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Concept Algebra and Frame-based Representation for Event and Event Class

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Abstract: Representation of event plays a key role in research of event ontology. In this study we propose a concept algebra and frame-based representation for both event and event class. The advantages of proposed representation model are; it represent dynamic state changing progress of event, it represent relationships between events and it construct event class from event instances by operations of concept algebra. Solid definitions and formal representation are given to explain the event model and relationships between events. Case studies demonstrate the model is effective to represent events and events class.

Key words: Event, event class, concept algebra, frame-based representation

INTRODUCTION

Ontologies are the backbone technology of the Semantic Web (Fensel, 2003). In traditional formalization of ontologies, events are treated as entities or relations. One of the insufficiencies is its lack of topical relations, defined as the "tennis problem" by Roger Chaffin (Fellbaum, 1997). These relations, which are considered by (Halliday and Hasan, 1976) as non-systematic semantic relations and collocation relations, account for the fact that two words refers to the same topic or to the same situation, e.g., doctor-hospital, burglar-policeman. In recent years, ontology researches have paid more attention to thematic relationships between entities. Thematic relationships can be explicitly stated in RDF graphs but many important spatial and temporal relationships (e.g., distance and elapsed time) are implicit and require additional computation (Ramakrishnan *et al*., 2005). We need scientific model that supports event as the unit of analysis, modeling and visualization. The research of event ontology provided solutions for all these problems.

Research on event ontology (Raimond *et al*., 2007; Masolo *et al*., 2009; Bittner and Smith, 2003; Scherp *et al*., 2009; Crofts *et al*., 2008; Lagoze and Hunter, 2001) develops rapidly, although it's still in the phase of beginning. Couples of representation formalisms for event ontology have been proposed, however they cannot reach a consensus. Their key differences lie in event definitions, classes, structures and applications of event ontology.

While the event based applications have been extensively studied, very litter of the work has been done on the field of semi-automatic construction of event ontology. In recent years, ontology researches have paid more attention to thematic relationships between entities. Thematic relationships can be explicitly stated in RDF graphs but many important spatial and temporal relationships (e.g., distance and elapsed time) are implicit and require additional computation.

Based on concept algebra, we analyze attributes of event and propose a frame-based representation model for both event and event class.

EVENT, EVENT CLASS AND UPPER EVENT CLASSES

Main title and author affiliation: What is 'event'? It is a complicated question that different researchers have given different definitions (Chen, 2003; Zacks and Tversky, 2001; Nelson and Gruendel, 1986). Disregarding difference, the viewpoint to cognize event as a basic cell of knowledge is consistent with human's thinking habit.

The definitions of event and event class have been given by Liu *et al*. (2009) as follows:

Definition 1: Event can be defined as a 6-tuple formally:

$$e: = <A, O, T, V, P, L,>$$

where, A means action set happening in an event, O means objects taking part in the event, including all actors and entities involved in the event, T means the period of time when event lasts; V means environment of event, including nature environment and social environment, such as location of event and background of event, P means assertions on the procedure of actions execution in an event (Assertions include pre-condition, post-condition and intermediate assertions. Pre-condition denotes the set of states that has to be satisfied for triggering the event. Post-condition is a result set of states after event happens. Intermediate assertions denote intermediate states and the process of state changing during the event), L means language

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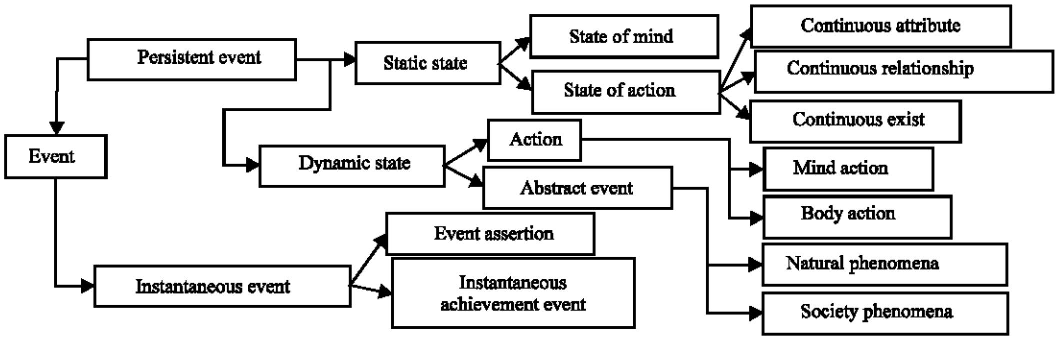

