Natural-Language Semantics for Associations

Joerg Evermann

School of Information Management, Victoria University, Wellington, New Zealand
joerg.evermann@mcs.vuw.ac.nz

1 Introduction

Conceptual models describe an application domain to further communication and understanding, and serve as the basis for subsequent software design and implementation. For a language to be used for conceptual modelling, the semantics of its constructs must be well-defined w.r.t. the application domain.

The semantics of the association construct[1], central to object-oriented modelling languages, are problematic from the software perspective [1, 2], as well as in conceptual modelling. The definitions in the literature often obscure, rather than clarify the meaning of the construct.

Prior research interpreted associations ontologically as mutual properties [3], and classified them according to linguistic and cognitive considerations [4]. The ontological interpretation confounds properties and interaction, while the latter does not explain the meaning of associations. Relationships and associations have been interpreted as relations, i.e. sets of tuples [2, 5] and in terms of their meaning for subsequent system implementation and programming [1].

The semantics of a language construct are defined by its semantic mapping to an element of the semantic domain [6]. For purposes of conceptual modelling, *the semantic domain consists of those concepts in which we perceive the application domain*, with which we think and reason about the domain. These concepts are human cognitive concepts.

Significance of Cognitive Linguistics Research in cognitive linguistics has demonstrated that the most fundamental cognitive concepts are those that are encoded syntactically or morphologically in natural language (e.g. [7, 8]). *Cross-linguistic research* shows that variations in syntactic features correspond to variations in cognition, confirming the close relationship between the two. Studies have shown evidence of such a relationship in a number of domains such as color categorization, spatial reasoning, gender systems, etc. *Developmental research* examines how the development of cognitive structures influence the development of linguistic competence, or vice-versa. Either direction of influence confirms the relationship between language and cognition.

[1] Composition and aggregation associations are outside the scope of this paper.

2 Natural Language Semantics for Associations

Noting the structure of associations, Embley hints at the possible semantics of the association: "Relationships associate one object with another, similar to the way verbs and verb phrases relate one noun or noun phrase to another" [9, p. 18]. Hence, identifying the semantics of verbs can be used to define and clarify the semantics of associations. A UML profile [10] is used to formalize the proposed semantics.

Verb Semantics The most fundamental distinction made in cognitive linguistics is between spatial entities, such as things, places and paths, and temporal entities, such as events and states. The former are expressed by nouns and noun phrases, the latter are expressed by verbs[2] [11–13]. The temporal domain consists of two concepts: states and events [11–16].

Consequently, we suggest that associations represent two types of concepts: states and events. For events, the main verb usually expresses dynamic action or activity, e.g. 'Customer has ordered product', 'Supplier will ship product'. In contrast, a state expresses static conditions that hold between associated objects. No change occurs in the objects and states are not commonly associated with activity. In English, they are generally expressed by the verb "be", e.g. 'Professor is member of faculty', 'Product is located in warehouse'.

Properties of Events As events and states are expressed by verbs, they possess all of the semantic concepts that natural languages mark on verbs or verb phrases. The upper part of Table 3 summarizes the set of such concepts proposed by cross-linguistic research [14–19] and research in cognitive linguistics [11–13, 18, 19], and gives explanations and examples. The table also shows how these distinctions are formally realized in the proposed UML profile.

Causation Beyond the semantic concepts for all events, natural languages mark a further set of semantic concepts for causal events [11]: *Directness, Immediacy, Coextensiveness*, and *Resistance*. They are shown, with explanation and examples, in the second part of Table 3.

Event Participants Events are expressed by verbs, which in turn possess one or more arguments [14–16]. As verbal arguments play thematic roles, so the participating classes or objects in associations must play thematic roles. Table 1 shows the roles proposed by [11, 14–17].

3 Example

Consider an association without the proposed semantics attached: A Shipping Clerk participates in a "shipping" association with a Customer and a Package. This model is ambiguous w.r.t. the semantic notions described in Sec. 2. For

[2] But see 'temporalization' and 'reification' in [11].

Role	Description
Agent	The performer of an action
Patient	To whom something is done, who undergoes an action
Object	To what something is done
Theme	The topic of the event
Experiencer	Who experiences (listens, sees, etc.) something
Beneficiary	Who undergoes an action with a benefit
Locative	The location of an event
Perceiver	The perceiver who sees, feels, etc. an action
Instrumental	The instrument by which the action is performed
Source	The source of the action (generally of a motion action)
Goal	The goal of the action
Reason	The reason for the action
Purpose	The purpose of the action
Author	The speaker or write (for communicative actions)
Recipient	Who receives something by means of the action
Comitative	Something that accompanies the action

