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Event Categories on the Semantic Web and Their Relationship/Object Distinction

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Abstract Events are a recurring topic in ontological modeling and the diversity of their encoding in the semantic web ontological language OWL is immense. We provide a lightweight comparative survey of approaches to event modeling in both foundational and semantic web ontologies, and build upon it a tentative system of four categories of what is commonly called 'event'. A substantial part of the categorization has to do with the distinction between an object and an relationship, as conceived in the lightweight ontological background modeling language PURO.

Keywords. events, semantic web, ontologies, conceptual modeling

1. Introduction

The notion of *event* has repeatedly received attention in philosophical ontology, and, consequently, also in formal ontological research within computer science, since dealing with temporal notions is nearly inevitable in any larger ontology. However, the community of "ontologists" developing models for the semantic web has recently grown extremely fast and its contours are fuzzy, the only unifying feature being the reliance on OWL [1] as modeling language. It thus cannot be reasonably expected that each ontology creator would absorb comprehensive literature on foundational ontologies, never mind philosophical ontology, prior to starting his/her design effort. More likely, s/he would tend to reuse, or at least take inspiration from, existing event models that are popular in semantic web circles, whether such popularity stems from their reference in other ontologies/vocabularies, their use in linked datasets, or just the fact that they are massively advertised via mailing lists or other channels. There is thus significant risk of uninformed decisions being taken that would, e.g., inadequately reduce the scope of what "event" can be, or mix it with inherently different notions.

Generally, the problem is that of heterogeneity occurring at two levels: first at the semantic level (the subjects of modeling themselves differ) and then at the syntactic level (even for the same kind of subject modeled, different language constructs and their combinations can be used). The PURO approach to *ontological background modeling* [2] has recently been proposed to alleviate the latter problem in connection with OWL ontology design and reuse. It attempts to map different syntactical patterns on a unique structure of the "world" behind them where possible; this allows, among other, to test the “conceptual coherence” of individual OWL models or compare the “local coverage” of multiple models of the same domain [3]. The problems tackled so far have however been mainly static and the notion of “event” or temporality in general has been missing.

This paper has a threefold objective: first, to investigate how eventive notions are encoded via popular OWL ontologies and vocabularies, second, to distill a lightweight bottom-up categorization of sub-notions of event that could serve as part of checklist in further design of relevant models, and third, to map the categories to one of the two main dichotomies in PURO, that of objects vs. relationships.

2. General Approaches to the Concept of Event

2.1. Philosophical Approaches

Events have become a topic of high interest in the philosophical debates in the last few decades, and their important ontological status soon became obvious.

Casati and Varzi list some facts that indicate that our language and thought contain some sort of “ontological commitment” to events:

> Pre-linguistic infants appear to be able to discriminate and “count” events, and the content of adult perception [...] endorses the discrimination and recognition as events of some aspects of the perceived scene.
> Humans [...] appear to form the intention to plan and execute actions, and to bring about changes in the world.
> Dedicated linguistic devices [...] are tuned to events and event structures, as opposed to entities and structures of other sorts.
> Thinking about the temporal and causal aspects of the world seems to require parsing those aspects in terms of events and their descriptions. [4]

If we contrast events with *objects* we can take note of some distinctions that are more or less commonplace in the philosophical literature. While objects are said to *exist*, events are usually said to *happen* or *take place*. Objects are taken as *continuants*, i.e. they persist through time as wholes, while events are taken as *occurrents*, this meaning that they have “temporal parts” and therefore are not wholly present at every moment (this dichotomy is incorporated into several foundational ontologies, see below). This distinction is however controversial, as there are philosophers who take objects as four-dimensional entities. This assumption in effect diminishes the distinction between objects and events; in this interpretation they both have spatial as well as temporal parts.

Besides the distinction between events and objects, there is also the question of their relations, especially of *dependence*. Events usually cannot exist without objects, but objects also cannot exist without events. There have been conceptualizations granting primary role to objects and others granting it to events. They can also be given an equal ontological status, but with one of them taken as primary *in the order of thought* [4]. It has been however argued by Strawson that a *pure event-based ontology* would not suffice as our “re-identifying practices” imply a stable frame of reference, which needs objects [5, p. 31]. While we can re-identify the same object reapearing in different situations in different times, we cannot re-identify events in the same way, because two events occurring in different times are never a single event, even if all their other aspects are identical. However, Davidson maintains that there is a symmetry in conceptual dependence between substances (i.e. objects) and their changes (i.e. events) [6, p. 175]. Not only re-identification but also other conceptual characteristics of objects require events, but also events conceptually require the existence of objects as their participants.

