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Towards a Contemporary Ontology

The New Dual Paradigm in Natural Sciences: Part II

Module 3: Formal philosophy and formal ontology

Introduction

Module 3: " Formal philosophy and formal ontology"

Course modules

Modules	Topic	Suggested Readings
SECTION ONE		
0.	<i>Introduction and Course Overview</i>	
1.	QFT: an evolutionary interpretation of nature from cosmology to neuroscience	Refs.: 1-5.
2.	QFT in fundamental physics and the Aristotelian-Thomistic ontology of nature	Refs.: 6 , chs. 5-6; 7-8.
SECTION TWO		
3.	Formal philosophy and formal ontology	Refs.: 9-11.
4.	The formal ontology of the conceptual natural realism (CNR)	Refs.: 12-15.
SECTION THREE		
5.	The formal ontology of the natural realism (NR)	Refs.: 16-18.
6.	The duality algebras/coalgebras in CT and the notion of Universal Coalgebra	Refs.: 19-24.
SECTION FOUR		
7.	“Modal logics are coalgebraic”: an application to NR and to the duality logical/ontological truth	Refs.: 24-28.
8.	<i>Conclusions</i>	

Bibliography

Bibliography of the Module 2

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- Main References:

1. G. BASTI, «Intelligence and reference. Formal ontology of the natural computation». In: *Computing Nature*, G. DODIG-CRNKOVIC AND R. GIOVAGNOLI (Eds.), Springer-Verlag, Berlin Heidelberg, 2013, pp. 139-159 (Sapere, 7) [[attached](#)]
2. G. BASTI, «The quantum field theory (QFT) dual paradigm in fundamental physics and the semantic information content and measure in cognitive sciences», in *Proceedings of AISB 2014 Convention. Symposium on: "Representation of Reality: Humans, Animals and Machine"*, London, April 1-4, 2014 <<http://doc.gold.ac.uk/aisb50/AISB50-S23/AISB50-S23-Basti-paper.pdf>> [accessed 24 May 2014] (in press) [[attached](#)]

- Other references:

3. G. BASTI & M. SHAHID (EDS.), *Ontologia formale e ontologie. Uno strumento per il dialogo interdisciplinare e interculturale*, Editrice Apes, Roma, 2015 (in press: with contributions of Habermas, Searle, Ales-Bello, etc.).

Bibliography II

3. A. ALES-BELLO, «Ontology and phenomenology». In: Roberto Poli – Johanna Seibt (eds.), *Theory and Applications of Ontology – Philosophical Perspectives*, Springer, Dordrecht 2010, chap. 14, 287-328 [[attached](#)]
4. N. COCCHIARELLA, «Logic and ontology», *Axiomathes*, 12(2001), 117-150 [[attached](#)]
5. B. SMITH, «Against fantology». In: M. E. Reicher, J. C. Marek (Eds.), *Experience and Analysis*. 153-170, Höbv & Hpt, Wien, 2005 [[attached](#)]

Module 3

Formal philosophy and formal ontology

Globalization of Science and Crisis of Humanistic Culture

- XX sec. started with the amazing event of **formalization** (symbolization + axiomatization) of scientific, mathematical language through the *Principia Mathematica* of Whitehead & Russell (1912-21).
- Through this achievement → the **globalization of Western Science/Technology** became possible for all non-Western peoples – Chinese people included.
 - In fact it was no longer necessary to study Western Culture for learning modern science/technology (only 4 years of a BS!)
- Two main **effects** of this phenomenon in less than one century:
 1. Tipping of the **world economic & (perhaps) political balance** from W → to E;
 2. **Globalization of the crisis** of the Humanistic and Religious Traditions both at W and at E, because of the ubiquitous and all-pervasive character of Scientific-Technological Culture → problem of outer lost of identities and inner cultural cohesion of each people.

