Comprehensive Survey on Ontologies about Event

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Abstract

In the literature, the notion of an event is ubiquitous. An event can be defined as a specific occurrence of something (action or series of action) that happens in a certain time, a certain place, due to certain reasons, involving one or more participants (such as objects, humans) and can frequently be described as a change of state. Formally it can be represented as a hexa-tuple: $e = \langle \mathbf{W}hat, \mathbf{W}here, \mathbf{W}hen, \mathbf{W}ho, \mathbf{W}hy, \mathbf{H}ow \rangle$. The elements of hexa-tuple are called *event elements*, that respectively describe **W***hat*: change and action, **W***hen*: specific time, **W***here*: possible place, **W***ho*: active/passive entities **W***hy*: possible reason of cause and **H***ow*: method by which an action was performed. This overview examines how existing ontologies represent an event and how they handle the representation of its 5W1H characteristics elements. The intent is not to present the ontologies fully in detail as overviews already exist, but rather to help to choose the ontology that will cover specific requirements based on the characteristics elements of an event that need to be represented. Furthermore, we are presenting the ideas how to represent 5W1H event constituents by creating a new event ontology.

Keywords

event, event ontology, event representation, event ontology model, semantic web

1. Introduction

With the constant growth in event-centric information on the web, news, and social media platforms (such as Twitter, Facebook etc.), the representation of events by assessing and analyzing an abundant amount of event-centric information plays an important role in a wide range of real-world applications in other domains. In the state of the art, an event is described as anything that happens at a particular time and location [1] such as meetings like phone calls and purchases, but also business buyouts, changes of management and health crises. Knowledge of these events is essential for humans to make decisions that will have an impact on future events. Many innovative applications can benefit or even emerge from a technology capable of extracting events from various sources, representing them, aggregating them, and exploiting them to predict future events. We can for example cite: anticipating demand for sanitary products, the supervision of

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cultural, advertising or festive events; but also the study of competition, the study of commercial markets, etcetera.

Ontologies were introduced to the computer science field around twenty years ago as a knowledge representation [2]. In recent years, several ontologies have been proposed and published to represent events using semantic web technologies, such as Event Ontology [3], Linked Open Description of Events (LODE) [4], F-model [5], Simple Event Model (SEM) [6]. Ontologies are classified as upper ontologies (domain-independent ontologies) and domain ontologies (ontologies related to specific areas of interest). Examples of upper ontologies representing events are BFO [7], UFO [8], DOLCE [9], YAMATO [10], SUMO [11] and examples of domain specific ontologies are CIDOC-CRM[12], ABC [13]. In other studies [14, 15], researchers discussed an overview and compared existing event models on their ability to represent spatial, temporal and the participants in the event. We propose an event definition in the paper based on the review of existing event definitions. This survey examines how existing ontologies represent the event and what it constitutes concerning 5W1H event element representation. The intent is not to present the ontologies fully in detail as overviews [16, 15, 17, 14] already exist, but rather to help to choose the ontology that will cover specific requirements based on the characteristics elements of an event that need to be represented. Tzelepis et al. [16] reviewed the notion of an event in multimedia. They also discussed the approaches for event representation and modeling and event inference methods for the problem of event identification in the audio, visual, and textual content. Astrova et al. [15] described the five ontologies: OpenCyc, Event Ontology, Event Model F, LODE, and ABC. They presented the main concepts such as time, space, participation and causality. Rodrigues and Abel [17] reviewed the ontology-based conceptual modeling of occurrents/events. They assessed 11 different ontologies (6 upper ontologies: YAMATO[10], UFO [8], DOLCE [9], SUMO[11] and the GFO [18, 19]) and five other ontologies: Event Model-F[5], SEM, ESO[20], VEL[21] and KAN[22]. The researchers have analyzed some general aspects: definition, participation, mereology, and causation. Similar to Astrova et al. [15], Ali et al. [14] described the eight ontologies: Event Ontology, SEM, Event model-F, LODE, OpenCyc, BBCCORE, SNaP and ABC. The objective of their study was to review, analyze and compare the design choices of these ontologies for representing the events. In this paper, we examine how existing ontologies such as CIDOC-CRM, Event ontology, LODE, F-model, SEM, FARO, ABC and DOLCE DnS Ultralite (DUL) are representing the event and what it constitutes concerning 5W1H event representation. Furthermore, we are presenting ideas on how to represent 5W1H event constituents by creating a new event ontology by introducing new classes to represent the "HOW" element of 5W1H and integrating FARO relations.

