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Abstract

Food packaging plays a crucial part in the post-harvest environmental impact of fresh foods. Packaging is usually wrongly considered as additional economical and environmental costs. However, by minimizing food waste and losses, it could significantly contribute to decrease the overall environmental impact of the food itself. A good balance between environmental burden (resource consumption and additional waste management issues) and real benefit in usage condition (reduction of food losses) should be thus defined when dimensioning a packaging for a given application. Beyond food waste and environmental impact reduction, various kinds of considerations about packaging, sometimes conflicting, are generally expressed by the stakeholders (food and packaging industries, health authorities, consumers, waste management authority, etc.) related to safety, practicality, perceptions of the packaging material, etc. Therefore, to help the parties deciphering all these arguments, we designed an argumentation-based tool to take into account the conflicting preferences expressed. The requirements concerning

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packagings are modeled by several arguments provided by the stakeholders expressing their viewpoints and expertise. Based on a new attack relation, the argumentation tool computes sets of compatible arguments which are used to rank alternative packagings under debate. In this paper, we present a complete workflow implemented as a software prototype starting by defining a structured representation of experts arguments and poll results, and ending by a ranking of packaging solutions. We show and discuss the results obtained by the software on a use case study (fresh strawberries) to determine the justifiable choices between several packaging materials based on stakeholders' arguments.

Keywords. Food Packaging, Logic-Based Argumentation, Argumentation Tool, Preference Management, Decision Support System.

1. Introduction

We propose a Multi-Criteria Decision Support system (MCDSS) which permits to take into account the points of view of several stakeholders of a food chain about a question under debate. In this paper, we want to be able to choose a packaging solution in a given list of possible alternatives, for a given food to pack. The case study chosen in this paper is fresh strawberries. Stakeholders' opinions (consumers, scientists, manufacturers, etc.) in favor or against specific options are expressed on different criteria (for instance the environmental impact of the packagings). The MCDSS, which implements an argumentation process, must be able to help the manager in charge of

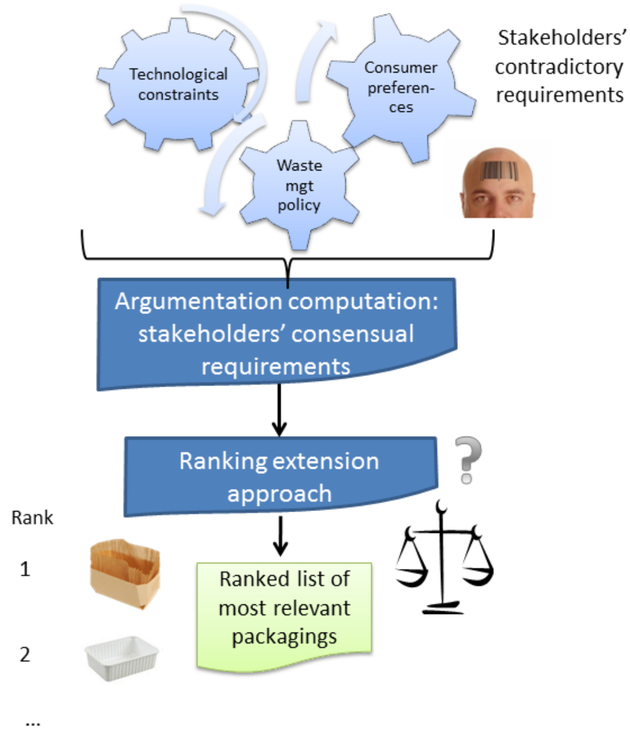


Figure 1: Global insight of the MCDSS.

the decision (for instance, a strawberry producer) to determine a ranked list of the alternative solutions taking into account food chain stakeholders' opinions and preferences expressed on the associated criteria.

For instance, a strawberry producer expresses the need for a new packaging to pack strawberries. The design of this new packaging needs to take into consideration the packaging industry constraints (ability to scale-up the production process, the availability of the raw material, etc.), the waste management administration rules about packaging end of life (biodegradability, recyclability, incineration, burying, etc.) and consumer preferences (transparent packaging, environment-friendly packaging, no extra-cost due to packaging, etc.).

In order to gather consumers' viewpoints, multiple methods can be used: text mining, gathering reviews, etc. We chose to focus on online polls so as to easily gather arguments from a variety of consumers.

Stakeholders' opinions are expressed as text arguments. As illustrated in Figure 1, these arguments are the input of the argumentation system which distinguishes for each option (wood packaging, open plastic packaging, etc.) the reasons leading to its acceptance or its rejection. Then, the argumentation system detects the conflicts among the arguments and computes the sets of coherent arguments which defend themselves against contradicting arguments. After that, it ranks the packaging solutions under debate using a given prioritization of the requirements.

Thus, packagings have to be selected according to several aspects or criteria (food conservation, shock protection, packaging end of life management, etc.) highlighted by arguments expressed by the stakeholders involved in the project. The problem at hand does not simply consist in addressing a multi-criteria optimization problem Bouyssou et al. (2009), since we want the MCDSS to be able to justify why certain packagings are chosen. To this aim, we use argumentation theory Dung (1995); Besnard and Hunter (2008); Rahwan and Simari (2009), in which some approaches combine argumentation and multi-criteria decision making such as Amgoud and Prade (2009) or recently Delhomme et al. (2017).

This paper details how arguments are modeled within a structured argumentation system and how the delivered justified conclusions can be used in the packaging ranking process. It extends the first stage presented in Yun et al. (2016) with several new contributions: (i) beside textual arguments, survey results are now integrated as a possible knowledge source; (ii) this raises a scaling-up issue, since high data volumes now have to be managed and automatically analyzed; (iii) the reasoning process, which was based on the computation of several coherent viewpoints, is now able to rank them using a prioritization of criteria.

The main contributions of the work are the following:

1. A MCDSS based on an argumentation system (AS). Arguments may be either manually entered or automatically generated from a set of responses to a given web survey.
2. A MCDSS designed to allow the ranking of packaging alternative solutions using the consensual sets of arguments (called extensions) computed by the argumentation system and a prioritization of requirements.
3. An evaluation of the MCDSS tool, based on the strawberry case study, in the framework of the Pack4Fresh project with an interdisciplinary collaboration between experts of packaging research, consumer behavior research, and computer science research.

The paper is structured as follows: in Section 2, we present the MCDSS global workflow which implements the desired functionalities expressed by the partners of the Pack4Fresh INRA-CIRAD project which financed this work. In Section 3, we briefly recall Dung's argumentation framework, used to compute extensions (maximal consistent sets of arguments) and we present the structured argumentation model we use and the way we automatically generate arguments from a set of answers to a given web survey. In Section 4, we present the model proposed to rank extensions according to a prioritization on requirements. Section 5 presents the case study and its results. Section 6 is dedicated to the implementation of the approach and Section 7 to related works. Finally, Section 8 recalls our contributions and introduces some perspectives.

2. MCDSS workflow overview

Figure 2 presents the main tasks of the MCDSS workflow.

