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FORMAL MODELS FOR PERSUASIVE ASPECTS OF ARGUMENTATION

Abstract: The aim of the paper is to provide a comprehensive survey of logical models for the persuasive argumentation. We show how different aspects of persuasion can be described formally. In particular, we present the frameworks representing protocols of persuasive dialogs, rhetorical tools such as threats, rewards and appeals, argumentation changing beliefs vs. argumentation changing behavior, interaction among goals, result and success in persuasion, and finally – persuasiveness and nonverbal arguments.

Keywords: protocols of dialog, emotional appeals, practical reasoning, success of persuasion, nonverbal arguments

1. Introduction

Among various processes of argumentation, we can distinguish logical arguments and persuasive (rhetorical) arguments. The aim of logical argumentation is to support a given statement i.e. to prove a claim, while the aim of **persuasive argumentation** is to influence an audience, i.e. to change its beliefs, attitudes or behavior. Obviously, supporting a statement should obey the general rules or conditions of valid justification, while persuading – is absolutely opposite – its effect depends on the subjective, and thus upredicatable, judgement of its audience.

In consequence, **formal models** pay much attention to representation of logical argumentation and little to rhetorical one. As long as no general rules governing the phenomenon can be found, there is no possibility for its formal description. On the other hand, unlike formal models **psycho-**

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logical models prefer persuasive to deductive argumentation since it is closer to the social practice (an excellent review of these models is given in (O'Keefe 2002)). One of the most influential contemporary approach to representing persuasion is Elaboration Likelihood Model proposed by Petty and Cacioppo (1986).[1] According to ELM there are two different processes which underly persuasion represented as central route and peripheral route to persuasion. Which one is activated depends on the degree of elaboration (issue-relevant thinking) in which the audience engages. In the central route, the persuasion's success is the result of its systematic consideration of the issue-relevant information (the arguments' quality). The peripheral route uses cognitive shortcuts such as simplifying decision rules. The success may be a result of the persuader's credibility or the audience's emotions.

The third type of models is provided by **informal logic**. Their main feature is an attempt to loosen the assumptions made by the formal logic and to bring logical models of argumentation closer to the every-day practice. It investigates rational (critical) argumentation which can be viewed as combination of logical approach with the elements of rhetorical or psychological account. That is, the informal logic tries to extend the model of the logical argumentation with the aspects specific for a real life communication. Nevertheless, the informal logic has still a different perspective than rhetoric itself, i.e., it is focused on different criteria of argument's evaluation – on the rationality of argumentation and not on its effectiveness. Moreover, informal logic considers some elements of ELM, e.g., the appeal to expert opinion or appeal to fear can be treated as the equivalents of some mechanisms of peripheral route, i.e. the communicator credibility and the fear arousal.

The aim of this paper is to show how different persuasion aspects included into the argumentation model by the informal logic were **again adopted** by various formal models. As noted above, since logical description of these aspects is an extremely difficult task, there are not a lot of such proposals. Thus, this becomes all the more significant and interesting to examine those several attempts which take up this challenge.

The remainder of this paper is structured as follows. Each section describes proposal of how to represent different aspects of persuasion such as protocols that govern the course of persuasion dialogs (Section 2), emotional

[1] Observe that the notion of persuasion is broader than the notion of persuasive argumentation. In this paper, we are interested in persuasion as long as its aspects refer to the argumentation process.

appeals like threats and rewards (Section 3), practical arguments aiming at the influence on audience's actions (Section 4), success as the measure of achieving goals in the real result of persuasion (Section 5), the gradation of persuasion success and nonverbal arguments (Section 6). The sections start with general informal description of a given aspect. Then, its formal model is presented. Throughout the paper, we make some changes in the original symbols for the needs of consistency of the notation.

2. Protocols of persuasion dialogs

Initially protocols of persuasion dialogs were studied within philosophical logic and argumentation theory (e.g. Hamblin 1970, Mackenzie 1979). An important moment was a work by Walton and Krabbe (1995). They identified a number of distinct **dialog types** used in human communication: persuasion, negotiation, inquiry, information-seeking, deliberation and eristic dialogs. Their specification was determined for criteria such as initial situation of a dialog and its main goal. Specifically, persuasion is defined as a dialog which initial situation is a conflict of opinion and the main goal is to resolve it by verbal means. This approach is related to the dialectical account of argumentation. Later, these concepts were adopted by theories in computer science and computational models of persuasion dialog.

