Modeling Human Decision Making with Defeasible Logic Programming

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Abstract. Decision making is an active research topic in several disciplines and it can be studied in as many ways as different research areas face the problems in this field of study. In Computer Science, decision-making problems have been mainly tackled from the research field of Artificial Intelligence; and *Argumentation* has contributed with its unique strengths. In this work, following a pychological perspective we show the adequacy of Defeasible Logic Programming to model the Dictator Game by emulating the answers contained in a survey we conducted. The Dictator Game is a well-known problem belonging to the field of experimental economic studies related to human decision making. Moreover, the obtained model is simpler than other leading approaches in the area.

Keywords: Human Decision Making, Defeasible Logic Programming, Experimental Economic Studies, Dictator Game

1 Introduction

The use of argumentative reasoning for decision making is an active research field in Artificial Intelligence (AI) [1, 4, 5, 7, 9–11, 13, 14, 17, 19, 20, 24, 25]. The state of the art is vast, and the different works related to argumentation-based decision making can be organized according to different dimensions, namely: the decision problem tackled (decision under uncertainty [1, 20], multi-criteria decision [1, 5, 11, 25], single-agent [10, 11, 13, 14], multi-agent [4, 20], etc.), how eligible alternatives are conceived (marketing approach [10, 11, 13, 14], goal-based [1, 17, 20], etc.) the underlying argumentation framework (abstract [1, 7, 9], dynamic [14], concrete [5, 10, 11, 13, 25], etc.) whether decision behavior is formalized with respect to a classical decision approach [1, 10, 11, 14] or not [4, 5, 9, 25], whether the decision process needs a particular agent architecture to be embeeded in [19, 24] or not [10, 11, 13, 14], among others.

As stated in [21], it is well-known that in AI all the developed systems that concern thinking and acting, can be broadly classified depending on whether they follow a human-centered approach or a rationalist approach. The former approach measures the systems success in terms of the fidelity to *human* performance, while the latter involves measuring the systems performance against the *ideal* one, so-called *rationality*.

Several disciplines have contributed ideas and techniques to AI, and in particular, regarding decision making, we can highlight Philosophy, Sociology, Psychology and Economics. As expected, in psychological research of individuals decision making there exist several research programs based on Simon's criticism of mainstream economic models of perfect rationality (e.g., see [23]). Moreover, as stated in [6], the decision making research program in psychology was dominated by Tversky and Kahneman's approach (e.g., see [26]) empirically testing Simon's suggestions and showing that they were correct.

In this context, [4] is an interesting paper arising from the Computer Science field, where different studies from experimental economic are modeled using an argumentative framework to reproduce the qualitative decisions that humans exhibited in the studies conducted. In particular two well-known games were studied, the Dictator game [15] and the Ultimatum game [18] and results were compared with those reported by humans with different cultural background. Argument schemes were used as the underlying argumentation approach and they were instantiated with Action-based Alternating Transition Systems (AATS) [27]. Instantiating the argument scheme used in [2] and its associated critical questions, allows to obtain the set of conflicting arguments. Once this set has been produced, in order to evaluate the arguments acceptability, they are organized in a Value-based Argumentation Framework (VAF) [3].

A VAF is an extension of the standard Argumentation Framework (AF) [8]. VAFs extend AFs in that each argument in the graph is associated with the value promoted by that argument. Whereas in an AF attacks always succeed, in a VAF they succeed only if the value associated with the attacker is ranked by the audience evaluating the VAF equal to, or higher than, the argument it attacks. Unsuccessful attacks are removed, and then the resulting framework is evaluated as a standard AF. The VAF thus accounts for elements of subjectivity in that the arguments that are acceptable are dependant upon the audience's ranking of the values involved in the scenario.

Another interesting proposal, where non-rational decision making is discussed even though it is not the primary focus of the paper, is the work presented in [14]—where the proposed argumentation-based model of decision-making generalizes the classical maximum-expected utility model using a Dynamic Argumentation Framework. Apart from this, the working methodology presented in [14] also paves the way for non-rational behavior to be taken into account in decision making by using argumentation. In fact, the methodology of [14] is similar to that of [12] in the way alternatives are compared in a pairwise manner, but where the use of decision rules is needed when decisions to be made must be rational.

