BFO and DOLCE: So Far, So Close…

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1. A BIT OF PERSONAL HISTORY

Let me start with a confession: I feel responsible for the fact that Barry Smith is not a philosopher anymore. "I used to be a philosopher," he keeps saying, "now I am an ontologist." On the other hand, somewhat paradoxically, Barry is definitely responsible for the fact that (as some people say) I am not an engineer anymore, being irreversibly contaminated by philosophy.[1]

Everything started almost 30 years ago, in the late 1980s, when I was struggling with the knowledge representation problems of medical expert systems, working in the domain of arrhythmia management. Obviously, one of the first problems I had to face was the proper representation of parthood relations. At that time, knowledge representation systems were already affected by the *belonging fallacy* (Wilensky 1987)—unfortunately still so frequent nowadays—which consists of aggregating together pieces of information (attributes) that may somehow belong to a particular object, without being explicit about the nature of the attribute relationship (Guarino 1992). Yet the importance of an explicit, proper modeling of the parthood relation seemed to me of utmost importance, especially for the medical domain. So, I started reading everything I was able to find on that topic. Fortunately, the lab where I was working at that time, despite being mainly devoted to systems dynamics and biomedical engineering, had a pretty good library covering also cognitive science and artificial intelligence, so I had the opportunity to discover the seminal paper on part-whole relations by Winston, Chaffin, and Herrmann (1987), which was really

illuminating to me. Among the references listed there, an obscure but intriguing title captured my attention:

Parts and Moments: Studies in Logic and Formal Ontology, edited by Barry Smith (1982)

The financial status of CNR at that time was much better than the present miserable situation, so I managed to order that expensive book. When I finally grabbed it, a whole new world opened up to me. The introduction "Pieces of a Theory" by Barry Smith and Kevin Mulligan (1982) was fascinating, although not an easy read for a person with an engineering background. In particular, what grabbed my attention was the passionate defense of

an ontological approach to the problem of the a priori, —an approach which stands in opposition to the logico-linguistic approach, inspired above all by Frege, which has come to be accepted as orthodoxy by Anglo-Saxon philosophers (Smith and Mulligan 1982).

While reading these words, I realized that the very same contrast between the logico-linguistic approach and the ontological approach was manifesting itself in the knowledge representation literature, which in that period was sacrificing expressivity in exchange of computational tractability. Stimulated by such discovery, I started a radical re-visitation of the literature, which ended up some years later in the proposal of a specific *ontological level* for knowledge representation primitives (1994; 2009), contrasted with the *epistemological level* proposed by Brachman (1979).[2]

At the same time, I went on reading "The Formalization of Husserl's Theory of Wholes and Parts," published by Peter Simons in the same collection (1982), and then Simons' book on parts (1987), a milestone in my personal discovery of formal ontology. I guess it was through these readings that I became aware of the Center for the Study of Mitteleuropean Philosophy, led by Roberto Poli. I went to Trento to visit him in 1992, and in the following year we organized together the first International Workshop on Formal Ontology in Conceptual Analysis and Knowledge Representation, held in Padova in March 1993. This was the first interdisciplinary conference on what is now called *applied ontology.* Barry Smith was an invited speaker, and we started cooperating. The following year, Barry invited me to the 1994 Wittgenstein symposium, organized by him (with Roberto Casati and Graham White) on the theme 'Philosophy and the Cognitive Sciences.' I presented there my first ideas on the ontological level, based on an ongoing work with Pierdaniele Giaretta and Massimiliano Carrara (1994). Then I relied a lot on his comments while writing my first journal paper defending "the systematic introduction of formal ontological principles in the current practice of knowledge engineering" (1995). In a few years, by the time of the Buffalo conference on *Applied Ontology* organized by Barry (1998), and the first conference on *Formal Ontology in Information Systems* held in Trento in June of the same year (Guarino 1998), the mutual contamination was consummated.

2. BFO AND DOLCE

After this personal historical note, I would like to comment on some work Barry and I started several years after our mutual contamination, namely around 2001, when each of us was involved in a funded project concerning the development of an upper level ontology: BFO and DOLCE were born more or less at the same time.[3] Since the beginning, we had several occasions to interact and compare our approaches, but the two projects took different directions. After the two ontologies started being adopted worldwide, on several occasions[4] we agreed in principle on the utility and importance of attempting some kind of alignment, but for various reasons the real work never started. Now, as a gift to Barry for this special occasion, I would like to briefly comment in this paper on the main differences and similarities between the two ontologies, suggesting some possible strategies for isolating a common core. At the same time, I will take this opportunity to comment on possible DOLCE extensions, adjustments or revisions whose need emerged in the past, at

least in my view. Indeed, differently from BFO, which underwent two main releases and was maintained more or less as a product, the original DOLCE axiomatization (unfortunately never published in an official academic venue) remained very stable over the years, except for a systematization of its core assumptions done by Borgo and Masolo (2009). Yet, I believe that a comparison with BFO may motivate a re-visitation of some DOLCE choices.