Inter-disciplinary and Inter-Cultural Dialogue as the Remedy

- Two possible reactions to the crisis:
 1. Desperate and/or violent reaction of **Traditionalists**
 2. Intelligent reaction of Traditional Values recovering through an open-minded **interdisciplinary** (science(s)-religion(s)) **intercultural** (among philosophies and religions) **dialogue**.
- → **Post-modern amazing discovery** of impressive contact points between the pre-modern (classical) Traditions, and:
 1. The contemporary sciences (e.g., cosmology and cognitive neuroscience)
 2. The different W and E TraditionsAgainst their modern, artificial contraposition.
- → **Constructive** post-modernity vs. **nihilist** post-modernity

Formal philosophy as a tool for this dialogue

- Since the first publication of Whitehead & Russell *Principia* in 1912 the American philosopher **Carol I. Lewis**, profetically:
 1. Warned against the misuse of **mathematical logic** for the analysis of philosophical & religious languages as it happened thereafter through the publication of L. Wittengstein's *Tractatus Logico-Philosophicus* by his mentor B. Russell (1917).
 2. Recognized that the power of **mathematical logic** is in its formalization → necessity of formalizing also the **philosophical logic**, so to understand clearly similarities and differences:
 - **Between science(s) and philosophy(ies)** and
 - **Among the different philosophies**, beyond the differences of ages, languages and cultures.

The birth of *philosophical* (vs. *mathematical*) logic and the *formal ontology*

- Lewis, by formalizing **modal logic**, started the so called approach of **philosophical logic and formal philosophy** - today one of the most promising in Western philosophy and computer science.
- I.e., by formally distinguishing several meanings of **being** and **necessity** in philosophy and natural languages, differently from their unique mathematical meaning (Cocchiarella 2007; Basti, 2009;2012;Girle 2009; Burgess 2009)
- Unfortunately, today in China, philosophical logic and formal ontology seem studied and widely applied only in computer science for achieving the so-called **semantic Web** or **“Web3 revolution”** i.e. making sw/hw artifacts able to simulate **human semantic tasks** (Deng Zhihong, 2001; LI Shan-Ping 2004; YUAN Mei-yu 2004; HUANG Ying-hui, 2008, etc.).
- We would fulfill this gap...

Axiomatic modal logic and its development

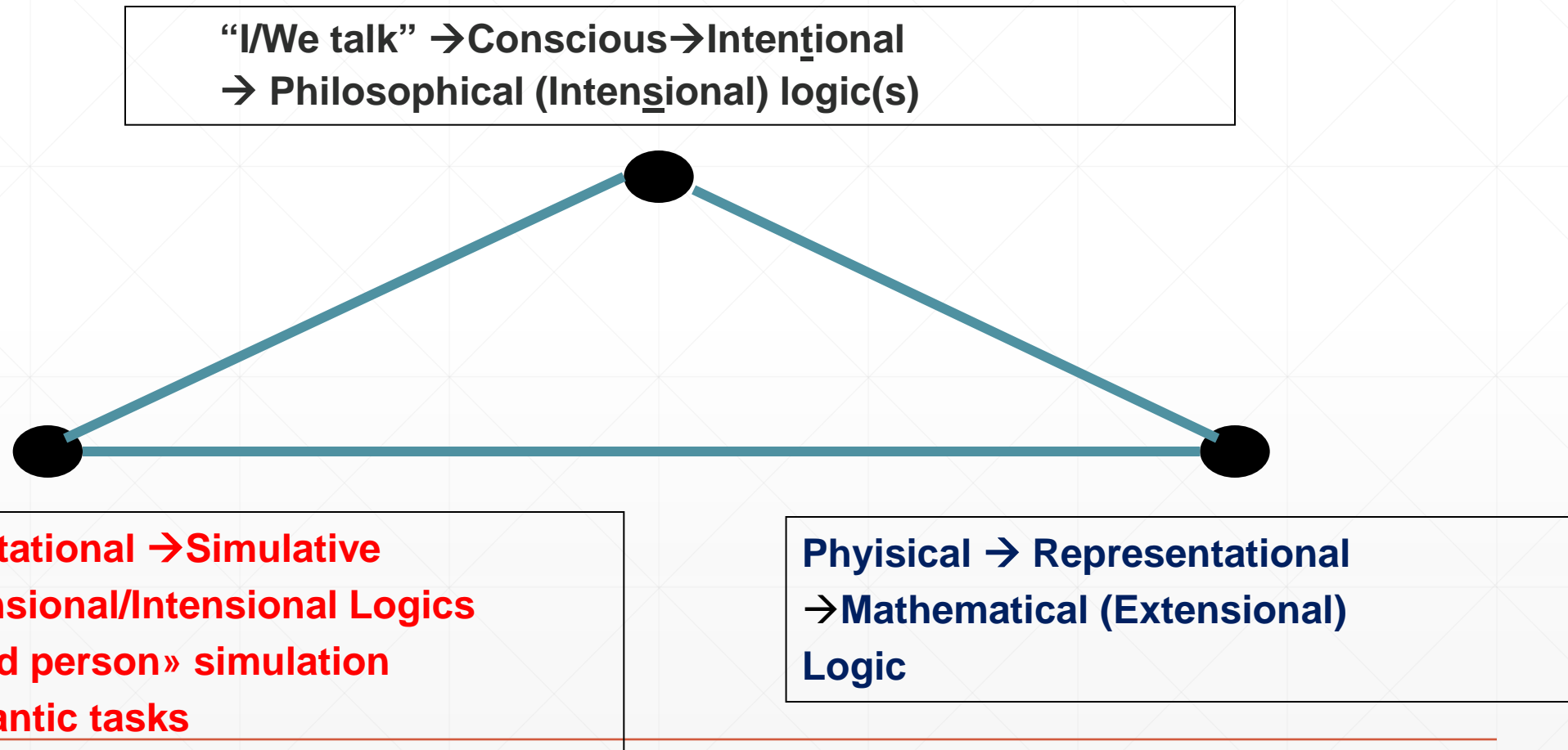
- Following (Blackburn, de Rijke & Venema, 2002) we can distinguish three eras of **modal logic** (ML) recent history:

1. Syntactic era (1918-1959): C.I.Lewis...

2. Classic era (1959-1988): S. Kripke's... relational semantics based on **frame theory**

3. Actual era (1988...): Aczel co-algebraic interpretation of modal logic → ML as fundamental tool in theoretical computer science, physics and biology.

ML relation triangle in philosophical/mathematical logic



Extensional (Mathematical) and Intensional (Philosophical) Logics

- **Intensional logics**: different types of **necessity**:
 1. **Alethic** (necessary/possible): **logic** (lawlike), **ontologic** (causal): physical or metaphysical;
 2. **Epistemic** (certainty(science)/uncertainty(opinion));
 3. **Deontic** (obligation/permission): in **ethics** and in **law**, etc.
- → Different **intensional logics** \equiv different **interpretations (models)** of **modal logical calculus** (set theory + modal axioms) \equiv different **truth conditions**.
- **Common features** of all **intensional** (philosophical) logics vs **extensional** (mathematical) logic (Zalta 1988):
 - **No extensionality axiom** $\mathbf{A} \equiv \mathbf{B} \not\rightarrow \mathbf{A} = \mathbf{B}$
 - **No existential generalization** $\mathbf{Pa} \not\rightarrow \exists x \mathbf{Px}$
 - Consequently, also **the Fegean notion of extensional truth**, based on the truth tables does not hold in the intensional predicate and propositional calculus.

Main axioms of ML syntax

- → ML relational structures with all their *intensional interpretations* are what is today defined as **philosophical logic** (Burgess 2009), as far as it is distinguished from the **mathematical logic**, the logic based on the extensional calculus, and the extensional notions of meaning, truth, and identity
- For our aims, it is sufficient here to recall that formal modal calculus is an extension of classical propositional, predicate and hence relation calculus with the inclusion of some further axioms:
- **N**: $\langle (\mathbf{X} \rightarrow \alpha) \Rightarrow (\Box \mathbf{X} \rightarrow \Box \alpha) \rangle$, where \mathbf{X} is a set of formulas (language), \Box is the necessity operator, and α is a meta-variable of the propositional calculus, standing for whichever propositional variable p of the object-language. **N** is the fundamental *necessitation rule* supposed in any normal modal calculus

