Ontological Considerations About the Representation of Events and Endurants in Business Models

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Abstract. Different disciplines have been established to deal with the representation of entities of different ontological natures: the business process modeling discipline focuses mostly on event-like entities, and, in contrast, the (structural) conceptual modeling discipline focuses mostly on object-like entities (known as *endurants* in the ontology literature). In this paper, we discuss the impact of the event vs. endurant divide for conceptual models, showing that a rich ontological account is required to bridge this divide. Accounting for the ontological differences in events and endurants as well as their relations can lead to a more comprehensive representation of business reality.

Keywords: Events · Endurants · Reification · Conceptual modeling · Ontology

1 Introduction

"Smiles, walks, dances, weddings, explosions, hiccups, hand-waves, arrivals and departures, births and deaths, thunder and lightning: the variety of the world seems to lie not only in the assortment of its ordinary citizens—animals and physical objects, and perhaps minds, sets, abstract particulars—but also in the sort of things that happen to or are performed by them" [1]. This variety is also evident in business reality, with "processes", "activities", "tasks", "events", "occurrences", "incidents" unfolding in time, and "objects", "actors" and "resources" persisting through time. In enterprise architecture and modeling frameworks, the distinction between behavioral elements and structural elements ("how" versus "what") is often invoked to account for the different nature of these elements [2, 3]. The distinction between these categories is commonplace in philosophical literature, with the former broadly referred to as "events" and the latter broadly referred to as "objects" [1].

Different disciplines have been established to deal with the representation of these two ontological categories, each of which with a different focus: the business process modeling discipline focuses on event-like entities, and, in contrast, the (structural) conceptual modeling discipline focuses on object-like entities. In each of these

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disciplines, entities of one of these ontological categories are first-class citizens, while the other category plays a marginal role (if any). Some notable exceptions in the process discipline are the so-called business artifact-centric approaches [4–7], and in the structural conceptual modeling discipline, the event reification approach [8].

In this paper we investigate the ontological nature of events and object-like entities (which we will call here *endurants* in line with the philosophical literature). We discuss the impact of the event vs. endurant divide in conceptual modeling. A modeling pattern to capture events in structural conceptual models is proposed. The conceptual foundations underlying this pattern serve as the basis for establishing a suitable semantic foundation for business process models that incorporate reference to object-like entities, as well as for structural conceptual models that incorporate reference to events.

2 Ontology-Driven Modeling of Business Endurants and Events

2.1 Endurants in Structural Conceptual Models

Suppose a Person named Mr. Anderson. Mr. Anderson can genuinely change in time in a qualitative manner while still maintaining his numerical identity. For instance, suppose that Mr. Anderson weighs 70 kg at t_1 and 85 kg at t_2. This qualitative change does not alter the *identity* of Mr. Anderson. Moreover, Mr. Anderson can bear some modal properties. For instance, Mr. Anderson is *necessarily* a person but only *contingently* a computer hacker. In other words, while he instantiates the type person in all possible situations that he exists, he can cease to be a computer hacker without this change having an effect on his identity. Finally, we can perform counterfactual reasoning with Mr. Anderson. For instance, we can ponder what if Mr. Anderson had decided to study law as opposed to becoming a computer hacker? When doing this, we admit that Mr. Anderson (that in a different world is a student of law) is the *same* individual as the Mr. Anderson who in this world is a computer hacker. These are all commonly accepted characteristics of what in ontology is termed an *endurant* [9, 10].

In ontology, endurants are entities that, whenever they exist, they are wholly present, i.e., whenever they are present, they are present with all their parts. Moreover, endurants have both *essential properties* (i.e., properties they must bear in all possible situations) and *accidental properties* (properties they bear in some possible situations) [9]. In other words, endurants can qualitatively change in certain respects while maintaining their identity; they can (or could have been) different from what they actually are with respect to their accidental properties. What defines the essential and accidental properties of an individual is its kind. We mean here "kind" in a technical sense [9]: a kind is a type instantiated by an individual that provides a *principle of identity*, *individuation and persistence* for that individual; it defines the boundaries and parts of that individual; it supports the judgment of whether that individual is identical or not to another individual (including itself in a different situation); it provides a criteria for what qualitative changes an individual can undergo and still be the same. For instance, suppose that the kind Car provides the following criteria of identity for the legal concept of a car: *two cars are identical iff they have the same chassis number*.

So, for an individual c of kind Car, c can change all aspects (e.g., color, tires) and it will be the same car as long as it has the same chassis number.

Mr. Anderson is of the kind Person. As it is always the case for *kinds*, Mr. Anderson instantiates that kind *necessarily*, i.e., in all possible situations. This is fundamental because a principle of identity must support identity judgments in all possible situations. Thus, a principle of identity must be supplied by a type that is instantiated necessarily by its instances. However, there are types that Mr. Anderson instantiate only *contingently*. For example, he is now an Adult Man but he was once a Boy; he is an employee of company X, but he could have been a student at university Y. Types such as Adult Man, Boy, Employee or Student are contingent types, i.e., for all instances of those types, these instances instantiate them only contingently. For example, an individual x can enter or leave the extension of a type such as Boy or Student without ceasing to exist as the very same individual.

There is a difference, however, between, on the one hand Adult Man and Boy and, on the other hand, Student and Employee; namely, individuals enter or leave the extension of the former sort of types due to a change in intrinsic properties (age, in this case) while they enter or leave the extension of the latter sort of types due to a change in their relational properties (the creation or termination of enrollments and employments, respectively, in this case). Types of the former sort (i.e., contingently and relationally-independent types) are named *phases* and of the latter sorts (i.e., contingently and relationally-dependent types) are named *roles* [9].

