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1 **An Argumentation System for**
2 **Eco-Efficient Packaging Material**
3 **Selection**

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Abstract

Within the framework of the European project EcoBioCap (ECOefficient BIODEgradable Composite Advanced Packaging), aiming at conceiving the next generation of food packagings, we have designed an argumentation-based tool for management of conflicting viewpoints between preferences expressed by the involved parties (food and packaging industries, health authorities, consumers, waste management authority, etc.). The requirements and user preferences are modeled by several rules provided by the stakeholders expressing their viewpoints and expertise. Based on these rules, the argumentation tool computes consensual preferences which are used to parametrize a flexible querying process of a packaging database to retrieve the most relevant solution to pack a given food. In this paper, we recall briefly the principles underlying the reasoning process, and we detail the main functionalities and the architecture of the argumentation tool. We cover the overall reasoning steps starting from formal representation of text arguments and ending by extraction of justified preferences which are sent to the database querying process. Finally, we detail its operational functioning through a real life case study to determine the justifiable choices between recyclable, compostable and biodegradable packaging materials based on stakeholders' arguments.

34 **Keywords.** Logic-based argumentation, argumentation tool, decision
35 support system, Food packaging.

36 1 Introduction

37 Within the framework of the European project EcoBioCap (ECOefficient
38 BIOdegradable Composite Advanced Packaging), we have designed a Deci-
39 sion Support System (called DSS) whose objective is to select, for a given
40 food, the most relevant packaging materials according to possibly conflict-
41 ing requirements (food to pack, shelf life, storage temperature, packaging
42 biodegradability, etc.) expressed by the involved parties (food and packag-
43 ing industries, health authorities, consumers, waste management authority,
44 etc.).

45 The DSS software, as depicted in Figure 1, realizes a multi-criteria flex-
46 ible querying process [Destercke et al., 2011] which takes as inputs desired
47 preferences associated with packaging characteristics (dimensions, minimum
48 shelf life, biodegradability, transparency, ...) and uses them to query a pack-
49 aging database to retrieve a ranked list of most relevant packagings. Optimal
50 permeabilities of the targeted packaging can be computed thanks to a Mod-
51 ified Atmosphere Packaging (MAP) simulation model [Guillard et al., 2012].
52 In this paper, we propose a new component of the DSS. It implements an
53 argumentation process which aims at combining several stakeholders (re-
54 searchers, consumers, food industry, packaging industry, waste management

55 policy, etc.) requirements expressed as simple textual arguments, to enrich
56 the querying process by stakeholders' justified preferences. Each argument
57 supports/opposes a choice justified by the fact that it either meets or does
58 not meet a requirement according to a particular aspect of the packagings
59 (end of life management, transparency, ...).

60 For example, a market shop manager expresses the need for a new pack-
61 aging to pack apricots such that its dimensions are 20 *cm* in length, 15 *cm*
62 in width and 15 *cm* in depth and ensures a minimum shelf life of 10 days.
63 The design of this new packaging needs also to take into consideration the
64 packaging industry constraints (ability to scale-up the production process,
65 the availability of the raw material, etc.), the waste management adminis-
66 tration rules about packaging end of life (biodegradability, recyclability, in-
67 cineration, burying, etc.) and consumer preferences (transparent packaging,
68 environment-friendly packaging, no extra-cost due to packaging, etc.).

69 As illustrated in Figure 1, the former conditions (dimensions and shelf
70 life in addition to the fresh food to pack, i.e. apricots in this case) are the
71 inputs of the virtual MAP simulator which returns the optimal parameters
72 for gaz (O₂ and CO₂) permeability to ensure the shelf life required to pre-
73 serve the apricots. The latter conditions are expressed as text arguments of
74 the form “*Biodegradable materials are suitable since they help to protect the*
75 *environment*” or “*Life cycle analysis results are not in favor of biodegradable*
76 *and compostable materials*”. These arguments are the input of the argumen-
77 tation system which distinguishes for each option (biodegradable material,

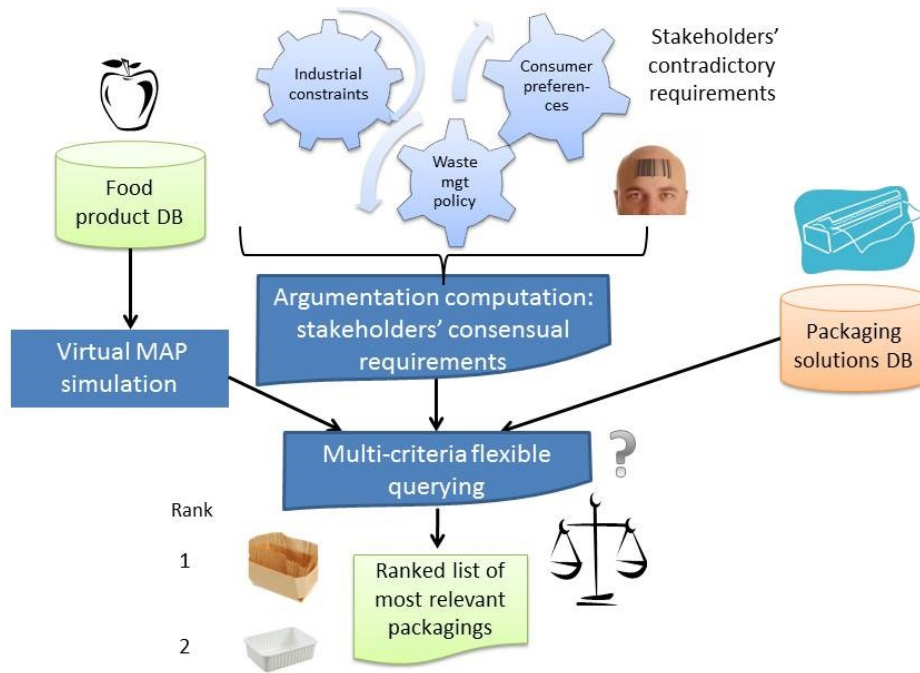


Figure 1: Global insight of the DSS.

78 compostable material, etc.) the reason leading to its acceptance or its re-
 79 jection. Then, the argumentation system detects the conflicts among the
 80 arguments and computes the sets of coherent arguments which defend them-
 81 selves against attacks. After that, it extracts from the winner arguments the
 82 most justified options (for instance biodegradable materials) as predicates
 83 in order to enrich the querying process. Finally, the multi-criteria flexible
 84 querying system combines the outputs of both virtual MAP system and ar-
 85 gumentation system to deliver from the Packaging Solution DB the list of
 86 packaging materials satisfying the requirements.

87 We detail in this paper how arguments are modeled within a structured

88 argumentation system and how the delivered justified conclusions can be used
89 in the querying process. This paper is a detailed and an extended version of
90 the previous work [Tamani et al., 2014].

91 Thus, packagings have to be selected according to several aspects or cri-
92 teria (permeance, interaction with the packed food, end of life, etc.) high-
93 lighted by arguments expressed by the stakeholders involved in the project.
94 The problem at hand does not simply consist in addressing a multi-criteria
95 optimization problem [Bouyssou et al., 2009], but the DSS would need to
96 be able to justify why certain packagings are chosen. To this aim, we
97 make use of argumentation theory [Dung, 1995, Besnard and Hunter, 2008,
98 Rahwan and Simari, 2009], in which some approaches combine argumenta-
99 tion and multi criteria decision making [Amgoud and Prade, 2009].

100 The arguments we consider in this paper are based on a defeasible rea-
101 soning. We rely in this work on a logical-based structured argumentation
102 system, called ASPIC [Amgoud et al., 2006] and on its extension ASPIC+
103 [Prakken, 2010, Modgil and Prakken, 2013], which (i) allows the expression
104 of logical arguments as a combination of atoms and rules, (ii) defines attack
105 and defeat relations among arguments based on a logical conflict relation.

106 The main contributions of the work are the following:

- 107 1. An instantiation of ASPIC argumentation system (*AS*) in a DSS dedi-
108 cated to the selection of packaging solutions well suited for a given food
109 product.

- 110 2. The study of the mutual influences between arguments expressed over
111 several options regarding different concerns. We show the limitation
112 of the regular instantiation of the ASPIC *AS*, and we propose to over-
113 come this limitation with a viewpoint approach in which arguments are
114 gathered according to packaging aspects or concerns. Each viewpoint
115 delivers subsets of non-conflicting arguments supporting or opposing a
116 kind of packaging according to a single topic (shelf life, cost, material
117 type, safety, end of life, etc.).
- 118 3. The use of the argumentation results for a multi-criteria flexible query-
119 ing of the packaging database. The coupling of both components pro-
120 vides a new multi criteria decision making tool dedicated to packag-
121 ing selection taking into account potentially contradictory stakeholders'
122 preferences.
- 123 4. Implementation of the approach as a java GXT/GWT web applica-
124 tion accessible on <http://pfl.grignon.inra.fr/EcoBioCapProduction/>. A
125 demonstration video is also accessible on
126 <http://umr-iate.cirad.fr/FichiersComplementaires/DemoRomeHD.mp4>.
- 127 5. Evaluation of the argumentation tool within the EcoBioCap project
128 with a collaboration of the experts of packaging industry.

129 In Section 2, we detail the main functionalities of the developed argumen-
130 tation tool. In Section 3, we introduce the main architecture of the developed

131 argumentation system. In Section 4, we recall briefly our approach defining
132 an argumentation theory relying on ASPIC. Then, we explain through a real
133 world example the rationale behind the notion of viewpoints in Section 5.
134 Section 6 is dedicated to the implementation and evaluation of the approach.
135 Section 7 sums up some related works, and finally, in Section 8 we recall our
136 contributions and introduce some perspectives.

137 **2 Functional specification of the argumentation** 138 **process**

139 We detail hereinafter the main functions of the argumentation system inte-
140 grated into the EcoBioCap Decision Support System. After discussions and
141 interviews with the project partners, we have identified some requirements
142 summarized in the following functionalities:

- 143 • *Formalize text arguments*: the argumentation system should provide
144 users with a user-friendly interface allowing them to express their argu-
145 ments as text and then formalizing them as concepts and rules. Here,
146 concepts can be linked to corresponding attributes of the packaging
147 database to permit the exportation of consensual preferences computed
148 by the argumentation system towards the multi-criteria flexible query-
149 ing of the packaging database. The system should also be equipped
150 with a function of import/export formalized arguments into/from an

151 XML format. Thus, one can load already formatted concepts and rules
152 directly in the system.

153 • *Process arguments*: the system should automatically compute the log-
154 ical arguments obtained from the set of concepts and rules. The argu-
155 ments can be gathered into pros and cons with regard to some packaging
156 alternative characteristics which are discussed by the stakeholders (for
157 example, the end of life characteristics of the packaging: biodegradable,
158 recyclable, etc). Once logical arguments are built, the system should
159 compute all conflicts or attacks among them.

160 • *Compute extensions*: an extension is the result of the argumentation
161 process and corresponds to a subset of non-conflicting arguments. The
162 system should implement different kinds of semantics proposed in the
163 literature (admissible, preferred, grounded, stable, etc.). In this way,
164 the user would be able to compute the extensions associated to a par-
165 ticular semantics or to all semantics.

166 • *Enrich the multi criteria flexible querying*: based on the obtained exten-
167 sions, the system should be able to automatically translate the exten-
168 sion into preferred values associated with attributes of the packaging
169 database. These attributes and eventually associated values become
170 predicates (conditions) which can be used later to enrich the multi cri-
171 teria flexible query which can be processed by the flexible querying
172 system of the DSS.

173 3 Architecture of the argumentation system

174 As illustrated in Figure 2, the proposed argumentation system relies on 5
175 main modules which implement the argumentation work flow, described be-
176 low.

