EMMO's Theoretical Foundations

Francesco A. Zaccarini [1] Emanuele Ghedini [1] Jesper Friis [2] Gerhard Goldbeck [3] Georg J. Schmitz [4]
Anne F. de Baas [3] Sebastiano Moruzzi [1]

[1]University of Bologna [2]SINTEF [3]Goldbeck Consulting [4]RWTH Aachen University

★ EMMC ★

Short Abstract

EMMO, the Elementary Multiperspective Material Ontology, is a **foundational ontology** expression of the common tenets and the general worldview at the core of **applied sciences**. It has been developed with the intent of providing a standard representational framework for **materials modeling knowledge**, while retaining a level of generality which makes it capable of being employed in any context to good results. **EMMO** is currently being formalized in First Order Logic with identity and **W3C**'s OWL 2 DL; a **Mereo-Causal** theory was developed specifically for the ontology.

Overview

EMMO's most notable innovative features (with respect to standard taxonomies and other ontologies – Foundational or LightWeight) come down to three interrelated points:

(1) the strong influence of **applied sciences** on its framework;
(2) its non-standard **architecture**, encompassing a common core and a **plurality** of "perspectives": modular extensions, each expression of a salient conceptual schema or offering useful tools to dissect the world, which can be employed in tandem to offer a full characterization of an entity;
(3) the explicit, reasoned separation of **background theoretical assumptions** and the theory/ontology's **commitments**, which is influenced by **pragmatic** considerations pertaining to usability, formal features, and expressive needs in **knowledge representation**.

(1) Applied Sciences Friendly

A framework endorsing a **worldview extrapolated from applied sciences** is arguably the most natural candidate for the representation of knowledge hinged on the latter. There are also good reason to believe that the **methodological principles and assumptions** allegedly responsible for the scientific enterprise's indisputable practical/operational **success** have the potential to **reduce conceptualization's inherent ambiguities** (a precondition for the full **exploitation in industrial environments**).

The focus on sciences is also in line with a current trend in **analytic metaphysics** (which have always exerted a considerable influence on applied ontology since the latter's origins), where **naturalistic/naturalized approaches** enjoy the most popularity, whereas the influence of linguistic/conceptual analysis has been declining. Specifically, in **EMMO** certain **commitments** are also **extrapolated from our best scientific theories** (e.g. Relativity and Quantum Mechanics for the uppermost module, Mereocausality – which theory shares some similarities with Causal Set Theory, and Robb's classic axiomatic formalization of Special Relativity, and which takes inspiration from Feynman's Diagrams).