Fig. 1: Upper event classification

Table 1: Examples of upper event

Event	Example
Persistent event	The roses bloom. etc.
State of mind	Happy / sad/ etc.
Continuous attribute	Flower is red./etc.
Continuous relationship	They are friends./ etc.
Continuous exist	The nine planets exist in solar system/ etc.
Mind action	Think/ recall/ etc.
Body action	Jump/ run/ etc.
Natural phenomena	Earthquake/ etc.
Society phenomena	They tennis this afternoon./ etc.
Event assertion	He is running./etc.
Instantaneous achievement event	Begin/ end/ etc.

expressions, including Core Word Set, Core Words Expressions and Core Words Collocations (Core Words are high-frequency words in sentences of the event. Core Word Expressions describe the position relationship between no-core factors words and core words. Core Word Collocations denote the fixed collocations between core words and other words.).

Definition 2: Event class means a set of events with common characteristics, defined as:

$$EC = (E, C_1, C_2, ..., C_6), \; C_i = \{c_{i1}, c_{i2}, ..., c_{im}, ...\}$$
$$(1 \leq i \leq 6, m \geq 0)$$

where, E is event set, called extension of event class, C_i is called intension of the event class. It denotes the common characteristics set of certain event factor (factor i). denotes one of the common characteristics of event factor i .

Upper event classification: According to situation of event, we define the upper event classification which is hierarchical structure and is illustrated as Fig. 1. Moreover, couples of examples of upper event classification are given in Table 1.

On the top level, events are separated into two types: Persistent Event and Instantaneous Event.

Persistent Event expresses the ongoing status of event which does not have an explicit flag for start or end (e.g., “He is running”) and constant features of entity(e.g., “The color of sky is blue”). Persistent Event can be divided into static state and dynamic state. Static state represents that event keeps static in the investigation period, which includes state of mind (e.g., happy or sad) and state of action which consists of continuous attribute (e.g., “flower is red”), continuous relationship (e.g., “earthquake arouse tsunami”) and continuous exist (e.g., The nine planets exist in solar system”). Dynamic state represents that event keeps ongoing in the investigation period, which includes action and abstract event. Furthermore, action can be divided into body action (e.g., run, jump) and mind action (e.g., think, recall). Abstract event expresses the overall description of some events, which can be subdivided into natural phenomena and society phenomena.

Instantaneous event represents status of event on a moment or instantaneously completed event and it can be subdivided into event assertion and instantaneous achievement event. Event assertion describes event status on a moment while instantaneous achievement event expresses instantaneous change caused by the event (e.g., die, collide).

The major difference between persistent event and instantaneous event is how long event lasts. Take t_1 as the moment of event beginning and t_n as end of event. It is persistent event when $t_1 < t_n$, whereas instantaneous event if $t_1 = t_n$.

Now event description words in natural language can sit in certain event category according to above classification. For instance, “I love him”, the word ‘love’ belongs to state of mind; ”The sky is blue”, the word “is” belongs to continuous attribute; “earthquake arouse tsunami”, the word ‘arouse’ is continuous relationship,’ earthquake’ and ‘tsunami’ are natural phenomena; “there is some water in the bottle”, the word ‘there is’ belongs to continuous exist; “The match is beginning”, the word ‘match’ is society phenomena and ‘beginning’ is event assertion; “He died” is instantaneous achievement Event.

Concept algebra: Concept in denotational mathematics are an abstract structure that carries certain meaning in almost all cognitive processes such as thinking, leaning and reasoning. Concepts are identified as the basic unit of both knowledge and reasoning in cognitive informatics, logic, linguistics, psychology, knowledge engineering and computational intelligence. The rigorous modeling and formal treatment of concepts are at the center of theories for knowledge presentation and manipulation. A concept in linguistics is a noun or noun-phrase that serves as the subject or object of a to-be statement.

