Towards an Ontology of Scenes and Situations

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***Abstract*— It is no surprise that the notion of situation is key to situation awareness. The development of the discipline can thus benefit from careful analysis of the notion. In this paper, we approach this by proposing an ontology of situations and scenes. The main contribution of this ontology is that it accounts for how situations progress in time changing qualitatively, constituting what we call scenes. The ontology is built by reusing basic elements from the Unified Foundational Ontology (UFO). It addresses objects, occurrences, and their formal relations to situations and scenes. We use the theory of embodiment proposed by the philosopher Kit Fine to explicate how scenes and situations form wholes constituted of parts.**

Keywords: situation; ontology; foundational ontology; scene;

I. INTRODUCTION

Situation awareness was defined by Endsley [12] as "the perception of the elements in the environment within a volume of time and space, and the comprehension of their meaning, and the projection of their status in the near future." Situation awareness requires thus minimally the ability to perceive the world and to identify in it patterns that characterize situations of interest (i.e., to "recognize situations" in the words of Kokar et al. [26]). More than that, it requires that this process somehow should be extended in time, as there is interest in the past and in how elements in the environment may unfold in the future.

In order to leverage the benefits of the notion of situation, it is key that it stands on firm grounds. The study of the notion of situation has a tradition that dates back to the seminal work of Barwise and Perry [3], [4]. They realized that "people use language in limited parts of the world to talk about (i.e., exchange information about) other limited parts of the world. They call those limited parts of the world situations." ([4] *apud* [26]). Their work was taken up by Devlin [11] and was instrumental in the development of the so-called situation semantics [25]. It has also influenced developments in information fusion and situation-awareness, and in particular ontology-based approaches such as Kokar et al. [26], Matheus et al. [28], and Baumgartner et al. [5].

Ontology-based approaches focus on the representation of knowledge about situations of interest to enable knowledge sharing and high-level reasoning [26], [35]. Despite the advances in ontology-based approaches for situations, there are still some features of situations that have not been explicitly account for. These include the notion that they can somehow be considered to extend in time and remain the same, even when constituent entities change. Consider for example a crowd management setting in which there are over 10,000 people in a soccer stadium attending a match. We are interested in the various elements in this setting as it unfolds in time regardless of whether some of these people change, with some entering and some (others) leaving the stadium. Accounting for such changes is not possible if a situation is conceptualized merely as a relation that holds between specific entities.

In addition to that, the focus of ontology-based approaches to situation has been mostly on objects and their (intrinsic and relational) attributes, relegating *occurrences* or *eventualities* ([2], [14]) to a secondary role. Occurrences enlarge the variety of entities in the world to include not only its "ordinary citizens" (such as animals, physical objects) but also the "things that happen to or are performed by them" [7]. These entities (e.g., events and processes) are particularly important in cognition, language and are key to account for the "dynamics" of elements in the world (to use the term employed by Endsley in [12]).

In this paper, we aim to address some of these conceptual challenges by proposing the notion of *scene* as complementary to the notion of *situation*. Each situation in a scene is a temporary part of the scene, forming a unified whole in time. The term is chosen to capture the intuition that a scene is not static, and involves a (temporal) succession of situations and occurrences involving the objects in the scene. In a theatrical scene, actors enter and leave, events take place and the scene persists even in the face of changes in its composition. We develop a simple, yet general, ontology for scenes and situations that we see aligned with the needs of situation awareness.

Our long-term aim is to develop a foundation for the conceptual modeling of scenes and situations. Here we approach the basic concepts required to develop such a foundation. We follow the tradition in the area of conceptual modeling in employing ontological theories in philosophical sense (i.e., axiomatic theories of categories and their ties) for developing languages, methodologies and tools for the discipline [20], [30], [34]. This branch of conceptual modeling is known as Ontology-Driven Conceptual Modeling (ODCM). The foundations of an ODCM approach should rely on an ontological system that reflects the deep conceptual meta-categories that humans actually employ to create their conceptualizations of reality. Such a system was developed by some of us in the last decade consistently putting together in the Unified Foundational Ontology (UFO) a number of theories originating from areas such as Formal Ontology in

Philosophy, Cognitive Science, Linguistics and Philosophical Logics. It comprises a number of micro-theories addressing fundamental conceptual modeling notions (types, objects, properties, relations and events among others) [34].