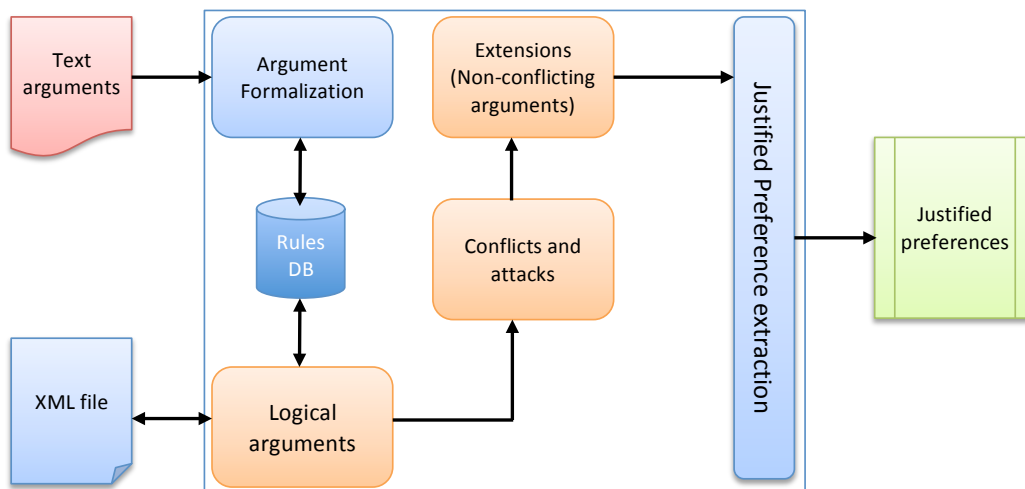


Figure 2: The architecture of the argumentation system.

- 177 • *Step 1: Argument formalization*: this module implements a user-friendly
178 interface for an interactive translation of text arguments into a formal
179 representation made of concepts and rules. A graphical representation
180 of the expressed rules is also built as the users formalize manually their
181 text arguments. The formal representation obtained is finally saved in
182 a database for a persistent storage allowing to reload argumentation
183 projects without rebuilding all the arguments and to reuse also the
184 already formatted rules in other projects.

- 185 • *Step 2: Logical arguments building*: this module receives as inputs the
186 list of concepts and rules corresponding to text arguments. This list
187 can be the result of the formalization module or given by the user as an
188 XML file. Then, by a derivation process, this module builds all possible
189 arguments according to the process defined in ASPIC/ASPIC+ logic-
190 based argumentation frameworks [Amgoud et al., 2006, Prakken, 2010]
191 and reused in [Tamani et al., 2013, Tamani et al., 2014]. This module
192 also implements a function to export the argument list into an XML
193 file.

- 194 • *Step 3: Conflicts and attacks detection*: this module relies on the log-
195 ical arguments built by the previous module. According to the nega-
196 tion operator, it detects all the conflicts among arguments and models
197 them as attacks with respect to the definition of attacks introduced
198 in [Tamani et al., 2013, Tamani et al., 2014]. The output of this mod-
199 ular is an argumentation graph made of arguments (nodes) and attacks
200 (edges).

- 201 • *Step 4: Extensions computation*: an extension is a subset of non-
202 conflicting (consistent) arguments which defend themselves from at-
203 tacking arguments. The computation of extensions is made under one
204 semantics (preferred, stable, grounded, etc.) as defined in [Dung, 1995].
205 This module allows the computation of one or all semantics considered
206 (preferred, stable, grounded, eager, semi-stable, naive).

207 • *Step 5: Extraction of the justified preferences*: the computation of ex-
208 tensions delivers one or several extensions. In the case of several ex-
209 tensions, the system lets the users select the most suitable extension
210 according to their objectives. If the users cannot reach an agreement
211 over the extensions, the system allows them to add new arguments and
212 re-compute the extensions on the fly. Finally, the selected extension
213 is then used to extract corresponding preferences underlying the con-
214 tained concepts. These preferences are expressed as a list of couples
215 (*attribute, value*), where *attribute* stands for a packaging attribute as
216 defined in the packaging database schema of the flexible querying sys-
217 tem part of the DSS, and *value* is the preferred value expressed for the
218 considered attribute.

219 In the next section, we introduce the logical language developed for ar-
220 gument formalization.

221 4 The argumentation framework

222 We recall in this section the Dung abstract framework for argumentation
223 (see subsection 4.1) and we instantiate it with the ASPIC framework (see
224 subsection 4.2).

225 4.1 Dung argumentation principles

226 A Dung abstract argumentation framework (AF) [Dung, 1995] is a tuple
227 $(\mathcal{A}, \mathcal{C})$, where $\mathcal{C} \subseteq \mathcal{A} \times \mathcal{A}$ is a binary attack relation on the set of arguments
228 \mathcal{A} . For each argument $X \in \mathcal{A}$, X is *acceptable* with regard to a set of
229 arguments $S \subseteq \mathcal{A}$ if and only if any argument attacking X , is attacked by
230 an argument of S . A set of arguments $S \subseteq \mathcal{A}$ is *conflict free* if and only if
231 $\forall X, Y \in S, (X, Y) \notin \mathcal{C}$. For any conflict free set of arguments S , S is a *naive*
232 *extension* [Bondarenko et al., 1997, Coste-Marquis et al., 2005] if and only if
233 it is maximal with respect to \subseteq , S is an *admissible extension* if and only if
234 $X \in S$ implies X is acceptable with regard to S . S is a *complete extension* if
235 and only if S is an *admissible extension* and $X \in S$ whenever X is acceptable
236 with regard to S ; S is a *preferred extension* if and only if it is a set inclusion
237 maximal complete extension; S is the *grounded extension* if and only if it
238 is the set inclusion minimal complete extension; S is a *stable extension* if
239 and only if it is preferred and $\forall Y \notin S, \exists X \in S$ such that $(X, Y) \in \mathcal{C}$. S
240 is called a *semi-stable extension* [Baroni et al., 2011, Caminada et al., 2011]
241 if and only if S is a complete extension where $S \cup S^+$ is maximal, where
242 S^+ is the set of arguments attacked by those of S . S is the *eager extension*
243 [Baroni et al., 2011] if and only if it is the greatest admissible set that is a
244 subset of each semi-stable extension.

245 **Example 1.** In figure 3 below, examples of extensions are presented on dif-
246 ferent argumentation graphs using Dung's semantics ($\{\text{admissible, complete,}$

247 preferred, grounded, stable}). Green nodes form the computed extension and
 248 nodes in red color correspond to those which do not belong to the computed
 249 extension. □

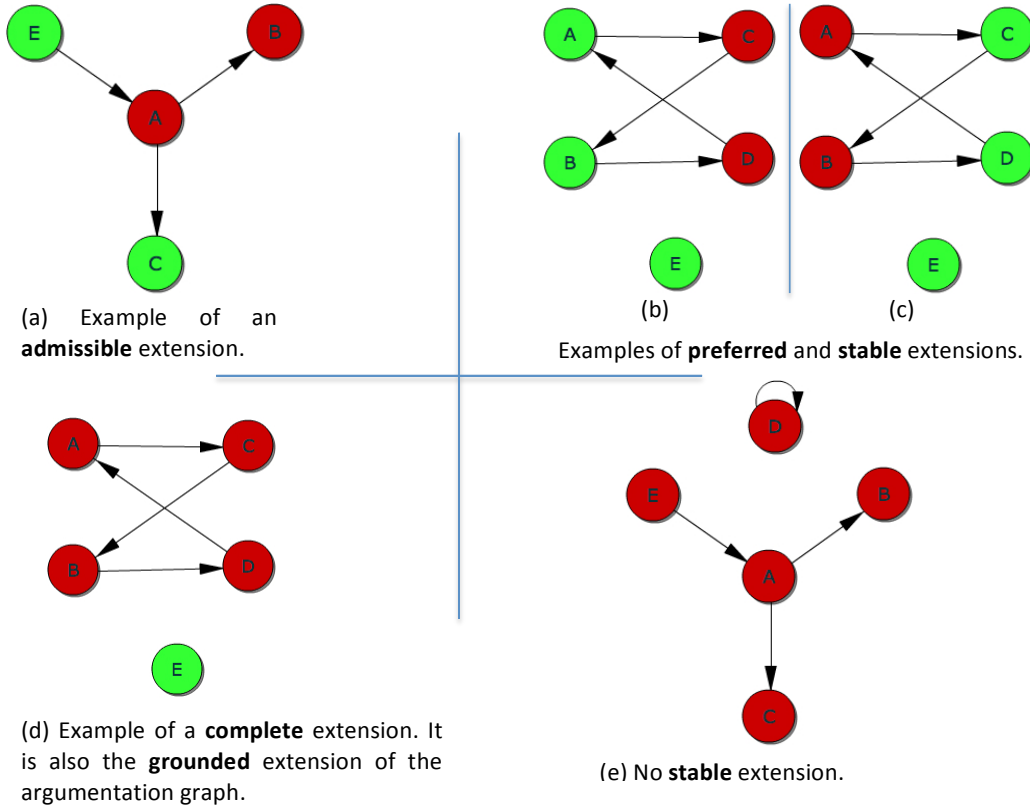


Figure 3: Examples of extensions under different Dung semantics.

250 For $T \in \{\text{admissible, complete, preferred, grounded, stable, semi-stable,}$
 251 $\text{eager, naive}\}$, X is skeptically (resp. credulously) justified under the T se-
 252 mantics if X belongs to all (resp. at least one) T extension.

253 **Example 2.** In figure 3, sub-graphs (b) and (c) illustrate the two pre-
 254 ferred extensions in the argumentation graph. Argument E is skeptically
 255 accepted under preferred semantics since it belongs to both preferred exten-
 256 sions, whereas arguments A , B , C and D are credulously accepted under
 257 preferred semantics.

258 We notice that some semantics can return empty or even no extensions.
 259 This situation occurs particularly when a user expresses at least one self-
 260 defeated argument, which is not attacked by any other argument, but attacks
 261 all the others. This kind of arguments are called contaminating arguments
 262 [Wu, 2012]. The current version of our system detects the rules leading to
 263 such arguments and discards them before performing the process of extension
 264 computations. The user is warned and the list of discarded rules is displayed.

265 4.2 ASPIC argumentation system

266 In this paper we consider a subset of ASPIC+ [Prakken, 2010] argumentation
 267 system, which is compatible with the ones presented in [Amgoud et al., 2006].
 268 An ASPIC+ argumentation system is denoted $AS = (\mathcal{L}, cf, \mathcal{R}, \geq)$, where:

- 269 • \mathcal{L} is the logical language of the system.
- 270 • cf is a contrariness function which associates to each formula f of \mathcal{L} a
 271 set of its incompatible formulas (in $2^{\mathcal{L}}$): in our case, cf corresponds to
 272 classical negation \neg .
- 273 • $\mathcal{R} = \mathcal{R}_s \cup \mathcal{R}_d$ is the set of strict (\mathcal{R}_s) and defeasible (\mathcal{R}_d) inference

274 rules where $\mathcal{R}_s \cap \mathcal{R}_d = \emptyset$. As stated in [Modgil and Prakken, 2013],
 275 ASPIC+’s inference rules can be used to encode domain-specific infor-
 276 mation but they could also express general laws of reasoning. In this
 277 paper we use these rules to encode packaging domain-specific informa-
 278 tion. Thus, a strict rule, denoted by \rightarrow , expresses a natural implication
 279 in the domain, as “*GlutenPackaging is a Packaging*”, and a defeasible
 280 rule, denoted by \Rightarrow , expresses an implication which is not always true,
 281 as “*GlutenPackaging can be a suited Packaging*”. For each strict rule
 282 $a \rightarrow b$, we add in \mathcal{R}_s the rule $\neg b \rightarrow \neg a$ to ensure the completeness
 283 and the consistency of reasoning (see [Caminada and Amgoud, 2007]
 284 for further details),

- 285 • \geq is a preference ordering over defeasible rules, not used in our frame-
 286 work.

287 A knowledge base in an $AS = (\mathcal{L}, cf, \mathcal{R}, \geq)$ is $\mathcal{K} \subseteq \mathcal{L}$, which contains the
 288 concepts defined in the domain and the alternative choices under discussion.

