Using Argumentation in a French Agrifood Chain Application: Technical Report

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Abstract

Evaluating food quality is a complex process since it relies on numerous criteria historically grouped into four main types: nutritional, sensorial, practical and hygienic qualities. They may be completed by other emerging preoccupations such as the environmental impact, economic phenomena, etc. However, all these aspects of quality and their various components are not always compatible and their simultaneous improvement is a problem that sometimes has no obvious solution, which corresponds to a real issue for decision making. This paper proposes a decision support method guided by the objectives defined for the end products of an agrifood chain. It is materialized by a backward chaining approach based on argumentation.

1 Introduction

In agrifood chains, the products traditionally go through the intermediate stages of processing, storage, transport, packaging and reach the consumer (the demand) from the producer (the supply). More recently, due to an increase in quality constraints, several parties are involved in production process, such as consumers, industrials, health and sanitary authorities, etc. expressing their requirements on the final product as different point of views which could be conflicting. The notion of reverse engineering control, in which the demand (and not the supply) sets the specifications of desired products and it is up to the supply to adapt and find its ways to respond, can be considered in this case.

In this article, we discuss two aspects of this problem. First, we accept the idea that specifications cannot be established and several complementary points of view - possibly contradictory - can be expressed (nutritional, environmental, taste, etc.). We then need to assess their compatibility (or incompatibility) and identify solutions satisfying a maximum set of viewpoints. To this end we propose a logical framework based on argumentation and introduce a method of decision making based on backward chaining for the bread industry.

Since a joint argumentation - decision support approach is highly relevant to the food sector [36], the contribution of the paper is twofold. First we present a real use case of an argumentation process in the agrifood domain. Second we introduce the notion of viewpoint / goal in this setting based on the notion of backwards chaining reasoning and show how to use those techniques in a concrete application.

In Section 2, we introduce the real scenario considered in the application. In Section 3, we motivate our technical and modeling choices. In Section 4, the developed approach is introduced. It relies on an instantiation of a logic based argumentation framework based on a specific fragment of first order logic. In Section 5, we explain the technical results that ensure the soundness and completeness of our agronomy application method. In Section 6, some evaluation results are presented. Finally, Section 7 concludes the paper.

2 Scenario

The case of study considered in this paper relates to the debate around the change of ash content in flour used for common French bread. Various actors of the agronomy sector are concerned, in particular the Ministry for Health through its recommendations within the framework of the PNNS ("National Program for Nutrition and Health"), the millers, the bakers, the nutritionists and the consumers.

The PNNS recommends to privilege the whole-grain cereal products and in particular to pass to a common bread of T80 type, i.e made with flour containing an ash content (mineral matter rate) of 0.8%, instead of the type T65 (0.65% of mineral matter) currently used. Increasing the ash content comes down to using a more complete flour, since mineral matter is concentrated in the peripheral layers of the wheat grain, as well as a good amount of components of nutritional interest (vitamins, fibres). However, the peripheral layers of the grain are also exposed to the phytosanitary products, which does not make them advisable from a health point of view, unless one uses organic flour.

Other arguments (and of various nature) are in favour or discredit whole-grain bread. From an organoleptic point of view for example, the bread loses out in its "being crusty". From a nutritional point of view, the argument according to which the fibres are beneficial for health is discussed, some fibres could irritate the digestive system. From an economic point of view, the bakers fear selling less bread, because whole-grain bread increases satiety – which is beneficial from a nutritional point of view, for the regulation of the appetite and the fight against food imbalances and pathologies. However whole-grain bread requires also less flour and more water for its production, thus reducing the cost. The millers also fear a decrease in the quality of the technical methods used in the flour production.

Beyond the polemic on the choice between two alternatives (T65 or T80), one can take the debate further by distinguishing the various points of view concerned, identifying the desirable target characteristics, estimating the means of reaching that point. The contribution of this paper is showing how using argumentation can help towards such practical goals.

3 Motivation

In this paper we will elicit the points of view and the desirable target characteristics semi - automatically by the means of interviews with agronomy experts. Once the target characteristics identified, finding the means of reaching them will be done automatically by a combination of reverse engineering and argumentation. The reverse engineering will be used in order to find the complete set of actions to take towards a given characteristic, for all characteristics. In certain cases the actions to take will be inconsistent. Argumentation will then be employed in order to identify actions that can be accepted together.

3.1 Reverse Engineering

While reverse engineering has been widely employed in other Computer Science domains such as multi agent systems or requirements engineering, it is quite a novel methodology when applied in agronomy. In agrifood chains, the products traditionally go through the intermediate stages of processing, storage, transport, packaging and reach the consumer (the demand) from the producer (the supply). It is only recently, due to an increase in quality constraints, that the notion of reverse engineering control has emerged. In this case the demand (and not the supply) sets the specifications of desired products and it is up to the supply to adapt and find its ways to respond. In what follows, starting from the desired target criteria for the final product, the methods allowing one to identify ways to achieve these criteria (by intervention on the various stages of the supply chain) are named "reverse engineering".

Reverse engineering is known to be challenging from a methodological viewpoint. This is due to two main aspects. First, the difficulty of defining the specifications for the expected finished product. The desired quality criteria are multiple, questionable, and not necessarily compatible. The second difficulty lies in the fact that the impact of different steps of food processing and their order is not completely known. Some steps are more studied than others, several successive steps can have opposite effects (or unknown effects), the target criteria may be outside of the characteristics of products. Second, reconciling different viewpoints involved in the food sector still raises unaddressed questions. The problem does not simply consist in addressing a multi-criteria optimisation problem [12]: the domain experts would need to be able to justify why a certain decision (or set of possible decisions) is taken.

3.2 Argumentation

Argumentation theory in general [22, 8, 34] is actively pursued in the literature, some approaches combining argumentation and multi criteria decision making [1].