Nilsson (1993, 2001) propose concept algebra which provides a denotational mathematical means for algebraic manipulations of abstract concepts.

The intended logical functioning of the algebraic operators is established by introducing appropriate theorems in the form of algebraic equations:

Theorem 1: For any concepts a,b,c in lattice, there are following equations:
Idempotency: $a+a = a$, $a\times a = a$
Commutativity: $a+b = b+a$, $a\times b = b\times a$
Associativity: $a+(b+c) = (a+b)+c$, $a\times (b\times c) = (a\times b) \times c$
Absorption: $a+(a\times b) = a$, $a\times(a+b) = a$
Distributivity: $a\times(b+c) = (a\times b)+(a\times c)$, $a+(b\times c) = (a+b)\times(a+c)$
Boundedness: $a+null = a$, $a\times null = null$, $a+univ = univ$, $a\times univ = a$
where, the operations + and × in lattice theory are known as join(supremum) and meet (infimum). And univ and null are Lattice top $\top$ and lattice bottom $\perp$.

Nilsson (2001) proposed the attributes of concepts denoted by r (φ) or r: φ, where r is attribute name of concept, φis the value of attribute. There are following two ways to represent concept c:

- **Function-based representation:**

$$cr_1(\varphi_1)\times r_2(\varphi_2)\times\ldots\times r_m(\varphi_m) \quad (1)$$

- **Frame-based representation:**

$$c=\begin{bmatrix} r_1 : \varphi_1 \\ r_2 : \varphi_2 \\ \ldots \\ r_m : \varphi_m \end{bmatrix} \quad (2)$$

where, attribute value φ_i ($I = 1, 2, \ldots, m$)can also be a sub-concept. It means that the representation models can express recursive definition.

Theorem 2: For attributes, there are following equations:
$r_i\,(x+y) = r_i\,(x)+r_i(y)$
$r_i\,(x\times y) = r_i\,(x)\times r_i\,(y)$
$r_i\,(null) = null$
$r_i\,(univ) = univ$
$((r_i+r_j)\,(x)) = r_i\,(x)+r_j\,(x)$
$((r_i\times r_j)\,(x)) = r_i\,(x)\times r_j\,(x)$

CONCEPT ALGEBRA FRAMEWORK FOR EVENT AND EVENT CLASS

Frame-based representation for event: In frame-based representation, event denoter acts as event concept and 6 factors mentioned in definition 1 are taken as attributes of event. The frame-based event representation model can be showed as following:

$$e_i = e_i\begin{bmatrix} \prod R_A : \phi_h \\ \prod R_O : \phi_j \\ \prod R_V : \phi_k \\ \prod R_T : \phi_l \\ \prod R_P : \phi_m \\ \prod R_L : \phi_n \end{bmatrix} = e_i \times \prod R_x : \phi_y = e_i \times r_{x1}(\phi_{y1})\times r_{x2}(\phi_{y2})\times\ldots\times r_{xx}(\phi_{yy}) \quad (3)$$

where, R_A,R_O,R_V,R_T,R_P,R_L correspond to attributes sets of event action, object, environment ,time, assertion and language expressions; $\phi_h,\phi_j,\phi_k,\phi_l,\phi_m,\phi_n$ are the values of those attributes and they can be either atomic values or nested sub-concepts;$r_{xi} \in \{R_A \cup R_O \cup R_V \cup R_T \cup R_P \cup R_L\}$.

Attributes of event: In this section all 6 attributes of event will be analyzed in detail. We will firstly introduce R_O, R_V, R_T, R_V, R_P, and R_L which describe meanings and dynamic features of event concept. At last, we will cover R_A which expresses relations between events.

- **Attribute of event objects O:**

Event objects O are event participants (people or things) which act different roles in event. Table 2 shows attributes for roles and sub-roles.

