Functional Parthood: A Dispositional Perspective

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Abstract. Functional parthood is relevant to the modeling of material objects and their complex interrelationships. For instance, it will be valuable for representing various kinds of objects in multi-layered biological reality. In this paper we sketch out a project to develop a dispositional approach to functional parthood based on a dispositional account of functions and a theory of parthood between dispositions.

Keywords. Functional parthood, part-whole relation, mereology, function, disposition

1. Introduction

1.1. General background

The part-whole relation is indispensable for ontology development. There are two major approaches to parthood (despite many other possible lines of inquiry such as Galton's [1]). On the first approach, mereology [2,3] explores a single kind of parthood relation that is standardly taken to be a partial order (reflexive, anti-symmetric, and transitive). Such mereological parthood relation is included in virtually all upper ontologies [4]. In contrast, the second approach [5] studies multiple kinds of part-whole relations that appear in natural language discourse and that are sometimes utilized in domain ontologies. For instance, the part-of relation found in the statement "Each soccer player is part of a soccer team" is a member-of relation. Characteristically, some domain-level relations may be transitive while others are non-transitive. As Keet [4] says, it is an open problem how to articulate upper and domain ontologies with respect to parthood: for example, which kind of parthood relation should be covered in upper ontologies.

This paper focuses on one of the most intensively studied mid- or domain-level relations: functional parthood (aka "component-integral object relation" [6]). Broadly speaking, it is such that, especially when the part and the whole are both so-called ordinary (material) objects (e.g. molecules, tables, and planets), the part plays some sort of "functional role" (in a non-technical sense of the term) in the whole, so that the whole

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can possess "functional integrity" [2]. Functional parthood is typically illustrated with biological objects and (technical) artifacts [7]: e.g. Vieu's [8] example of this cell being a functional part of the heart and Winston et al.'s [6] example of wheels being functional parts of cars.[2]

Functional parthood is intimately connected with fundamental issues about parthood. For instance, there is a debate between monism and pluralism concerning parthood [9]. Monism insists that there is a single privileged kind of parthood, whereas pluralism counters that there are multiple kinds of parthood relations that are equally basic from an ontological viewpoint (see, for details, McDaniel's [9] more precise formulation). In particular, monism agrees (but pluralism disagrees) that various domain-level relations, including functional parthood, can be reduced to mereological parthood and other relations. (We will illustrate later this point with a monist approach to functional parthood.) Although monism may be a prevailing view of parthood, there is nowadays an increasing usage of a pluralistic approach in ontology. Examples of topics investigated along pluralistic lines include part-whole relations relating to physical objects [10,11], locations [12], and a specific language [13,14].

1.2. Purpose and methodology

In this paper we will outline a "dispositional perspective" on functional parthood. This proposal is motivated by further development of biological and biomedical ontologies. Biological reality is so complex that we can observe many other kinds of material entities than typically conceived ones such as cells and organs. To illustrate this point, it has been suggested [15,16] that a fuller representation of the biological domain should require a more refined classification of material entities than the three subtypes of the category of "materiel entity" of the upper ontology Basic Formal Ontology (BFO) [17]: objects (e.g. cells and organs), object aggregates (e.g. a group of bacteria in blood), and fiat object parts (e.g. an upper torso). There is also a growing demand for a granularity-sensitive representation of the life sciences [18] because different kinds of material entities are closely related to different granular levels of reality [19].

The part-whole relation plays a vital role in modeling the correlation between variegated material entities in biomedicine as well as in many other domains. Indeed, (time-indexed) mereological parthood has been extensively utilized in biological and biomedical ontologies [20] in support of data-driven life sciences [21]. However, more fine-grained part-whole relations remain largely unspecified from a foundational perspective, although e.g. Relation Ontology (RO) [20] includes some specific subtypes of the mereological part-whole (or whole-part) relation such as "member of" and "has component". It will be thus worthwhile to consider carefully functional parthood in order to have a more accurate representation of multifarious biological objects.