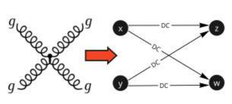


Figure 1. From Feynman's Diagrams to Mereocausality

(2) EMMO's Architecture

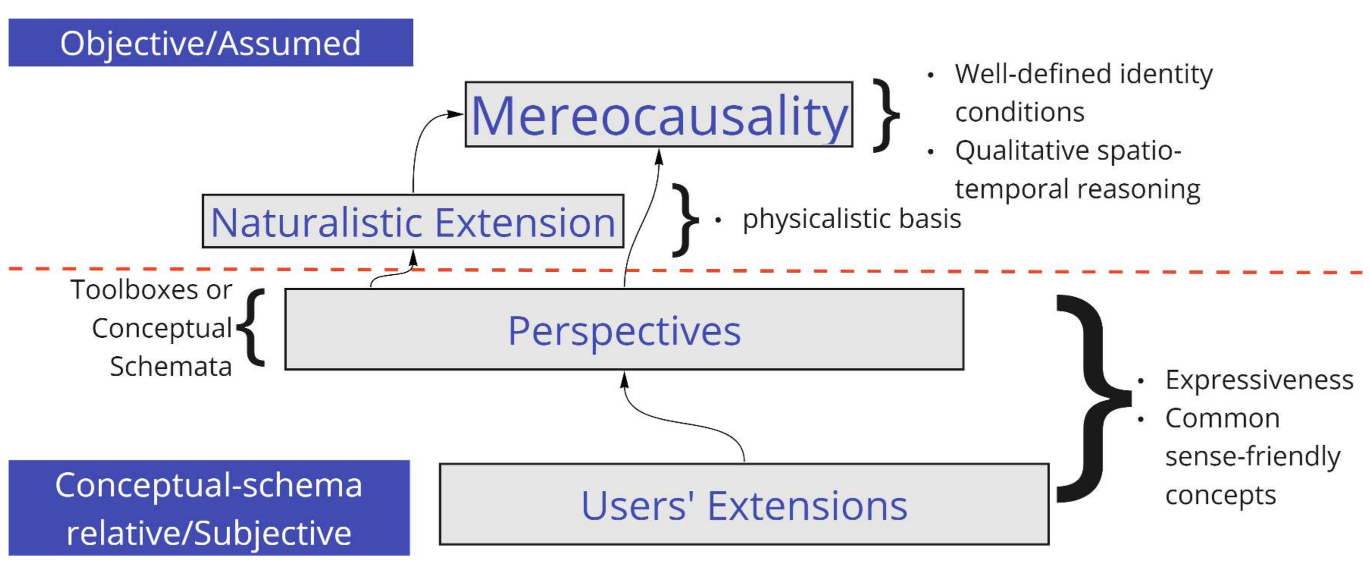


Figure 2. EMMO's General Architecture

(3) Theoretical Background and EMMO's Pragmatic Stance

Expressive needs and pragmatic considerations have no place in metaphysics, but they reside at the core of ontology engineering. Nevertheless, strong theoretical foundations are the key for the establishment of a coherent, effective framework.

Theoretical Assumptions

EMMO subscribes to a pragmatic form of **ontological reductionism** resting on the assumption that our scientific theories (and our commonsensical worldview) all provide representations of the same world. **Representational pluralism** is the result of focusing on different sources of empirical information and interpretative under-determination. Given an empiricist stance, and the further assumption that observation requires (causal) interaction, a form of **nominalistic ontological naturalism** follows: EMMO's domain encompasses only natural entities. More specifically, **EMMO** allows in its domain only (non-virtual) **elementary particles** –as they are described by the **Standard Model of particle physics**– and individuals composed of said entities; the former as *bona fide* entities and the latter chiefly for the sake of convenience. **EMMO** is neutral with respect to **semantic reductionism**, understood as the thesis that the ideological commitments of a representation of the world can be reduced to that of another.

Pragmatic Compromises

In **EMMO** **(1)** some classes are included in the ontology purely for the sake of **(a) expressiveness** and/or **(b) usability**; **(2)** certain formalization choices are made for **convenience** despite there being equivalent alternatives which are more appropriate from a purely theoretical point of view (e.g., AGEM & the choice of $\mathtt{C}$ –rather than $\mathtt{dC}$, more adequate from a naturalistic point of view– as a primitive [1]); **(3)** **architecture design** is taken into account when choices are made.

References

Ghedini E., et al (Forthcoming).
An Introduction to EMMO's Mereo Causal Foundations.

Formalization

EMMO's **Mereocausality module** is based on two **primitives**: $\mathtt{P}(x,y)$, which reads "x is *part of* y" and $\mathtt{C}(x,y)$, which reads "x *causes* y", and has a strong naturalistic interpretation extrapolated from Feynman's Diagrams. The most relevant definitions and axioms are reported below:

Mereology (AGEM)

a1 $\mathtt{P}(x,x)$ *(Parthood: Reflexivity)*
a2 $\mathtt{P}(x,y) \land \mathtt{P}(y,x) \rightarrow x = y$ *(Parthood: Antisymmetry)*
a3 $\mathtt{P}(x,y) \land \mathtt{P}(y,z) \rightarrow \mathtt{P}(x,z)$ *(Parthood: Transitivity)*
d1 $\mathtt{PP}(x,y) := \mathtt{P}(x,y) \land \neg\mathtt{P}(y,x)$ *(Proper Part)*
d2 $\mathtt{O}(x,y) := \exists z(\mathtt{P}(z,x) \land \mathtt{P}(z,y))$ *(Overlap)*
a4 $\neg\mathtt{P}(y,x) \rightarrow \exists z(\mathtt{P}(z,y) \land \neg\mathtt{O}(z,x))$ *(Strong Supplementation)*
d3 $\sigma x\langle\phi(x)\rangle := \iota z(\forall y(\mathtt{O}(y,z) \leftrightarrow \exists x(\phi(x) \land \mathtt{O}(x,y))))$ *(Fusion)*
d4 $\mathtt{SUM}(x,y,z) := x = \sigma w\langle\mathtt{P}(w,y) \lor \mathtt{P}(w,z)\rangle$ *(Binary Sum)*
d5 $\mathtt{PRD}(x,y,z) := x = \sigma w\langle\mathtt{P}(w,y) \land \mathtt{P}(w,z)\rangle$ *(Binary Product)*
d6 $\mathtt{DIF}(x,y,z) := x = \sigma w\langle\mathtt{P}(w,y) \land \neg\mathtt{O}(w,z)\rangle$ *(Binary Difference)*
d7 $\mathtt{u} := \sigma x\langle\mathtt{P}(x,x)\rangle$ *(Universe)*
a5 $\exists x(\phi(x)) \rightarrow \exists y(y = \sigma x\langle\phi(x)\rangle)$ *(Unrestricted Composition)*
d8 $\mathtt{Q}(x) := \neg\exists y(\mathtt{PP}(y,x))$ *(Quantum - Mereological Atom)*
d9 $\mathtt{qP}(x,y) := \mathtt{P}(x,y) \land \mathtt{Q}(x)$ *(Quantum Part)*
a6 $\forall x\exists y(\mathtt{qP}(y,x))$ *(Atomicity)*