Example 1: The event 'He fell asleep' can be represented as:

Table 2: Role attribute and Sub-role attribute

Role attribute	Abbreviation	Sub-role attribute	Abbreviation
Agent	AGT	is_a	ISA
Patient	PNT	Subclass	SUB
Instrument	INS	Part_of	PAT
Participator	POR	Member_of	MEMB
Collaborator	COR	Property	PROP
Involoved	INV	Measures	MEAS
Other attributes…		Way	WAY
		Color	COL
		Quantity	QUAN
		Quality	QUAL
		Degree	DEG
		Unit	UNIT
		Gender	GEN
		Other attributes…	

Table 3: Position/environmental attribute

Attribute	Abbreviation
On	ON
At	AT
Near	NER
Under	UND
Over	OVR
Below	BLOW
Above	ABOV
In/Inside	IN
Among	AMON
Between	BETE
Behind	BEHD
Across	ACRS
Opposite	OPP
Departure	DEP
Against	AGA
Direction	DIRECT
In front of	IFO
Location of	LOC
Destination	DES
Round/Around	ROND
Metonymy location	METLOC
Next to/by/Beside	BY
Other attributes…	…

$$\text{asleep}\left[\text{AGT: he}\begin{bmatrix}\text{ISA: human}\\ \text{GEN: male}\end{bmatrix}\right]$$

Example 2: The event 'The earthquake with magnitude 7.8' can be represented as:

earthquake [UNIT: magni-tude [DEG: 7.8]]

- **Attribute of event environment V:**

Event environment V is to describe surrounding and location where event happens. It includes nature environment and social environment, such as location of event, background of event. Table 3 shows environmental attribute of event.

Example 3: The event Tom fell asleep under her bed' can be represented as:

$$\text{Asleep}\begin{bmatrix}\text{AGT: Tom}\begin{bmatrix}\text{ISA: cat}\\ \text{UNDER: bed}\end{bmatrix}\\ \text{INV: her}\begin{bmatrix}\text{ISA: human}\\ \text{GEN: female}\end{bmatrix}\\ \text{INV: bed}\begin{bmatrix}\text{ISA: furniture}\\ \text{ON:ground}\end{bmatrix}\end{bmatrix}$$

Example 4: The event 'The earthquake with magnitude 7.8 happened in Sichuan' can be represented as:

$$\text{Earthquake}\begin{bmatrix}\text{UNIT: magnitude}[\text{DEG: 7.8}]\\ \text{LOC:Sichuan}[\text{UNIT: province}]\end{bmatrix}$$

Table 4: Time attribute

Attribute	Abbreviation
Date	DATE
Year	Y
Monty	M
Hour	H
Minute	MINT
Second	S
Period	PER
Ahead	AHEAD
Delay	DELAY
End time	END
Start time	START
Frequency	FREQ
Absolute time	ABST
Relative time	RELA
Time duration	DUR
Duration time point	DURP
Tense(past, present, future)	TENSE
Other attributes…	

- **Attribute of event time T:**

Event time T describes the time when event happens. Table 4 shows attributes of event time.

Example 5: The event 'The earthquake with magnitude 7.8 happened in Sichuan on May 12th, 2008'. can be represented as:

$$\text{Earthquake}\begin{bmatrix}\text{UNIT: magnitude}[\text{Degree: 7.8}]\\ \text{LOC:Sichuan}[\text{Unit: province}]\\ \text{DATE:May12th, 2008}[\text{TENSE: past}]\end{bmatrix}$$

- **Attribute of event assertion P:**

Event assertion P is to describe the dynamic progress of event. In order to express event process explicitly, we will analyze changes of event states along with time line.

Definition 3: Event State, denoted as P , is a set of entities (include entities' attributes) participated in the whole progress of an event:

$$^{ti}P = {}^{ti}(\{O\} \cup \{V\}) \tag{4}$$

where, O and V represent event objects and environment respectively. $O = (o_1, o_2, \ldots, o_n)$ where o_i $(0 \le i \le n)$ and t_i is a time tag.