Main modal axioms

D	def	$\Box A \rightarrow \Diamond A$
T	def	$\Box A \rightarrow A$
4	def	$\Box A \rightarrow \Box \Box A$
E	def	$\Diamond A \rightarrow \Box \Diamond A$
B	def	$A \rightarrow \Box \Diamond A$
Tr	def	$\Box A \equiv A$
M	def	$\Box \Diamond A \rightarrow \Diamond \Box A$
G	def	$\Diamond \Box A \rightarrow \Box \Diamond A$
H	def	$(\Diamond A \wedge \Diamond B) \rightarrow [\Diamond(A \wedge B) \vee \Diamond(A \wedge \Diamond B) \vee \Diamond(B \wedge \Diamond A)]$
Grz	def	$\Box(\Box(A \rightarrow \Box A) \rightarrow A) \rightarrow A$
Dum	def	$\Box(\Box(A \rightarrow \Box A) \rightarrow A) \rightarrow (\Diamond \Box A \rightarrow A)$
W	def	$\Box(\Box A \rightarrow A) \rightarrow \Box A.$

In the formulas given above:

- **D** comes from *deontic*
- **T** is a traditional name of the axiom (after Feys)
- **4** is characteristic for logic **S4** of Lewis
- **E** comes from *Euclidean*
(this axiom is often denoted by **5**)
- **B** comes after *Brouwer*
- **Tr** abbreviates *trivial*
- **M** comes after *McKinsey*
- **G** comes after *Geach*
- **H** comes after *Hintikka*
- **Grz** comes after *Grzegorzczuk*
- **Dum** comes after *Dummett*
- **W** comes from *reverse well founded*
(it is also known as the Löb axiom).

Main Modal Systems

- By combining in a consistent way several modal axioms, it is possible to obtain several **modal systems** which constitute as many **syntactical structures available for different intensional interpretations**.
- So, given that **K** is the fundamental modal systems, constituted by the ordinary propositional calculus **k** plus the necessitation axiom **N**, some interesting modal systems for our aims are: **KT4 (S4, in early Lewis' notation)**, typical of the physical ontology; **KT5 (S5, in early Lewis' notation)**, typical of the metaphysical ontology; **KD45 (Secondary S5)**, with application in deontic logic, but also in epistemic logic and in ontology.

Modal logic correspondence principle (Van Benthem)

Correspondences in Kripke semantics

Given a modal axiom the question is what Kripke frames validate the axiom. If the property is expressed in the classical first-order logic then we have a *correspondence* between modal axiom and the first-order property.

Examples of correspondences

Formula	Property of R
D	$\forall x. \exists y. R(x, y)$ (R is serial)
T	$\forall x. R(x, x)$ (R is reflexive)
4	$\forall x, y, z. (R(x, y) \wedge R(y, z)) \rightarrow R(x, z)$ (R is transitive)
E	$\forall x, y, z. (R(x, y) \wedge R(x, z)) \rightarrow R(y, z)$ (R is Euclidean)
B	$\forall x, y. (R(x, y) \rightarrow R(y, x))$ (R is symmetric)
Tr	$\forall x, y. (R(x, y) \equiv x = y)$ (R is trivial)
G	$\forall x, y, z. ((R(x, y) \wedge R(x, z)) \rightarrow \exists w (R(y, w) \wedge R(z, w)))$ (R is directed)
$\Diamond\alpha \rightarrow \Box\alpha$	$\forall x, y, z. (R(x, y) \wedge R(x, z)) \rightarrow y = z$ (R is a partial function)
$\Diamond\alpha \equiv \Box\alpha$	$\forall x. \exists! y. R(x, y)$ (R is a function)
$\Box\Box\alpha \rightarrow \Box\alpha$	$\forall x, y. R(x, y) \rightarrow \exists z (R(x, z) \wedge R(z, y))$ (R is dense)

A list of the main modal systems

KT = T = logic of Gödel/Feys/Von Wright
KT4 = S4
KT4B = KT4E = S5
K4E = K45
KD = deontic T
KD4 = deontic S4
KD4B = deontic S5
KTB = Brouwer logic
KT4M = S4.1
KT4G = S4.2
KT4H = S4.3
KT4Dum = D = Prior logic
KT4Grz = KGrz = Grzegorzcyk logic
K4W = KW = Löb logic
KTr = KT4BM = trivial logic.