The remainder of this paper is organized as follows: Section 2 discusses the definition of event. Section 3 presents the event-based ontologies and the last section presents the conclusion and future directions.

2. Overview of Event Definition

In the literature, the notion of an event is ubiquitous; however, researchers have proposed different definitions concerning specific domains even though they share common characteristics [16, 23]. For multimedia, researchers have introduced event notion as a change of state in multimedia entities such as audio or visual. In the social media domain, events are defined as a change in the size of textual data that concerns the associated topic at a specific time and location [24]. Both multimedia and social media event definitions describe the event as a change. The research journey of events and their constituents started in 1950 [25, 26, 27, 28] Mourelatos [27] in 1978 and Pustejovsky in 1991 [28] probed events and presented the basic definition of events such as Mourelatos [27] defined events in ontological terms as intrinsically countable situations whereas Pustejovsky [28] described the basic event structures associated with verbs. Allan et al. [1] regarded an event as anything that happens at particular time and location. For example, "The Eruption of Mt. Pinatubo on June 15th, 1991"[1]. Automatic Content Extraction (ACE) [29] defined an event as a specific occurrence of something that happens involving participants (such as persons, locations, time, etc.), which can frequently be described as a change of state. The study [30] addressed event processing; defined an event as a real-world happening that a system has grasped. Horie et al.[31] explained an event as a certain action and represented it with the 5Ws (who, whom, what, when, and where). For a given occurrence as a sentence, they decomposed the sentence using dependency parsing into the associated subject, object, temporal/time, and location as 5Ws (who, whom, what, when, and where) respectively. Chen and Li [23] described the events as an action or series of actions or a change occurring at a particular time for specific reasons involving entities such as objects, humans, and locations. Considering generality, Chen and Li adopted the representation of an event composed of 5W1H (What: change and action, When: specific time, Where: possible place, Who: active/passive entities and Why and How: possible reason)[23]. Furthermore, Chen and Li categorized the event form into four categories on the basis of 5W1H: Explainable events (events with 5W1H non-empty values), completely formed events (events with What, Who, Where, When, and How values), well-formed events (events with What, When, Where, and Who values) and loosely formed events (events with less than 4 non-empty values in 5W1H representation). Further, Hamborg et al. [32] discussed that "why" answers the reason or cause of the event and "how" answers the method by which an action was performed. Hamborg et al. [32] research work focused on extractions of event characteristics from News articles. Other research work [33] focused on social media event detection and defined events as an occurrence of interest in the real world that initiates a dialogue on the event-related topic among diverse social media users. Another common definition is a series of actions accomplished between more than one agent (referring to people or machines)[34]. Like Allan et al.[1], Dou et al.[24] described social media events as a change in the size of textual data that concerns the associated topic at a specific time and location. Wang et al. [35] designed a verb based approach to extract news event information using 5W1H (Who, What, Whom, When, Where, and How).

Definition of event Based on the different definitions previously cited, we propose to consider an event as the specific occurrence of something (an action or series of actions) that happens at a certain time, a certain place, due to certain reasons, involves one or more participants (such as objects or humans), which can frequently be described as a change of state. Formally it can be represented as a hexa-tuple: $e = \langle \mathbf{W}hat, \mathbf{W}here, \mathbf{W}hen, \mathbf{W}ho, \mathbf{W}hy, \mathbf{H}ow \rangle$. The elements of hexa-tuple are called event elements, where $\mathbf{W}hat$: change and action, $\mathbf{W}hen$: specific time, $\mathbf{W}here$: possible place, $\mathbf{W}ho$: active/passive entities $\mathbf{W}hy$: possible reason of cause and $\mathbf{H}ow$: method by which an action was performed. The form of event represented by this hexa-tuple is also known as an explainable event. Figure 1 illustrates the example of event with its

On January 25, 2023, a car accident happened in Toulouse;due to fog car driver didn't see the bus and hit the bus.
5W1H:What, When, Where, Who, Why and How .