These conceptions emphasize the differences between events and objects, but they also presuppose that they have some important features in common: both events and objects are situated in space and time, they are individuals (*particulars*), can be counted, referred to, and quantified over. If events are particular temporal "entities", they should be distinguished from *a*-temporal *facts*. If we talk about concrete temporal events, we can also talk about their corresponding facts. For example, the event of Caesar's death that took place in Rome in 44 BC has a corresponding fact *that* Caesar died in Rome in 44 BC (facts expressed in English are usually syntactically distinguished by the "*that*-clause"). In Wittgenstein's *Tractatus Logico-Philosophicus* [7] a *fact* is the existence (or non-existence) of a *state of affairs*. A fact can be positive, reflecting the existence of a state of affairs, or negative, reflecting non-existence of a state of affairs (2.06). A state of affairs is a combination (connection, configuration) of objects, things (2.01). It has a *structure*, which is the way the objects are connected in it (2.032).

Wittgenstein's conception also roughly corresponds to theories that use similarly the term *situation*. These claim that although "[t]here is no consensus about what situations are, just as there is no consensus about what possible worlds or events are," it is still proposed to understand situations as "structured entities consisting of relations and individuals standing in those relations." [8] Situations have also often been discussed in connection with J. Barwise's work on situations in direct perception reports. [9] Other related theories follow the considerations of *situation semantics* and develop a general theory of information content with the key notion of *states of affairs* (see *ibid.*).

From all the notions we have considered so far in this section, facts, states of affairs and situations are concepts standing very close to each other; in fact so close that we can use them interchangeably. Now, states of affairs (or situations) and events seem to be two different kinds of "things": events *happen*, while states of affair *exist*, although in a somewhat different sense that objects do. They are not "substances" (as substances are things, objects, while states of affairs are just configurations of these). Wittgenstein's approach to states of affairs seems to be a-temporal. However, if we interpret the objects which enter into the states of affairs as the kind of objects we daily encounter, it is obvious that the states of affairs, as configurations, *start and cease to exist*, therefore they are temporal just like events are.

Another approach to events can be found in Davidson's analysis of "action sentences", i.e. sentences about *somebody doing something*. The analysis aims at establishing the *logical form* (expressible in predicate logic) of this type of sentences. In an essay entitled *The Logical Form of Action Sentences*, Davidson analyzes this sentence:

(1) Jones buttered the toast in the bathroom with a knife at midnight. [6, p. 107]

The first take on establishing the logical form of such a sentence would be to treat "buttered" as a five-place predicate and the sentence as this predicate with its places filled with Jones, toast, bathroom, knife and midnight. Yet, if we take another sentence:

(2) Jones buttered the toast,

then we would analyze it in the same manner as a sentence containing a two-place predicate "buttered". But the two sentences have obviously the predicate element in common and this analysis fails to take in into account as the two predicates (five-place "buttered" and two-place "buttered") are distinct. According to Davidson, our usual talk about actions suggests there are such *things* as actions, which can be described in various ways while retaining their identity; it is the same "buttering" even if we describe in one case as in (1) and in another case as in (2). Roughly, these considerations lead Davidson to treat actions (and more generally events) as entities, of which a lot of things can be predicated, and to give the corresponding predicates an "event-place" in the analysis (see [6, p. 118]). Consequently, Davidson sees good reasons to treat actions and events as particulars: we quantify over them "in much of our ordinary talk" [6, p. 166]. This conception is based on Quine's famous slogan "to be is to be the value of a variable", which connects the existence (of particulars) with the possibility to quantify over them [10].

2.2. Events in Foundational Ontologies

Foundational ontologies often incorporate the already mentioned distinctions between *continuants* and *occurrents*. In this approach, *events* can be said to be either identical with *occurrents* or their subclass. We briefly show how events are modeled in three selected foundational ontologies.

KR Ontology The Knowledge Representation Ontology by J. F. Sowa [11][1] has twelve central categories based on three basic distinctions.[2] The most interesting for us is that of *continuants* on the one hand and *occurrents* on the other. It is obvious that events belong to occurrents. But there are still other distinctions that can be applied to occurrents. We can tell that events are *physical*, because that means in the KR Ontology: "An entity that has a location in space-time". That leaves us with three basic categories under which can be subsumed what we call events: process, participation and situation; these categories are in turn *independent*, *relative* and *mediating*. The terms are briefly explained as follows: "An independent entity need not have any relationship to anything else, a relative entity must have some relationship to something else, and a mediating entity creates a relationship between two other entities". These categories are themselves subjects to further distinctions: process, for example, has several further types including event in sense of a discrete (as opposed to continuous) change. Yet, the event category does not necessarily include everything we call events in all contexts. One of the reasons may be that process is defined as an *independent* physical occurrent, but the independence of events can be questioned.