Causation

a7 $\neg\mathtt{C}(x,x)$ *(Causation: Irreflexivity)*
a8 $\mathtt{C}(x,y) \land \mathtt{C}(y,z) \rightarrow \mathtt{C}(x,z)$ *(Causation: Transitivity)*
d10 $\mathtt{dC}(x,y) := \mathtt{C}(x,y) \land \neg\exists z(\mathtt{C}(x,z) \land \mathtt{C}(z,y))$ *(Direct Causation)*
a9 $\mathtt{C}(x,y) \rightarrow \mathtt{dC}(x,y) \lor \exists zw(\mathtt{C}(x,z) \land \mathtt{dC}(z,y) \land \mathtt{dC}(x,w) \land \mathtt{C}(w,y))$
(Causation: Discreteness / Direct Causation's Necessity)

$\mathtt{P}$-$\mathtt{C}$ Bridge (Reductionistic Assumption)

a10 $\mathtt{C}(x,y) \rightarrow \mathtt{Q}(x) \land \mathtt{Q}(y)$ *(Quantum Causation)*

Naturalistic Commitments (extrapolated from Feynman's Diagrams)

a11 $\mathtt{dC}(x,y) \rightarrow \exists z((\mathtt{dC}(x,z) \lor \mathtt{dC}(z,y)) \land y \neq z \land x \neq z)$ *(Minimal Causal Structure)*
a12 $\mathtt{dC}(x,y) \land \mathtt{dC}(x,z) \land \mathtt{dC}(w,y) \rightarrow \mathtt{dC}(w,z)$ *(Locality)*
As a result of (a12) the models of the theory are such that single **interactions** are **Complete Bipartite Graphs**. Complete Bipartite Graphs can be represented in Cartesian Spaces with **dimensionality** ≤ 4.

MacroCausation

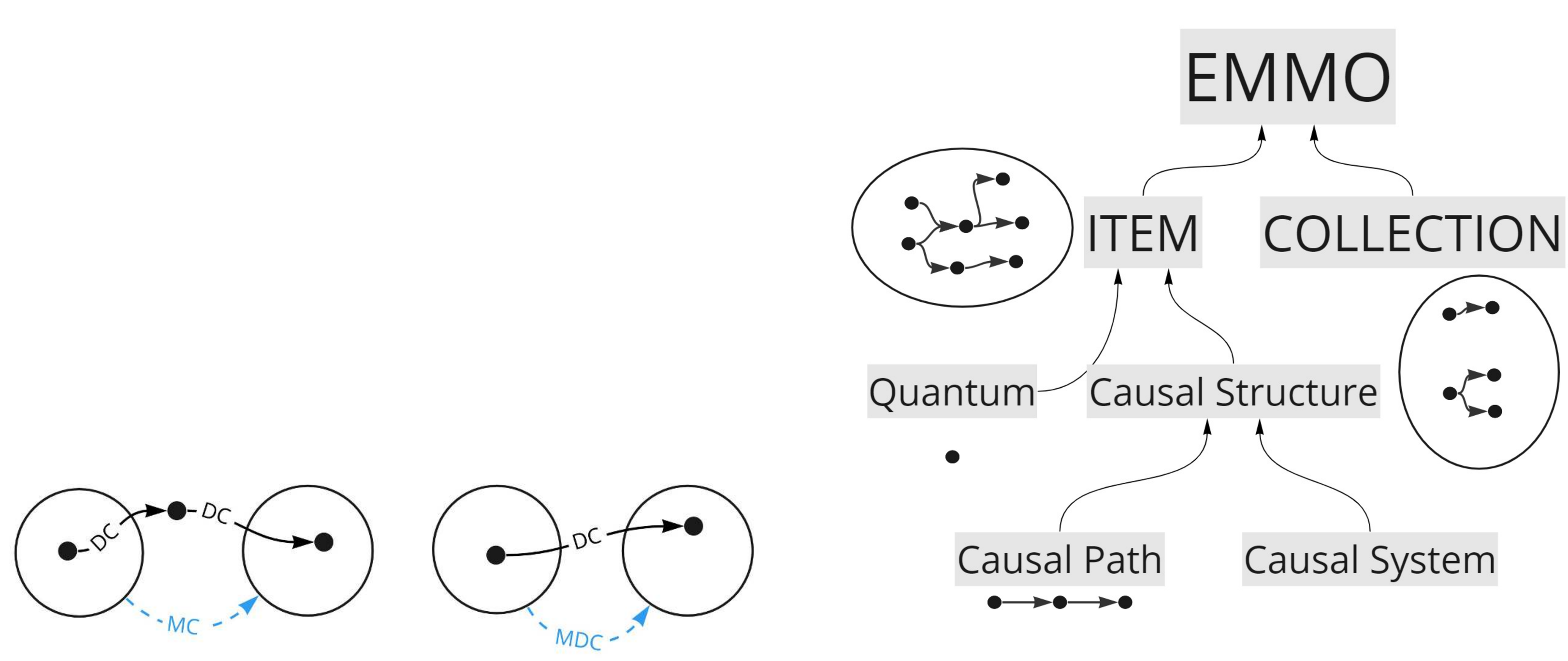
d11 $\mathtt{MC}(x,y) := \neg\mathtt{O}(x,y) \land \exists wz(\mathtt{qP}(w,x) \land \mathtt{qP}(z,y) \land \mathtt{C}(w,z))$ *(Macro Causation)*
d12 $\mathtt{MdC}(x,y) := \neg\mathtt{O}(x,y) \land \exists wz(\mathtt{qP}(w,x) \land \mathtt{qP}(z,y) \land \mathtt{dC}(w,z))$ *(Macro Direct Causation)*
d13 $\mathtt{CNT}(x,y) := \mathtt{MdC}(x,y) \lor \mathtt{MdC}(y,x)$ *(Contact)*