Therefore, by considering the approach of [12], in the paper at hand we model human decision making by using *Defeasible Logic Programming* (DeLP) [16], a formalism that combines results of Logic Programming and Defeasible Argumentation. It is worth mentioning, that in [12], the focus of the work is the combination of autonomous navigation with high-level reasoning and decision making is based on a greedy policy, by using DeLP as well. Besides this real world domain, DeLP has been used to solve other real world problems (cf. [22]). Moreover, DeLP has been succesfully used to model rational decision making [10] and showing its flexibility to model human decision making as well, makes richer its application field. In particular, in this work we will tackle the Dictator game by modeling the answers contained in a survey conducted by us.

The rest of the paper is organized as follows. Section 2 introduces DeLP, the argumentation formalism used to model the Dictador game. Then, Sect. 3, presents the formulation of this game based on DeLP. Finally, Sect. 4 disscuss the model proposed considering other related works and draws the conclusions.

2 Defeasible Logic Programming in a Nutshell

As mentioned in the introductory section, DeLP [16] is the argumentation formalism that it will be used for knowledge representation, reasoning and finally model human decision making. Besides, the literal-based criterion used to decide between conflicting arguments is also presented, since it is not the default criterion provided by the formalism.

A DeLP-program $\mathcal{P}$ is denoted (Π, Δ), where the set Π containing indisputable knowleged (facts and strict rules) is distinguished from Δ containing defeasible rules. *Facts* are ground literals representing atomic information or the negation of atomic information, by using *strong* negation ("$\sim$"). *Strict rules* are denoted $L_0 \leftarrow L_1, \ldots, L_n$ and represent firm information, whereas *defeasible rules* are denoted $L_0 \mathrel{-\!\!\prec} L_1, \ldots, L_n$ and represent tentative information. In both cases, the *head* L_0 is a literal and the *body* $\{L_i\}_{i>0}$ is a set of literals. Strict and defeasible rules are ground, however, following the usual convention, some examples will use "schematic rules" with variables. It is worth noticing that strong negation is allowed in the head of program rules, and hence may be used to represent contradictory knowledge.

In DeLP, to deal with contradictory and dynamic information, *arguments* for conflicting pieces of information are built and then compared to decide which one *prevails*. An *argument* for a literal L, denoted $\langle \mathcal{A}, L \rangle$, is a minimal set of defeasible rules $\mathcal{A} \subseteq \Delta$, such that $\mathcal{A} \cup \Pi$ is non-contradictory and there is a derivation for L from $\mathcal{A} \cup \Pi$. To establish if $\langle \mathcal{A}, L \rangle$ is a non-defeated argument, *argument rebuttals* or *counter-arguments* that could be *defeaters* for $\langle \mathcal{A}, L \rangle$ are considered, i.e. counter-arguments that by some criterion are preferred to $\langle \mathcal{A}, L \rangle$. Since counter-arguments are arguments, defeaters for them may exist, and defeaters for these defeaters, and so on. Thus, a sequence of arguments called *argumentation line* is constructed, where each argument defeats its predecessor in the line (for a detailed explanation of this dialectical process see [16]). The prevailing argument provides a warrant for the information it supports. A literal L is *warranted* from (Π, Δ) if a non-defeated argument $\mathcal{A}$ supporting L exists. Given a query Q there are four possible answers: YES, if Q is warranted; NO, if the complement of Q is warranted; UNDECIDED, if neither Q nor its complement are warranted; and UNKNOWN, if Q is not in the language of the program.

In DeLP, *generalized specificity* is used as default criterion to compare conflicting arguments, but an advantageous feature of DeLP is that the comparison criterion among arguments can be replaced in a modular way. Therefore, in our proposal, we use an appropriate literal-based criterion—that was originally proposed in [10]. In a program $\mathcal{P}$, a subset of literals *comp-lits*$(\mathcal{P}) \subseteq \Pi$ called *comparison literals* will be distinguished. This set of comparison literals will be used by the comparison criterion defined below.

Definition 1 (L-order). *Let $\mathcal{P}$ be a DeLP-program and comp-lits$(\mathcal{P})$ be the set of comparison literals in $\mathcal{P}$. An* L-order *over $\mathcal{P}$ is a partial order over the elements of comp-lits$(\mathcal{P})$.*

An L-order must be provided as a set of facts within the program. These facts are written as $L_1 > L_2$, stating that a literal L_1 is preferred to a literal L_2, and they will be used to decide when an argument is better than another. Based on a given L-order, the following argument comparison criterion can be defined.

