Mereocausality & Causal Mereotopology: A New Concept[1]

Robert J. Rovetto[2]

Abstract. How is causality/causation associated with parthood? Do the parts of a whole interact in distinct causal manners? I introduce a novel concept I call 'mereocausality' and its cognates, merging two foundational topics used in both theoretical and practical disciplines: causality and parthood (or mereology). Topology is often associated with mereology, yielding mereotopology to which this conceptual synthesis also applies. I apply inquiry into causality and formal causal relations to mereology, developing a new formal concept: *mereocausality*, *mereocausation*, *causal mereo(topo)logy*, and cognates. This paper offers a preliminary exploration, introducing broad concepts, research questions and terminology for what can be a new branch of inquiry: *casual mereology* and *causal mereotopology*. Future work will involve a more structured investigation, developing and applying the basic ideas presented here. I hope to produce a conceptual system for exploring the intersection of causality, mereology and topology. A contribution of this work is the creation of a new concept and associated terminology. This work is relevant to a variety of disciplines and activities: philosophy, such as metaphysics; conceptual analysis and development; formal and applied/computational ontology (ontology engineering, knowledge engineering); topics in ontology development, such as foundational (upper or top-level) ontology development; knowledge representation and reasoning in artificial intelligence; conceptual modeling; semantic data modeling; psychology and cognitive science; linguistics; etc.

1. Introduction

I introduce a novel concept I call *mereocausality*, and its cognates such as: mereocausation, causal parthood, mereotopological causality, causal mereotopology, and others. These concepts combine the foundational ones of causality, causation, parthood, mereology and topology (or mereotopology). For the purposes of this paper, I present preliminary ideas for what may become a new branch of inquiry, *causal mereology*. I offer early independent ideas[3], asking both ontological (metaphysics) and practical questions such as: Does causality vary among (or in virtue of) parts and their whole? Does causality vary among the same at different scales? Is there utility in

[2] Robert J. Rovetto. Email: rrovetto@terpalum.umd.edu. ORCID: https://orcid.org/0000-0003-3835-7817
[3] This concept was first expressed by the author in a section within a 2014 paper submitted to, but rejected from, the Journal of Philosophy, entitled "Causal Relations for Formal Ontology". That paper attempted to develop various types of abstract causal relations. [7]

positing and asserting mereocausal relations? What are useful, formal characterizations? How can they be applied to computational disciplines?

Future work will involve development of the concepts, terminology, and tasks introduced here, along with an exploration of relevant literature. Part of the contribution of this work, then, is the introduction of novel concepts for philosophical and computational disciplines, i.e., conceptual innovation with an interdisciplinary character. The overall project [7] is relevant to the philosophy of causality, mereology, the development of knowledge organization systems[4] for data applications, and knowledge representation and reasoning (KRR) in artificial intelligence (AI). I hope this paper offers innovative and interesting concepts for various lines of intellectual pursuit.

The paper is structured as follows: Section 2 gives a brief summary of causality and mereology, followed by a description of the synthesized core idea in 3. Sections 4 through 7 presents preliminary research questions, candidate terminology, possible limitations, and relevance. Section 8 closes.

2. Causality and Mereology

The concepts of causality and causation [1] [3] have been explored across disciplines. There are likewise various accounts of parthood. For the purposes of this paper, I do not summarize the characterizations of causality and mereology. Suffice it to say that the concepts of *causality* and *causation* essentially express the principle(s), law(s), theory(s) or relation(s) of cause and effect. At the very least, they may reflect a belief or supposition thereof. The philosophy of causality includes investigation into the metaphysical nature of causality, causality conceived as a relation, the causal relata, and so on. Here, 'causality' and 'causation' are used interchangeably for simplicity, but distinctions may be mentioned where needed.

Mereology [2][4][5][6] is generic (often philosophical and mathematical) inquiry into the inter-relations of parts and (their) wholes, i.e., *parthood*. It is about theory(s) of parthood, the relationship of part to whole. Mereologies are specific formal theories about parthood which may employ symbolic logics. Classical or General Extensional Mereology [2] is an example. *Topology* is, in part, the study of connectedness, boundary, and the properties of geometric structures (e.g., shapes, surfaces, etc.) under changes of various sorts. It is concerned, for example, with the characteristics of objects that are preserved under homeomorphisms. *Mereotopology* merges mereology with topology. In a similar manner, the premise of this work is the merger of mereotopology and causality.