Here we examine scenes and situations building up on UFO's basic concepts and using the theory of *embodiment* as put forward by Fine [13]. The theory has two parts: a theory of *rigid embodiment*, which deals with objects whose constitution is rigid or fixed; and a theory of *variable embodiment*, which deals with objects whose constitution or matter can vary. These notions are the basis to define scenes and situations as wholes constituted by parts.

The paper is further structured as follows: Section II briefly characterizes situations and sets requirements for our approach (largely based on our earlier work in [8], [10]); Section III introduces our proposal to conceive of scenes and situations in terms of Fine's theory of embodiments; Section IV presents the ontological categories characterizing the various constituents of situations and scenes; Section V discusses how scenes and situation types can be defined from these elements; Section VI discusses related work, clarifying in particular how the term scene as used here differs from other notions in the literature. Finally, Section VII presents concluding remarks.

II. Situations: A Preliminary View

Situations are composite entities whose constituents are other entities, their properties and the relations in which they are involved [10]. Situations support us in conceptualizing certain "parts of reality that can be comprehended as a whole" [24] (following [4]). Examples of situations include "John is working", "John has fever", "John is working and has fever", "John and Paul are outdoors, at a distance of less than 10m from each other", "Brazil is under attack", etc. (Technically, the sentences we use to exemplify situations are utterances of propositions which hold in the situations we consider; however, we are interested here in the situations themselves as parts of reality.)

Situations are often reified (such as in [4], [10]), or ascribed an "object" status [26], which enables one not only to identify situations but also to consider its properties. For example, we could consider the location in space and time of a particular situation, which would enable us to say that, e.g., the situation "John has fever" existed yesterday.

As highlighted in "situation theory" [4], situations are characterized by objects (or generally entities) standing in certain relations. For example, the situation that "John is in his room" concerns the objects "John" and "his room" and a suitable relation of "located in".

Occurrences (e.g., events, processes) are also in the realm of the entities that are considered to be in a relation to other entities (objects and other occurrences) [4]. Thus "Brazil is under attack", could be understood as relating an object ("Brazil") and an event or process ("an attack"). If this situation is current, we will naturally be interested in its fate in time, as the attack unfolds, and the constituent events occur. (Our usage of the term "occurrences" in this paper corresponds to the usage of the term "eventuality" by Bach [2] and Galton [14].)

An important feature of situations is that they can be conceived of having a complex mereological structure, with situations constituting other situations. For example, "John is driving and (simultaneously) fiddling with his phone" could be understood as particular structure relating the situations "John is driving" and "John is fiddling with his phone". This hierarchical fashion can be exploited in the reuse of situation specifications ([10], [35]).

Finally, not unlike objects, we are able to consider invariant aspects of classes of situations using some notion of category or type. A situation type [26] (or situation universal [23], [24]) enables us to consider general characteristics of situations of a particular kind, capturing the criteria of unity and identity of situations of that kind. An example of situation type is "Patient has fever". This type is multiply instantiated in the cases in which instances of "Patient" (such as "John", "Paul") can be said to "have fever". Thus "John has fever" and "Paul has fever" are instances of "Patient has fever". These examples reveal the need to refer to entity types such as "Patient" in the conceptualization of a situation type. The same can be said for "has fever" which, in this case, is defined in terms of a particular quality of entities which instantiate the entity type "Patient" (namely "body temperature"). Situation types are also useful in structuring taxonomies ranging from more general situation types (e.g., "Patient has symptom") to more specific situation types (e.g., "Patient has fever").

III. Situations and Scenes as Embodiments

In line with "situation theory", we assume here that situations are parts of reality that can be comprehended as a whole in its own right and in which entities stand in a relation [4]. We propose that situations should be given an explicit entity status using the notion of *rigid embodiment* proposed by Fine [13]: "Given objects a, b, c, ... and given a relation R that may hold or fail to hold of those objects at any given time, we suppose that there is a new object—what one may call 'the objects a, b, c, ... in the relation R.' […] Intuitively, this new object is an amalgam or composite of the component objects a, b, c, ... and the relation R. […] the relation R preserves its predicative role and somehow serves to modify or qualify the components." [13] (The relation R can give place to a single property P in case there is only one object in the embodiment.)