As for related work, functional parthood tends to be conceptualized and formalized in terms of the notion of (generic) functional dependence: roughly, a functional version of ontological dependence that is based on the primitive *functioning-as* predicate [8,22]. To borrow Vieu's [8, p. 150] explanation: " 'Functioning as a *X*' refers to the fact that, at a given time, the entity is actually displaying a *X* function, the function generally expected for it to be described as a *X*." For instance, this heart "functions as" a heart

[2] Winston et al. [6] originally discuss a part-whole relation between the terms "wheel" and "car". In this paper we treat this example ontologically as a part-whole relation between individuals, i.e. between this particular (steering) wheel and this particular car.

when it is pumping blood through the body. However, the idea of functional dependence may be too weak to capture fully the alleged "functional role" involved in functional parthood.[3] Therefore, it would be more desirable to investigate functional parthood using some more specific view of functions (refer to e.g. Mizoguchi & Borgo [23] for a previous example of this line of research).

In this direction, we will propose a dispositional approach to functional parthood with a focus on its usefulness in biological and biomedical ontologies. In the remainder of this paper, Section 2 presents a dispositional interpretation of functions [24] and a theory of parthood between dispositions [25]. Section 3 sketches out how functional parthood can be considered in terms of "disposition-parthood". Section 4 concludes the paper with a brief discussion and some remarks on future work. As for formalization (in Courier) in first-order predicate logic, we will restrict the domain of discourse to particular entities (e.g. *this* heart). We will also use unary predicates to refer to classes (i.e. without reifying classes) and omit universal quantifiers for the sake of readability.

2. Preliminaries

2.1. A dispositional account of functions

To examine functional parthood *vis-à-vis* the biological domain, we will presuppose an ontology of dispositions [26,27] and stipulate that functions are a subtype of dispositions, as illustrated by Spear et al.'s [24] current BFO account of functions, which we will assume and present briefly below. A disposition is a causal property that inheres in (binary:`INH`) a bearer (e.g. objects) and that is linked (binary:`REL`) to a realization, namely to a specific possible behavior of the bearer of the disposition. To be realized in a process, a disposition needs to be triggered (binary:`TRI`) by some other process. Classical examples include fragility (the disposition to break when pressed with a force) and solubility (the disposition to dissolve when put in a solvent). Characteristically, dispositions may exist even if they are not realized or even triggered: for instance, a glass is fragile even if it never breaks or even if it never undergoes any shock.

A dispositional view of functions would distinguish sharply between a function (as a subtype of disposition) and its functioning (as the realization of the disposition). For instance, the biological function of this heart to pump blood is its disposition that can be realized in a process of blood pumping (in which the heart participates) when the heart receives blood. Such a dispositional view of functions is explicitly advocated by Spear et al. [24]. They submit that functions are dispositions that their bearers come to have either through natural selection (in the case of biological entities) or through intentional design (in the case of artifacts).

Although it has been subject to criticism [28,29], a dispositional theory of functions would fit well with our purpose to consider functional parthood with an emphasis on biological objects. In the first place, many existing accounts of biological functions would seem to "understand that functions are a kind of *dispositional* and *causal* effect" [30, p. 236]. Moreover, a dispositional approach to functions may help to scrutinize closely the functionality of biological objects. For instance, Vogt [18] develops a domain

[3] Vieu [8, p. 154] states: "the notion of function used here is perhaps too general and arguably weak, simply relying on a 'functioning as' primitive predicate, very lightly axiomatized. The real functional role of the part within the whole (…) remains unanalyzed in this proposal."

granularity framework for the life sciences and proposes an additional subtype of "causal unity" that is used in the elucidation of the BFO category of "object". That is: "*Causal unity via bearing a specific function* unifies an entity through the function that the entity bears, with its functional component parts bearing sub-functions" [18, p. 10]. Granted that a disposition is a causal property, this function-related notion of causal unity may be better clarified in terms of a dispositional perspective on functions. Finally, a dispositional theory of functions can have the added advantage of being integrated well into a broader dispositional framework for biomedical ontologies, as illustrated by analysis of pathological dispositions such as diseases and risks [31].