While doing this comparison between the two ontologies, let me clarify immediately that I will not attempt here to enter into the realist/antirealist debate, which in the last years has been at the core of almost all discussions on BFO (Merrill 2010; Smith and Ceusters 2010). I must say that, although contaminated with philosophy, I still have the soul of a pragmatic engineer, so I evaluate ontological choices on the basis of their actual utility, independently of any deep metaphysical doctrine. To me, ontologies are useful not only for the integration of scientific data, but more in general for the integration of software systems and databases. To this purpose, the specific role of ontologies is to make explicit people's assumptions about the domain of interest of software applications, independently of the metaphysical nature of such assumptions, and even independently of their scientific accuracy. In this perspective, the main utility criterion I adopt is based on language, namely on the degree an ontological distinction reflects a distinction in the way people talk of a particular domain. That's why DOLCE takes a descriptive approach towards language, avoiding any deep metaphysical commitment. That said, I am convinced that many of the choices made by BFO may be useful under the DOLCE perspective, and vice versa.

2.1 Objects

While analyzing the basic notion of object, BFO and DOLCE took different directions from the beginning. Although both ontologies agree that objects are "endurants with unity," DOLCE puts a lot of attention in characterizing the differences and the relationships between physical objects and amounts of matter, without investigating the notion of unity in detail, mainly because different subtypes of objects may have different unity criteria. BFO, on the contrary, adopts a common notion of causal unification and maximal self-connection for all objects, and develops on this basis a sophisticated theory of fiat parts, outer boundaries and sites. Letting aside a radical difference concerning DOLCE's multiplicative approach to deal with the relationship between objects and amounts of matter,[5] this is certainly an area where some integration may be achieved, in the sense that some BFO

axioms and definitions may be somehow incorporated in DOLCE, and efforts may be joined to further develop some useful notions which are still weakly characterized, such as the notion of a site.[6] A lot of literature exists already on places, boundaries and topological unity, while in my opinion further unity criteria concerning morphological, functional, and social wholes might be considered. Also, a further analysis of the notion of causal unification defined in terms of relative movement might be particularly useful for the ontology of mechanical assemblies, possibly in connection with the notion of degrees of freedom.[7]

2.2   Qualities, roles, and dispositions

The treatment of individual qualities is probably one of DOLCE's most original contributions. The idea of distinguishing the intension of a term like *the color of this rose* from its actual extension, which may change at different times, was firm in my mind from my early work on knowledge representation (Guarino 1991). The problem we faced with DOLCE was to reconcile this intuition with the notion of trope, which is similar but not identical: a standard example of a trope is *the particular color of this rose,* or, in Barry Smith's words, "the particular case of redness of a particular fly eye." This means that tropes are classically understood as *super-determinate* particularized properties. Under this view, if *the color of this rose* denotes a trope, then the only way to account for a change in color is to admit a mechanism of trope replacement. But if a particular color is replaced by another particular color, then sure, we can say that the rose has genuinely changed, but we cannot say that its *color* has genuinely changed! So, we decided to deal with this problem by postulating the existence of *individual qualities* as dependent particulars that abstract away from classic tropes, being able to genuinely change while "moving" within a quality space. Several years later, I discovered that Friederike Moltmann (2007; 2013) made a very similar choice while challenging the standard trope theory by taking inspiration from Fine's powerful idea of *variable embodiment,* and treating trope-referring terms like the color of this rose or the temperature of this room as variable tropes, i.e., variable embodiments of standard tropes. In a recent paper with Giancarlo Guizzardi (2016), I revisited the DOLCE approach to qualities in the light of these ideas, proposing a general approach to reification and truthmaking according to which qualities are *weak truth-makers* (Parsons 1999) of descriptive properties: it is the color of the rose, because of the way it contingently is, that makes it true that the rose has a certain color.