The result of this operation is a whole (the so-called *rigid embodiment*) whose components are related. Fine defines a number of postulates for rigid embodiments including that:

- The rigid embodiment *a, b, c, .../R* exists at time *t* iff the relation *R* holds of *a, b, c, ...* at *t*;
- If the rigid embodiment *e = a, b, c, ... /R* exists at a time *t*, then *e* is located at the point *p* at *t* iff at least one of *a, b, c, ...* is located at *p;*
- The rigid embodiments *a, b, c, ... /R* and *a', b', c', ... /R'* are the same iff *a = a', b=b', c=c', ...* and *R=R'*.

The entities *a, b, c, ...* of a rigid embodiment are *timeless parts* of the rigid embodiment of which they are part. This is because a rigid embodiment does not admit variation in constitution. This does not mean that the rigid embodiment is frozen in time or unchanging, as the parts themselves may change qualitatively, with the rigid embodiment enduring in time. For example, consider the situation "John has fever". John's body temperature may change, and nevertheless, the situation exists as long as his temperature is high enough. As we have discussed before, these entities in the relation may also be occurrences. So, we may conceive of the situation in which "Bob and Clara participate in a meeting". This situation also endures in time as long as they are participating in the meeting and ceases to exist as soon as the meeting ends.

While the notion of rigid embodiment is applicable to conceptualize a situation, it is not suited when the constituent entities may change. Consider the crowd management setting we raised before. How do we conceptualize a particular setting in which "over 10,000 people are located inside the Maracanã soccer stadium"? To deal with this situation solely with the notion of a relation applying to objects, we could abstract away from the persons in the stadium and posit a relation between Maracanã and an abstract quantity, thus involving: "Maracanã", the number "10,000", and the two-place relation "number of people located in". However, this alternative fails to acknowledge the individuals in the situation. In order to account for this, we use the notion of *variable embodiment*.

Fine explains this notion with the following analogy: "We may talk of 'the water in a river.' But this phrase may be understood in two rather different ways. On the one hand, it may be taken to signify that given quantity of water that is, at a given time, the water in the river. In this sense of the phrase, the water in the river at one time is rarely, if ever, the same as the water at another time. On the other hand, the phrase may signify a variable quantity of water—that water, whatever it is, that is in the river. It is in this sense of the phrase that we may say that the water in the river is rising, since it is the very same thing that was once relatively low and now is relatively high. I take it that the water in the river in the second sense—what we may call the variable water—is now constituted by one quantity of water and now by another. […] In the case of the variable water, there is a function, or 'principle,' that determines which quantity of water constitutes the variable water at any given time." [13]

For Fine, a variable embodiment is an individual *f* that at time *t* 'picks up' a particular rigid embodiment according to a given principle *F* (the rigid embodiment is in this case termed *the manifestation of f at t*). Fine also defines a number of postulates for variable embodiments, including: a variable embodiment *f* is present at *t* iff it has a manifestation (the rigid embodiment) at *t*; if *f* is present at *t* then it has the location of its manifestation at *t*. Furthermore, Fine defines what he calls a *transfer principle* recognizing that there are a number of properties of the variable embodiment that hold in virtue of the properties possessed by its manifestation at that time, i.e., properties the variable embodiment inherits from the rigid embodiment at a particular point in time.

He exemplifies how this accounts for changing (or "temporary") parts by explaining how it applies to a car and its parts: "at each time at which a particular car exists, it is constituted by a certain rigid embodiment. This embodiment will be the various major parts of the car (the engine, the chassis, etc.) arranged in the general manner characteristic of a car. As these parts change or as the general arrangement changes then so will the rigid embodiment. Thus, the car will be a variable embodiment /F/ whose principle F picks out various rigid embodiments. And since these rigid embodiments will include the engine and the like as timeless parts, there will be no difficulty in supposing that they are temporary parts of the car." [13]

Our proposal is to conceptualize *scenes* as variable embodiments. We use the term *scene* to denote a variable embodiment whose manifestations (rigid embodiments) are *situations*. Let us consider again (but now with a sharper focus) the *scene* in which "over 10,000 people are located inside the Maracanã soccer stadium." In this case, at each time the scene exists, it is manifested in a situation (rigid embodiment) with a particular number of persons (exceeding 10,000). The *scene* as a whole now remains the same, i.e., keeps its identity, while changing with respect to the number of people in the stadium. The scene is characterized (at a particular point in time) by a number of participants, which it inherits from the rigid embodiment that is manifested at that point in time (this is always more than 10,000 by virtue of the relation that applies in each rigid embodiment). While this *scene* exists, each person that is in the stadium is a temporary part of the scene, as each person is a (timeless) part of a situation that is a manifestation of the *scene*. We are able now to account for how elements of the environment constitute the scene over time. (Note that "scene" was used by Barwise [4] to denote "visually perceived situations". In that sense, they are simply rigid embodiments.)