S4, S5 and KD45 Modal Systems

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Different truth conditions for alethic vs. deontic contexts

- Generally, in the *alethic* (either logical or ontological) interpretations of modal structures the necessity operator $\Box p$ is interpreted as “ p is true in all possible world”, while the possibility operator $\Diamond p$ is interpreted as “ p is true in some possible world”. In any case, the so called **reflexivity principle** for the necessity operator holds in terms of axiom **T**, i.e.,

$$\Box p \rightarrow p.$$

- Where “reflexivity principle” means the principle by which the modal operator applied on its argument gives back the argument as **true** in the actual world. In term of **T** the demonstration is evident, if p is true in all possible worlds is true also in the actual one.
- This is not true in **deontic** contexts. In fact, “if it is obligatory that all the Italians pay taxes, does not follow that all Italians really pay taxes”, i.e.,

$$\Box p \not\rightarrow p$$

Reflexivity in deontic contexts

- In fact, the obligation operator $\mathbf{O}p$ must be interpreted as “ p is true in all *ideal* worlds” different from the actual one, otherwise $\mathbf{O}=\square$, i.e., we should be in the realm of metaphysical determinism where freedom is an illusion, and ethics too. The reflexivity principle in deontic contexts, able to make obligations really effective in the actual world, must be thus interpreted in terms of an *optimality operator* \mathbf{O}_p for *intentional agents* x , i.e.,

$$(\mathbf{O}p \rightarrow p) \Leftrightarrow ((\mathbf{O}_p(x,p) \wedge c_a \wedge c_{ni}) \rightarrow p)$$

Where the clauses $c_a \wedge c_{ni}$ mean respectively, «acceptance condition» and «non-impediment condition». Of course, in the case of **legal** and non-ethical obligations c_a does not hold.

Reflexivity in epistemic context

- In similar terms, in **epistemic** contexts, where we are in the realm of representations of the real world. The interpretations of the two modal epistemic operators $\mathbf{B}(x,p)$, “ x believes that p ”, and $\mathbf{S}(x,p)$, “ x knows that p ” are the following:
- $\mathbf{B}(x,p)$ is true iff p is true in the realm of representations believed by x . $\mathbf{S}(x,p)$ is true iff p is true for all the **founded** representations believed by x . Hence the relation between the two operators is the following:

$$\mathbf{S}(x, p) \Leftrightarrow (\mathbf{B}(x, p) \wedge \mathbf{F})$$

Where \mathbf{F} is a **foundation clause**.

Finitistic and not finistic interpretations

- So, for instance, in the context of a **logician** ontology, such a **F** is interpreted as a supposed **actually infinite capability** of human mind of attaining the logical truth. We will offer, on the contrary, a different **finitistic** interpretation of **F** within NR .
- **Anyway**, while:

because of **F**

$$\mathbf{B}(x, p) \not\rightarrow p$$

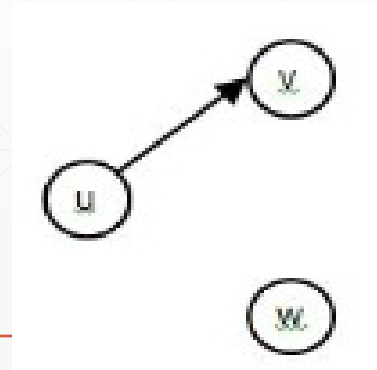
$$\mathbf{S}(x, p) \rightarrow p$$

Kripke relational semantics

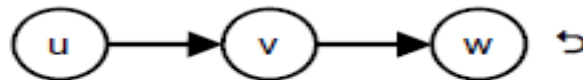
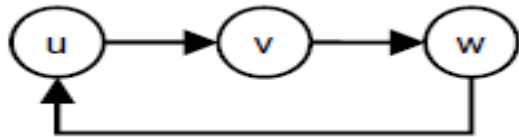
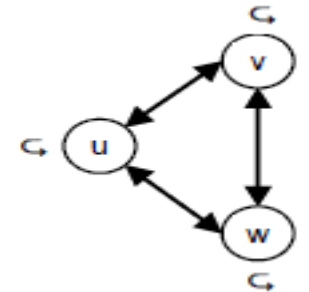
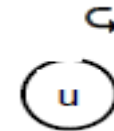
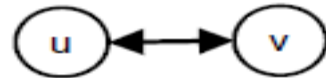
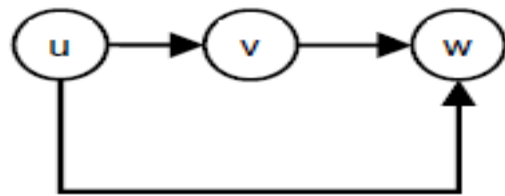
- Kripke relational semantics is an evolution of Tarski formal semantics, with two specific characters: 1) it is related to an **intuitionistic logic** (i.e., it considers as non-equivalent excluded middle and contradiction principle, so to admit coherent theories violating the first one), and hence 2) it is compatible with the **necessarily incomplete character** of the formalized theories (i.e., with Gödel theorems outcome), and with the **evolutionary character** of natural laws not only in biology but also in cosmology.
- In other terms, while in Tarski classical formal semantics, the truth of formulas is concerned with the state of affairs of **one only actual world**, in Kripke relational semantics the truth of formulas depends on states of affairs of **worlds different from the actual one** (= possible worlds).
- → **Stipulatory character** of Kripke's possible worlds

Kripke notion of frames

- Kripke notion of **frame** main novelty in logic of the last 50 years → **relational structure**.
- This is an ordered pair, $\langle \mathbf{W}, R \rangle$, constituted by a domain \mathbf{W} of possible worlds $\{u, v, w, \dots\}$, and a by a two-place *relation* R defined on \mathbf{W} , i.e., by a set of ordered pairs of elements of \mathbf{W} ($R \subseteq \mathbf{W} \times \mathbf{W}$), where $\mathbf{W} \times \mathbf{W}$ is the *Cartesian product* of \mathbf{W} per \mathbf{W} .
- E.g. with $\mathbf{W} = \{u, v, w\}$ and $R = \{uRv\}$, we have:



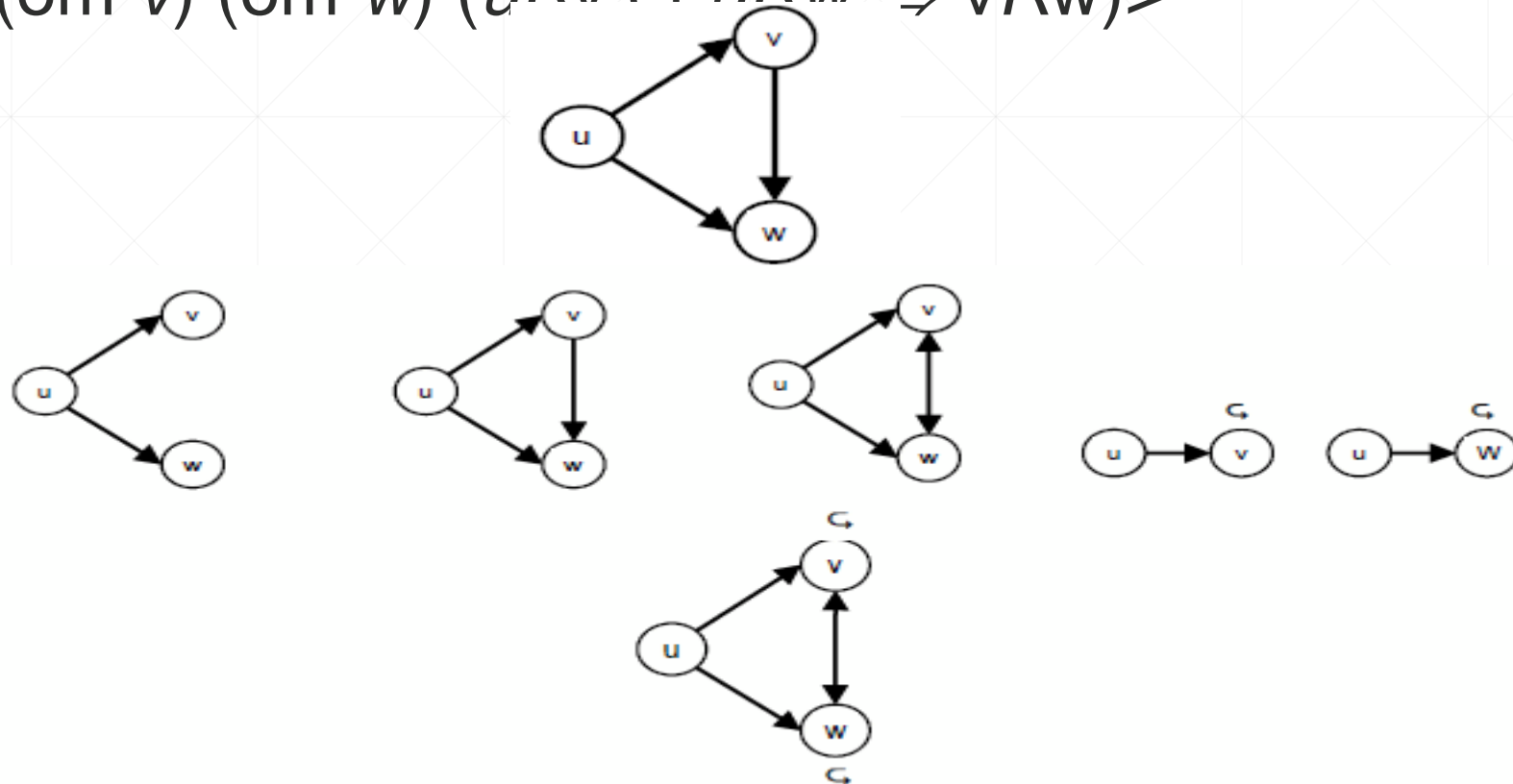
Relations defined on frames



Seriality: $\langle (\text{om } u)(\text{ex } v)(uRv) \rangle$

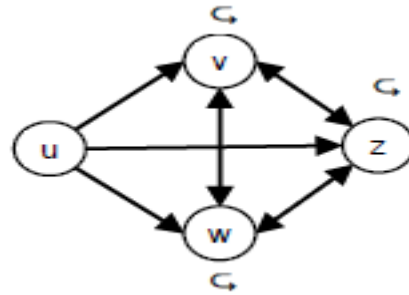
Euclidean property

- $\langle (\text{om } u) (\text{om } v) (\text{om } w) (uRv \ \& \ uRw \Rightarrow vRw) \rangle$

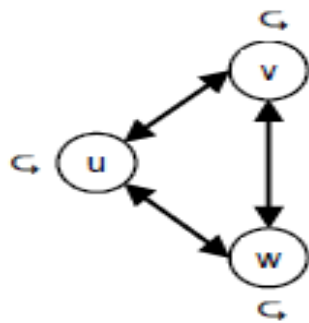


Ontological interpretation

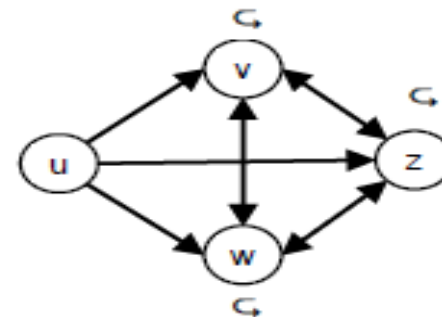
- Of course, this procedure of a (logical) *equivalence constitution by iteration of a transitive and serial (=causal) relation* can be extended indefinitely:



KD45 as a secondary S5 (KT45)



S5(KT45)



KD45

Natural languages, ontologies, formal ontology

- Three sources of **meaning** → linguistic and logical analyses (Peirce):
 - **Syntax:** meaning ← Relations among language parts;
 - **Semantics:** meaning ← Relations with language content (→ metalanguage-language);
 - **Pragmatics:** meaning ← Relations with language agents
- → **Natural Languages** (NL)= implicit ontologies of their user community (ontological commitment) made explicit in their philosophical (religious) **descriptive ontologies**.

What is an ontology

- “An ontology (*BenTiLun*) is an explicit specification of a conceptualization. The term is borrowed from philosophy, where an Ontology is a systematic account of Existence **for a given group**” (Gruber 1993; HUANG Ying-hui, 2008).
- In other terms, an “ontology” is an explicit description of **what exists** for a given human group.

