Expressing Preferences in a Viewpoint Ontology

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Abstract. This paper proposes a definition of viewpoints in a "kind of" ontology. The use of viewpoints allows one to simplify user interface and to facilitate the expression of user preferences on such an ontology. This work has been applied in the framework of an information system dedicated to the quality of food products.

1 Introduction

This study has taken place in a French project whose mission is to create a decision-making tool for the analysis of the nutritional and sanitary quality of food products. As a first step of the project, scientific data from several hundreds of publications concerning the impact of technological processes on nutritional or toxic components have been gathered in a database and a querying system has been built in order to explore them.

The question we deal with rises from two characteristics of the data: (i) the data are not abundant enough to answer every query. This characteristic led us to propose a flexible way of expressing the queries, by allowing the user to indicate levels of preference in his search. For instance, the user may ask for milk as a first choice or yoghourt as a second choice; (ii) the data (food products, bacteria, nutritional components, ...) are organized in ontologies. For instance, milk and yoghourt (quoted in the example above), as well as the other food products, are part of a taxonomy of substrates, in which *Whole milk* is a kind of *Milk*, which is a kind of *Milk product*, etc. For the user, asking for milk as a first choice and yoghourt as a second choice means associating preference degrees with the elements of the taxonomy of substrates.

Previous results [1, 2] concerning the expression of preferences in an ontology led to two issues: firstly, the need to simplify graphical user interface, and secondly, the necessity of expressing preferences on domains composed of exclusive and exhaustive elements. Therefore in Section 2 we introduce the notion of viewpoint in an ontology. Section 3 deals with the expression of preferences in a viewpoint ontology, in regard to user interface and to the semantics of such preferences for the querying.

2 Viewpoints in Ontologies

We focus on ontologies defined as sets of elements partially ordered by the "kind of" relation. An example of such an ontology is given (partially) in Figure 1.

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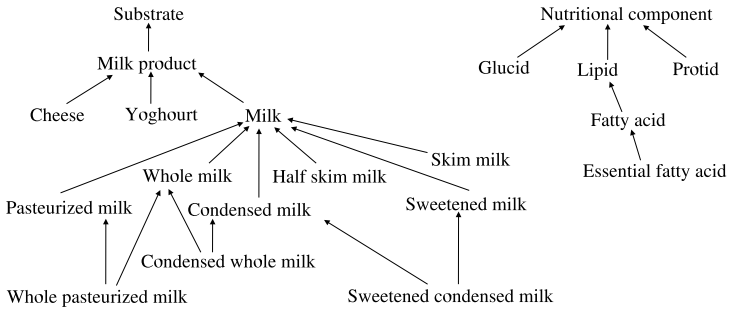

Fig. 1. Part of an ontology

In this section we give a brief introduction to viewpoints, then we propose a definition of a viewpoint ontology.

2.1 Introduction to Viewpoints

In the ontology of Figure 1, we can notice that the subelements of *Milk*, for instance, do not all have the same "statute". Any instance of *Milk* is necessarily an instance of either *Whole milk* or *Half skim milk* or *Skim milk*. That is, these three elements are exclusive and, moreover, they cover all cases of *Milk*. Thus they form a partition of *Milk*. This partition corresponds to a "creaming" criterion. Another partition of *Milk* could be obtained with *Pasteurized milk*, *Raw milk* and *Sterilized milk* (the latter two are not represented in Figure 1). This partition corresponds to a "thermization" criterion. On the contrary, an instance of *Milk* may be an instance of both *Whole milk* and *Pasteurized milk*. These two elements are not exclusive. Therefore they have a common subelement *Whole pasteurized milk*. The "creaming" and "thermization" partitions are complementary. Any instance of *Milk* can be represented in both.

For a given domain of knowledge, several criteria can be used to observe an object. These different perceptions of the world are called viewpoints or perspectives. One of the first references to viewpoints was proposed by [3] with a spacial connotation. Examples of systems that implement viewpoints in object representations are [4, 5, 6, 7]. A good overview is given in [8]. [9] introduces viewpoints in the conceptual graph model, in a "corporate memory" context. In UML (Unified Modeling Language), the specification of viewpoints is possible through the use of labels in multiple generalization: a partition can be represented by the "disjoint" and "complete" generalization constraints.