Value based Argumentation Frameworks [6] have been proposed where the strength of an argument corresponds to the values it promotes. What we call viewpoint later on in this paper would then correspond to the notion of audience in such setting. While this approach is very close in nature to our intuition, it cannot be applied due to the nature of the application. Here a value can be "split" into several audiences: there could be contradictory goals even from the same viewpoint. The notion of viewpoint and goals introduced in this setting also remind those proposed by [3].

3.2.1 Logic-based Argumentation

In this paper we present a methodology combining the reverse engineering and logical based argumentation for selecting the actions to take towards the agronomy application at hand. The logical instantiation language is a subset of first order logic denoted in this paper $\mathcal{SRC}$ equivalent to Datalog+- [14], Conceptual Graphs or Description Logics (more precisely the $\mathcal{EL}$ fragment [4] and DL-Lite families [15]). All above mentioned languages are logically equivalent in terms of representation or reasoning power. The reason why this application is using $\mathcal{SRC}$ is the graph based representation proper to $\mathcal{SRC}$ (and not to the other languages). This graph based representation (implemented in the Cogui tool [17, 30]) makes the language suitable for interacting with non computing experts [30].

Here we use the instantiation of [18] for defining what an argument and an attack is. While other approaches such as [24], [7], [31] etc. address first order logic based argumentation, the work of [18] uses the same $\mathcal{SRC}$ syntax and graph reasoning foundations. In Figure 1 the visual interface of Cogui is depicted: knowledge is represented as graph which is enriched dynamically by rule application. More on the visual appeal of Cogui for knowledge representation and reasoning can be found in [30].

4 Approach

In this paper we use an instantiation of logic based argumentation based on a specific fragment of first order logic. As mentioned before, this subset is equivalent to Datalog+- [14], Conceptual Graphs or Description Logics (the $\mathcal{EL}$ fragment [4] and the DL-Lite families [15]). The reason for which our application required this specific logic fragment is related to the information capitalisation needs of the food sector. The long term aim is to enrich ontologies and data sources based on these ontologies and join the Open Data movement. This entails that the language used by the food applications needs to be compatible with the Semantic Web equivalent languages as mentioned

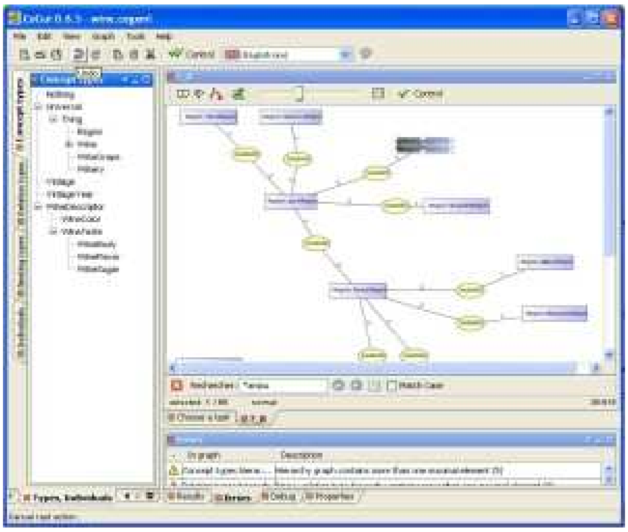


Figure 1: The Cogui visual graph based interface

before.

The choice of the $\mathcal{SRC}$ syntax and graph reasoning mechanism is justified by the visual appeal of this language for non computing experts.

In a nutshell our methodology is as follows. The set of goals, viewpoints as well as the knowledge associated with the goals / viewpoints is elicited either by the means of interviews with the domain experts or manually from different scientific papers. This step of the application is the most time consuming but the most important. If the knowledge elicited is not complete, sound or precise the outcome of the system is compromised. Then, based on the knowledge elicited from the knowledge experts and the goals of the experts, we enrich the knowledge bases using reverse engineering (implemented using backwards chaining algorithms). Putting together the enriched knowledge bases obtained by backwards chaining from the different goals will lead to inconsistencies. The argumentation process is used at this step and the extensions yield by the applications computed. Based on the extensions and the associated viewpoints we can use voting functions to determine the application choice of viewpoints.

4.1 Use Case Real Data

Expressing the target characteristics – or goals – according to various points of view consists of identifying the facets involved in the construction of product quality: points of view, topics of concern such as nutrition, environment, technology, etc. In addition, such viewpoints have to be addressed according to their various components (fibres, minerals, vitamins, etc). Desirable directions need to be laid down, and in a first step we consider them independent one from another.

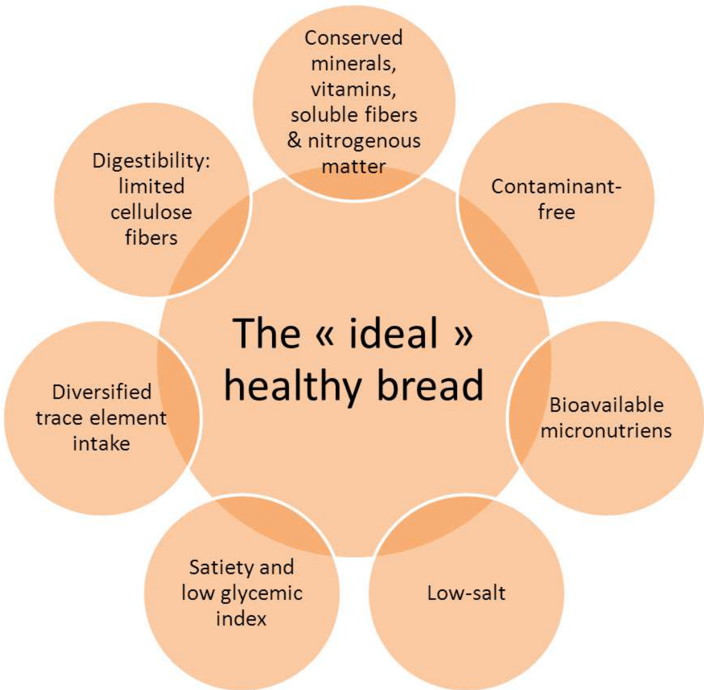
The considered sources of information include, from most formal to less formal: (1) peer reviewed scientific papers; (2) technical reports or information posted on websites; (3) conferences and scientific meetings around research projects; (4) expert knowledge obtained through interviews. The scientific articles we have analysed include: [11, 35, 21, 25, 29]. [11] compares the different types of flour from a nutritional point of view. [35] explores the link between fibre and satiety. [21, 25] deal with consumer behaviour and willingness to pay. They focus on French baguette when information concerning the level of fibres is provided, and they base their results on statistical studies of consumer panels. [29] provides a summary of the nutritional aspects of consumption of bread and the link with technological aspects.