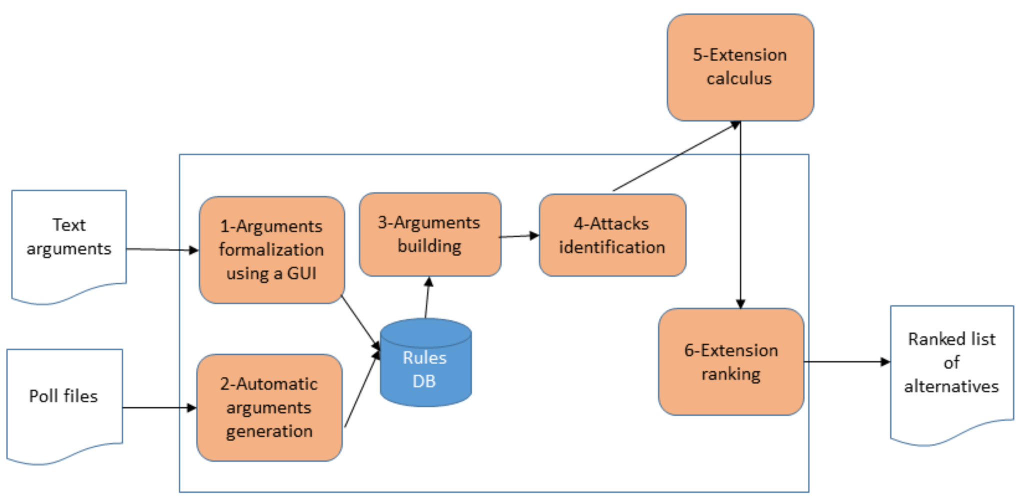


Figure 2: MCDSS workflow overview.

- *Task 1: Argument structuring*: in this task, a textual opinion is encoded into a logic-based structured argument thanks to a dedicated graphical user-friendly interface (GUI).

- *Task 2: Automatic argument generation*: this task automatically transforms some poll's answers into formal arguments made of concepts and rules using the framework described in Section 3.

- *Task 3: Logical arguments derivation*: Using the framework described in Section 3.2, this task builds all possible arguments by a derivation process.

- *Task 4: Attacks detection*: According to the definition of attacks defined in Section 3.2, this task computes an argumentation graph made of arguments (nodes) and attacks (edges).

- *Task 5: Extensions computation*: This task computes the set of extensions, i.e. the subsets of non-conflicting (consistent) arguments which defend themselves from attacking arguments (cf. Section 3.1). To scale up and manage high volumes of arguments from web survey results, connection with the Aspartix platform Dvorak et al. (2011) is performed.

- *Task 6: Extension rankings*: the computation of extensions delivers one or several extensions. In the case of several extensions, the system uses the prioritization on criteria using the framework described in Section

4.1 in order to rank the extensions and to select the top-ranked. Finally, the selected extension is then used to extract preferences associated with its arguments.

Next section introduces the model we propose for argument formalization and the way arguments may be automatically generated from a poll.

3. Logic argumentation model and poll-based arguments generation

In this section, we recall Dung's argumentation principles and present an instantiation of this framework thanks to a logical language, then we show how arguments are automatically generated from a set of answers to a given web survey.

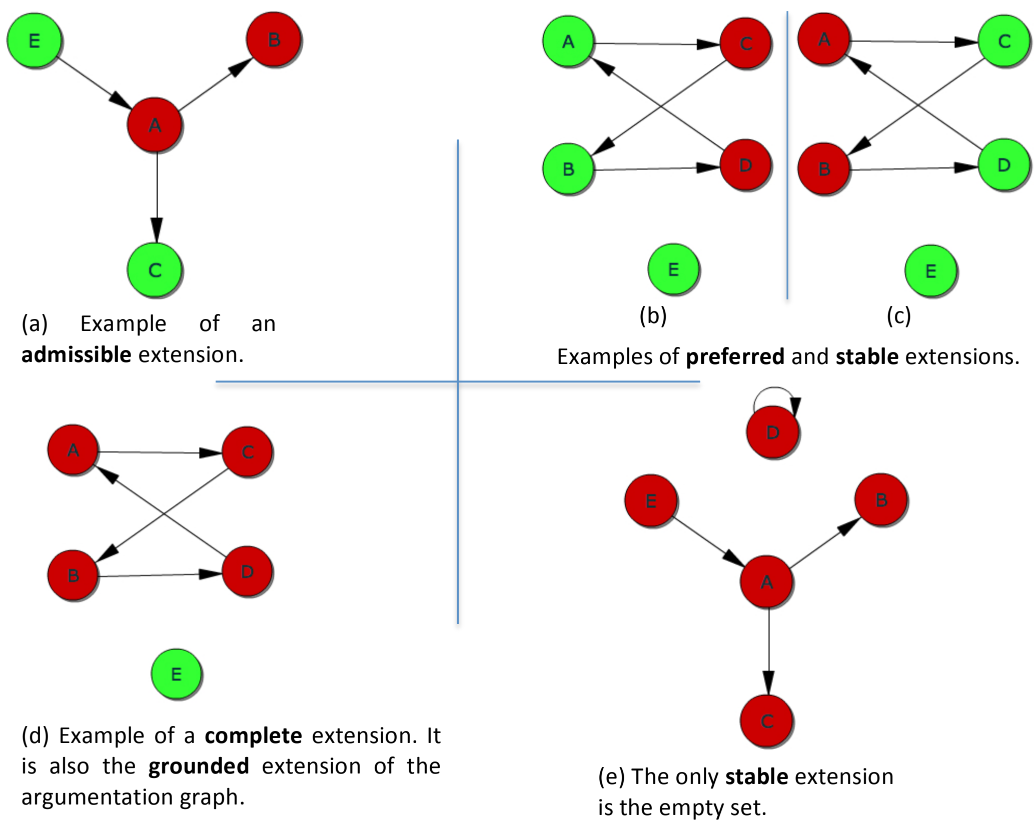
3.1. Dung argumentation principles

A Dung's argumentation framework (AF) Dung (1995) is a tuple $(\mathcal{A}, \mathcal{C})$, where $\mathcal{C} \subseteq \mathcal{A} \times \mathcal{A}$ is a binary attack relation on the set of arguments $\mathcal{A}$. For each argument $X \in \mathcal{A}$, X is *acceptable* w.r.t. a set of arguments $\mathcal{E} \subseteq \mathcal{A}$ if and only if any argument attacking X is attacked by an argument of $\mathcal{E}$. A set of arguments $\mathcal{E} \subseteq \mathcal{A}$ is *conflict free* if and only if $\forall X, Y \in \mathcal{E}, (X, Y) \notin \mathcal{C}$. $\mathcal{E}$ is an *admissible extension* if and only if it is conflict-free and $\forall X \in \mathcal{E}$, X is acceptable w.r.t. $\mathcal{E}$; $\mathcal{E}$ is a *complete extension* if and only if $\mathcal{E}$ is admissible and $X \in \mathcal{E}$ whenever X is acceptable w.r.t. $\mathcal{E}$; $\mathcal{E}$ is a *preferred extension* if and only if it is a set inclusion maximal complete extension; $\mathcal{E}$ is the only *grounded* *extension* if and only if it is the set inclusion minimal complete extension; $\mathcal{E}$ is a *stable extension* if and only if it is preferred and $\forall Y \notin \mathcal{E}, \exists X \in \mathcal{E}$ such that $(X, Y) \in \mathcal{C}$. For a given semantics, the set of extensions of an argumentation framework is denoted by E.

Example 1. *Figure 3 illustrates some examples of argumentation graphs, upon which extensions under the Dung's semantics (admissible, complete, preferred, grounded and stable) are computed (nodes in green color). Note that sub-graphs* (b) *and* (c) *illustrate the two preferred extensions in the argumentation graph.*

3.2. Logic argumentation model

A knowledge base contains the concepts of the considered domain expressed using a logical language $\mathcal{L}$ (such as propositional logic in this paper), the alternative choices in debate and two reserved concepts ACC, REJ referring to the decisions (respectively the *accepted* and *rejected* denominations) with $\tilde{\neg}ACC = REJ$ and conversely. An argumentation system $\mathcal{AS} = (\mathcal{L}, \tilde{\neg}, \mathcal{R}_s, \mathcal{R}_d)$ is composed of the logical language $\mathcal{L}$, a negation function, a set of strict rules $\mathcal{R}_s$ and a set of defeasible rules $\mathcal{R}_d$. A strict subsumption, denoted $\sqsubset$, expresses natural inclusion in the domain, as *"Plastic trays are packagings"*. A defeasible subsumption, denoted $\Subset$, expresses an inclusion which is not always true, as *"Plastic packagings can be reusable"*. A knowledge base in an $\mathcal{AS} = (\mathcal{L}, \tilde{\neg}, \mathcal{R}_s, \mathcal{R}_d)$ is a tuple $(\mathcal{K}, Cr)$ such that



(a) Example of an **admissible** extension.