289 **Argument structure.** An ASPIC argument A can be of the following
 290 forms:

- 291 1. c with $c \in \mathcal{K}$, such that $Prem(A) = \{c\}$, $Sub(A) = \{A\}$ and $Conc(A) =$
 292 c , with $Prem$ returns premises of A , Sub returns its sub-arguments and
 293 $Conc$ returns its conclusion,
- 294 2. $A_1, \dots, A_m \Rightarrow c$ (resp. $A_1, \dots, A_m \rightarrow c$), such that there exists a strict

295 (resp. defeasible) rule in \mathcal{R}_s (resp. \mathcal{R}_d) of the form
 296 $Conc(A_1), \dots, Conc(A_m) \Rightarrow c$ (resp. $Conc(A_1), \dots, Conc(A_m) \rightarrow c$),
 297 with $Prem(A) = Prem(A_1) \cup \dots \cup Prem(A_m)$, $Conc(A) = c$, $Sub(A) =$
 298 $Sub(A_1) \cup \dots \cup Sub(A_m) \cup \{A\}$.

299 Form 1 associates one argument with each alternative choice defined in
 300 the argumentation system AS . Based on arguments generated by Form 1,
 301 Form 2 permits to create new arguments by applying a derivation process
 302 over the set of strict (\mathcal{R}_s) and defeasible (\mathcal{R}_d) rules defined in AS . A step
 303 in the derivation process considered in this case means that, if a set of final
 304 conclusions of a given set of arguments matches the antecedents of a rule
 305 then the arguments can be combined by applying the rule, thus creating
 306 a new argument. Each step in this derivation process forms an argument.
 307 We make the assumption that the set of arguments constructed from the
 308 argumentation system is finite. An argument is said strict if and only if it
 309 does not involve any defeasible rules. Otherwise, it is called defeasible.

310 The set of strict rules \mathcal{R}_s is consistent if and only if it is impossible to
 311 construct in the argumentation system two strict arguments having conflict-
 312 ing conclusions ($\nexists A, B$ such that A, B are strict arguments and $Conc(A) =$
 313 $\neg Conc(B)$).

314 **Notation.** To improve the readability, by abuse of notation, we associate to
 315 each argument a label made of a capital letter followed by a subscript number.
 316 The labels are then used in an argument to refer to its sub-arguments. In

317 this notation, a label followed by colon is not a part of the argument.

318 Let AS be an ASPIC argumentation system defining the strict rule $a, b \rightarrow c$

319 and the alternative choices a, b . The knowledge base is $\mathcal{K} = \{a, b, c\}$. The

320 set of strict rules (closed under transposition) is $\mathcal{R}_s = \{a, b \rightarrow c; \neg c, b \rightarrow$

321 $\neg a; a, \neg c \rightarrow \neg b\}$. The following arguments can be built:

322 • $A_1 : a$

323 • $A_2 : b$

324 • $A_3 : A_1, A_2 \rightarrow c$.

325 A_3 means that $Conc(A_1)$ and $Conc(A_2)$ are the hypothesis that lead to the

326 claim c , by applying the rule $a, b \rightarrow c$.

327 **Example 3.** We consider the following textual arguments expressed about

328 biodegradability of packaging materials.

329 • Life Cycle Analysis (LCA) results are not in favor of biodegradable
330 materials, regarding their high environmental impact during the pro-
331 duction process.

332 • Consumers are in favor of biodegradable materials since they could help
333 to protect the environment.

334 We model these arguments by using the proposed logical language as

335 follows:

- 336 • BP is a concept referring to biodegradable packaging materials.
- 337 • PEV , HIP are concepts referring to packagings which respectively pro-
338 tect the environment and have a high environmental impact (according
339 to LCA).
- 340 • ACC , REJ are concepts referring to the global decisions (accepted,
341 rejected) about the packaging to choose according to the aspect consid-
342 ered (in this example, the biodegradability of the material). Intuitively,
343 $ACC = \neg REJ$ and $REJ = \neg ACC$. We can syntactically replace REJ
344 with $\neg ACC$.

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

- 346 • $\mathcal{R}_s = \{BP \rightarrow HIP, \neg HIP \rightarrow \neg BP, HIP \rightarrow \neg ACC, ACC \rightarrow \neg HIP\}$
- 347 • $\mathcal{R}_d = \{BP \Rightarrow PEV, PEV \Rightarrow ACC\}$

348 Please notice that strict rules are used to model reliable knowledge based
349 on measured parameters by using well-defined and stated procedures, or
350 expressed with linguistic terms such as “must”, “shall”, “mandatory”, “im-
351 portant”, etc. On the other hand, defeasible rules model knowledge based
352 on empirical observations or expressed with linguistic terms such as “may”,
353 “could”, “optional”, etc. Here, the rules involve HIP are considered as strict
354 and those involving PEV are defeasible.

355 The following structured arguments can be built on the knowledge base
356 $\mathcal{K} = \mathcal{K}_p = \{BP\}$:

- 357 • $A_0 : BP$
- 358 • $A_1 : A_0 \rightarrow HIP$
- 359 • $A_2 : A_1 \rightarrow \neg ACC$
- 360 • $B_1 : A_0 \Rightarrow PEV$
- 361 • $B_2 : B_1 \Rightarrow ACC$
- 362 • $B_3 : B_2 \rightarrow \neg HIP$
- 363 • $B_4 : B_3 \rightarrow \neg BP$

364 **ASPIC/ASPIC+ attack and defeat relations.** We only consider in
 365 this work the rebutting attack as defined in [Modgil and Prakken, 2013]:

366 Argument A *rebutts* argument B on B' if and only if $Conc(A) \in cf(\varphi)$
 367 (where φ is an atom in the language) for some $B' \in Sub(B)$ of the form
 368 $B'_1, \dots, B'_m \Rightarrow \varphi$.

369 Finally, A *defeat* B if A rebutts B .

370 **Example 4.** Let us consider the arguments built in Example 3. Argument
 371 A_2 rebutts argument B_2 since $Conc(B_2) = ACC$ and $Conc(A_2) = \neg ACC$
 372 and $B_2 : B_1 \Rightarrow ACC$, which means that ACC stems from a defeasible rule,
 373 therefore it is less strong than A_2 and B_2 cannot attack A_2 . Then, A_2 defeats
 374 B_2 .

375 **Extension output.** The output of an extension \mathcal{E} is defined as the union
376 of the conclusion of its arguments: $Output(\mathcal{E}) = Concs(\mathcal{E}) = \{Conc(A), A \in$
377 $\mathcal{E}\}$, where $Conc(A)$ is the conclusion of argument A .

378 **Example 5.** Let us consider again the arguments built in Example 3.
379 Only one preferred extension $\mathcal{E}_1 = \{A_0, A_1, A_2, B_1\}$ can be computed over
380 this set of arguments. The output of \mathcal{E}_1 is $Output(\mathcal{E}_1) = Concs(\mathcal{E}_1) =$
381 $\{BP, HIP, PEV, \neg ACC\}$.

382 It is worth noticing that as we obtain only one extension then all its ar-
383 guments are both skeptically and credulously accepted in the argumentation
384 system, under the preferred semantics.

385 In the following, we detail how this argumentation system has been in-
386 stantiated with the EcoBioCap project knowledge.

387 5 ASPIC instantiation for packaging selection 388 application

389 In this section we introduce the instantiation of our logical representation
390 of text arguments within ASPIC *AS*. We describe in Subsection 5.1 how
391 textual arguments are modeled as options and rules, which are used after
392 that to instantiate ASPIC *AS* for argument derivation, conflict detection,
393 extension computation and predicate extraction. We show in Subsection 5.2
394 the drawback of a direct instantiation of the ASPIC argumentation system in

395 our application context and we introduce our solution based on viewpoints.

396 **5.1 Logical modeling of text arguments in ASPIC AS**

397 As described in Section 3, we aim at developing an argument-based applica-
398 tion for packaging selection in order to be able:

- 399 • to model logically the stakeholders' arguments in order to extract the
400 underlying knowledge that could enrich the querying process,
- 401 • to compute the extensions (the subsets of consistent arguments that
402 defend themselves against attacks),
- 403 • to extract from the chosen extension the predicates to use in the query-
404 ing process, called justified preferences.

405 The first requirement can be achieved by defining two levels of modeling:
406 syntactical level and logical level. At the syntactical level, we identify in
407 each argument the concepts involved, their corresponding attributes in the
408 database and optionally the values associated with attributes. A concept is
409 seen as a subclass of packaging. The concepts syntactically correspond to the
410 atoms of the propositional language used to instantiate the argumentation
411 framework. At the logical level, we distinguish for each argument the body
412 (or the premises) and the head (or the conclusion) of the underlying rules
413 and we specify if the extracted rule is either strict or defeasible. The body
414 and the head of a rule correspond to concepts defined at the syntactical level.

415 **Example 6.** Let us consider the following argument:

416 “*Life Cycle Analysis (LCA) results are not in favor of biodegradable ma-*
417 *terials, regarding their high environmental impact during the production pro-*
418 *cess, expressed by the carbon footprint $\geq 5kg$ eq. CO_2 ”.*

419 At the syntactical level, we define the following concepts:

420 • *BiodegradablePackaging*: it corresponds to the biodegradable packag-
421 ing; it is related to the attribute *Biodegradability* which is already de-
422 fined in the database schema and to the value *TrueBiodegradablePackaging*
423 also defines one of the possible choices of packaging, which are discussed
424 in the argumentation system.

425 • *HighEnvImpactPackaging*: it corresponds to packaging having a bad
426 carbon footprint value. This concept is related to the attribute
427 *CarbonFootPrint* and the value $\geq 5kg$ eq. CO_2 . In the case that the
428 attribute is not defined in the database schema; the application allows,
429 however, the user to add the required information to define it (value
430 type, measure unit, minimal value, etc.), and to suggest it as a possible
431 extension of the database schema.

432 At the logical level, the argument is translated into the following rules:

433 • $BiodegradablePackaging \rightarrow HighEnvImpactPackaging$

434 • $HighEnvImpactPackaging \Rightarrow NotAccepted$

435 These rules express the fact that each biodegradable packaging is a pack-
436 aging having a high environmental impact (considered here as strict for the

437 sake of demonstration), and such packaging are not accepted or rejected (rep-
438 resented as a defeasible rule as a decision is generally defeasible). The user
439 specifies both rules at once using the same user interface, and indicates also
440 for each rule if it is strict or defeasible. The application automatically adds
441 the transposed rule in the case of strict rules.

442 The rules and the options (seen as premises), in addition to the de-
443 cision atoms *Accepted* and *Not Accepted*, are used to instantiate the AS-
444 PIC *AS*. Once ASPIC *AS* is instantiated, the system derives the argu-
445 ments (as illustrated in Example 3), detects the conflicts amongst them
446 (as in Example 4), computes the extensions (like in Example 5), and fi-
447 nally extracts the predicates to send to the querying process. As illustrated
448 in Example 5, the argumentation system recommends the rejection of the
449 biodegradable packaging. This recommendation is translated into the predi-
450 cate *Biodegradable = False*, which can be expressed in a SQL query. This
451 query is afterwards addressed to the database containing the packaging ma-
452 terials in order to retrieve the packaging which are not biodegradable.

453 In the next subsection, we show the limitation of a direct instantiation
454 of the ASPIC *AS* based on our logical approach for argument modeling, and
455 we introduce a solution relying on viewpoints.

456 5.2 Viewpoint-based ASPIC *AS* for packaging selection

457 When stakeholders are engaged in an argumentation process, they express
458 their arguments for or against the acceptance of some kinds of packagings

459 according to some characteristics, corresponding to their concerns and objec-
460 tives. Let us consider the following text arguments expressed by the stake-
461 holders obtained by interviews and surveys.

