Modelling a Dynamic Process in the Conceptual Graph Model: Extension Needed?

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Abstract. In a food processing chain, a process is a succession of unit operations leading to the food product. As a first step, we will use a single assertional conceptual graph to represent the process steps. But reasoning with expert rules on this assertional graph raises some issues (activation of rules, readability). We propose an extension of the conceptual graph model, in order to introduce the 'Becomes' relation to structure the set of concept types in the support. This extension allows one to consider an extended set of concept types and conformity relation and to create another kind of graph rules and assertional graph representing the process, resolving these issues. We present the application of this extension to the case of the expert knowledge base about durum wheat transformation process.

1 Introduction

The representation of a dynamic process, where an entity is transformed, along different steps, raises questions about knowledge elicitation, conceptual representation and logic formalization. During a process, raw material undergoes a series of transformations (unit operations) to give a product. This sequence of transformations has an impact on the product properties. We propose to represent knowledge about a processing chain with the conceptual graph model [Sow84]. Its graphical representation has the advantage to be legible for a non-expert, while it is also well-founded from a logical point of view. Two kinds of information are considered here: expert rules, represented as conceptual graph rules, and sequences of unit operations,represented as assertional graphs.
The *priorean approach* [OS04], in a first order and hybrid logic framework, allows one to represent a succession of events in a formal manner using first order logic predicates limited to existential and conjonctive fragments. A first grade defines tenses entirely in terms of objective instants and an earlier-later relation, allowing one to express sentences such as "it will be the case that p" or "it has been the case that p".

Previous work on the conceptual graph model has considered the introduction of temporal elements in the model. On the one hand, the representation

of temporal intervals is proposed in [TAB01] and [EN90]. [MD94] present an approach to model temporal information found in discourses. [Koc03] deals with the issue of knowledge validation, introducing the notion of temporal context. On the other hand, [Del91] extends the concetual graphs with "demons" that take concepts as input parameters, but assert or retract concepts as the result of their action, [Min98] extend these ideas by allowing conceptual graphs as input and ouput parameters which is applied in [BC01].
The present study is closer to this latter approach. However after a presentation of the limits of the "classical" conceptual graph model to represent the process (Section 2), our approach is based on the introduction of a relation denoted "Becomes", in the support, to express the expected life cycle of an entity during the process (Section 3). Its use is presented in Section 4.

2 Representation and reasoning in the framework the "classical" conceptual graph model

Conceptual graphs rules [BS06] were proposed as an extension of Simple Conceptual Graphs (CGs) [Mug00] to represent knowledge of the form "if A then B", where A and B are simple CGs. We present a set of rules obtained by expert statements, and we propose to infer these statements with two ways (2.2 and 2.3) of process representation.

2.1 Unitary rules

Traditional pasta is exclusively based on high-quality durum wheat semolina. Pasta processing is a traditional technology. Even today, pasta process involves three basic unit operations: mixing of components (dough preparation), shaping, and drying of pasta products. Pasta are prepared for consumption in boiling water, during which they become soft. Pasta products are characterized by specific organoleptic (e.g. color, texture) and nutritional (e.g. glycemic index, vitamin content) qualities. Properties of pasta products depend on the raw material used and processing conditions.

A corpus of rules has been formulated by food science experts. This kind of rule expresses and describes the impact of one unit operation on a property of the food product. All these rules are designed in a homogeneous way, following the pattern : "if a product undergoes one unit operation and contains one component characterized by a given property, then this property can be subjected to modification due to the unit operation". We call this kind of rules "unitary rules". Fig.1(1) is an example of a unitary rule : "if a food product undergoes cooking in water and contains vitamin characterized by a given content, then this content decreases".

