Modelling Argumentation with Belief Networks

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Abstract. We present a probabilistic framework in the logic of counterarguments which may be useful to create a computational model of arguments in natural language.

1 INTRODUCTION

An appropriate knowledge representation is a good starting point for simplifying the solution of AI problems. In this paper, we advocate for the use of belief networks as a formalism for representing argumentation exchanges. Although we will now consider only their use in simulating the reasoning process (evaluation of argumentation strategies and recover after undermining attempts), it is our future plan to show also their properties in favoring automatic generation of messages.
We start from some example sentences in the healthy eating domain, to analyze them in the light of Walton's argumentation schemas [15]:

1. *"The FDA Agency in the UK, which is an expert in healthful living, says that eating vegetables is a form of healthy eating: so, this should be taken as true. "*
2. *"You should eat more vegetables, because eating vegetables contributes to maintaining good health."*
3. *"You don't smoke and participate in sport. So, you wish to have a good appearance".*

1 is a typical example of argumentation *From Expert Opinion*:

- **MAJOR PREMISE**: E is an expert in domain D
- **MINOR PREMISE**: E asserts that A is known to be true (false)
- **MINOR PREMISE**: A is within D
- **CONCLUSION**: A may plausibly be taken to be true (false)

2 is an example of argumentation *From Positive Consequence*:

- **PREMISE**: If A is brought about, then good consequences will (may plausibly) occur.
- **CONCLUSION**: A should be brought about

3 is an example of argumentation *From Sign* :

- **PREMISE**: A is true in this situation
- **PREMISE**: Event B is generally indicated as true when its sign, A, is true in this kind of situation
- **CONCLUSION**: B is true in this situation

Arguments based on these schemas need not to be conclusive but can be defeasible: whether they justify their conclusion depends on the counterarguments available at a certain stage of the argumentation process [14]. For instance, the strength of argument 2 depends on the strength of the likelihood that the cited consequences will (may, must, etc.) occur, on what evidence supports this claim and on whether there are consequences of the opposite value that should be taken into account [15]. An argumentation schema comes with a set of critical questions (CQs). For instance, the following are CQs in the *From Expert Opinion schema* [15]:

a *Is E a genuine expert in D?*
b *Is A within domain D?*
c *Did E really assert that A is known to be true?*
d *Did Expert E make a mistake?*
e *Is A relevant to domain D?*
f *Is A consistent with what other experts in D say?*
g *Is A consistent with known evidence in D?*

CQs are *information-seeking questions that inquire about the conditions or circumstances that tend to rebut inferences using that schema* [1]. They may play different roles:

- criticizing a schema's premises (as in a, b and c):
  4. *"Is FDA Agency a genuine expert in the domain of healthful living?"*
- point to exceptional situations in which the schema should not be used (as in d):
  5. *"Did the FDA Agency make a mistake?"*
- criticizing the condition for a schema's use, as in e:
  6. *"Is eating vegetables relevant to the domain of healthful living?"*
- point to other possible arguments relevant for the schema conclusion (as in f-g).

CQs specify potential arguments against the schema's use: a precondition for using a schema is that its premises are true, well supported and justified. For instance, an argument built upon CQ 4 may be used to contradict argument 1:

7. *"It is not true that the FDA Agency is a genuine expert in the domain of healthful living"*

In natural conversation, elementary arguments are instances of a schema while complex arguments are chains of instances of one or more schemas. In complex arguments, a premise of a schema can occur as a conclusion in another: this enables verifying if a CQ is satisfied. For instance, to answer CQ 4, premises for the conclusion *"FDA Agency is a genuine expert in the domain of healthful living"* may be investigated. According to a common definition of *'expert'*, if:

8. *"FDA is a credible information source in the domain of healthful living"* and
9. *"FDA is a trustful source in the domain of healthful living"* then
10. *"FDA Agency is a genuine expert in the domain of healthful living".*

The chaining process enables constructing arguments pro o cons premises, starting from CQs:

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11. *"FDA is not a genuine expert in the domain of healthful living, because it is not a credible information source in this domain"*