(b) (c) Examples of **preferred** and **stable** extensions.

(d) Example of a **complete** extension. It is also the **grounded** extension of the argumentation graph.

(e) The only **stable** extension is the empty set.

Figure 3: Examples of different Dung semantics.

$\mathcal{K} \cup Cr \subseteq \mathcal{L}$, where $\mathcal{K}$ contains the alternative choices in debate and Cr contains the reasons/criteria that may underlie an argument.

An argument A is of the form $\emptyset \Subset c_0 \sqsubset_1 c_1 \sqsubset_2 c_2$[1], where $\sqsubset_i \in \{\sqsubset, \Subset\}$, $c_0 \in \mathcal{K}$, $c_1 \in Cr$, $c_2 \in \{ACC, REJ\}$ and for all $i \in \{1, 2\}$, there exists a strict (resp. defeasible) rule in $\mathcal{R}_s$ (resp. $\mathcal{R}_d$) of the form $c_{i-1} \sqsubset c_i$ if $\sqsubset_i = \sqsubset$ (resp. $c_{i-1} \Subset c_i$ if $\sqsubset_i = \Subset$). We denote by $Choice(A) = c_0$ the alternative

[1]The notation $\emptyset \Subset c_0$ indicates that the alternative c_0 is given and does not necessitate any justification in general.

$\sqsubset$	Strict subsumption
$\Subset$	Defeasible subsumption
$\tilde{\neg}$	Logical negation

Table 1: Summary of logical symbols used in arguments

concerned by the argument A, $Reason(A) = c_1$ the reason associated with the argument A and $Den(A) = c_2$ the decision associated with the argument A.

We say that an argument A attacks an argument B iff at least one of the two following conditions is satisfied:

- $Choice(A) = Choice(B)$, $Den(A) \neq Den(B)$ and B is of the form $\emptyset \Subset c_0 \sqsubset_1 c_1 \Subset c_2$.
- $Choice(A) \neq Choice(B)$, $Den(A) = Den(B) = ACC$ and B is of the form $\emptyset \Subset c_0 \sqsubset_1 c_1 \Subset c_2$.

Example 2. *We consider the following arguments expressed about biodegradability of packaging materials considered here as one possible alternative of end of life management:*

- *Life Cycle Analysis (LCA) results are not in favor of biodegradable materials, regarding their high environmental impact,*
- *Consumers are in favor of biodegradable materials since they help to protect the environment.*

We model these arguments by using the proposed logical language as follows:

- BP *is a concept referring to biodegradable packaging materials,*
- PEV, HIP *are concepts referring to packagings which respectively protect the environment and have a high environmental impact (according to LCA),*
- ACC, REJ *are concepts referring to the decisions (accepted, rejected).*

The set of rules $\mathcal{R} = \mathcal{R}_s \cup \mathcal{R}_d$ *is:*

- $\mathcal{R}_s = \{BP \sqsubset HIP, \tilde{\neg}HIP \sqsubset \tilde{\neg}BP, HIP \sqsubset REJ, \tilde{\neg}REJ \sqsubset \tilde{\neg}HIP\}$
- $\mathcal{R}_d = \{BP \Subset PEV, PEV \Subset ACC\}$

Please notice that strict rules are used to model reliable knowledge based on measured parameters by using well-defined and stated procedures, or expressed with linguistic terms such as "must", "shall", "mandatory", "important", etc.. Instead, defeasible rules model knowledge based on empirical observations or expressed with linguistic terms such as "may", "can", "optional", etc. Here, the rules involve HIP *are considered as strict and those involving* PEV *are defeasible.*

The following structured arguments can be built on the knowledge base $(\mathcal{K}, Cr)$ *with* $\mathcal{K} = \{BP\}$ *and* $Cr = \{HIP, PEV\}$*:*

- $A : \emptyset \Subset BP \sqsubset HIP \sqsubset REJ$

- $B : \emptyset \Subset BP \Subset PEV \Subset ACC$

Argument A attacks argument B since $Choice(A) = Choice(B)$*,* $Den(A) = REJ$*,* $Den(B) = ACC$ *and* $B : \emptyset \Subset BP \Subset PEV \Subset ACC$*.*

3.3. Poll-based argument generation

Let us now describe the process used to generate poll-based arguments. It is composed of several steps:

- *Step 1: Creation of the poll:* as defined in Section 3.2, elements of $\mathcal{K}$ represent the alternatives that are in discussion. They may be different packagings, products, etc. We propose to design a set $\mathcal{Q}$ of general questions that can be answered by "Yes", "No" or "Neutral" about concepts, i.e. elements of Cr, which will be used as criteria to rank the alternatives under discussion. An example of a question can be q_1 ="Do you think that $x \in \mathcal{K}$ protects the environment?" or q_2 ="Do you think that $x \in \mathcal{K}$ is harmful for strawberries?" The set of questions $\mathcal{Q} = \{q_1, q_2, \ldots, q_m\}$ is asked for every alternative of $\mathcal{K}$. Please note that we denote by $Con(q_1) = Protect\_environment$ (resp. $Con(q_2) = Harmful$), the underlying concept of question q_1 (resp. q_2). We also define a function $\sigma : Cr \rightarrow \{ACC, REJ\}$, given by domain experts, that tells us if a concept is an element in favor (ACC) or against (REJ) a given alternative. For instance, $\sigma(Con(q_1)) = ACC$ (resp. $\sigma(Con(q_2)) = REJ$).

- *Step 2: Getting the answers:* The poll is proposed to an audience composed of n persons. The result of the poll can be represented with three functions:

  - *positive* : $\mathcal{Q} \times \mathcal{K} \rightarrow \mathbb{N}$ that takes as input a question and an alternative and returns the number of persons that answered "Yes",
  - *negative* : $\mathcal{Q} \times \mathcal{K} \rightarrow \mathbb{N}$ that takes as input a question and an alternative and returns the number of persons that answered "No" and
  - *neutral* : $\mathcal{Q} \times \mathcal{K} \rightarrow \mathbb{N}$ that takes as input a question and an alternative and returns the number of persons that answered "Neutral". It is obvious that for every $k_i \in \mathcal{K}$ and every question $q_j \in \mathcal{Q}$, $positive(q_j, k_i) + negative(q_j, k_i) + neutral(q_j, k_i) = n$.

- *Step 3: Processing the answers:* Once the answers received, we process them using an aggregation function agg for filtering purposes.

$$agg(q_j, k_i) = \begin{cases} 0 & \text{if } neutral(q_j, k_i) > positive(q_j, k_i) + negative(q_j, k_i) \\ -1 & \text{else if } positive(q_j, k_i) < negative(q_j, k_i) \\ 1 & \text{otherwise} \end{cases}$$

  We do not use answers to questions with $agg(q_j, k_i) = 0$ because the answers are not pertinent enough w.r.t. the metric used.

- *Step 4: Creating the arguments:* In this step, we first select a "certainty" threshold $\alpha \in \{0, 1, \ldots, n\}$ and create the following arguments:

$\forall k_i \in \mathcal{K}, \forall q_j \in \mathcal{Q}$:

- if $agg(q_j, k_i) = 1$ and $|positive(q_j, k_i) - negative(q_j, k_i)| > \alpha$ then $\emptyset \Subset k_i \Subset Con(q_j) \sqsubset \sigma(Con(q_j))$,
- if $agg(q_j, k_i) = 1$ and $|positive(q_j, k_i) - negative(q_j, k_i)| \leq \alpha$ then $\emptyset \Subset k_i \Subset Con(q_j) \Subset \sigma(Con(q_j))$,
- if $agg(q_j, k_i) = -1$ and $|positive(q_j, k_i) - negative(q_j, k_i)| > \alpha$ then $\emptyset \Subset k_i \Subset \tilde{\neg}Con(q_j) \sqsubset \tilde{\neg}\sigma(Con(q_j))$,
- if $agg(q_j, k_i) = -1$ and $|positive(q_j, k_i) - negative(q_j, k_i)| \leq \alpha$ then $\emptyset \Subset k_i \Subset \tilde{\neg}Con(q_j) \Subset \tilde{\neg}\sigma(Con(q_j))$.

