions of the two attributes we have the logical space of the Dynamic Frame:

State Descriptions	Propositions
w_1	$(R \wedge \neg P)b \wedge (W \wedge \neg C)f$
w_2	$(R \wedge \neg P)b \wedge (\neg W \wedge C)f$
w_3	$(\neg R \wedge P)b \wedge (W \wedge \neg C)f$
w_4	$(\neg R \wedge P)b \wedge (\neg W \wedge C)f$

- The set $\{w_i\}$ is the set of Dynamic Frame state descriptions.

Dynamic Frame and Semantic Information - Probability I

We now define a probability measure on the logical space associated with the Dynamic Frame.

- If the Dynamic Frame **has no constraints** each state description w_i is equiprobable, so if we have n states, the probability measure is:

$$m(w_i) = \frac{1}{n}$$

- If Dynamic Frame **has constraints** the function c(-,-) is useful for calculating the probability measure.

Dynamic Frame and Semantic Information - Probability II

- The following relations are valid:

$$c(h,e) = \frac{m(h \wedge e)}{m(e)} = 1.0$$

- for an hypothesis h that is **true** based on evidence e.

$$c(h,e) = \frac{m(h \wedge e)}{m(e)} = 0.0$$

- for an hypothesis h that is **false** based on evidence e.

Dynamic Frame and Semantic Information - Probability III

Example: determine the probability measure of the logical space associated with the Dynamic Frame 'bird' with constraints.

- Impose the constraint $foot = webbed \Longrightarrow beak = round$ where evidence is $e : foot = webbed$ and the hypothesis is $h : beak = round$

$$c(h,e) = \frac{m(Rb \wedge Wf)}{m(Wf)} = \frac{m(w_1)}{m(w_1) + m(w_3)} = 1 \Longrightarrow m(w_3) = 0$$

- Impose the constraint $foot = clawed \Longrightarrow beak = pointed$ with the evidence $e : foot = clawed$ and the hypothesis $h : beak = pointed$

$$c(h,e) = \frac{m(Pb \wedge Cf)}{m(Cf)} = \frac{m(w_4)}{m(w_2) + m(w_4)} = 1 \Longrightarrow m(w_2) = 0$$

Dynamic Frame and Semantic Information - Probability IV

- from which we derive that the only states with non-zero probability are $w_1$and w_4 which are equiprobable.
- The probability measure on the logical space becomes:

State Descriptions	Propositions	m
w_1	$(R \wedge \neg P)b \wedge (W \wedge \neg C)f$	0.5
w_2	$(R \wedge \neg P)b \wedge (\neg W \wedge C)f$	0
w_3	$(\neg R \wedge P)b \wedge (W \wedge \neg C)f$	0
w_4	$(\neg R \wedge P)b \wedge (\neg W \wedge C)f$	0.5

Dynamic Frame and Semantic Information - INF I

The amount of information for a state description of the logical space associated with a Dynamic Frame is

$$inf(w_i) = -\log(m(w_i))$$

Note that each state description is equivalent to a subordinate concept of the Dynamic Frame from which it is derived:

$$inf(sub\_concept) = -\log(m(w_i))$$

The amount of information of the Dynamic Frame is also defined as:

$$inf(F) = \sum_i m(w_i) \bullet inf(m(w_i))$$

Dynamic Frame and Semantic Information - INF II

Example: determine the amount of information of the Dynamic Frame 'bird'

- Applying the previous formulas we have:

State Desc.	**Propositions**	**Sub_Conc**	**m**	**inf**
w_1	$(R \wedge \neg P)b \wedge (W \wedge \neg C)f$	water-bird	0.5	1
w_2	$(R \wedge \neg P)b \wedge (\neg W \wedge C)f$	-	0	0
w_3	$(\neg R \wedge P)b \wedge (W \wedge \neg C)f$	-	0	0
w_4	$(\neg R \wedge P)b \wedge (\neg W \wedge C)f$	land-bird	0.5	1