Fine also employs his theory to other entities capable of having variable constitutions. He exemplifies this in the following passage: "A process—such as the erosion of a cliff, for example— may be taken to be a variable embodiment whose manifestations are the different states of erosion of the cliff." [13] We propose that this feature be used to account for occurrences in scenes. By that, we intend to capture the intuition in the following definition for scene in the dictionary: "a place, with the people, objects, and events in it, regarded as having a particular character" [32]. So, in fact we consider that the occurrences involving the objects that are part of the scene are also parts of scene. The ongoing soccer match (with all its constituent events such as kicks, goals, penalties), an occasional fire, these are all parts of the scene. Because the (past) events are now part of the scene, the scene may have properties that are transferred from those events. For example, we could talk about the total number of penalties in the soccer match, or about the current score of the match (numbers of goals of each team). In these cases, the properties of the whole (scene) are accumulated from all situations that are part of it thus far (a similar idea was applied to occurrences in [15]).

IV. FOUNDATIONAL ELEMENTS

Scenes and situations are ultimately founded on objects, their properties, relations and the occurrences they participate in. In this section, we introduce ontological categories for these entities which constitute scenes and situations. In order to maintain the generality of the notions, we employ broad ontological categories from the Unified Foundational Ontology (UFO). Here we select only those elements that are required to characterize scenes and situations. We adjust terminology for a brief and focused presentation. An in-depth discussion, formal characterization and discussion regarding empirical support for UFO's categories see [18].

A. Entities

We begin with the distinction between types and individuals. Types are patterns of features that can be realized in a number of individuals. For example, "John" and "Mary" are individuals that instantiate the types "Man" and "Woman" respectively. Individuals cover: (i) what we ordinarily call *objects* (a person, a forest, a work of art, a university, a fighter jet, a contract, a marriage), which are existentially-independent individuals; (ii) *tropes* (a person's weight, the height of the Statue of Liberty, John and Mary's marriage), which are objectified properties that are dependent on other entities (named their bearers), as well as (iii) *occurrences* (a soccer match, an earthquake, a school meeting, a bushfire), which are things that can go on in time, involving ultimately the participation of objects and the tropes they bear. The latter category can be subdivided into *events* and *processes*. As discussed in [15] processes embody new events as time passes by and accumulate all previous parts.

Individuals are related to types by the basic formal relation of *instantiation*. The distinctions among individuals are reflected in a taxonomy of *types*. *Object types* have objects as instances (e.g., "Person" is instantiated by "John", "Mary", "Mick Jagger"), *trope types* have tropes as instances (e.g., the quality type "Age" is instantiated by "Mick Jagger's age", "John's age"), and *occurrence types* have occurrences as instances (e.g., "War" is instantiated by "Second-World War", "Earthquake" by "the 1986 Mexico City Earthquake").

Tropes that are dependent on a single individual ("John's body temperature") are termed *intrinsic tropes*. They can be further distinguished into: (i) those that, whenever they exist, have a value in an abstract quality structure and are termed *qualities* (e.g. "a car's weight" has a measurable value in a one-dimensional structure of positive numbers), and (ii) those that cannot be directly associated with a quality structure and that can bear their own tropes are termed *modes* (e.g., "John's knowledge of Dutch", "Mary's belief in God"). Relational tropes that are dependent on a plurality of individuals are termed *relators* (e.g. a marriage, an employment, an enrollment). As discussed in depth in [16], reifying relationships into relators has a number of benefits when contrasted to other strategies to model relationships.

B. Relations

A trope is related to an object (or another trope) by a basic formal relation called *inherence* ("John's height" *inheres in* "John"). A *quality* has a further basic relation to a value which is said to be the *quale of* the quality ("John's temperature" has – at a determined time t_0 – a *quale of* 37C.) *Relators* in their turn, are said to *involve* (or *mediate*) their relata. For example, "Bob and Clara's marriage" *involves* Bob and *involves* Clara.