Example 3. *Suppose that there is a question q = "Do you think that x protects strawberries from shocks?" and that $Plastic\_not\_closed$ is an alternative in $\mathcal{K}$ corresponding to a plastic packaging that is not closed. We ask the question q to the consumers and we get that* 394 *persons answered "No",* 179 *persons answered "I do not know" and* 272 *persons answered "Yes". Since we have that*

$$neutral(q, Plastic\_not\_closed) \leq positive(q, Plastic\_not\_closed) + negative(q, Plastic\_not\_closed)$$

and

$$positive(q, Plastic\_not\_closed) < negative(q, Plastic\_not\_closed),$$

we compute that $agg(q, Plastic\_not\_closed) = -1$. Now, if we define $\alpha =$ 200*, the only argument produced, meaning that "not closed plastic packagings are rejected because they do not protect strawberries from shocks", is:*

$$\emptyset \Subset Plastic\_not\_closed \Subset \tilde{\neg}Shocks\_protection \Subset REJ$$

4. Ranking extensions

We suppose in this section that arguments generated from polls as described in Section 3.3 or manually entered by experts are available in the knowledge base. Extensions are computed using the semantics recalled in Section 3.1. We explain in this section the proposed method to rank extensions according to preferences expressed on requirements.

We first define the necessary notions used in this section. Let $\mathcal{E}$ be an extension. We define the *accepted requirements* and the *rejected requirements* of an extension $\mathcal{E}$ as:

$$AReq(\mathcal{E}) = \bigcup_{A=\emptyset \Subset c_0 \sqsubset_1 c_1 \sqsubset_2 ACC \in \mathcal{E}} \{c_1\}$$

$$RReq(\mathcal{E}) = \bigcup_{A=\emptyset \Subset c_0 \sqsubset_1 c_1 \sqsubset_2 REJ \in \mathcal{E}} \{c_1\}$$

Considering the definition of attacks provided in Section 3.2, it must be noticed that for a given extension $\mathcal{E}$, $AReq(\mathcal{E})$, if not empty, gathers positive arguments in favor of a given alternative in debate and $RReq(\mathcal{E})$ gathers negative arguments against all the other alternatives in debate.

4.1. Refining extensions using semantics

In this section, we introduce our method for ranking a set of extensions E using the locally, Pareto and globally optimal semantics inspired by Croitoru et al. (2015). These semantics return subsets of the original set of extensions. We introduce here the three notions which are based on the notion of domination (preference) between concepts of the accepted requirements.

An extension $\mathcal{E}$ is said not to be locally optimal if we can find another extension $\mathcal{E}'$ such that the concepts of $\mathcal{E}$ are either included in $\mathcal{E}'$ or dominated by elements of $\mathcal{E}'$ (there is at most one concept dominated).

Definition 1. *We say that an extension $\mathcal{E} \in E$ is locally optimal if and only if $\nexists x \in AReq(\mathcal{E})$ and a concept y such that there exists $\mathcal{E}' \in E \backslash \{\mathcal{E}\}$, $((AReq(\mathcal{E}) \backslash \{x\}) \cup \{y\}) \subseteq AReq(\mathcal{E}')$ and $x < y$.*

An extension $\mathcal{E}$ is said not to be Pareto optimal if we can find another extension $\mathcal{E}'$ such that the concepts of $\mathcal{E}$ are either included in $\mathcal{E}'$ or dominated by elements of $\mathcal{E}'$ (they are dominated by a single concept).

Definition 2. *We say that an extension $\mathcal{E} \in E$ is Pareto optimal if and only if $\nexists X \subseteq AReq(\mathcal{E})$ and a concept y and $X \neq \emptyset$ such that there exists $\mathcal{E}' \in E \backslash \{\mathcal{E}\}, ((AReq(\mathcal{E}) \backslash X) \cup \{y\}) \subseteq AReq(\mathcal{E}')$ and for every $x \in X, x < y$.*

An extension $\mathcal{E}$ is said not to be globally optimal if we can find another extension $\mathcal{E}'$ such that the concepts of $\mathcal{E}$ are either included in $\mathcal{E}'$ or dominated by elements of $\mathcal{E}'$ (no restrictions).

Definition 3. *We say that an extension* $\mathcal{E} \in E$ *is globally optimal if and only if* $\nexists X \subseteq AReq(\mathcal{E})$ *and a set of concepts* Y *and* $X \neq \emptyset$ *such that there exists* $\mathcal{E}' \in E \setminus \{\mathcal{E}\}, ((AReq(\mathcal{E}) \setminus X) \cup Y) \subseteq AReq(\mathcal{E}')$ *and for every* $x \in X$*, there exists* $y \in Y$ *such that* $x < y$*.*

Note that while those semantics allow to refine the set of considered extensions, they may be unable to output only one extension. This is of course dependent of the preferences the user has expressed: the more preferences are used, the more refinements are going to happen. Note also that it is possible to use the preferences differently, namely in a more "quantitative" fashion based on argument count. We study this new approach in the next section.

4.2. Ranking methods using scores

This new approach using scores is interesting in many ways. First, it is obviously easier and faster to compute than the approach introduced in the previous section (and based on Croitoru et al. (2015)). Furthermore, an extension can be accurately scored (using the preferences) even if we do not have the entire set of extensions. This can be useful in the event that we do not have enough time to compute all the extensions. In this section, we introduce two scores for ranking extensions.

4.2.1. First scoring: Higher score based on positive arguments means less dominated

The first method only considers positive arguments in favor of one of the alternatives in debate. It gives the highest score to the extension that is the least dominated. Namely, the score of an extension $\mathcal{E}$ is:

Definition 4. $Score_1(\mathcal{E}) = \sum_{a \in AReq(\mathcal{E})} |\{c \mid c \textit{ is a concept and } c < a\}|$

With this score, the best extension is the one with the highest score.

4.2.2. Second scoring: Higher score based on negative arguments means less dominated

The second method only considers negative arguments against the alternatives in debate. It gives the highest points to the extension whose negative arguments are the most dominated. Namely, the score of an extension $\mathcal{E}$ is:

Definition 5. $Score_2(\mathcal{E}) = \sum_{a \in RReq(\mathcal{E})} |\{c \mid c \textit{ is a concept and } a < c\}|$

Again, with this score, the best extension is the one with the highest score.

A research issue is to find a way to combine the two scores in order to produce a more efficient ranking. This can be achieved by using multi-criteria methods. We provide a naive way to combine the two scores, namely $Score_3(\mathcal{E}) = Score_1(\mathcal{E}) + Score_2(\mathcal{E})$.

Figure 4: Four considered packaging options: Plastic not closed, Wood packaging, Plastic rigid lid, Plastic with plastic film.