Furthermore, we can have that both Mr. Anderson and Company X can play the roles of *renter* in a car rental. Types such as *renter* seem at first to be like a role since they are: contingently instantiated by their instances (no renter is necessarily a renter); relationally dependent (in order to be a renter someone needs to be connected to a rental). However, a role (like a phase) is what is called a *sortal*: a type whose instances are all of the same *kind*. In contrast, the type renter classifies entities that belong to multiple kinds. These are termed dispersive types or *mixins*. A mixin that is contingent and relationally dependent is termed a *role mixin* [9]. Finally, *kinds*, *phases*, *roles* and *role mixins* (among others) are sorts of types that apply to endurants, not only to objects like Mr. Anderson [11, 12]. For instance, the weight of Mr. Anderson is a *quality* (an objectified property) of Mr. Anderson that can also change while maintaining its identity. For instance, when we say: "the weight of Mr. Anderson is changing", we don't mean that 70 kg are changing! There is an entity there, localized in time and space, which can change in a qualitative way while maintaining its identity. Analogously, the employment of Mr. Anderson can change: it can go from being a non-tenured to a tenured employment (two *phases* of the employment); it can itself play the *role* of a legally recognized employment in a given jurisdiction. In summary, entities such as the weight, the hacking skills, the employment, the enrollment, the eventual marriage, the car rental are also endurants. However, different from Mr. Anderson himself, these are *existentially dependent* endurants, frequently called *qualities* [11].

In Fig. 1, we have a model partially representing a domain such as the one just described. In this domain there are only three *kinds* of objects (in dark grey), namely, *Person*, *Organization* and *Car*. There is one single kind of relational endurant (i.e., a *relator*), namely, *Car Rental*. These are the kinds of things that exist in this domain.

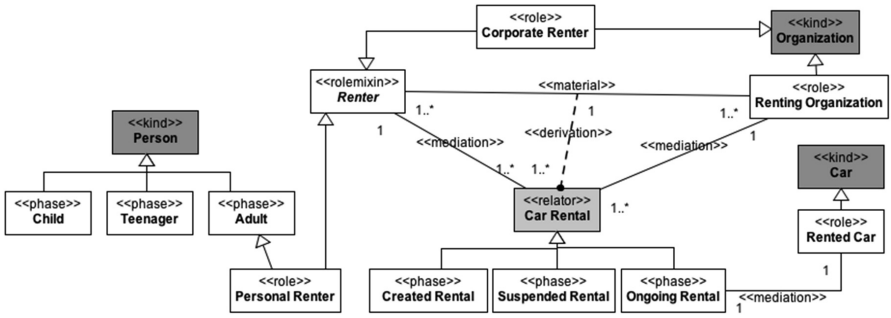

Fig. 1. Representing the possibility of change for endurants

Everything else in the model is a representation of a type that these kinds of things can instantiate contingently.

This model of Fig. 1 is represented in a conceptual modeling language termed OntoUML [9]. This language has been design to reflect the ontological distinctions and axiomatization put forth by the Unified Foundational Ontology (UFO) [9, 13]. In particular, this language has as modeling primitives those that represent ontological distinctions between all the aforementioned sorts of types (e.g., kinds, phase, roles, role mixins, relators). Figure 1 represents the possibility of change, i.e., how things could possibly be for the entities that are assumed to exist in this domain (i.e., people, organizations, cars and car rentals). In this approach, the OntoUML model of Fig. 1 can be automatically translated to knowledge representation languages such as OWL to support automated reasoning [13]. Moreover, as discussed in [13], the OntoUML approach offers a support for model validation via visual simulation. In this approach, the simulation of this model exposes its *ontological commitment* and allows us to find the possible difference between the intended state of affairs of this domain and the valid instances of this model. For instance, by simulating this model, one could find out that there is a possible instance in which an organization rents a car to itself (i.e., the roles of renter and renting organization are played by the very same entity).

One way to exclude these unintended modes is to enrich the model with formal constraints. The idea is to provide an axiomatization for the model such that set of its valid instances and the set of instances representing intended states of affairs of the domain coincide [13]. Some of these constraints are temporal constraints dealing, for example, with the life cycle of the endurants in the model. In particular, in the OntoUML approach, one can include temporal constraints (in temporal OCL) prescribing the permissible phase transitions in the model, for instance, from Child, to Teenager and (only then) to Adult, or governing the more complex transitions involved in the phases of a car rental [14].

2.2 Events in Business Process Models

As previously discussed, structural models such as in Fig. 1 represent what can possibility change and what has to remain the same in the properties of endurants, i.e., regarding matters of *necessity* and *possibility*. In the visual simulation support for the

OntoUML language, the modeler can appreciate how these endurants can possibly change in a possible worlds structure showing: which properties can change, which must remain the same; which worlds are accessible from other worlds and, hence, which are the permissible order of phase transitioning and role playing. But what are these changes? The answer is *events*.

In the philosophical literature, this aspect of events as changes is widely recognized. For instance, in [15, 16], events are basically defined as relations between states of affairs. In the UFO ontology [17], this is a fundamental aspect of events, i.e., events are also mappings from and to situations in the world, in which endurants are characterized by bearing certain properties (including relational ones). Among these changes, events can bring about situations in which endurants (including qualities) are brought into existence (i.e., are created), go out of existence (i.e., are destroyed), change their properties (via the creation and destruction of their intrinsic and relational qualities) or that they simply participate playing certain *processual roles*. For instance, in the killing of Caesar by Brutus with the dagger, we have the participation of three endurants (Caesar, Brutus, the dagger). However, their participations are of a completely different nature and it is the nature of these participations that induce their playing certain roles (victim, killer and murder instrument) in that event.

In UFO, these aspects of (i) change promoted by events and of (ii) endurant participation in events are only two among many aspects of events that receive an axiomatic treatment there. The ontology defines a fully axiomatized mereology of events (*extensional mereology*) prescribing how events relate to its parts. Moreover, it defines a theory about temporal precedence involving events, whose axiomatization incorporate the well-known *Allen Relations*. Additionally, it contemplates a *theory of causation* connecting situations brought about by events, which, in turn, trigger the occurrence of other events and so on, thus, making the world "tick". As much as for the case of endurants, events in UFO can be subject of predication. For instance, a conversation can be interesting or boring; a fight can be violent; a trip can be pleasant. Events typically also have qualities representing temporal and spatial features.