In the recent years, BFO has adopted a position[7] concerning qualities which is very similar to DOLCE's: in BFO, the color of a rose is a dependent continuant that uniquely inheres in the rose, and remains identical to itself throughout the rose's life, while possibly instantiating different *determinate universals* (like being a red color or a brown color) at different times. On the other hand, DOLCE *reifies* such determinate universals, associating each of them to a region, which belongs to a *quality space* that is characteristic of each quality kind. In this way we have two advantages: we are able to talk of quality "values" (what we called *qualia*) since they are in the domain of discourse, and we can describe the structure of quality spaces. For instance, we can say that the red region, in the space of colors, is opposite to the green region and close to the brown region. Stefano Borgo and Claudio Masolo (2009) have described this approach in detail. In conclusion, the ontology of qualities is another interesting area where efforts might be joined. I mention here some open problems, which in my opinion may be addressed independently of the philosophical positions of the two groups, whose solution may contribute to strengthen the applied ontology field.

Local qualities. When we describe extended entities, like a vase or a river, we refer to their qualities in different ways. A river has (more or less) a definite length, but its width varies with the distance from the source, typically getting higher towards the end. Similarly, a vase has a definite height, but its width may vary. So, at least for certain entities, quality kinds such as length, height and width don't behave in the same way: length or height just inhere to these objects with no need of further qualification, while width requires a spatial localization in order to be determined. In my view, length and height, in these examples, behave as *global qualities,* while width behaves as a *local quality.* A local quality of a certain object is a quality which actually inheres to a *part* of that object, but, despite this fact, is somehow considered (I would say, from the cognitive point of view) as a quality of the whole object: so, we rarely say "the width of this river stretch is 100 meters," but we prefer to say "the river's width is 100 meters *here.*" Analogously, we say "the depth of the Adriatic Sea is much higher along the Croatian coast than along the Italian coast," referring to "the sea's depth" as one single entity, although, so to speak, spread out in space. Indeed, in many simple cases, we describe the *qualitative shape* of a certain object in terms of the behavior of a local spatial quality along a certain dimension.

Of course, the distinction between global and local qualities is very general, and goes much beyond purely spatial qualities. Consider for instance the mass or volume of a physical object vs. its density or its temperature, or the duration of a rain vs. its intensity. In all these cases, we observe different ways qualities of things behave with respect to the parts of such things. The problem at hand, therefore, is the *mereological behavior of qualities.* Looking at the philosophical literature, the phenomenon we have described appears to be connected to a more general one, concerning the mereological behavior of properties. A classic distinction in this respect is that between homoeomerous and anomoeomerous properties, based on whether or not a property holding for a whole also holds for all its parts, and discussed in particular by Armstrong (1978). Ingvar Johansson (1989) built on this work in the light of the distinction between determinates and determinables, focusing his attention to the case of determinate properties belonging to the same determinable, and to the ontological nature of patterns like a distribution of colored areas on a surface (Johansson 1998). This was, at least in my knowledge, one of the few works addressing in some detail the mereological behavior of qualities, and not just that of generic properties. I have elaborated on these ideas in a workshop paper (2013b), but much more should be done in this area, which looks very relevant for many practical applications.

Relational and quasi-relational qualities. In BFO, relational qualities are qualities that have a plurality of independent continuants as their bearers. A classic example is a marriage bond. In the BFO 2.0 specification, a relational quality is defined as a quality that inheres in two different individuals. This violates a very plausible and important principle concerning inherence, present in DOLCE, which says that if x inheres in y and x inheres in z, then $y=z$. This the so-called *non migration principle,* which says that inherence is functional: a quality only inheres in a single thing. A possibility to avoid this problem is to assume that a relational quality inheres in a mereological sum of continuants, instead of inhering separately in both of them. However, I believe that we can get rid of relational qualities so defined, and rather adopt a general ontological theory of relationships based on ordinary qualities and what I will call—following Moltmann— *quasi-relational qualities.*[8] A quasi-relational quality is a quality that, besides inhering in a single individual, is also specifically dependent on a different individual. For example, the commitment towards a partner, in a marriage bond,

can be seen as a quasi-relational quality that inheres in a partner and depends on the other one.

To accommodate this view, we need to give up an axiom—built into DOLCE—saying that a quality inheres in an individual throughout its life. Clearly this doesn't hold for quasi-relational qualities, since a commitment towards a person comes into being only after somebody becomes at least acquainted with that person, and may last only for a short time. Once we add quasi-relational qualities to ordinary (non-relational) qualities, we have in our hands a powerful tool to account for the nature of (some) relationships, which may be seen just as mereological sums of qualities. This is the view developed in my recent work with Giancarlo Guizzardi (2015; 2016). In this view, a marriage relationship is seen as a mereological sum of quasi-relational qualities (the mutual commitments), while a comparative relationship, such as the height relationship between a father and his son, is just a sum of ordinary qualities: the two heights. Note that, despite the fact that the two *relations* involved in these examples (say, *married-with* and *taller-than*) have a different nature, still it is important for both of them to have a clear ontological account for their instances, namely the corresponding *relationships.*[9] A practical advantage of seeing relationships as sums of qualities is that we can talk of them, describing for instance their behavior in time or their causal interactions with the world. Note that this picture only works for certain kinds of relations, namely those that Guizzardi and I called *descriptive relations,* which hold in virtue of some qualities of their relata. Non-descriptive relations, such as the *formal relations* of inherence, dependence or parthood, just hold between their relata as such, without the need for qualities.