Dynamic Frame and Semantic Information - INF III

From which we deduce that each **subordinate concept** requires **1 bit of information**.
The amount of semantic information of the entire frame is

$$inf(bird) = \sum_i m(w_i) \bullet inf(m(w_i)) = 0.5 \bullet 1.0 + 0.5 \bullet 1.0 = 1$$

so the frame has an ammount of information of **1 bit.**

Outline

The concept of physical object - Dynamic Frame I

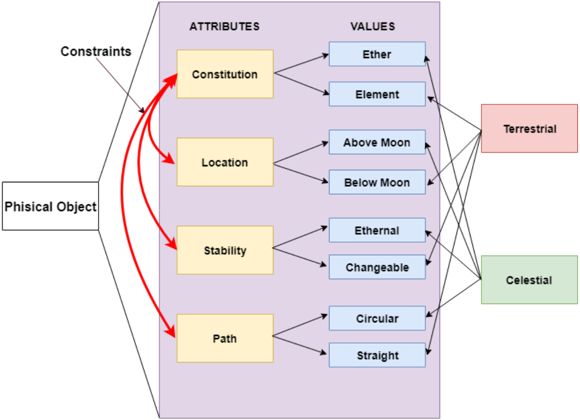
- One of the main innovations of the Copernican revolution was to eliminate the distinction between **celestial objects** and **terrestrial objects**.
- The distinction was determined by Aristotelian Physics, based on the following properties:
  - The world was made up of **5 elements**: earth, water, air, fire and ether.
  - Each element tended to its 'natural' place.
  - The world was divided into two macro-regions: the **below-moon world** and the **above-moon world.**
  - The above-moon world was made up of the ether and enclosed the sphere of the fixed stars and the spheres occupied by the wandering stars, the sun and the moon.

The concept of physical object - Dynamic Frame II

- The above-moon world was eternal, it was not subject to change.
- The motion of objects in the above-moon world was circular, as the 'perfect' motion suited to eternal objects.
- The below-moon world was made up of the other elements, excluding the ether. The natural places of the elements were concentric spheres that went from the heaviest element (earth) to the lightest one (fire).
- The motion of the elements in the below-moon world was rectilinear as they tended towards their natural place.
- The below-moon world was subject to change. The change was linked to the movement of the elements towards their natural place and to the motion of the above-moon spheres which transferred the movement from the sphere of the fixed stars towards the lower spheres.

The concept of physical object - Dynamic Frame III

The Dynamic Frame associated with Aristotelian physics is as follows:



The concept of physical object - Logical Space I

- The Dynamic Frame of 'physical object' has 4 attributes and is therefore associated with 4 Languages, each of which is made up of 1 individual constant (the attribute) and 2 predicates (the values).

$$phys\_obj = (const, loc, stab, path) \Rightarrow (L_2^{const}, L_2^{loc}, L_2^{stab}, L_2^{path})$$

$$phys\_obj = (const, loc, stab, path) \Rightarrow (L_2^{c}, L_2^{l}, L_2^{s}, L_2^{p})$$

The concept of physical object - Logical Space II

- The logical space of attributes is similar across attributes; let's consider the logical space of the 'constitution' attribute.

$$L_2^{const} = (const, \{Ether, Elements\}) = (c, \{CE, CT\})$$

Base State Descriptions	Propositions	m
w_1	$(CE \wedge \neg CT)c$	0.5
w_2	$(\neg CE \wedge CT)c$	0.5

- If we consider the logical space of the entire frame we will have that it is the combination of the base state descriptions of the various attributes. We therefore have 16 state descriptions represented by the following propositions:

The concept of physical object - Logical Space III

Propositions
$(CE \wedge \neg CT)c \wedge (LAM \wedge \neg LBM)l \wedge (SE \wedge \neg SC)s \wedge (PC \wedge \neg PS)p$
$(CE \wedge \neg CT)c \wedge (LAM \wedge \neg LBM)l \wedge (SE \wedge \neg SC)s \wedge (\neg PC \wedge PS)p$
$(CE \wedge \neg CT)c \wedge (LAM \wedge \neg LBM)l \wedge (\neg SE \wedge SC)s \wedge (PC \wedge \neg PS)p$
$(CE \wedge \neg CT)c \wedge (LAM \wedge \neg LBM)l \wedge (\neg SE \wedge SC)s \wedge (\neg PC \wedge PS)p$
$(CE \wedge \neg CT)c \wedge (\neg LAM \wedge LBM)l \wedge (SE \wedge \neg SC)s \wedge (PC \wedge \neg PS)p$
$(CE \wedge \neg CT)c \wedge (\neg LAM \wedge LBM)l \wedge (SE \wedge \neg SC)s \wedge (\neg PC \wedge PS)p$
$(CE \wedge \neg CT)c \wedge (\neg LAM \wedge LBM)l \wedge (\neg SE \wedge SC)s \wedge (PC \wedge \neg PS)p$
$(CE \wedge \neg CT)c \wedge (\neg LAM \wedge LBM)l \wedge (\neg SE \wedge SC)s \wedge (\neg PC \wedge PS)p$

The concept of physical object - Logical Space IV

Propositions
$(\neg CE \wedge CT)c \wedge (LAM \wedge \neg LBM)l \wedge (SE \wedge \neg SC)s \wedge (PC \wedge \neg PS)p$
$(\neg CE \wedge CT)c \wedge (LAM \wedge \neg LBM)l \wedge (SE \wedge \neg SC)s \wedge (\neg PC \wedge PS)p$
$(\neg CE \wedge CT)c \wedge (LAM \wedge \neg LBM)l \wedge (\neg SE \wedge SC)s \wedge (PC \wedge \neg PS)p$
$(\neg CE \wedge CT)c \wedge (LAM \wedge \neg LBM)l \wedge (\neg SE \wedge SC)s \wedge (\neg PC \wedge PS)p$
$(\neg CE \wedge CT)c \wedge (\neg LAM \wedge LBM)l \wedge (SE \wedge \neg SC)s \wedge (PC \wedge \neg PS)p$
$(\neg CE \wedge CT)c \wedge (\neg LAM \wedge LBM)l \wedge (SE \wedge \neg SC)s \wedge (\neg PC \wedge PS)p$
$(\neg CE \wedge CT)c \wedge (\neg LAM \wedge LBM)l \wedge (\neg SE \wedge SC)s \wedge (PC \wedge \neg PS)p$
$(\neg CE \wedge CT)c \wedge (\neg LAM \wedge LBM)l \wedge (\neg SE \wedge SC)s \wedge (\neg PC \wedge PS)p$

The concept of physical object - Logical Space V

- If we **do not consider constraints**, the probability measure for each state description is

$$m(w_i) = \frac{1}{16}$$

- Each state description holds a quantity of information:

$$inf(w_i) = -\log(m(w_i)) = 4bit$$

- The same amount of information is associated with the entire frame (since each state is equally probable):

$$inf(phys\_obj) = \sum_i m(w_i) \bullet inf(m(w_i)) = 16 \bullet \frac{1}{16} \bullet 4 = 4bit$$

The concept of physical object - Logical Space VI

- If we **consider constraints**, we need to use the equation $c(h,e) = 1 \setminus 0$
- Let's examine the case in which
  - evidence $e = (CE \wedge \neg CT)c \wedge (LAM \wedge \neg LBM)l \wedge (SE \wedge \neg SC)s$
  - test the hypothesis $h = (\neg PC \wedge PS)p$

$$c(h,e) = \frac{m(w_2)}{m(w_1) + m(w_2)} = 0 \Longrightarrow m(w_2) = 0$$

- If we apply all the constraints of the Dynamic Frame, we obtain the following result:

$$m(w_1) \neq 0,\ m(w_{16}) \neq 0,\ [m(w_i) = 0, i \neq 1, 16]$$

The concept of physical object - Logical Space VII

- and so we have the result

$$m(w_1) = m(w_{16}) = 0.5$$

- note that the state w_1 is the subordinate concept 'celestial object' and the state w_{16} is the subordinate concept terrestrial object'.
- from which it can be deduced that the amount of information for the two subordinate concepts is:

$$inf(w_i) = -\log(m(w_i)) = 1bit$$

- Finally, the entire frame has the same amount of information:

$$inf(phys\_obj) = \sum_i m(w_i) \bullet inf(m(w_i)) = 2 \bullet \frac{1}{2} \bullet 1 = 1bit$$

Outline

The concept of physical object after Copernicus I

- The Dynamic Frame 'physical object' based on Aristotelian physics was challenged by weakening some constraints.
  - The constraint *constitution* $\Longrightarrow$ *stability*: Galileo's telescopic observations (the face of the moon, the phases of Venus, the satellites of Jupiter) demonstrated that some celestial objects could undergo changes.
  - The constraint *constitution* $\Longrightarrow$ *location*: the study of the position of comets (Tycho Brahe) showed that some objects believed to be terrestrial were above the position of the moon.