Finally, in UFO, events are manifestations of properties, in particular, of particular qualities and dispositions [17, 18]. So, for an event to unfold, the potentiality of that unfolding must exist as a concrete property of an endurant. As consequence, events are dependent on particularized properties (again, dispositions), which are in turn dependent on endurants. Ergo, events are dependent on endurants. For instance, the event of the *heart pumping* is the manifestation of the *heart's capacity to pump*; the event of the metal being attracted by the magnet is the manifestation of a number of dispositions of these entities (including the magnet's disposition to attract metallic material); Paul's Dengue Fever as a complex event is the manifestation of a number of complex dispositions that qualify that disease inhering in Paul; John & Mary's marriage as a process is the manifestation of a number of relational properties that constitute their marriage as an endurant (e.g., commitments and claims, expectations, etc.). Dispositions include propensities, capacities, capabilities, liabilities, etc. [18].

These aspects of UFO have been successfully used in the past to analyze and provide ontological foundations for Business Process Modeling languages such as ARIS [19], UML Activities Diagram [20] and BPMN [21], as well as Discrete Event Simulation approaches [22]. The results of these analyses provide for well-grounded

representational mechanism that can be used to represent aspects of temporal ordering and (at least partially) aspects of object participation in events playing certain processual roles as well as aspects of event mereology. The notion of events as manifestation of dispositions inhering in certain endurants has been fundamental in our ontological analysis of the notion of *service* [23] as well as the notion of *capability* in enterprise architecture [24]. In this paper, this notion will play a key role in Sect. 3.4.

The aspect of events as changes can be represented by variations of state-machines capturing how the occurrence of events in certain conditions can promote a transition of an endurant to a different state [28]. For example, referring to model of Fig. 1, one can represent all allowed transitions between the phases of Car Rental as well as the events and conditions that promote these changes. Capturing this aspect of events is of uttermost importance and, in particular, for the case of relators. This is because the main goal of social reality (and, hence, of information systems) is to represent and control: the *life* of social relators such as enrollments, employments, contracts, rentals, allocations, presidential mandates, marriages; the social roles induced by them; and the events (including *speech acts*) that constitute their lives. We should highlight that in state-machine-like models such as in [7, 25], the events that can appear in these models are events that exist in potentially as *operations*, *functions* or *"services"* of the endurants that exist in that domain. This is conformant with a view that takes these operations, functions or "services" as dispositions (capacities, capabilities) of these endurants: they inhere in these endurants even if they are never manifested but all events that occur are manifestation of these dispositions.

In a language such as OntoUML, the possibility of change is explicitly represented in terms of contingent types such as phases and roles, and their relations. For instance, in Fig. 1, we can represent that only when an adult, a person can play the role of a Car Renter and only when a rental is ongoing we have a car associated to it. On the other hand, an OntoUML model, such as the one in this figure, explicitly identifies *phase partitions* as natural connection points for integrating behavioral models of changes (e.g., state-machines) with structural models of possibilities. In other words, OntoUML give us a clear methodological support for deciding for which types in a model of endurants we should specify a behavioral model of changes.

As discussed in this section, one of the aspects of events is that of events as changes. However, can we meaningfully talk about *changes in events*? This is a fundamental but often neglected topic in the literature of conceptual modeling. We shall address it in the next sections.

3 Events in Structural Conceptual Models

Structural conceptual models, such as the one of Fig. 1, have traditionally focused on the representation of endurants (e.g., objects, their intrinsic and relational properties, the types they instantiate, the roles they play, their parts, etc.). In fact, in classical conceptual modeling, events are rarely represented in these structural models as first-classes citizens. As a result, we can rarely represent the qualities of events as well as the underlying conceptual spaces from which these qualities can take their values. Although the representation of events as first-class citizens in structural conceptual

models is openly defended in the literature [8], there is still no foundation for guiding their modeling with respect to a number of fundamental issues. Given that reference conceptual models should provide conceptual clarification and explicit characterization for notions comprising complex worldviews, and given that many of these notions refer to events, we find ourselves in a problematic situation. In this section, we address one of these fundamental issues, namely, the notion of identity, change and reference for events, exploring the consequences for the representation of events in structural conceptual models.

3.1 The Immutability of Events

Previously in this article, we talked about an endurant such as Mr. Anderson, who can: bear essential and accidental properties; qualitatively change in certain aspects while remaining the same; and, be the subject of counterfactual reasoning. Now, how shall we answer these questions regarding events? Can events genuinely change their properties while remaining the same? Can an event be the bearer of modal properties? In particular, can an event exhibit properties contingently? Can an event be different from what it is? Is there identity between events in different possible worlds?

If we look to *all classical axiomatized ontologies of events*, we would need to answer '*no'* to all these questions. According to these theories, an event is an extensional entity defined by the sum of its parts [17, 26]. It can be seen as a succession of changes in the world [15, 16], fully determined by participants, a temporal interval and the properties that are exemplified by the manifestation of the event [27, 28]. As a consequence, following these theories, an event could not been different from what it is. Had it been different, it would have different parts, it would be a different succession belonging to a different history and, hence, a different event. Furthermore, in the traditional literature, a key difference between endurants and events is that in the case of events there is nothing that endures, qualitatively changing while maintaining its identity [10]. If a discussion is peaceful at t_1 and litigious at t_2, there are different temporal parts of the discussion that bear these otherwise incompatible properties. In this view, there is nothing that is entirely present throughout the duration of the discussion. More precisely, take the branching-time possible worlds structure depicted in Fig. 2(a). Each of these branches corresponds to a *possible world as a possible history*. In these classical views, an event exists solely within one of these branches. For instance, events E_1, E_2, E_3 and E_4 are temporal parts of E'. Suppose there is another complex event E'' composed by E_1, E_2, E_3 and E_5. In this case, E_1, E_2, E_3 are overlapping parts of both E' and E''. However, E' and E'' are distinct events.