The **protocols** determine the rules that the participants of a persuasion dialog must obey to resolve the conflict. In particular, such a protocol may regulate what utterances the participants can make and under which conditions, what are the effects of their utterances on their propositional commitments, when a dialog terminates and what is the outcome of the dialog.

In the field of multi-agent systems persuasion dialogs are incorporated into models of agents' interactions. In order to achieve given goals, intelligent agents often need to interact with other agents. The main modes of interaction where persuasion can be applied are information seeking, deliberation or negotiation. In these cases participants may disagree about relevant factual matters, credibility of an information resource, effects of plans or actions etc. and need to resolve the conflict to fulfil their goals.

L. Carlson (1983) proposes a **game-theoretic approach** to dialogs, in which speech acts are viewed as moves in a game and rules for their appropriateness are formulated as rules of the game. Almost all the works

on formal dialog systems follow this approach and two aspects are discussed: rules of the game (which moves are allowed) and strategies and heuristics for individual players (how to play the game successfully). The critical review of the persuasion dialog systems is presented in (Prakken 2006). H. Prakken compares approaches introduced by J. Mackenzie (1979), D. Walton and E. Krabbe (1995), L. Amgoud, N. Maudet, S. Parsons, P. McBurney, M. Wooldridge (Amgoud, Maudet & Parsons 2000, McBurney & Parsons 2002, Parsons, Wooldridge & Amgoud 2002, Parsons, Wooldridge & Amgoud 2003), H. Prakken (2005) and others, and shows the expressiveness and strictness of their models. On the basis of his work we describe the main features and elements of persuasion dialogs.

Let Agt be a set of **participants** of a dialog (agents). To describe a topic of the conversation, the participants use **topic language** $\mathcal{L}_t$, which is a language of some logic L. This logic may or may not be monotonic and may or may not be argument-based. The only assumption is that $\mathcal{L}_t$ is closed under the classical negation. Sometimes in the set $\mathcal{L}_t$ a subset K called the **context** is distinguished. The context contains fixed knowledge which must be respected during the dialog, e.g., relevant laws in a legal dispute.

The persuasion dialog is initiated by conflict of opinion about one or more topics $T \subseteq \mathcal{L}_t$ and the **dialog purpose** is to resolve this conflict, i.e. to lead to a situation in which all parties share the same point of view on the topic. Thereby the participants can play different roles. Suppose that $t \in \mathcal{L}_t$ is a conflict topic. Then, $prop(t) \subseteq Agt$ is a set of **proponents**, i.e., all participants with a positive point of view towards t, and $opp(t) \subseteq Agt$ is a set of **opponents**, i.e., all participants with a doubtful point of view towards t. For any t, the sets $prop(t)$ and $opp(t)$ are disjoint but do not necessarily jointly exhaust Agt. So in the set Agt may be also participants which are neutral towards t.

Furthermore, a participant i may or may not have a, possibly inconsistent, belief base $\Sigma_i \subseteq 2^{\mathcal{L}_t}$ which may or may not change during dialogs. The most important attribute of every participant i is, possibly empty, set of **commitments** $C_i(d) \subseteq \mathcal{L}_t$ which usually changes during a dialog d. Commitments of a participant are publicly declared points of view about some topics and may or may not coincide with the participant's beliefs.

Agents communicate using **communication language** $\mathcal{L}_c$. Formally **dialog** is defined as a sequence from $\mathcal{L}_c$. The set of all dialogs is denoted by $M^{\leq\infty}$ and the set of all finite dialogs is denoted by $M^{<\infty}$. The most common speech acts applied in dialogs are:

- *claim* φ – the speaker asserts that φ is the case,
- *why* φ – the speaker challenges that φ is the case and asks for reasons why it would be the case,
- *concede* φ – the speaker admits that φ is the case,
- *retract* φ – the speaker declares that he is not committed (any more) to φ,
- φ *since* S – the speaker provides reasons why φ is the case,
- *question* φ – the speaker asks another participant's opinion on whether φ is the case.

As an example of a persuasion dialog let us consider one quoted from (Prakken 2006).

