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## Choice of environment-friendly food packagings through argumentation systems and preferences

Bruno Yun, Pierre Bisquert, Patrice Buche, Madalina Croitoru, Jean Guillard, Valérie V. Guillard, Rallou Thomopoulos

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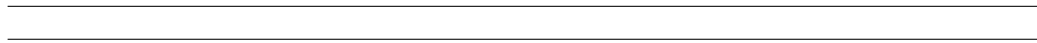
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1       Choice of environment-friendly food packagings  
2       through argumentation systems and preferences

3       Bruno Yun<sup>c</sup>, Pierre Bisquet<sup>c,d</sup>, Patrice Buche<sup>c,d</sup>, Madalina Croitoru<sup>c</sup>,  
4       Valérie Guillard<sup>d</sup>, Rallou Thomopoulos<sup>c,d</sup>

5       <sup>a</sup>*LIRMM, Univ Montpellier, CNRS, INRIA GraphIK, Montpellier, France*

6       <sup>b</sup>*IATE, Univ Montpellier, INRA, CIRAD, Montpellier SupAgro, Montpellier, France*



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*Email addresses: yun@lirmm.fr (Bruno Yun), pierre.bisquet@inra.fr (Pierre Bisquet), patrice.buche@inra.fr (Patrice Buche), croitoru@lirmm.fr (Madalina Croitoru), guillard@univ-montp2.fr (Valérie Guillard), rallou.thomopoulos@inra.fr (Rallou Thomopoulos)*

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9 Bruno Yun<sup>c</sup>, Pierre Bisquet<sup>c,d</sup>, Patrice Buche<sup>c,d</sup>, Madalina Croitoru<sup>c</sup>,  
10 Valérie Guillard<sup>d</sup>, Rallou Thomopoulos<sup>c,d</sup>

11 <sup>c</sup>*LIRMM, Univ Montpellier, CNRS, INRIA GraphIK, Montpellier, France*

12 <sup>d</sup>*IATE, Univ Montpellier, INRA, CIRAD, Montpellier SupAgro, Montpellier, France*

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13 **Abstract**

14 Food packaging plays a crucial part in the post-harvest environmental im-  
15 pact of fresh foods. Packaging is usually wrongly considered as additional  
16 economical and environmental costs. However, by minimizing food waste  
17 and losses, it could significantly contribute to decrease the overall environ-  
18 mental impact of the food itself. A good balance between environmental  
19 burden (resource consumption and additional waste management issues) and  
20 real benefit in usage condition (reduction of food losses) should be thus de-  
21 fined when dimensioning a packaging for a given application. Beyond food  
22 waste and environmental impact reduction, various kinds of considerations  
23 about packaging, sometimes conflicting, are generally expressed by the stake-  
24 holders (food and packaging industries, health authorities, consumers, waste  
25 management authority, etc.) related to safety, practicality, perceptions of  
26 the packaging material, etc. Therefore, to help the parties deciphering all  
27 these arguments, we designed an argumentation-based tool to take into ac-  
28 count the conflicting preferences expressed. The requirements concerning

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*Email addresses:* [yun@lirmm.fr](mailto:yun@lirmm.fr) (Bruno Yun), [pierre.bisquet@inra.fr](mailto:pierre.bisquet@inra.fr) (Pierre Bisquet), [patrice.buche@inra.fr](mailto:patrice.buche@inra.fr) (Patrice Buche), [croitoru@lirmm.fr](mailto:croitoru@lirmm.fr) (Madalina Croitoru), [guillard@univ-montp2.fr](mailto:guillard@univ-montp2.fr) (Valérie Guillard), [rallou.thomopoulos@inra.fr](mailto:rallou.thomopoulos@inra.fr) (Rallou Thomopoulos)

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

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39 **Keywords.** Food Packaging, Logic-Based Argumentation, Argumenta-  
40 tion Tool, Preference Management, Decision Support System.

## 41 1. Introduction

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

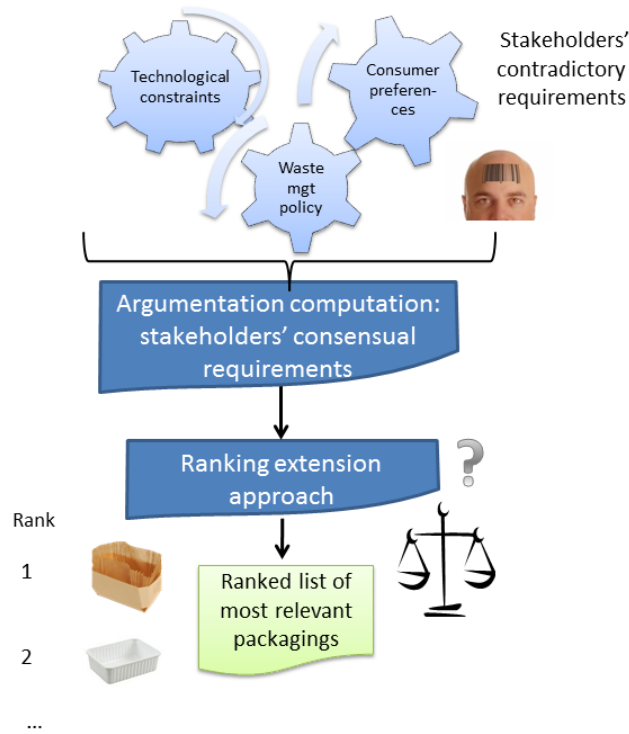


Figure 1: Global insight of the MCDSS.