- 462 1. Packaging materials with low environmental impact are preferred, low
463 environmental impact corresponds to carbon footprint of value $[0, 10]$
464 $kg CO_2$,
- 465 2. Waste management authority aims at collecting at least 75 % of recy-
466 clable packaging,
- 467 3. Consumers are unwilling to sort packaging cause of its extra tax,
- 468 4. Life Cycle Analysis (LCA) results are not in favor of biodegradable and
469 compostable materials,
- 470 5. Consumers are in favor of biodegradable material because they help to
471 protect the environment,
- 472 6. Biodegradable materials could encourage people to throw their pack-
473 aging in nature, causing visual pollution,
- 474 7. Micro-perforated packaging can increase the shelf life by about 20 days,
- 475 8. Multilayered byproduct made packagings allow a good permeance,
- 476 9. Multilayered byproduct made packagings are generally expensive to
477 produce,

- 478 10. Mono-layered byproduct made packagings are easier to produce,
479 11. Consumers do not want to pay an extra cost greater than 5% for a
480 product packed with biodegradable or compostable packaging,
481 12. According to the waste management agency, recycling can create new
482 job opportunities.

483 Here, we distinguish several packaging options: *Biodegradable*, *Recyclable*,
484 *Compostable*, *Micro-Perforated*, *Multilayered*, *Mono-layered* packagings.

485 Let us consider all the above mentioned arguments to instantiate an AS-
486 PIC/ASPIC+ argumentation system. In this case, the argumentation system
487 returns extensions (in any Dung semantics) which are not enough informa-
488 tive to make a decision, as shown by the following instantiation limited to
489 arguments 5 and 9 (but without loss of generality):

490 **Example 7.** Arguments 5 and 9 are defeasible and involve two different
491 options: Biodegradable (denoted by *Bio*) and Multi-layered (denoted by
492 *Mul*) materials. A classical ASPIC argumentation system derives from these
493 text arguments the following 6 logical arguments:

- 494 • $A_0 : Bio$
- 495 • $A_1 : A_0 \Rightarrow ProtectEnvironment$
- 496 • $A_2 : A_1 \Rightarrow Accepted$
- 497 • $B_0 : Mul$

498 • $B_1 : B_0 \Rightarrow Expensive$

499 • $B_2 : B_1 \Rightarrow Not Accepted$

500 Argument A_2 attacks Argument B_2 and vice-versa and we get 2 preferred
501 extensions:

502 • $\mathcal{E}_1 = \{A_0, A_1, A_2, B_0, B_1\}$

503 • $\mathcal{E}_2 = \{A_0, A_1, B_0, B_1, B_2\}$

504 The output of each extension¹ are as follows:

505 • $Concs(\mathcal{E}_1) = \{Bio, ProtectEnvironment, Mul, Expensive, Accepted\}$

506 • $Concs(\mathcal{E}_2) = \{Bio, ProtectEnvironment, Mul, Expensive, Not Accepted\}$

507 We notice that the conclusions of \mathcal{E}_1 and \mathcal{E}_2 are identical, except for the
508 decision (*Accepted*, *Not Accepted*). Therefore, they cannot be used for deci-
509 sion support because their conclusions say that we accept and we reject both
510 options *Mul* and *Bio* for the same reasons.

511 To alleviate this situation, we suggest to separate the options according
512 to the topic or the concern considered. Each topic is called *viewpoint*, which
513 gathers arguments involving some options or alternatives and dealing with
514 the same subject. Hence, we can handle arguments for both acceptance and
515 rejection of packaging but considered only from one packaging aspect. In this

¹We recall that the output of an extension is the set of its argument conclusion.

516 way, decisions reached in each viewpoint are based on one packaging aspect
517 debated by stakeholders' arguments.

518 A viewpoint helps the users to express their arguments by connecting
519 an option with the reason behind its acceptance or rejection. The resulted
520 extensions in a viewpoint not only provide accepted (resp. rejected) options
521 but provide some information explaining why they are accepted (resp. re-
522 jected) as well. A viewpoint facilitates the analysis of the output of the
523 argumentation framework for decision making, since we get one extension
524 which contains the accepted options and all the reasons leading to their ac-
525 ceptance, and a second extension which contains the rejected options and all
526 the reasons leading to their rejection.

527 Each viewpoint instantiates our logical approach for argument modeling.
528 Decisions can then be made relying on the computed extensions correspond-
529 ing to the consensual solutions from a single packaging attribute. We then
530 obtain several attributes with their related values, which are finally used to
531 enrich the querying process for packaging selection, handled by the multi-
532 criteria flexible querying system.

533 It is worth noticing that this approach is a simplification of a theoretical
534 viewpoint model introduced in [Tamani et al., 2013].

535 **Example 8 (Cont. Example 7).** In the above example, the first argu-
536 ment deals with the end of life characteristics of the material to use, and
537 the second argument deals with the design of the packaging. Thus, we can

538 consider two viewpoints: End of life and Design. Each viewpoint instantiates
539 an ASPIC argumentation system. We here obtain one preferred extension
540 per viewpoint:

- 541 • $\mathcal{E}_{End_of_life} = \{A_0, A_1, A_2\}$ from which we extract the predicate
542 “*Biodegradability = True*”,
- 543 • $\mathcal{E}_{Design} = \{B_0, B_1, B_2\}$ from which we extract the predicate
544 “*Multilayered = False*”.

545 Both predicates are finally available for the querying process to retrieve from
546 the database the packaging material satisfying them. The user can select
547 both predicates since they are not contradictory or just one of them, which
548 is considered as the most important predicate according to his/her needs. It
549 amounts to decide which of the viewpoints is the most important for his/her
550 query.

551 The above twelve arguments can be split into the following viewpoints:

- 552 • *end of life*: in this viewpoint, stakeholders (waste management author-
553 ity, users, researchers) argue between biodegradability, compostability
554 and recyclability of the packaging. It contains arguments 1 to 6, 11
555 and 12,
- 556 • *design for a better shelf life*: this viewpoint contains arguments 7 to 10,
557 the choice is between mono-layered, multilayered and micro-perforated
558 packagings.

559 It is worth noticing that there is not a crisp boundary between viewpoints
560 and it is possible to have arguments expressed on more than one aspect of
561 packaging. For instance, arguments 11 and 12 could be gathered into a
562 new viewpoint about the *economic* concerns. For the sake of flexibility, the
563 current version of the system does not impose any restriction on the process
564 of affectation of the arguments to the viewpoints. In addition, it allows users
565 to duplicate such arguments in more than one viewpoint to see their effects
566 on different aspects of packaging.

567 The benefits of viewpoints are the following:

- 568 • Helping the stakeholders to express their argument by considering one
569 topic at a time, and to analyse the results delivered from the argumen-
570 tation framework.
- 571 • Associating subsets of arguments to attributes defined in the database
572 schema. It facilitates the querying process, which retrieves the list of
573 packaging materials.
- 574 • Reducing the mutual influence between arguments expressed about dif-
575 ferent issues.
- 576 • Possible reduction of the CPU-time for extension computation, since
577 the number of arguments and attacks to consider is less than all the
578 arguments to handle in the argumentation framework. It has been
579 proven in [Vreeswijk, 2006] that the extension computation is expo-

580 nential in time. The higher the number of conflicts among arguments
581 in the system is, the higher the response time for extensions will be.

582 The drawback of viewpoints lies in the fact that it is possible in some case
583 that a single option is accepted in one viewpoint and rejected in another one,
584 since the argumentation system does not forbid the use of a single option in
585 more than one viewpoint. For instance, biodegradable packaging is accept-
586 able from the environment (end of life) viewpoint but not accepted from the
587 economic viewpoint. The system is designed to be flexible enough to give
588 the experts the ability to decide which extensions to consider and which ones
589 to discard. In this case, as said above, it is up to the user to decide which
590 viewpoint is the most important for the querying process.

591 In the next section we describe the functionalities implemented of the
592 argumentation system through several screenshots showing the process of
593 instantiation of the argumentation system on the *end of life* viewpoint as
594 well as the results delivered.

595 **6 Implementation and evaluation of the argu- 596 mentation approach**

597 We detail in Subsection 6.1 the implementation of the approach as a web-
598 based application. Then, we evaluate in Subsection 6.2 the argumentation
599 tool for packaging selection according to the *end of life* viewpoint with experts

600 from four european countries (France, Hungary, Italy and Sweden), involved
601 in the EcoBioCap project.

602 **6.1 Implementation of the argumentation tool**

603 The implementation of the approach was done in the context of the Eco-
604 BioCap DSS. A java GXT/GWT web interface was developed and an open
605 version is accessible on <http://pfl.grignon.inra.fr/EcoBioCapProduction/>. A
606 short demonstration video is available for download². Hereinafter, some user
607 interfaces are displayed showing the obtained result in the case of the view-
608 point “end of life”.

609 The main interface of the system is illustrated in Figure 4. It is divided
610 into 5 zones. Zone 1 corresponds to the task bar implementing general func-
611 tions applied on projects (create, load, close, refresh, export, etc.). Zone 2
612 lists the text arguments by stakeholders. Zone 3 displays the extracted con-
613 cepts and rules from the text arguments, they are also listed by stakeholders.
614 Zone 4 displays the graphical representation of the formalized concepts and
615 arguments. Zone 5 is a notification area displaying the computed conflicts
616 and extensions.

²<http://umr-iate.cirad.fr/FichiersComplementaires/DemoRomeHD.mp4>

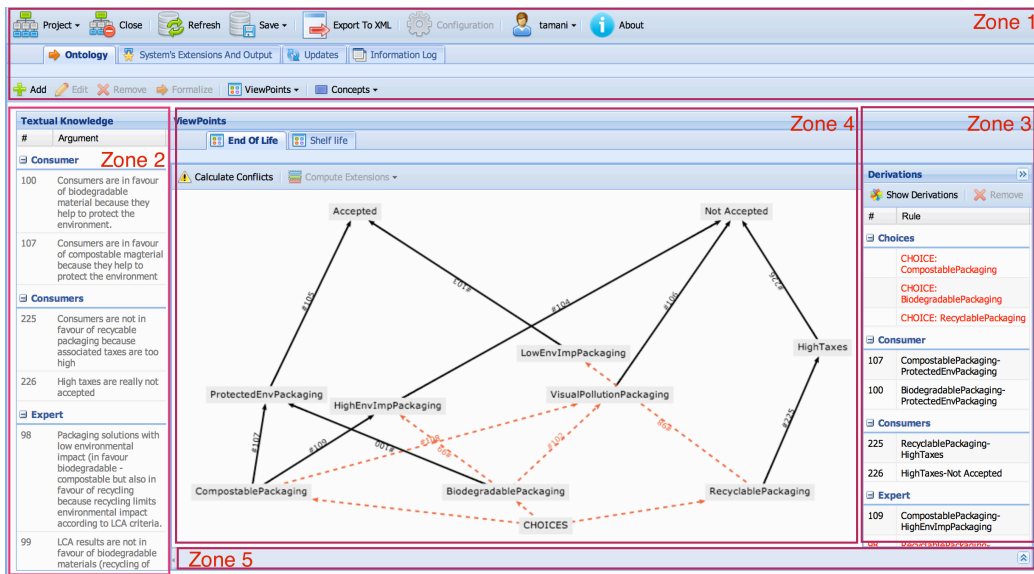


Figure 4: The main interface of the argumentation system.

617 After logging in, the user can create a new project, load an existing one
 618 or import a new project from an XML file. Then, stakeholder arguments
 619 can be entered as (i) an XML file, by using the *import from XML* function,
 620 or (ii) text arguments to formalize them as concepts and rules by using a
 621 dedicated user interface (Figures 5, 6, 7 and 8) guiding and helping the
 622 user during all the process of formalization. A new concept has a name
 623 and a short code, it can be defined as either a choice or not and can be
 624 related to a packaging attribute (as in Figure 5, *BiodegradablePackaging*
 625 corresponds to packagings having the attribute *Biodegradability* equals *True*
 626 in the packaging database), not related to any information in the database
 627 (as in Figure 6 for the concept *HighTaxes*), or can suggest a new attribute to

628 enrich the packaging description in the database (as in Figure 7, the concept
629 *HighEnvPackaging* suggests the new attribute *CarbonFootPrint*, with the
630 measure unit of *Kg CO₂ eq.* to describe the packaging).