Ontology, Confucianism, Aristotelianism

- It is a *leit-motiv* in philosophy characterizing Western modern epistemology as **representational** – knowledge as *inner* representation (symbolic analysis by syntax-semantics) of an *outer* reality – vs. Confucian but also Aristotelian approach relating systematically knowledge with **action** (pragmatics), epistemology with ontology .
- This **pragmatic approach to knowledge** is the proper of the **naturalistic** ontologies, both in philosophical logic (Cocchiarella 2007; Basti 2009) and in computer science (Gruber 2003; HUANG Ying-hui, 2008):
- This integration of pragmatics with syntax and semantics for **formally analyzing** ontologies, is one of the main differences between **formal logic** and **formal ontology** → problem how to integrate in a **common formalism of relations, real (causal) and logical relations.**

Formal ontology in TCS

- “We say that an agent **commits to an ontology** if its observable actions are consistent with the definitions in the ontology. The idea of ontological commitments is based on the *Knowledge-Level perspective* (Newell, 1982). The Knowledge Level is a level of description of the knowledge of an agent that is independent of the symbol-level representation used internally by the agent. Knowledge is attributed to agents by observing their actions; an agent “knows” something if it acts *as if it had the information and is acting rationally to achieve its goals.*” (Gruber 2003)

From formal logic to formal ontology

- All this brings us immediately to understand the notion of **formal ontology**. Effectively, the contemporary notion of “formal ontology”, as distinguished from “formal logic”, is derived from Edmund Husserl research and teaching. Indeed, in his “Third Logical Research” (Husserl, 1913/21), he distinguishes between:
 1. **Ontology** as a discipline studying relationships between *things* (like “objects and properties”, “parts and wholes”, “relations and collections, etc.); and
 2. **Logic** as a discipline studying relationships among *truths* (come “consistency”, “validity”, “conjunction”, “disjunction”, etc.).
- On the other hand, Husserl continues, both disciplines are *formal* in the sense that they are “domain independent”.
- Husserl and his school developed the formal ontology analysis using the **phenomenological method**. Today, however, in the scientific and philosophical realms, when we speak about “formal ontology”, we intend generally the “**formalized ontology**”, i.e., the formal ontology developed according to the **axiomatic method**, using the formal means of modal and philosophical logic.

Predication vs. Membership

- “Being” in ML reduced to (set/class) **membership** by satisfaction of a series of abstract (representational) definitions (logic relations):

$$\exists x Mx \equiv \exists x x \in \mathbf{M}$$

- “Being” in an Aristotelian FO means **individual instantiation of a texture of causal (real) relations** common to all the individuals of the same natural kind (genus):

$$(\forall^k A) (\forall y A) \square^C (E!(x) \rightarrow x=y \wedge x \in \mathbf{A})$$

- W languages: natural **properties** vs natural **kinds** \equiv **adjectival** (“John is fat” $\rightarrow Fx$) vs **nominal** (“John is a man” $\rightarrow xM$) predication \rightarrow different **logical necessity degrees** \leftarrow different **causal necessity degrees** (Aristotle: *accidental* vs *essential* predication) .

A taxonomy of different ontologies

- In fact, the main ontologies of whichever philosophy can be formalized like as many **theories of predication** — *nominalism, conceptualism, realism* —, and/or like as many **theories of universals**, where by “universal” — as distinguished from “class” or “set” — we intend “what can be predicated of a name”, according to Aristotle’s classical definition (*De Interpretatione*, 17a39).
- So, from the standpoint of the predicate logic supposed by each ontology, it is evident that all the **nominalist ontologies** suppose only a *first order* predicate logic, since in such ontologies it is forbidden quantifying over predicate symbols. The predicates, indeed, in nominalism, cannot denote anything: the “universals” do not exist at all in such ontologies. There exist only individuals: universals are only linguistic conventions. → When they use second order quantification on the predicates it is only in a **substitutional sense**.
- **The other ontologies** admit the existence of universals, even though in different **interpretations**.

A scheme of the main ontologies