DOLCE The Descriptive Ontology for Linguistic and Cognitive Engineering)[3] uses a basic distinction between *endurants* and *perdurants*, which actually correspond to continuants and occurrents.[4] There are various kinds of perdurants in DOLCE, distinguished by notions of *homeomericity* and *cumulativity* [12, p. 17]. Again, event here appears as a subclass of perdurants. A comparison with the KR Ontology might be interesting: there was event along with state subsumed under (discrete) process. In DOLCE there is event standing against stative; but process is defined as a kind of stative (along with state). Similarly as in KR, events are considered subclass of occurrents (perdurants).

[1] `http://www.jfsowa.com/ontology/`

[2] `http://www.jfsowa.com/ontology/toplevel.htm`

[3] `http://www.loa.istc.cnr.it/old/DOLCE.html`

[4] Endurants and perdurants are, along with *qualities*, "spatio-temporal particulars" in DOLCE. Similarly to the KR Ontology, DOLCE also includes abstract particulars besides spatio-temporal ones.

UFO-B It is an event-modeling extension of UFO, Unified Foundational Ontology [13]. UFO works with the already familiar distinction between enduring and perduring entities but here the perduring entities are explicitly called *events*. This means that the notion of event is somewhat more general here than in KR and DOLCE. Examples of events (i.e. perdurants) given are fairly intuitive: "a conversation, a football game, a symphony execution, a birthday party, or a particular business process" [13].

3. PURO: Bridging Between Ontological Modeling and Encoding

The design and usage of "ontological" artifacts nowadays follows two different (yet internally heterogeneous) paradigms, characterized by Kuhn [14] as *modeling* vs. *encoding*. The former primarily deals with constraining human and machine interpretation of vocabularies, and benefits from maximal expressiveness of the underlying language. In contrast, the latter aims to support automated reasoning (or other kinds of bulk manipulation with data) and thus sets limits to the expressiveness allowed. Although OWL is a language featuring a rich variety of primitives, the decidability concerns informed this inventory (never mind that of its specific "profiles") in a way that is often inconvenient for modeling purposes. First, the repertory does not include such ubiquitous ontological notions as role, event or partonomy. Second, even its basic "triad" of constructs – individual, class (i.e. type) and property (i.e. relationship) – is constrained in the sense that types of types (meta-types) or relationships with arity higher than 2 cannot be directly expressed and require the use of specific patterns/conventions. The PURO ontological language [2] has been designed so as to allow modeling free of the latter category of limitations, while preserving the "minimal viable" repertory basically identical with the OWL triad. Thanks to that, transformation from PURO patterns to different *encoding styles*[5] in OWL can be captured by a relatively small set of transformation patterns and (semi-)automatically executed [15]. PURO is not primarily meant for use by reasoning applications[6] but rather as a tool allowing the ontological engineers to either create new background models, from which alternative foreground models (for different use-cases) in OWL can be generated, or to analyze or compare the content and modeling style of existing OWL ontologies (through PURO meta-properties by which the OWL models can be annotated, quite analogously to using, e.g., OntoClean [17] meta-properties).

The PURO acronym reflects the two basic distinctions: *Particular* vs. *Universal* and *Relationship* vs. *Object*. There is also a third possibility added to the relationship/object distinction – *valuation*, which is an assignment of a quantitative value. The combination of these distinctions determines the six basic PURO terms:[7]

- $\mathscr{B}$-object (particular object),
- $\mathscr{B}$-type ("universal object", i.e. type of objects/types),
- $\mathscr{B}$-relationship (particular relationship),
- $\mathscr{B}$-relation (type of relationships),
- $\mathscr{B}$-valuation (particular assertion of quantitative value), and
- $\mathscr{B}$-attribute (type of valuations).

[5] In earlier papers we used the term "modeling styles"; however, the term "encoding" is more appropriate.
[6] Although its (partial) direct translation to higher-order description logic is also under study [16].
[7] The "$\mathscr{B}$" stands for "background".