Definition 2 (Literal-based comparison criterion). *Let $\mathcal{P} = (\Pi,\Delta)$ be a DeLP-program and let "$>$" be an L-order over $\mathcal{P}$. Given two argument structures $\langle \mathcal{A}_1, h_1 \rangle$ and $\langle \mathcal{A}_2, h_2 \rangle$, the argument $\langle \mathcal{A}_1, h_1 \rangle$ will be preferred over $\langle \mathcal{A}_2, h_2 \rangle$ iff:*

1. *there are two literals L_1 and L_2 such that $L_1 \in^* \mathcal{A}_1$, $L_2 \in^* \mathcal{A}_2$, $L_1 > L_2$, and*
2. *there are no literals L'_1 and L'_2 such that $L'_1 \in^* \mathcal{A}_1$, $L'_2 \in^* \mathcal{A}_2$, and $L'_2 > L'_1$.*

Notation: *$L \in^* \mathcal{A}$ iff there exists a defeasible rule $(L_0 \prec L_1, L_2, \ldots, L_n)$ in $\mathcal{A}$ and $L = L_i$ for some i $(0 \leq i \leq n)$.*

3 Modeling the Dictator Game

In this section we show how DeLP can be used to model the Dictator Game [15]. We begin by considering the problem formulation. Following the problem statement from [4], we will consider the same limited number of options that comprise the set of alternatives (actions) $\mathbf{A}$ and we assume 1000 units of money to be divided. The set $\mathbf{A}$ thus comprises the following five actions corresponding to different divisions of the money, namely: $\mathbf{a_1} = give(70\%)$, $\mathbf{a_2} = give(100\%)$, $\mathbf{a_3} = give(50\%)$, $\mathbf{a_4} = give(0\%)$ and $\mathbf{a_5} = give(30\%)$. The dictator starts having the whole money and the "motivations" to share it that we have considered are mentioned below:

Money: Most obvious is money's value. This is what the economic man is supposed to maximize. Given that we need to recognize that the other player having money may be considered positively by the dictator, we need to distinguish money for the dictator himself from money for the other.

Giving: It can be held that giving a gift is a source of pleasure, and this is what motivates the dictator to share.

Image: Another consideration is the desire not to appear mean before the experimenter that motivates sharing. It could even be that one does not want to appear mean to oneself.

Equality: Equality, as defined by an equal distribution, characterizes a sense of fairness.

In our model, these motivations are used as the criteria to compare the alternatives among each other. Some of these motivations establish well-defined preference orderings among the alternatives; for example, the money the dictator has for himself that will be represented by the comparison literal ms, clearly produces the following ordering among the alternatives: $a_4 \prec a_5 \prec a_3 \prec a_1 \prec a_2$—where $a_i \prec a_j$ denotes that action a_i is preferred to a_j. Conversely, "the money for the other" motivation (mo) generates a mirror-like ordering of the alternatives: $a_2 \prec a_1 \prec a_3 \prec a_5 \prec a_4$.

The remaining motivations can be considered more subjectives and different orderings can be obtained depending on the individuals' personality and cultural background. In this context, one possible ordering of all the alternatives according to these motivations is the one presented in Table 1, as facts that belong to set Π of the DeLP-program that will be used to model the game. It is worth noticing that this table contains more information than the ordering itself. The particular ordering we refer is represented as black-colored comparison literals (factual information) while the references to arguments names in other colors will be discussed later. We can see for example, in the first two columns of the table –in a pairwise comparison manner– the two above-mentioned orderings regarding ms and mo motivations.

Having as a guideline the working methodology of previous works [10, 12, 14] which have used a literal-based comparison criterion for arguments, we have built the set Δ of our DeLP-program as shown below in Fig. 1(a). Besides, the L-order of the comparison literals is presented in Fig. 1(b). This L-order states that the preferences on the motivations used as criteria are the following: $giv \prec mo \prec ms \prec im \prec eq$—and it was obtained from the survey we conducted to carried out this reasearch.