Figure 1: Example of event. Highlighted phrases are representing the 5W1H event characteristics.

elements. In figure, highlighted phrases are representing the 5W1H event characteristics. An Event class can be defined as set of event showing the similar characteristics and represented by $C_E = (E, \mathbf{W}hat, \mathbf{W}here, \mathbf{W}hen, \mathbf{W}ho, \mathbf{W}hy, \mathbf{H}ow)$ where E is the set of events and also called an extension of event class. Where $(\mathbf{W}hat, \mathbf{W}here, \mathbf{W}hen, \mathbf{W}ho, \mathbf{W}hy, \mathbf{H}ow)$ are the intentions of the event class, which are the set of the same characteristics of some aspects of each event. Event ontology defined as quadruple $E_onto = (C_Es, P, A, I)$ where $C_Es = (C_{E1}, C_{E2}, ..., C_{En})$ is the set of event classes, P is the properties, and A is the Axioms, and I is the instantiation.

This survey examines how existing ontologies represent the event and what it constitutes concerning 5W1H event representation.

3. Ontologies about Event

In this section, we discuss the existing event ontologies. Several different ontologies about event have been developed with classes and properties to model event. For this survey, we adopted our event definition to understand the components of events defined by existing event ontologies. Therefore, we selected ontologies that represent event. There are also other ontologies such as OpenCy, BBCCore, Simple News and Press(SNap) [14] and CultureSampo [6] that represent events but have very little documentation available, so we have not considered them for this survey. Table 1 presents the list of selected existing event ontologies with their design purpose and URI. Table 2 describes the definition of top-level event classes of event ontologies. Now, we explain each ontology one by one and discuss how it represents the Ws elements of our definition.

3.1. Existing Ontologies

CIDOC-CRM [12] was built to represent museum artifacts and to enhance their exchange across musea. This model is large, with 140 classes and 144 properties. A subset of this model can be used to describe events [6]. Some properties permit interlinking events such as temporal relation (P176 starts before the start of), mereological relation (P9 consist of), causal relation (P17 was motivated by) [36]. In this model "What" is defined by "E2 Temporal Entity" class, it includes all phenomena such as the instances of classes "E4.Periods", "E5.Events" and "state" that occurred over a period of time. "Where" is denoted by the property "P7.took place", instances of class "E53.Place" may have the location names, but it does not link an event to the location name except by particular spatial extent [4]. "When" is represented by property "P4.has time span", the time at which the event occurred. "Who" is defined by two properties: "P12.occurred in the presence of" and "P11.had participant". "Why" is denoted by "P17 was motivated by" that explains an item or items that are considered as a basis for carrying out the activity. It represents an event with 5Ws.

Table 1
List of ontologies representing event

Event Model/ Ontology	Design Purpose
CIDOC-CRM[12]	museums and libraries, class based model with few constraints
Event ontology[1][3]	digital music, property-based model with few classes and constraints
LODE[4]	event as linked data, domain-independent, property-based model with few classes and constraints
F-model[5]	pattern-oriented ontology for capturing and representing occurrents in the real world
SEM[6]	representation of events on the web, domain-independent, class based model with properties and constraints
FARO[36]	Ontology for representing different types of relationships between events and conditions
ABC[2][37]	digital libraries, class based models
DOLCE DnS UL (DUL)[3]	event aspects in social reality

[1] https://motools.sourceforge.net/event/event.html
[2] https://dcpapers.dublincore.org/pubs/article/view/655
[3] http://www.ontologydesignpatterns.org/ont/dul/DUL.owl

Event ontology was designed by the Centre for Digital Music at Queen Marie, University of London, to represent digital music events such as performances or sound generation. It employs a simple, straightforward design pattern and includes four classes (Event, Agent, Factor, and Product) and seventeen properties. This ontology describes the minimal event and uses external vocabulary such as foaf:agent [6]. Events represented by this model are well-defined events with 4Ws. In this ontology, “What" is defined by “Event" class, “Where" is denoted by “place" property, which relates an event to a spatial object, “When" is described by “time" property, which relates an event to a time object, and “Who" is represented by one property: “agent" and two classes: “Factor" and “Product". “Factor" class describes passive participants, such as a tool or instrument, whereas property agent depicts active participants, such as a person or computer. “Product" class defines something produced during the event, such as a sound or pie.