The model we propose to handle argumentation schemas builds upon the $Araucaria$ framework [11]. $Araucaria$ supports the characterization of conclusion, premises and critical questions in argumentation schemas and allows instances of a schema to be associated with parts of an argument. To evaluate an argument, every part can be marked to indicate its evaluative strength either qualitatively or probabilistically. However, in real life arguments, the degree of belief in the conclusion depends on the degree of belief in the premises and on the way premises affect the conclusion in a given situation. When an argument is built in a dynamic and goal-directed conversation, as in real life, a model is needed in which premises are plausible evidences rather than true or false facts and the argumentation process is non-monotonic. In the model we propose, argumentation is an asymmetric process during which arguments are presented and counterarguments are putted forward and the arguments employed are defeasible (using Verheij's terminology). Consequently, whether an argument no longer justifies its conclusion depends on three factors: (i) the structure of the argument; (ii) the strength of counterarguments and (iii) the argumentation stage. Counterarguments involve conditions of exceptions for an argument (rebuttals R, in Toulmin's terminology or a kind of CQs in Walton's framework), but can have several functions: Verheij [14] distinguishes among *defeating (or rebutting) the conclusion*, the *applicability of the warrant* and the *authority of the warrant*, in a way that fits all the elements of Toulmin's schema. The argumentation stage represents the arguments and the counterarguments currently under consideration and the parts of the arguments which have been accepted or rejected so far.

2 ARGUMENT STRUCTURE

We represent the structure of an argument according to Toulmin's argumentation model [13] and Bruschke's review [2]. According to Toulmin's model [13], a claim C may be supported by presenting one or more data D. These data act as variables that may be accepted in the scope of a warrant W; they are evidences supporting the claim with a given degree of strength (specified by a qualifier Q). The power of the warrant may be increased or decreased by introducing a backing of warrant B or a rebuttal R. According to Bruschke [2], the qualifier (Q) only produces a particular kind of claim. For instance, in the healthy eating domain:

12. *"You wish to have good appearance"* and
13. *"Almost certainly you wish to have good appearance"*

are two different kinds of claim: "almost certainly" does not function as a discrete part of the argument. As a consequence, the qualifier should be considered as a move in the direction of reducing the probability of the claim's truth; rebuttal can serve the same function. Given the analogy between a data and a claim, an argument consists of *several connected data/claims* [2].
A warrant may also take on the character of data/claim: in addition to connecting data and claim (as in Toulmin's model) it may be thought as *any assumption that must be true for the data to be relevant to the claim* [2]. If the warrant is a particular kind of data/claim, then the backing is a data that supports the warrant. Figure 1 shows an example of how arguments may be represented according to Bruschke's model, in our example domain:

14. *"You wish to have good appearance"* is the claim (Central datum/claim)
15. *"You don't smoke"* is the datum
16. *"Persons who do not smoke and participate in sport generally wish to have a good appearance"* is the warrant
17. *"Statistics"* is the backing

Notice that more then a single piece of data may support a higher-ordered data/claim. The more evidences there are that support a higher-ordered data/claim, the less likely appears that exceptions exist, as every evidence contributes to make the claim more likely. For instance, more data may be added in support of the claim 14: *"You participate in sport"* (as in Figure 1).

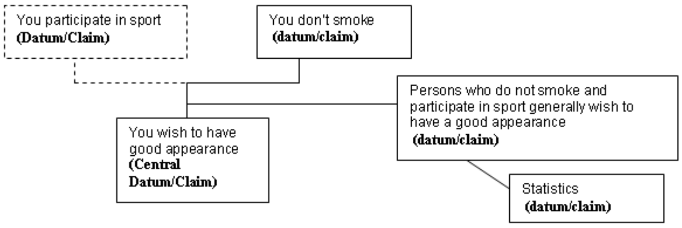

Figure 1. A simple argument in the healthy eating domain

How can we tell that an argument is a good argument? Bruschke says that an argument is good *to the extent that the claim and only the claim is supported by the data and that all relevant data have been presented* [2]. Let us consider the claim 14. In figure 1, the datum *"You don't smoke"* is certainly consistent with the claim (according the to the warrant). Notice that every evidence might make the claim more likely (e.g. *"You participate in sport"*). To test that only this claim is supported by the datum, alternative claims that explain the data may be suggested. The more claims explaining all the evidences exist, the less sound the considered claim may be believed to be. Let us imagine that also the following argument is represented:

18. *"You wish to be in good health" is the claim* (Main datum /claim)
19. *"You don't smoke "* is the datum
20. *"Persons who do not smoke generally wish to be in good health"* is the warrant

Let us assume that the arguer has only presented *"You don't smoke"*, as an evidence for the claim *"You wish to have good appearance"*. A defense might suggest an alternative claim that explains the datum: *"I wish to be in good health"*. This alternative claim is equally consistent with the evidence and weakens the original one. Of course, additional evidence to support the *"You wish to have good appearance"* claim (such as *"You participate in sport"*) would suggest the original explanation.
This reasoning schema does not necessarily apply to all claims. It is very likely that several sorts of claims which cannot be evaluated with this method exist. In the following section, different ways to defeat an argument will be presented.