Take, again, Mr. Anderson, our prototypical example of an endurant. While Mr. Anderson exists, there is a complex event associated with him, namely, Mr. Anderson's life (see Fig. 2(b)). Mr. Anderson's life can be seen as the successive exemplification of a number of (intrinsic and relation) properties of his. However, suppose that we are in a given point in time t_1 in which Mr. Anderson has to decide to either take the blue pill or take the red pill. If he takes the red pill, then in the moment succeeding t_1 (say, t_{1+1}) Mr. Anderson's life is a particular event E' (that includes the taking of the red pill). If instead, he takes the blue pill then, in the moment succeeding

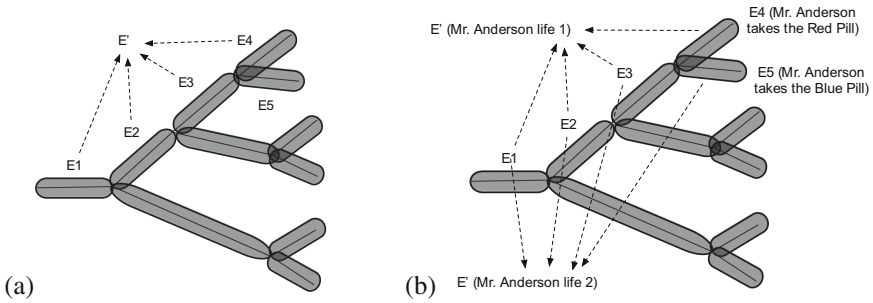

Fig. 2. (a) Events and their proper parts; (b) the life of an endurant as an event

that action, Mr. Anderson's life will be a different event E" (including the event of taking of the blue pill). Clearly, given all classical theories of events, E and E' are distinct individuals as they have different parts and incompatible properties.

3.2 The Role of Object Identifiers

In [29], Wieringa and de Jong report on a detailed study of the role of object identifiers in conceptual modeling. According to them, an object identifier should work as a *rigid designator* picking up the same individual in all possible worlds. For instance, they state that *"object identifiers (oids) are special kinds of proper names for denoting real-world objects"* and require an OID to refer in each state of the world to exactly one object. They term this requirement *singular reference* and point out that this requirement also appears in authors such as Kent [30] (*singular* requirement for identifiers). The authors also require for an OID to remain referring to the very same object across different states of the world (in which they refer at all). They term the latter requirement *rigid reference*. As another example, in UML, the extension of a class C in a *class diagram* is a set of OIDs. These OIDs are supposed to trace the identity of the very same individual across different states.

With these requirements in mind, we should analyze Fig. 2(b). In particular, we should focus on the moment t_1 in which Mr. Anderson is pondering whether to take the red or the blue pill. As we have seen, "Mr. Anderson" should be a rigid designator, i.e., the referent of "Mr. Anderson" at a time t should be the same as the referent of "Mr. Anderson" at any time t'. Now, at time t_1, the referent of "Mr. Anderson" is the individual deliberating on what he should do regarding the pills. Whatever he does, the referent of "Mr. Anderson" at t_{1+1} is still Mr. Anderson. To see that, we can easily imagine HIM regretting his decision in t_{1+1} and thinking what HIS life (i.e., the alternative life of the SAME individual) would be like had he taken a different pill.

Now, a fundamental question is: can "Mr. Anderson's life" work as a rigid designator at t_1? If the referent of "Mr. Anderson's life" is an event than the answer must be negative, since: (i) if "Mr. Anderson's life" at t_1 refers to an individual, then it must refer to the same individual in all possible worlds; (ii) in a possible world (in which he takes the red pill), Mr. Anderson's life at t_{1+1} refers to event E' (the event that includes

the taking of the red pill); (iii) in a different possible world (in which he takes the blue pill), Mr. Anderson's life at t_{1+1} refers to event E'' (the event that includes the taking of the blue pill); (iv) E' is not identical to E''. Ergo, "Mr. Anderson's life" does not rigidly designate at t_1. In fact, and this is very important, if "Mr. Anderson's life" cannot rigidly designate at t_1 then it cannot rigidly designate at any point (again, after taking the red pill, there will be other points of branching). The only exception is when Mr. Anderson's life is over (i.e., when no other possibilities of branching exist).

"Mr. Anderson's life" cannot even function as a definite description at t_1, unless we take it to refer to *Mr. Anderson's life up to that point*. This definite description takes a different referent at each time point picking up whatever event happens to be the accumulation of temporal parts that is Mr. Anderson's life up to that point and in that particular world (as history). For instance, at t_{1+1} (supposing that Mr. Anderson takes the red pill), we can refer to the event of taking the red pill in a determinate way as we can refer to "Mr. Anderson's life up to t_1", which is part of "Mr. Anderson's life up to t_{1+1}". In other words, when fixing a world, "Mr. Anderson's life up to t_1" is a rigid designator picking up a determinate individual. In contrast, "Mr. Anderson's life" is not (except for when Mr. Anderson's life is over). As a consequence, while the former can serve as a candidate for an OID, the latter can't.

3.3 Ongoing Events and Object Identifiers

In the previous sections, we have established two premises, namely that: (i) events cannot change or bear modal properties; (ii) object identifiers are rigid designators. Now, if we accept premise 1 (i.e., the classical ontological theories of events in which events obey extensional mereology, cannot qualitatively change, cannot be bearer of modal properties and are locked inside a history) and premise 2 (i.e., OIDs should work as proper names obeying singular and rigid reference) then the inescapable conclusion is: we can only have OIDs referring to events after the point in which there is no possibility of branching, i.e., *we can only have OIDs referring to historical events*.

In summary, Mr. Anderson is not identical to any event that will culminate to be Mr. Anderson's life in a given world. In fact, it correlates to a set of possible lives or possible unfoldings. That is, the proper name (or OID) "Mr. Anderson" can be used to refer to the very same individual in the past and in the present and we can use it in counterfactual reasoning (e.g., what if Mr. Anderson hadn't taken that pill and continued to be a law-abiding computer programmer?; What if Mick Jagger hadn't dropped the London School of Economics and pursued a career as an economist?). In contrast, "Mr. Anderson's life at t_1" could NOT have been different from what it is. Although, the very SAME Mr. Anderson could have had a different life up to that point.