Our survey is composed by 276 samples, i.e. 276 different people that played the Dictador game. They are mainly students of the National University of San Luis but also 2.9% of the people are employed in the private industry and 3.3% work in the public sector. Considering their origin, 84% were born in the capital of San Luis and the remaining 16% were born in 19 different cities from San Luis province and other provinces from Argentina. All the people live in San Luis at present. Ages ranged from 17 to 54 years old, with an approximate mean of 22 years old. Regarding educational level, 96% of the participants have completed secondary education and only 4% have completed a tertiary level. When gender is considered, 73% of the samples correspond to female individuals and 27% to male individuals. Finally, it is worth mentioning that 93% of the people do not have children, while the remaining 7% do.

The answers obtained from the survey reported that 66.67% of people chose $\mathbf{a_3} = give(50\%)$, 10.87% chose $\mathbf{a_2} = give(100\%)$, 9.78% chose $\mathbf{a_4} = give(0\%)$,

Table 1. Factual information stating how alternatives are deemed considering the comparison literals.

$ms(a_4, a_1)$	$\mathcal{A}_{1}$ $\mathcal{A}_{2}$	$mo(a_2, a_1)$	$\mathcal{A}_{21}$ $\mathcal{A}_{22}$	$giv(a_3, a_4)$	$\mathcal{A}_{41}$ $\mathcal{A}_{42}$	$im(a_1, a_4)$	$\mathcal{A}_{61}$ $\mathcal{A}_{62}$	$eq(a_3, a_1)$	$\mathcal{A}_{81}$ $\mathcal{A}_{82}$
$ms(a_4, a_2)$	$\mathcal{A}_{3}$ $\mathcal{A}_{4}$	$mo(a_2, a_3)$	$\mathcal{A}_{23}$ $\mathcal{A}_{24}$	$giv(a_3, a_5)$	$\mathcal{A}_{43}$ $\mathcal{A}_{44}$	$im(a_2, a_4)$	$\mathcal{A}_{63}$ $\mathcal{A}_{64}$	$eq(a_3, a_2)$	$\mathcal{A}_{83}$ $\mathcal{A}_{84}$
$ms(a_4, a_3)$	$\mathcal{A}_{5}$ $\mathcal{A}_{6}$	$mo(a_2, a_4)$	$\mathcal{A}_{25}$ $\mathcal{A}_{26}$	$giv(a_3, a_2)$	$\mathcal{A}_{45}$ $\mathcal{A}_{46}$	$im(a_3, a_4)$	$\mathcal{A}_{65}$ $\mathcal{A}_{66}$	$eq(a_3, a_4)$	$\mathcal{A}_{85}$ $\mathcal{A}_{86}$
$ms(a_4, a_5)$	$\mathcal{A}_{7}$ $\mathcal{A}_{8}$	$mo(a_2, a_5)$	$\mathcal{A}_{27}$ $\mathcal{A}_{28}$	$giv(a_3, a_1)$	$\mathcal{A}_{47}$ $\mathcal{A}_{48}$	$im(a_5, a_4)$	$\mathcal{A}_{67}$ $\mathcal{A}_{68}$	$eq(a_3, a_5)$	$\mathcal{A}_{87}$ $\mathcal{A}_{88}$
$ms(a_5, a_3)$	$\mathcal{A}_{9}$ $\mathcal{A}_{10}$	$mo(a_1, a_3)$	$\mathcal{A}_{29}$ $\mathcal{A}_{30}$	$giv(a_5, a_4)$	$\mathcal{A}_{49}$ $\mathcal{A}_{50}$	$im(a_2, a_1)$	$\mathcal{A}_{69}$ $\mathcal{A}_{70}$	$eq(a_5, a_4)$	$\mathcal{A}_{89}$ $\mathcal{A}_{90}$
$ms(a_5, a_2)$	$\mathcal{A}_{11}$ $\mathcal{A}_{12}$	$mo(a_1, a_4)$	$\mathcal{A}_{31}$ $\mathcal{A}_{32}$	$giv(a_5, a_2)$	$\mathcal{A}_{51}$ $\mathcal{A}_{52}$	$im(a_2, a_3)$	$\mathcal{A}_{71}$ $\mathcal{A}_{72}$	$eq(a_5, a_2)$	$\mathcal{A}_{91}$ $\mathcal{A}_{92}$
$ms(a_5, a_1)$	$\mathcal{A}_{13}$ $\mathcal{A}_{14}$	$mo(a_1, a_5)$	$\mathcal{A}_{33}$ $\mathcal{A}_{34}$	$giv(a_5, a_1)$	$\mathcal{A}_{53}$ $\mathcal{A}_{54}$	$im(a_2, a_5)$	$\mathcal{A}_{73}$ $\mathcal{A}_{74}$	$eq(a_1, a_2)$	$\mathcal{A}_{93}$ $\mathcal{A}_{94}$
$ms(a_3, a_1)$	$\mathcal{A}_{15}$ $\mathcal{A}_{16}$	$mo(a_3, a_4)$	$\mathcal{A}_{35}$ $\mathcal{A}_{36}$	$giv(a_4, a_1)$	$\mathcal{A}_{55}$ $\mathcal{A}_{56}$	$im(a_1, a_3)$	$\mathcal{A}_{75}$ $\mathcal{A}_{76}$		
$ms(a_3, a_2)$	$\mathcal{A}_{17}$ $\mathcal{A}_{18}$	$mo(a_3, a_5)$	$\mathcal{A}_{37}$ $\mathcal{A}_{38}$	$giv(a_4, a_2)$	$\mathcal{A}_{57}$ $\mathcal{A}_{58}$	$im(a_1, a_5)$	$\mathcal{A}_{77}$ $\mathcal{A}_{78}$		
$ms(a_1, a_2)$	$\mathcal{A}_{19}$ $\mathcal{A}_{20}$	$mo(a_5, a_4)$	$\mathcal{A}_{39}$ $\mathcal{A}_{40}$	$giv(a_1, a_2)$	$\mathcal{A}_{59}$ $\mathcal{A}_{60}$	$im(a_3, a_5)$	$\mathcal{A}_{79}$ $\mathcal{A}_{80}$		