3 REPRESENTING ARGUMENTS WITH BELIEF NETWORKS

In this section, we show how Belief Networks (BN) allow representing many of the factors we examined in the previous one. A BN is a graphical model whose nodes represent discrete random variables and whose arcs represent dependencies between variables in terms of conditional probabilities [9]. We enrich the semantics of belief networks to represent all the elements of Toulmin's and Walton's models, by introducing the following *node types*:

- ***Evidence Nodes*** represent domain facts to which a prior probability may be assigned; they are 'root' nodes of the network and correspond to facts that cannot be justified. For example: `Non-Smoker(U)`: *U does not smoke.*

- ***Truth Nodes*** represent domain facts whose truth value may be justified by some argumentation step. A truth node may have different kinds of parents:
  1. *Single Justification*:
     (a) only one *Warrant Node* (see the definition in the following) and
     (b) as many nodes (*evidence* or *truth nodes*) as the other premises which are needed to conclude on the current node, through the warrant.
  2. *Multiple Justifications*: as many *Proof Nodes* (see the definition in the following) as the different ways of concluding on the current node.
- ***Warrant Nodes*** represent *Warrants*. They show the relationship linking premises and conclusion in a particular application of an *argumentation schema*. Both premises and warrants are parents of the node that represents the conclusion: the link among the warrant node, other premise nodes (Evidence or Truth) and the conclusion represents the way in which specific data and conclusion are linked through the general rule expressed in the warrant.
  To show how the qualifier moves in the direction of reducing the probability of the claim's truth, we categorize the degree of belief in the warrant in three classes: $\{AlmostCertainly, VeryLikely, Likely\}$[2]. Every class affects the probability of the conclusion when all the premises are true, through the conditional probability table associated with the conclusion. Parents of warrant nodes are generally truth nodes: this enables representing *backings of warrant*. The argument 1 is represented in figure 2 and Table 1[3], in the formulation proposed by Walton.

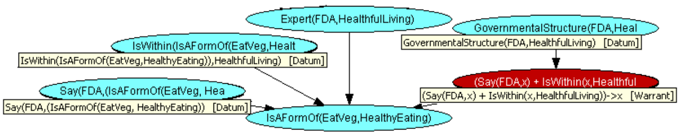

Figure 2. Argumentation Schema *From Expert Opinion* (with backing)

It includes the following *premises*:

1. `(Say(FDA,x)+Expert(FDA,x)+ IsWithin(x,HealthfulLiving))->?x` (C): *"Statements of FDA dealing with healthful living, in which they are expert, are true"*
2. `Say(FDA,(IsAFormOf(EatVeg, HealthyEating)))` (D): *"FDA says that eating vegetables is a form of healthy eating"*.
3. `Expert(FDA,HealthfulLiving)` (A): *"FDA is an expert in healthful living"*
4. `IsWithin(IsAFormOf(EatVeg,HealthyEating), HealthfulLiving)` (B): *"The statement 'eating vegetables is a form of healthy eating' deals with healthful living"*

and the *conclusion*: `IsAFormOf(EatVeg, HealthyEating)`: *"Eating vegetables is a form of healthy eating"*. The warrant is represented in item 1, while items 2, 3 and 4 are the other premises of the argumentation schema *From Expert Opinion*. The link between the warrant node and the conclusion, together with the premises 2, 3 and 4, represents the instantiated rule.

If U is convinced that *"Statements of FDA dealing with healthful living, in which they are expert, are almost certainly true"*, that *"FDA says that eating vegetables is a form of healthy eating"*, that *"FDA is an expert in healthful living"* and that *"The statement 'eating vegetables is a form of healthy eating' deals with healthful living"* and the link between premises and conclusion is defined probabilistically as shown in Table 1, then saying: *"The FDA Agency in the UK, which is an expert in healthful living, says that eating vegetables is a form of healthy eating"*, produces a *very high* level of belief in the conclusion: `P(IsAFormOf(EatVeg,HealthyEating)=.99`.

Table 1. An example of conditional probability table.

	IsAFormOf(EatVeg,HealthyEating)							
A	False							
B	False							
C	AlmCertai		VeryLikely		Likely		NotApplic	
D	False	True	False	True	False	True	False	True
False	.8	.75	.82	.8	.85	.8	.01	.01
True	.2	.25	.18	.2	.15	.2	.99	.99
A	False							
B	True							
C	AlmCertai		VeryLikely		Likely		NotApplic	
D	False	True	False	True	False	True	False	True
False	.75	.7	.8	.75	.8	.78	.99	.99
True	.25	.3	.2	.25	.2	.22	.01	.01
A	True							
B	False							
C	AlmCertai		VeryLikely		Likely		NotApplic	
D	False	True	False	True	False	True	False	True
False	.75	.7	.8	.75	.8	.78	.99	.99
True	.25	.3	.2	.25	.2	.22	.01	.01
A	True							
B	True							
C	AlmCertai		VeryLikely		Likely		NotApplic	
D	False	True	False	True	False	True	False	True
False	.65	.01	.7	.2	.75	.3	.99	.99
True	.35	.99	.3	.8	.25	.7	.01	.01