To be the best of our knowledge, this problem has not been discussed in the conceptual modeling literature up to now. When events are represented in structural conceptual models, they are always assumed to be both instantaneous and atomic [8]. Now, if events are instantaneous and atomic, they are only instantiated when they are over, i.e., all event instances are historical instances. For this reason, the aforementioned problem does not arise. However, frequently in structural conceptual models,

we want to represent and refer via an OID to *ongoing events*. We want to talk about the conversation, the marriage, the employment, the presidential mandate, the football game, and the car rental as on going events that seem to somehow "change". For instance, while referring to the marriage between John and Mary, we would like to refer to it by a proper name, i.e., to use an OID that refers to something that can truly change qualitatively while remaining the same (e.g., John and Mary's marriage as a whole used to be passionate and now it is cold and distant) and to something that could have been different (e.g., John and Mary's marriage would have lasted longer hadn't they moved to Australia).

There are two possible strategies one might consider to try to escape the aforementioned consequences. As expected, they amount to denying at least one of the premises (1) and (2). In any case, this leads to dire consequences. If we reject premise (2), we need to replace it with a completely non-classical semantics for structural conceptual models in which OIDs do not satisfy either singular reference or rigid designation. If we reject premise (1), we need to come up with a completely non-classical ontological theory of events. One that is at odds with the commonly accepted view in linguistics [28] and in formal ontology in philosophy [26]. In particular, one that is at odds with the commonly shared view of events present in the foundational ontologies that are most commonly employed in the foundations of conceptual modeling [9, 10].

In the next section, we explore a modeling alternative that accepts both premises (1) and (2), but that also allows for proper names such as "John & Mary's marriage" or "Paul's Dengue Fever" to refer to entities that can change and that can be the bearers of modal properties, namely, existentially dependent endurants.

3.4 Where Do Events Come from?

As previous discussed, we take events to be the manifestation of qualities and, in particular, of *dispositions* [11, 17, 18]. So, for an event to unfold, the potentiality of that unfolding must exist as a concrete property of an endurant. As consequence, events are dependent on particularized properties (again, qualities and dispositions), which are in turn dependent on endurants. Ergo, events are dependent on endurants. For instance, the event of the *heart pumping* is the manifestation of the *heart's capacity to pump*; the event of the metal being attracted by the magnet is the manifestation of a number of dispositions of these entities (including the magnet's disposition to attract metallic material); Paul's Dengue Fever as a process is the manifestation of a number of complex dispositions that qualify that disease inhering in Paul; John & Mary's marriage as a process is the manifestation of a number of relational properties that constitute their marriage as an endurant (e.g., commitments and claims, intentions, desires, expectations, etc.).

Since events are existentially dependent on endurants and are manifestations of particular aspects of these endurants, whenever an event unfolds, these aspects (and the endurants they inhere in) must be present. For this reason, we frequently use the same term to refer both to the event and these underlying aspects. This is a case of *systematic polysemy* [31], a phenomenon that occurs very frequently in language. Take, for

instance, the sentences: (a) *this duck in the backyard is common around Europe*; (b) *this book is heavy to carry but easy to read*; (c) *we can meet in front of the bank around the corner that specializes in sub-prime loans*. In (a), we have a polysemic reference to both an individual (that duck in the backyard) and a kind (ducks in general); in (b) to a physical object (the bound volume) and an information content (the book as literary work); in (c) to a physical space (the bank's building) and to an organization. In an analogous manner, when we use the term "John & Mary's marriage" or "Paul's Dengue Fever", we sometimes refer to the endurant (a complex of particularized properties) and sometimes to the event that is the accumulated manifestation of this endurant up to a certain point, i.e., as a definite description. Given the discussion in the previous section, we claim that whenever we refer to something that is on going, that can qualitatively change and still maintain its identity, we are not referring to an event but to the endurant underlying that event. So, when we say that Paul's Dengue Fever up to now has been composed of episodes of high fever, followed by episodes of joint pain that lasted for days, we are referring to the event; when we say that Paul's Dengue Fever has changed and has become a case of Dengue Hemorrhagic Fever now, we are referring to a complex of dispositions (an endurant). Given our previous discussion, if we want to use "Paul's Dengue Fever" as an OID, it must refer to the latter endurant. That is why in Fig. 1, what is referred by the term "Car Rental" is the endurant, the relator, which can change in time, go through phases, etc. Of course, as a manifestation of the many dispositions (e.g., commitment, claims, liabilities, capacities) constituting this car rental relator, we have, in a particular unfolding of the world, a car rental complex event.