We also reviewed technical reports available on official websites on health policy: the public PNNS (National Program for Nutrition and Health) [32, 33], the European project Healthgrain (looking at improving nutrition and health through grains) [19, 26], as well as projects and symposia on sanitary measures regarding the nutritional, technological and organoleptic properties of breads [20, 13, 2, 23]. Finally, several interviews were conducted to collect domain expert knowledge, in particular technology specialists in our laboratory.

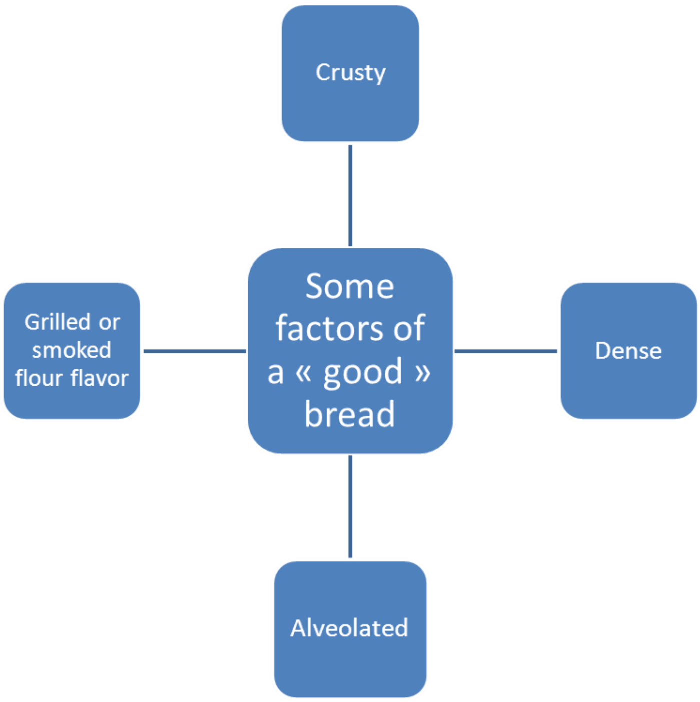
A summary of the results obtained in the baking industry is synthesised in Figure 2 regarding nutritional and organoleptic aspects.

5 Technical Soundness

In this section we explain the technical results that ensure the soundness and completeness of our agronomy application method. The section is composed of three parts. A first subsection explains the logical subset of first order logic language employed in the paper. The second subsection shows how



(a)



(b)

Figure 2: Nutritional (a) and organoleptic (b) goals

to construct arguments and attacks in order to obtain extensions when a knowledge base expressed under this language is inconsistent. Last, the third section shows how we used reverse engineering to complete the knowledge base with all possible actions and how argumentation can be used in order to select consistent subsets of knowledge which support given actions.

5.1 The Logical Language

In the following, we give the general setting knowledge representation language used throughout the paper.

A knowledge base is a 3-tuple $\mathcal{K} = (\mathcal{F}, \mathcal{R}, \mathcal{N})$ composed of three finite sets of formulae: a set $\mathcal{F}$ of facts, a set $\mathcal{R}$ of rules and a set $\mathcal{N}$ of constraints. Let us formally define what we accept as $\mathcal{F}$, $\mathcal{R}$ and $\mathcal{N}$.

Facts Syntax. Let $\mathbf{C}$ be a set of constants and $\mathbf{P} = P_1 \cup P_2 \ldots \cup P_n$ a set of predicates of the corresponding arity $i = 1, \ldots, n$. Let $\mathbf{V}$ be a countably infinite set of *variables*. We define the set of *terms* by $\mathbf{T} = \mathbf{V} \cup \mathbf{C}$. As usual, given $i \in \{1 \ldots n\}$, $p \in P_i$ and $t_1, \ldots, t_i \in \mathbf{T}$ we call $p(t_1, \ldots, t_i)$ an *atom*. A *fact* is the existential closure of an atom or an existential closure of a conjunction of atoms. (Note that there is no negation or disjunction in the facts and that we consider a generalised notion of facts that can contain several atoms.)

- *Bread, Cereal, LowSalt, ContaminantFree* are examples of unary predicates (arity 1) and *IsIngredientOf* is a binary predicate (arity 2).
- *Wheat, oats, rye, barley* are constant examples.
- *Cereal (wheat)* is an atom.
- $\exists$ *x (Bread(x)* $\wedge$ *IsIngredientOf(wheat, x))* is a fact.

Due to lack of space we do not show the full semantic definitions of facts (or rules and constraints in the following section). For a complete semantic depiction of this language please check [17, 30, 18]. It is well is known that $F' \models F$ (read the fact F' entails the fact F) if and only if there is a homomorphism from F to F' [17].