A PURO OBM is composed of instances of these six primitives and of the relationships *subTypeOf* and *instanceOf*. The modeling is "by example": while the OBM also contains universals, they are glued with (real-world, artificial, or just placeholder) particulars. PURO allows for higher-order $\mathscr{B}$-types and, as it is not limited by the data model of RDF, $\mathscr{B}$-relationship do not have their arity limited to two and their arguments can be even $\mathscr{B}$-types, $\mathscr{B}$-relationships or $\mathscr{B}$-valuations. Consequently, relationships requiring "reification" in OWL can be expressed directly in PURO. Similarly, the "classes as property values" problem [18] not only disappears[8] as a $\mathscr{B}$-type can naturally participate in a $\mathscr{B}$-relation, but PURO also allows to model, at background level, inherently different motivations of making a class a property value, as shown in [19]. Obviously, PURO also overarches minor syntactic varieties arising in OWL models, such as the use of data properties instead of object properties for linking to notions (e.g., countries) represented with string codes rather than IRI identifiers (which is common, e.g., in markup vocabularies). Due to space limitations we do not include examples of concrete PURO models here; the reader can consult the previously published papers ([3,2,19] or other).

One reason for introducing PURO in this paper as a preliminary is the correlation of its R-O dichotomy with the even categorization later introduced in Section 6. Another is the potential role of PURO as intermediate representation for "downgrading" models expressed in more principled modeling languages to their pragmatic OWL encoding, which could correspond to the vocabularies described in 4.

There is also another important more general work whose authors discuss concepts of relation and event in ontologies [20]. Their main concern (related to our work) is whether a relation could be understood as a kind of event. This is exactly the opposite question than the one that concern us here.

4. Events in Popular OWL Ontologies

In this section we survey selected semantic web ontologies that are designed for modeling events. Our starting point and main source of these ontologies is the *Linked Open Vocabularies* (LOV) portal, especially its event section.[9] We start with ontologies utilizing a very general notion of event, of which the *Event ontology* seems to be most prominent. Subsequently we will look at ontologies[10] built on top of the general Event Ontology and specializing its notion of event for specific domains and purposes. This will allow us to see what "kinds of events" we can encounter on the semantic web.

4.1. The Event Ontology

This ontology[11] was developed in the Centre for Digital Music in Queen Mary, University of London. Its core notion is that of *reified* event. Events are seen as "the way by which cognitive agents classify arbitrary time/space regions".[12] They are characterized by dedicated properties place, time, factor, agent and product, and may be composed of

[8]This effect can be achieved in OWL itself by allowing OWL Full or syntactically via so-called punning.
[9]`http://lov.okfn.org/dataset/lov/vocabs?tag=Events`
[10]They have been retrieved using the LOV's SPARQL endpoint.
[11]`http://purl.org/NET/c4dm/event.owl#`
[12]`http://motools.sourceforge.net/event/event.html`

sub-events. While the Event Ontology does not have subclasses for specific event types, these (as well as subproperties of the mentioned properties) are defined in ontologies that reuse the Event Ontology.

As mentioned, *events* are understood as *reifications*, thus not assumed to be "true" entities *in the background*; they are just "arbitrary time/space regions", merely classified as events by some cognitive agents. This seems to partially undermine the natural language meaning of "event" as term, since even if we approved its subordination to the term "time/space region", we would hardly see it as "arbitrary".

An important feature of events is the temporal dimension.[13] A (*particular*) event has to happen in time. In the range of event:time is time:TemporalEntity, which could be either an instant or an interval.

There are other ontologies for describing events that have a similar structure as the *Event Ontology* in the sense that there is a central "event" class and several properties for linking its instances to the event's "constituents". Next we survey some of these ontologies, particularly with respect to their difference from the Event ontology and also the way they model time.

4.2. Alternative Ontologies/Patterns of Events

SEM (The Simple Event Model Ontology) [22][14] has "core" classes and corresponding properties that allow us to model the basic facts in a similar fashion as in the Event Ontology. These basic classes are: Event, Actor, Place and Time. It has also means to express different points of view concerning an event.[15] Furthermore, there are classes of types of the entities from the "core" classes and properties with these classes in their range. Types of events, for example, are therefore modeled as instances of class EventType, while in the ontologies specializing the *Event Ontology* they are modeled as subclasses of the main class entitled Event (thus using a different "modeling style", in PURO terms).

SEM also has its own way of modeling the time aspect of events. It includes seven time stamp data properties such as hasTimeStamp and hasBeginTimeStamp.