9.42% chose $\mathbf{a_5} = give(30\%)$ and 3.26% chose $\mathbf{a_1} = give(70\%)$. It is beyond the scope of our present study to analyze the possible reasons of these behaviors, but as mentioned above, this ordering of the alternatives resulted in the L-order presented in Fig. 1(b). This is due to the fact that having this L-order, our DeLP-program has the same choice behavior than the one observed in our survey. As expected, different answer would produce different L-orders so that the DeLP-program can perform a choice behavior conformant to the survey.

As mentioned above, Table 1 contains factual information where actions are compared in a pairwise manner considering the motivations to share the money that the dictador has. These facts were stated considering the rules of the game and our understanding of some elements of subjectivity—like for instance, if giving more than half of the money is a source of pleasure for the dictator. In our view it is not, and that is why facts like $giv(a_2, a_1)$, $giv(a_2, a_3)$, $giv(a_2, a_4)$, $giv(a_2, a_5)$, $giv(a_1, a_3)$, $giv(a_1, a_4)$, $giv(a_1, a_5)$ and $giv(a_5, a_4)$, were not included in Π. In this way, taking into account the factual information present in Π about the comparison literal giv where alternative $\mathbf{a_3}$ is deemed better than the other ones when compared among each other, provided us a firm reason to set this comparison literal in the first place of the L-order.

Then mo was placed second in the L-order given its direct relation with the fact that $\mathbf{a_2}$ was the second action chosen in the survey. Following a similar pattern of reasoning ms was placed third given its relation with $\mathbf{a_4}$. First and second columns of Table 1 show the facts encoding the alternatives orderings according

(1) $better(X,Y) \prec ms(X,Y)$	
(2) $\sim better(Y,X) \prec ms(X,Y)$	$giv(Z,W) > ms(W,Z)$
(3) $better(X,Y) \prec mo(X,Y)$	$giv(Z,W) > mo(W,Z)$
(4) $\sim better(Y,X) \prec mo(X,Y)$	$giv(Z,W) > im(W,Z)$
(5) $better(X,Y) \prec giv(X,Y)$	$giv(Z,W) > eq(W,Z)$
(6) $\sim better(Y,X) \prec giv(X,Y)$	$mo(Z,W) > ms(W,Z)$
(7) $better(X,Y) \prec im(X,Y)$	$mo(Z,W) > im(W,Z)$
(8) $\sim better(Y,X) \prec im(X,Y)$	$mo(Z,W) > eq(W,Z)$
(9) $better(X,Y) \prec eq(X,Y)$	$ms(Z,W) > im(W,Z)$
(10) $\sim better(Y,X) \prec eq(X,Y)$	$ms(Z,W) > eq(W,Z)$
	$im(Z,W) > eq(W,Z)$
(11) $choose(X) \prec better(X,Y)$	
(12) $\sim choose(X) \prec better(Y,X)$	
(a)	(b)

Fig. 1. (a) Set Δ containing the rules to compare the alternatives among each other and choosing the final alternative. (b) L-order over the comparison literals.

to these criteria, where as aforesaid, they are objective. Finally, comparison literals *im* and *eq* which are also subjectives were placed fourth and fifth in the L-order, respectively—*im* was placed before than *eq*, given that all the actions can be compared against each other with this criterion and with *eq* cannot.