2.2. A theory of disposition-parthood

Barton et al. [25] develop a theory of part-whole relations (binary:DP) between dispositions in terms of mereological parthood (binary:P). They define a "disposition complex" as a disposition that has some proper "disposition part" (binary:DPP) and propose three formal constraints on disposition-parthood. First, the bearer of a disposition part is a (proper or improper) part of the bearer of the disposition complex:

(DP-BER) $[\mathrm{DP}(d_1,d_2) \wedge \mathrm{INH}(d_1,x) \wedge \mathrm{INH}(d_2,y)] \rightarrow \mathrm{P}(x,y)$

Second, if a disposition complex is realized in a process, then at least one of its proper disposition parts is realized in a part of this process:

(DP-REL) $[\exists d_1\ \mathrm{DPP}(d_1,d_2) \wedge \mathrm{REL}(d_2,x)]$
$\rightarrow \exists d_3,y[\mathrm{DPP}(d_3,d_2) \wedge \mathrm{REL}(d_3,y) \wedge \mathrm{P}(y,x)]$

Third and finally, if a disposition complex is triggered, then at least one of its proper disposition parts is triggered:

(DP-TRI) $[\exists d_1\ \mathrm{DPP}(d_1,d_2) \wedge \mathrm{TRI}(d_2,x)]$
$\rightarrow \exists d_3,y[\mathrm{DPP}(d_3,d_2) \wedge \mathrm{TRI}(d_3,y)]$

3. A dispositional perspective on functional parthood

We will consider functional parthood based on a dispositional account of functions and a theory of parthood between dispositions. Here we will adopt a monist approach to functional parthood, partly because it would seem to be a traditional characterization of specific part-whole relations in biomedical ontologies (e.g. RO [20]). In particular, we will espouse the simple view [3,9,32] that functional parthood (binary:FP) between particular objects is defined as the conjunction of mereological parthood (P) between them and some "playing-a-functional-role-in" relation (binary:FR) between them.[4] To put it formally:

[4] For another monist approach, Johansson [33,34] opines that an apparently binary functional parthood relation implicitly assumes a third relatum (refer to Varzi [32] for criticism). In this paper we respect the common understanding of functional parthood as a binary relation. Notably, it would have the added advantage of fitting better with the existing theory of binary parthood relations between dispositions [25].

(D1) $FP(x,y) =_{def.} P(x,y) \wedge FR(x,y)$ [5]

To consider functional parthood dispositionally, let us consider Vieu's [8] cell/heart example of functional parthood. Suppose that this cardiomyocyte (cardiac muscle cell) $\mathbf{c_1}$ is a functional part of this heart $\mathbf{h_1}$. According to our monist approach, **c** is a mereological part of **h** and $\mathbf{c_1}$ also plays a functional role in $\mathbf{h_1}$. Let $\mathbf{Fc_1}$ be the function of $\mathbf{c_1}$ to contract. Let $\mathbf{Fh_1}$ be the function of $\mathbf{h_1}$ to pump blood through the body. Given a dispositional account of functions, $\mathbf{Fc_1}$ and $\mathbf{Fh_1}$ are dispositions. More specifically, the fact that $\mathbf{Fc_1}$ is a dispositional part of $\mathbf{Fh_1}$ is supported by the observation that three formal requirements of disposition-parthood are satisfied with respect to $\mathbf{Fc_1}$ and $\mathbf{Fh_1}$:

> (DP-BER) The bearer (i.e. $\mathbf{c_1}$) of $\mathbf{Fc_1}$ is a (proper) part of the bearer (i.e. $\mathbf{h_1}$) of $\mathbf{Fh_1}$.
> (DP-REL) If $\mathbf{Fh_1}$ is realized in a process (of $\mathbf{h_1}$ pumping blood through the body), then $\mathbf{Fc_1}$ is realized in a part of this process (namely the contracting process of $\mathbf{c_1}$). (See Section 4 for thoughts on parthood between processes.)
> (DP-TRI) If $\mathbf{Fh_1}$ is triggered (by a process of $\mathbf{h_1}$ receiving blood from the lungs), then $\mathbf{Fc_1}$ is triggered (by this process).

Intuitively, the claim that $\mathbf{Fc_1}$ is a dispositional parthood of $\mathbf{Fh_1}$ would be explanatorily relevant to the "functional integrity" [2] or the "causal unity via bearing a specific function" [18] of $\mathbf{h_1}$, since it is a part-whole relation between functions. $\mathbf{c_1}$ plays a functional role in $\mathbf{h_1}$ because $\mathbf{Fc_1}$ is a disposition part of $\mathbf{Fh_1}$. This can be then generalized into the following axiom stating that if a material entity **x** plays a functional role in another material entity **y**, then there is a function (unary:F) of **x** and a function of **y** such that the former is a disposition part of the latter:

(A1) $FR(x,y) \rightarrow \exists z,w(F(z) \wedge F(w) \wedge INH(z,x) \wedge INH(w,y) \wedge DP(z,w))$

We make three remarks on A1. First, one may consider making A1 stronger by replacing the conditional therein by the biconditional ("↔"). However, the legitimacy of such a change would depend on the details of a dispositional account of functions, which is beyond the scope of this paper. Such a change might also require taking classes into consideration, as type-level functions are vital in prior works on functional parthood [8,22] and the identity of particular dispositions is determined by type-level triggers and realizations [27]. Second, from the right hand side of A1 and DP-BER, we can deduce that $P(x,y)$. That is, "playing-a-functional-role-in" (FR) implies mereological parthood (P). In other words, from D1 and A1, we simply get:

$FP(x,y) \leftrightarrow FR(x,y)$.

Said differently, as soon as we adopt A1, there is no difference between "being-a-functional-part" and "playing-a-functional-role-in". Third and finally, as the existential quantifier in A1 shows, our approach is compatible with the claim that a material entity might have several functions: for example, a lamp has both a lighting function and a decorative function. In other words, not all functions of a material object would be relevant for functional parthood presently concerned that is involved in this object.

[5] Vieu [8] rightly maintains that a fuller analysis of functional parthood requires adding time as a third argument to a binary functional parthood relation. We will use a binary FP relation for simplicity and leave its temporalization for future work.

4. Discussion and concluding remarks

We have proposed a dispositional perspective on functional parthood while being motivated by its utilization in the biomedical domain. We will now provide a few important pointers to its future development (besides the temporalization of the binary `FP` relation mentioned in Section 3). First and foremost, further investigation is required into the theory of disposition-parthood that underlies our approach. Barton et al. [25] identify several subtypes of disposition-parthood**,** but their classification is not meant to be exhaustive. A more comprehensive account of disposition-parthood will enable us to give a more meticulous analysis of the "functional role" involved in functional parthood, such as a classification of `FR` relations based on subtypes of the `DP` relation.[6]

In addition, we will need to address a long-standing problem of the transitivity of functional parthood [8,22,32-34,36] (as well as other candidate mereological principles such as "supplementation axioms" [37]). Functional part is transitive in many cases, such as the cuff/sleeve/jacket example [38] and the carburetor/engine/car example [8]. Functional parthood may not be transitive, however.[7] There are at least two directions of research in which we will be able to proceed so as to tackle such a fundamental issue regarding functional parthood. The first line of inquiry is about DP-REL in the theory of disposition-parthood (see Section 2.2). This axiom is deeply rooted in a part-whole relation between processes (recall "`P(y,x)`" therein). This means that close scrutiny of disposition-parthood will necessitate a well-developed account of parthood between processes, which will in turn necessitate a well-established ontology of processes. This task will comprise, for example, dealing with a vexed granularity problem of how to individuate processes, which has been extensively explored in philosophy [39,40] and in formal ontology [41,42].