In conclusion, coming back to BFO, I don't think there is a need to introduce relational qualities inhering in a plurality of bearers: their respective (ordinary or quasi-relational) qualities will do.

Qualities and dispositions. Within specifically dependent continuants, BFO makes a sharp distinction between qualities and realizable entities. The former "are fully exhibited or manifested or realized" within the entity they inhere in. The latter, in contrast, "can inhere without being realized," and "are exhibited only through certain characteristic processes of realization." In turn, a process of realization is defined in the present BFO 2.0 specification (Smith 2016) as a process which has as participant the bearer of a realizable entity, so that it seems to me there is a circularity which should somehow be fixed.

Anyway, within realizable entities, BFO distinguishes between roles and dispositions. I will postpone the discussion on roles, focusing here on the distinction between qualities and dispositions, which I must say I find very confusing. My point is that there is a reasonably clear difference between dispositional and non-dispositional (so-called categorical) *properties*, but this difference is not reflected, at the ontological level, in a distinction among specifically dependent continuants of different kinds.[10] In other words, the truth-maker of the property *being fragile* seems to be the same as the truth-maker of the property *having a certain crystalline structure*. This means that there is a certain quality inhering in an object—its crystalline structure—that is responsible for a certain conditional behavior. The connection between a particular kind of crystalline structure and the corresponding conditional behavior is given by a law of nature, whose ontological presuppositions do not require the existence of other specifically dependent continuants besides the crystalline structure itself. Of course, it may be important, for scientific reasons, to be able to *represent* such laws of nature, but this is not a good reason to introduce an ad hoc ontological category. After all, the very fact that the same material basis may be responsible of many different dispositions, and the difficulty of distinguishing one disposition from another (Arp et al. 2016) is a good evidence of their problematic ontological status.

Another reason for not postulating a further kind of specifically dependent continuants besides qualities is that many—if not all—ordinary qualities may be described as dispositions: *colors* are an obvious case, but also an individual *mass* can be understood as a disposition to maintain a body's velocity, a *size* as a disposition to pass through holes, a *happiness* as a disposition to interact with people in a certain way, and so on. Finally, a further reason for being suspicious about dispositions conceived as a genuine ontological category is bound to the notion of realization. The possibility to participate to certain "characteristic processes" is allegedly reserved only to dispositions, but I would say that all ordinary qualities do participate to characteristic processes, where they manifest themselves in various ways. For example, a body's temperature may manifest itself in a heating process, and a body's shape may manifest itself in a deformation process.

In conclusion, I believe that it is enough, for our purposes, to admit qualities of different degrees of complexity: there are simple qualities like mass or length, more complex qualities like color or taste, and very complex qualities like fragility. Complex qualities are specifically dependent on simpler

qualities. Each of these qualities can be described in a dispositional or non-dispositional way.

Roles. Given the semi-personal nature of this essay, let me say that I have been always obsessed by roles. One of my earliest papers in knowledge representation is entitled "What's in a role?" (1990), and yet I confess that I don't have a fully satisfactory answer to this question, although I have certainly learned a lot since then. I have been always fascinated by the subtle aspects of this notion, and by its ubiquitous relevance for practical applications. Yet, differently from dispositions, roles haven't been much considered in the analytic ontology literature, while of course they have been studied by linguistics and sociology, and play a prominent role (allow me the pun) in applied ontology.

It is not a surprise therefore to see roles appearing in BFO, but their characterization as realizable specifically-dependent continuants reflects a very peculiar understanding of the role notion which, although useful, would require a broader framework. Let me first clarify some terminological issues. In the past (2009; 2000), I have always used the term 'role' to refer to anti-rigid externally-dependent properties. However, I acknowledge it makes sense to reserve this term to particulars, so I agree with the distinction between roles and role-related defined classes *(role properties)* adopted in BFO (Arp et al. 2016). Of course, we have to clarify what kind of particulars we are talking of. In this respect, a useful analysis of different kinds of roles has been proposed by Frank Loebe (2007), who distinguishes among three role types: *relational roles, processual roles, and social roles*. Now, I think that BFO roles may be adequate to represent relational roles, but fall short of accounting for processual roles and social roles. Let me informally discuss the three cases, presenting a view which is slightly different from that discussed by Loebe, and is still largely work in progress.