Definition 4: Event states can be subdivided into event assertion $P = \{P_{pre}, P_{pro}, P_{post}\}$, i.e.,

P_{pre} and P_{post} represent event state on event-start moment and event-end moment, respectively. P_{pro}

represents variation of event states during the period between event-start and event-end moment. According to Fig. 2 P_{pre} is the event state on time point t_1, P_{post} is the event state on time point t_n, P_{pro} is the variation of event states during the period (t_1,t_n).

Event assertion can be expressed as below (t_1 is the start time of event, Δt is how long the event lasts and end time $t_n = t_1+\Delta t$):

$P_{pre} = {}^{t1}P = {}^{t1}(\{O\} \cup \{V\})$ reflects the start event state

$P_{post} = {}^{tn}P = {}^{tn}(\{O\} \cup \{V\})$ reflects the end event state

$P_{pro} = {}^{ti}P = {}^{ti}(\{O\} \cup \{V\})$ $(t_1<t_i<t_n)$ reflects the changes of states during the period of event. Showed as Fig. 3. Let $P_{pre} = \{y_{11}, y_{12}, \ldots, y_{1m}\}$, $P_{post} = \{y_{n1}, y_{n2}, \ldots, y_{nm}\}$ and $P_{pro} = \{y_{i1}, y_{i2}, \ldots, y_{im}\}$, where $1<i<n$.

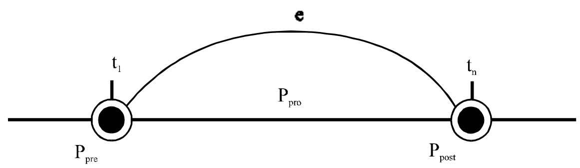

Fig. 2: Event assertion

$$\left(\begin{array}{ccccc} & x_1 & x_2 & \cdots & x_m \\ t_0 & \perp & \perp & \cdots & \perp \\ t_1 & y_{11} & y_{12} & \cdots & y_{1m} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ t_i & y_{i1} & y_{i2} & \cdots & y_{im} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ t_n & y_{n1} & y_{n2} & \cdots & y_{nm} \end{array}\right)$$

Fig. 3: Event assertion expression

According to the upper event classification, there are following three cases:

- If the event belongs to Static State, event states P remain same on every time point t_i
- If the event belongs to Dynamic State, event states P change along with time line, which is represented by P_{pro}
- If the event belongs to Instantaneous Event, $\Delta t = 0$, $P_{pre} = \{y_{11}, y_{12}, \ldots, y_{1m}\}$ represents event state of beginning, $P_{post} = \{y_{n1}, y_{n2}, \ldots, y_{nm}\}$ represents event state of end and $P_{pre} \neq P_{post}$.

The process of event can be represented by changes of event states. For many cases, it is not necessary to describe every change of state during event goes. Instead, the most important two are states at begin and end which can be expressed by P_{pre} and P_{post}. The simplified representation model of event process is showed in Fig. 4. For 'Static State', we have $P_{pre} = P_{post}$; Regarding 'Dynamic State', what we concerns are the changes of states after happen of event rather than the intermediate states, obviously $t_1 \neq t_n$ and $P_{pre} \neq P_{post}$; For 'Instantaneous Event', the intermediate changes of states can be ignored and we have $t_1 = t_n$, $P_{pre} \neq P_{post}$.

Attribute of event assertion can express the dynamic features of event. The flags T_1 and T_n are used to represent P_{pre} and P_{post}.