2.2 Representation of a whole process, problem of arity predetermination

We want to represent the successive unit operations undergone by a food product in a single assertional graph in order to deduce the impact (by activation of unitary rules) of this process on the properties of the food product. To design this assertional graph, we use the basis of the pattern outlined previously (2.1). Firstly, we propose to introduce a relation type "undergoes" in the unitary rule: if a food product undergoes n unit operations then the arity of relation type 'undergoes' is $n+1$ (because of the food and n operations). This representation informs on the sequence order of unit operations. However, the "undergoes" relation is represented by a binary arity in the support. An example of this assertional graph type is given (Fig.1(2)). However, there is a failure to project the hypothesis (Fig.1(1)) of the unitary rule in the assertional graph (Fig.1(2)), because of the difference of arity between the relation type 'undergoes' of the unitary food and the relation type "undergoes" of the assertional graph, this graph is not a specialization of the unitary graph rule hypothesis. Moreover, the

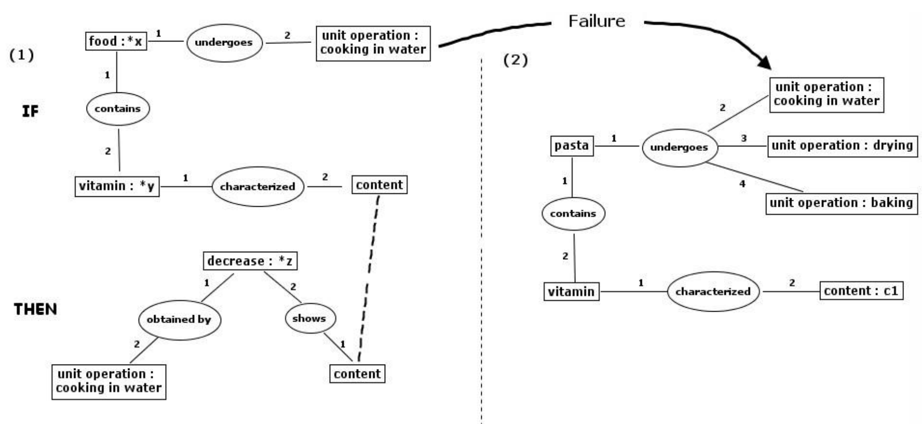

Fig. 1. Inability to project the assumption of the unitary rule in the assertional graph

conceptual graph model does not allow conceptual relations to have an arity which varies. For this reason, an alternative proposal has to be considered.

2.3 Representation of a whole process allowing the activation of unitary rules by conserving a binary arity of the relation type 'undergoes'

To remedy the problem, we represent all unit operations undergone by a food product in the assertional graph with a different representation.

Assertional graph representing whole process. We create as many branches -(undergoes)-[unit operation : *] as there exists unit operations in the modelled process. We complete the assertional graph with some information about the order of unit operations through the introduction of an anteriority relationship -(before)-. An example of such an assertional graph is given in Fig.2(2).

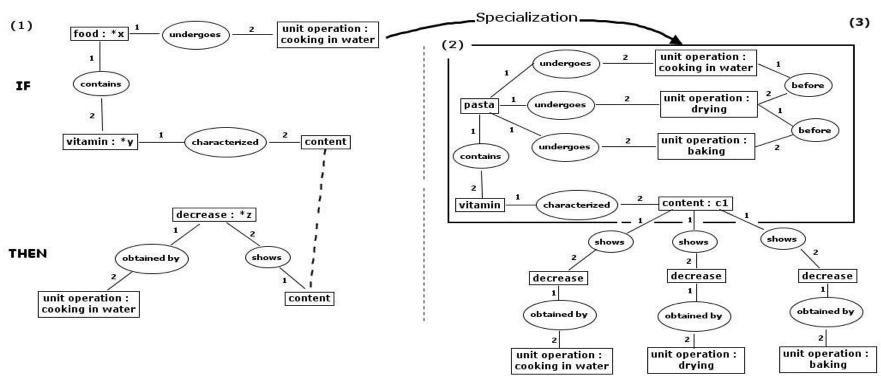

Fig. 2. Projection and activation of the unitary rule assumption in the assertional graph

Activation of unitary rules to infer a final assertional graph. The projection of the unitary rule hypothesis (Fig.2(1)) is possible for the assertional graph, thus we can proceed to successive activations of unitary rules from this graph to infer a final assertional graph (Fig.2(3)).

3 Extension of the conceptual graph model to introduce the 'Becomes' relation as a relation between concept types of the support

The evolution of a food product during a process is common to all food products of a given type (all pasta, etc). This characteristic is not expressed by the assertional graph representing a process, which has an existential logical interpretation. Hence, in the following, we introduce a new relation between concept types in the support, denoted "Becomes" (complementary of the "IsAKindOf" relation), that links together the states of the product between the differents stages of process transformation.