LODE (Linking Open Descriptions of Events) LODE [16] is explicitly focused on describing *historical* events and "mapping between other event-related vocabularies and ontologies". It only defines one class, which is called, unsurprisingly, Event. There are properties for defining the usual aspects of events (place, time, involved agents and objects) and an interesting property illustrate for linking things ("typically media objects") to events which they illustrate. The Event class is in the ontology's documentation defined as follows: "An event consists of some temporal and spatial boundaries subjectively imposed on the flux of reality or imagination, that we wish to treat as an entity for the purposes of making statements about it." This definition reminds us of that one used in the description of the Event Ontology. "Boundaries" of events are "subjective" (at least this time not "arbitrary"), while what is "objective" is arguably just some spatio-temporal "flux" lacking all boundaries.

Similarly to the Event Ontology, time is specified using time:TemporalEntity, which is in this case in range of lode:atTime.

[13] About capturing temporal dimension of linked data see [21].
[14] `http://semanticweb.cs.vu.nl/2009/11/sem/`
[15] See examples in the SEM documentation for this rather complex matter.
[16] `http://linkedevents.org/ontology/`

Time-Indexed Situation Design Pattern This pattern[17] from the respected ODP library has basically the same structure as the mentioned ontologies. It is an extension of the more general *Situation pattern*;[18] the properties atTime and forEntity have a common super-property in the Situation pattern (isSettingFor), and so have, analogously, their inverse properties. Therefore, more specific properties can be added to distinguish between various kinds of things for which the situation "is setting" (similarly to things like agents, products etc. in the Event Ontology).

Time is specified using the *Time Interval* pattern[19] with class TimeInterval and its two data properties: hasIntervalStartDate and hasIntervalEndDate.

Time-indexed situation and *Event Ontology* have the same basic structure in the foreground; while there is formally a difference in their central notions (*event* vs. *situation*), these notions are actually very similar and therefore both could be used to represent more-or-less the same "real-world" facts. The differences of the two notions may be too subtle for the semantic web world; however, using the terms interchangeably or jointly without specifying their difference may cause some confusion.

Schema.org This vocabulary, primarily intended for web page markup, also has a class called *Event*.[20] In this case it however seems more specific compared than the previous cases: it is defined as "an event happening at a certain time and location, such as a concert, lecture, or festival." *schema.org*'s notion of event is thus not (primarily) intended to model events in the broad sense: being focused on concerts, lectures, festivals etc. it contains specific properties that are useful for describing such events (such as attendee, doorTime etc). There are also several more specific types of events defined, for example BusinessEvent, LiteraryEvent, SportsEvent etc.

For specifying time, (datatype) properties doorTime, duration, startDate and endDate with conjunction with date/time in ISO 8601 format can be used.

DBpedia Ontology It "is generated from the manually created specifications in the DBpedia Mappings Wiki",[21] which means that it can change in dependence on what data are extracted from Wikipedia and added to DBpedia. The conditions of its origin are therefore different from the other ontologies mentioned. It is however important for our survey as it is used to represent large amounts of data on the semantic web. The ontology contains, like the others, a class called Event.[22] There are several notable properties connected with it: datatype properties with Event in their domain, such as participant, numberOfPeopleAttending or startDate, and also properties with Event in both domain and range: followingEvent, nextEvent and previousEvent. DBpedia ontology contains a taxonomy of events that was missing in the aforementioned ontologies (except for schema.org). There are four subclasses at the top level:[23] Competition, LifeCycleEvent, NaturalEvent and SocietalEvent. Most of the hierarchy falls under SportsEvent, which is one of the subclasses of SocietalEvent. This reflects the fact that the hierarchy is boot-

[17] http://www.ontologydesignpatterns.org/cp/owl/timeindexedsituation.owl
[18] http://www.ontologydesignpatterns.org/cp/owl/situation.owl
[19] http://www.ontologydesignpatterns.org/cp/owl/timeinterval.owl
[20] http://schema.org/Event
[21] http://dbpedia.org/ontology/
[22] http://dbpedia.org/ontology/Event
[23] For the whole hierararchy, see http://mappings.dbpedia.org/server/ontology/classes/#Event

strapped from particular Wikipedia articles converted to DBpedia and does not follow any thorough considerations on all thinkable types of events.

The ontology includes datatype properties for specifying date and/or time, e.g. startDate, endDate and duration.

4.3. Ontologies Reusing the Event Ontology

The Event Ontology has more than thirty "incoming links" documented in LOV.[24] Most of them are from vocabularies that "specialize" it.[25] These can give us an idea of what "kinds of events" can be ranged under the *Event* class from the *Event Ontology*.