Relational roles are those aspects of an entity that are *actually involved* in a relationship. In a love relationship between John and Mary, John's love towards Mary is the role he *has*. Describing his role in the relationship means describing his love (which may change in time). Such love inheres in John and is externally dependent on Mary, so it is an externally dependent continuant, that is, a BFO role. The *actual* role of a doctor in a treatment relationship with a patient is again a (complex) externally dependent continuant, including his *actual* competencies, commitment, and so on. According to the discussion above, the treatment relationship itself is the mereological sum of the doctor's (relational) role and the patient's (relational) role. Note that 'externally dependent

continuant' is just a synonym of what I have called 'quasi-relational quality' in the above discussion on relationships.

Processual roles are defined by Loebe as 'slices' of processes with respect to the dimension of participants. Using his example, when John moves his pen, he and the pen are the participants to that process, and the processual role John *has* in the process captures what John does in that participation ("Thinking of a mime who moves an imaginary pen should be a good illustration of the notion of a processual role.") Clearly, processual roles are not externally dependent continuants, so they do not fall under the category of BFO roles. Yet, a great practical relevance have the various *kinds* of processual roles (not mentioned by Loebe), which in my opinion correspond exactly to what in linguistics are called *thematic roles:* ways of participation in a process (or an event). Classic examples are *agent, patient, instrument,* and so on. A continuant is the agent of a process (that is, it has the *agent* role-property) if and only if its participation in that process (i.e., its processual role) is of the kind *agent*.

Finally, *social roles*[11] differ in my opinion from the previous cases since they are conventional behaviors (so, behavior *kinds*) reflecting social expectations or intentional goals. The etymology of 'role' is illuminating in this respect: the term comes from the French *rôle*, which in turn comes from the old French *rolle,* used to denote the roll (of paper) on which an actor's part was written. So, we can assume that behind each social role there is an (implicit or explicit) *role description* stating certain behavioral rules. Having a social role means being *expected* or being *wanted* to comply to such rules. The distinction between wanted and expected behaviors marks a radical difference between social roles, which I have discussed in some detail in a paper (2013a) on functional roles and replaceability in the light of Anscombe's (and Searle's) notion of *direction of fit* (Anscombe 1957). To put it shortly, there is a difference between the *customer* role and the *employee* role: the former's behavior is expected, while the latter's is wanted. A striking consequence of this difference is that you can replace an employee, but you can't replace a customer (you can get another customer, or change your customer, but—at least in the ordinary way of speaking—you don't replace customers). A further linguistic evidence is that only for *wanted* roles[12] we can properly say that they are *played*: it makes perfect sense to play the employee role, but it is a bit strange to play the customer role or the friend role. This is the reason why previously I emphasized the fact that things do not *play* relational or processual roles, but they just *have* those roles.

Going back to BFO roles, it is clear that, being specifically-dependent externally-grounded continuants (that is, quasi-relational qualities), they are very similar to the relational roles I have discussed above. The difference is that they are assumed as being realizable entities, while this notion of realizability is not present (or at least not necessary) for relational roles, and seems to be somehow related to social roles, which presuppose the realization of an expected or wanted behavior. However, social roles, in the way I defined them, cannot *inhere* in continuants, simply because they are not particulars, but universals (behavior kinds). Of course, having a social role implies having a number of quasi-relational qualities (such as commitments, claims, duties, and expectations) but these are not social roles in the ordinary sense: they are rather relational roles, whose manifestations (the *actual* behavior) may or not be in agreement with the *expected* or *wanted* behavior. In conclusion, it seems that BFO can only account for a notion that is *related* to the ordinary notion of social role, namely the *actual* attitude/commitment/disposition to exhibit a social behavior, but is not a social role in the ordinary sense.[13] Indeed, only for social roles, but not for the other roles, it makes sense (and is relevant) to express the distance between an *actual* relational behaviour and the expected or wanted behavior characteristic of a given social role. This distance is usually expressed by a *compliance* relationship.