Taxonomy & Core Structures

d14 $\mathtt{ITEM}(x) := \forall yz(\mathtt{SUM}(x,y,z) \land \neg\mathtt{O}(y,z) \rightarrow \mathtt{CNT}(y,z))$ *(Item)*
a13 $\mathtt{ITEM}(\mathtt{u})$ *(Self-Connected Universe)*
d15 $\mathtt{COLL}(x) := \neg\mathtt{ITEM}(x)$ *(Collection)*
d16 $\mathtt{CSTR}(x) := \mathtt{ITEM}(x) \land \neg\mathtt{Q}(x)$ *(Causal Structure)*
d17 $\mathtt{LNK}(x,y) := \mathtt{qP}(x,y) \land \forall wz(\mathtt{P}(w,y) \land \mathtt{P}(z,y) \land \mathtt{dC}(w,x) \land \mathtt{dC}(z,x)) \rightarrow w = z) \land$
$\forall uv(\mathtt{P}(u,y) \land \mathtt{P}(v,y) \land \mathtt{dC}(x,u) \land \mathtt{dC}(x,v)) \rightarrow u = v)$ *(Link)*
d18 $\mathtt{CPTH}(x) := \mathtt{CSTR}(x) \land \forall y(\mathtt{qP}(y,x) \rightarrow \mathtt{LNK}(y,x))$ *(Causal Path)*
d19 $\mathtt{CSYS}(x) := \mathtt{CSTR}(x) \land \neg\mathtt{CPTH}(x)$ *(Causal System)*
d20 $\mathtt{X}(x,y,w,z) := \mathtt{dC}(x,y) \land \mathtt{dC}(x,w) \land \mathtt{dC}(z,y) \land \mathtt{dC}(z,w) \land x \neq z \land y \neq w$ *(X-Structure)*

The Emergence of Spatio-Temporal Relations

d21 $\mathtt{tCNT}(x,y) := \mathtt{MdC}(x,y) \land \neg\mathtt{MdC}(y,x)$ *(Temporal Contact)*
d22 $\mathtt{sCNT}(x,y) := \mathtt{MdC}(x,y)(x,y) \land \mathtt{MdC}(x,y)(y,x) \land$
$\forall v(\mathtt{qP}(v,x) \land \mathtt{MdC}(x,y)(y,v) \rightarrow \exists uwz(\mathrm{X}(u,v,w,z) \land \mathtt{P}(u,x) \land \mathtt{P}(w,y) \land \mathtt{P}(z,y))) \land$
$\forall n(\mathtt{qP}(n,y) \land \mathtt{MdC}(x,y)(x,n) \rightarrow \exists mop(\mathrm{X}(n,m,o,p) \land \mathtt{P}(m,y) \land \mathtt{P}(o,x) \land \mathtt{P}(p,x)))$ *(Spatial Contact)*



(a) $\mathtt{dC}$ & $\mathtt{MdC}$ (b) **EMMO**: Mereocausality's taxonomy.

Figure 3

Acknowledgments

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OpenModel VIMMP OntoTrans ReaxPro OntoCommons Oyster NanoMECommons MarketPlace SimDOME