[4] Computational ontologies, semantic models, conceptual models, knowledge graphs, etc.

The combined concept I introduce here was conceived independently of causal and mereological accounts. However, this project will explore whether asserting *mereocausal* accounts will vary based on any given set of particular causal and mereological accounts.

3. What is Mereocausality and Causal mereology?

Mereocausality and *Causal mereology* [7] is about causality among parts and their wholes. The inquiry is motivated by the question of whether distinct forms of causality exist, whether causality varies at different scales or granularities, and if so, whether the interaction among parts and the whole exhibits distinct forms. Figures 1 and 2 present a visualization of the overall idea for combining causality and mereology into a new concept of mereocausality.

If causality is one or more principles of cause and effect, then *mereocausality* may be a one or more principles of cause and effect *among* parts and their respective wholes. Mereocausality can thereby be characterized as a specialized type of causality.

If causation is construed as one or more causal relations, then *mereocausation* may be one or more causal relations specifically obtaining among parts and their wholes.

In the sense of a field of study, *Causal Mereology* is study concerned with the actual or potential causal efficacy, causality, causal relations, or causation among parts and between parts and their composing (or constituting) whole. It is concerned with phenomena picked out by, characterized by, or described by associated predicates, including cognates such as ‘causal influence’, ‘causal structure’, ‘causal connectedness’, etc.

This inquiry includes both *metaphysical questions* about relationships, as well as *practical questions* about the utility to assert formal distinctions, including formal causal relations among parts and wholes. The distinction between relationships and relation is not needed for the purposes of this communication, but one may wish to tentatively approximate it as: the supposed ontological (metaphysics) aspects of the world, and any asserted, prescribed or declared constructs (e.g., predicates in an symbolic logic) that may or may not refer to those aspects, respectively. Although the metaphysical question of the existence of mereocausality and mereocausal relations is interesting from philosophical perspectives, the data-centric reader may ignore it, opting instead to consider what computable framework of mereocausal relations would like like and whether (and how) it can be of value. In this way, one may be agnostic with respect to the metaphysical question.