2.3 SNAP and SPAN

While concluding this essay,[14] which has given me a nice opportunity to better understand Barry's philosophical positions and practical motivations, I cannot avoid mentioning one of the aspects of BFO that mostly puzzles me: the choice to consider objects and processes as alternative ways of describing reality, and not as complementary aspects of the same reality. Fortunately, it seems to me that this choice is more a concern of theå old philosopher than a preoccupation of the present applied ontologist, and has almost disappeared now: while participation was presented as a "trans-ontological relation" by Grenon and Smith (2004), in the present BFO 2.0 specification it appears as an ordinary relation. Indeed, without seeing objects and processes as parts of the same ontology, it would have been difficult to define realizable entities in terms of realized processes of certain kind.

A further, subtler evidence of the unavoidable entanglement of objects and processes lies in the choice (in practice, the need) to distinguish among multiple processes occurring in the same space-time. In deciding about SNAP and SPAN,

Barry Smith drew on an intuition of Zemach that "a spatio-temporal world can be cut in several *radically* different ways" (Zemach 1970). However, as clarified in the BFO 2.0 specification, "where events, for Zemach, are identified with the entire contents of some given spatiotemporal region, BFO allows that the same spatiotemporal region may be occupied by multiple different processes (as for example your *running* process and your simultaneous process of *getting warmer*)" (Smith 2016, p. 16). But how would these different processes be isolated from the global process occurring in that spatiotemporal region? The boundaries of a spatiotemporal region are very reasonable individuation criteria for 'global' processes, but if we want a more fine-grained granularity we need to adopt suitable criteria to distinguish a running process from a warming process. A natural way to do this is to consider processes as *manifestations of qualities* inhering in continuants: for example, a warming process is a manifestation of a temperature quality inhering in a particular continuant. So, being able to isolate a warming process from a global process occurring in a spatiotemporal region requires being able to *focus* (Guarino and Guizzardi 2016) on such specific quality and continuant. But this requires an ontology that admits continuants and occurrents as parts of the same reality.

I think that this idea of processes as manifestation of qualities (or, vice-versa, as qualities as the focus of processes) is something that can hopefully inspire, together with the other suggestions I made in this paper, for the various foundational ontologies (such as DOLCE, BFO, GFO, and UFO) that are more or less based on the Aristotelian square and on Lowe's four-category ontology. I am convinced that Barry and I can agree on a common core, and I really hope we can mutually understand the different reasons for extending such core in different directions.

NOTES

1   Despite this, I am still a proud engineer, especially since I am more interested in finding solutions than finding problems (supposedly the key difference between philosophers and engineers). That's why, while being enormously grateful to philosophy for helping me to understand problems, I tend to be very agnostic towards deep metaphysical positions, picking up in a very eclectic way just what I need to find solutions that work enough.

2   In retrospect, the position I defended then was very much similar to the one advocated by Barry with his criticism of "fantology" (Smith 2005).

3   The first version of BFO was published in the DOLCE deliverable (Masolo, Borgo, Gangemi, Guarino, and Oltramari 2003).

4   Most notably, in a workshop on applied ontology organized by Jonathan Lowe in May 2013, shortly before his early departure.

5   Amounts of matter seem to be absent in BFO. There is a notion of 'object aggregate' (say, a collection of bricks), but—as far as I understand—if this collection of bricks forms a house, the relationship between the house and the collection of bricks (which would be a constitution relation in DOLCE), is not analysed in BFO.

6   The BFO 2.0 specification (Smith 2016) defines a site as "a three-dimensional immaterial entity that is (partially or wholly) bounded by a material entity or it is a three-dimensional immaterial part thereof." I wonder whether all immaterial entities included within the convex hull of a material object but not being part of it would count as sites. For instance, is the space between your neck and your shoulder a site?

7   This position is clearly documented in the BFO V2.0 specification. Previously it was less clear, and on several occasions I had the feeling that BFO qualities were super-determinate tropes. For instance, "the particular case of redness of a particular fly eye" example is taken from a lecture on "Towards a Standard Upper Level Ontology" given by Barry Smith in September 2011. In any case, I am glad for the convergence now.

8   In the past, I have often used the term *relational qualities* to denote what I now call *quasi-relational qualities*.

9   So I disagree with the view adopted by BFO that comparative relationships are not entities in their own right (Arp, Smith, and Spear 2016).

10 As far as I understand, this is the position held by Mumford in his book on dispositions (1998).

11 I refer here to social roles in the strict sense, not in the very general sense discussed in (Masolo et al. 2004).

12 It seems to me that all *wanted* roles are *functional* roles, but I will not touch this aspect here.

13 I must add however that even this interpretation of BFO roles is problematic, since their definition prescribes that a role "is not such that, if it ceases to exist, then the physical make-up of the bearer is thereby changed" (Smith 2016, p. 57). I think that, especially for social roles, the corresponding attitudes/commitments/dispositions are not independent from the physical make-up of their bearer. For instance, the commitment to realize a student role of course requires some changes in the brain's "make-up" of its bearer. I would say that, in general, *active* role-properties *(being the lover of Mary)* presuppose some (non-essential) change in the physical make-up of their role bearers, while this is not required for passive roles *(being loved by John)*.