In this way, with an L-order defined, based on the factual information presented in Table 1 and through the application of the defeasible rules in Fig. 1(a) aiming at comparing the alternatives, 94 arguments can be built supporting whether an action $\mathbf{a_i}$ is better or not than another action $\mathbf{a_j}$. For example, in Fig. 2(b), ten arguments are shown and they were built using rule (5) from Fig. 1(a) together with the facts of third column of Table 1. The names of these arguments also appear in the top-right corner of each cell of this column indicating that they can be built from the factual information included in the cell. The same notation is used for all the cells at the table, and due to space constraints it is not possible to show all these arguments in the paper at hand.

It is worth noting that the colors each argument name has (on the top-right corner of the cell), are related to the attack graph depicted in Fig. 2(a). This so-called attack graph is not the usual attack graph from abstract argumentation frameworks; it rather is a graphical representation that we found convenient to summarize how the different arguments generated support which alternative is better than another one depending on the criterion considered. As it can be observed, the nodes correspond to the alternatives and they are differently colored as well as their outcoming arcs. The labels on the arcs represent the number of the argument by which an alternive is supported better than another one. For instance, number 55 labels the arc from $\mathbf{a_4}$ to $\mathbf{a_1}$, and its corresponding argument $\mathcal{A}_{55}$ can be observed in Fig. 2(b). But also, argument $\mathcal{A}_1$ –colored in violet in Table 1– supports that action $\mathbf{a_4}$ is better than $\mathbf{a_1}$ by means of rule (1) (cf. Fig. 1(a)). Besides, all the arguments names colored in gray which appear on

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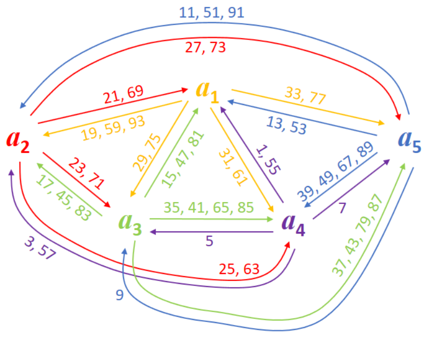

(a)

$$\begin{aligned}
\mathcal{A}_{41} &= \{better(a_3, a_4) \multimap giv(a_3, a_4)\} \\
\mathcal{A}_{43} &= \{better(a_3, a_5) \multimap giv(a_3, a_5)\} \\
\mathcal{A}_{45} &= \{better(a_3, a_2) \multimap giv(a_3, a_2)\} \\
\mathcal{A}_{47} &= \{better(a_3, a_1) \multimap giv(a_3, a_1)\} \\
\mathcal{A}_{49} &= \{better(a_5, a_4) \multimap giv(a_5, a_4)\} \\
\mathcal{A}_{51} &= \{better(a_5, a_2) \multimap giv(a_5, a_2)\} \\
\mathcal{A}_{53} &= \{better(a_5, a_1) \multimap giv(a_5, a_1)\} \\
\mathcal{A}_{55} &= \{better(a_4, a_1) \multimap giv(a_4, a_1)\} \\
\mathcal{A}_{57} &= \{better(a_4, a_2) \multimap giv(a_4, a_2)\} \\
\mathcal{A}_{59} &= \{better(a_1, a_2) \multimap giv(a_1, a_2)\}
\end{aligned}$$

(b)

Fig. 2. (a) Attack graph relating the alternatives and the different arguments supporting their comparison. (b) Subset of arguments supporting the comparison of different alternatives based on the comparison literal *giv*.

the bottom-right corner of each cell of Table 1, correspond to the complementary arguments that can be obtained with the fact in the cell together with one of the defeasible rules having the literal $\sim better(Y, X)$ in their heads—and that were not included in the graphical representation of Fig. 2(a).