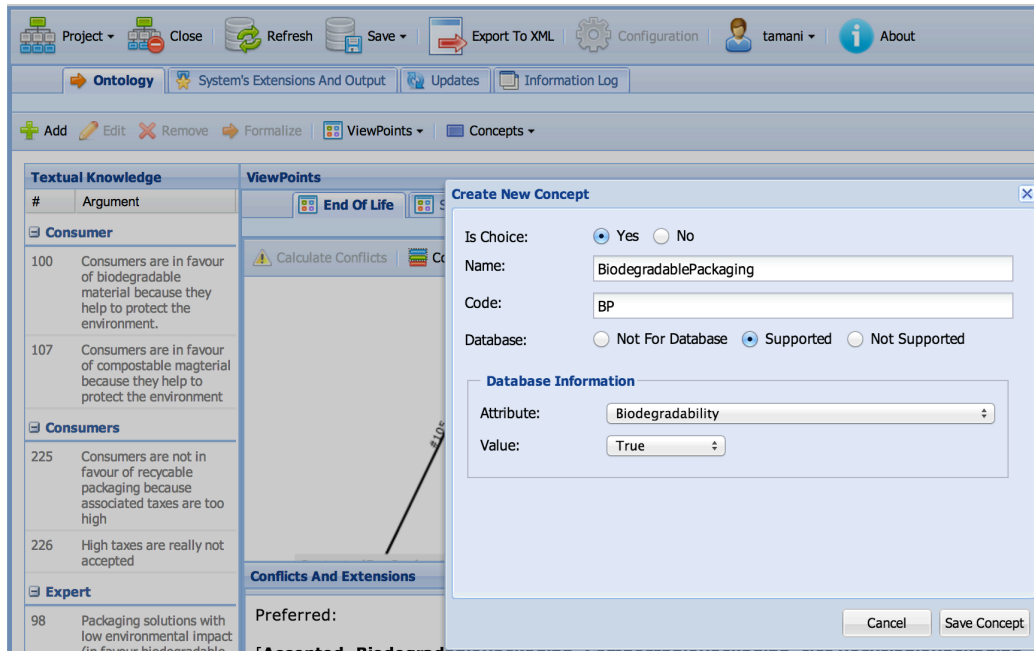


Figure 5: Adding a concept based on a defined attribute in the packaging database.

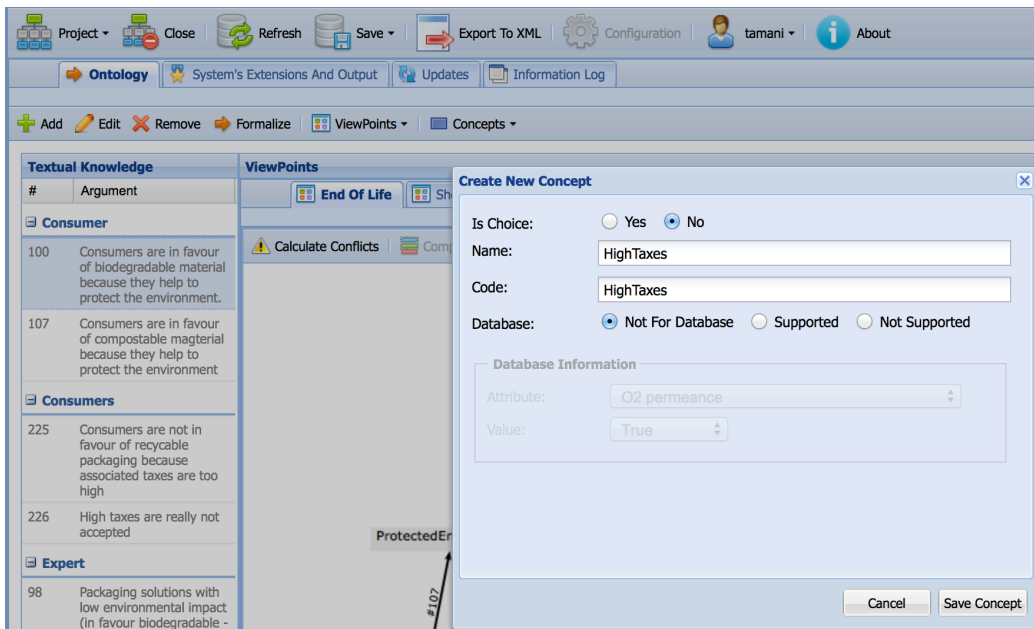


Figure 6: Adding a concept which is not related to the database.

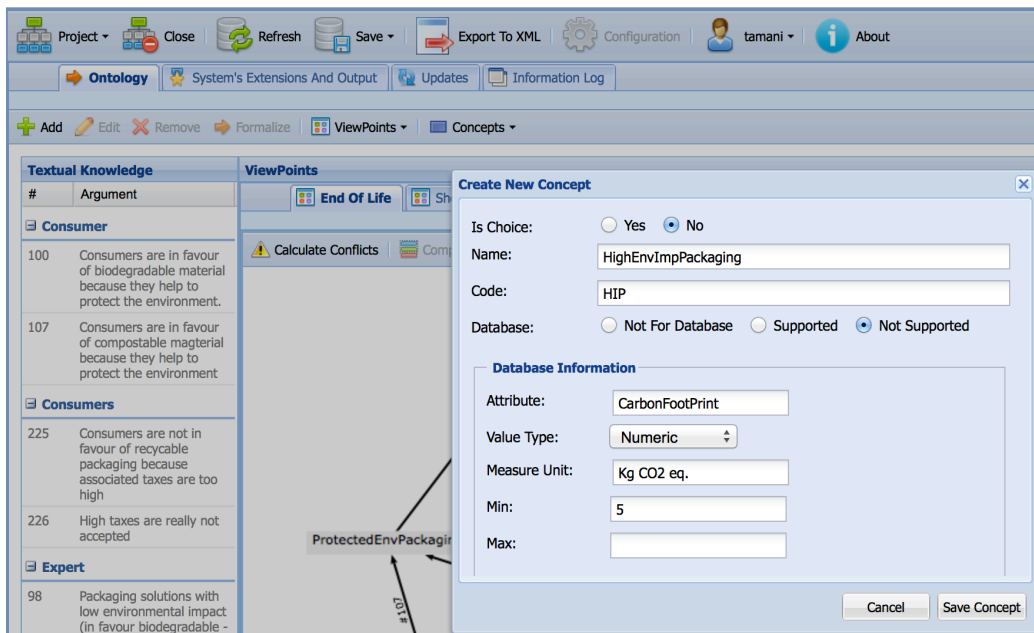


Figure 7: Adding a concept not supported yet in the packaging database but suggested for addition.

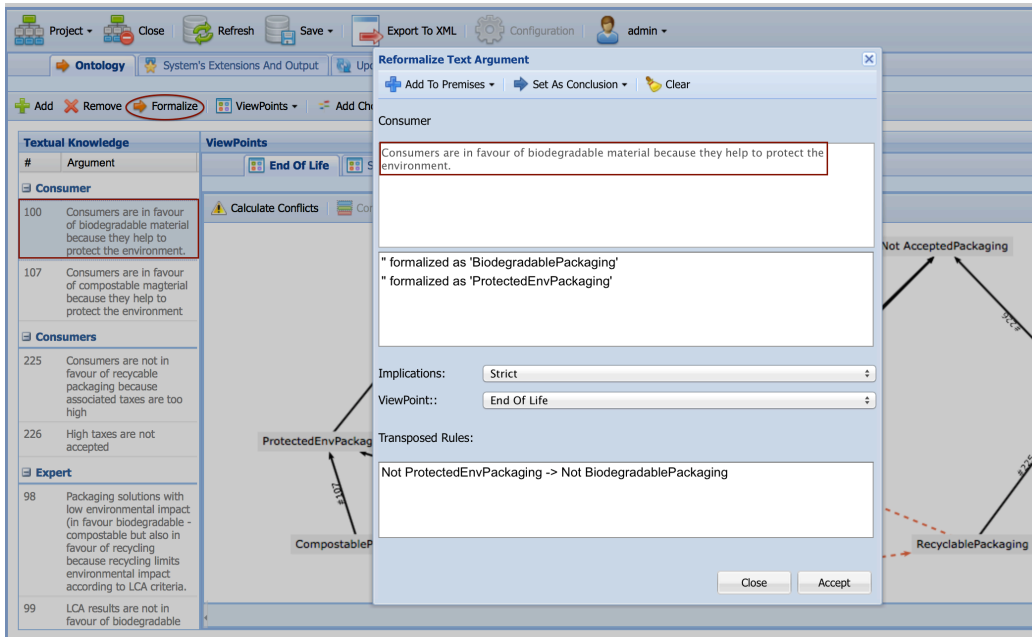


Figure 8: Formalizing a text argument as concepts and rules.

631 Figure 8 shows the formalizing interface in which a user can select the
 632 already created concepts as premise or conclusion to form the rule underlying
 633 the text argument. The rule is then connected to a decision (*Accepted*, *Not*
 634 *Accepted*). The rule and its decision can be specified either as a strict or as
 635 a defeasible rule.

636 Figure 9 illustrates the obtained rules in the case of the viewpoint *end*
 637 *of life* in which stakeholders argued about biodegradability, recyclability and
 638 compostability.

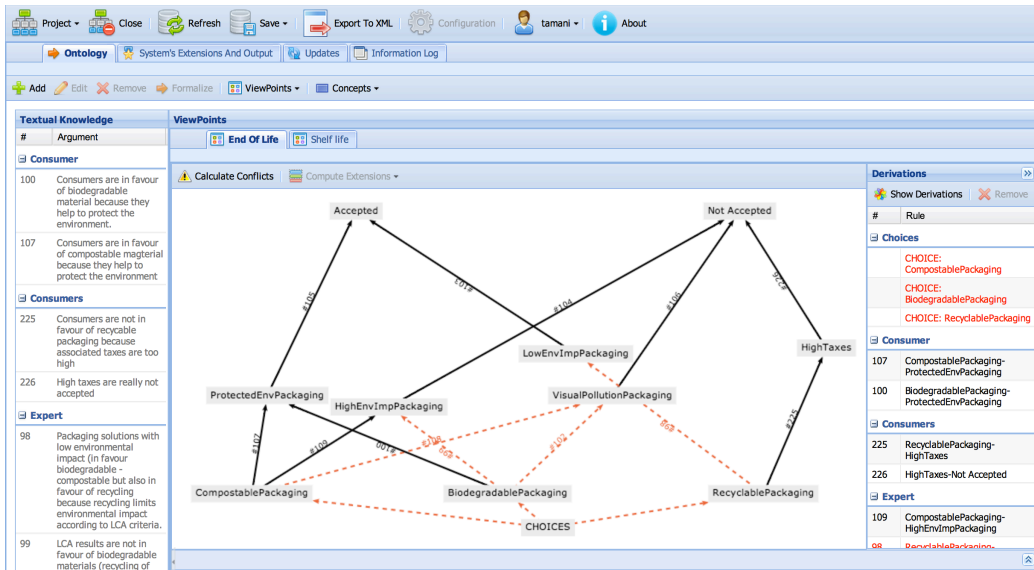


Figure 9: Example of the rules built upon the viewpoint *end of life*.

639 The system generates arguments and computes conflicts and attacks as
 640 shown in Figure 10. For the arguments of *end of life* viewpoint, the system
 641 detected 409 conflicts.