Table 1 is defined so that every premise requires the help of the others to support the conclusion (*linked arguments*, see [5]). Consequently, if any premise in such an argument is doubtful, the argument cannot establish its conclusion. However, arguments occurring in natural conversation may be characterized by a weaker conclusion, due to lack of information or uncertainty about some of the premises. If, for instance, uncertainty occurs about the warrant node, then: `P(((Say(FDA,x)+Expert(FDA,x)+ IsWithin(x,HealthfulLiving))->?x)=.333333` for the three states: `AlmostCertainly`, `VeryLikely` and

[2] However, we suspect that a more refined set of values should be involved
[3] From a preliminary sensitivity analysis of our BN, we did not find any parameter or combination of parameters, which would be responsible for significant changes in the probabilities of the output nodes.

`Likely`. In the same conditions of the previous example, the probability value associated with the conclusion then decreases from .9 to .62.

A backing of warrant may be presented to strengthen the warrant and consequently also the conclusion. Saying *"The FDA Agency in the UK, **which is declared by a governmental act as an expert in healthful living**, says that eating vegetables is a form of healthy eating"* produces a higher level of belief in the conclusion (from .62 to .88). Notice that this level of belief is quite less if it derives from certainty about a baking of warrant than if it derives from certainty about the warrant itself.

BN enable also representing argument chaining: a node may be a claim or a data, depending on the stage of the argumentation process. In Figure 3, for instance, the node `(Expert(FDA,HealthfulLiving))` may be a conclusion of the argumentation schema *From Verbal Classification* [15], which is based on the warrant `(Credible(x,y)+Honest(x,y))->? Expert(x,y)`.

Argumentation chaining allows dealing with the CQ that are aimed at criticizing a schema's premises (i.e., CQs a, b and f in the schema *From Expert Opinion*, section 1). In our formalism, CQs of this kind are already given as subnetworks concluding on the truth node that represents the premise to which CQ refers.

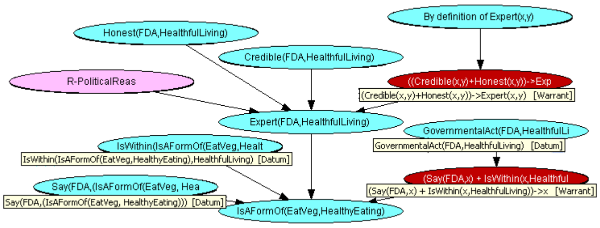

Figure 3. Argumentation Schema: *From Expert Opinion* and *From Verbal Classification*

Let us consider again the portion of belief network in figure 3. The probability of `Expert(FDA,HealthfulLiving)` being true depends on the truth value of its parents (according to the argumentation schema *From Verbal Classification*). To answer to CQ 4, premises for the conclusion `Expert(FDA,HealthfulLiving)` has to be investigated:

– ?`Credible(FDA,HealthfulLiving)`:*"Is the FDA a credible information source in the domain of healthful living?"* and

– ?`Honest(FDA,HealthfulLiving)`: *"Is FDA a trustful source in the domain of healthful living?"*

Depending on the degree of belief in these premises an on the applicability of the warrant `(Credible(x,y)+Honest(x,y))->? Expert(x,y)`, the conclusion `Expert(FDA,HealthfulLiving)` will be accepted, with a degree of belief which depends also on the qualifier.

- ***Rebuttal Nodes*** represent exceptions to the rule expressed by the warrant (or CQs of the second type in Walton terminology).

Let us consider the argument *From consequences*, defined in section 1 and represented in figure 4, which includes the following premises:

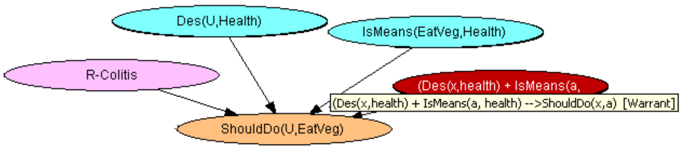

Figure 4. Argumentation schema *From Positive Consequences* with exception

1. `(Des(x,health)+IsMeans(a,health))->? ShouldDo(x,a)`: *"If someone desires to be in good health and action a contributes to maintaining good health, then he or she should perform this action"* (warrant)
2. `IsMeans(EatVeg,Health)`: *"Eating vegetables contributes to maintaining good health"*.
3. `Des(U,Health)`: *"U desires to be in good health"*

and the conclusion `ShouldDo(U,EatVeg)`: *"U should eat vegetables"*.