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

54 For instance, a strawberry producer expresses the need for a new pack-  
 55 aging to pack strawberries. The design of this new packaging needs to take  
 56 into consideration the packaging industry constraints (ability to scale-up the  
 57 production process, the availability of the raw material, etc.), the waste man-  
 58 agement administration rules about packaging end of life (biodegradability,  
 59 recyclability, incineration, burying, etc.) and consumer preferences (trans-

60 parent packaging, environment-friendly packaging, no extra-cost due to pack-  
61 aging, etc.).

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

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

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

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

92 The main contributions of the work are the following:

- 93 1. A MCDSS based on an argumentation system (*AS*). Arguments may  
94 be either manually entered or automatically generated from a set of  
95 responses to a given web survey.
- 96 2. A MCDSS designed to allow the ranking of packaging alternative solu-  
97 tions using the consensual sets of arguments (called extensions) com-  
98 puted by the argumentation system and a prioritization of require-  
99 ments.
- 100 3. An evaluation of the MCDSS tool, based on the strawberry case study,  
101 in the framework of the Pack4Fresh project with an interdisciplinary  
102 collaboration between experts of packaging research, consumer behav-  
103 ior research, and computer science research.

104 The paper is structured as follows: in Section 2, we present the MCDSS  
105 global workflow which implements the desired functionalities expressed by

106 the partners of the Pack4Fresh INRA-CIRAD project which financed this  
 107 work. In Section 3, we briefly recall Dung’s argumentation framework, used  
 108 to compute extensions (maximal consistent sets of arguments) and we present  
 109 the structured argumentation model we use and the way we automatically  
 110 generate arguments from a set of answers to a given web survey. In Section  
 111 4, we present the model proposed to rank extensions according to a priori-  
 112 tization on requirements. Section 5 presents the case study and its results.  
 113 Section 6 is dedicated to the implementation of the approach and Section 7  
 114 to related works. Finally, Section 8 recalls our contributions and introduces  
 115 some perspectives.

## 116 2. MCDSS workflow overview

117 Figure 2 presents the main tasks of the MCDSS workflow.

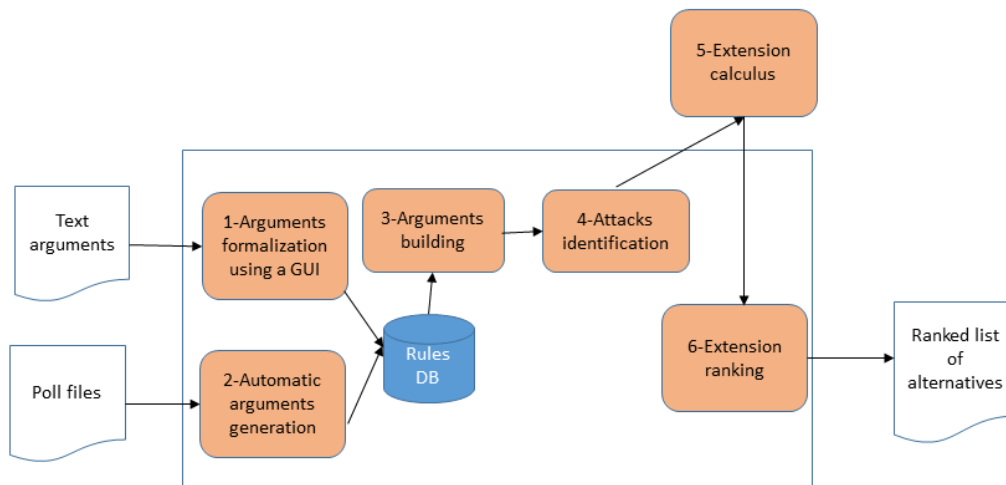


Figure 2: MCDSS workflow overview.



- 118 • *Task 1: Argument structuring*: in this task, a textual opinion is encoded  
119 into a logic-based structured argument thanks to a dedicated graphical  
120 user-friendly interface (GUI).
- 121 • *Task 2: Automatic argument generation*: this task automatically trans-  
122 forms some poll's answers into formal arguments made of concepts and  
123 rules using the framework described in Section 3.
- 124 • *Task 3: Logical arguments derivation*: Using the framework described  
125 in Section 3.2, this task builds all possible arguments by a derivation  
126 process.
- 127 • *Task 4: Attacks detection*: According to the definition of attacks de-  
128 fined in Section 3.2, this task computes an argumentation graph made  
129 of arguments (nodes) and attacks (edges).
- 130 • *Task 5: Extensions computation*: This task computes the set of exten-  
131 sions, i.e. the subsets of non-conflicting (consistent) arguments which  
132 defend themselves from attacking arguments (cf. Section 3.1). To  
133 scale up and manage high volumes of arguments from web survey re-  
134 sults, connection with the Aspartix platform Dvorak et al. (2011) is  
135 performed.
- 136 • *Task 6: Extension rankings*: the computation of extensions delivers one  
137 or several extensions. In the case of several extensions, the system uses  
138 the prioritization on criteria using the framework described in Section

139 4.1 in order to rank the extensions and to select the top-ranked. Finally,  
140 the selected extension is then used to extract preferences associated  
141 with its arguments.