The second line of inquiry concerns non-functional causal unity of material entities. As we alluded to in Section 2.1, Vogt [18] argues for causal unity via bearing a specific function. This is nonetheless proposed as an addition to the three kinds of causal unity specified in BFO: causal unity via internal physical forces, causal unity via physical covering, and causal unity via engineered assembly of components. It would be plausible to think that these non-functional types of causal unity are closely entwined with non-functional part-whole relations embedded in material entities (see, for details, Masolo et al.'s [43] exploration using mereological parthood). Therefore, a dispositional approach to functional parthood may require closer examination of such non-functional and more fundamental part-whole relations by means of disposition-parthood.

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[6] A positive by-product of a more advanced theory of disposition-parthood would be to solidify the dispositional account of functions (such as Spear et al.'s [24]), given Burek's [35] desideratum that an ontology of functions should support function decomposition by analysis of sub-functions. That is to say, such sub-functions would be some of the disposition parts of the overall function.

[7] For instance, Lyons's [38] handle/door/house example is frequently taken to be a case of the non-transitivity of functional parthood in the relevant literature, but it is nonetheless highly controversial. To take one example, Vieu [8] contends that it would become a case of the transitivity of functional parthood by replacing the word "door" by another term "door handle": "changing 'handle' in 'door handle' contributes to specifying what is the role of the handle with respect to the house, i.e., a component of a door, which is (assumed to be) a component of the house" (p. 149). This observation motivates her to adopt a lexical approach to functional parthood. From an ontological (monist, in particular) perspective, by contrast, it might possibly imply that functional parthood involved in the handle/door/house example may not preserve transitivity given one construal of a functional role, but it may preserve transitivity given another construal. We will leave closer examination of this example for the future.

References

[1] Galton A. Yet another taxonomy of part-whole relations. In: Jansen L, Radicioni DP, Gromann D, editors. Proceedings of the 4th Joint Ontology Workshops (JOWO 2018); 2018 Sep 17-18; Cape Town, South Africa: CEUR Workshop Proceedings, vol. 2205; c2018. p. 1-7.

[2] Simons P. Parts: a study in ontology. Oxford: Clarendon Press; 1987. 390 p.

[3] Casati R, Varzi AC. Parts and places. the structures of spatial representation. Cambridge, MA: MIT Press; 1999. 248 p.

[4] Keet CM. A note on the compatibility of part-whole relations with foundational ontologies. In: Galton A, Neuhaus F, editors. Proceedings of the 3rd Joint Ontology Workshops (JOWO 2017); 2017 Set 21-23; Bozen-Bolzano, Italy: CEUR Workshop Proceedings, vol. 2050; c2017. p. 1-10.

[5] Keet CM, Artale A. Representing and reasoning over a taxonomy of part-whole relations. Appl. Ontol. 2008;3(1-2):91-110.

[6] Winston M, Chaffin R, Herrmann D. A taxonomy of part-whole relations. Cogn Sci. 1987;11(4):417-44.

[7] Borgo S, Franssen M, Garbacz P, Kitamura Y, Mizoguchi R, Vermaas PE. Technical artifact: an integrated perspective. Appl. Ontol. 2014;9(3-4):217-35.

[8] Vieu L. On the transitivity of functional parthood. Appl. Ontol. 2006;1(2):147-55.

[9] McDaniel K. Parts and wholes. Philos. Compass. 2010;5(5):412-25.