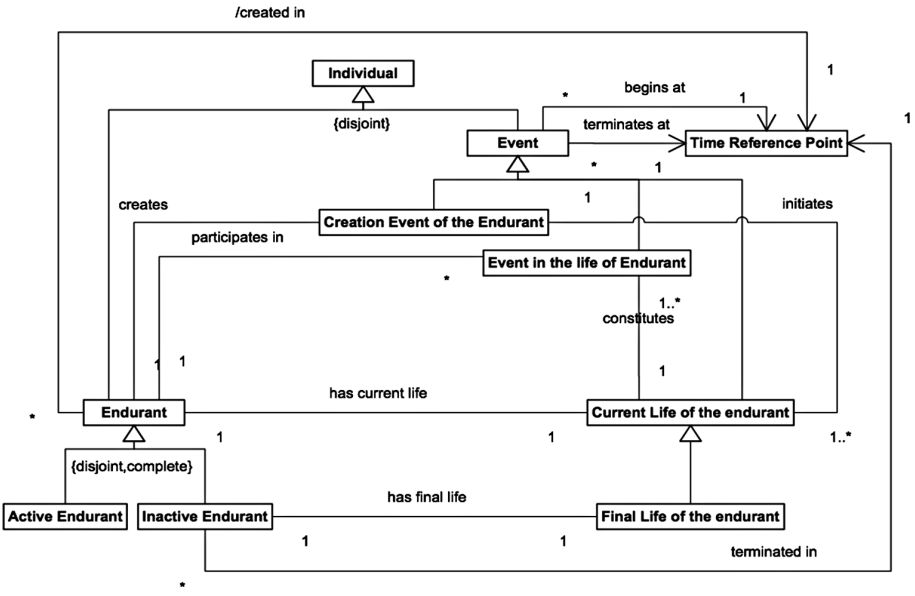

Fig. 3. A modeling pattern for representing events in structural business models

In the sequel, we propose a *modeling pattern* that captures the relation between endurants and the events whose parts accumulate as their manifestations (Fig. 3). In this pattern, endurants are *created by creation events*. As events, creation events begin and end at certain time points. The creation moment of an endurant *(created in* relation) is derived from the termination time point of its creation event. Endurants have a causally active phase (e.g., a living person, an on-going disease, an active enrollment). In this phase, the particularized properties (qualities and dispositions) of this endurant are manifested through a number of events (events in the life of endurant) that accumulate to constitute, at each point, a different process that represents the *current life of the endurant*. Endurants also have a causally inactive phase (e.g., a deceased person, a finished assignment, a legally terminated marriage). In this latter phase, the properties of that endurant can no longer be manifested and, its qualities are immutable regarding their values. Moreover, in that phase, we can refer to the *final life of the endurant* as the total accumulation of all *events in the life of the endurant*.

As an example, suppose Peter makes an appointment with Jane (his supervisor) to discuss his Ph.D. thesis in the subsequent week. After they have agreed to meet (an event), the *appointment* does not yet exist as an event, but it does exist as an aggregation of mutual commitments, individual goals, mutual expectations, etc. (again, an endurant, more precisely, a relator). So, we take the agreement event as an atomic event that creates the *appointment*. The appointment can change (they might decide to drop of the topics of the agenda), it might be postponed, its manifestation (i.e., the appointment as an event) might even not occur at all. While occurring, this appointment can be manifested through a number of events that will accumulate to be the "life of the appointment", a particular event in which Paul and Jane participate.

3.5 An Illustration

In [32], Olivé discusses the issue of relationship reification and elaborates on the connection between reified relationships and their temporal properties. He discusses the following example: suppose an employee *works in* a project. In that project, the employee has a number of worked hours per daily time interval. Moreover, for each convex time interval someone works in that project, he is connected to a single task and has a single pre-fixed deadline. Moreover, for all the non-convex time intervals that are periods in which he works in that project, the employee has the same role and the same manager. Olivé then proposes three different types of temporal relationship reifications: ***(1) per instant:*** a relationship r is reified into a different entity e for each time point in which r holds. In this example, for each working day in a given project, we have a different entity e which captures the worked hours in that day; ***(2) per interval:*** a relationship *r* is reified into a different entity *e'* for each temporal interval during which *r* holds. In this example, e' can then capture properties such as deadline and objective; ***(3) per life span:*** a relationship *r* (instance of *WorksIn*) is reified into a single entity *e*, which is the same during the whole life span of *r*. In this example, e'' can then capture properties such as assigned role and manager.

Given the analysis presented in this paper, the first question that comes to the mind is: what kinds of entities are being represented in these examples? If we take (1), in the

solution presented by Olivé in the paper, the reified entity is termed.*Work Day* having properties such as *HoursWorked* and produced deliverable(s) (if any). Olivé highlights two meta-properties of this entity: it is instantaneous and atomic. Given the chosen name (and these meta-properties), a salient interpretation is that the reified entity represents an event, individuated by a pre-fixed time-interval. If this is the case, then an instance of this relationship corresponds to an *event*. An exemplar instance of *Work Day* is the event in which John worked 10 h and produced deliverables d_1 and d_2 in March 20th, 2013. Since events cannot change in a qualitative way, then both the attribute *HoursWorked* and the relationship with the produced deliverable(s) are immutable (and thus are marked as *readOnly* in UML).

Let us take now the case (2). In that case, Olivé's solution produces an entity termed *Assignment* connecting an Employee and a Project. An assignment, is connected to a task and a deadline and is associated to a given time convex interval. Now, in this second case, it is not obvious that Assignment is an event. Assignment can have modal properties (e.g., it can fulfilled before the deadline, it can be delayed, it can be fulfilled in time), an assignment can be manifested through a number of possible processes (for instance, being constituted by a different number of actual WorkDay instances), an assignment can change in a qualitative way (for instance, the number of current worked hours can change). Moreover, although Olivé assumes that the deadline is fixed, one can easily imagine a situation in which the deadline for an assignment can be renegotiated and, hence, possible changed. In fact, an Assignment can even fail to manifest at all (for example, if the employee fails to actually work in the project or to deliver the object of the assignment goal). However, even if this is the case, the Assignment (as a bundle of commitments and claims) holds for the entire time interval (for example, between creation and deadline, fulfillment or abandonment of the assignment) which is different from the time (sub)intervals in which the particularized properties in this assignment are actually being manifested through events. Of course, one can still assume here that what we have is a historical model that only models assignment once their manifestations are finished. Again, what we would have here would be the representation of a historical event. Once more, all properties of the relationship would be immutable (e.g., the actual number of worked hours, if the task was fulfilled or not, etc.). Finally, let us analyze case (3). In that case, Olivé's solution reifies the relationship by something (interestingly) termed Participation. Unlike in cases (1) and (2), however, a Participation is not correlated to a convex time interval. In other words, a *Participation* can be active or inactive being, hence, correlated with multiple disconnected time intervals. Once more, in case we only look at participations in hindsight, Participations can be thought as complex historical facts correlated to the mereological sum of possibly several historical events (i.e., historical participations). However, it seems that in this case the most salient interpretation is to have participation as a complex bundle of commitments (a better name could be *Project Allocation*) that can change qualitatively in many ways (e.g., the number of working hours can change, the value paid by worked hour can change), can bear modal properties (e.g., it can be active or not – I can be allocated to a project even if I am in a medical leave) and can be manifested by a number of possible processes and, hence, it can correspond to a number of possibly different participations (in the sense defended here). In these different possible manifestations of John's allocation to project P1, he can have

different task assignments, which can be fulfilled or not, with different performance evaluations, in different dates with different amounts of effort, etc. In any case, in the latter (arguably more realistic) interpretation, the lifetime of the *Project Allocation* is potentially different from the sum of the time intervals in which this this relator is being manifested, i.e., different from the lifetime of the participations in the corresponding event.