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

### 144 **3. Logic argumentation model and poll-based arguments genera-** 145 **tion**

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

#### 150 *3.1. Dung argumentation principles*

151 A Dung’s argumentation framework (*AF*) Dung (1995) is a tuple  $(\mathcal{A}, \mathcal{C})$ ,  
152 where  $\mathcal{C} \subseteq \mathcal{A} \times \mathcal{A}$  is a binary attack relation on the set of arguments  $\mathcal{A}$ . For  
153 each argument  $X \in \mathcal{A}$ ,  $X$  is *acceptable* w.r.t. a set of arguments  $\mathcal{E} \subseteq \mathcal{A}$  if  
154 and only if any argument attacking  $X$  is attacked by an argument of  $\mathcal{E}$ . A  
155 set of arguments  $\mathcal{E} \subseteq \mathcal{A}$  is *conflict free* if and only if  $\forall X, Y \in \mathcal{E}, (X, Y) \notin \mathcal{C}$ .  
156  $\mathcal{E}$  is an *admissible extension* if and only if it is conflict-free and  $\forall X \in \mathcal{E}, X$  is  
157 acceptable w.r.t.  $\mathcal{E}$ ;  $\mathcal{E}$  is a *complete extension* if and only if  $\mathcal{E}$  is admissible and  
158  $X \in \mathcal{E}$  whenever  $X$  is acceptable w.r.t.  $\mathcal{E}$ ;  $\mathcal{E}$  is a *preferred extension* if and  
159 only if it is a set inclusion maximal complete extension;  $\mathcal{E}$  is the only *grounded*

160 *extension* if and only if it is the set inclusion minimal complete extension;  
 161  $\mathcal{E}$  is a *stable extension* if and only if it is preferred and  $\forall Y \notin \mathcal{E}, \exists X \in \mathcal{E}$   
 162 such that  $(X, Y) \in \mathcal{C}$ . For a given semantics, the set of extensions of an  
 163 argumentation framework is denoted by  $E$ .

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

### 169 3.2. Logic argumentation model

170 A knowledge base contains the concepts of the considered domain ex-  
 171 pressed using a logical language  $\mathcal{L}$  (such as propositional logic in this paper),  
 172 the alternative choices in debate and two reserved concepts  $ACC$ ,  $REJ$   
 173 referring to the decisions (respectively the *accepted* and *rejected* denomi-  
 174 nations) with  $\tilde{\neg}ACC = REJ$  and conversely. An argumentation system  
 175  $\mathcal{AS} = (\mathcal{L}, \tilde{\neg}, \mathcal{R}_s, \mathcal{R}_d)$  is composed of the logical language  $\mathcal{L}$ , a negation func-  
 176 tion, a set of strict rules  $\mathcal{R}_s$  and a set of defeasible rules  $\mathcal{R}_d$ . A strict sub-  
 177 sumption, denoted  $\sqsubset$ , expresses natural inclusion in the domain, as “*Plastic*  
 178 *trays are packagings*”. A defeasible subsumption, denoted  $\Subset$ , expresses an  
 179 inclusion which is not always true, as “*Plastic packagings can be reusable*”.  
 180 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

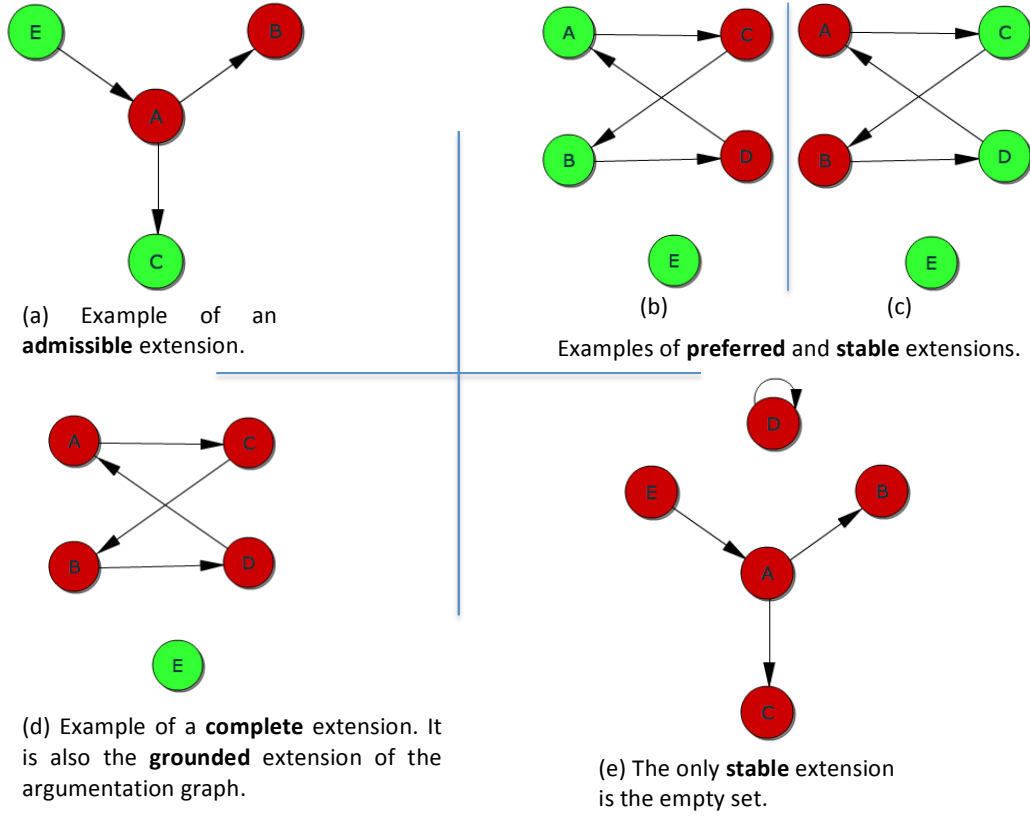


Figure 3: Examples of different Dung semantics.