Rules. A rule R is a formula of the form

$$\forall x_1, \ldots, \forall x_n\ \forall y_1, \ldots, \forall y_m\ (H(x_1, \ldots, x_n, y_1, \ldots,\ y_m) \rightarrow \exists z_1, \ldots \exists z_k\ C(y_1, \ldots, y_m, z_1,\ \ldots z_k))$$

where H, the hypothesis, and C, the conclusion, are atoms or conjunctions of atoms, $n, m, k \in \{0, 1, \ldots\}$, $x_1, \ldots, x_n$ are the variables appearing in H, $y_1, \ldots, y_m$ are the variables appearing in both H and C and $z_1, \ldots, z_k$ the new variables introduced in the conclusion. An example of a rule is the following: $\forall$ *x (Bread(x)* $\wedge$ *PesticideFree(x)* $\wedge$ *MycotoxinFree(x)* $\rightarrow$ *ContaminantFree(x))*.

In the following we will consider rules without new existential variables in the conclusion.

Reasoning consists of applying rules on the set $\mathcal{F}$ and thus inferring new knowledge. A rule $R = (H, C)$ is *applicable* to set $\mathcal{F}$ if and only if there exists $\mathcal{F}' \subseteq \mathcal{F}$ such that there is a homomorphism σ from the hypothesis of $\mathcal{R}$ to the conjunction of elements of $\mathcal{F}'$. A rule $R = (H, C)$ is inversely applicable to a fact F if there is a homomorphism π from C to F. In this case, the inverse application of R to F according to π produces a new fact F' such that $R(F') = F$. We then say that the new fact is an immediate inverse derivation of F by R, abusively denoted $R^{-1}(F)$.

Note that this technique is commonly used, for example, for backward chaining query answering [5, 28] where a query is rewritten according to the rules. The same mechanism is also discussed by abductive reasoning algorithms [27] where minimal sets of facts (in the set inclusion sense) are added to the knowledge base in order to be able to deduct a query.

Let $F =$ *Bread(bleuette)* $\wedge$ *PesticideFree(bleuette)* $\wedge$ *MycotoxinFree(bleuette)* and R the rule $\forall$ *x (Bread(x)* $\wedge$ *PesticideFree(x)* $\wedge$ *MycotoxinFree(x)* $\rightarrow$ *ContaminantFree(x))*.

R is applicable to F and produces by derivation the following fact: *Bread(bleuette)* $\wedge$ *PesticideFree(bleuette)* $\wedge$ *MycotoxinFree(bleuette)* $\wedge$ *ContaminantFree(bleuette)*.

Let $F =$ *Bread(bleuette)* $\wedge$ *ContaminantFree(bleuette)* and R the rule $\forall$ *x (Bread(x)* $\wedge$ *PesticideFree(x)* $\wedge$ *MycotoxinFree(x)* $\rightarrow$ *ContaminantFree(x))*.

R inversely applicable to F and produces by inverse derivation the fact: $F' =$ *Bread(bleuette)* $\wedge$ *PesticideFree(bleuette)* $\wedge$ *MycotoxinFree(bleuette)*.

Let F be a subset of $\mathcal{F}$ and let $\mathcal{R}$ be a set of rules. A set F_n is called an $\mathcal{R}$-*derivation* of F if there is a sequence of sets (called a *derivation sequence*) $(F_0, F_1, \ldots, F_n)$ such that $F_0 \subseteq F$, F_0 is $\mathcal{R}$-consistent, for every $i \in \{1, \ldots, n-1\}$, it holds that F_i is an immediate derivation of F_{i-1}.

Given a set $\{F_0, \ldots, F_k\} \subseteq \mathcal{F}$ and a set of rules $\mathcal{R}$, the closure of $\{F_0, \ldots, F_k\}$ w.r.t. $\mathcal{R}$, denoted $\mathtt{Cl}_{\mathcal{R}}(\{F_0, \ldots, F_k\})$, is defined as the smallest set (with respect to $\subseteq$) which contains $\{F_0, \ldots, F_k\}$, and is closed for $\mathcal{R}$-derivation (that is, for every $\mathcal{R}$-derivation F_n of $\{F_0, \ldots, F_k\}$, we have $F_n \subseteq \mathtt{Cl}_{\mathcal{R}}(\{F_0, \ldots, F_k\})$). Finally, we say that a set $\mathcal{F}$ and a set of rules $\mathcal{R}$ *entail* a fact G (and we write $\mathcal{F}, \mathcal{R} \models G$) iff the closure of the facts by all the rules entails F (i.e. if $\mathtt{Cl}_{\mathcal{R}}(\mathcal{F}) \models G$).

Constraints. A constraint is a formula $\forall x_1 \ldots \forall x_n\ (H(x_1, \ldots, x_n) \rightarrow \bot)$, where H is an atom or a conjunction of atoms and $n \in \{0, 1, 2, \ldots\}$. Equivalently, a constraint can be written as $\neg(\exists x_1, ..., \exists x_n H(x_1, ...x_n))$. As an example of a constraint, consider $N = \neg(\exists\ x\ (Growth(x) \wedge Decrease(x)))$.

Given a knowledge base $\mathcal{K} = (\mathcal{F}, \mathcal{R}, \mathcal{N})$, a set $\{F_1, \ldots, F_k\} \subseteq \mathcal{F}$ is said to be *inconsistent* if and only if there exists a constraint $N \in \mathcal{N}$ such that $\{F_1, \ldots, F_k\} \models H_N$, where H_N denotes the existential closure of the hypothesis of N. A set is consistent if and only if it is not inconsistent. A set $\{F_1, \ldots, F_k\} \subseteq \mathcal{F}$ is $\mathcal{R}$-*inconsistent* if and only if there exists a constraint $N \in \mathcal{N}$ such that $\mathtt{Cl}_{\mathcal{R}}(\{F_1, \ldots, F_k\}) \models H_N$, where H_N denotes the existential closure of the hypothesis of N.