Paul: My car is safe. (*making a claim*)
Olga: Why is your car safe? (*asking grounds for a claim*)
Paul: Since it has an airbag. (*offering grounds for a claim*)
Olga: That is true (*conceding a claim*) but this does not make your car safe. (*stating a counterclaim*)
Paul: Why does that not make my car safe? (*asking grounds for a claim*)
Olga: Since the newspapers recently reported on airbags expanding without cause. (*stating a counterargument by providing grounds for the counterclaim*)
Paul: Yes, that is what the newspapers say (*conceding a claim*) but that does not prove anything, since newspaper reports are very unreliable sources of technological information. (*undercutting a counterargument*)
Olga: Still your car is not safe, since its maximum speed is very high. (*alternative counterargument*)
Paul: OK, I was wrong that my car is safe. (*retracting a claim*)

Every utterance $\varphi \in \mathcal{L}_c$ can influence participants commitments. Results of utterances are determined by **effect rules** which are specified as functions

$$C_i : M^{<\infty} \to 2^{\mathcal{L}_t}$$

for a participant $i \in Agt$. For example if in the above dialog we assume that stating a claim "My car is safe" by Paul is denoted by d then $C_{Paul}(d) = = \{safe\}$. This means that after a sequence of utterances d Paul becomes committed to this claim.

Legal moves at each stage of a dialog are defined by **protocol**, which is a function

$$P : 2^{\mathcal{L}_t} \times D \to 2^{\mathcal{L}_c}$$

where $D \subseteq M^{<\infty}$ is a set of **legal finite dialogs**. For instance, $P(K, d) = = \{m_1, m_2, m_3\}$ where K is a context, d – claiming by Paul "My car is

safe", and the move m_1 is Olga's question "Why is your car safe?", m_2 is Olga's claiming "Your car is not safe", m_3 is Olga's concede "Your car is safe". That is, on the stage of the dialog d the possible moves that Olga has are $m_1,\ m_2,\ m_3$. In dialog systems for every speech act a set of acceptable **replies** is defined (see Table 1).

Table 1

Speech acts and typical replies

Speech act	Replies
claim φ	*why* φ, *claim* $\neg\varphi$, *concede* φ,
why φ	φ *since* S (alternatively: *claim* S), *retract* φ
concede φ	
retract φ	
φ *since* S	*why* ψ $(\psi \in S)$, *concede* ψ $(\psi \in S)$
question φ	*claim* φ, *claim* $\neg\varphi$, *retract* φ

For the example dialog, used speech acts and possible replies are depicted in Figure 1. The structure of the dialog shows key features of a persuasion dialog. Notice that participants of a dialog may exchange arguments and counterarguments or claim as well as challenge, concede or retract some propositions.

Announced arguments can be **attacked**. According to J. Pollock's theory about rebutting and undercutting counterarguments (Pollock 1995), the attack can be performed in two ways: (1) by giving argument for the opposite conclusion, (2) by saying that in the given circumstances the premises of the argument do not support its conclusion. For example Paul says "My car is safe since it has an airbag". Then Olga can reply giving argument for opposite conclusion: "Your car is not safe since its maximum speed is very high" or saying that the premises do not support the conclusion: "That is true that your car has an airbag but this does not make your car safe". The second situation is related to the fact that in natural language some parts of arguments can be implicit. That is, Paul may say that his car is safe since it has airbag while having in mind that cars with airbags are usually safe. Observe that the participants may give replies for arguments and counterarguments immediately or may postpone their replies or return to earlier choices and provide alternative arguments.