However viewpoints rely on semantic and subjective notions that are difficult to formalize. Therefore most previous approaches are unformal or operational – they focus on a particular implementation of viewpoints. Systems that do not explicitely deal with viewpoints use multiple inheritance to model them, as in the ontology of Figure 1 for instance. In Figure 1, the "creaming" and "thermization" viewpoints do not explicitly appear, although they could help

the user define querying preferences. Moreover they may have different levels of importance for the user.

2.2 A definition of Viewpoints

We propose a definition of a viewpoint ontology that relies on specializations of the "kind of" relation. A specialization of the "kind of" relation is based on the criterion used to establish the "kind of" relation between two elements. This citerion can be general or specific, thus leading to several levels of specialization of the "kind of" relation. In formalisms from the family of semantic networks, like description logics [10] or conceptual graphs [11], relations between concepts can be specialized. However the "kind of" relation plays a particular part in these models, as specialization is based on it. Here we propose to specialize the "kind of" relation itself, just as other relations can be specialized.

Definition 1. *A* **specialization** *of the "kind of" relation is a restriction of the "kind of" relation obtained by specifiying the criterion used to establish the "kind of" relation between elements. A particular specialization of the "kind of" relation, denoted "kind of by conjunction", is used to indicate that a common sub-element is obtained by multiple inheritance.*

Remark 1. *The "kind of by conjunction" relation may itself be specialized.*

Example 1. *The "kind of, in regard to thermization" relation and the "kind of, in regard to creaming" relation are specializations of the "kind of, in regard to process" relation, which is a specialization of the "kind of" relation. They are used in the ontology of Figure 2. The abbreviations "ko", "koP", "koT", "koC", "conj" are respectively used for "kind of", "kind of, in regard to process", 'kind of, in regard to thermization", "kind of, in regard to creaming", "kind of by conjunction".*

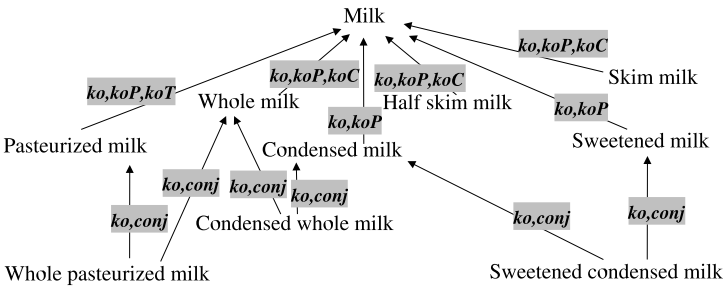

Fig. 2. Examples of specializations of the "kind of" relation in the *Milk* ontology

Example 2. *Figure 3 shows an ontology about fatty acids, in which the following specializations of the "kind of" relation are used:*

– the "kind of, in regard to chemistry" relation (denoted "koCh"), which is itself specialized into the "kind of, in regard to the presence of double bonds" (denoted "koPr") and "kind of, in regard to the number of double bonds" (denoted "koN") relations, is used to distinguish the elements Saturated fatty acid, Unsaturated fatty acid, Mono-unsaturated fatty acid *and* Poly-unsaturated fatty acid*;*
– the "kind of, in regard to state at ambient temperature" relation (denoted "koSt"), is used to distinguish between Solid at ambient temperature fatty acid *and* Liquid at ambient temperature fatty acid*;*
– the "kind of, in regard to origin" relation (denoted "koO"), is used to distinguish between Essential fatty acid *(which cannot be synthetized by the human organism) and* Synthetized fatty acid *(which can be synthetized by the human organism);*
– the "kind of, by conjunction with state at ambient temperature" relation (denoted "conjSt") and the "kind of, by conjunction with presence of double bounds" relation (denoted "conjPr") are both specializations of the "kind of by conjunction" relation. They are used to obtain common subelements of saturated/unsaturated fatty acids and solid/liquid fatty acids (multiple inheritance).