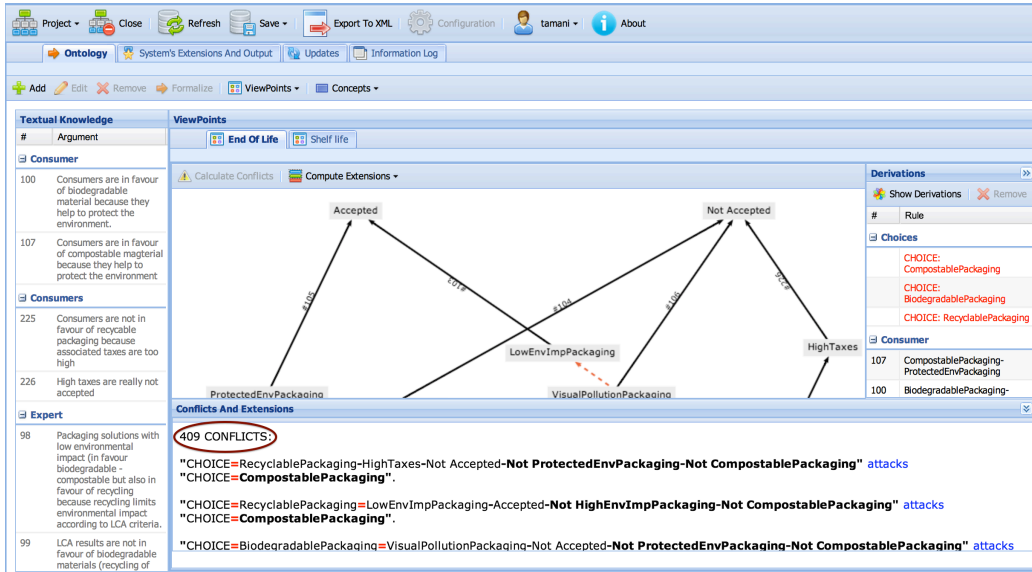


Figure 10: Conflicts computed in the viewpoint *end of life*.

642 The extensions under different semantics (stable, preferred, admissible,
 643 grounded, naive) are after that computed and their contents are displayed
 644 to the user in Figure 11, by using the Java DungAF API³. For the sake
 645 of simplicity, we made the design choice to display only the conclusions of
 646 the arguments belonging to an extension. To highlight the recommendations
 647 in each extension, the concepts playing the role of the choices and decision
 648 variables (*Accepted* and *Not Accepted*) are displayed in bold font.

649 It is worth noticing that all the extensions recommending the rejection
 650 (*Not Accepted*) are displayed in a positive way by negating all concepts con-
 651 tained (NOT “Not *C*” becomes “*C*” and NOT “*C*” becomes “Not *C*” with *C*
 652 is either a concept or a decision). The reason for this translation is to address

³<https://github.com/jtdevereux/javaDungAF>

653 one of the expert feedbacks obtained during an early test of the user interface.
 654 In fact, the experts considered that it is not intuitive to choose an extension
 655 recommending a rejection (which contains the decision *Not Accepted*).

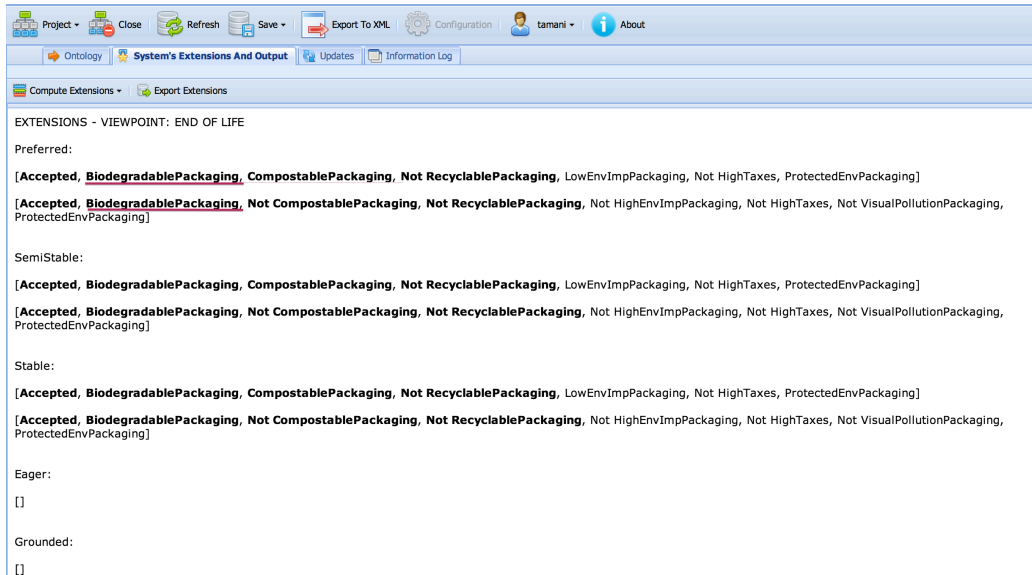


Figure 11: Delivered extensions in the *end of life* viewpoint.

656 In Figure 11, the system concludes skeptically that biodegradable pack-
 657 agings are the most justified ones under the preferred semantics (the concept
 658 underlined in red).

659 In addition to its ability to aggregate non-structured knowledge expressed
 660 as text arguments, the argumentation process also provides the user with
 661 some justifications supporting the recommended result. For example, we no-
 662 tice in Figure 11 that biodegradable packagings are accepted because they
 663 help protecting the environment (*ProtectEnvPackaging*), as they have a low

664 environmental impact and do not imply any additional taxes (*Not HighTaxes*)
665 to be paid by the society (industries, population, etc.).

666 Furthermore, the proposed approach is also dynamic in the sense that
667 if an expert does not agree with the argumentation results, he/she can add
668 on the fly additional arguments to express his/her disagreement. Then, the
669 application detects the conflicts generated by the added arguments and re-
670 compute the extensions accordingly.

671 The extensions obtained are stored as a list of *attribute = value* (Figure
672 12) to be used in the flexible querying system in addition to some other
673 parameters useful for the querying process (*value 1* and *value 2* corresponding
674 to the values *min* and *max* in Figure 7, their respective data type: columns
675 *Type*, the attribute is either negated or not: the column *Negated*, and finally
676 the attribute is either defined in the database schema or not: the column
677 *Supported in DB*).

678 In the context of *end of life* viewpoint, the condition *Biodegradable =*
679 *True* is sent to the querying process to be used as a justified preference for
680 packaging material selection.

EXT	Extension	ViewPoint	Concept	Attribute	Value 1	Value 2	Type	Type	Negated	Supported in DDBB
Pref	1	End Of Life	RecyclablePackaging	Recyclability	True	-	boolean	boolean	true	false
[Ac]	1	End Of Life	HighTaxes	TaxesLevel	True	-	boolean	boolean	true	false
Prot	1	End Of Life	ProtectedEnvPackaging	EnvImpact	30	50	percentage	percentage	false	false
	1	End Of Life	BiodegradablePackaging	Biodegradability	True	-	boolean	boolean	false	true
	1	End Of Life	CompostablePackaging	Compostability	True	-	boolean	boolean	false	false
Ser	1	End Of Life	LowEnvImpPackaging	EnvImpact	10	30	percentage	percentage	false	false
	2	End Of Life	BiodegradablePackaging	Biodegradability	True	-	boolean	boolean	false	true
[Ac]	2	End Of Life	ProtectedEnvPackaging	EnvImpact	30	50	percentage	percentage	false	false
	2	End Of Life	HighEnvImpPackaging	EnvImpact	50	70	percentage	percentage	true	false
[Ac]	2	End Of Life	CompostablePackaging	Compostability	True	-	boolean	boolean	true	false
Prot	2	End Of Life	HighTaxes	TaxesLevel	True	-	boolean	boolean	true	false
	2	End Of Life	RecyclablePackaging	Recyclability	True	-	boolean	boolean	true	false
Stat	2	End Of Life	VisualPollutionPackaging	Pollution	True	-	boolean	boolean	true	false
	3	Shelf life	BiodegradablePackaging	Biodegradability	True	-	boolean	boolean	false	true
[Ac]	3	Shelf life	MicroperforatedPackaging	MicroperforatedPack	True	-	boolean	boolean	false	false
Prot	3	Shelf life	ExtendShelfLifePackaging	NS	True	-	boolean	boolean	false	false

Figure 12: Exporting the extensions composed of concepts and associated attributes belonging to the database.

681 In fact, the user can select the extensions, previously translated into couples
 682 $attribute = value$, from the graphical user interface of the flexible multi-
 683 criteria querying system as displayed in Figure 13.

The image shows two overlapping dialog boxes. The left one, titled 'Preferences associated with criteria', has a checked box for 'allow the ranking of packagings with unknown values for' and three input fields for 'enlarge min', 'min', and 'max' values. Below these are input fields for 'O2 permeance', 'CO2 permeance', and 'Temperature'. A 'Biodegradability' section has a checked box and a list of options: 'transparent', 'translucent', and 'opaque'. The right dialog box, titled 'Argumentation extensions', shows a tree view of extensions. Under 'Example 1' > 'End Of Life' > '31', the 'Biodegradability' concept is selected with the value 'true'. An 'add' button is at the bottom right.

Figure 13: Selecting preferences associated with the *end of life* viewpoint to complete the query with $Biodegradable = True$. (File 31 corresponds to Extension 1 in Figure 12).

684 Figure 14 finally displays the final result after execution of the multi-
 685 criteria querying which takes into account the consensual preferences about
 686 the biodegradability attribute. Four packagings are ranked according to their
 687 relevance to the query preferences.

The screenshot shows a software interface with two main sections. The top section, titled "Preferences associated with criteria", contains several settings:

- A checked checkbox: "allow the ranking of packagings with unknown values for mandatory criteria".
- Four input fields for numerical values: "enlarge min", "min", "max", and "enlarge max".
- Four rows of values:
 - O2 permeance: 9.881786e-12, 1.270515e-11, 1.552852e-11, 1.835189e-11
 - CO2 permeance: 9.064443e-11, 1.165428e-10, 1.424412e-10, 1.683397e-10
 - Temperature: 14, 18, 22, 26
- A checked checkbox: "Biodegradability".
- A list for "Transparency" with options: transparent, translucent, and opaque. There are navigation arrows to the right of this list.
- Two buttons: "argumentation" and "rank packagings".

 The bottom section, titled "Packagings ranking", is a table with the following data:

ranking	name	type
1	Polyethylene HD	Polyolefin
2	Corn-zein coated PP films	Proteins
3	Myofibrillar proteins	Proteins
4	Corn-zein coated PP films	Proteins

Figure 14: The final result after running the multi-criteria querying process.

688 6.2 Evaluation of the argumentation tool

689 The evaluation of the tool has been carried out in two phases. The first
 690 one was performed at the middle of the implementation process when only
 691 main user interfaces and functions were implemented. The second phase was
 692 performed at the end of the implementation process.

693 The first evaluation aimed at validating the user interfaces and the us-
 694 ability of the tool. The evaluation method was based on the implementation

695 of real use cases in which some experts involved in the project were invited
696 to express some text arguments. Then, we guided them through the argu-
697 mentation process, from argument formalization to extension computation.
698 The main evaluation criteria considered here were:

- 699 • The intuitiveness of the user interfaces,
- 700 • The relevance of the functions implemented,
- 701 • The usefulness of the graphical representation of the data (argument
702 graph made of arguments and attacks, argument derivation, alterna-
703 tives and rules representation),

704 The conclusions drawn from this early evaluation is as follows.

- 705 • The experts (who are not computer scientists) were more interested on
706 the input and the output of the tool than on the detailed process it
707 goes through. Thus, argument modeling and extension outputs are the
708 main functions of the tool from the experts' standpoint.

709 Consequently, we have hid by default the graphical representation
710 of the arguments, attacks amongst them and the argument derivation
711 process so as the information shown to the users focus on the text argu-
712 ment, the result of modeling and the output of extensions. The users
713 can still display on demand further details about the argumentation
714 process.

715 • The second feedback was about the rule modeling as either defeasible
716 or strict, which is seen by the experts as an important limitation of
717 the expressiveness of arguments, since a rule could be less/more de-
718 feasible than another. As mentioned on future work, this issue gave
719 birth to fuzzy argumentation framework [Tamani and Croitoru, 2014b,
720 Tamani and Croitoru, 2014a].

721 The second evaluation process aimed at validating the reasoning process
722 by the experts. During a 2-day workshop, we have collected text arguments
723 on diverse options about the end of life of packaging in different European
724 countries. We have modeled the arguments and compute the extensions,
725 which we have after that shown to the experts the second day to evaluate the
726 likelihood and the coherence of the results obtained. The evaluation criterion
727 considered here is the correctness of the implementation of the reasoning
728 process.

729 The evaluation of the argumentation tool has been carried out for the
730 following four countries: France, Hungary, Italy and Sweden. We summarize
731 in Table 1 the data collected via discussions and interviews with diverse
732 experts from each country about the aspect packaging’s “*end of life*”. For
733 each country, we listed the discussed options according to the local context
734 and the number of text arguments collected. We refer the reader to Tables
735 3, 4, 5 and 6 in appendix A for the text arguments gathered for France,
736 Hungary, Italy and Sweden, respectively.