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

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

<sup>1</sup>The notation  $\emptyset \in c_0$  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

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

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

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

196 **Example 2.** *We consider the following arguments expressed about biodegrad-*  
197 *ability of packaging materials considered here as one possible alternative of*  
198 *end of life management:*

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

203 We model these arguments by using the proposed logical language as fol-  
204 lows:

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

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

- 211 •  $\mathcal{R}_s = \{BP \sqsubset HIP, \sim HIP \sqsubset \sim BP, HIP \sqsubset REJ, \sim REJ \sqsubset \sim HIP\}$
- 212 •  $\mathcal{R}_d = \{BP \Subset PEV, PEV \Subset ACC\}$

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

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

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

223 •  $B : \emptyset \in BP \in PEV \in ACC$

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

### 226 3.3. Poll-based argument generation

227 Let us now describe the process used to generate poll-based arguments.

228 It is composed of several steps:

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

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

247 – *positive* :  $\mathcal{Q} \times \mathcal{K} \rightarrow \mathbb{N}$  that takes as input a question and an  
 248 alternative and returns the number of persons that answered “Yes”,

249 – *negative* :  $\mathcal{Q} \times \mathcal{K} \rightarrow \mathbb{N}$  that takes as input a question and an  
 250 alternative and returns the number of persons that answered “No”  
 251 and

252 – *neutral* :  $\mathcal{Q} \times \mathcal{K} \rightarrow \mathbb{N}$  that takes as input a question and an alterna-  
 253 tive and returns the number of persons that answered “Neutral”.

254 It is obvious that for every  $k_i \in \mathcal{K}$  and every question  $q_j \in \mathcal{Q}$ ,  
 255  $positive(q_j, k_i) + negative(q_j, k_i) + neutral(q_j, k_i) = n$ .

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

$$258 \quad agg(q_j, k_i) = \begin{cases} 0 & \text{if } neutral(q_j, k_i) > positive(q_j, k_i) + negative(q_j, k_i) \\ -1 & \text{else if } positive(q_j, k_i) < negative(q_j, k_i) \\ 1 & \text{otherwise} \end{cases}$$

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

261 • *Step 4: Creating the arguments:* In this step, we first select a “certainty”  
 262 threshold  $\alpha \in \{0, 1, \dots, n\}$  and create the following arguments:



- 263  $\forall k_i \in \mathcal{K}, \forall q_j \in \mathcal{Q} :$
- 264 – if  $agg(q_j, k_i) = 1$  and  $|positive(q_j, k_i) - negative(q_j, k_i)| > \alpha$  then
- 265  $\emptyset \in k_i \in Con(q_j) \sqsubset \sigma(Con(q_j)),$
- 266 – if  $agg(q_j, k_i) = 1$  and  $|positive(q_j, k_i) - negative(q_j, k_i)| \leq \alpha$  then
- 267  $\emptyset \in k_i \in Con(q_j) \in \sigma(Con(q_j)),$
- 268 – if  $agg(q_j, k_i) = -1$  and  $|positive(q_j, k_i) - negative(q_j, k_i)| > \alpha$
- 269 then  $\emptyset \in k_i \in \tilde{Con}(q_j) \sqsubset \tilde{\sigma}(Con(q_j)),$
- 270 – if  $agg(q_j, k_i) = -1$  and  $|positive(q_j, k_i) - negative(q_j, k_i)| \leq \alpha$
- 271 then  $\emptyset \in k_i \in \tilde{Con}(q_j) \in \tilde{\sigma}(Con(q_j)).$

272 **Example 3.** Suppose that there is a question  $q =$  “Do you think that  $x$

273 protects strawberries from shocks?” and that *Plastic\_not\_closed* is an al-

274 ternative in  $\mathcal{K}$  corresponding to a plastic packaging that is not closed. We

275 ask the question  $q$  to the consumers and we get that 394 persons answered

276 “No”, 179 persons answered “I do not know” and 272 persons answered “Yes”.