5. Use-case

The use case is coming from the INRA Glofoods Pack4Fresh project which, as explained in the introduction, aims at designing innovative packaging solutions for fresh food products. For best packaging selection support, one aspect to take into account is the consumers' expectations in terms of packaging characteristics. In the project it has been tested for strawberries. Four packaging options have been considered (see Figure 4):

- an opened plastic basket (without lid or film)
- a wood packaging (without lid)
- a plastic basket with rigid lid
- a plastic basket with plastic film

5.1. Automated generation of arguments from the poll

A survey upon a sample of 840 people has provided the following 38 arguments using the poll-based argument automatic generation process presented in Section 3.3 with a "certainty" threshold of 756 people (90% of the

840 respondents, which indicates a very certain, nearly consensual, general opinion):

Arg id	**Textual argument**	**Formal argument**
a1	Consumers are in favour of wood packaging because it preserves the flavour of strawberries	$Wood\_packaging \Subset Protect\_flavor \Subset ACC$
a2	Consumers are in favour of wood packaging because it preserves strawberries from shocks	$Wood\_packaging \Subset Shocks\_protection \Subset ACC$
a3	Consumers are in favour of wood packaging because it is reusable	$Wood\_packaging \Subset Reusable \Subset ACC$
a4	Consumers are in favour of wood packaging because it is recyclable	$Wood\_packaging \Subset Recyclable \Subset ACC$
a5	Consumers are in favour of wood packaging because it incites to eat strawberries	$Wood\_packaging \Subset Incite\_to\_eat \Subset ACC$
a6	Consumers are in favour of wood packaging because they can see the strawberries	$Wood\_packaging \Subset Can\_see \Subset ACC$
a7	Consumers are in favour of wood packaging because they can smell the strawberries	$Wood\_packaging \Subset Can\_smell \Subset ACC$
a8	Consumers are in favour of wood packaging because they think it protects the environment	$Wood\_packaging \Subset Protect\_environment \Subset ACC$
a9	Consumers are not in favour of wood packaging because it harms strawberries	$Wood\_packaging \Subset Harmful \Subset REJ$
a10	Consumers are in favour of plastic packaging with plastic film because they can see the strawberries	$Plastic\_with\_plastic\_film \Subset Can\_see \Subset ACC$
a11	Consumers are not in favour of plastic packaging with plastic film because it is not reusable	$Plastic\_with\_plastic\_film \Subset \tilde{\neg}Reusable \Subset REJ$
a12	Consumers are not in favour of plastic packaging with plastic film because it does not preserve strawberries from shocks	$Plastic\_with\_plastic\_film \Subset \tilde{\neg}Shocks\_protection \Subset REJ$
a13	Consumers are not in favour of plastic packaging with plastic film because it is not recyclable	$Plastic\_with\_plastic\_film \Subset \tilde{\neg}Recyclable \Subset REJ$

Arg id	Textual argument	Formal argument
a14	Consumers are not in favour of plastic packaging with plastic film because it does not enable good fridge conservation	$Plastic\_with\_plastic\_film$ $\Subset \tilde{\neg} Good\_fridge\_conservation \Subset REJ$
a15	Consumers are not in favour of plastic packaging with plastic film because they think it does not protect the environment	$Plastic\_with\_plastic\_film$ $\Subset \tilde{\neg} Protect\_environment \Subset REJ$
a16	Consumers are not in favour of plastic packaging with plastic film because it does not enable good ambiant conservation	$Plastic\_with\_plastic\_film$ $\Subset \tilde{\neg} Good\_ambiant\_conservation \Subset REJ$
a17	Consumers are in favour of plastic packaging with plastic film because it incites to eat strawberries	$Plastic\_with\_plastic\_film$ $\Subset Incite\_to\_eat \Subset ACC$
a18	Consumers are not in favour of plastic packaging with plastic film because they cannot smell the strawberries	$Plastic\_with\_plastic\_film$ $\Subset \tilde{\neg} Can\_smell \Subset REJ$
a19	Consumers are in favour of plastic packaging with plastic film because it preserves the flavour of strawberries	$Plastic\_with\_plastic\_film$ $\Subset Protect\_flavor \Subset ACC$
a20	Consumers are in favour of plastic packaging with plastic film because it does not harm strawberries	$Plastic\_with\_plastic\_film$ $\Subset \tilde{\neg} Harmful \Subset ACC$
a21	Consumers are in favour of plastic packagings with rigid lids because they can smell the strawberries	$Plastic\_rigid\_lid$ $\Subset Can\_smell \Subset ACC$
a22	Consumers are in favour of plastic packagings with rigid lids because they protect the environment	$Plastic\_rigid\_lid$ $\Subset Protect\_environment \Subset ACC$
a23	Consumers are not in favour of plastic packagings with rigid lids because they are not reusable	$Plastic\_rigid\_lid$ $\Subset \tilde{\neg} Reusable \Subset REJ$
a24	Consumers are in favour of plastic packagings with rigid lids because they are recyclable	$Plastic\_rigid\_lid$ $\Subset Recyclable \Subset ACC$

Arg id	**Textual argument**	**Formal argument**
a25	Consumers are in favour of plastic packagings with rigid lids because they are not harmful for strawberries	$Plastic\_rigid\_lid$ $\Subset \tilde{\neg} Harmful \Subset ACC$
a26	Consumers are in favour of plastic packagings with rigid lids because they protect flavour	$Plastic\_rigid\_lid$ $\Subset Protect\_flavor \Subset ACC$
a27	Consumers are in favour of plastic packagings with rigid lids because they incite to eat strawberries	$Plastic\_rigid\_lid$ $\Subset Incite\_to\_eat \Subset ACC$
a28	Consumers are in favour of plastic packagings with rigid lids because they can see the strawberries	$Plastic\_rigid\_lid$ $\Subset Can\_see \Subset ACC$
a29	Consumers are in favour of plastic packagings with rigid lids because they preserve strawberries from shocks	$Plastic\_rigid\_lid$ $\Subset Shocks\_protection \Subset ACC$
a30	Consumers are not in favour of plastic packagings that are not closed because they do not protect the environment	$Plastic\_not\_closed$ $\Subset \tilde{\neg} Protect\_environment \Subset REJ$
a31	Consumers are in favour of plastic packagings that are not closed because they are reusable	$Plastic\_not\_closed$ $\Subset Reusable \Subset ACC$
a32	Consumers are in favour of plastic packagings that are not closed because they are recyclable	$Plastic\_not\_closed$ $\Subset Recyclable \Subset ACC$
a33	Consumers are not in favour of plastic packagings that are not closed because they are harmful for strawberries	$Plastic\_not\_closed$ $\Subset Harmful \Subset REJ$
a34	Consumers are in favour of plastic packagings that are not closed because they permit to see the strawberries	$Plastic\_not\_closed$ $\Subset Can\_see \Subset ACC$
a35	Consumers are in favour of plastic packagings that are not closed because they permit to smell the strawberries	$Plastic\_not\_closed$ $\Subset Can\_smell \Subset ACC$

Arg id	Textual argument	Formal argument
a36	Consumers are in favour of plastic packagings that are not closed because they protect flavour	$Plastic\_not\_closed \Subset Protect\_flavor \Subset ACC$
a37	Consumers are not in favour of plastic packagings that are not closed because they do not protect strawberries from shocks	$Plastic\_not\_closed \Subset \tilde{\neg}Shocks\_protection \Subset REJ$
a38	Consumers are in favour of plastic packagings that are not closed because they incite to eat strawberries	$Plastic\_not\_closed \Subset Incite\_to\_eat \Subset ACC$

5.2. Arguments provided by experts

The previous consumers' arguments have been assessed by experts in food packaging. The experts have then provided other arguments. This process allows us to "simulate" a kind of debate.