[10] Ru Y, Grüninger M. Parts unknown: mereologies for solid physical objects. In: Galton A, Neuhaus F, editors. Proceedings of the 3rd Joint Ontology Workshops (JOWO 2017); 2017 Set 21-23; Bozen-Bolzano, Italy: CEUR Workshop Proceedings, vol. 2050; c2017. p. 1-9.

[11] Ru Y, Grüninger M. More than just one box. In: Barton A, Seppälä S, Porello D, editors. Proceedings of the 4th Joint Ontology Workshops (JOWO 2018); 2019 Sep 23-25; Graz, Austria: CEUR Workshop Proceedings, vol. 2518; c2019. p. 1-10.

[12] Aameri B, Grüninger M. Location ontologies based on mereotopological pluralism. Appl. Ontol. 2020 May;15(2):135-84.

[13] Keet CM, Khumalo L. On the ontology of part-whole relations in Zulu language and culture. In: Borgo S, Hitzler P, Kutz O, editors. Proceedings of the 10th International Conference of Formal Ontology in Information Systems (FOIS 2018); 2018 Sep 17-21; Cape Town, South Africa: Amsterdam: IOS Press; c2018. p. 225-38.

[14] Keet CM, Khumalo L. Parthood and part-whole relations in Zulu language and culture. Appl. Ontol. 2020 Aug;15(3):361-84.

[15] Vogt L, Grobe P, Quast B, Bartolomaeus T. Top-level categories of constitutively organized material entities - suggestions for a formal top-level ontology. PLoS ONE. 2011 Apr;6(4):e18794.

[16] Vogt L, Grobe P, Quast B, Bartolomaeus T. Accommodating ontologies to biological reality - top-level categories of cumulative-constitutively organized material entities. PLoS ONE. 2012 Jan;7(1):e30001.

[17] Arp R, Smith B, Spear AD. Building ontologies with Basic Formal Ontology. MIT Press; 2015. 248 p.

[18] Vogt L. Levels and building blocks - toward a domain granularity framework for the life sciences. J. Biomed. Semant. 2019 Jan;10:4.

[19] Vogt L, Grobe P, Quast B, Bartolomaeus T. Fiat or bona fide boundary - a matter of granular perspective. PLoS ONE. 2012 Dec;7(12):e48603.

[20] Smith B, Ceusters W, Klagges B, Köhler J, Kumar A, Lomax J, Mungall C, Neuhaus F, Rector AL, Rosse C. Relations in biomedical ontologies. Genome Biol. 2005 Apr;6:R46.

[21] Hoehndorf R, Schofield PN, Gkoutos GV. The role of ontologies in biological and biomedical research: a functional perspective. Brief Bioinform. 2015 Nov;16(6):1069-80.

[22] Guizzardi G. The problem of transitivity of part-whole relations in conceptual modeling revisited. In: van Eck, P, Gordijn J, Wieringa R, editors. Proceedings of the 21st International Conference on Advanced Information Systems Engineering (CAiSE'09), 2009 Jun 8-12; Amsterdam, Netherlands: LNCS, vol. 5565, Springer; c2009. p. 94-109.

[23] Mizoguchi R, Borgo S. A preliminary study of functional parts as roles. In: Galton A, Neuhaus F, editors. Proceedings of the 3rd Joint Ontology Workshops (JOWO 2017); 2017 Set 21-23; Bozen-Bolzano, Italy: CEUR Workshop Proceedings, vol. 2050; c2017. p. 1-9.

[24] Spear AD, Ceusters W, Smith B. Functions in Basic Formal Ontology. Appl. Ontol. 2016 Jun;11(2):103-28.

[25] Barton A, Jansen L, Ethier JF. A taxonomy of disposition-parthood. In: Galton A, Neuhaus F, editors. Proceedings of the 3rd Joint Ontology Workshops (JOWO 2017); 2017 Set 21-23; Bozen-Bolzano, Italy: CEUR Workshop Proceedings, vol. 2050; c2017. p. 1-10.