Audio Features Ontology contains a small event taxonomy for representing structural segments of audio signals (music or speech). They are organized into two main groups: Point and Segment (points are instantaneous, while segments last for an interval of time), including, for example, KeyChange (point) and Laugh (segment).

The Bibliographic Ontology contains several subclasses of Event: Conference, Hearing, Interview, Performance, PersonalCommunication and Workshop, and a subproperty of product named presents (with Document in its range).

BIO vocabulary contains a rich classification of personal events, both "group" and "individual" ones, for example Marriage, Divorce, Birth, Death (with other subclasses including Murder), Graduation etc., and several properties with Event in their range and/or domain.

British Library Terms schema contains a class PublicationEvent (along with PublicationStartEvent and PublicationEndEvent). Note that these are candidates for being reified relationships, since the importance of the "publishing" as event in time and space is in most cases negligible compared to the legal etc. consequences of the relationship between the publisher and the work.[26]

In the Music Ontology [23] there are Event subclasses: Activity, Arrangement, Composition, Festival, Performance, Recording, Show and others.

BBC Sport Ontology has a class Competition as another example of subclass of event:Event. "Competition" here means "a competitive sporting event".

These examples demonstrate that clearly different kinds of things are called *events*; and not just called – by consequence of using the Event Ontology they are subsumed under a common class. They include structural components of temporal entities like audio recordings (point, segment), social events organized by people (conference, workshop, festival, performance, sporting competition etc.), are *actions* in the sense that "somebody did something" (like marriage[27], publication, composition, broadcast, identification etc.) and also events in the sense that "something happened" (e.g. birth, death, occurrence).

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[24] see `http://lov.okfn.org/dataset/lov/vocabs/event`

[25] voaf:specializes; that "[i]ndicates that the subject vocabulary defines some subclasses or subproperties of the object vocabulary, or local restrictions on those" (`http://lov.okfn.org/vocommons/voaf/v2.3/#specializes`).

[26] See `http://tomhanzal.github.io/owl-modeling-styles/`.

[27] In a different sense, marriage can also be a social event.

5. Lessons Learned

The surveyed OWL ontologies for modeling events generally share the basic structure, although they differ in certain details: same things are modeled using different "modeling styles". What is always central is the class of *events* whose instances have time properties and are connected to other entities – place, agents etc. – using dedicated properties. In some cases there are additions to this basic model, for example modeling of different views (SEM). At first sight, this structure seems to copy the structure of Davidson's analysis of action sentences, i.e. it speaks about events as entities which can be quantified over and about which many different things can be said. But the views of at least some of the authors of the discussed ontologies concerning the ontological status of events differ from Davidson's: they do not count events as "real" entities, like physical objects, along with *space* and *time*. Therefore, while the foreground model of, e.g., the Event Ontology is practically the same as would be a semantic web ontology for events based on Davidson's account of events, the ontological considerations *on the background* are quite different. The question now is: does it matter? Are these "background" ontological considerations relevant for modeling on the semantic web, or, on the contrary, is it so that we can say, along with Quine, "Save the structure and you save all" [24, p. 8]?

We have already argued that for example the Time-indexed situation pattern can be used to model the same facts as the Event Ontology because it has the same structure and (more-or-less) equivalent means for expressing the relevant relations. The difference is that we talk about *situations* instead of events but we effectively *refer to the same entities*. It is not a problem as long as we do not need to distinguish between events and situations (and we have seen that many philosophical conceptions do not use or need this distinction). But if we deny "substantiality" to events and talk about "reified" events, like the authors of the Event Ontology, we effectively approximate events to *reified relationships*. That could even mean that we believe that events are actually *relationships* between things, places and times, that they are reified in the OWL ontologies in the same way as any n-ary relations, and that the class event:Event is just a class of a special kind of reified relations. This is actually no problem for modeling, as long as the arity of these relations remains indeterminate (otherwise we would encounter the very same difficulties Davidson wanted to eliminate with his analysis).