14 I am thankful to Giancarlo Guizzardi for his useful comments on a previous draft of this paper.

REFERENCES

Anscombe, G. E. M. (1957). *Intention*. Cambridge: Harvard University Press.

Armstrong, D. M. (1978). *Universals and scientific realism, volume 2: A theory of universals*. Cambridge University Press.

Arp, R., Smith, B., and Spear, A. (2016). *Building ontologies with basic formal ontology*. Cambridge, MA: MIT Press.

Borgo, S., and Masolo, C. (2009). *Foundational choices in DOLCE*. In: S. Staab, S. Staab, and R. Studer (Eds.) *Handbook on ontologies*. Berlin: Springer Verlag, pp. 361–381.

Brachman, R. J. (1979). On the epistemological status of semantic networks. In: N. V. Findler (Ed.), *Associative networks: Representation and use of knowledge by computers*. New York: Academic Press, pp. 1–48.

Grenon, P. and Smith, B. (2004). SNAP and SPAN: Towards dynamic spatial ontology. *Spatial Cognition and Computation,* 4(1): 69–103.

Guarino, N. (1990). *What's in a role: Towards an ontological foundation for terminological logics*. Padova: LADSEB-CNR Int. Rep. 06/90

Guarino, N. (1991). A concise presentation of ITL. *Lecture Notes in Computer Science* Vol. 567. Berlin/Heidelberg: Springer-Verlag, pp. 141–160. http://doi.org/10.1007/bfb0013526

Guarino, N. (1992). Concepts, attributes and arbitrary relations. *Data & Knowledge Engineering*, 8(3): 249–261. http://doi.org/10.1016/0169-023X(92)90025-7

Guarino, N. (1994). The ontological level. In: R. Casati, B. Smith, and G. White (Eds.), *Philosophy and the cognitive sciences*. Vienna: Hölder-Pichler-Tempsky, pp. 443–456.

Guarino, N. (1995). Formal ontology, conceptual analysis and knowledge representation. *International Journal of Human and Computer Studies*, 43(5/6): 625–640.

Guarino, N. (1998). Formal ontology in information systems. In: N. Guarino (Ed.) *Formal ontology in information systems*. Amsterdam/Washington DC: IOS Press, pp. 3–15.

Guarino, N. (2009). The Ontological level: Revisiting 30 years of knowledge representation. In: A. T. Borgida, V. K. Chaudhiri, P. Giorgini, and E. S. Yu (Eds) *Conceptual modeling: Foundations and applications: Essays in honor of John Mylopoulos*. Berlin: Springer Verlag, pp. 52–67.

Guarino, N. (2013a). Artefactual systems, missing components and replaceability. In: M. Franssen, P. Kroes, T. Reydon, and P. E. Vermaas (Eds.) *Artefact kinds: Ontology and the human-made world*. Heidelberg: Springer, pp. 191–206. http://doi.org/10.1007/978-3-319-00801-1_11

Guarino, N. (2013b). Local qualities, quality fields, and quality patterns: A preliminary investigation. In: O. Kutz, M. Bhatt, S. Borgo, and P. Santos (Eds.) *The shape of things: Proceedings of the second interdisciplinary workshop on the shape of things*. CEUR Workshop Proceedings, pp. 75–81. ISSN 1613-0073.

Guarino, N., and Guizzardi, G. (2015). We need to discuss the relationship: Revisiting relationships as modeling constructs. In: J. Zdravkovic, M. Kirikova, and P. Johannesson (Eds.) *Proceedings of the Advanced Information Systems Engineering 27th International Conference, CAiSE 2015: Lecture Notes in Computer Science* Vol. 9097. Heidelberg: Springer, pp. 279–294. http://doi.org/10.1007/978-3-319-19069-3_18

Guarino, N., and Guizzardi, G. (2016). Relationships and events: towards a general theory of reification and truthmaking. In: G. Adorni, S. Cagnoni, S. Gori, and M. Maratea (Eds.) *Proceedings of the AI*IA 2016 Advances in Artificial Intelligence XVth International Conference of the Italian Association for Artificial Intelligence: Lecture Notes in Computer Science* Vol. 10037. Heidelberg: Springer, pp. 237–249. http://doi.org/10.1007/978-3-319-49130-1_18

Guarino, N., Oberle, D., and Staab, S. (2009). What is an ontology? In: S. Staab and R. Studer (Eds.), *Handbook of ontologies*. Berlin/Heidelberg: Springer, pp. 1–17. http://doi.org/10.1007/978-3-540-92673-3

Guarino, N., and Welty, C. (2000). A formal ontology of properties. In: R. Dieng and O. Corby (Eds.) *Knowledge engineering and knowledge management: Methods, models and tools. 12th International Conference, EKAW 2000*. Berlin: Springer Verlag, pp. 897–112.