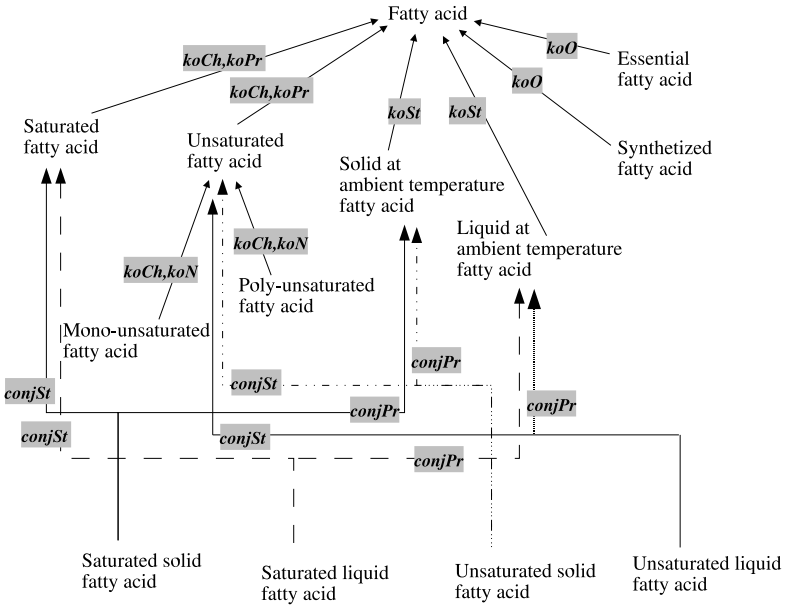

Fig. 3. Examples of viewpoints in the *Fatty acid* ontology

We propose a recursive definition of a viewpoint.

Definition 2. *Let Ω be a set of elements partially ordered by the "kind of" relation and by a set S of its specializations. A* **viewpoint** *on Ω is a pair $(elt, s) \in \Omega \times S$ such that the set of the direct predecessors of elt through s, denoted P, is either empty or satisfies:*

– *P forms a partition of elt;*
– $\forall p \in P$, (p, s) *is a viewpoint.*
The set composed of elt and of its predecessors through s is then called the **view** *induced by* (elt, s).

Remark 2. *Knowledge on partition satisfaction is not derived from the ontology, but declared as expert knowledge (this point is not developed here).*

Example 3. *In Figure 2,* (Milk,koC) *is a viewpoint because the set of direct predecessors of* Milk *through* koC*, that is* {Whole milk, Half skim milk, Skim milk} *forms a partition of* Milk. Whole milk, Half skim milk *and* Skim milk *have no predecessors through* koC.

On the contrary, (Milk,koT) *is not a viewpoint: the set of direct predecessors of* Milk *through* koT*, that is* {Pasteurized milk}*, is not a partition of* Milk *because it is not complete, it does not cover all cases of* Milk. (Milk,koP) *is not a viewpoint either: the set of direct predecessors of* Milk *through* koP*, that is* {Pasteurized milk, Whole milk, Condensed milk, Half skim milk, Sweetened milk, Skim milk}*, is not a partition of* Milk *as its elements are not exclusive.*

Example 4. *In Figure 3, all the pairs* (elt, s) *composed of an element of the ontology and a relation among the represented specializations of the "kind of" relation ("koCh", "koPr", "koN", "koSt", "koO", "conjSt" and "conjPr") are viewpoints. We have the three following cases:*
– *elt has no predecessors through s. This is the case, for instance, of the pairs* (Essential fatty acid, koSt)*,* (Saturated fatty acid, koN)*, etc.*
– *elt has direct predecessors through s (that form a partition of elt) and these predecessors have no predecessors through s. This is the case, for instance, of* (Fatty acid, koSt)*,* (Fatty acid, koPr)*,* (Unsaturated fatty acid, koCh)*,* (Saturated fatty acid, conjSt)*, etc.*
– *elt has direct predecessors through s (that form a partition of elt) and some of these predecessors also have predecessors through s. This is the case for* (Fatty acid, koCh).