Arg id	Textual argument	Formal argument
a39	Experts are not in favour of wood packaging because it does not concentrate the smell	$Wood\_packaging \Subset \tilde{\neg}Concentrate\_smell \Subset REJ$
a40	Experts are in favour of wood packaging because, due to exudate absorption, it contributes to good ambiant conservation	$Wood\_packaging \Subset Good\_ambiant\_conservation \Subset ACC$
a41	Experts are in favour of wood packaging because, due to exudate absorption, it contributes to good fridge conservation	$Wood\_packaging \Subset Good\_fridge\_conservation \Subset ACC$
a42	Experts are not in favour of plastic packaging with rigid lid because, due to consumers' manipulations to see under the pack, it contributes to shocks	$Plastic\_rigid\_lid \Subset \tilde{\neg}Shocks\_protection \Subset REJ$
a43	Experts are in favour of plastic packaging with rigid lid because it concentrates the smell	$Plastic\_rigid\_lid \Subset Concentrate\_smell \Subset ACC$

Arg id	Textual argument	Formal argument
a44	Experts are not in favour of plastic packaging with plastic film because condensation may hide strawberries	$Plastic\_with\_plastic\_film \Subset Condensation \Subset REJ$
a45	Experts are in favour of plastic packaging with plastic film because it permits to reduce waste (thanks to modified atmosphere)	$Plastic\_with\_plastic\_film \Subset Protect\_environment \Subset ACC$
a46	Experts are not in favour of non-closed plastic packaging because it does not concentrate the smell	$Plastic\_not\_closed \Subset \neg Concentrate\_smell \Subset REJ$

5.3. Extensions computation

Using the argumentation model presented in Section 3.2, 1519 attacks have been generated upon the 46 arguments. Thanks to these arguments and attacks, five preferred extensions have been calculated using Aspartix. Please note that the preferred semantics is used because it is simple and allows to preserve every existing point of view (cf. Section 3.1). One can observe that the first four extensions are composed of:

- the set of positive arguments in favor of a given alternative,
- the set of negative arguments against the other alternatives in debate.

For instance, extension $\mathcal{E}_4$ is associated with the alternative Wood Packaging. Arguments a1, a2, a3, a4, a5, a6, a7, a8 are positive arguments in favor of Wood Packaging and arguments a11, a12, a13, a14, a15, a16, a18, a23, a30, a33, a37, a40, a41, a42, a44, a46 are negative arguments against the three other alternatives.

$\mathcal{E}_1$	{a9, a10, a17, a19, a20, a23, a30, a33, a37, a39, a42, a45, a46}
$\mathcal{E}_2$	{a9, a11, a12, a13, a14, a15, a16, a18, a23, a31, a32, a34, a35, a36, a38, a39, a42, a44}
$\mathcal{E}_3$	{a9, a11, a12, a13, a14, a15, a16, a18, a21, a22, a24, a25, a26, a27, a28, a29, a30, a33, a37, a39, a43, a44, a48}
$\mathcal{E}_4$	{a1, a2, a3, a4, a5, a6, a7, a8, a11, a12, a13, a14, a15, a16, a18, a23, a30, a33, a37, a40, a41, a42, a44, a46}
$\mathcal{E}_5$	{a9, a11, a12, a13, a14, a15, a16, a18, a23, a30, a33, a37, a39, a42, a44, a46}

Table 4: Preferred extensions of the use-case.

The remaining extension $\mathcal{E}_5$ contains all the negative arguments associated with all the alternatives. In this use case, this last extension will be considered as useless since negative arguments are already available in the other extensions.

5.4. Scenario analysis

We will consider the following three scenarios:

- Scenario SECURE: "not nefast effect" (i.e. not harmful) concept is preferred to all the other concepts.
- Scenario GREEN: "Protect_environment", "recyclable" and "reusable" are preferred to all the other concepts.
- Scenario PLEASURE: "can see", "can smell", "protect flavor" and "incite to eat" are preferred to all the other concepts.

In the following, we only detail the results obtained for scenario SECURE and we present globally the results obtained for the three scenarios. The in-

Locally optimal	$\{Plastic\_with\_plastic\_film, Plastic\_rigid\_lid, Wood\_packaging\}$
Pareto optimal	$\{Plastic\_with\_plastic\_film, Plastic\_rigid\_lid\}$
Globally optimal	$\{Plastic\_with\_plastic\_film, Plastic\_rigid\_lid\}$

Table 5: Results obtained for scenario SECURE refining extensions using the locally, Pareto and globally optimal semantics.

terested reader will find the detailed results for the other scenarios in Section AppendixA.

Preferences associated with concepts for scenario SECURE are the following:

- $Protect\_flavor < \tilde{\neg}Nefast\_effect$
- $Protect\_environment < \tilde{\neg}Nefast\_effect$
- $\tilde{\neg}Protect\_environment < \tilde{\neg}Nefast\_effect$
- $Shocks\_protection < \tilde{\neg}Nefast\_effect$
- $\tilde{\neg}Shocks\_protection < \tilde{\neg}Nefast\_effect$
- $Reusable < \tilde{\neg}Nefast\_effect$
- $Recyclable < \tilde{\neg}Nefast\_effect$
- $\tilde{\neg}Reusable < \tilde{\neg}Nefast\_effect$
- $\tilde{\neg}Recyclable < \tilde{\neg}Nefast\_effect$
- $Incite\_to\_eat < \tilde{\neg}Nefast\_effect$

Packaging	**Score$_1$**	**Score$_2$**	**Score$_3$**
$Wood\_packaging$	0	14	14
$Plastic\_with\_plastic\_film$	21	8	29
$Plastic\_not\_closed$	0	12	12
$Plastic\_rigid\_lid$	21	14	35

Table 6: Results obtained for scenario SECURE ranking extensions using scoring functions.

- $Can\_see < \tilde{\neg}Nefast\_effect$
- $Can\_smell < \tilde{\neg}Nefast\_effect$
- $\tilde{\neg}Can\_smell < \tilde{\neg}Nefast\_effect$
- $Nefast\_effect < \tilde{\neg}Nefast\_effect$
- $\tilde{\neg}Good\_fridge\_conservation < \tilde{\neg}Nefast\_effect$
- $\tilde{\neg}Good\_ambiant\_conservation < \tilde{\neg}Nefast\_effect$
- $Good\_ambiant\_conservation < \tilde{\neg}Nefast\_effect$
- $Good\_fridge\_conservation < \tilde{\neg}Nefast\_effect$
- $Concentrate\_smell < \tilde{\neg}Nefast\_effect$
- $Condensation < \tilde{\neg}Nefast\_effect$
- $\tilde{\neg}Concentrate\_smell < \tilde{\neg}Nefast\_effect$

We can see in Table 7 that the results obtained using the two indicators $Globally\_optimal$ and $Score_1$ are the same for the alternatives in first position. $Score_3$ indicator is more discriminant than $Globally\_optimal$

Scenario	Globally optimal	Score$_1$	Score$_3$
SECURE	$\{Plastic$ $\_with\_plastic\_film,$ $Plastic\_rigid\_lid\}$	$Plastic$ $\_with\_plastic\_film$ $\sim Plastic\_rigid\_lid$ $> Wood\_packaging$ $\sim Plastic\_not\_closed$	$Plastic\_rigid\_lid$ $> Plastic$ $\_with\_plastic\_film$ $> Wood\_packaging$ $> Plastic\_not\_closed$
GREEN	$Wood\_packaging$	$Wood\_packaging$ $> Plastic\_rigid\_lid$ $\sim Plastic\_not\_closed$ $> Plastic$ $\_with\_plastic\_film$	$Wood\_packaging$ $> Plastic\_rigid\_lid$ $> Plastic\_not\_closed$ $> Plastic$ $\_with\_plastic\_film$
PLEASURE	$\{Plastic\_not\_closed,$ $Plastic\_rigid\_lid,$ $Wood\_packaging\}$	$Wood\_packaging$ $\sim Plastic\_rigid\_lid$ $\sim Plastic\_not\_closed$ $> Plastic$ $\_with\_plastic\_film$	$Wood\_packaging$ $\sim Plastic\_rigid\_lid$ $> Plastic\_not\_closed$ $> Plastic$ $\_with\_plastic\_film$

Table 7: Summary of the results obtained for the three scenarios.

and $Score_1$. Indeed, in scenarios SECURE and PLEASURE, $Score_3$ provides an advantage to alternatives with less negative arguments which are $Plastic\_rigid\_lid$ and $Wood\_packaging$.