DOLCE DnS Ultralite (DUL) is a lightweight upper ontology that has been considerably reused and it is a foundational ontology. It delivers a set of upper-level notions to enable interoperability among ontologies. The most heightened notion of the DUL is dul:Entity; beneath this notion, four disjoint classes are described: dul:Event, dul:Object, dul:Abstract and dul:Quality. dul:Event defines perduring entities that develop over time (for example, an event takes place at a time). dul:Object describes enduring entities that evolve over space (for example, active or passive entities). The dul:Quality defines the aspect of the instances of dul:Event and dul:Object. dul:Abstract class defines value spaces (for example, time interval of the event) [38]. In this model, “What" is described by the “Event" class, “Where" is denoted by two properties: “hasRegion" and “hasLocation" where the “hasRegion" property is the relation between entities and region, and “hasLocation" shows the relative spatial location. “When" is defined by two properties: “isObservableAt" and “hasTimeInterval" where “hasLocation" is a relation that shows past, presentm or future “TimeInterval" at which an Entity is observable, and “hastimeInterval"

Table 2
Event-based class definition from ontologies

Event Model/Ontology	Definition
cidoc:E2.Temporal.Entity	"[E2.Temporal Entity] comprises all phenomena, such as the instances of E4.Periods,E5.Events and states, which happen over a limited extent in time."[12]
eo:Event	"An arbitrary classification of a space/time region, by a cognitive agent."[3]
lode:Event	""Something that happened," as might be reported in a news article or explained by a historian."[4]
F-model:Event	"...perduring entities (or perdurants or occurants) that unfold over time, i.e., they take up time.."[5]
sem:Event	"Events are things that happen. This comprises everything from historical events to web site sessions and mythical journeys. Event is the central class of SEM."[6]
faro:Event	"A possible or actual event, which can possibly be defined by precise time and space coordinates."[36]
abc:Event	"An Event marks a transition between Situations."[37]
dul:Event	"Any physical, social, or mental process, event, or state."[4]

[4] http://www.ontologydesignpatterns.org/ont/dul/DUL.owl

property is a relation between events and time intervals. "Who" is also denoted by two properties: "hasParticipant" and "involvesAgent" where "hasParticipant" shows a relation between two objects participating in the same event and "involvesAgent" presents agent participation.

LODE ontology describes historical events as Linked Data and map other event-related vocabularies and ontologies like the CIDOC-CRM, Event Ontology, and DUL by using owl:sameAs and rdfs:subPropertyOf [6]. The main objective of this ontology is to minimal modeling of events. It has one class, i.e. "Event" and six properties: "atTime", "Circa", "inSpace", "atPlace", "involved" and "involvedAgent". In this model, "Who" represented by two properties: "involved" (physical, social or mental object) and "involvedAgent" (involved agent); "Where" is denoted by two properties: "atPlace" (named or relatively specified location) and "inSpace" (an abstract location (for example, a geospatial point). Similar to "Who" and "Where", "When" is also represented by two properties: "atTime" (abstract or interval of time) and "circa" (precisely explained by calendar dates and clock times).

F-model is a formal model developed on top of the DUL ontology, a lightweight upper ontology [5] to facilitate the response to emergency events [36]. It describes new properties and classes for modeling participation in events, causal relations and correlation between events. It presents six patterns: participation pattern, mereology pattern, causality pattern, correlation pattern, documentation pattern and interpretation pattern [39]. In this model, events contain different kinds of information, such as object involved (active/passive), stored time point (absolute/relative). The F-model does not describe any taxonomy or type of event except for those that illustrate the roles played by the events within each pattern, such as component [17]. It doesn't provide a direct association between the composite super event and its elements sub-events (similar for cause-effect) [36]. In this model, "What", "Where", "When", "Who" and "Why" are defined by

“Event" class, “SpaceRegion" class, “TimeInterval" class, “hasEventParicipant" property, and “Cause" class respectively. It is a complex model that is difficult to understand and adopt.