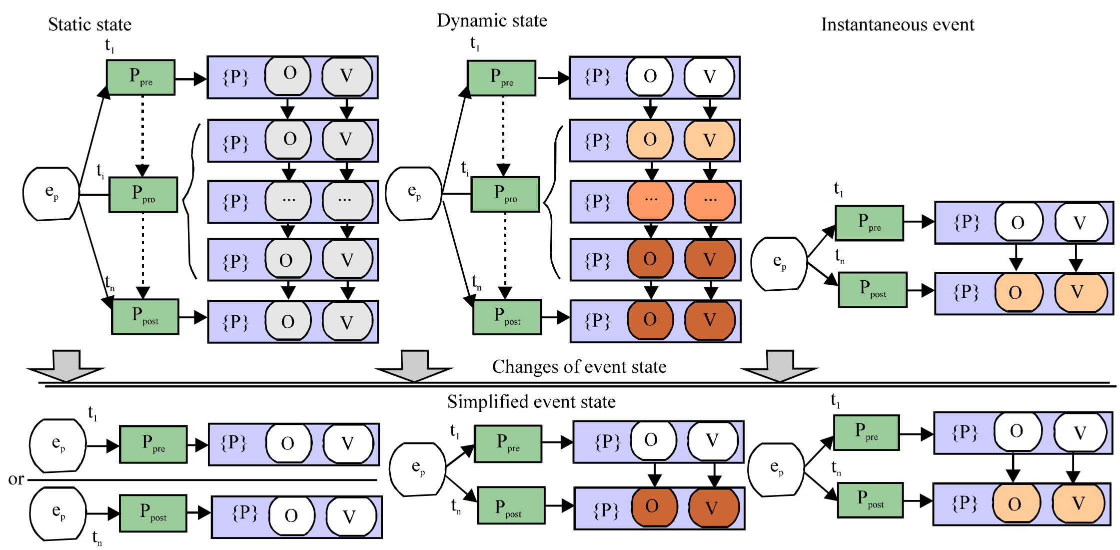

Fig. 4: Simplified event process

Table 5: Language attribute

Attribute	Abbreviation
Synonym	SYNM
Antonym	ANTM
Near-synonym	NSYNM

Example 6: The event 'Exhaust gas from cars pollutes the air' can be represented as:

$$\text{Pollute}\begin{bmatrix}\text{AGT : gas}[\text{WAY:exhauxt[AGT:car]}]\\ \text{PNT : air}\begin{bmatrix}(\text{QUAL}\times T_1)\text{:clearness}\\ (\text{QUAL}\times T_n)\text{:dirty}\end{bmatrix}\end{bmatrix}$$

Above example illustrates that event' pollute' change the quality of air:

$$\text{PNT : air}\begin{bmatrix}(\text{QUAL}\times T_1)\text{:clearness}\\ (\text{QUAL}\times T_n)\text{:dirty}\end{bmatrix}$$

shows that the value of quality, as an attribute, changes from clear to dirty after happen of event.

- **Attribute of language expressions L:**

Language expressions L is utilized to semantically express concept of event and it contains Synonym, Antonym and Near-synonym (Table 5).

Example 7: The event 'Mother love baby' can be represented as:

$$\text{Love}\begin{bmatrix}\text{AGT : mother}\begin{bmatrix}\text{ISA : human}\\ \text{GEN : female}\\ \text{Kinship : baby}\end{bmatrix}\\ \text{PNT : baby}\begin{bmatrix}\text{ISA : human}\\ \text{Kinship : mother}\end{bmatrix}\\ \\ \text{SYNM : (like}\times\text{be\_fond\_of)}\end{bmatrix}$$

- **Attribute of actions set relationship A:**

Attribute of actions set is to describe relationships between events, which include hierarchy, time and logic relations as showed in Table 6 and Fig. 5-6.

Example 8: The event 'He is sleeping and snoring' can be represented as:

$$\text{Sleep}\begin{bmatrix}\text{AGT : He}\begin{bmatrix}\text{ISA : human}\\ \text{GEN : male}\end{bmatrix}\\ \text{PAR : snore[LOOP : snore]}\end{bmatrix}$$

sleep PAR: snore [LOOP: snore] means 'snore' and 'sleep' happen at same time and 'snore' keeps on happening.

Table 6: Events relationship

Attribute	Abbreviation
Contain	CONN
Really contain	RCONN
Meets	MET
Before	BEF
Overlaps	OVL
Starts	STR
Ends	END
During	DUR
Equals	EQU
Embedded	EMB
Cause	CAU
Selection	SEL
Condition	CON
Paralleling	PAR
Loop	LOOP
Other attributes…	...