So, what does it *mean* to call something on the semantic web for example an event:Event? Since there are no OWL restrictions in the Event Ontology related to this matter, we can only rest upon the textual definition of event quoted previously: "...an arbitrary classification of a space/time region, by a cognitive agent. An event may have actively participating agents, passive factors, products, and a location in space/time." None of the things an event "may have" is explicitly made obligatory but we can infer that it *must* have location in space and time (at least implicitly) because it is, according to the definition, a "space/time region". The definition implies that the "place" of events is not in ontology (in the philosophical sense) but in epistemology. But it goes even further: it says that the classification of something (to be exact: some "space/time region") as an event is *arbitrary*. It depends, of course, on how we understand the notion of "arbitrariness". If we understand is as "it *could* be just as well some other way", like if we say, for example, that dogs could be called "cats" instead, then that classification of something as an event would arbitrary. However, then the classification of "space/time regions" (or anything else) as *objects* might not be less arbitrary; calling *this* a house is arbitrary because we could just as well classify *it* as an aggregate of "parts of wall", a roof etc.

The reason for undertaking this scrutiny is that, as we have seen above, a lot of ontologies specialize the Event Ontology by defining subclasses of event:Event. One issue of this approach is that it is unlikely that the authors of all these ontologies would agree that performances, births, publication etc. are "arbitrarily classified space/time regions"; in many cases they might prefer to understand events (such as that somebody died, somebody took a walk etc.) as more ontologically, rather than just epistemologically, grounded. A second issue is that the classes of different "things" dispersed in different models and merely subsumed under a common class of "events" creates a relatively flat hierarchy, which would be difficult to make sense of as whole. The solution would be to create another level between the class of all events and these more particular classes. There are of course such hierarchies under *occurrents* or *perdurants* in the foundational ontologies; however, as mentioned in the introduction, we probably also need a concise model using easily comprehensible terms.

6. Empirical Categorization of Events and Its Reflection for PURO

Based on the preceding survey and discussion, our tentative classification of kinds of events into four categories is as follows:

C1 - Actions. They assume an explicit or implict deliberate agent performing them.

C2 - Happenings. They cover the situations when "something happened" without being initiated by a deliberate agent.

C3 - Planned "social" events. Besides being planned, they typically put emphasis on the spatio-temporal frame rather than on concrete participants.

C4 - Structural components of temporal entities. This, possible less salient, type is inspired by the Audio Features Ontology (see above) which has a common creator with the Event Ontology. These events are "more arbitrary" than those falling under other categories and can be viewed as "regions", however, as merely temporal (and not spatio-temporal) ones.

Let us recall once more that the classification is not drawn from *a priori* metaphysical distinctions but springs from our literature survey carried out with special focus on the semantic web community. Consequently it does not have ambitions to feed back into principled philosophical considerations but rather to help pave the way to sound engineering solutions (possibly based on PURO), deviating as little as possible from the foundational distinctions while being comprehensible to the larger audience of users/developers of the semantic web.

Whether we want to design PURO OBM for events from scratch or from existing ontologies, we need to revisit the previous scrutiny of the notion of "event". A fundamental question is whether events in general should be globally treated as either $\mathscr{B}$-objects or $\mathscr{B}$-relationships. Alternatively, it might be more adequate to distinguish between multiple "kinds of events" (e.g., as we indicated in the previous section) such that some kinds of "events" might be better understood as relationships and some as objects.

In our previous research we postulated that the distinction between $\mathscr{B}$-relationships and $\mathscr{B}$-objects is not always sharp and that application of the distinction is also a modeling decision, though not as arbitrary as is often the case in "foreground OWL models". The distinction is essentially based on the criterion "whether the (reifying) object would be meaningful even without explicitly considering the other participants in the relationship" [2, p. 10]. Could everything we call an "event" be taken as an n-ary relationship in this sense? Composition of a musical piece or publication of a book can, since the arguments of the relationship are indispensable there. Personal events like birth or marriage arguably can, too; but what about events like conferences, festivals etc.? Here we feel a difference. When talking about publication of a book or a marriage (as a personal event, which is probably its meaning, e.g., in the BIO vocabulary), we can easily reformulate our sentences so as to avoid talking about the "reified" events and thus we have no problem modeling the fact as a relationship. For example: "John and Mary's marriage took place at 11 o'clock." can be transformed into "John married Mary at 11 o'clock." It is hard to imagine something similar when talking about conferences or festivals. But why? Are these "events" qualitatively different, or is there just a difference in scale? Is it so that if we feel this difference, we should just make a modeling decision, and by consequence model (in the ontological background), e.g., the marriage as an *n-ary relation* between Mary, John and the time (and maybe also place) of the marriage, but a conference or festival is to be seen as an *object*? The marriage in this example is meant as a personal event occurring "between" two people. However, marriages are also planned social events with many participants, quite like festivals. If we still apply our tentative criterion for distinguishing between *events as relationships* and *events as objects*, can we still talk about the marriage without mentioning it as an event and come up with an n-ary relation that would encompass all the relevant features of it? This depends on what features we take for relevant. What about "John married Mary at 11 o'clock in the church, Jenny, Bob and thirty other people attended, and there was a delicious cake"? We still do not have to say explicitly that there was a marriage yet. However, if we add more participants and factors, we will probably reach a point where such a linguistic representation would not be possible and we will have to talk about the marriage as an object, similarly to festivals and conferences. Actually, some people happen to talk about marriages in this sense on a daily basis. Therefore, if there is a relation reification present, it is not at the level of representation adequate for a practical semantic web model.