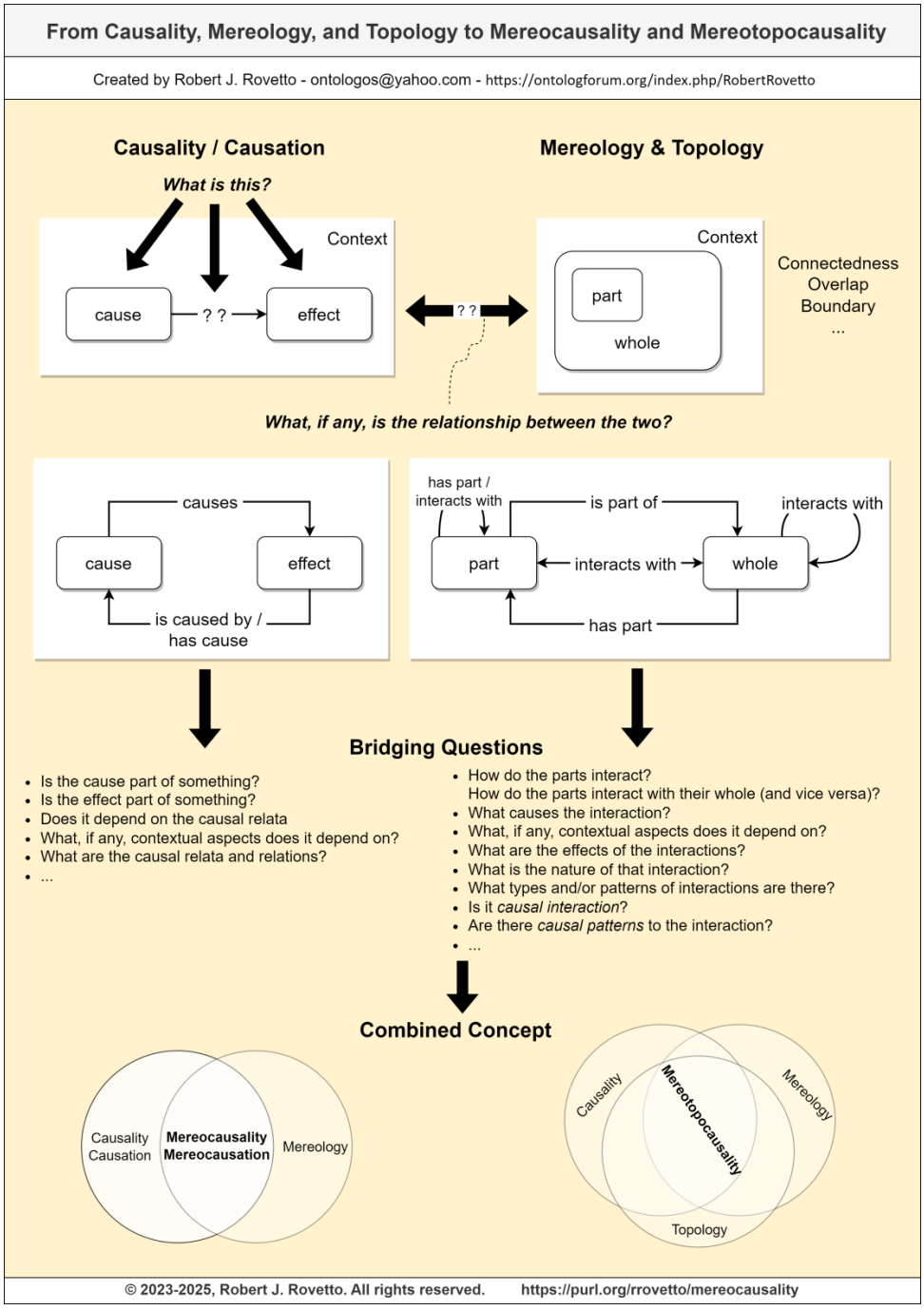

Figure 1. From mereology and causality to mereocausality

Pertinent questions for mereocausality are identified by considering the concept of *causal parts*. Causal parts are those parts (of a whole) that have causal efficacy.

Causal efficacy is here asserted as a primitive concept. If we cast a wide net, taking into account various causal theories, causal parts can be characterized as those parts that stand in causal relations, those that exert causal powers, those that have a causal function, etc.

Non-causal parts, then, are parts that do not have causal efficacy, i.e., they are *causally inert*. If we include in our ontology the category of causal parts, then the transition to that of mereocausality is obvious. If there are both causal parts and non-causal parts, then we can ask: Does the causal efficacy or causal influence vary? If so, then upon what does it differ? Does it vary based on the type of part, or the type of interaction? An example of interaction among parts is from whole to part, namely *downward causation*.

4. Some Questions of Merocausality and Causal Mereology

Questions about the intersection of mereology, topology and causality can be asked from distinct perspectives: metaphysics (philosophical), practical, linguistic, etc. The philosophical perspective is concerned with the nature of the world. Both philosophical and scientific perspectives are concerned with whether it can explain phenomena. The practical (e.g., computational) perspective is concerned, in part, with the potential need and utility of formally asserting computable symbol-structures (e.g., predicates, classes, axioms) for use in or on various information systems. Listed below are some questions of mereocausality, with an occasional rephrasing for clarity.

As suggested earlier, the research questions and their answers may depend on various assumptions (philosophical or otherwise), such as ones stance on nature of causality (i.e., a given account of causality and/or mereology).[5]

- What is the relationship, if any, of causality to mereology, topology (and mereotopology)?
- To the extent that there is a fundamental nature of the world,
    - Does it include distinct forms of causality at distinct scales or granularities?
    - Is there causality at different scales/granularities?

  (The metaphysical/ontological question)
- If there are distinct forms of causality, what is their nature? (The metaphysical/ontological question)
- Is causality different for parts of a whole as compared to one another?