277 Since we have that

$$278 \quad \begin{aligned} neutral(q, Plastic\_not\_closed) &\leq positive(q, Plastic\_not\_closed) \\ &\quad + negative(q, Plastic\_not\_closed) \end{aligned}$$

279 and

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

281 we compute that  $agg(q, Plastic\_not\_closed) = -1$ . Now, if we define  $\alpha =$

282 200, the only argument produced, meaning that “not closed plastic packagings

283 are rejected because they do not protect strawberries from shocks”, is:

284  $\emptyset \in Plastic\_not\_closed \in \tilde{\sim} Shocks\_protection \in REJ$

#### 285 4. Ranking extensions

286 We suppose in this section that arguments generated from polls as de-  
287 scribed in Section 3.3 or manually entered by experts are available in the  
288 knowledge base. Extensions are computed using the semantics recalled in  
289 Section 3.1. We explain in this section the proposed method to rank exten-  
290 sions 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:

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

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

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

295 *4.1. Refining extensions using semantics*

296 In this section, we introduce our method for ranking a set of exten-  
 297 sions  $E$  using the locally, Pareto and globally optimal semantics inspired by  
 298 Croitoru et al. (2015). These semantics return subsets of the original set  
 299 of extensions. We introduce here the three notions which are based on the  
 300 notion of domination (preference) between concepts of the accepted require-  
 301 ments.

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

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

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

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

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

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

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

#### 328 4.2. Ranking methods using scores

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

336 *4.2.1. First scoring: Higher score based on positive arguments means less*  
337 *dominated*

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

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

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

343 *4.2.2. Second scoring: Higher score based on negative arguments means less*  
344 *dominated*

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

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

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

351 A research issue is to find a way to combine the two scores in order  
352 to produce a more efficient ranking. This can be achieved by using multi-  
353 criteria methods. We provide a naive way to combine the two scores, namely

354  $Score_3(\mathcal{E}) = Score_1(\mathcal{E}) + Score_2(\mathcal{E})$ .



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

## 355 5. Use-case

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

- 362 • an opened plastic basket (without lid or film)
- 363 • a wood packaging (without lid)
- 364 • a plastic basket with rigid lid
- 365 • a plastic basket with plastic film

### 366 5.1. Automated generation of arguments from the poll

367 A survey upon a sample of 840 people has provided the following 38  
368 arguments using the poll-based argument automatic generation process pre-  
369 sented in Section 3.3 with a “certainty” threshold of 756 people (90% of the

370 840 respondents, which indicates a very certain, nearly consensual, general  
 371 opinion):

<b>Arg id</b>	<b>Textual argument</b>	<b>Formal argument</b>
a1	Consumers are in favour of wood packaging because it preserves the flavour of strawberries	<i>Wood_packaging</i> $\in$ <i>Protect_flavor</i> $\in$ <i>ACC</i>
a2	Consumers are in favour of wood packaging because it preserves strawberries from shocks	<i>Wood_packaging</i> $\in$ <i>Shocks_protection</i> $\in$ <i>ACC</i>
a3	Consumers are in favour of wood packaging because it is reusable	<i>Wood_packaging</i> $\in$ <i>Reusable</i> $\in$ <i>ACC</i>
a4	Consumers are in favour of wood packaging because it is recyclable	<i>Wood_packaging</i> $\in$ <i>Recyclable</i> $\in$ <i>ACC</i>
a5	Consumers are in favour of wood packaging because it incites to eat strawberries	<i>Wood_packaging</i> $\in$ <i>Incite_to_eat</i> $\in$ <i>ACC</i>
a6	Consumers are in favour of wood packaging because they can see the strawberries	<i>Wood_packaging</i> $\in$ <i>Can_see</i> $\in$ <i>ACC</i>
a7	Consumers are in favour of wood packaging because they can smell the strawberries	<i>Wood_packaging</i> $\in$ <i>Can_smell</i> $\in$ <i>ACC</i>
a8	Consumers are in favour of wood packaging because they think it protects the environment	<i>Wood_packaging</i> $\in$ <i>Protect_environment</i> $\in$ <i>ACC</i>
a9	Consumers are not in favour of wood packaging because it harms strawberries	<i>Wood_packaging</i> $\in$ <i>Harmful</i> $\in$ <i>REJ</i>
a10	Consumers are in favour of plastic packaging with plastic film because they can see the strawberries	<i>Plastic_with_plastic_film</i> $\in$ <i>Can_see</i> $\in$ <i>ACC</i>
a11	Consumers are not in favour of plastic packaging with plastic film because it is not reusable	<i>Plastic_with_plastic_film</i> $\in$ $\neg$ <i>Reusable</i> $\in$ <i>REJ</i>
a12	Consumers are not in favour of plastic packaging with plastic film because it does not preserve strawberries from shocks	<i>Plastic_with_plastic_film</i> $\in$ $\neg$ <i>Shocks_protection</i> $\in$ <i>REJ</i>
a13	Consumers are not in favour of plastic packaging with plastic film because it is not recyclable	<i>Plastic_with_plastic_film</i> $\in$ $\neg$ <i>Recyclable</i> $\in$ <i>REJ</i>

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



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

Arg id	Textual argument	Formal argument
a36	Consumers are in favour of plastic packagings that are not closed because they protect flavour	<i>Plastic_not_closed</i> $\in$ <i>Protect_flavor</i> $\in$ <i>ACC</i>
a37	Consumers are not in favour of plastic packagings that are not closed because they do not protect strawberries from shocks	<i>Plastic_not_closed</i> $\in$ $\neg$ <i>Shocks_protection</i> $\in$ <i>REJ</i>
a38	Consumers are in favour of plastic packagings that are not closed because they incite to eat strawberries	<i>Plastic_not_closed</i> $\in$ <i>Incite_to_eat</i> $\in$ <i>ACC</i>