One of the possible conditions of exception is represented in the node: `R-Colitis(U)` (*"Unless U suffers of colitis"*).

The argument may be formulated as follows: *"You should eat more vegetables, because eating vegetables contributes to maintaining good health, unless you suffer of colitis."*

The whole BN shows the idea of argumentation expressed by Toulmin [13]:

– *Case1*: the belief in `ShouldDo(U,EatVeg)=True` will be *pretty high* if the probabilities of `Des(U,Health)` and `IsMeans(EatVeg,Health)`are *high* and, at the same time, the probability of `R-Colitis(U)` is *low*; The belief in the conclusion also depends on the formalization of the qualifier, that is on the state of the warrant (`AlmostCertainly`, `VeryLikely` or `Likely`).

– *Case2:* The belief in `ShouldDo(EatVeg)=true` will be *pretty low* if:

  ∗ `IsMeans(EatVeg,Health)` and `Des(U,Health)` are `False` (independently of the belief of `R-Colitis(U)`) and the warrant `(Des(x,health)+IsMeans(a,health)->?ShouldDo(x,a)` is `NotApplicable`

  ∗ the beliefs in the mentioned nodes are `True` but the belief in `R-Colitis(U)` is also `True`

- ***Proof Nodes*** allow representing convergent or linked arguments. In a convergent argument, each premise supports the conclusion to some extent by itself, independently of the others [5]. So even if a premise in such an argument is doubtful, it is possible that the others still establish the conclusion.

  For instance, figure 5 shows two different ways of arguing in favour of `ShouldDo(U,EatVeg)`: `Proof1(ShouldDo(U, EatVeg))` and `Proof2(ShouldDo(U, EatVeg))`.

  Both arguments appeal to the positive consequences of doing an action, but they are based on different premises.

  If *being in good health* `(Des(U,GoodHealth))` is more important, to U, than *having a good appearance* `(Des(U,Health))` and U is convinced about the means-end relationship between *eating vegetables* and *being in good health* `(IsMeans(EatVeg,Health)=True)`, then saying: *"You should eat more vegetables, because eating vegetables con-*

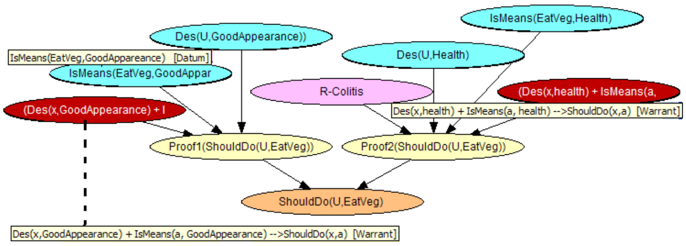

Figure 5. Representing convergent arguments in Proof nodes

tributes to maintaining good health" produces a satisfying level of belief in the conclusion (`P(ShouldDo(U,EatVeg))=.7`), due to the conditional probabilities shown in Table 2. By varying these parameters, linked arguments may be represented: if *being in good health* is so important as *having good appearance* to U, and U is convinced about the *means-end relationship between eating vegetables*, *being in good health* and *having a good appearance*, saying: *"You should eat more vegetables, because eating vegetables contributes to maintaining good health and also to having a good appearance"* produces a satisfying level of belief in the conclusion (`P(ShouldDo(U,EatVeg))`=.8, due to the conditional probabilities shown in Table 3.

Table 2. An example of conditional probability table.

	ShouldDo(U,EatVeg)			
Proof1(ShouldDo(U,EatVeg))	False		True	
Proof2(ShouldDo(U,EatVeg))	False	True	False	True
False	.99	.3	.6	.01
True	.01	.7	.4	.99

Table 3. An example of conditional probability table.

	ShouldDo(U,EatVeg)			
Proof1(ShouldDo(U,EatVeg))	False		True	
Proof2(ShouldDo(U,EatVeg))	False	True	False	True
False	.99	.4	.3	.01
True	.01	.6	.7	.99

4 DEFEATING AN ARGUMENT

We now describe how our models may be employed to simulate undermining of an argument which supports a given conclusion. According to Verheij [14], there are five parts of Toulmin's schema that can be argued against: (1) the datum D, (2) the claim C, (3) the warrant W, (4) the implicit conditional *"If D, then C"* which expresses the bridge from datum to claim and (5) the implicit conditional *"If W, then if D, then C"*, which expresses the bridge between the warrant and the previous implicit conditional. Reasons against any of these statements can be seen as a kind of rebuttal (in the sense of Toulmin's) of an argument that consists of warrant, datum and claim. Given an argument formulated by the Arguer, depending on the kind of objection the Respondent makes, several categories of recovery strategies can be distinguished, as illustrated in Table 4.