Figure 4 shows a model for this scenario, revisiting Olivé's example and containing an instantiation of the pattern of Fig. 3. In this model, a *Task Assignment* is an endurant that throughout its active life is manifested through a number of *Work Day* events, which are events in the life of the *Task Assignment*. An instance of *Work Day* is also possibly a creation event for another endurant, namely, a *Deliverable*. When a *Task Assignment* is in a causally inactive phase (i.e., it has terminated), we have a complex historical process (*Task Assignment Process*), which is the final life of the *Task Assignment*, and is composed of all *Work Day* manifestations of it. As previously discussed, since events are mereological sums of their parts, all *Work Day* events

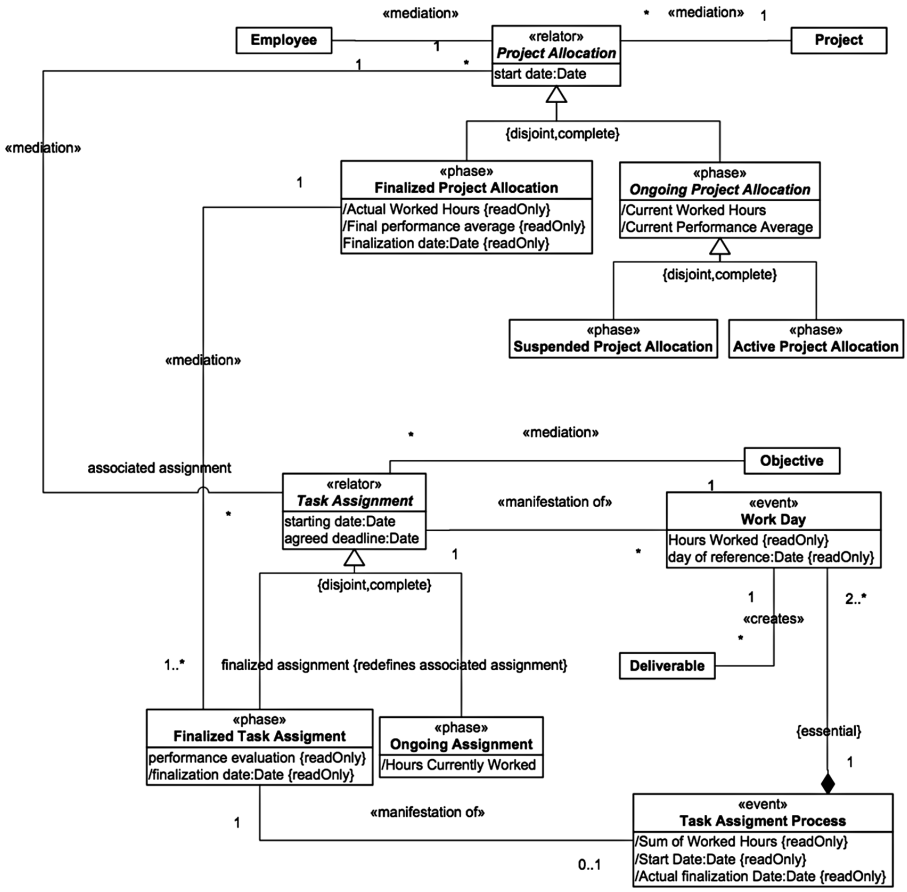

Fig. 4. Olivé's example revisited

composing a *Task Assignment Process* are essential to it. Moreover, attributes such as starting date and finalization date (for *Project Allocation* and *Task Assignment*) are specializations of the general relations of *created in* and *terminated in*, respectively (in Fig. 3). In this figure, we have the attribute day of reference in *Work Day* representing both the start and end time reference points for that event (since, by definition of work day, they are the same). The start and actual finalization dates of the *Task Assignment Process* are derived from the attributes of its constituent events, namely, the date of references of the first and last of the *Work Day* events.

4 Final Considerations

Several approaches to enterprise modeling manage the complexity of an organization by describing the organization from different perspectives. The need to relate various partial descriptions of the organization is addressed in virtually all enterprise modeling approaches and has been recognized in Zachman's early work in 1987 [2]: "each of the different descriptions has been prepared for a different reason, each stands alone, and each is different from the others, even though all the descriptions may pertain to the same object and therefore are inextricably related to one another."

This need has led to the development of *relations between architectural domains* in enterprise architecture and enterprise modeling approaches [3]. One of these domains, namely that of organizational behavior, has received significant attention in the context of business process modeling and management. Another important domain, that of object-like entities (or "structure") is strongly inter-related with the process domain. While the process domain focuses on "how" the business process activities are structured and performed, the structure domain focuses on "who" performs these activities and "what" undergoes change.

We have shown in this paper that a rich ontological account is required to explain the relation between both domains. This account enables us to understand how events can be incorporated in a structural conceptual model. We have discussed a modeling pattern that arises from dealing with the different nature of events and endurants; in this pattern, endurants and related events coexist, complementing each other through well-defined relations. The pattern extends the treatment of reified events that was proposed in [8].

We believe that the conceptual foundations discussed here can serve to improve the understanding of artifact-centric business process approaches [4–7] as well as case handling [33]. Note that the focus here is not on "data objects" but rather on real-world objects (including social objects, commitments, relationships) that are pervasive in the business world; representing these objects and their relations to events is key to capturing business reality accurately.