Table 1. Thematic roles (cases) marked on verbs

Stereo type	Base Class	Parent	Description (Additional Semantics)	Tags
State Association	Association	N/A	A static condition involving two or more objects	Tense
Event Association	Association	N/A	A dynamic interaction between two or more objects	Tense, Aspect, Progressivity, Iterativity, Punctuality, Telicity, Modality, Volitionality, Opposition, Success
Causal Event Association	Association	Event Association	An event association where the dynamic interaction is caused by an object (or event)	Directness, Immediacy, Coextensiveness, Resistance
Event Participant	Association End	N/A	An association end linked to either a state or event association, and linked to an object or event participating in this association	Thematic Role

Table 2. Stereotypes for the Natural Language Semantics Profile

example, we don't know whether the association represents planned shipments, shipments in progress, past shipments or recurring (standing) shipping orders.

To explicate the intended semantics, we employ the proposed profile (Fig. 1). The model now shows the roles of the participants: The shipping clerk is the agent, the packages are the objects, and the customer plays the locative role. This indicates that the packages are shipped to or from the customer, rather than for the customer (i.e. at customer's cost/on the customer's account).

The explicit tags show that the association expresses past (Tense), completed (Aspect), shipping events, not for example current, in-progress shipping. Ship-

Name	Explanation	Examples	Type	Multiplicity	Values
Tense	Relative temporal position of activity	Order was taken (past tense), order is taken (present tense)	Enumeration	1..1	Past, Present, Future
Aspect	State of completion of activity	Order has been processed (imperfective), order had been processed (perfective)	Enumeration	1..1	Perfective, Imperfective
Progressivity	Does the activity have a final state?	Shipper delivers product (final state), factory manufactures products (keeps manufacturing, no final state))	Boolean	1..1	
Iterativity	Is the activity repetitious?	Customer picks up orders on Wednesday morning (repeats every Wednesday), customer picks up the order next Wednesday morning (once only)	Boolean	1..1	
Punctuality	Temporal distribution or interval	Product leaves assembly (punctual), product is being painted (durative)	Enumeration	1..1	Punctual, Durative
Telicity	Does the activity have a goal?	Inventory is reduced (accidentally), inventory is cleared (purposefully, goal-driven)	Boolean	1..1	
Modality	Permission, ability, obligation, etc.	Customer (can) pick up order (Possible), Customer (must) pick up order (Obligatory)	Enumeration	1..*	Actual, Desirable, Predicted, Obligatory, Possible, Impossible, Optional, Permissible, Forbidden
Volitionality	Is the activity willful?	Machinist repaired the machine (neutral), machinist was made to repair the machine (willful)	Boolean	0..1	
Opposition	Positive or negative effects	Customer defrauds business (negative), customer refunds money owing (positive)	Enumeration	0..1	Negative, Positive
Success	Is success the effect or prevention of change?	Staff enters area (prevention), staff enters area (effect)	Enumeration	0..1	Effect, Prevent
Directness	Number of links in causal chain	Machine damaged product (1), machine caused profits to drop (> 1)	Integer	1..1	
Immediacy	Temporal continuity in causal chain	Shipping product reduces inventory (continuous), Shipping product increases profits (discontinuous, effect may be delayed)	Enumeration	1..1	Continuous, Discontinuous
Coextensiveness	Temporal overlap of cause and effect	Breaking the machine caused faulty products (Onset, cause does not need to be maintained), lowering the temperature to harden the product (Extended, cause must be maintained)	Enumeration	1..1	Onset, Extended
Resistance	Effectuating or enabling causation	Using the forklift to unload goods (Effectuating), opening the valves to unload goods (Enabling, removing blockage)	Enumeration	1..1	Effectuating, Enabling
Thematic Role			Enumeration	1..1	*ref. Tab. 1*

Table 3. Tag Definition and Tag Values for the Natural Language Semantics Profile

ping progressed towards a goal (Progressivity, the delivery of the package) and occurred once only, not repeatedly. Shipping was durative, i.e. it took some time, and was the effort of some agent (telicity). The association represents actual shipping events of the past, rather than past plans, abilities, etc. (modality).

Stereotyping the association as a 'Causal Event Association' makes it clear that the shipping clerk caused the object to the be shipped. The causation is indirect: The shipping clerk is twice removed (directness of degree 3), she did not ship the packages herself, nor did she herself cause the courier to ship the packages. Instead, she had the courier ship the packages. The immediacy indicates that is a discontinuous causation, i.e. there is a time lag between the cause and the effect. Perhaps the shipping order takes some time to be processed by the courier. The event is a type of onset causation, as the shipping clerk does not have to maintain any action to sustain the shipping activity. Finally, the event is caused by enabling it, rather than effecting it. For example, shipping orders may already be issued but need to be approved by the shipping clerk. The approval removes the blockage and the event can proceed. In contrast, for an effectuating causation, the agent issues the shipping orders, rather than remove a hindrance.