372 5.2. Arguments provided by experts

373 The previous consumers' arguments have been assessed by experts in food  
374 packaging. The experts have then provided other arguments. This process  
375 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	<i>Wood_packaging</i> $\in$ $\neg$ <i>Concentrate_smell</i> $\in$ <i>REJ</i>
a40	Experts are in favour of wood packaging because, due to exudate absorption, it contributes to good ambient conservation	<i>Wood_packaging</i> $\in$ <i>Good_ambient_conservation</i> $\in$ <i>ACC</i>
a41	Experts are in favour of wood packaging because, due to exudate absorption, it contributes to good fridge conservation	<i>Wood_packaging</i> $\in$ <i>Good_fridge_conservation</i> $\in$ <i>ACC</i>
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	<i>Plastic_rigid_lid</i> $\in$ $\neg$ <i>Shocks_protection</i> $\in$ <i>REJ</i>
a43	Experts are in favour of plastic packaging with rigid lid because it concentrates the smell	<i>Plastic_rigid_lid</i> $\in$ <i>Concentrate_smell</i> $\in$ <i>ACC</i>

Arg id	Textual argument	Formal argument
a44	Experts are not in favour of plastic packaging with plastic film because condensation may hide strawberries	<i>Plastic_with_plastic_film</i> $\in$ <i>Condensation</i> $\in$ <i>REJ</i>
a45	Experts are in favour of plastic packaging with plastic film because it permits to reduce waste (thanks to modified atmosphere)	<i>Plastic_with_plastic_film</i> $\in$ <i>Protect_environment</i> $\in$ <i>ACC</i>
a46	Experts are not in favour of non-closed plastic packaging because it does not concentrate the smell	<i>Plastic_not_closed</i> $\in$ $\sim$ <i>Concentrate_smell</i> $\in$ <i>REJ</i>

376 *5.3. Extensions computation*

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

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

385 For instance, extension  $\mathcal{E}_4$  is associated with the alternative Wood Pack-  
386 aging. Arguments a1, a2, a3, a4, a5, a6, a7, a8 are positive arguments in  
387 favor of Wood Packaging and arguments a11, a12, a13, a14, a15, a16, a18,  
388 a23, a30, a33, a37, a40, a41, a42, a44, a46 are negative arguments against  
389 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.

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

#### 394 5.4. Scenario analysis

395 We will consider the following three scenarios:

- 396 • Scenario SECURE: “not nefast effect” (i.e. not harmful) concept is  
397 preferred to all the other concepts.
- 398 • Scenario GREEN: “Protect\_environment”, “recyclable” and “reusable”  
399 are preferred to all the other concepts.
- 400 • Scenario PLEASURE: “can see”, “can smell”, “protect flavor” and “incite  
401 to eat” are preferred to all the other concepts.

402 In the following, we only detail the results obtained for scenario SECURE  
403 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.

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

406 Preferences associated with concepts for scenario SECURE are the fol-  
407 lowing:

- 408 •  $Protect\_flavor < \sim Nefast\_effect$
- 409 •  $Protect\_environment < \sim Nefast\_effect$
- 410 •  $\sim Protect\_environment < \sim Nefast\_effect$
- 411 •  $Shocks\_protection < \sim Nefast\_effect$
- 412 •  $\sim Shocks\_protection < \sim Nefast\_effect$
- 413 •  $Reusable < \sim Nefast\_effect$
- 414 •  $Recyclable < \sim Nefast\_effect$
- 415 •  $\sim Reusable < \sim Nefast\_effect$
- 416 •  $\sim Recyclable < \sim Nefast\_effect$
- 417 •  $Incite\_to\_eat < \sim Nefast\_effect$

<b>Packaging</b>	<b>Score<sub>1</sub></b>	<b>Score<sub>2</sub></b>	<b>Score<sub>3</sub></b>
<i>Wood_packaging</i>	0	14	14
<i>Plastic_with_plastic_film</i>	21	8	29
<i>Plastic_not_closed</i>	0	12	12
<i>Plastic_rigid_lid</i>	21	14	35

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

- 418 •  $Can\_see < \sim Nefast\_effect$
- 419 •  $Can\_smell < \sim Nefast\_effect$
- 420 •  $\sim Can\_smell < \sim Nefast\_effect$
- 421 •  $Nefast\_effect < \sim Nefast\_effect$
- 422 •  $\sim Good\_fridge\_conservation < \sim Nefast\_effect$
- 423 •  $\sim Good\_ambient\_conservation < \sim Nefast\_effect$
- 424 •  $Good\_ambient\_conservation < \sim Nefast\_effect$
- 425 •  $Good\_fridge\_conservation < \sim Nefast\_effect$
- 426 •  $Concentrate\_smell < \sim Nefast\_effect$
- 427 •  $Condensation < \sim Nefast\_effect$
- 428 •  $\sim Concentrate\_smell < \sim Nefast\_effect$

429 We can see in Table 7 that the results obtained using the two indi-  
430 cators *Globally\_optimal* and *Score<sub>1</sub>* are the same for the alternatives in  
431 first position. *Score<sub>3</sub>* indicator is more discriminant than *Globally\_optimal*