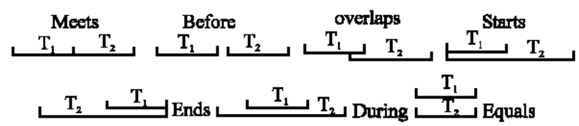

Fig. 5: Event time relations

Frame-based representation for event class: The same frame-based representation model can be used for both event and event class. As for event, it's specific and is represented by concrete content. Regarding event class, it's more general and is represented by common knowledge.

Following is an example of event 'procreate':

$$\text{Procreate}\begin{bmatrix}\text{AGT:}\left(\text{human1}\begin{bmatrix}\text{GEN: female}\\ \text{Status: mother}\\ \text{Kinship: human2}\end{bmatrix}+\text{animal1}\begin{bmatrix}\text{GEN: female}\\ \text{Status: mother}\\ \text{Kinship: animal2}\end{bmatrix}\right)\\ \text{PNT:}\left(\text{human2}\begin{bmatrix}\text{Status: baby}\\ \text{Kinship: human1}\\ \text{Age: infant}\\ (\text{IN}\times T_1)\text{:body[Part\_of:human1]}\\ (\text{OUT}\times T_n)\text{:body[Part\_of:human1]}\end{bmatrix}+\text{animal2}\begin{bmatrix}\text{Status: baby}\\ \text{Kinship: animal1}\\ \text{Age: infant}\\ (\text{IN}\times T_1)\text{:body[Part\_of:animal1]}\\ (\text{OUT}\times T_n)\text{:body[Part\_of:animal1]}\end{bmatrix}\right)\\ \text{LOC:place[On: earth + In: water]}\\ \text{DUR:long}\begin{bmatrix}\text{START:x}\\ \text{END:y}\\ \text{UNIT: (seconds + minutes + hours)}\end{bmatrix}\\ \\ \text{SYNM: (bear}\times\text{give\_birth\_to)}\end{bmatrix}$$

Frame-based derivation of event class from event: According to Theorem 1 and 2, we could derive features of event class from several event instances:

$$\text{Earthquake [UNIT: magnitude [DEG: 5]]+}$$

$$\text{Earthquake}\begin{bmatrix}\text{UNIT : magnitude}[\text{DEG : 7.8}]\\ \text{LOC:Sichuan}[\text{UNIT : province}]\end{bmatrix}+$$

$$\text{Earthquake}\begin{bmatrix}\text{UNIT : magnitude}[\text{DEG : 7.3}]\\ \text{LOC:Japen}[\text{DIRECT : Northeast}]\\ \text{DATE:December 7th,2012[TENSE : past]}\end{bmatrix}=$$

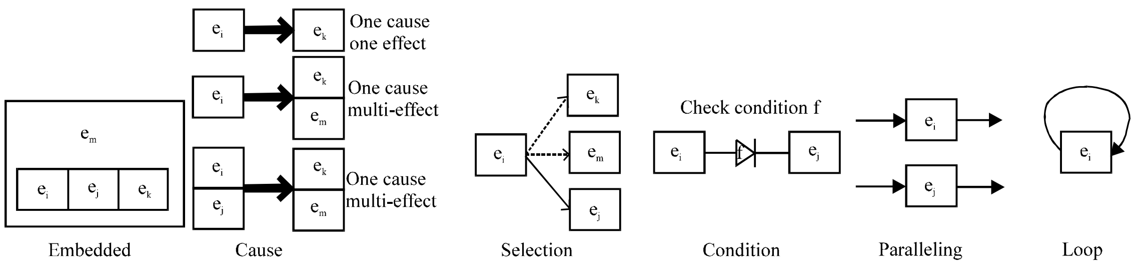

Fig. 6: Event logic relations

$$\text{Earthquake}\begin{bmatrix} \text{UNIT}:\text{magnitude}[\text{DEG}:(5+7.8+7.3)] \\ \text{LOC}:(\text{univ}+\text{Sichuan}[\text{UNIT}:\text{province}]+\text{Japen}[\text{DIRECT}:\text{Northeast}]) \\ \text{DATE}:(\text{univ}+\text{univ}+\text{December 7th},2012[\text{TENSE}:\text{past}]) \end{bmatrix}=$$