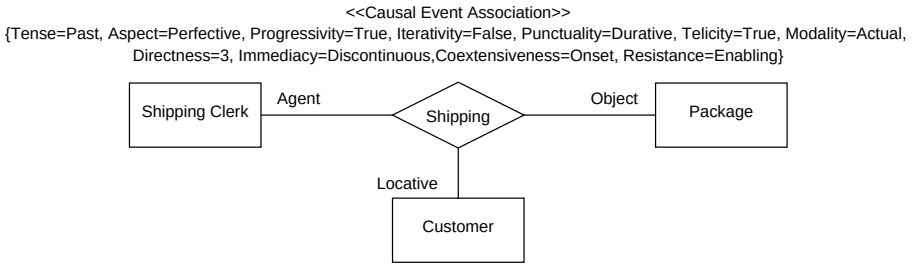

Fig. 1. Example association representing causation using the proposed profile

Without the proposed profile, the example could be interpreted in many different ways. Semantic distinctions are often implicit and based on domain or background knowledge. When this knowledge is not shared among modeller and model interpreter, the model may be interpreted incorrectly. The proposed profile forces the modeller to explicate the possible semantic distinctions and rely less on assumed background knowledge. Hence, it leads to more accurate model interpretations.

4 Discussion and Conclusion

Especially in the context of MDA, we need to consider not only conceptual modelling, but also implementation concerns. This proposal does not introduce new

constructs, nor does it constrain the use of constructs. It has therefore no consequences for IS implementation. We believe that disambiguating the semantics of associations is a valuable contribution by itself.

The fact that some distinctions may appear to be not applicable in some situations does not indicate a shortcoming of the present proposal. The cognitive linguistics research on which this proposal is based, suggests that, while not all languages make all distinctions, every distinction is grammaticized in some natural languages. Instead of dismissing concepts such as 'opposition' or 'success' as not relevant, they can offer insights into the application domain and its dynamics which may be hidden and require further exploration. They may also have significance in cross-cultural or cross-linguistic IS development contexts.

Finally, the fact that events may be represented as classes instead of associations, e.g. 'Shipment', 'Enrollment', 'Use', etc. shows the need for further exploration of this research. The present paper is intended to clarify the semantics of associations, rather than the representation of events and states.

References

1. Stevens, P.: On the interpretation of binary associations with the unified modelling language. Software and Systems Modeling **1** (2002) 68–79
2. Genova, G., Llorens, J., Martinez, P.: The meaning of multiplicity of n-ary associations in UML. Software and Systems Modeling **1** (2002) 86–97
3. Wand, Y., Storey, V.C., Weber, R.: An ontological analysis of the relationship construct in conceptual modeling. ACM TODS **24** (1999) 494–528
4. Storey, V.: Understanding semantic relationships. VLDB J **2** (1993) 455–488
5. Dey, D., Storey, V.C., Barron, T.M.: Improving database design through the analysis of relationships. ACM TODS **24** (1999) 453–486
6. Harel, D., Rumpe, B.: Meaningful modeling: What's the semantics of "semantics"? IEEE Computer (2004) 64–72
7. Bowerman, M., Levinson, S.C., eds.: Language acquisition and conceptual development. CUP, Cambridge, UK (2001)
8. Gentner, D., Goldin-Meadow, S., eds.: Language in Mind: Advances in the Study of Language and Thought. The MIT Press, Cambridge, MA (2003)
9. Embley, D.W.: Object-oriented systems analysis: a model-driven approach. Prentice Hall, Inc., Englewood Cliffs, NJ (1992)
10. OMG: The Unified Modelling Language Specification. Version 1.5. (2003)
11. Talmy, L.: Toward a cognitive semantics : Concept Structuring Systems. Volume 1. The MIT Press, Cambridge, MA (2000)
12. Jackendoff, R.: Semantics and Cognition. The MIT Press, Cambridge, MA (1983)
13. Jackendoff, R.: Semantic Structures. The MIT Press, Cambridge, MA (1990)
14. Frawley, W.: Linguistic Semantics. Lawrence Erlbaum, Mahwah, NJ (1992)
15. Whaley, L.J.: Introduction to Typology. The Unity and Diversity of Language. Sage Publications, Thousand Oaks (1997)
16. Palmer, F.R.: Grammatical Roles and Relations. CUP, Cambridge, UK (1994)
17. Cook, W.A.: Case Grammar Applied. The Summer Institute of Linguistic and The University of Texas at Arlington, Dallas, TX (1998)
18. Croft, W.: Typology and Universals. CUP, Cambridge, UK (1990)
19. Falk, Y.N.: Lexical Functional Grammar. An Introduction to Parallel constraint-based syntax. CSLI Publications, Stanford, CA (2001)