

Towards a radically attribute-centered perspective on frames

According to Barsalou (1992), frames, understood as recursive attribute-value structures, “provide the fundamental representation of knowledge in human cognition”. The attributes in a concept frame are the general properties or dimensions by which the respective concept is described. Their values are concrete or underspecified specifications. Barsalou’s frames are recursive in the sense that the value of an attribute can itself be further described by attributes. Being motivated primarily by empirical research, Barsalou’s focus in developing his frame theory was not on providing a formal theory. In recent years, based on the frame hypothesis that all representations in the human cognitive system correspond to frames, a new interest has developed towards a frame theory that is cognitively adequate and empirically founded as well as formally rigid (cf. Löbner 2011, Petersen & Werning 2007).

Formally, frames can be regarded as a generalization of classical typed feature structures (cf. Carpenter 1992) as they are defined as recursive attribute-value structures that are restricted by type signatures. In contrast to feature structures, frames do not necessarily exhibit a root. Thus frames can be represented by connected directed graphs with labeled arcs and nodes of which one is marked as being the central node of the frame. This is the node which represents the objects referred to by the frame (in feature structures this node is always a root of the graph). The nodes are labeled with types and the arcs with attributes. It is assumed that attributes assign unique values and thus correspond to functional relations. The task of the type signature is to restrict the class of admissible frames by providing the set of types and defining the domains and ranges of the attributes.

In the talk, we will give a short introduction to frame theory and focus on the ontological status of the frame elements and especially on the role of the type signature. Two questions will be central: First, how are attributes and types related to each other? And second, is it appropriate to handle types for qualities, classes and instances in a uniform way? In the classical theory of typed feature structures, attributes and types are defined as disjoint sets and all types are treated alike. The following oversimplified typed feature structure illustrates the problem:

$$\left[\begin{array}{l} \text{PHON: /nait/} \\ \text{AGR: } \left[\begin{array}{l} \text{PERS:third} \\ \text{NUM:singular} \\ \text{CASE:case} \end{array} \right] \end{array} \right]_{\text{agr}} \text{noun}$$

The six types ‘/nait/’, ‘agr’, ‘noun’, ‘third’, ‘singular’, and ‘case’, which occur in the feature structure, are of different kinds, they describe a class of objects (e.g., ‘noun’), a quality (e.g., ‘case’) or an instance (e.g., ‘/nait/’). Furthermore, the parallel naming of the attribute AGR (resp. CASE) and the type ‘agr’ (resp. ‘case’) in the structure suggests a systematic relationship between them that is not captured by the theory, which treats attributes and types as disjoint, unrelated sets. In our talk we will approach those problems along the lines of the theory of formal ontologies, which tackles these types of problems (cf. Guarino 2009).

Guided by the considerations in Guarino (1992), Petersen (2007) drops the artificial distinction between attributes and types and claims that the attribute set is merely a subset of the type set. It follows that attributes are a special kind of types which may occur in two different roles: as names of binary functional relations between types and as types themselves. In our talk we will drop the distinction between attributes and types too, but investigate the

problem from a radically attribute-centered perspective which takes attributes as the most basic units and defines types as being based on them. This view paves the way for a natural model-theoretic interpretation of attributes and types and thus for a model-theoretic semantics of type signatures and frames: Given a universe of instances, attributes are partial functions and types can be seen as labels for intersection sets of domains and ranges of attribute functions. It follows that instances are not types themselves and that the type hierarchy is simply a hierarchy based on set inclusion.

In the second part of the talk, we will discuss advantages of the new attribute-centered perspective. First, we will demonstrate, how the new view on attributes simplifies the task of modeling monotonic constraints such as “the older a stamp, the more valuable it is”, which play an important role in our world knowledge about concepts. Up to now, it was difficult to include scales into type signatures since types usually form a finite set which is partially ordered by subsumption. However, domain and range sets of functions may be ordered sets themselves – like numbers, for instance. Hence, by viewing types as labels for sets, we do not need to include continuous scales directly into type signatures; it is sufficient to define constraints as continuous functions between linearly ordered sets which are labeled by types. Additionally, subtypes may refer to scale segments, without leading to inconsistencies in the type system. Second, we will discuss the question of the cognitive plausibility of type signatures and especially of their learnability. It will turn out, that the question of how type signatures can be learned by observing untyped frames of single instances can be tackled along the lines of Petersen (2008): The system FCAType for the automatic induction of type signatures from sets of untyped feature structures builds in principal on the assumption that types merely name intersection sets of attribute domains and ranges.

Barsalou, L. (1992): Frames, Concepts, and Conceptual Fields. In Lehrer, A. & Kittay, E.F. (eds.): *Frames, Fields, and Contrasts*, Lawrence Erlbaum Associates Publishers, 21-74.

Carpenter, B. (1992): *The Logic of Typed Feature Structures*. CUP.

Guarino, N. (1992): Concepts, attributes and arbitrary relations: some linguistic and ontological criteria for structuring knowledge bases. In *Data Knowl. Eng., Elsevier Science Publishers B. V.*, 8, 249-261.

Guarino, N. (2009). The Ontological Level: Revisiting 30 Years of Knowledge Representation. In A. Borgida, V. Chaudhri, P. Giorgini, E. Yu (eds.): *Conceptual Modeling: Foundations and Applications*, Springer, 52–67.

Löbner, S. (2011): Evidence for frames from human language. Unpublished manuscript.

Petersen, W. (2007): Representation of Concepts as Frames. In: *The Baltic International Yearbook of Cognition, Logic and Communication*, Vol. 2, p. 151-170.

Petersen, W. (2008): Type Signature Induction with FCAType. In: S. Yahia, E. Nguifo, R. Belohlavek (eds.): *Concept Lattices and Their Applications*. LNAI 4923, p. 276-281, Springer.

Petersen, W.; Werning, M. (2007): Conceptual Fingerprints: Lexical Decomposition by Means of Frames – a Neuro-cognitive Model. In: Polovina, S.; Hill, R.; Priss, U. (eds.): *Conceptual Structures: Knowledge Architectures for Smart Applications (ICCS 2007)*. LNAI 4604, p. 415-428, Springer.