Property 1. *There is no multiple inheritance within a given view.*

Proof 1. *Having multiple inheritance within a given view v would imply that there exists an element a in v that has two successors b and c through s, such that b and c are not comparable through s but have a non-empty intersection. This is excluded by definition 2, as both b and c are obtained by successive partitions of elt, where non-comparable elements are all exclusive by construction.*

Example 5. *In Figure 3, the element* Saturated solid fatty acid *is obtained by multiple inheritance of both* Saturated fatty acid *and* Solid at ambient temperature fatty acid*, which do not belong to the same views.*

Saturated fatty acid *belongs to the view* {Fatty acid, Saturated fatty acid, Unsaturated fatty acid} *induced by the viewpoint* (Fatty acid, koPr)*, to the view* {Fatty acid, Saturated fatty acid, Unsaturated fatty acid, Mono-unsaturated fatty acid, Poly-unsaturated fatty acid} *induced by the viewpoint* (Fatty acid,

koCh) *and to the view* {Saturated fatty acid, Saturated solid fatty acid, Saturated liquid fatty acid} *induced by the viewpoint* (Saturated fatty acid, conjSt).

Solid at ambient temperature fatty acid *belongs to the view* {Fatty acid, Solid at ambient temperature fatty acid, Liquid at ambient temperature fatty acid} *induced by the viewpoint* (Fatty acid, koSt) *and to the view* {Solid at ambient temperature fatty acid, Saturated solid fatty acid, Unsaturated solid fatty acid} *induced by the viewpoint* (Solid at ambient temperature fatty acid, conjPr).

Definition 3. *A* **viewpoint ontology** Ω_v *is a set of elements partially ordered by a set* S *of specializations of the "kind of" relation, such that each pair* $(elt, s) \in \Omega_v \times S$ *is a viewpoint.*

Example 6. *Figure 3 is an example of a viewpoint ontology.*

3 Preferences in a Viewpoint Ontology

3.1 Simplifying User Interface

In Figure 3, four elements obtained by multiple inheritance have been represented: *Saturated solid fatty acid*, *Saturated liquid fatty acid*, *Unsaturated solid fatty acid* and *Saturated liquid fatty acid*. Their graphical representation makes the ontology much more difficult to read, compared to the same ontology without multiple inheritance being represented, i.e. without conjunction viewpoints.

Moreover Figure 3 is far from being complete. Elements like *Essential unsaturated fatty acid*, *Mono-unsaturated solid fatty acid*, *Mono-unsaturated liquid synthetized fatty acid*, etc., are not represented. Representing all possible conjunction viewpoints would lead to an unreadable result. Indeed, predecessors of *Fatty acid* from different viewpoints on *Fatty acid* using non comparable specializations of the "kind of" relation can be combined to create a common subelement. The viewpoint V_1 = *(Fatty acid, koCh)* provides 4 (strict) predecessors of *Fatty acid*. The viewpoint V_2 = *(Fatty acid, koSt)* provides 2. The viewpoint V_3 = *(Fatty acid, koO)* also provides 2. Thus the number of elements obtained by double inheritance is $card(V1) \times card(V2) + card(V1) \times card(V3) + card(V2) \times card(V3) = 8 + 8 + 4 = 20$ and the number of elements obtained by triple inheritance is $card(V1) \times card(V2) \times card(V3) = 16$. That would lead to 36 common subelements to represent.

Our choice is to simplify the graphical user interface by not visualizing elements that are obtained by multiple inheritance, as they are simply conjunctions of other viewpoints. We thus obtain ontologies that have tree structures and may easily be handled in a browser, as proposed in Figure 4 for instance.