[5] For example, is causality a metaphysical relationship? What is the nature of parthood (to the degree it has a nature)? The latter question can be partially restated from an operational perspective as: how do parts interact, and how do parts and their whole interact? Upon discovering that interaction, some relationships should become clear.

- Does the interaction of part(s) upon the whole exhibit a distinct form of causality as compared with the interaction of the whole upon its part(s)?

  Or: Is causality different for the *part-whole interaction* as opposed to *whole-part interaction*? (Inquiry into downward causation should be helpful.)

- Do mereological and topological *structures* exhibit distinct forms of causality?
- What effect does causality have on parts vis-à-vis their wholes?
- Do parts causally interact in different ways according to their type or kind?
  - *Example*: biological parts exhibiting a distinct form of causality as opposed to abiotic parts.
- If parts and their whole exhibit distinct forms of causality, upon what does that depend, or in virtue of what is that the case?
- Can we identify, discover, or assert generic or universal physical principles of merocausality?
  - Can we do so for a subset of types of parts? Or for certain contexts and disciplines (e.g., in biology, chemistry, physics, etc.)?

Two aspects of causality and parthood are relevant for formulating the questions of Causal Mereology. One is asserting distinct *kinds of parthood* (e.g., functional, material, etc.). The second is the classic question of *causal relata* (assuming a causation relation).

Type-Dependent Mereocausal Relations.

If there are various types of mereocausal relations…

- Do they differ depending on the kind(s) of part and kind of whole?
- Do they differ depending on the type of casual relata?
- Do mereocausal relations vary when considering an external object or part (i.e., external to a given whole) interacting with the given whole (or the parts of the whole)?
  (A question about *context*)

Methodological, Meta-level, Meta-philosophcal and Explanatory questions.

- Does it make sense to ask these questions? (A meta-metaphysics question)
- Are they answerable? If so, in what way?
- Is there a need for making these distinctions?
  (whether in metaphysics or in computational disciplines)
  - Is there a practical need to make these distinctions in disciplines such as data science, KRR, ontology engineering, conceptual (data) modeling, computational linguistics, natural language processing, geographic information science, etc.?
    - What is the computational (or other) utility of asserting computable symbol-structures for forms mereocausal relations?
    - What are concrete applications and examples where the concept of mereocausality is needed or otherwise useful?
- What phenomena can the concept of mereocausality explain?
  - Can it explain natural language (or linguistic) phenomena?

- Can it explain mind-external and mind–independent phenomena?

Theory-dependent Questions.

Lastly, we ask questions in terms of particular causal and mereological accounts. Examples of particular accounts are the Process account of causality, and General Extensional Mereology, respectively.

- Can two (or more) given accounts be combined in meaningful and useful ways?
- Can we assert unique mereocausal relations that vary with the given set of causal and mereological accounts?

The various philosophical and non-philosophical accounts of causality [3] may yield distinct answers to these questions, and distinct formulations to mereocausal and merotopologico-causal structures and relations.

The philosopher will be interested in the preceding questions toward forming metaphysical theories and claims about the world. The practitioner of computational disciplines and interdisciplinary activities such as KRR can, however, ask some of these questions (and give answers) without making metaphysical claims. The latter would attempt to formulate a consistent and coherent computable model without necessarily arguing for the metaphysical actuality of the given mereocausal account. They would more simply provide a set of defined mereocausal symbolic constructs to serve some data function(s).