So far, all the arguments considered aim at comparing the actions among each other, and the following literals are warranted: $bt(a_1, a_2)$, $\sim bt(a_2, a_1)$, $bt(a_3, a_1)$, $\sim bt(a_1, a_3)$, $bt(a_3, a_2)$, $\sim bt(a_2, a_3)$, $bt(a_3, a_4)$, $\sim bt(a_4, a_3)$, $bt(a_3, a_5)$, $\sim bt(a_5, a_3)$, $bt(a_4, a_1)$, $\sim bt(a_1, a_4)$, $bt(a_4, a_2)$, $\sim bt(a_2, a_4)$, $bt(a_5, a_1)$, $\sim bt(a_1, a_5)$, $bt(a_5, a_2)$, $\sim bt(a_2, a_5)$, $bt(a_5, a_4)$ and $\sim bt(a_4, a_5)$. We have abbreviated literal *better* as *bt* to improve the sentence reading. These literals can be used together with rules (11) and (12) (cf. Fig. 1(a)) to build arguments supporting which action must be chosen.

Given that action $\mathbf{a_3}$ is deemed better than the other alternatives based on the most preferred comparison literal (*giv*), by using rule (12), three arguments supporting $\sim choose(a_1)$, $\sim choose(a_4)$ and $\sim choose(a_5)$ can be built. These arguments will act as blocking defeaters for the arguments that can be built supporting $choose(a_1)$, $choose(a_4)$ and $choose(a_5)$, respectively. Because all of them are based on comparison literal *giv*, considering the comparison criterion used (cf. Definition 2) the answer of the DeLP interpreter is UNDECIDED. Conversely, the arguments built –by means of rule (11)– that support conclusion $choose(a_3)$ cannot be defeated and hence $choose(a_3)$ is warranted, and the answer of the DeLP interpreter is YES—coinciding with the most chosen action in the survey.

4 Conclusions

In this paper we have given an account of argumentation-based decision making in a simple scenario from experimental economics, like the Dictator game. In particular, DeLP was used to model human choice behavior from a survey we conducted. The obtained program was simple and there was no need to use the decision device called *decision rules*; a device widely used in previous works [10, 11, 14] where rational decision making was pursued rather than human decision making. Besides, regarding the DeLP-program used in [12], the current proposal is also more concise since only two rules of the form $choose(X) \multimap better(X, Y)$ and $\sim choose(X) \multimap better(Y, X)$, were needed to decide the final action to be chosen. Naturally, if the answers in the survey had been different, we could have had to resort to add more rules for choosing alternatives or even using decision rules despite not being modeling a rational decision behavior.

Regarding the leading work presented in [4], our proposal is simpler since all the modeling is performend within DeLP instead of performing a two-stage process to instantiate an argument scheme with an AATS to obtain the set of conflicting arguments and then building a VAF in order to evaluate the arguments acceptability. With this work, we aimed at showing the flexibility that DeLP has to model different decision making scenarios and not necessarily those strictly related to rational decisions thus making richer its application field.

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References

1. Amgoud, L., Prade, H.: Using arguments for making and explaining decisions. Artificial Intelligence 173(3-4), 413–436 (2009)
2. Atkinson, K., Bench-Capon, T., McBurney, P.: Computational representation of practical argument. Synthese 152(2), 157–206 (2006)
3. Bench-Capon, T.: Persuasion in practical argument using value-based argumentation frameworks. Journal of Logic and Computation 13(3), 429–448 (June 2003)
4. Bench-Capon, T., Atkinson, K., McBurney, P.: Using argumentation to model agent decision making in economic experiments. Autonomous Agents and Multi-Agent Systems 25(1), 183–208 (2011)
5. Buron Brarda, M., Tamargo, L.H., García, A.J.: An approach to enhance argument-based multi-criteria decision systems with conditional preferences and explainable answers. Expert Systems with Applications 126, 171–186 (2019)
6. Campitelli, G., Gobet, F.: Herbert simon's decision-making approach: Investigation of cognitive processes in experts. Review of General Psychology 14(4), 354 (2010)
7. Carstens, L., Fan, X., Gao, Y., Toni, F.: Graph Structures for Knowledge Representation and Reasoning: 4th International Workshop, GKR 2015, Revised Selected Papers, chap. An Overview of Argumentation Frameworks for Decision Support, pp. 32–49. Springer (2015)
8. Dung, P.M.: On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games. Artificial Intelligence 77(2), 321–358 (1995)
9. Fan, X., Toni, F.: Theory and Applications of Formal Argumentation: Second International Workshop, TAFA 2013, Revised Selected papers, chap. Decision Making with Assumption-Based Argumentation, pp. 127–142. Springer (2014)