Let $\mathcal{K} = (\mathcal{F}, \mathcal{R}, \mathcal{N})$ where:

- $\mathcal{F}$ contains the following facts:
  - $F_1 = Bread(bleuette) \wedge ContaminantFree(bleuette)$
  - $F_2 = \exists\ e\ ExtractionRate(e, bleuette)$
  - $F_3 = \exists\ f\ (FiberContent(f, bleuette) \wedge High(f))$
- $\mathcal{R}$ consists of the following rules:
  - $R_1 = \forall\ x,y\ (Bread(x) \wedge ExtractionRate(y,x) \wedge PesticideFree(x) \rightarrow Decrease(y))$
  - $R_2 = \forall\ x,y,z\ (Bread(x) \wedge ExtractionRate(y,x) \wedge FiberContent(z,x) \wedge High(z) \rightarrow Growth(y))$
  - $R_3 = \forall\ x\ (Bread(x) \wedge ContaminantFree(x) \rightarrow PesticideFree(x) \wedge MycotoxinFree(x))$
- $\mathcal{N}$ contains the following negative constraint:
  - $N = \neg(\exists\ x\ (Growth(x) \wedge Decrease(x)))$

$\mathcal{K}$ is inconsistent since $(\mathcal{F}, \mathcal{R}) \models N$. Indeed, F_1 and R_3 allow to deduce *PesticideFree(bleuette)*. Combined to F_2 and R_1 we obtain *Decrease(e)*. F_3 and R_2 deduce *Growth(e)*, violating the negative constraint N.

Given a knowledge base, one can ask a conjunctive query in order to know whether something holds or not. Without loss of generality we consider boolean conjunctive queries (which are facts). As an example of a query, take $\exists x_1 cat(x_1)$. The answer to query α is positive if and only if $\mathcal{F}, \mathcal{R} \models \alpha$.

Answering Q, traditionally, has two different algorithmic approaches: either forward chaining or backwards chaining. The two approaches come to either (1) finding an answer of Q in the $\mathcal{R}$-derivations of the facts in the knowledge base or (2) computing the inverse $\mathcal{R}$-derivations of the query and finding if there is a match in the facts. We will focus on the latter approach in the following.

5.2 Arguments and Attacks

This section shows that it is possible to define an instantiation of Dung's abstract argumentation theory [22] that can be used to reason with an inconsistent ontological KB.

We first define the notion of an argument. For a set of formulae $\mathcal{G} = \{G_1, \ldots, G_n\}$, notation $\bigwedge G$ is used as an abbreviation for $G_1 \wedge \ldots \wedge G_n$.

Definition 1 *Given a knowledge base $\mathcal{K} = (\mathcal{F}, \mathcal{R}, \mathcal{N})$, an argument a is a tuple $a = (F_0, F_1, \ldots, F_n)$ where:*

- *$(F_0, \ldots, F_{n-1})$ is a derivation sequence with respect to $\mathcal{K}$*
- *F_n is an atom, a conjunction of atoms, the existential closure of an atom or the existential closure of a conjunction of atoms such that $F_{n-1} \models F_n$.*

This definition, following the definition of [18] is a straightforward way to define an argument, since an *argument* corresponds to a *derivation*.

To simplify the notation, from now on, we suppose that we are given a fixed knowledge base $\mathcal{K} = (\mathcal{F}, \mathcal{R}, \mathcal{N})$ and do not explicitly mention $\mathcal{F}$, $\mathcal{R}$ nor $\mathcal{N}$ if not necessary. Let $a = (F_0, ..., F_n)$ be an argument. Then, we denote $\texttt{Supp}(a) = F_0$ and $\texttt{Conc}(a) = F_n$.

Arguments may attack each other, which is captured by a binary attack relation $\texttt{Att} \subseteq \texttt{Arg}(\mathcal{F}) \times \texttt{Arg}(\mathcal{F})$.

Definition 2 *Let $\mathcal{K} = (\mathcal{F}, \mathcal{R}, \mathcal{N})$ be a knowledge base and let a and b be two arguments. The argument a attacks argument b, denoted $(a, b) \in Att$, if and only if there exists $\varphi \in \texttt{Supp}(b)$ such that the set $\{Conc(a), \varphi\}$ is $\mathcal{R}$-inconsistent.*

This attack relation is not symmetric. To see why, consider the following example. Let $\mathcal{F} = \{p(m), q(m), r(m)\}$, $\mathcal{R} = \emptyset$, $\mathcal{N} = \{\forall x_1 (p(x_1) \wedge q(x_1) \wedge$

$r(x_1) \rightarrow \bot)\}$. Let $a = (\{p(m), q(m)\}, p(m) \wedge q(m))$, $b = (\{r(m)\}, r(m))$. We have $(a, b) \in \texttt{Att}$ and $(b, a) \notin \texttt{Att}$. This will ensure that the naive extension is different, at least in theory, from the preferred, stable, etc. semantics. However, in our application they all entail the same information as shown later on.