Table 4. Possible next move of the argument generation system

Respondent's response	Respondent's objection	Possible next move of the Arguer
Defeating Datum D	Contradicting a datum	Arguing about the defeated datum
	Questioning a datum	Providing more information
	Constructing an argument against the datum	Proposing a new argumentation strategy that concludes on the datum
Defeating Warrant W	Contradicting or questioning the warrant	Proposing a backing of warrant W
Defeating "If D, then C"	Rebutting the argument	Proposing an new explanation for true premises

4.1 Defeating Datum

Here, R may contradict the datum, question it or construct an argument against it. Let us consider again the argument in figure 4. As we said, this argument involves four premises:

1. *"If someone desires to be in good health and action a contributes to maintaining good health, then it is likely that he or she should perform this action"* (Warrant)
2. *"Eating vegetables contributes to being in good health"*. (datum)
3. *"U desires to be in good health"* (datum)
4. *"Unless U suffers of colitis"*. (rebuttal)

and the conclusion: *"U should eat vegetables"*.
If R desires to be in good health and s/he is convinced about item 1 and 2, and that no exceptions exist to this rule (`R-Colitis(U)=False`), saying: *"You should eat vegetables, because eating vegetables contributes to maintaining good health"*, produces a level of belief in the conclusion equal to .7. The argument therefore justifies this conclusion, even if the belief level is *not very high*: this is due to the `'Likely'` value of the qualifier. A situation like this might lead to the following exchange:

> S_1: *You should eat more vegetables, because eating vegetables contributes to maintaining good health*
> U_1: *Health is not important to me* or
> U_2: *It is not true that eating vegetables contributes to maintaining good health*

In U_1 and U_2 a datum is contradicted: an evidence on the state `False` of the nodes `Des(U,Health)` (U_1) or `IsMeans(EatVeg,Health)` (U_2) is introduced and propagated in the network (figure 6). If, for instance, U_1 occurs, the probability of the conclusion decreases from .7 to .22.

In the same conditions, questioning the datum could lead to the following exchange:

> S_1: *You should eat more vegetables, because eating vegetables contributes to maintaining good health*
> U_3: *Why do you think that health is important to me?*

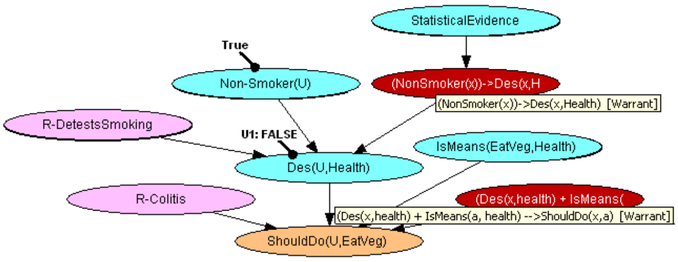

Figure 6. Arguing about a defeated datum

If it is unknown whether U desires to be in good health, the argument no longer justifies its conclusion. The probability of conclusion decreases from .7 to .46.
Similarly, U may construct an argument against the datum:

S_1: *You should eat more vegetables, because eating vegetables contributes to maintaining good health*
U_4: *It is not true that eating vegetables contributes to maintaining good health, because vegetables are full of pesticides.*

4.1.1 *Recovery Strategy*

Contradicting a datum at a certain stage of the argumentation process is due to a difference between second order beliefs (what the Arguer believes the recipient U believes) and real U's beliefs. To solve this discordance, it is necessary to *find out the causes that generated it*. The recovery strategy consists in arguing about the defeating datum, to show the argument which supports it. This strategy consists in a back-chaining on the defeated datum. Argumentation on the main claim is temporarily abandoned and a new argumentation stage starts: the datum now plays the role of the (current) claim, and a valid argument must be presented.

Let us reconsider the previous example. If `Des(U,Health)` is contradicted, the recovery strategy will involve the argument *From Sign* (see section 1) in figure 6, whose conclusion is the node itself. This argument involves three premises:

1. `(NonSmoker(x))->?(Des(x,Health)`: *"If a person does not smoke, s/he almost certain wishes to be in good health"* (warrant)
2. `NonSmoker(U)`: *"U does not smoke"*. (datum)
3. `R-DetestsSmoking(U)`: *"U detests smoking"* (rebuttal)

and the conclusion `Des(U,Health)`: *"U desires to be in good health"*.
The conclusion `(Des(U,Health))` fails unless premises justify it. This could lead to the following exchange:

S_1: *You should eat more vegetables, because eating vegetables contributes to maintaining good health*
U_1: *Health is not important to me*
S_2: *But... You don't smoke and those who do not smoke almost certainly considers health important, unless they detest smoking.*