10. Ferretti, E., Errecalde, M., García, A., Simari, G.: Decision rules and arguments in defeasible decision making. In: 2nd International Conference on Computational Models of Arguments (COMMA). pp. 171–182. IOS Press (2008)
11. Ferretti, E., Errecalde, M., García, A., Simari, G.: A possibilistic defeasible logic programming approach to argumentation-based decision-making. Journal of Experimental & Theoretical Artificial Intelligence 26(4), 519–550 (2014)
12. Ferretti, E., Kiessling, R., Silnik, A., Petrino, R., Errecalde, M.: New Trends in Electrical Engineering Automatic Control, Computing and Communication Sciences, chap. Integrating vision-based motion planning and defeasible decision making for differential-wheeled robots: A case of study with the Khepera 2 robot. LOGOS Verlag, Berlin, Germany (2010)
13. Ferretti, E., Errecalde, M.: Argumentation-Based Proofs of Endearment: Essays in Honor of Guillermo R. Simari on the Occasion of His 70th Birthday, chap. A P-DeLP Instantiation of a Dynamic Argumentation Framework for Decision Making. College Publications, England (2018)
14. Ferretti, E., Tamargo, L.H., García, A.J., Errecalde, M.L., Simari, G.R.: An approach to decision making based on dynamic argumentation systems. Artificial Intelligence 242, 107 – 131 (2017)
15. Forsythe, R., Horowitz, J.L., Savin, N.E., Sefton, M.: Fairness in simple bargaining experiments. Games and Economic Behavior 6(3), 347–369 (1994)
16. García, A., Simari, G.: Defeasible logic programming: An argumentative approach. Theory and Practice of Logic Programming 4(1-2), 95–138 (2004)
17. Matt, P., Toni, F., Vaccari, J.R.: Argumentation in Multi-Agent Systems: 6th International Workshop, ArgMAS 2009. Revised Selected and Invited Papers, chap. Dominant Decisions by Argumentation Agents, pp. 42–59. Springer (2010)
18. Nowak, M.A., Page, K.M., Sigmund, K.: Fairness versus reason in the ultimatum game. Science 289, 1773–1775 (2000)
19. de Oliveira Gabriel, V., Panisson, A.R., Bordini, R.H., Adamatti, D.F., Billa, C.Z.: Reasoning in bdi agents using toulmin's argumentation model. Theoretical Computer Science 805, 76–91 (2020)
20. Rieke, R.D., Sillars, M.O., Peterson, T.R.: Argumentation and Critical Decision Making. Pearson, 8th edn. (2012)
21. Russell, S., Norvig, P.: Artificial Intelligence: A Modern Approach. Prentice Hall, 3 edn. (2010)
22. Schlesinger, F., Ferretti, E., Errecalde, M., Aguirre, G.: An Argumentation-based BDI Personal Assistant. In: 23rd International Conference on Industrial, Engineering and Other Applications of Applied Intelligent Systems (IEA-AIE) (2010)
23. Simon, H.A.: A behavioral model of rational choice. The Quarterly Journal of Economics 69(1), 99–118 (1955)
24. Sosa Toranzo, C., Ferretti, E., Errecalde, M.: Intention Reconsideration like Dichotomous Choice: an Argumentation-based Approach. In: XLIII Latin American Computer Conference (CLEI). IEEE, Córdoba, Argentina (September 2017)
25. Teze, J.C., Gottifredi, S., García, A.J., Simari, G.R.: An approach to generalizing the handling of preferences in argumentation-based decision-making systems. Knowledge-Based Systems 189, 105–112 (2020)
26. Tversky, A., Kahneman, D.: Rational choice and the framing of decisions. Journal of Business 59(4) (1986)
27. Wooldridge, M., van der Hoek, W.: On obligations and normative ability: Towards a logical analysis of the social contract. Journal of Applied Logic 3, 396–420 (2005)