Objects are related to occurrences by a basic formal relation we call *participation* [19]. For example, "Freddy Mercury" (and many others) *participated* in "1985's Rock in Rio". Similar to the case of objects, the (temporal) properties of occurrences (*begin-point, end-point*) can also be conceptualized using the notion of quality structures. For instance, we can have a quality structure organized into time intervals and time intervals themselves structured into time points. By decoupling the temporal property from its value space, we can have a model of time that admit intervals that are delimited by begin and end points as well as open intervals, continuous and non-continuous intervals, intervals with and without duration (instants) [19]. Occurrences can also have spatial qualities, and can thus be considered located in certain points or regions of space according to suitable quality structures. In addition to participation and qualities, [19] also discusses *causation* as a relation between events.

Beyond the basic formal relations of *inherence*, *quale of a quality, involvement* and *instantiation*, we can identify the so-called *domain relations*. These include *domain formal relations* and *domain material relations*. Domain formal relations are those that can be reduced to the intrinsic tropes of the related entities. For example, "taller than" can be reduced to a comparison of heights. Domain formal relations can also be applied to occurrences, in particular with respect to their temporal locations. This allows us to encompass temporal relations such as the well-known set defined by Allen [1] (see [19] for treatment of these formal relations). Differently from domain formal relations, *material relations* cannot be reduced to intrinsic tropes and require the mediation of a *relator*. For example, "married to" concerns a "Marriage" and the *involvement* of two persons in the same marriage.

V. FORMING SITUATION TYPES AND SCENES

Figure 1 shows an overview of the elements of our ontology, focusing on the taxonomy of foundational elements and on relations involving the notions of situation and scene. Note that scenes have as temporary parts situations, which are constituted by the various entities that are timeless parts of them. A situation also has as a constitutive part a *relation* that applies to its parts. (We have omitted the temporary parthood relation between scenes and entities, as it can be derived by chaining temporary and timeless parts via situations and their constituent entities.) Using these elements, we now concentrate on the definition of situation types and the identification of scenes.

In the case of a situation type, the variety of relations we have identified (basic formal, domain formal and material relations) can be used to articulate more complex relations and thereby define conditions a situation should satisfy in order to be an instance of the type. For example, the situation type in which "Person has fever and is undergoing examination" is

instantiated in situations in which: (i) an object instantiates "Person", (ii) a quality that inheres in the object instantiates "Body Temperature", (iii) the quale of this quality exceeds a certain threshold value; (iv) the object participates in an event that (v) is an instance of "Examination". The qualities of the situation that instantiate this type are transferred from the parts of the situation (the person, the examination).

Instantiating a situation type is not enough to provide a principle for the situations that constitute a scene. We are certainly not interested in putting together a scene that consists of situations with over 10,000 people over different years in Maracanã (assuming that the stadium is empty most of the time). What is required is a criterion of unity for the situations that are part of the scene. This is ultimately the role of the principle of variable embodiment in the theory. Here, we can understand the principle of a scene as a container [13] capable of holding a variety of situations, and the flexibility of the approach to defining scenes can be compared in a metaphor to the variety of container shapes available.

One way of establishing the principle of a scene, is to define a particular "volume of time and space" (using the terminology proposed by Endsley [12] to define situation awareness) and pick up all the situations involving objects and events within these temporal and spatial boundaries (this is similar to the kind of principle discussed for variable embodiments of occurrences in [17]).

Other ways of defining a scene may omit altogether a reference to defined temporal and spatial boundaries, by making reference to individual objects or occurrences. We could for instance make reference to an individual process as part of the principle. Consider for example "the scene involving all objects and events during Rock in Rio second edition in 1991". The process "Rock in Rio second edition" is key to determining the situations that constitute the scene. At every instant in which the scene exists, it has as temporary part a situation in which the particular process is ongoing, and which contain as parts the objects that participate in the process. Whenever participants enter or leave the process or new events unfold with the participants, new situations come into existence and become part of the scene. In addition to these situations, all situations involving as parts the objects participating in "Rock in Rio second edition" are parts of the scene, along with all other events in which they participate while participating in the process (a phone call, a kiss, a fight). Note that the spatial and temporal properties of a scene defined in this way are not elements of the principle. They are however, transferred from the parts to the scene.

The same approach can be used to establish a scene with respect to the participation of a particular object in an event. For example, we may be interested in the scene involving an agent such as a jet pilot during a flight. In this case, the scene consists in all the objects and events that exist and take place in the vicinity of the pilot. The spatiotemporal boundaries of the scene vary according to the location of the pilot and a distance threshold defined for the scene.