The SEM was developed to represent events in the broadest essence emanating from diverse disciplines such as history, culture, heritage, multimedia, and geography without using domain-specific vocabulary. There are four core classes: “sem:Event" (to record “what" happens), “sem:Actor" (“who" or what participated in the event), “sem:Place" (“where" did it happen), “sem:Time" (“when" did it happen). The SEM model does not allow to link different events nor provide a relation between the classes of the same type except “sem:hasSubEvent". SEM represents an event with the 4Ws (What, Who, Where, and Who) that is well-formed. The most common point between SEM and Event ontology is the modularity in the design: the majority of the classes are optional in Event ontology [6]. SEM also describes the notion of views by which events are considered [17]. Researchers have applied SEM for abstracting and reasoning overship trajectories [40] and some researchers have extended SEM to build narrative structure [41], biographical timeline generation [42], Multi-modal Event Knowledge Graph towards universal representation [43] and a tourism knowledge graph [44]. SEM has also been used for modeling case activity in the building and application of Covid-19 infectors activity information knowledge graph [45]. Bosanska et al.[46] have used SEM to visualize EHR data in RDF format as an evolving sequence of events and sub-events in time.

ABC event model was built within the Harmony international digital library project to deliver a standard abstract model to enable interoperability between metadata ontologies from various disciplines. This model is used for metadata definitions of complex objects supplied by CIMI museums and libraries [37]. In this model, “What" is defined by “Event" class, “Where" is described by the “Place" class, which represents the spatial location, “When" is denoted by the “Time" class which shows either a time span or point in time, and “Who" is represented by “Agent" class, which describes participants (may be persons, instruments, organizations, etc.) present during an event.

FARO has been designed to represent event and fact relations. It was released last year. It permits the representation of 25 different relations, such as contingent relations, temporal relations, comparative relations, and mereological relations. The main objective is to devise a structure that makes it likely to guide through semantic links between events, exploring the flow of events backward, forward, or passing through other connections [36]. In FARO, “What" is defined by “Event" class, and “Why" is represented by “causes" property, which connects an event with its effect. FARO does not represent “When", however, it allows temporal relations, this means FARO Event has the answer of “When" implicitly. FARO ontology mitigates the limitations of SEM to some extent. The limitation of SEM is that it does not allow to link different events nor provide a relation between the classes of the same type except “sem:hasSubEvent".

4. Analysis

Table 3 depicts the Excerpt of approximate mapping classes and properties from event ontologies representing components of 5W1H. Considering the 5W1H features of the listed existing ontologies that are presented in Table 3 their focus and approach differ. However, as these ontologies treat events as objects at the same level, these models have pros and cons, which are explained in

Table 4. As we have described in Section 2, there are four types of events on the basis of 5W1H: explainable events, completely formed events, well-formed events and loosely formed events. From Table 3 it is observed that the majority of ontologies represent well-formed events with 4Ws (What, When, Where, and Who) except CIDOC-CRM, F-model, and FARO. Well-formed events are considered as essential components within completely formed and explainable events since they lack a latent relationship among them.

Table 3
Excerpt of approximate mapping classes and properties from Event Ontologies representing components of 5W1H

Name of Ontology	What (change and action)	Where (possible place)	When (specific time)	Who (Participants)	Why (causes)	How (method)
CIDOC-CRM [12]	E2 Temporal.Entity: class	P7.took place at: property	P4.has timespan: property	P12.occurred in the presence of: property, P11.had participant: property	P17 was motivated by	✗
Event ontology [3]	Event: class	place: property	time: property	agent: property, Factor: class, Product: class	✗	✗
DUL	Event: class	hasRegion: property, hasLocation: property	isObservableAt: property, hasTimeInterval: property	hasParticipant: property, involvesAgent: property	✗	✗
LODE [4]	Event: class	atPlace: property, inSpace: property	atTime: property, circa: property	involved: property, involvedAgent: property	✗	✗
F-model[5]	Event: class	SpaceRegion: class	TimeInterval: class	hasEventParticipant: property	Cause: class	✗
SEM [6]	Event: class	Place: class	Time: class	Actor: class , Object: class	✗	✗
ABC	Event: class	Place: class	Time: class	Agent: class	✗	✗
FARO [36]	Event: class	✗	✗	✗	causes: property	✗