In [Pri68], the first grade defines tenses entirely in terms of objective instants and an earlier-later relation. For instance, a sentence as *Fp*, "it will be the case that p" or "there exists some instant t which is later than now, and p is true at t" can be defined in DF (Definition of Future) as follows:

(DF) $T(t, \boldsymbol{F}p) \equiv_{def} \exists t_1 \text{: } t \leq t_1 \wedge T(t_1, p)$

For two concept types C and C' linked by the Becomes relation, the proposition $\phi(C \xrightarrow{b} C')$ meaning "C becomes C'" can be formulated as follows (I is the set of individual marker):

$$\phi(C \xrightarrow{b} C') \quad \forall\, x \in I,\, C(x) \rightarrow \mathbf{F}C'(x)$$
$$\phi(C \xrightarrow{b} C') \quad \forall\, x \in I,\, C(x) \rightarrow \exists t_1\text{: } t \leq t_1 \wedge T(t_1, C'(x))$$

Reflexivity For a concept type C, the proposition $\phi(C \mapsto C)$ meaning "C becomes C" can be formulated as follows:

$$\phi(C \xrightarrow{b} C) \quad \forall\, x \in I,\, C(x) \rightarrow \mathbf{F}C(x)$$
$$\phi(C \xrightarrow{b} C) \quad \forall\, x \in I,\, C(x) \rightarrow \exists t_1\text{: } t \leq t_1 \wedge T(t_1, C(x))$$

The reflexivity property is obtained for t = t_1.

Transitivity For three concept types C, C' and C'', the proposition $\phi(C \mapsto C' \mapsto C'')$ meaning "C becomes C' and C' becomes C''" can be formulated as follows:

$$\phi(C \xrightarrow{b} C' \xrightarrow{b} C'') \; \forall\, x \in I,\, C(x) \rightarrow \mathbf{F}C'(x) \bigcap C'(x) \rightarrow \mathbf{F}C''(x)$$
$$\phi(C \xrightarrow{b} C' \xrightarrow{b} C'') \; \forall\, x \in I,\, C(x) \rightarrow \exists t_1\text{: } t \leq t_1 \wedge T(t_1, C'(x)) \bigcap$$
$$C'(x) \rightarrow \exists t_2\text{: } t_1 \leq t_2 \wedge T(t_2, C''(x))$$

$\phi(C \xrightarrow{b} C' \xrightarrow{b} C'') \rightarrow \phi(C \mapsto C'')$ because of the transivity of relation $\leq$.

$$\phi(C \xrightarrow{b} C'') \quad \forall\, x \in I,\, C(x) \rightarrow \exists t_2\text{: } t \leq t_2 \wedge T(t_2, C''(x))$$
$$\phi(C \xrightarrow{b} C'') \quad \forall\, x \in I,\, C(x) \rightarrow \mathbf{F}C''(x)$$

Thus, the transitivity property is obtained. The Becomes relation being reflexive and transitive, it is a partial preorder on the set of concept types. The set of concept types extended to the Becomes relation, denoted $T_{c.ext}$, is defined as follows.

Definition 1. *$T_{c.ext}$ is a set of concept types partially ordered by two relations, the IsAKindOf relation and the Becomes relation.*

An example of this extended set of concept types is given in Fig.3 for the durum wheat process. For clarify the representation, concept types ordonned by the Becomes relation appear in an horizontal plan with a curved corner rectangle.