737 Table 2 summarizes the results obtained for each country in terms of

Table 1: Options discussed within the arguments collected for each country.

Country	Options discussed for <i>end of life</i> viewpoint	Number of text arguments
Hungary	Biodegradable Packaging Compostable Packaging Recyclable Packaging	9
Italy	Biodegradable Packaging Compostable Packaging Recyclable Packaging	8
Sweden	Biodegradable Packaging Compostable Packaging Incinerated Packaging Landfill Packaging Recyclable Packaging	13
France	Biodegradable Packaging Burying Packaging Compostable Packaging MultiLayered Recyclable Packaging Recyclable Packaging Other (Incinerated) Packaging	25

738 the number of logical arguments, number of conflicts, number of preferred
739 extensions⁴ returned and the skeptical output of the argumentation system.
740 The skeptical output contains the consensual options (displayed in bold font)
741 which are supported by arguments present in any extension, in addition to
742 other concepts corresponding to reasons why these options are delivered.

743 In the case of Hungary, the argumentation tool returns two preferred ex-
744 tensions and two skeptically accepted choices, namely: *Biodegradable* and
745 *Not Recyclable* packaging. The argumentation tool recommends biodegrad-
746 able packaging because they have a positive image regarding the protection
747 of the environment, which increases their marketing attractiveness. The re-
748 cyclable packaging are discarded cause of the extra taxes imposed by the
749 local authorities.

750 In the case of Italy, the argumentation tool returns the same skeptical
751 outputs as for Hungary and for quite similar reasons. Biodegradable pack-
752 aging are returned for their positive image toward the protection of the en-
753 vironment, but marketing aspects are not important for Italy. Recyclable
754 packaging are discarded because of the taxes the consumers would have to
755 pay.

756 In the case of Sweden, the argumentation tool returns two preferred ex-
757 tensions and three skeptically accepted choices: *Biodegradable*, *Incinerated*

⁴We computed for each country the extensions under diverse semantics (admissible, preferred, stable, semi-stable, ground, etc.), but we limit our analysis to the preferred semantics since it delivers the largest sets of non-conflicting arguments that defend themselves against attacks.

Table 2: Obtained results for each country.

Country	Number of logical arguments	Number of Conflicts	Number of preferred extensions	Number of skeptical outputs
Hungary	50	316	2	Biodegradable Packaging Not Recyclable Packaging <i>Marketing Attractive Packaging</i> <i>Not HighTaxes</i> <i>Protect Env Packaging</i>
Italy	54	409	2	Biodegradable Packaging Not Recyclable Packaging <i>Not HighTaxes,</i> <i>Protect Env. Packaging</i>
Sweden	146	2445	2	Biodegradable Packaging Incinerated Packaging Not Landfill Packaging <i>Energy Recovery Packaging</i> <i>Gas Production Packaging</i> <i>Protect Env. Packaging</i>
France	117	4408	2	Not MultiLayered Recyclable Packaging OtherPack (incinerated) <i>BonusTax Packaging</i> <i>Energy Production Packaging</i> <i>High Env. Impact Packaging</i> <i>HighTreatmentCost</i> <i>Low Env. Impact Packaging</i> <i>Not MalusTax</i> <i>Not NoChain</i> <i>Not Recycling Disturb sorting</i> <i>Not Visual Pollution</i> <i>Partially Recycled Packaging</i>

758 and *Not Landfill* packaging. The main reasons here to accept biodegrad-
759 able packaging are energy bio-gas production in addition to the environment
760 protection. Incinerated packaging are also accepted since they are used to
761 produce energy. The landfill packaging are rejected in all situations because
762 the authorities forbid all kinds of landfilling solution for packaging.

763 In the case of France, due to the number of arguments and conflicts gen-
764 erated⁵, the computation of extensions takes a long time and the server ran
765 out of resources (because of the Java DungAF which implements exponential
766 algorithms as shown in [Vreeswijk, 2006]). Therefore, we simplified the ar-
767 gumentation graph by deleting the rules leading to self-attacked arguments.
768 The result delivered from the argumentation tool is actually an approxima-
769 tion. From the returned two preferred extensions, two skeptically accepted
770 choices are obtained, namely: *Not MultiLayered recyclable Packaging* and
771 *incinerated Packaging* (also denoted by *OtherPack*). The incinerated pack-
772 aging produce energy and the multilayered recyclable packaging are rejected
773 since there is no recycling chain available. The rest of listed reasons are re-
774 lated to the other discarded options (biodegradable, compostable, recyclable
775 and burying packaging). There have been returned by the system because of
776 the simplification of the argumentation graph.

777 These results are however validated by the experts with respect to the
778 text arguments used in the computation of extensions.

779 To conclude this section, we have learned from this evaluation that:

⁵The original argument graph contains 289 logical arguments and 27113 conflicts.

- 780 • The argumentation process delivered coherent results, in the sense of
781 attack definition,
- 782 • The process can be time consuming when the number of text arguments
783 is important,
- 784 • The need for an explanation function when the output contains some
785 unexpected results, or in the contrary does not contain some expected
786 results.

787 **7 Related work**

788 Related work can be considered according to application standpoints in the
789 argumentation field. Based on the recent survey [Schneider et al., 2013] and
790 the web site http://www.phil.cmu.edu/projects/argument_mapping/, appli-
791 cations and tools developed for argumentation can be divided into the two
792 following categories:

- 793 • Software for argument expression and modeling. This software, such as
794 Araucaria [Reed and Rowe, 2004], Argunet [Schneider et al., 2007] and
795 DebateGraph,⁶ allows the expression of arguments as texts to manually
796 formalize them as hypothesis and conclusions. The user can after that
797 save the arguments as an XML file.

⁶www.debategraph.org

798 • Software for extension computation (we recall that an extension is a
799 conflict-free subset of arguments defending themselves against attacks)
800 over an argumentation graph given as input, like OVA-GEN⁷ and Ar-
801 guLab⁸.

802 Despite the plethora of available software in the field of argumentation,
803 there are few argumentation software systems implementing an argumen-
804 tation process from argument expression to extensions computation, while
805 providing users with several graphical user interfaces to visualize the entire
806 process. In addition to the software introduced in this paper we can cite
807 ArgTrust [Parsons et al., 2013], in which the authors considered the uncer-
808 tainty underlying the sources of the knowledge used in the argumentation
809 framework for decision making; CISpaces framework [Toniolo et al., 2014],
810 which supports collaborative intelligence analysis of conflicting information
811 in collaboration exploiting argumentation schemes; “*Quaestion-it.com*”
812 [Evrpidou and Toni, 2014] which is a social intelligence debating platform,
813 based on computational argumentation, for modeling and analyzing social
814 discussions, and demonstrate a question-and-answer web application provid-
815 ing support for extracting intelligent answers to user-posed questions; and
816 the Carneades argumentation system web version [Gordon, 2013], which pro-
817 vides software tools based on a common computational model of argument
818 graphs useful for policy deliberations.

⁷<http://ova.computing.dundee.ac.uk/ova-gen/>

⁸<https://code.google.com/p/pyafl/>

819 We presented in this paper a real world application based on argumen-
820 tation reasoning and connected to the querying process by harnessing the result
821 of the argumentation process as justified preferences expressing consensual
822 solutions encompassing the stakeholders needs and requirements. It is to the
823 best of our knowledge an original contribution in the field of food packaging.

824 8 Conclusion and Future Work

825 In this paper we applied an argumentation approach to a real use case from
826 the industry, based on an ASPIC argumentation system specifications al-
827 lowing stakeholders to express their preferences and providing the system
828 with stable concepts and inference rules of a domain. We have proposed
829 an argumentation system in which each criterion (attribute or aspect) is
830 considered as a viewpoint in which stakeholders express their arguments in
831 homogeneous way. Each viewpoint delivers extensions supporting or oppos-
832 ing certain choices according to one packaging aspect, which are then used
833 in the querying process. The approach was implemented as a web-based ap-
834 plication and evaluated in real use cases modeling possible packaging *end of*
835 *life* solutions in four european countries.

836 Compared to the current stakeholder decision-making practices, this DSS
837 is a significant breakthrough in the field of food packaging. The DSS proposed
838 in this paper answers to multi-criteria queries including several food packag-
839 ing characteristics. Moreover, the DSS is able to aggregate in a consensual

840 way the arguments expressed by to the packaging food chain stakeholders
841 about their constraints, acceptances and needs considering several criteria
842 (biodegradability, transparency etc). To the best of our knowledge, this type
843 of tool was never attempted previously in that field. Among the list of possi-
844 ble packagings retrieved by the DSS, the user has to choose one (usually the
845 one ranked on top) and then to test it in real condition of use. Compared
846 to the empirical approach that requires numerous experimental trials, using
847 the DSS the user will have only one trial to perform (validation step). For
848 the aforementioned reasons, the DSS proposed in this paper can be of help
849 for decision-making in the field of food packaging for fresh produce.

850 As future work, we need to improve the scalability of the argumenta-
851 tion system regarding the number of arguments expressed within a view-
852 point. This issue could be tackled either by considering recently intro-
853 duced effective approaches and algorithms for computation, such as SAT-
854 based approach [Cerutti et al., 2014a, Cerutti et al., 2014b], recursive meta-
855 algorithm [Cerutti et al., 2014c], and algorithms for decision problems
856 [Nofal et al., 2014]. Another possible solution could be splitting again argu-
857 ments' viewpoint into subtopics which would be easier to handle as small
858 subsets of arguments. This solution imposes to study how to aggregate the
859 solutions delivered by subtopics to compute the final recommendation of a
860 given viewpoint.

861 The approach proposed and implemented in this paper can benefit from
862 the diverse argumentation approaches for decision making, such as the value-

863 based argumentation approaches [Atkinson and Bench-Capon, 2007]
864 [Bench-Capon et al., 2011, Bench-Capon et al., 2013, Prakken, 2012] which
865 argument schemes are used as means to deliberate or to reason with legal
866 cases using values. Besides, it is also possible to refine the reasoning with pref-
867 erences which can be expressed over the arguments or the alternatives like in
868 [Amgoud and Prade, 2009, Modgil and Prakken, 2013, van der Weide et al., 2011]
869 or by multi-criteria argument selection such as in [van der Weide et al., 2012].

870 Besides, some experts feedback pointed out the difficulties to consider a
871 rule as either strict or defeasible and expressed the need to be able to specify
872 a sort of importance encompassing the notions of strictness and defeasibility.
873 One work in progress [Tamani and Croitoru, 2014b, Tamani and Croitoru, 2014a]
874 is to extend the proposed approach to fuzziness to make it possible to deal
875 with vague and uncertain concepts and rules. Another important feedback
876 from the expert was about explaining the results delivered from the argu-
877 mentation process. The experts expressed the need for explanation function
878 which is capable to provide more information about how a given conclusion
879 was or was not delivered. The issue of explaining is currently undertaken and
880 some preliminary results have already published such as [Arioua et al., 2014a]
881 in which the authors introduced a preliminary approach to explain why a re-
882 sult was delivered, and [Arioua et al., 2014b] in which the authors proposed
883 a dialogical approach to explain why a given conclusion was not delivered by
884 the argumentation process.

885 Another line to develop consists of studying the bipolarity in our con-

886 text of argumentation, since extensions can be formed to support/oppose
887 decisions. Therefore a bipolar reasoning process could be considered as a
888 refinement of the introduced argument-based reasoning process, especially
889 when a single choice is accepted by some viewpoints and rejected by others.

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Table 3: Text Arguments collected for France.