None of the ontologies have represented explainable events. Explainable events are long-term events that have multiple elements and relate to them in different relationships (e.g., evolution and causal relationships) [23]. These events are represented by 5W1H. These events can be used to gather and store all related events of a specific event so that intra-event analysis can be conducted. These events are ideal for mundane people to comprehend clearly why and how they happen. Specifically, these events have sufficient information about their relationships with different events, which is helpful and necessary for numerous invaluable event-related applications, such as hierarchical event search, missing data recovery, event prediction, etcetera [23].

From our considered ontologies, CIDOC-CRM and F-model ontologies are representing the events with 5Ws, which answer the "Why" question. CIDOC-CRM has many classes and properties, but only a subset defines the event. In contrast, event model F is complex and challenging to understand and adopt. The events represented by these ontologies are not completely formed events because completely formed events are represented by 4W1H skipping "Why" from 5W1H. Completely formed events act as the intermediary between explainable events and well-formed events. Similar to explainable events, these events have multiple elements to comprehend how they happen and evolve, and this knowledge can be used in some event handling applications such as event prediction and event evolution pattern discovery[23].

Among existing ontologies, CIDOC CRM and ABC are designed in domains closely related to libraries. However, these ontologies do not align with other upper ontologies. CIDOC CRM is more complex than ABC Ontology, which is simpler and more event-centric than CIDOC CRM [47]. However, both ontologies are domain-dependent ontologies, and they do not support interoperability. The SEM, LODE, and Event Ontology are similar to each other. These ontologies are simple without many constraints and also enable interoperation. The FARO ontology is rich in representing the relations between events.

Table 3 shows that different ontologies that have represented W's by classes and object properties. The majority of ontologies have created a class Event to represent Event. It is observed from Table 2 that the Event class definition of the considered existing ontologies shares the common characteristics of something that happened/occurred over or at a specific time and place. CIDOC does not make a clear distinction between "E2.Temporal.Entity: E3.Condition_state and E5.Event" [4]. All ontologies represent the "Where" constituent of 5W1H except FARO ontology. ABC, CIDOC, and Event ontology only provide linking to spatial regions. The place/space distinction between Place and SpaceRegion is explicitly described in LODE and DUL[4]. SEM is using WGS841[5] vocabulary to support absolute spatial information. Defining the difference between named regions and spatial regions facilitates appropriately dealing with places that change their spatial location over time[4]. There are two methods to link the time to the Event[4]. The first method is to link the Event using datatype properties like XML schema datatypes such as xsd:date or xsd:dateTime. The second method links the Event by presenting a class for representing time intervals and using object properties to connect event instances with instances of this class[4]. ABC, CIDOC, and EO are using the second method. The Event Ontology employs "TemporalEntity" class from Owl-Time. [48]. DUL supports both methods. LODE is using "TemporalEntity" from OWL-Time like Event ontology. LODE declare "atTime" as a subclass of DUL's "isObservableAt" property, and it is also a sub-property of CIDOC's "P4.has_time_span". To represent WHO, ABC ontology describes one class: "Agent" and two properties: "involves" and "hasResult" for connecting an Event to a tangible thing. CIDOC-CRM describes a property "P12.occured_in_the_presence_of" like ABC involves property that relate "E5.Event" to a "E77.Persistent_item" (it includes tangible and intagible concepts)[4]. DUL describes a property "hasParticipant" for connecting an Event to an Object. DUL objects comprise social, mental, and physical objects. Event ontology has not defined a range for factor properties. Its property product