Scenario	Globally optimal	Score <sub>1</sub>	Score <sub>3</sub>
SECURE	{ <i>Plastic</i> <i>_with_plastic_film</i> , <i>Plastic_rigid_lid</i> }	<i>Plastic</i> <i>_with_plastic_film</i> $\sim$ <i>Plastic_rigid_lid</i> $>$ <i>Wood_packaging</i> $\sim$ <i>Plastic_not_closed</i>	<i>Plastic_rigid_lid</i> $>$ <i>Plastic</i> <i>_with_plastic_film</i> $>$ <i>Wood_packaging</i> $>$ <i>Plastic_not_closed</i>
GREEN	<i>Wood_packaging</i>	<i>Wood_packaging</i> $>$ <i>Plastic_rigid_lid</i> $\sim$ <i>Plastic_not_closed</i> $>$ <i>Plastic</i> <i>_with_plastic_film</i>	<i>Wood_packaging</i> $>$ <i>Plastic_rigid_lid</i> $>$ <i>Plastic_not_closed</i> $>$ <i>Plastic</i> <i>_with_plastic_film</i>
PLEASURE	{ <i>Plastic_not_closed</i> , <i>Plastic_rigid_lid</i> , <i>Wood_packaging</i> }	<i>Wood_packaging</i> $\sim$ <i>Plastic_rigid_lid</i> $\sim$ <i>Plastic_not_closed</i> $>$ <i>Plastic</i> <i>_with_plastic_film</i>	<i>Wood_packaging</i> $\sim$ <i>Plastic_rigid_lid</i> $>$ <i>Plastic_not_closed</i> $>$ <i>Plastic</i> <i>_with_plastic_film</i>

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

432 and  $Score_1$ . Indeed, in scenarios SECURE and PLEASURE,  $Score_3$  pro-  
433 vides an advantage to alternatives with less negative arguments which are  
434 *Plastic\_rigid\_lid* and *Wood\_packaging*.

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

442 It may be noticed that this last argument was not present in the MCDSS  
443 knowledge base as an expert argument but it exists as a consumer argument  
444 (*a20*). The addition of this new argument will not change the ranking for

445 all the indicators as the MCDSS does not take into account the fact that  
 446 the same argument may be expressed by different stakeholders. An option  
 447 could be to introduce a weight which will provide more power to arguments  
 448 which are supported by several stakeholders; such an approach could benefit  
 449 from the notion of ranking semantics such as Amgoud and Ben-Naim (2013);  
 450 Amgoud et al. (2016); Bonzon et al. (2016); Baroni et al. (2018) where ar-  
 451 guments' strength is computed based on the attacks in the framework. So,  
 452  $Score_3$  seems to bring an additional piece of information which is not taken  
 453 into account by the expert.

454 Concerning scenario GREEN, the expert has defined three individual  
 455 rankings for each of the criteria Protect environment, Reusable and Recy-  
 456 clable:

457 • **Protect environment:**  $Plastic\_with\_plastic\_film >$   
 458  $Wood\_packaging > Plastic\_rigid\_lid = Plastic\_not\_closed$  con-  
 459 sidering that  $Plastic\_with\_plastic\_film$  (with modified atmosphere)  
 460 permits to reduce waste and  $Wood\_packaging$  has less impact on en-  
 461 vironment than  $Plastic\_rigid\_lid$  and  $Plastic\_not\_closed$  in terms  
 462 of biodegradability duration.

463 • **Reusable:**  $Wood\_packaging = Plastic\_not\_closed >$   
 464  $Plastic\_rigid\_lid > Plastic\_with\_plastic\_film$  considering the prac-  
 465 tical point of view of reuse of the packaging material for another usage.

466 • **Recyclable:**  $Wood\_packaging > Plastic\_not\_closed =$



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

470 Considering that *Wood\_packaging* is the only one appearing in first position  
471 for “Reusable” and “Recyclable” and in second position for “Protect environ-  
472 ment”, we can state that the expert agrees with the result proposed by the  
473 MCDSS for the three indicators *Globally\_optimal*, *Score<sub>1</sub>* and *Score<sub>3</sub>*.

474 Concerning scenario PLEASURE, the expert did not want to assess the  
475 criterion *Incite\_to\_eat* as it is a question of consumer’s perception. How-  
476 ever, the expert considers that all packagings are ex-aequo for the three  
477 remaining criteria (*can\_see*, *can\_smell* and *protect\_flavor*). This corre-  
478 sponds to the result expressed by the MCDSS for the indicators *Globally\_*  
479 *optimal* and *Score<sub>1</sub>*, except for the case of *Plastic\_with\_plastic\_film*  
480 which is ranked behind the other packagings by the MCDSS. This is due  
481 to the fact that consumers consider the *Plastic\_with\_plastic\_film* pack-  
482 aging not to allow smelling the strawberries (Argument a18), whereas the  
483 expert considers this is compensated by its ability to concentrate smell. The  
484 latter compensation effect, however, is not coded in the MCDSS.