The various ways to define scenes can be combined to reflect the interest or scope with which it is conceived: e.g., other scenes could have been identified by further constraining time boundaries (the scene that unfolded during the first half of "Rock in Rio second edition"), by setting spatial boundaries (to consider only the objects and events in the stage area of "Rock in Rio second edition"), by making reference to the types of entities of interest (e.g., to consider only the actions of the soccer players and the referees, and leave out actions of the crowd).

Finally, note that the model shown in Figure 1 accounts for the mereological structure of scenes and situations, and in particular allows for these entities to be composed of other scenes and situations. This allows us to build scenes composed of other scenes, situations composed of other situations, and even situations composed of scenes (in which case the relation between the scenes is fixed). For example, we could be interested in the situation in which there are two parallel scenes (e.g., two scenes each involving a protest in a city). In this case, the relation between the scenes is a temporal relation of overlap [1], and the situation exists whenever the

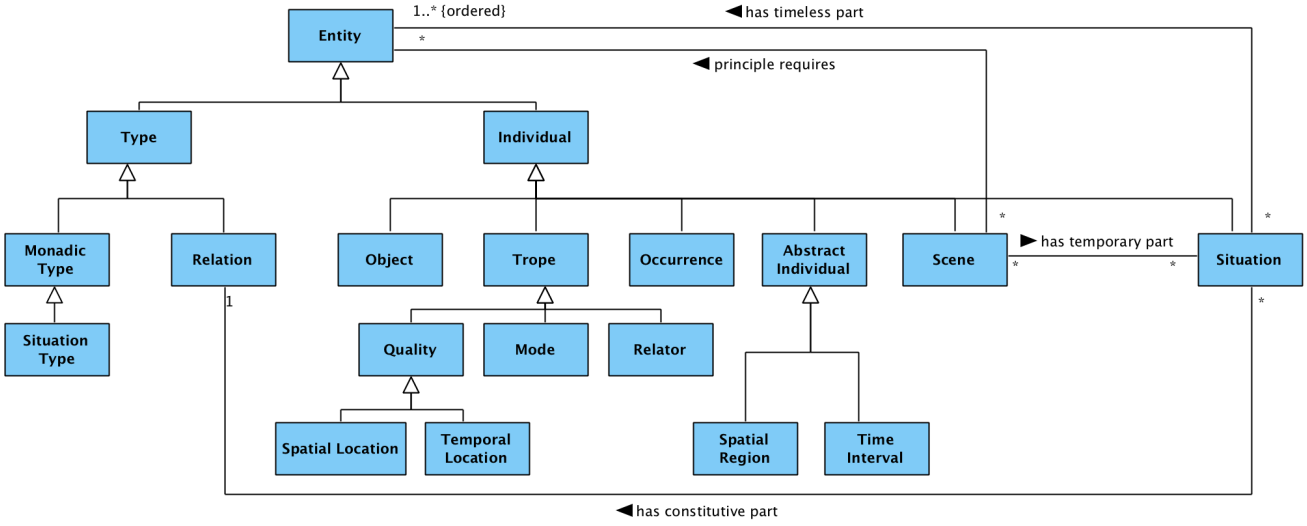

Figure 1 Relating scenes and situations to their constituent elements

scenes are ongoing in parallel (see [8] for a discussion on the use of Allen relations to ongoing situations).

VI. Related Work

There are a number of ontology-based approaches to situation in the literature. We focus here on those that, similar to our work, reify particular situations or that use a notion akin to our notion of scene. (See [36] for a survey of situation specification approaches, including ontology-based ones.)

In [28], Matheus et al. proposed a core ontology for situation awareness (the core SAW ontology.) They focus on situations following Barwise's situation theory, and, concerning the situation fragment of SAW (situation objects, situations and relations), our approach is quite similar to theirs. Differently from our approach, they did not identify a notion akin to scene, or address the mereological structure of situations in time. Events are used in the SAW ontology to represent sensor observation occurrences, not covering thus processes and other real-world occurrences. Four years later, the same group of authors (in [26]) proposed the STO ontology, which extended SAW to cover also the agent's perspective. The account appeals to the notion of *infon* or informational content, following closely Devlin [11]. STO is aligned with SAW concerning the basic elements for situations and as such does not aim to cover scenes. Considering the examples given in [26], occurrences seem to be implicitly modelled through relations between participants. In [5], Baumgartner et al. have extended SAW and STO by addressing spatial and temporal relations as primitive elements of the proposed "BeAware! SAW core ontology". Occurrences such as "Accident", "Traffic Jam", and "road weather-related concepts" are treated as "Objects". No notion similar to scene is employed.