The same scenarios have been presented to a food packaging expert in order to assess the MCDSS results. Concerning scenario SECURE, the expert agrees with results obtained with $Globally\_optimal$ and $Score_1$ indicators and disagrees with result obtained with $Score_3$. Indeed, the expert prefers $Plastic\_with\_plastic\_film$ to $Plastic\_rigid\_lid$ as the first one permits to control in a better way modified atmosphere which extends shelf life (expressed in Argument $a45$) and avoids moisture and microorganism growth.

It may be noticed that this last argument was not present in the MCDSS knowledge base as an expert argument but it exits as a consumer argument ($a20$). The addition of this new argument will not change the ranking for all the indicators as the MCDSS does not take into account the fact that the same argument may be expressed by different stakeholders. An option could be to introduce a weight which will provide more power to arguments which are supported by several stakeholders; such an approach could benefit from the notion of ranking semantics such as Amgoud and Ben-Naim (2013); Amgoud et al. (2016); Bonzon et al. (2016); Baroni et al. (2018) where arguments' strength is computed based on the attacks in the framework. So, $Score_3$ seems to bring an additional piece of information which is not taken into account by the expert.

Concerning scenario GREEN, the expert has defined three individual rankings for each of the criteria Protect environment, Reusable and Recyclable:

- **Protect environment**: $Plastic\_with\_plastic\_film > Wood\_packaging > Plastic\_rigid\_lid = Plastic\_not\_closed$ considering that $Plastic\_with\_plastic\_film$ (with modified atmosphere) permits to reduce waste and $Wood\_packaging$ has less impact on environment than $Plastic\_rigid\_lid$ and $Plastic\_not\_closed$ in terms of biodegradability duration.
- **Reusable**: $Wood\_packaging = Plastic\_not\_closed > Plastic\_rigid\_lid > Plastic\_with\_plastic\_film$ considering the practical point of view of reuse of the packaging material for another usage.
- **Recyclable**: $Wood\_packaging > Plastic\_not\_closed =$

$Plastic\_rigid\_lid = Plastic\_with\_plastic\_film$ considering that none of the three plastic materials are recyclable at the state of the art and that wood packaging is the only recyclable one.

Considering that $Wood\_packaging$ is the only one appearing in first position for "Reusable" and "Recyclable" and in second position for "Protect environment", we can state that the expert agrees with the result proposed by the MCDSS for the three indicators $Globally\_optimal$, $Score_1$ and $Score_3$.

Concerning scenario PLEASURE, the expert did not want to assess the criterion $Incite\_to\_eat$ as it is a question of consumer's perception. However, the expert considers that all packagings are ex-aequo for the three remaining criteria (can_see, can_smell and $protect\_flavor$). This corresponds to the result expressed by the MCDSS for the indicators $Globally\_optimal$ and $Score_1$, except for the case of $Plastic\_with\_plastic\_film$ which is ranked behind the other packagings by the MCDSS. This is due to the fact that consumers consider the $Plastic\_with\_plastic\_film$ packaging not to allow smelling the strawberries (Argument a18), whereas the expert considers this is compensated by its ability to concentrate smell. The latter compensation effect, however, is not coded in the MCDSS.

We may note that in several of the above evaluation cases, discordances between MCDSS and expert rankings are not due to the ranking method itself but to missing information to be included into the MCDSS, or pieces of information included in the MCDSS but not taken into account by the expert (by example negative arguments). This highlights the interest of an iterative process for argument elicitation in order to obtain complete information in the MCDSS, as recommended in Thomopoulos et al. (2013); Johnson et al. (2010); Thomopoulos et al. (2009). On the contrary, similar information lead to similar rankings, which constitutes a positive expert validation feedback on the MCDSS reasoning engine. Another significant finding was that in complex cases, as in the GREEN scenario for instance, providing a unique global ranking was a difficult task for the expert. Thus we can conclude that (i) there is a recognized added value of providing MCDSS results and (ii) expert evaluation has to be achieved firstly on simple cases, which can be intuitively apprehended by human reasoning. Interestingly, these remarks are in line with a well-known distinction between different approaches to decision support Tsoukiàs (2007). The normative approach, more common in the Anglo-Saxon school of decision support, derives decision models from rationality norms established a priori. Expert decision deviating from these norms is interpreted as a mistake which highlights the need for MCDSS aid in order to decide in a rational way Fishburn (1970). On the contrary, in the descriptive approach, more common in the European school of decision support, decision models are derived from observing how expert make decisions, in order to reproduce their way of reasoning in the MCDSS Bell et al. (1988). In our system, normative decision support is expected from the MCDSS in complex cases, whereas the descriptive approach is used for MCDSS evaluation in simple cases.

6. Implementation of the approach

The MCDSS has been implemented as a Java GXT/GWT web application (although the access is restricted). This MCDSS takes as input a collection of textual arguments in favor or against a set of alternatives under debate. It implements the entire process described in Section 2 from argument elicitation to extension ranking and it also provides several GUIs for visualisation purposes. The main interface of the system is illustrated in Figure 5; it displays the graphical representation of the formalized concepts and arguments.

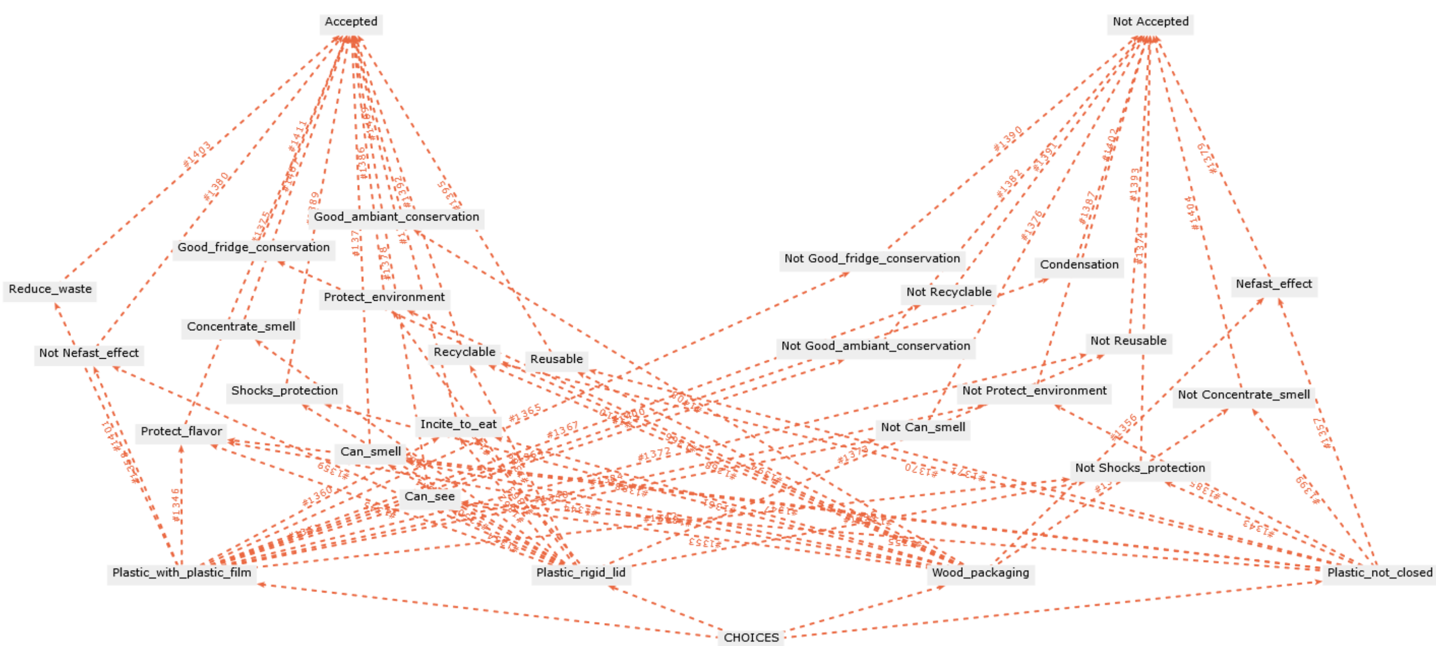
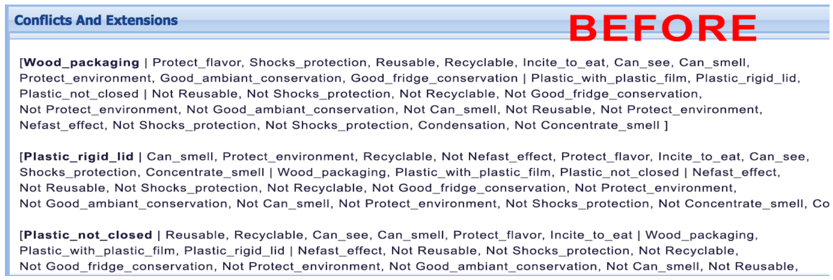