In U_1 the premise (`Des(U,Health)=False`) is contradicted, and, consequently, the main claim (`ShouldDo(U,EatVeg)`) is not supported. A new argumentation stage starts. The current claim becomes the contradicted premise (`Des(U,Health)`). A new argument is proposed in S_2. Saying: *"But... You don't smoke and those who do not smoke almost certain considers health important, unless they detest smoking"* produces a level of belief in the main conclusion (*"You should eat vegetables"*) equal to .68 as consequence of the belief about `Des(U,Health)`(=.8).
If the datum is questioned, the recovery strategy consists in *providing more information about the questioned fact*. The outlined recovery strategy consists in a back-chaining, like in the case of contradicting a datum.
Finally, if an argument against the datum is proposed, the recovery strategy employs *proof nodes*: as we said, each proof node (if any) which is parent of the datum corresponds to a different argument pro or cons the datum. By means of a *what-if* type of reasoning, the most convenient argument pro the datum is proposed. If the system is unable to recover the situation, it has to accept the user's argument.

4.2 Defeating Warrant

U may respond to an argument by contradicting or questioning it: this situation involves *warrant nodes*. Let us suppose, for instance, that U is not convinced that *"If a person does not smoke, s/he almost certain wishes to be in good health"* (`(NonSmoker(x))->?(Des(x,Health)=False)`). This could lead to the following exchange:

S_1: *You should eat more vegetables, because eating vegetables contributes to maintaining good health.*
U_1: *Health is not important to me*
S_2 : *But... You don't smoke and those who do not smoke almost certainly consider health as important, unless they detest smoking*
U_5: *It is not true that those who do not smoke almost certainly consider health as important* or
U_6: *Why should a person who does not smoke almost certainly consider health as important?*

In U_5, the warrant is explicitly denied; in U_6, it is questioned. If U_5 occurs, an evidence on the state `NotApplicable` of the node `(NonSmoker(x))->?(Des(x,Health)` is introduced and propagated in the network: the probability of the main conclusion (`P(ShouldDo(U,EatVeg))`) decreases from .68 to .1. U_5 and U_6 point to two different kinds of negations: on one hand, the relationship between *not smoking* and the *importance of being in good health* may be contradicted or questioned; on the other hand, the *qualifier* may be contradicted or questioned: e.g. *It is not true that those who do not smoke almost certainly consider health as important but this is only likely.* In this case, an evidence on the state `Likely` of the node `(NonSmoker(x))->?(Des(x,Health)` is introduced and propagated in the network.

4.2.1 *Recovery Strategy*

The recovery strategy consists in *proposing a backing for the defeated warrant*. Figure 3 shows a possible backing of warrant for the argument in focus: *results of statistical studies*:

S_1: *You should eat more vegetables, because eating vegetables contributes to maintaining good health.*
U_1: *Health is not important to me*
S_2 : *But... You don't smoke and those who do not smoke almost certainly consider health as important, unless they detest smoking*
U_5: *It is not true that those who do not smoke almost certainly consider health as important*
S_3: *But a number of statistical studies show this!*

S_3 represent the situations in which an evidence on the state True of the node (StatisticalEvidence) is introduced and propagated in the network; the probability of the main conclusion increases from .1 to .6.

4.3 Defeating "If D, then C"

A Rebuttal may be presented by the Respondent to defeat a warrant if and only if this warrant was included in a previous stage of the argumentation process. Let us suppose, this time, that U detests smoking (figure 6, R-DetestsSmoking=True). This could lead to the following exchange:

> S_1: *You should eat more vegetables, because eating vegetables contributes to maintaining good health.*
> U_1: *Health is not important to me*
> S_2 : *But... You don't smoke and those who do not smoke almost certainly consider health as important, unless they detest smoking*
> U_9: *I do detest smoking.*

Even if data and warrant are both accepted, the presence of the rebuttal (in U_9) may reduce the strength of the whole argumentation: in this case, the probability of the current conclusion (Des(U,Health)) decreases from .8 to .7. As a consequence, the degree of belief about the main conclusion (ShouldDo(U,EatVeg)) becomes .49.