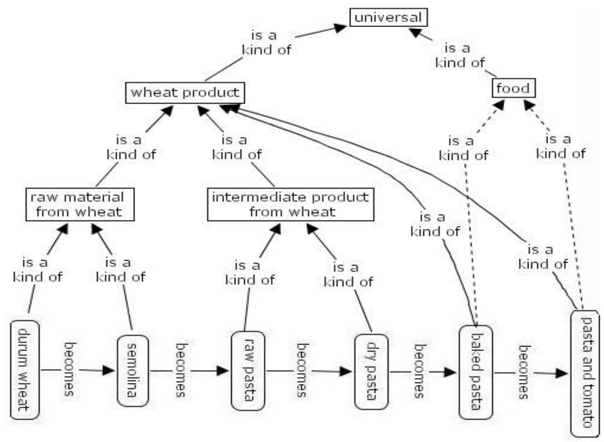

Fig. 3. Extended set of concept types for the durum wheat sector

4 Use of the extended support

In [Gua92], the notion of "natural type" is distinguished from the notion of "role type". Whereas natural types are conserved by instances during their whole life, role types can change. A similar distinction is conveyed by the IsAKindOf and Becomes relations, Becomes expressing a succession of states in the life cycle of an instance.
A marker can successively conform to all the concept types ordered by the Becomes relation in $T_{c.ext}$. Therefore, we introduce a new conformity relation, denoted τ_{ext}.

Definition 2. *τ_{ext}: $I \rightarrow T_{c.ext}$, associates each individual marker x with an "initial" role type denoted C_{init}. If an individual marker conforms to role type C_{init}, it can also conform to all role types situated after C_{init} in the Becomes relation.*

A marker typed by two differents types (ordered by a Becomes relation in $T_{c.ext}$) can be represented on a same conceptual graph. We introduce extended unitary rules which conceptualize an evolution of a role type undergoing a unit operation during a process or describe characteristics of each role type. We represent directly role types in assertional graphs and graphs rules. In these graphs, we precise for users which concept types are role types by curved corners. An example is given in Fig.4 showing several extended unitary rules.

Thus, we propose an extended assertional graph which can model a food product in a given state and the sequence of unit operations undergone by this product. Fig.5 is an example of extended assertional graph: "durum wheat undergoes fractionation, extrusion and hydratation". With this proposition, we can infer several logic assertions with successive activations of extended unitary rules.

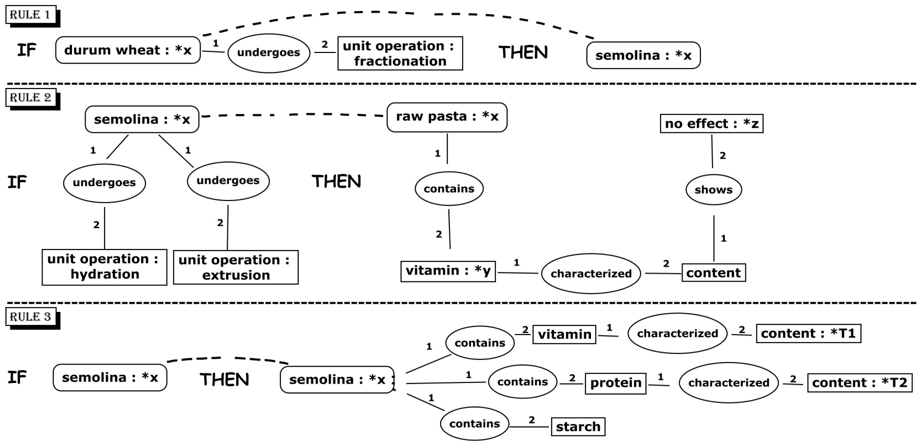

Fig. 4. Examples of extended unitary rules

In the graph G of Fig.5, the following rules of Fig.4 are successively applied : Rule 1 applied to G gives a graph G_1, Rule 3 applied to G_1 gives a graph G_2 and Rule 2 applied to G_2 gives a graph G_3.

Fig. 5. An example of extended assertional graph

In this example of extended assertional graph, the Rule 3 can't be applied before the Rule 2. When Rule 2 is applied, the Rule 3 can no longer be applied. Thus, the extended rules defines a non-monotonic system, which is a difference with simple CG rules.

5 Conclusion

This paper has raised the issue of the representation of a process in the conceptual graph model. We have proposed to represent the successive unit operations undergone by a food product in a single assertional graph in order to deduce the impact of this process on its properties. But these assertionnal graphs don't allow one to project expert rules or to be legible for users. Thus, we have introduced an extended set of concept types partially ordered by an additional relation, denoted "Becomes", allowing the representation of type changes during a process. Future work will focus on the becoming of a set of concept types during the process. Several combined concept types can produce a new concept type. For instance, mixing pasta and tomato in a food product chain produces the concept type "tomato and pasta". This observation raises a possible introduction of a composition law into a set of concept types, that will be considered in future work.

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