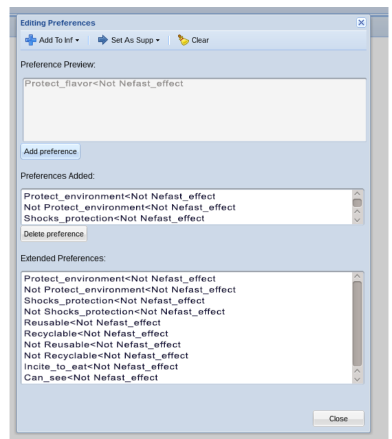
Figure 5: Main interface of the argumentation system showing a global overview on the alternatives under debate.

We integrated a simple and intuitive interface in the web application for



(a) Extensions outputted by the argumentation framework.

(b) Extensions outputted by the argumentation framework after preferences filtering.



(c) Preference elicitation interface.

Figure 6: Interfaces for preference management and extension ranking.

inputting preferences which enables users to clearly visualize the preferences implied (see Figure 6c). The preferences are saved in a database and are specific to a particular argumentation case. We also implemented all the preferences methods discussed in this paper. The processing of the argumentation framework is hidden to the user and only the different extensions produced are displayed (see Figure 6a). The user can then add preferences and use the refining methods introduced in Section 4.1 (see Figure 6b).

7. Related work

This work presents a novel application of preference based logical argumentation systems for food science. As illustrated in Figure 2, our approach follows the following work-flow: generation of arguments (from text or polls), attack computation and generation of argumentation framework and, last, use of preferences for extension ranking.

Regarding the first step of the work-flow, i.e. the argument generation, we used the structured argument definition of Prakken (2010) but changed to our particular application needs (our arguments are always in favour or not of an option). In the second work-flow step, the attack used in this paper, albeit satisfying the rationality postulates of Caminada and Amgoud (2007), also follows the intuition of Prakken (2010). Last, the preferences are applied to the extensions of the argumentation framework built upon the first two steps. Ordinal preference handling follows the work of Croitoru et al. (2015). This work differs from classical argumentation approaches (for an overview please check Modgil and Prakken (2013)) in the fact that the attack relation is not modified (i.e. changed, deleted) but the preferences are used directly on the outputted extensions. The numerical preference handling takes this work further in a cardinal setting. A discussion on the rationales of different kinds of attacks can be found in Yun et al. (2018).

This work uses the software interface described in Tamani et al. (2015) for logical argument elicitation from text. This software, similarly to other argumentation software such as Araucaria Reed and Rowe (2004), Argunet

Schneider et al. (2007) and DebateGraph[2], allows the expression of arguments as texts to manually formalize them as hypothesis and conclusions but also to compute the extensions and the preference induced ranking. In this respect, our interface is the only software allowing to compute all steps of the workflow described in Figure 2.

While this work presents a significant and original application of argumentation theory in food science, let us also highlight other numerous argumentation applications developed recently in various fields: ArgTrust Parsons et al. (2013), in which the authors considered argumentation frameworks for decision making; CISpaces framework Toniolo et al. (2014), which supports collaborative intelligence analysis of conflicting information; *"Quaestion-it.com"* Evripidou and Toni (2014) which is a social intelligence debating platform that demonstrates a question-and-answer web application providing support for user-posed questions; Carneades Gordon (2013), which provides software tools based on a common computational model of argument graphs useful for policy deliberations, etc.

8. Conclusion

In this paper we proposed a complete methodology, from texts and online polls, until final decision support, in order to (i) model possibly conflicting arguments from various actors involved and regarding several criteria, (ii)

[2] www.debategraph.org

structure an argumentation system, (iii) deliver justified conclusions based on extension computation, (iv) use criteria prioritization to rank the solutions. Using this methodology, a case study concerning the choice of the most suitable eco-packaging for fresh food products is presented and its expert evaluation discussed.

This system is a significant breakthrough in two different fields. On the one hand, it extends explanatory approaches of multi-criteria and multi-actor decision by allowing for scaling up to high data volumes, which have to be managed and automatically analyzed, due to the use of online polls as a data source. On the other hand, it opens the way to sustainable choices to reduce the post-harvest environmental impact of fresh foods, since food packaging plays a crucial part in it. Moreover, in opposition to classical "black box" approaches, users can access and assess the reasons behind the provided decision, which allows the iterative process of adding new arguments if some pieces of information are missing. This guarantees the fact that decision biases can be corrected by knowledge enrichment.

The aim of this paper was to present, assess and show the relevance of the MCDSS workflow. An interesting future methodological study would be to fine-tune the current MCDSS workflow parameterization, notably with regards to the aggregation function used to compute arguments from the polls, the "certainty" threshold used to distinguish between strict and defeasible arguments, and the semantics used to compute extensions.

Moreover, as a future work, this methodology is promising to support innovation by guiding the design of new-generation, biosourced, “intelligent”, eco-efficient food packagings. Research is active in this area but mainly focused on technical aspects such as the properties of the materials in an extremely small size scale. However, to be acceptable and used, these new-generation solutions have to take into account all the considerations and expectations raising from end-users all along the supply chain, from production to consumption and after use, with a life-cycle sight.

Appendix AppendixA: Detailed results for the use case

Locally optimal	$\{Plastic\_rigid\_lid, Wood\_packaging\}$
Pareto optimal	$Wood\_packaging$
Globally optimal	$Wood\_packaging$

Table A.8: Results obtained for scenario GREEN refining extensions using the locally, Pareto and globally optimal semantics.

Packaging	**Score**$_1$	**Score**$_2$	**Score**$_3$
$Wood\_packaging$	57	42	99
$Plastic\_with\_plastic\_film$	19	24	33
$Plastic\_not\_closed$	38	36	74
$Plastic\_rigid\_lid$	38	42	82

Table A.9: Results obtained for scenario GREEN ranking extensions using scoring functions.

Locally optimal	$\{Plastic\_not\_closed, Plastic\_rigid\_lid, Wood\_pack\}$
Pareto optimal	$\{Plastic\_not\_closed, Plastic\_rigid\_lid, Wood\_pack\}$
Globally optimal	$\{Plastic\_not\_closed, Plastic\_rigid\_lid, Wood\_pack\}$

Table A.10: Results obtained for scenario PLEASURE refining extensions using the locally, Pareto and globally optimal semantics.

Packaging	**Score$_1$**	**Score$_2$**	**Score$_3$**
$Wood\_packaging$	72	56	128
$Plastic\_with\_plastic\_film$	54	32	86
$Plastic\_not\_closed$	72	48	120
$Plastic\_rigid\_lid$	72	56	128

Table A.11: Results obtained for scenario PLEASURE ranking extensions using scoring functions.

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