Stakeholder	Argument
Consumer	Consumers are in favour of biodegradable material because they help to protect the environment.
Consumer	Consumers are in favour of compostable material because they help to protect the environment.
Consumer	Consumers are not in favour of recyclable packaging because associated taxes are too high.
Consumer	Concerning other pack (incineration), consumers express concerns because of dioxin production which has an impact on human health.
Expert	Packaging solutions with low environmental impact (in favour biodegradable - compostable but also in favour of recycling because recycling limits environmental impact according to LCA criteria.
Expert	LCA results are not in favour of biodegradable materials (recycling of the matter is favoured).
Expert	Compostable materials produce high environmental impact.
Expert	In France, recyclable materials benefit from eco-tax bonus.
Expert	A European directive forbids burying in the horizon of 2020.
Expert	Compostable material has no value if there is no chain of collection, sorting and industrial composting.
Expert	In France, only PET and PE made bottles and cans containers are actually recycled. Other types of containers are not recyclable.
Industry	No recycling chain for multi-layered packaging is available.
Researcher	Biodegradable materials could encourage people to throw their packaging in nature, causing visual pollution.
Researcher	Compostable materials produce visual pollution.
Researcher	In France, burying (landfill) is encouraged (because of low cost) therefore it won't last because it is not sustainable.
Researcher	Visual pollution of packaging could not be the worst effect. Knowledge on the toxicity impact of micro and nanoparticles of partially degraded plastic is needed (potentially negative impact on health if high concentration of nanoparticles).
Researcher	The use of PLA leads to a penalty on eco-tax Eco-Packaging.
Researcher	The bio-polyesters (compostable) as PLA are disturbing of PET recycling (non-organic polyester).

Waste Management	In France, numerous waste management facilities are available (incineration, burying, composting organic waste, methane production or Anaerobic digestion) which encourages biodegradable materials.
Waste Management	In France, numerous waste management facilities are available (incineration, burying, composting organic waste, methane production or Anaerobic digestion) which encourages compostable materials.
Waste Management	Biodegradable materials may disturb the sorting of recyclable packagings. For example PLA material disturbs the PET recycling.
Waste Management	Compostable materials may disturb the sorting of recyclable packagings. For example PLA material disturbs the PET recycling.
Waste Management	In France, burying is encouraged (low cost around 80 euros per ton).
Waste Management	In France, Composting is not encouraged (high treatment cost around 130 euros per ton).
Waste Management	Incineration (other pack) permits to produce energy.

1056 **A Lists of text arguments collected and frag-**
1057 **ments of the obtained formal arguments for**
1058 **each country**

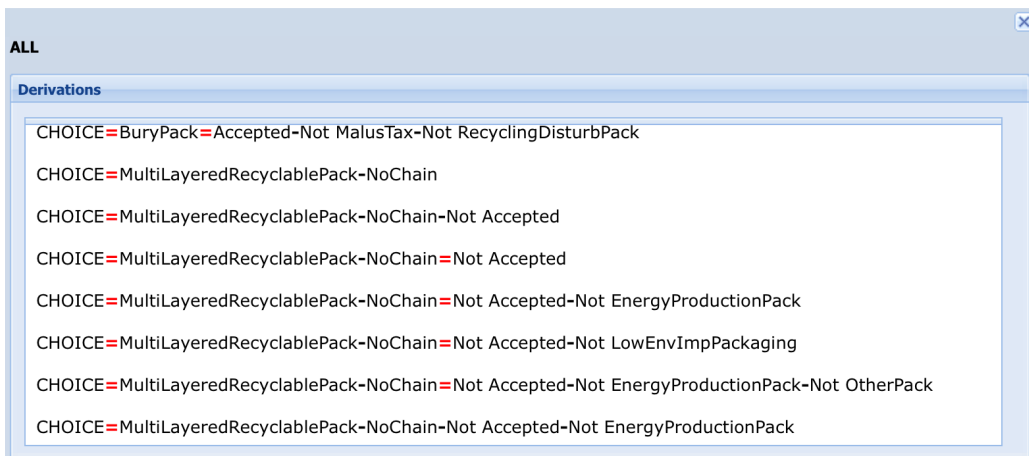


Figure 15: A fragment of formalized rules and obtained attacks in the case of France (approximated model).

Table 4: Text Arguments collected for Hungary.

Stakeholder	Argument
Consumer	Consumers are in favour of biodegradable material because they help to protect the environment.
Consumer	Consumers are in favour of compostable material because they help to protect the environment.
Consumer	Consumers are not in favour of recyclable packaging because associated taxes are too high.
Expert	Packaging solutions with low environmental impact (in favour biodegradable - compostable but also in favour of recycling because recycling limits environmental impact according to LCA criteria).
Expert	LCA results are not in favour of biodegradable materials (recycling is favoured).
Expert	Compostable materials produce high environmental impact.
Expert	Biodegradable packaging are not well familiarized by the food manufacturer (until now only 1-2 suppliers entered into the Hungarian market), but in the closely future, the companies would like to use the biodegradable packaging as an effective marketing tool.
Researcher	Biodegradable materials could encourage people to throw their packaging in nature, causing visual pollution.
Researcher	Compostable materials produce visual pollution.

1059 Figures 15, 16, 17 and 18 display fragments of formal arguments derived from
1060 the formalized choices and concepts, in the case of France, Hungary, Italy
1061 and Sweden respectively. The red symbol “=” connecting concepts means
1062 that the rule used is defeasible and the black symbol “-” means that the rule
1063 used is formalized as strict. The user can access to this view by clicking on
1064 the button “Show Derivations” in the main interface of the tool (see Zone 3
1065 in Figure 4).

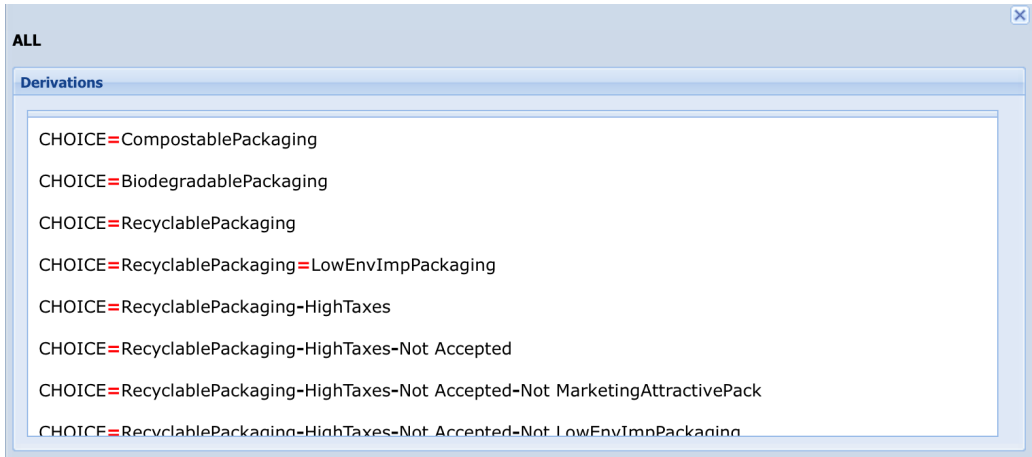


Figure 16: A fragment of formalized rules and obtained attacks in the case of Hungary.

Table 5: Text Arguments collected for Italy.

Stakeholder	Argument
Consumer	Consumers are in favour of biodegradable material because they help to protect the environment.
Consumer	Consumers are in favour of compostable material because they help to protect the environment.
Consumer	Consumers are not in favour of recyclable packaging because associated taxes are too high.
Expert	Packaging solutions with low environmental impact (in favour biodegradable - compostable but also in favour of recycling because recycling limits environmental impact according to LCA criteria).
Expert	LCA results are not in favour of biodegradable materials (recycling is favoured).
Expert	Compostable materials produce high environmental impact.
Researcher	Biodegradable materials could encourage people to throw their packaging in nature, causing visual pollution.
Researcher	Compostable materials produce visual pollution.

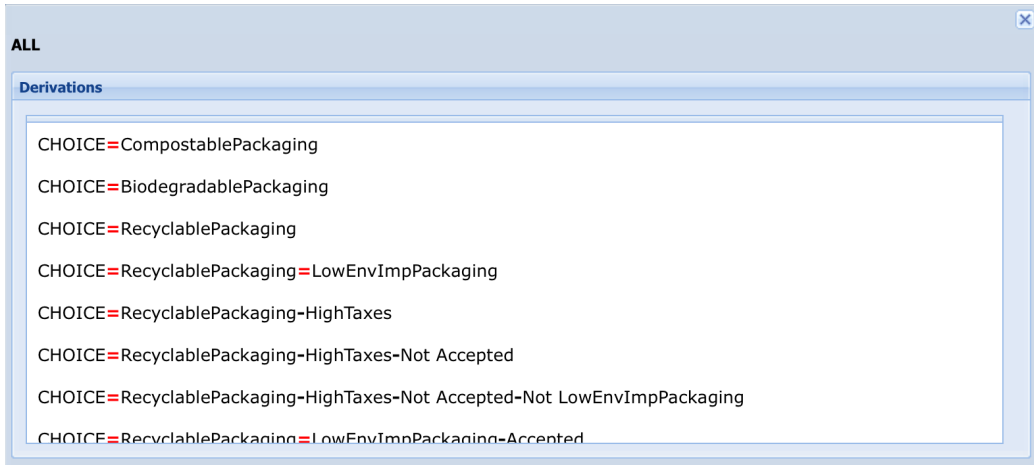


Figure 17: A fragment of formalized rules and obtained attacks in the case of Italy.

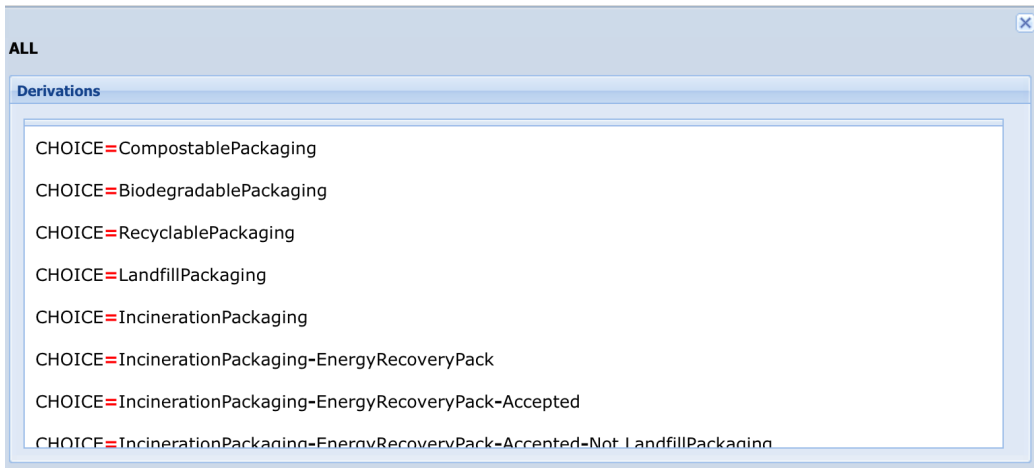


Figure 18: A fragment of formalized rules and obtained attacks in the case of Sweden.

Table 6: Text Arguments collected for Sweden.

Stakeholder	Argument
Consumer	Consumers are in favour of biodegradable material because they help to protect the environment.
Consumer	Consumers are in favour of compostable material because they help to protect the environment.
Consumer	Consumers are not in favour of recyclable packaging because associated taxes are too high.
Expert	Packaging solutions with low environmental impact (in favour of biodegradable - compostable but also in favour of recycling because recycling limits environmental impact according to LCA criteria).
Expert	LCA results are not in favour of biodegradable materials (recycling is favoured).
Expert	Compostable materials produce high environmental impact.
Expert	Landfill (or any waste) is not allowed.
Expert	Waste incineration with energy recovery is important for many cities in Sweden (district heat, for heating houses).
Expert	For Biodegradable: Anaerobic digestion plants (with organic waste) for bio-gas production are present and well developed in many Swedish cities.
Expert	For Compostable packaging: Anaerobic digestion plants (with organic waste) for bio-gas production are present and well developed in many Swedish cities.
Researcher	Biodegradable materials could encourage people to throw their packaging in nature, causing visual pollution.
Researcher	Compostable materials produce visual pollution.
Researcher	Food producer and consumer are obliged to put plastic, paper, glass and aluminum/metal to recycling.