Definition 3 *Given a knowledge base $\mathcal{K} = (\mathcal{F}, \mathcal{R}, \mathcal{N})$, the* corresponding argumentation framework $\mathcal{AF}_K$ *is a pair* $(\mathcal{A} = \texttt{Arg}(\mathcal{F}), \texttt{Att})$ *where* $\texttt{Arg}(\mathcal{F})$ *is the set of all arguments that can be constructed from $\mathcal{F}$ and* $\texttt{Att}$ *is the corresponding attack relation as specified in Definition 2.*

Let $\mathcal{E} \subseteq \mathcal{A}$ and $a \in \mathcal{A}$. We say that $\mathcal{E}$ is conflict free *iff there exists no arguments $a, b \in \mathcal{E}$ such that $(a, b) \in Att$. $\mathcal{E}$* defends *a iff for every argument $b \in \mathcal{A}$, if we have $(b, a) \in Att$ then there exists $c \in \mathcal{E}$ such that $(c, b) \in Att$.*

$\mathcal{E}$ is admissible *iff it is conflict free and defends all its arguments. $\mathcal{E}$ is a* complete extension *iff $\mathcal{E}$ is an admissible set which contains all the arguments it defends. $\mathcal{E}$ is a* preferred extension *iff it is maximal (with respect to set inclusion) admissible set. $\mathcal{E}$ is a* stable extension *iff it is conflict-free and for all $a \in \mathcal{A} \setminus \mathcal{E}$, there exists an argument $b \in \mathcal{E}$ such that $(b, a) \in Att$.*

$\mathcal{E}$ is a grounded extension *iff $\mathcal{E}$ is a minimal (for set inclusion) complete extension.*

For an argumentation framework $AS = (\mathcal{A}, Att)$ we denote by $Ext_x(AS)$ (or by $Ext_x(\mathcal{A}, Att)$) the set of its extensions with respect to semantics x. We use the abbreviations c, p, s, and g for respectively complete, preferred, stable and grounded semantics.

An argument is sceptically accepted if it is in all extensions, credulously accepted if it is in at least one extension and rejected if it is not in any extension.

Based on this definition of arguments and attacks in [18] was also shown that the rationality postulates of [16] are respected. This instantiation respects the direct, indirect consistency and well as the closure.

5.3 Formalising the use case

In this subsection we formalise the notions presented in section 4.

Let $\mathcal{K} = (\mathcal{F}, \mathcal{R}, \mathcal{N})$ be a consistent knowledge base. This is the knowledge base that all actors share and agree upon. In this paper we assume that the rules and negative constraints are common to everybody.

The goals of the different actors can be seen as a set of existentially closed conjuncts. We denote them by $G_1, G_2, ..., G_n$.

Let G_i be a goal and $\mathcal{K}$ the knowledge base. $\mathcal{K}$ is consistent and $\mathcal{K}$ does not entail G_i. We compute the inverse $\mathcal{R}$-derivations of G_i (where $\mathcal{R}$ is the set of rules of the knowledge base). We add all of the $\mathcal{R}^{-1}(G_i)$ to the facts. We thus obtain a new knowledge base $\mathcal{K}_i$ which differs from $\mathcal{K}$ solely by its facts set (which now also includes $\mathcal{R}^{-1}(G_i)$): $\mathcal{K} = (\mathcal{F} \cup \mathcal{R}^{-1}(G_i), \mathcal{R}, \mathcal{N})$. We also impose that $\mathcal{K}_i$ is consistent.

Let $\mathcal{G}$ be the set of goals $\mathcal{G} = \{G_1, G_2, ..., G_n\}$. The goals correspond to a set of viewpoints $\mathcal{V}$ (there exists a function $\kappa : \mathcal{G} \to 2^{\mathcal{V}}$). This function can assign a goal to one or more viewpoints and each viewpoint can be associated with one or more goals. Given a goal G_i, the (set of) viewpoint(s) associated with this goal is denoted by $\kappa(G_i)$. Similarly, given a viewpoint v_i, the set of goals associated with it is denoted by $\kappa^{-1}(v_i)$.

Example 1 *Let the set of viewpoints $\mathcal{V}$ = {nutrition, sanitary, organoleptic} and $\mathcal{G}$ consisting of the following goals: $G_1 = \exists$ x (Bread(x) $\wedge$ LowSalt(x)), $G_2 = \exists$ x (Bread(x) $\wedge$ ContaminantFree(x)), $G_3 = \exists$ x (Bread(x) $\wedge$ Crusty(x)), $G_4 = \exists$ x (Bread(x) $\wedge$ TraceElementRich(x)).*

We have $\kappa(G_1) = \kappa(G_4) = nutrition$, $\kappa(G_2) = sanitary$ and $\kappa(G_3) = organoleptic$. Conversely $\kappa^{-1}(nutrition) = \{G_1, G_4\}$, $\kappa^{-1}(sanitary) = \{G_2\}$ and $\kappa^{-1}(organoleptic) = \{G_3\}$.

The rules will correspond to the set of sufficient conditions needed for the goal G_i. In the context of our practical application this is illustrated in Figure 3 (with respect to nutrition goals).

Example 2 *To reach the goal $G_1 = \exists$ x (Bread(x) $\wedge$ LowSalt(x)), the knowledge base $\mathcal{K}$ contains the following rule: $\forall$ x,y (Bread(x) $\wedge$ SaltAdjunction(y,x) $\wedge$*

Decrease(y) $\to$ LowSalt(x))

Let us now consider the set of goals $\mathcal{G} = \{G_1, G_2, ..., G_n\}$ and the initial knowledge base $\mathcal{K} = (\mathcal{F}, \mathcal{R}, \mathcal{N})$. As described above we compute the n knowledge bases, corresponding to each goal: $\mathcal{K}_i = (\mathcal{F} \cup \mathcal{R}^{-1}(G_i), \mathcal{R}, \mathcal{N})$ for each $i = 1, ..., n$. We consider the union of all these knowledge bases:

$$\mathcal{K}_{agg} = (\mathcal{F} \bigcup_{i=1,...,n} \mathcal{R}^{-1}(G_i), \mathcal{R}, \mathcal{N})$$