[26] Röhl J, Jansen L. Representing dispositions. J. Biomed. Semant. 2011 Aug;2(Suppl 4):S4.

[27] Barton A, Grenier O, Jansen L, Ethier JF. The identity of dispositions. In: Borgo S, Hitzler P, Kutz O, editors. Proceedings of the 10th International Conference of Formal Ontology in Information Systems (FOIS 2018); 2018 Sep 17-21; Cape Town, South Africa: Amsterdam: IOS Press; c2018. p. 113-26.

[28] Röhl J, Jansen L. Why functions are not special dispositions: an improved classification of realizables for top-level ontologies. J. Biomed. Semant. 2014 Jun;5:27.
[29] Jansen L. Functions, malfunctioning, and negative causation. In: Christian A, Hommen D, Retzlaff N, Schurz G, editors. Philosophy of science. European studies in philosophy of science, vol 9. Cham: Springer; 2018. p. 117-35.
[30] Saborido C. New directions in the philosophy of biology: a new taxonomy of functions. In: Galavotti MC, Dieks D, Gonzalez WJ, Hartmann S, Uebel T, Weber M, editors. New directions in the philosophy of science. Springer International Publishing, Cham; 2014. p. 235-51.
[31] Barton A, Grenier O, Ethier JF. The identity and mereology of pathological dispositions. In: Jaiswal P, Cooper L, Haendel MA, Mungall CJ, editors. Proceedings of the 9th International Conference on Biological Ontology (ICBO 2018); 2018 Aug 7-10; Corvallis, Oregon, U.S.: CEUR Workshop Proceedings, vol. 2285; c2018. p. 1-6.
[32] Varzi AC. A note on the transitivity of parthood. Appl. Ontol. 2006;1(2):141-6.
[33] Johansson I. On the transitivity of the parthood relations. In: Hochberg H, Mulligan K, editors. Relations and predicates. Frankfurt: Ontos Verlag; 2004. p. 161-81.
[34] Johansson I. Formal mereology and ordinary language - reply to Varzi. Appl. Ontol. 2006;1(2):157-61.
[35] Burek R. Ontology of functions: a domain-independent framework for modeling functions [dissertation]. Leipzig University; 2006. 258 p. Available from: http://www.onto-med.de/publications/2007/burek-p-2007-a.pdf
[36] Cruse DA. On the transitivity of the part-whole relation. J. Linguist. 1979 Mar;15(1):29-38.
[37] Cotnoir AJ. Strange parts: the metaphysics of non-classical mereologies. Philos. Compass. 2013 Sep;8(9):834-45.
[38] Lyons J. Semantics: volume I. Cambridge: Cambridge University Press; 1977. 897 p.
[39] Kim J. Events as property exemplifications. In: Brand M, Walton D, editors. Action theory. Dordrecht: Reidel; 1976. p. 159-77.
[40] Davidson D. Essays on actions and events. 2nd ed. Oxford: Clarendon Press; 2001. 324 p.
[41] Smith B. Classifying processes: an essay in applied ontology. Ratio. 2012 Dec;25(4):463-88.
[42] Guarino N, Guizzardi G. Relationships and events: towards a general theory of reification and truthmaking. In: Adorni G, Cagnoni S, Gori M, Maratea M, editors. Proceedings of the 15th International Conference of the Italian Association for Artificial Intelligence on Advances in Artificial Intelligence (AI*IA 2016); 2016 Nov 29-Dec 1; Genova, Italy: LNCS, vol. 10037, Springer; c2016. p. 237-49.
[43] Masolo C, Vieu L, Ferrari R, Borgo S, Porello D. Collectives, composites and pluralities. In: Proceedings of the 11th International Conference of Formal Ontology in Information Systems (FOIS 2020); 2021 Sep 13-16; Bozen-Bolzano, Italy: Amsterdam: IOS Press; c2020. To appear.