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References

1. Casati, R., Varzi, A.: Events. In: Zalta, E.N. (ed.) The Stanford Encyclopedia of Philosophy (2015). http://plato.stanford.edu/archives/win2015/entries/events/
2. Zachman, J.A.: A framework for information systems architecture. IBM Syst. J. **26**(3), 276–292 (1987)
3. Lankhorst, M., et al.: Enterprise Architecture at Work - Modelling, Communication, and Analysis. Springer, Heidelberg (2005)
4. Meyer, A., Weske, M.: Activity-centric and artifact-centric process model roundtrip. In: Lohmann, N., Song, M., Wohed, P. (eds.) BPM 2013. LNBIP, vol. 171, pp. 167–181. Springer, Heidelberg (2013)
5. Liu, R., Bhattacharya, K., Wu, F.Y.: Modeling business contexture and behavior using business artifacts. In: Krogstie, J., Opdahl, A.L., Sindre, G. (eds.) CAiSE 2007 and WES 2007. LNCS, vol. 4495, pp. 324–339. Springer, Heidelberg (2007)
6. Nigam, A., Caswell, N.S.: Business artifacts: an approach to operational specification. IBM Syst. J. **42**(3), 428–445 (2003)
7. Cohn, D., Hull, R.: Business artifacts: a data-centric approach to modeling business operations and processes. Bull. IEEE Comput. Soc. Tech. Committee Data Eng. **32**(3), 3–9 (2009)
8. Olivé, A., Raventós, R.: Modeling events as entities in object-oriented conceptual modeling languages. Data Knowl. Eng. **58**, 243–262 (2006)
9. Guizzardi, G.: Ontological Foundations for Structural Conceptual Models, Telematica Instituut Fundamental Research Series No. 15, The Netherlands (2005). ISBN 90-75176-81-3
10. Borgo, S., Masolo, C.: Foundational choices in DOLCE. In: Staab, S. (ed.) Handbook on Ontologies, pp. 361–381. Springer, Heidelberg (2009)
11. Guarino, N., Guizzardi, G.: Relationships and events: towards a general theory of reification and truthmaking. In: 15th International Conference of the Italian Association for Artificial Intelligence (2016, submitted)
12. Guarino, N., Guizzardi, G.: "We need to discuss the relationship": revisiting relationships as modeling constructs. In: Zdravkovic, J., Kirikova, M., Johannesson, P. (eds.) CAISE 2015. LNCS, vol. 9097, pp. 279–294. Springer, Heidelberg (2015)
13. Guizzardi, G., et al.: Towards ontological foundation for conceptual modeling: the unified foundational ontology (UFO) story. Appl. Ontol. **10**(3–4), 259–271 (2015). IOS Press
14. Guerson, J.: Representing dynamic invariants in ontologically well-founded conceptual models. Master thesis, Computer Science Department, Federal University of Espírito, Santo, Brazil (2005)
15. Lombard, L.B.: Events: A Metaphysical Study. Routledge, London (1986)
16. Bunge, M.: Treatise on Basic Philosophy the Furniture of the World Ontology I. Springer, Heidelberg (1977)
17. Guizzardi, G., Wagner, G., de Almeida Falbo, R., Guizzardi, R.S., Almeida, J.P.A.: Towards ontological foundations for the conceptual modeling of events. In: Ng, W., Storey, V.C., Trujillo, J.C. (eds.) ER 2013. LNCS, vol. 8217, pp. 327–341. Springer, Heidelberg (2013)
18. Molnar, G.: Powers: A Study in Metaphysics. Oxford University Press, Oxford (2006). Ed. by Stephen Mumford
19. Santos Jr., P.S., Almeida, J.P.A., Guizzardi, G.: An ontology-based semantic foundation for ARIS EPCs. In: 25th ACM Symposium on Applied Computing (ACM SAC 2010), Sierre, Switzerland (2010)

20. Martins, A.F., et al.: Using a Foundational Ontology to Address Ambiguity in Business Process Modeling. In: 7th Brazilian Symposium on Information Systems (SBSI 2011), Salvador, Brazil (2011). (in Portuguese)
21. Guizzardi, G., Wagner, G.: Can BPMN be used for making simulation models? In: Barjis, J., Eldabi, T., Gupta, A. (eds.) EOMAS 2011. LNBIP, vol. 88, pp. 100–115. Springer, Heidelberg (2011)
22. Guizzardi, G., Wagner, G.: Towards and ontological foundation of discrete event simulation. In: 16th International Winter Simulation Conference, Baltimore, USA (2010)
23. Nardi, J., et al.: A Commitment-Based Reference Ontology for Services Information Systems. Oxford University Press, Oxford (2015)
24. Azevedo, C., et al.: Modeling Resources and Capabilities in Enterprise Architecture: A Well-Founded Ontology-Based Proposal for ArchiMate Information Systems. Oxford University Press (OUP), Oxford (2015)
25. Estañol, M., Queralt, A., Sancho, M.R., Teniente, E.: Artifact-centric business process models in UML. In: La Rosa, M., Soffer, P. (eds.) BPM Workshops 2012. LNBIP, vol. 132, pp. 292–303. Springer, Heidelberg (2013)
26. Simons, P.M.: Parts. An Essay in Ontology. Clarendon Press, Oxford (1987)
27. Kim, J.: Events as property exemplifications. In: Action Theory, pp. 159–177. Reidel (1976)
28. Moltmann, F.: Events tropes and truthmaking. Philos. Stud. **134**, 363–403 (2007)
29. Wieringa, R., de Jonge, W.: Object identifiers, keys, and surrogates: object identifiers revisited. Theor. Pract. Object Syst. **1**(2), 101–114 (1995)
30. Kent, W.: Data and Reality. Elsevier Science Ltd, Amsterdam (1978)
31. Ravin, Y., Leacock, C.: Polysemy: Theoretical and Computational Approaches. Oxford University Press, Oxford (2002)
32. Olivé, À.: Relationship reification: a temporal view. In: Jarke, M., Oberweis, A. (eds.) CAiSE 1999. LNCS, vol. 1626, pp. 396–410. Springer, Heidelberg (1999)
33. van der Aalst, W.M.P., Weske, M.: Case handling: a new paradigm for business process support. Data Knowl. Eng. **53**(2), 129–162 (2005)