3.2 Clarifying the Semantics of Preferences

Furthur to previous studies [1, 2], expressing preferences using fuzzy sets [12] in an unambiguous way implies that the definition domains of these fuzzy sets were exhaustive and composed of exclusive elements. Both properties are characteristics of partitions. The scope of this section is to extend the expression of

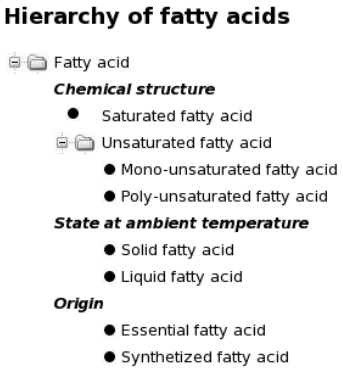

Fig. 4. Viewpoint ontologies without conjunction viewpoints have tree structures that can easily be handled in a browser

preferences to the case of a viewpoint ontology (thus handling partitions) where conjunction viewpoints are not represented (thus simplifying user interface as seen in Section 3.1). We propose a two-step method:

1. Intra-viewpoint preferences . After choosing an element of interest *elt* in the ontology (e.g. *Fatty acid*), the user can visualize its sub-elements through the different viewpoints and thus, within a partition of the chosen element, indicate the querying preferences by ordering the elements that compose the partition. This ordering is computed as a fuzzy set [12]. The left part of Figure 5 gives an example of intra-viewpoint preferences. They are computed as the fuzzy set *1/Liquid at ambient temperature fatty acid + 0.5/Solid at ambient temperature fatty acid*.

2. Inter-viewpoint preferences . If preferences have been defined on several viewpoints, the user can specify an order of importance between these viewpoints. This ordering is computed as weights associated with the selected viewpoints. The right part of Figure 5 gives an example of inter-viewpoint preferences. They are computed as weights 3, 1 and 1 respectively attributed to viewpoints *(Fatty acid, koCh)*, *(Fatty acid, koSt)* and *(Fatty acid, koO)*.

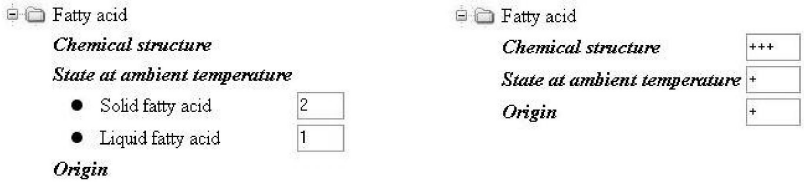

Fig. 5. Intra and inter-viewpoint preferences

Definition 4. *An expression of preferences on a viewpoint ontology is a set* $\{< V_1, w_1, F_1 >, \ldots, < V_n, w_n, F_n >\}$*, where* $V_1, \ldots, V_n$ *are viewpoints on a given element elt,* $w_1, \ldots, w_n$ *are weights respectively asociated with these viewpoints and* $F_1, \ldots, F_n$ *are fuzzy sets respectively defined on partitions of elt in the views induced by* $V_1, \ldots, V_n$*.*

Example 7. *An example of preferences expressed on the* Fatty acid *viewpoint ontology is given by:*

{<(Fatty acid, koCh), 3, 0.3/Saturated fatty acid + 0.7/Mono-unsaturated fatty acid + 1/Poly-unsaturated fatty acid>, <(Fatty acid, koSt), 1, 1/Liquid at ambient temperature fatty acid + 0.5/Solid at ambient temperature fatty acid>, <(Fatty acid, koO), 1, 1/Essential fatty acid + 0.5/Synthetized fatty acid>}.

Remark 3. *The agregation of the preferences criteria to order the data that are being queried according to their relevance is not discussed here (see e.g. [13]).*

4 Conclusion

This paper has proposed a definition of a viewpoint ontology that relies on specializations of the "kind of" relation. A viewpoint corresponds to a partition of an element of the ontology using a given specialization of the "kind of" relation. Partitions are exploited to clarify the semantics of preferences expressed on an ontology, by providing exhaustive domains of exclusive values, used as definition domains of preference fuzzy sets. Moreover within a given viewpoint there is no multiple inheritance, the latter being the result of a conjunction between several viewpoints. This property is used to propose a simplification of user interface. Finally we propose the use of weights – called inter-viewpoint preferences – to specify levels of importance between viewpoints in which preferences have been defined as fuzzy sets – called intra-viewpoint preferences.

The proposed methodology is based on the use of specializations of the "kind of" relation that produce a partition of possible cases. This is not the case for all of the possible specializations of the "kind of" relation. A future work will consist in specifying the conditions that lead to the obtention of partitions.

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