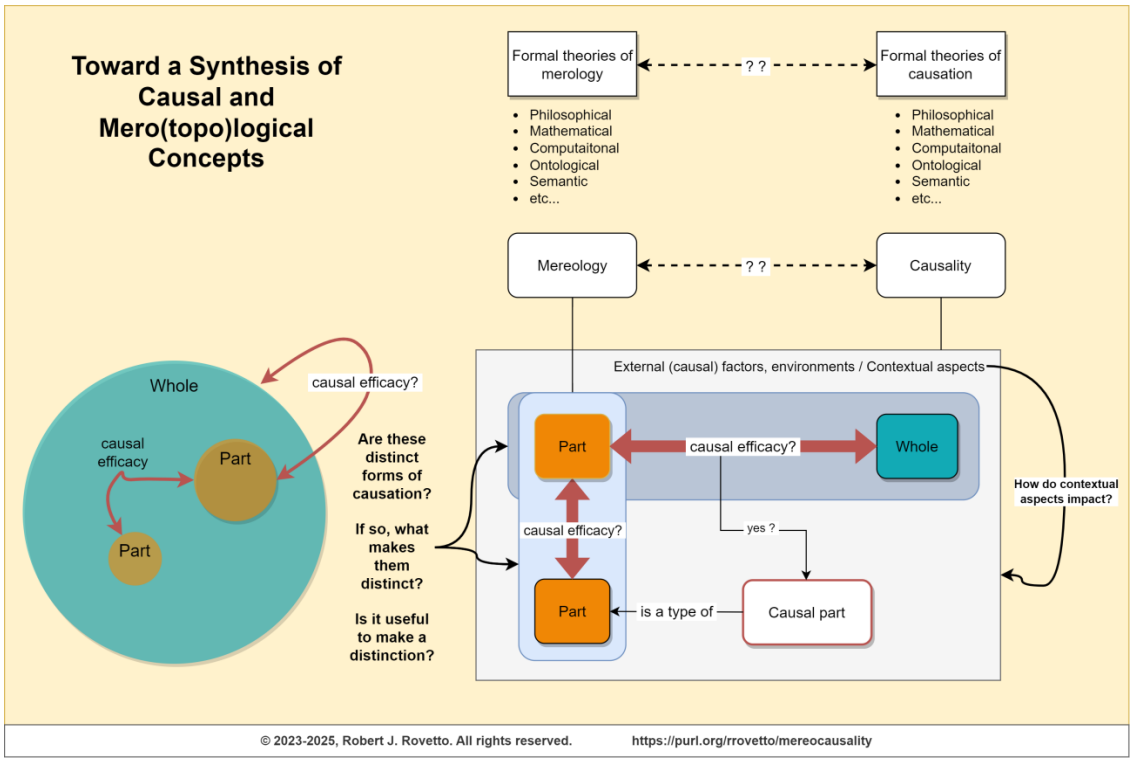

Figure 2. Toward a Synthesis of Causal and Mereo(tomereology and causality to mereocausality

5. Terminology

This section proposes candidate terms and definitions for use in the study of the causal interaction of parts and (their) wholes. These terms would express ideas (a) and/or (b), forming a preliminary vocabulary for mereocausality and Causal Mereology.

- That (a) causality may be different among parts and wholes (or during their interactions), i.e., that there are different forms of causality (the metaphysical question), or
- That (b) we may postulate and formally specify distinct types of causality at various scales or granularities for theoretical and practical purposes.

Causality at various *granularities* is signified by the term 'granular causality', with cognate 'causal granularity'.

Causal mereology, as a branch of inquiry, may be partially expressed by the terms in Table 1. Very briefly, the content may be perceived as tautologies, but that is not necessarily the intent. It is subject to revision in any case. Primitives (undefined terms), have been noted, and unless otherwise stated, undefined terms are assumed to be primitive. Future work anticipates describing terms: 'causal relation'. 'causal structure' and 'causal system'. Future work will also formalize the vocabulary in first-order logic.

Table 1. Candidate Vocabulary of Mereocausality & Causal Mereology

Term	Clarification
causal part	A part that is causally efficacious[6] upon its whole or upon some other part of the whole.
mereocausality	Causality among parts vis-à-vis their whole. Causality among parts and whole.
mereocausation	(If not synonymous with 'mereocausality') One or more causal relations that obtains between parts and/or parts and their respective wholes.
causal mereology	A type of mereology concerned with the causal relationships among part and whole. To the extent that there are causal parts, or to the extent that

[6] *Causally efficacious* (and *causal efficacy*) is primitive in this paper, but can be interpreted as encompassing all candidate causal relations and forms for causality. Depending on the account, a causal part may be described as, say, a part that exerts causal powers.

	asserting such an ontological category is useful, it is the mereology of causal parts. It is the study of part-whole (partonomic) relationships among causal parts, and/or the study of the causal relationships between parts and wholes.
causal mereotopology	A type of mereotopology that studies the causal relationships among connected parts, or the mereotopology of causal parts. It describes the causal connectedness of parts and whole.
mereotopological causality	Causality among parts and wholes which stand in topological relations to one another.
mereotopological causation	One or more causal relations that obtains when parts and whole stand in topological relations to one another.