[5] http://www.w3.org/2003/01/geo/

is similar to “hasResult" property of ABC, which connects an Event to something that is the result of the Event. LODE describes property “invovled" to connect events to arbitrary things and defines “involvesAgent" property to connect events to agents. These two properties are equivalent to DUL properties “hasParticipant" and “involvesAgent" respectively, and indirectly equivalent to CIDOC’s “P12.occured_in_the_presence_of" and “P11.had_participant" [4]. SEM defines class “Actor" that connects an Events to entities that participated either actively or passively in those Events. It also defines class “Object" as a subclass of “Actor" to represent passive and inanimate actors. It is also observed from Table 3 that CIDOC-CRM, F-model and FARO ontology are representing the “Why" element of 5W1H. FARO ontology represents Why implicitly through “FARO:causes". Because according to the definition provided by FARO, “FARO:causes" can be used to connect the Event with its effect. However, when we have the scenario, where Event A causes event B, in this case, FARO:causes will answer the “Why" question of event B. None of the ontologies have represented the How element of 5W1H characteristics.

5. Our ideas for a New Event Ontology (NEO)

From our analysis, it appears that currently, in the literature, no ontology exists that represents an explainable event with 5W1H. SEM is one of the most popular models among existing ontologies and has been applied to many research works [40, 41, 42, 45, 43, 46, 44]. These studies shows how researchers have extended SEM to represent events to fulfill their requirements. Similarly, we have created NEO by extending SEM to represent explainable events with 5W1H by integrating some other ontologies, such as the FARO ontology, which is rich in relations, and introducing new classes and properties to represent “How". The schema of NEO is presented in Figure 2 based on SEM. We have created “NEO:Event" to represent the event as a subclass of “sem:Event" and “FARO:Event" and other key classes of SEM and NEO are “sem:Actor" representing active/-passive entities participating in the event, “sem:Place" representing the location, and “sem:Time" representing the time. We have also introduced new sub-classes in “sem:Core" to represent Why and How by “NEO:Cause", and “NEO:Method" respectively. Events are connected to entities, places, time, cause, and method through the object properties “sem:hasActor", “sem:hasPlace", “sem:hasTime", “NEO:caused_due_to" and “NEO:how_it_occur" respectively. In this NEO, we have mitigated the limitation of SEM by creating “NEO:Event" as a subclass of “FARO:Event" that provides a rich set of relations that connect different events. Figure 3 illustrates the example of NEO with 5W1H. In this example, we cannot use “FARO:causes" because, according to the definition provided by FARO, “FARO:causes" can be used to connect the event with its effect. However, when we have the scenario where event A causes event B, in this case “FARO:causes" will answer the “Why" question of event B. Generally, “Why" constituent is the most difficult to obtain among other constituents since human resources need to be greatly involved [23]. Two important relationships (i.e., the content reference relationship and the dependence relationship) among events can provide information about the Why dimension[23].

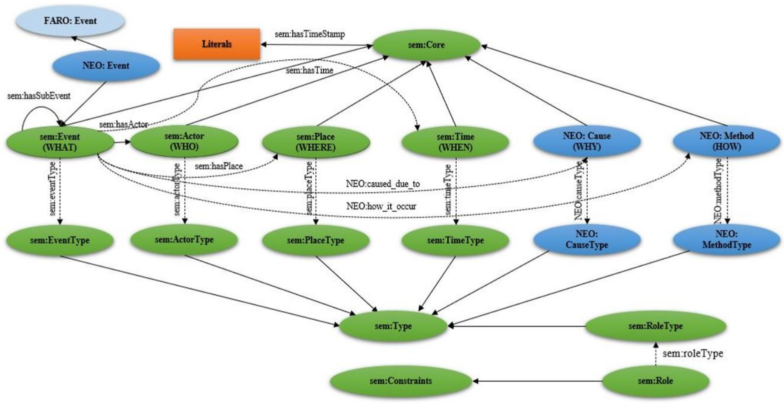

Figure 2: New Event Ontology (NEO). Regular arrows representing rdfs:subClassOf properties between the classes and dash lines with arrow are representing rdfs:domain and rdfs:range restrictions on properties between instances of the classes