The outlined linguistic view in combination with the quoted "participant" principle (which are, obviously, quite correlated) together yield a possible decision structure for modeling an "event" as $\mathscr{B}$-relationship vs. $\mathscr{B}$-object:

1. If the event can hardly be considered without also considering some of its participants then $\mathscr{B}$-relationship is preferred
2. If we feel that by writing important facts about the event without mentioning it in the form of a noun phrase leads to loss of context then $\mathscr{B}$-object is preferred
3. If none of the above holds then we have a borderline case where both options are equally possible.

Now we can return to the categorization from the end of Section 6. Events like a publication of a book (and similarly a walk down the street etc.), for which condition 1 usually holds and condition 2 does not, are more specifically *actions* (**C1**); someone did something (and we can just possibly add: at some time, at some place, in some way etc.). Music festivals and conferences, on the other hand, are planned social events (**C3**), e.g., in the sense of *schema.org*, and the validity of the two conditions for them is usually opposite (no. 2 holds and no. 1 does not). It is worth mentioning that each such an event often has its proper *name*. If we put the "structural components of temporal entities" category (**C4**) aside, as it is not quite clear if these are events in the commonsensical way we are chiefly concerned about, there remains the category of “happenings” (**C2**). That *somebody did something* and that *something happened* seem grammatically very similar and could be arguably modeled in a similar way. The obvious difference is that in the first case there is an “active participant” (or *agent*, in the terminology of the Event Ontology). This by itself does not seem to preclude modeling them, preferably, as $\mathscr{B}$-relationships as well, even if it is somewhat less intuitive in some cases. Happenings, similarly to actions, normally have some time and place; therefore they are relationships between a time, a place and some other things – but not necessarily, e.g., “it rained at time X at place Y”. (In the rain, in a sense, the raindrops participate, but does it count? Why would we model it?).

As observed by Davidson, the number and roles of participants may vary even for what is inherently the same kind of relationship (event), for example, there can be many variants of an OBM for walks, because there is always something – a $\mathscr{B}$-object or a $\mathscr{B}$-valuation – we can add (destination, starting point, trajectory, ground, pace, etc.). PURO however allows for relationships with indeterminate arity: the relationship as element of graph[28] remains the same if the number of edges changes.

7. Conclusions and Future Work

We have seen that the notion of event can be comprehended in different ways, not only in the “wilderness” of the semantic web but also in philosophy and in foundational ontologies, which are, unlike most of the semantic web vocabularies, directly based on philosophical considerations. A certain degree of heterogeneity is therefore inevitable in faithful modeling of the “eventive” real world. As preliminary means of transferring the variety of event notions to semantic web and linked data circles we propose a 4-fold categorization. Accordingly, when modeling the ontological background of ontologies/vocabularies in PURO style, we anticipate, at least, four different patterns; each will be able to generate multiple surface (OWL) patterns, which can be tailored to the syntactical requirements of applications processing the OWL models themselves or the data based on them. This way the inherent and inevitable heterogeneity in event modeling could be cleanly separated from undesirable ad hoc heterogeneity, similarly as shown for the “classes as property values” problem/patterns [19].

The imminent future work is, clearly, to construct a formal library of “eventive” PURO patterns and exposing them on a server (both as diagrams and in an RDF serialization to support their automated processing); such a library for static PURO models is currently work in progress. The librari/es will be equipped with textual guidelines, and most likely with verbalizers allowing to check if a structured model fragment indeed reflects what the designer “wanted to say”. This would be analogous to the solution proposed by Seyed [25] for setting the rigidity metaproperty – which is, in fact, another “background model pattern”, although substantially different from those of PURO. We will also continuously scan the semantic web vocabulary collections, such as LOV, for “eventive” entities that could give rise to yet another inherently different event category.

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[28] In the supporting visual tool called PURO Modeler [3] the common diamond shape is used for it.

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