If we distinguish between causality and causation, we can also describe these concepts as follows. Where causality is the/a *principle* of cause and effect, then mereocausality is the principle of the cause and effect among parts and their wholes. If causation is the *relation* of cause and effect, e.g., causality exemplified as a metaphysical relationship, then mereocausation is the (or a set of) causal relation(s) among parts and wholes.

When distinguishing between relation and relationship, the instance-universal, type-token, and generic-specific distinction can be applied: the metaphysical relationship (generic) with relations (specific instances).

Mereotopological causality is a type of causality exhibited by parts, their wholes and (or in virtue of) their topological relations or properties. Concepts of *causal connectedness*, and corresponding predicates are thereby relevant.

Similarly, *Causal Merotopology* is a type of mereotopology investigating the causal relationships among connected parts, or the mereotopology of causal parts. It would aim to describe the connectedness of causal parts, i.e., causal-connectedness of parts and whole. Causal connection and influence should be explicated also in relation to resultant changes and effect events.

There is another way to construe mereocausality, but it does not seem as coherent: as the parts or parthood of causality. But what are the parts of causality? And what are the parts of a causal relation? Do these questions even makes sense?

If causal parts are parts that are causally efficacious upon other parts and/or the whole of which they compose, we should also ask about *causal wholes*. How does the whole, the unity, causally influence its parts? Is that causation subject to differentiation, i.e., does it admit of distinguishing mereocausal relations?

If there is mereocausality and mereocausation (metaphysical question), or if it is useful to assert mereocausal categories and conceptual modeling constructs (the practical question), then mereocausal relations may have the generic categories of Part and Whole as relata. A more specialized characterization is using categories, such Biological Part, Physical Part, Functional Part, and so on. This can yield a conceptual framework of mereocausal relations by type of causal part relata.

Figure 3 partially summarizes by illustrating the intersection of the combined concepts and fields of study to form that of mereocausality/causation & mereotopocausality.

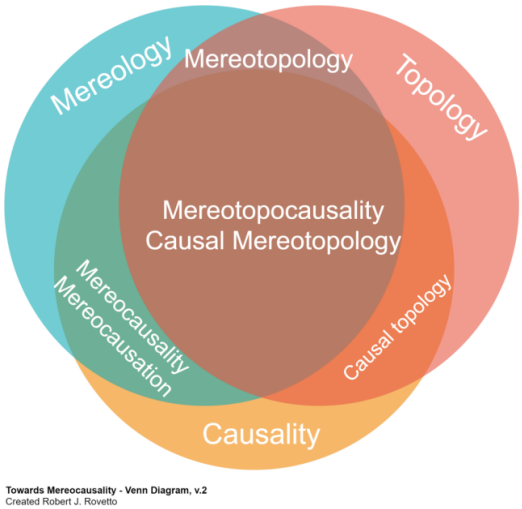

Figure 3: Venn diagram merging concepts toward mereocausality

6. Criticisms

Some criticisms of the new concept and proposed study may take deflationist, eliminativist, or reductionist lines. The questions of mereocausality, for example, may be the questions of causality, simpliciter. If so, then the critic may argue that we do not need the novel concept. Similarly those who subscribe to ontological or conceptual parsimony may consider it unnecessary. So they would ask questions such as: Is the concept redundant? From a metaphysical perspective a philosopher

that subscribes to parsimony may ask, does the world exhibit (in a phenomenological manner, in a mind-independent manner, etc.) mereocausality, a mereocausal structure, or mereocausal phenomena? They may answer in the negative. By contrast, a non-reductionist view would consider mereocausality to be irreducible to either.