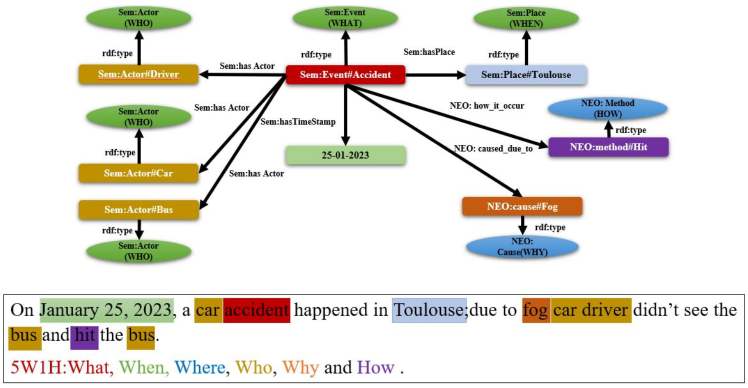

Figure 3: Representation of Example through NEO to represent 5W1H.

6. Conclusion

This research article examines how existing ontologies represent the event and what it constitutes concerning 5W1H event representation. The intent is not to present the ontologies fully in detail as overviews already exist, but rather to help to choose the ontology that will cover specific requirements based on the characteristics elements of an event that need to be represented. In this paper, we presented an overview of the event definition and discussed how the event definition has evolved. Furthermore, we described the existing ontologies representing the events and we have also explained existing ontologies' pros and cons. From our analysis, it has been observed that none of the ontology has represented the explainable events, i.e., 5W1H. However, explainable events representation with 5W1H characteristics can be achieved by creating a new ontology that describes all constitutes of 5W1H. Therefore, we have proposed a tentative draft of New Event Ontology (NEO) to represent 5W1H characteristics elements by integrating multiple ontologies such as SEM and FARO and introducing new classes NEO:Cause and NEO:Method to answer the question “Why" and “How" respectively. Furthermore, to overcome the limitation of SEM, we have created NEO:Event as a subclass of FARO:Event that provides a rich set of relations connecting events to different events.

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Table 4
Pros and Cons of Existing Ontologies

Name of Ontology	Pros	Cons
CIDOC-CRM [12]	It is one of the prevalent models among libraries and cultural institutions [36]. Roles are defined as constraints on property. It applies property type to all entities.	Roles are associated with Actors only. It applies TemeStamp to Temporal entities: Roles, Types. Other event elements are without Timestamped. It has many classes and properties, but only a subset defines the event. It doesn't represent "How" element of 5W1H.
Event ontology [3]	It is designed to represent music-related events. Since it has no specific music related terms, so, it may be applied to model other domains' events [14].	Event ontology defines sub-event property for mereological relationships. However, it does not facilitate to model more complex mereological relationships. It does not qualify for the modeling of complicated relations related to the complex domain [14].
DUL	It is a lightweight upper ontology that has been considerably reused, and it is foundational ontology. F-model ontology is developed on top of DUL. It delivers a set of upper-level notions to enable interoperability among ontologies.	DUL is the foundation ontology; however, it may not have adequate coverage for certain specialized domains.
LODE [4]	It enables interoperability by formally mapping the class properties to other event ontology models, such as CIDOC-CRM, and Event ontology by using owl:sameAs and rdfs:subPropertyOf.	This ontology aims for minimal modeling of events.
F-model [5]	It presents six patterns: participation pattern, mereology pattern, causality pattern, correlation pattern, documentation pattern, interpretation pattern.	F-model is not describe any taxonomy or type of event except for those that illustrate the roles played by the events within each pattern, such as component [17]. It doesn't provide a direct association between the composite super event and its elements sub-events (similar to cause-effect)[36]. It is a complex model and difficult to understand and adopt.
SEM [6]	The types classes sem:EventType, sem:RoleType, sem:ActorType and sem:PlaceType could be used to detect more generic narratives to determine narrative schemes rather than instantiated narratives.	It does not allow to link different events nor provide a relation between classes of the same type.
ABC	It is straight forward ontology that describe constituents of events.	It is domain-dependent ontologies, and it does not support interoperability for ontologies.
FARO [36]	It permits the representation of 25 different relations, such as contingent relations, temporal relations, comparative relations, and mereological relations.	FARO does not represent "When" explicitly, however, it allows temporal relations, this means FARO Event has the answer of "When" implicitly. Also,it does not define classes or properties for "Where" and "Who" explicitly.