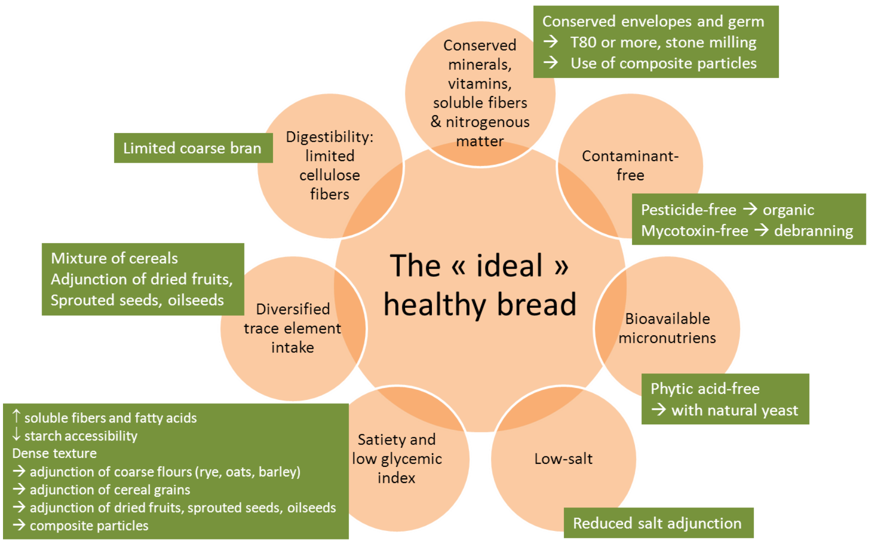


Figure 3: Ways to reach nutritional goals

Example 3 *Let* $\mathcal{K} = (\mathcal{F}, \mathcal{R}, \mathcal{N})$ *where :*

- $\mathcal{F} = \{F_1\} = \{CurrentExtractionRate(T65)\}$
- $\mathcal{R}$ *contains the following rules:*
  - $R_1 = \forall\ x,y\ (Bread(x) \land ExtractionRate(y,x) \land Decrease(y) \rightarrow Digestible(x))$
  - $R_2 = \forall\ x,z\ (Bread(x) \land SaltAdjunction(z,x) \land Decrease(z) \rightarrow LowSalt(x))$
  - $R_3 = \forall\ x,y\ (Bread(x) \land ExtractionRate(y,x) \land Growth(y) \rightarrow TraceElementRich(x))$
  - $R_4 = \forall\ x,y\ (Bread(x) \land ExtractionRate(y,x) \land Decrease(y) \rightarrow PesticideFree(x))$
- $\mathcal{N}$ *contains the following negative constraint:*
  - $N = \neg(\exists\ x\ (Growth(x) \land Decrease(x)))$

Let the goal set $\mathcal{G}$ as follows:

- $G_1 = \exists\ p$ *(Bread(p)* $\wedge$ *Digestible(p)),* where $\kappa(G_1) = nutrition$
- $G_2 = \exists\ p$ *(Bread(p)* $\wedge$ *LowSalt(p)),* where $\kappa(G_2) = nutrition$
- $G_3 = \exists\ p$ *(Bread(p)* $\wedge$ *TraceElementRich(p)),* where $\kappa(G_3) = nutrition$
- $G_4 = \exists\ p$ *(Bread(p)* $\wedge$ *PesticideFree(p)),* where $\kappa(G_4) = sanitary$.

Then:

- $\mathcal{K}_1 = (\mathcal{F}_1, \mathcal{R}, \mathcal{N})$ *where* $\mathcal{F}_1 = \mathcal{F} \cup \mathcal{R}^{-1}(G_1)$ *contains the following facts:*
  - $F_1 =$ *CurrentExtractionRate(T65)*
  - $F_2 =$ *Bread(p)* $\wedge$ *ExtractionRate(τ,p)* $\wedge$ *Decrease(τ)*
- $\mathcal{K}_2 = (\mathcal{F}_2, \mathcal{R}, \mathcal{N})$ *where* $\mathcal{F}_2 = \mathcal{F} \cup \mathcal{R}^{-1}(G_2)$ *contains the following facts:*
  - $F_1 =$ *CurrentExtractionRate(T65)*
  - $F_3 =$ *Bread(p)* $\wedge$ *SaltAdjunction(s,p)* $\wedge$ *Decrease(s)*
- $\mathcal{K}_3 = (\mathcal{F}_3, \mathcal{R}, \mathcal{N})$ *where* $\mathcal{F}_3 = \mathcal{F} \cup \mathcal{R}^{-1}(G_3)$ *contains the following facts:*
  - $F_1 =$ *CurrentExtractionRate(T65)*
  - $F_4 =$ *Bread(p)* $\wedge$ *ExtractionRate(τ,p)* $\wedge$ *Growth(τ)*
- $\mathcal{K}_4 = (\mathcal{F}_4, \mathcal{R}, \mathcal{N})$ *where* $\mathcal{F}_4 = \mathcal{F} \cup \mathcal{R}^{-1}(G_4)$ *contains the following facts:*
  - $F_1 =$ *CurrentExtractionRate(T65)*
  - $F_2 =$ *Bread(p)* $\wedge$ *ExtractionRate(τ,p)* $\wedge$ *Decrease(τ)*

Finally $\mathcal{K}_{agg} = (\mathcal{F} \bigcup_{i=1,\ldots,n} \mathcal{R}^{-1}(G_i), \mathcal{R}, \mathcal{N})$ *where* $\mathcal{F} \bigcup_{i=1,\ldots,n} \mathcal{R}^{-1}(G_i) = \{F_1, F_2, F_3, F_4\}$.

As observed in the previous example, it may happen that $\mathcal{K}_{agg}$ is inconsistent (and it does so even for goals belonging to the same viewpoint). We then use argumentation, which, by the means of extensions will isolate subsets of facts we can accept together (called extensions). Furthermore, the extensions will allow us to see which are the viewpoints associated to each maximal consistent subset of knowledge (by the means of the function κ). Once we obtain this we can either use simple voting procedures to find out which viewpoint to follow or other preference based selection.