4.3.1 *Recovery strategy*

The focus comes back to the main claim and a new argumentation strategy for it should be explored. The argument is based on a set of premises, or points of departure for the argumentation: the more the premises accepted by the recipient, the more successful the argument will tend to be [10]. As a consequence, the next system's move should be based on premises which were already accepted by the recipient. Let us continue the previous example: figure 7 shows the portion of BN in focus. This BN suggests an alternative explanation of the premise *"U does not smoke"* (NonSmoker(U)): *"U wishes to have a good appearance"* (Des(U,GoodAppearance)). This alternative explanation may be employed in a new argumentation, which could lead to the following exchange:

> S_1: *You should eat more vegetables, because eating vegetables contributes to maintaining good health.*
> U_1: *Health is not important to me*
> S_2 : *But... You don't smoke and those who do not smoke almost certainly consider health as important, unless they detest smoking*
> U_9: *I do detest smoking.*
> S_3: *Oh, I see! But then.. probably you wish to have a good appearance.*

S_3 represents the situations in which the evidence on the state True of the node NonSmoker(U) produced a degree of belief higher than .5 about the node Des(U,GoodAppearance).

5 CONCLUSIONS AND FUTURE WORK

In this paper we have presented a probabilistic framework for reasoning with arguments via *Belief networks*. Uncertain reasoning is required in argumentation [7] and belief networks have been already applied successfully to these cases [18, 3]. However, in order to better unpack the reasoning patterns which are used in natural language arguments we enriched the semantics of BN: the crux of our framework is the notion of argumentation schema.

In our framework, information about the user's attitudes (a user image model) implements a rhetorical aspect of arguments: it informs about the best argumentation move the system has to make, in a given situation. The problem of how to select the most appropriate argument has been the object of study of several argumentation systems. To achieve this goal, authors have discussed the meaning and proposed a measuring method for concepts like *argumentation strength* [12], *probative weight* [17], *dialectical relevance* [16] or *impact* [18]

In other papers we explore more rhetorical aspects, like the use of emotions and deception in argument, pointing on persuasion [8, 4].

A very crucial skill in argumentation is the construction of counterexample for arguments and the use of them to access the degree of support of premises for their conclusion [6]. We employ our formalism to simulate undermining of an argument. We have still to clarify a number of problems before producing a system that simulates the subtleties of argumentation. For instance we aim at simulating the situation in which the User may respond to an argument generated by the system by proposing questions about the argument schema which has been employed. S/he may explicitly deny the schema or question it. This could lead to the following exchange in the healthy eating domain:

> S_1: *You should eat more vegetables, because eating vegetables contributes to maintaining good health.*
> U_1: *Health is not important to me*
> S_2 : *But... You don't smoke and those who do not smoke almost certainly consider health as important, unless they detest smoking*
> U_{10}: *This is a case were a reasonable person shouldn't relay to evidences* or
> U_{11}: *Why should a reasonable person relay to evidence in this case?*

U_{10} represents the situations in which the schema's use is explicitly denied. U_{11} represents the situations in which it is questioned.

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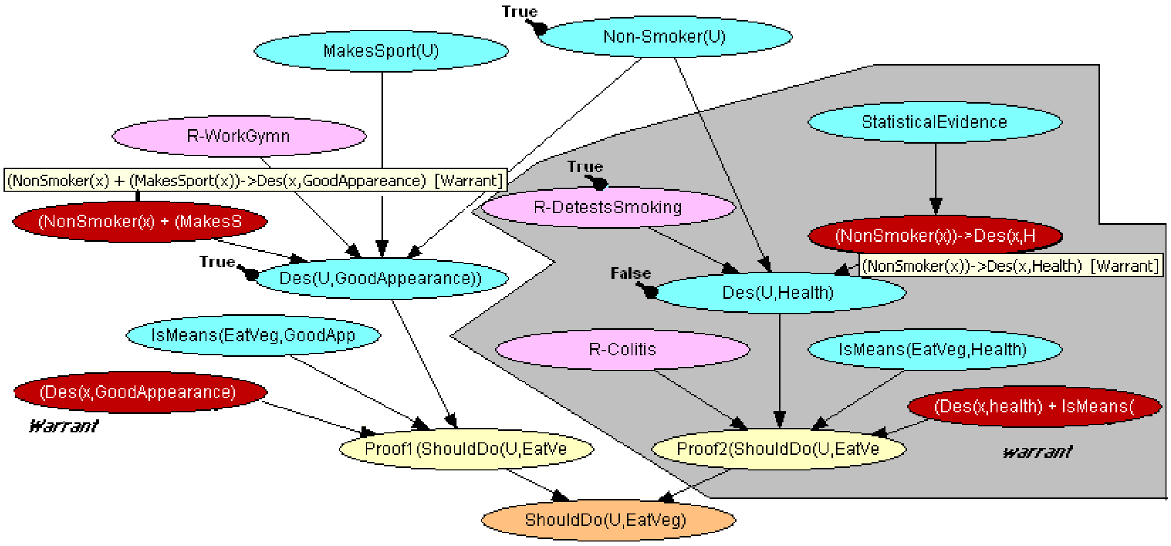

Figure 7. Rebutting an argument

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