Johansson, I. (1989). *Ontological investigations: An inquiry into the categories of nature, man and society*. London: Routledge.

Johansson, I. (1998). Pattern as an ontological category. In: N. Guarino (Ed.) *Formal ontology in information systems*. Amsterdam: IOS Press, pp. 86–94.

Loebe, F. (2007). Abstract vs. social roles: Towards a general theoretical account of roles. *Applied Ontology* 2(2): 127–158.

Masolo, C., Borgo, S., Gangemi, A., Guarino, N., and Oltramari, A. (2003). *WonderWeb: Ontology infrastructure for the semantic web,* European Community IST Project 2001-33052 (The DOLCE Ontology). Deliverable D18.

Masolo, C., Vieu, L., Bottazzi, E., Catenacci, C., and Ferrario, R. (2004). In: D. Dubuois, C. Welty, and M. Williams (Eds.) *Principles of knowledge representation and reasoning: Proceedings of the 9th international conference KR 2004*. Menlo Park: AAAI Press, pp. 267–277.

Merrill, G. H. (2010). Ontological realism: Methodology or misdirection? *Applied Ontology* 5(2): 79–108. http://doi.org/10.3233/AO-2010-0076

Moltmann, F. (2007). Events, tropes, and truthmaking. *Philosophical Studies: An International Journal for Philosophy in the Analytic Tradition* 134(3): 363–403. http://doi.org/10.2307/40208723?ref=no-x-route:697f249ae0122ba49bb626df847ad10c

Moltmann, F. (2013). *Abstract objects and the semantics of natural language*. Oxford: Oxford University Press. http://doi.org/10.1093/acprof:oso/9780199608744.001.0001

Mumford, S. (1998). *Dispositions*. Oxford: Oxford University Press.

Parsons, J. (1999). There is no "truthmaker" argument against nominalism. *Australasian Journal of Philosophy* 77(3): 325–334. http://doi.org/10.1080/00048409912349081

Simons, P. M. (1982). The formalization of Husserl's theory of wholes and parts. In: B. Smith (Ed.) *Parts and moments: Studies in logic and formal ontology*. München: Philosophia Verlag, pp. 113–159.

Simons, P. M. (1987). *Parts: A study in ontology*. Oxford: Clarendon Press.

Smith, B. (1998). Applied ontology: a new discipline is born. *Philosophy Today*, 12(29): 5–6.

Smith, B. (2005). Against fantology. In: M. E. Reicher and J. C. Marek (Eds.) *Experience and analysis: Proceedings of the 27th Wittgenstein symposium*. Vienna: ÖBV and HPT, pp. 153–170.

Smith, B. (2016). *Basic formal ontology 2.0: Specification and user's guide*. https://github.com/BFO-ontology/BFO/raw/master/docs/bfo2-reference/BFO2-Reference.pdf

Smith, B. (Ed.). (1982). *Parts and moments: Studies in logic and formal ontology*. München: Philosophia Verlag.

Smith, B. and Ceusters, W. (2010). Ontological realism: A methodology for coordinated evolution of scientific ontologies. *Applied Ontology*, 5(3-4): 139–188. http://doi.org/10.3233/AO-2010-0079

Smith, B., and Mulligan, K. (1982). Pieces of a theory. In: B. Smith (Ed.), *Parts and moments: Studies in logic and formal ontology*. München: Philosophia Verlag, pp. 15–109.

Wilensky, R. (1987). *Some problems and proposals for knowledge representation, Technical report No. AD-A172 989*. Berkeley: University of California, Berkeley.

Winston, M. E., Chaffin, R., and Herrmann, D. (1987). A taxonomy of part-whole relations. *Cognitive Science* 11(4): 417–444. http://doi.org/10.1207/s15516709cog1104_2

Zemach, E. M. (1970). Four ontologies. In: *Mass terms: Some philosophical problems*. Dordrecht: Springer Netherlands, pp. 63–80. http://doi.org/10.1007/978-1-4020-4110-5_6