The argument framework we can construct from the above knowledge base is $(\mathcal{A}, Att)$ where $\mathcal{A}$ contains the following:

- $a = (\{F_2\}, F_2, R_1(F_2))$ where $R_1(F_2) =$ *Bread(p)* $\wedge$ *ExtractionRate(τ,p)* $\wedge$ *Decrease(τ)* $\wedge$ *Digestible(p).*

• $b = (\{F_4\}, F_4, R_3(F_4))$ where $R_3(F_4) =$ *Bread(p)* $\wedge$ *ExtractionRate(τ,p)* $\wedge$ *Growth(τ)* $\wedge$ *TraceElementRich(p)*.

• $c = (\{F_2\}, F_2, R_4(F_2))$ where $R_4(F_2) =$ *Bread(p)* $\wedge$ *ExtractionRate(τ,p)* $\wedge$ *Decrease(τ)* $\wedge$ *PesticideFree(p)*.

• $d = (\{F_3\}, F_3, R_2(F_3))$ where $R_2(F_3) =$ *Bread(p)* $\wedge$ *SaltAdjunction(s,p)* $\wedge$ *Decrease(s)* $\wedge$ *LowSalt(p)* and
$Att = \{(a, b), (b, a), (b, c), (c, b)\}$.

In this argumentation system defined we now obtain:

• $Ext_{stable}(\mathcal{A}, Att) = Ext_{semi-stable}(\mathcal{A}, Att) =$

• $Ext_{prefered}(\mathcal{A}, Att) = \{\{a, c, d\}, \{b, d\}\}$.

Starting from the extensions $Ext_x(\mathcal{A}, Att)$, the proposed decision support system functions as follows: for every extension $\varepsilon \in Ext_x(\mathcal{A}, Att)$:

- Consider the facts occurring in the arguments of ε ;
- Identify the knowledge bases $\mathcal{K}_i$ where these facts occur;
- Obtain the goals G_i which are satisfied by the extension;
- Using the κ function to obtain the viewpoints corresponding to these goals;
- Show domain experts the set of goals, and compatible viewpoints corresponding to the given extension.

This method allows us to obtain a set of options equal to the cardinality of $Ext_x(\mathcal{A},\ Att)$. For taking a final decision several possibilities can be considered and presented to the experts:

- Maximise the number of goals satisfied;
- Maximise the number of viewpoints satisfied;
- Use preference relations of experts on goals and / or viewpoints.

In the previous example (please recall that the goals G_1 and G_2 are associated with the nutritional viewpoint while G_4 is associated with the sanitary viewpoint) we have:

- The first extension $\{a, c, d\}$ is based on the facts F_2 and F_3 obtained from $\mathcal{K}_1$, $\mathcal{K}_2$ and $\mathcal{K}_4$ that satisfy the goals G_1, G_2 and G_4.

- The second extension $\{b, d\}$ is based on F_3 and F_4 obtained from $\mathcal{K}_2$ and $\mathcal{K}_3$ satisfying G_2 and G_3 both associated with the nutritional viewpoint.

One first possibility (corresponding to the extension $\{a, c, d\}$) consists of accomplishing F_2 and F_3 and allows to satisfy the biggest number of goals and viewpoints.

The second possibility (corresponding to the extension $\{b, d\}$) consists of accomplishing F_3 and F_4. It would satisfy two goals and one viewpoint. It could be considered though if the goal G_3 (not satisfied by the first option) is preferred to the others.

6 Evaluation

The evaluation of the system implemented was done via a series of interviews with domain experts. The above knowledge and reasoning procedures were implemented using the Cogui knowledge representation tool [30], with an extension of 2000 lines of supplemental code. Three experts have validated our approach: two researchers in food science and cereal technologies of the French national institute of agronomic research, specialists respectively of the grain-to-flour transformation process and of the breadmaking process, and one industrial expert - the president of the French National Institute of Bread and Pastry.

The first meeting dealt with the delimitation of the project objectives and addressed fundamental questions such as: Is it possible to uniquely define a "good" bread? Which scenarii of "good bread" should be considered? How could they be defined from a nutritional, sanitary, sensorial and economic point of view? Which are the main known ways to achieve them? Then a series of individual interviews constituted the elicitation phase. Each expert gave more arguments which were complementing one each other.

In the following plenary meeting the real potential of the approach was shown. The experts were formulating goals and viewpoints they were interested in and the Cogui system together with the argumentation extension was yielding the associated possible propositions.

Two interests of the approach were more particularly highlighted. They concern cognitive considerations. Firstly, experts were conscious that the elicitation procedure was done according to their thought processes, that is, in a forward way which is more natural and intuitive. The system was thus able to restitute the knowledge in a different manner than the experts usually do. Secondly, from a problem that could initially seem simple, the experts realized that it covered a huge complexity that a human mind could hardly address alone. The tool is currently available to them under restricted access.

7 Conclusion

Even if argumentation based decision making methods applied to the food industry were also proposed by [9, 10], this paper addresses a key point in the context of current techniques used by the food sector and namely addressing reverse engineering. Also, in this approach, an argument is used here as a method computing compatible objectives in the sector. This case study represents an original application and an introspective approach in the agronomy field by providing an argumentation based decision-support system for the various food sectors. It requires nevertheless the very expensive task of knowledge modelling. Such task, in its current state cannot be automated. It strongly depends on the quality of expert opinion and elicitation (exhaustiveness, certainty, etc). The current trend for decision-making tools includes more and more methods of argumentation as means of including experts in the task of modelling and the decision-making processes. Another element to take into account, not discussed in this paper, is the difficulty of technologically (from an agronomy viewpoint) putting in place the facts of each option. Modelling this aspect in the formalism is still to be studied.

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