485 We may note that in several of the above evaluation cases, discordances  
486 between MCDSS and expert rankings are not due to the ranking method  
487 itself but to missing information to be included into the MCDSS, or pieces of  
488 information included in the MCDSS but not taken into account by the expert  
489 (by example negative arguments). This highlights the interest of an iterative

490 process for argument elicitation in order to obtain complete information in  
491 the MCDSS, as recommended in Thomopoulos et al. (2013); Johnson et al.  
492 (2010); Thomopoulos et al. (2009). On the contrary, similar information lead  
493 to similar rankings, which constitutes a positive expert validation feedback  
494 on the MCDSS reasoning engine. Another significant finding was that in  
495 complex cases, as in the GREEN scenario for instance, providing a unique  
496 global ranking was a difficult task for the expert. Thus we can conclude that  
497 (i) there is a recognized added value of providing MCDSS results and (ii)  
498 expert evaluation has to be achieved firstly on simple cases, which can be  
499 intuitively apprehended by human reasoning. Interestingly, these remarks  
500 are in line with a well-known distinction between different approaches to  
501 decision support Tsoukiàs (2007). The normative approach, more common  
502 in the Anglo-Saxon school of decision support, derives decision models from  
503 rationality norms established a priori. Expert decision deviating from these  
504 norms is interpreted as a mistake which highlights the need for MCDSS aid  
505 in order to decide in a rational way Fishburn (1970). On the contrary, in  
506 the descriptive approach, more common in the European school of decision  
507 support, decision models are derived from observing how expert make de-  
508 cisions, in order to reproduce their way of reasoning in the MCDSS Bell  
509 et al. (1988). In our system, normative decision support is expected from  
510 the MCDSS in complex cases, whereas the descriptive approach is used for  
511 MCDSS evaluation in simple cases.

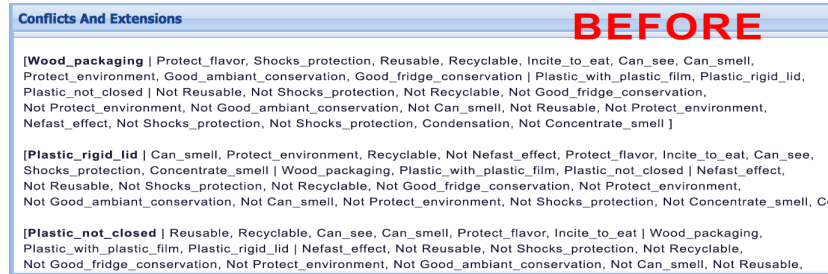
512 **6. Implementation of the approach**

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



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

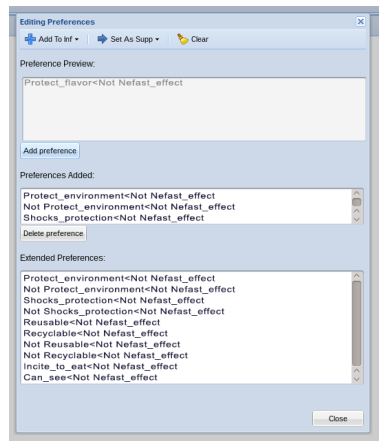
521 We integrated a simple and intuitive interface in the web application for



(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.

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

## 529 7. Related work

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

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

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

552 Schneider et al. (2007) and DebateGraph<sup>2</sup>, allows the expression of arguments  
553 as texts to manually formalize them as hypothesis and conclusions but also to  
554 compute the extensions and the preference induced ranking. In this respect,  
555 our interface is the only software allowing to compute all steps of the work-  
556 flow described in Figure 2.

557 While this work presents a significant and original application of argumen-  
558 tation theory in food science, let us also highlight other numerous argumen-  
559 tation applications developed recently in various fields: ArgTrust Parsons et al.  
560 (2013), in which the authors considered argumentation frameworks for de-  
561 cision making; CISpaces framework Toniolo et al. (2014), which supports col-  
562 laborative intelligence analysis of conflicting information;  
563 “*Quaestion-it.com*” Evripidou and Toni (2014) which is a social intelligence  
564 debating platform that demonstrates a question-and-answer web application  
565 providing support for user-posed questions; Carneades Gordon (2013), which  
566 provides software tools based on a common computational model of argument  
567 graphs useful for policy deliberations, etc.

## 568 8. Conclusion

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

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<sup>2</sup>[www.debategraph.org](http://www.debategraph.org)

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

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

588 The aim of this paper was to present, assess and show the relevance of  
589 the MCDSS workflow. An interesting future methodological study would be  
590 to fine-tune the current MCDSS workflow parameterization, notably with re-  
591 gards to the aggregation function used to compute arguments from the polls,  
592 the “certainty” threshold used to distinguish between strict and defeasible  
593 arguments, and the semantics used to compute extensions.

594 Moreover, as a future work, this methodology is promising to support

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

602 **Appendix AppendixA: Detailed results for the use case**

Locally optimal	$\{Plastic\_rigid\_lid, Wood\_packaging\}$
Pareto optimal	<i>Wood_packaging</i>
Globally optimal	<i>Wood_packaging</i>

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

<b>Packaging</b>	<b>Score<sub>1</sub></b>	<b>Score<sub>2</sub></b>	<b>Score<sub>3</sub></b>
<i>Wood_packaging</i>	57	42	99
<i>Plastic_with_plastic_film</i>	19	24	33
<i>Plastic_not_closed</i>	38	36	74
<i>Plastic_rigid_lid</i>	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 <sub>1</sub>	Score <sub>2</sub>	Score <sub>3</sub>
<i>Wood_packaging</i>	72	56	128
<i>Plastic_with_plastic_film</i>	54	32	86
<i>Plastic_not_closed</i>	72	48	120
<i>Plastic_rigid_lid</i>	72	56	128

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

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