Concerning the fragments in which the SAW and STO core ontologies overlap with our own, we believe the approaches can be combined (and thus support both scenes, the agent's perspective and a comprehensive set of spatio-temporal relations).

With the purpose of facilitating event detection in surveillance video applications, SanMiguel et al. [31] have proposed a basic ontology to describe the contents of a "scene", including objects and occurrences. Differently from our approach they focus on the contents of the scene rather than on the notion of scene itself. This seems justifiable given their intended application, which is interested in the portion of the world that "can be observed by one or several cameras".

There are also a number of works approaching similar notions in the applied ontology literature. For example, our notion of scene is similar to that of *situoid* as proposed for the GOL foundational ontology by Hoehdorf and colleagues [23], [24]. In GOL, a situoid is an occurring entity that, in the same spirit of our scenes, can include endurants and other occurring entities (e.g., events and processes). A situation, in contrast, is said to be an endurant and a projection of a situoid into a time boundary. Situoids are said to be "more than a mere sequence of situations" [24], as situoids can also include continuous processes. Unlike our scenes, however, situoids are bound to connected spatiotemporal regions. In [24], the author writes: "Since we believe it impossible to comprehend entities, that are separated in time or space, as a whole, we will restrict situoids and situations to connected space and time locations." We, instead, pose no such a limitation to our scenes, since they can also be defined by occurrences (as well as objects) that do not have themselves to be spatiotemporally connected. We take spatiotemporally connected regions as just one of the possible "containers" for defining a scene.

The term scene was also used by Guarino and Guizzardi recently in [17]. In that work, scenes are maximal occurrences located in a convex region of space-time, containing all occurrences that take place there as parts. The approach to scenes we have used here diverges from that one in that scenes are not constituted solely by occurrences, but also include objects in their constitution. Further, we have discussed principles of individuation of scenes that differ from the one suggested in [17]. Despite the terminological difference, both approaches can be combined to focus on the whole scene (in our sense) or on the occurrences that are part of a scene.

Finally, the work of Little and Rogova [27] has stressed the importance of formal ontology to obtain solid grounds for higher-level fusion in situation awareness. They have explored the distinctions underlying the BFO ontology and in its SNAP/SPAN portions, to argue that both objects and occurrences (and their interrelations) are key to characterizing knowledge about the environment. They propose that ontologies for situation awareness should use the distinctions of foundational ontologies, in particular reuse the various formal relation types that they define. Our approach is fully aligned with the vision they put forward, although we explore a different foundational ontology (UFO) [18], [20]. With the notion of scene, we offer a more concrete means to apply some of foundational considerations for situation ontology in [27].

VII. Concluding Remarks

In this paper, we have approached the notions of scene and situation using the theory of rigid and variable embodiment of the philosopher Kit Fine. This has enabled us to provide a general account for how situations constitute a scene in time. We have also discussed how scenes can be formed out of more basic elements of a foundational ontology.

We consider this to be the first step in a research agenda to clarify and employ these notions in conceptual modeling and situation awareness applications. Further work is required in the refinement of the ontology and in particular in its formalization. One area of attention concerns the specification of the principles that define scenes (and their types). We believe that a taxonomy of (general-purpose) scene types may arise out of the various ways in which a scene's principle can be defined. Identifying these general scene types is a pre-requisite to addressing the specification of domain-specific scenes and scene types. We believe that reifying types in the spirit of [6] is required to establish invariant rules for scenes in terms of object types, relator types, quality types, process types, etc.

In our earlier work, some of us have also addressed: (i) the specification of situation types in a domain-specific situation modeling language (SML) [8] and (ii) the runtime detection of situations in a rule-based platform [29]. We intend to investigate how to extend both approaches to address scenes fully. Concerning the domain-specific language, it does already include some support for modeling scene types. However, this support is limited to the use of an existence quantifier to allow for flexibility in parts of a scene. No support for occurrences is present, and the types are defined solely in terms of the types of objects, their qualities and relations. Concerning the rule-based platform, we intend to identify which kinds of scene forming principles can be included in the platform, and that can be the basis for the efficient detection and management of scenes at runtime. Further, the notion of scene (since it is properly integrated with the notion of occurrence) will guide us in integrating the current situation detection approach with the existing event processing capabilities of the rule-based platform we employ.

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