7. Relevance & Candidate Use-cases

The relevance of the preceding can be seen from more than perspective. First, it is relevant as an intellectual and academic endeavor to develop novel ideas. In this case, it explores the combination of concepts that have been widely used in various disciplines. This encourages creativity and innovation in concept formation, conceptual analysis, ideation, and the potential identification of solutions to problems in other disciplines.

Second, we see relevance by reflecting on the metaphysical questions: if good reason is found to hold that mereocausality is a distinct form of causality, then it will be a contribution (perhaps a discovery) for philosophy and metaphysics, if not human intellectual activity. Perhaps the combined concepts can help glean insights into observed phenomena in (and at the intersection of) the so-called hard sciences and the soft sciences [6]. The metaphysician is, in any case, interested as it relates to fundamental and broad questions about the world. Linguists and philosophy of language specialists will be interested, in part, with semantic aspects. The lexical and semantic particulars may find utility in natural language processing, as semantic web applications.

Third, we can envision application to symbolic disciplines such as KRR, conceptual (data) modeling, semantic (data) modeling, and formal ontology. For example, statistical (e.g. Judea Pearl) and other models of causality are employed in knowledge representation activities where machine inference is desired. These sorts of models are applied to distinct disciplines and topics such as economics, biology, medicine, risk, etc. It is particularly relevant in more recent times, where so-called AI research and applications have been increasingly adopted.

Just as causal analysis and mereology have had application in KRR, qualitative reasoning, and spatio-temporal reasoning, so can causal mereology. Overlapping with the metaphysician, the formal ontologist will be interested in formulating, identifying or asserting (symbolically represent) invariant or otherwise widely applicable mereocausal features. Lastly, the computer and data science

practitioner will be interested because they can assert various computable symbol-structures (e.g. symbolic n-ary predicates) to represent a finer degree of causal detail for their data or other entities.

Fourth, to my knowledge there has been no such concept as presented here in the relevant communities, which we can argue is a contribution unto itself. Through this communication I have offered ideas toward a preliminary conceptual framework for what may be a new philosophical (e.g., metaphysics) and interdisciplinary topic.

Examples where a conceptual framework of mereocausality can find use-cases are those in which causal histories and knowledge about complex systems are desired. This includes topics in biology and medicine, such as etiopathogenesis. It includes engineered systems with various subsystems and components, as well as systems-of-systems that may consist of entities of various kinds. The impact of mental and psychological phenomena on non-mental is another use-case. For example, how mental states impacts well-being, physical health, physiological states, processes, etc.

Lastly, expected output of this project includes the completion of in-progress works that present practical applications. One example of in-progress work is with qualitative spatial reasoning formalisms such as Allen's Interval Algebra, and the Region Connection Calculus (RCC), forming what I call the Causal RCC. The relationship to modality (in the metaphysical sense, i.e., possibility, necessity, etc.) will also be a novel addition, formulating concepts such as *Modal Causality* and *Modal Mereology*, *Mereomodality*, and *Causal Meromodality*.

8. Closing & Future Work

This paper has introduced a novel concept I call *mereocausality*. It represents a potentially new branch of study and conceptual innovation, *causal mereology* (and *causal mereotopology*). I have sketched an outline of research questions, terminology, and critical considerations for this merger of causal, partonomic and topological concepts. Just as we can assert, if not discover, distinct part-whole (or parthood) relations between distinct kinds of entity, perhaps we assert or identify distinct mereocausal relations.

Future work includes a systematic examination of the broader literature: causality, mereology, mereotopology, formal representations thereof, etc. It will also include further conceptual analysis, terminology refinement and development, more

rigorous definitions, and logic-based formalization. Other topics to support the development of the mereocausal conceptual framework are: Context (contextual or situational factors to a given potential (mereo)causal scenario), dispositions, properties, mechanism, the impact of causality on social phenomena (e.g., groups), and so on.

Through this project I aim to formulate a coherent system describing causality and causal relations that incorporates mereology, topology, and modality. As an unfunded project to date, interested readers are encouraged to contact the author toward work collaborations and formal support to sustain this promising line of research.

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