Earthquake [UNIT: magnitude [DEG: (5+7.8+7.3)]] =

Earthquake [UNIT: magnitude [DEG: real-number]]

CONCLUSION

The study propose a concept algebra and frame-based representation model for event and event class. The model is novel and effective in ontology research because most of works in this area focus on entities instead of events. Moreover, it can effectively represent all 6 attributes of event and the advantage of the frame-based representation model is its feasibility of computer process and reasoning. Solid definitions and formal representation are given to explain the event models and relationships between events. In future research following contents are expected to be covered: (1) Build event model reasoning rules based on event relationships; (2) Automatic construction of event ontology.

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REFERENCES

Bittner, T. and B. Smith, 2003. Granular spatio-temporal ontologies. Proceedings of the AAAI Symposium on Foundations and Applications of Spatio-Temporal Reasoning, March 24-26, 2003, Stanford, California, pp: 12-17.

Chen, X., 2003. Why did John Herschel fail to understand polarization? The differences between object and event concepts. Stud. History Philosophy Sci. A, 34: 491-513.

Crofts, N., M. Doerr, T. Gill, S. Stead and M. Stiff, 2008. Definition of the CIDOC conceptual reference model. ICOM/CIDOC CRM Special Interst Group, Paris. http://www.cidoc-crm.org/docs/cidoc_crm_version_5.0_Dec08.pdf

Fellbaum, C., 1997. WordNet an Electronic Lexical Database. MIT Press, New York.

Fensel, D., 2003. Ontologies: A Silver Bullet for Knowledge Management and Electronic Commerce. Springer-Verlag, Berlin, Germany, ISBN-13: 978-3540003021, Pages: 172.

Halliday, M.A.K. and R. Hasan, 1976. Cohesion in English. 1st Edn., Longman, London, ISBN: 0582550416.

Lagoze, C. and J. Hunter, 2001. The ABC ontology and model. Proceedings of the International Conference on Dublin Core and Metadata Applications, October, 22-26, 2001, British Computer Society and Oxford University Press, Tokyo, Japan, pp: 1-18.

Liu, Z.T., M.L. Huang, W. Zhou, Z.M. Zhong, J.F. Fu, J.F. Shan and H.L. Zhi, 2009. Research on event-oriented ontology model. Comput. Sci., 36: 189-192.

Masolo, C., S. Borgo, A. Gangemi, N. Guarino and A. Oltramari, 2009. WonderWeb deliverable D18, ontology library (final). Final Report, Laboratory For Applied Ontology - ISTC-CNR, Trento, Italy.

Nelson K. and J. Gruendel, 1986. Event Knowledge: Structure and Function in Development. 1st Edn., Lawrence Erlbaum Associates, Hillsdale, NJ, ISBN-13: 978-0898596571, Pages: 288.

Nilsson, J.F., 1993. A concept object algebra CA $^{+x\,()}$. In: Information Modelling and Knowledge Bases IV, Kangassalo, H. *et al.* (Eds.). IOS Press, Amsterdam, pp: 42.

Nilsson, J.F., 2001. A logico-algebraic framework for ontologies. Proceedings of the 1st International OntoQuery Workshop, (OQW'01), University of Southern Denmark, Kolding, pp: 43-56.

Raimond, Y., S. Abdallah, M. Sandler and F. Giasson, 2007. The music ontology. Proceedings of the International Conference on Music Information Retrieval, September 23-27, 2007, Vienna, Austria, pp: 417-422.

Ramakrishnan, C., W.H. Milnor, M. Perry and A.P. Sheth, 2005. Discovering informative connection subgraphs in multi-relational graphs. ACM SIGKDD Explor. Newslett., 7: 56-63.

Scherp, A., T. Franz, C. Saathoff and S. Staab, 2009. F-A model of events based on the foundational ontology DOLCE+DnS ultralight. Proceedings of the 5th International Conference on Knowledge Capture, September 1-4, 2009, Redondo Beach, CL., USA., pp: 137-144.

Zacks, J.M. and B. Tversky, 2001. Event structure in perception and conception. Psychol. Bull., 127: 3-21.