The concept of physical object - comet theory I

- Aristotle in *Metereologica* had proposed a theory of comets as terrestrial objects, belonging to the sphere of fire.
  - Comets are transitory and not eternal objects.
  - Comets change their appearance from night to night.
  - Comets are masses of incandescent vapors.
- Aristotle proposed two theories for the nature of comets:
  - Comets are formed in the transition from the sphere of air to that of fire.
  - Comets are formed when the sphere of fire meets the sphere of the moon or other planets.
- **Toscanelli** made numerous observations on comets (1433-1472). At first he is interested in their shape, but then he focuses on their position. He determines the position of comets in accordance with Aristotelian theory.

The concept of physical object - comet theory II

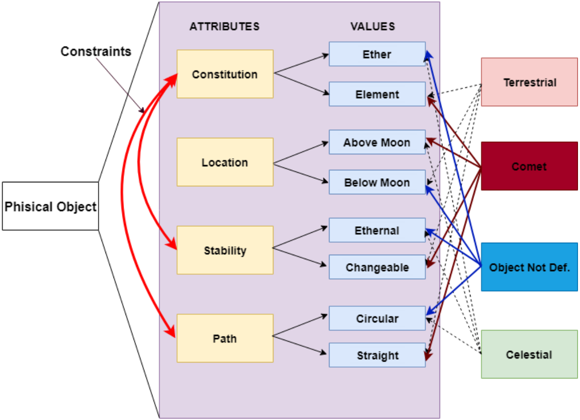
- **Regiomontano** introduces the parallax method to calculate the position of comets. He still obtains results compatible with Aristotle, but the method introduced does not depend on cosmological considerations ("*Sixteen Questions on Comets*" - 1531).
- **Regiomontano** also introduces doubts about the constitution of comets: "*No irruption of air can supply, from natural causes, flaming vaporous material for the comet for a period of one year; but comets come from secret causes of nature...*", but introducing doubts on the constitution also imposes rethinking on their position since in Aristotelian physics the two attributes are linked.

The concept of physical object - comet theory III

- **Tycho Brahe** (1577), based on the methods implemented by Regiomontano, determines the positions of the comets with greater precision, showing that they are located in the above-moon region.

The concept of physical object - Dynamic Frame I

- So deleting the constraint *constitution* $\Longrightarrow$ *location* we have the frame:



The concept of physical object - Dynamic Frame II

- The logical space still consists of 16 states
- The abolition of the constraint leads to a modification of the probability distribution

$$m(w_1) = m(w_{16}) = m(w_5) = m(w_{12}) = \frac{1}{4}$$

- The state w_5 corresponds to the subordinate-concept "object not defined"
- The state w_{12} corresponds to the subordinate-concept "comet"
- The amount of information for the two subordinate concepts is:

$$inf(w_i) = -\log(m(w_i)) = 2bit$$

The concept of physical object - Dynamic Frame III

- Finally, the entire frame has the same amount of information:

$$inf(phys\_obj) = \sum_i m(w_i) \bullet inf(m(w_i)) = 4 \bullet \frac{1}{4} \bullet 2 = 2bit$$

- **Result**: the elimination of a constraint made the amount of information necessary to define a Dynamic Frame greater.
- **Result**: the elimination of constraints increases the complexity of the Dynamic Frame which is reflected in a greater amount of information necessary to define it.

Summary

- We introduced the concept of information.
- We have associated the concept of information with that of Dynamic Frame.
- We have seen how the elimination of a constraint in a revolutionary phase of science increased the complexity of the dynamic frame under examination.

- Outlook
  - Deepen the link between semantic information and dynamic frames.
  - Go into more detail about the historical part.