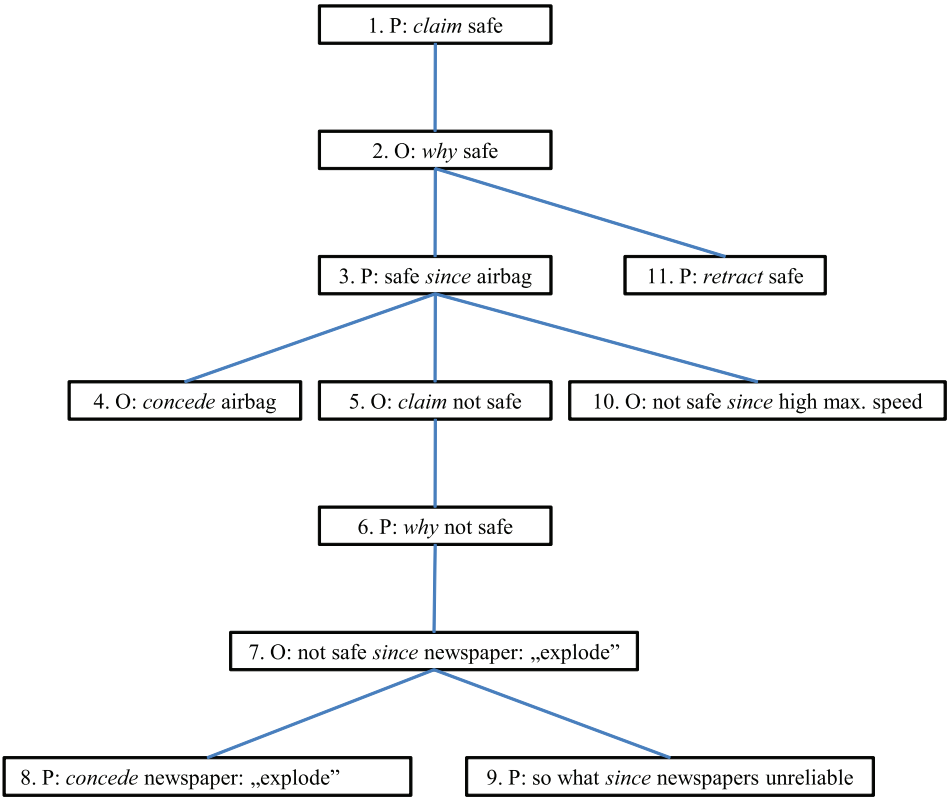

Figure 1. Reply structure for the example dialog

A dialog **terminates** in a situation where no next move is legal or some specific conditions hold. Moreover a **turntaking function** is defined. It determines which player (or players) can move next. The outcome of a dialog is established by **outcome rules** O, which in persuasion dialogs fix the winner and the loser. More precisely, O consists of two functions win w and loss l:

$$w : D \times 2^{\mathcal{L}_t} \times \mathcal{L}_t \to 2^{Agt},$$

$$l : D \times 2^{\mathcal{L}_t} \times \mathcal{L}_t \to 2^{Agt}.$$

In the running example for terminated dialog d' the winner is Olga, $w(d', K, safe) = \{\text{Olga}\}$ and the looser is Paul, $l(d', K, safe) = \{\text{Paul}\}$.

The functions w and l satisfy the following conditions. For every legal finite dialog d, context K, and topic t it holds:

– $w(d, K, t) \cap l(d, K, t) = \emptyset$ – a participant can not be a winner and a looser at the same time,

- $w(d, K, t) = \emptyset$ iff $l(d, K, t) = \emptyset$ – there is no winner iff there is no looser,
- if $|Agt| = 2$, then $w(d, K, t)$ and $l(d, K, t)$ are at most singletons – if there are two players then both of them can not be winners and losers at the same time.

In persuasion dialogs it is assumed that at the start of dialog ($d = \emptyset$) commitments of proponents and opponents must tally with their points of view, i.e.:

- if $i \in prop(t)$ then $\overline{t} \notin C_i(\emptyset)$,
- if $i \in opp(t)$ then $t \notin C_i(\emptyset)$,

where the complement $\overline{t}$ of a formula t is $\neg t$ if t is a positive formula and t' if t is a negative formula $\neg t'$. Moreover, only one side (proponents or opponents) give up and the winner does not change its point of view:

- $w(d, K, t) \subseteq prop(t)$ or $w(d, K, t) \subseteq opp(t)$,
- if $i \in w(d, K, t)$ then
  - if $i \in prop(t)$ then $t \in C_i(d)$,
  - if $i \in opp(t)$ then $t \notin C_i(d)$.

On the basis of the above notions a **pure persuasion** is defined. A dialog system is for pure persuasion iff for any terminated dialog d it holds that $i \in w(d, K, t)$ iff

- either $i \in prop(t)$ and $t \in C_j(d)$ for all $j \in prop(t) \cup opp(t)$,
- or $i \in opp(t)$ and $t \notin C_j(d)$ for all $j \in prop(t) \cup opp(t)$.

Informally it means that after the dialog all participants share the point of view of the winner. Otherwise, i.e., if the outcome is not fully determined by the participant's point of view and commitments, a dialog is for **conflict resolution**. For example a proponent loses the dialog about t even if at termination he is still committed to t – like in a trial when a crime suspect is found guilty by a jury (the third party) even though he maintenances his innocence.

In this section we showed how persuasion is modeled within the game-theoretic framework for dialogs. In the next section we will discuss the proposal of representing the persuasive tools in negotiation.

3. Threats, rewards and appeals

Douglas Walton distinguishes three types of critical argumentation: deductive argument (such as Modus Ponens), inductive argument (probabilistic generalization) and plausible argument (such as appeal to expert opinion) (Walton 2006). He also describes some persuasive tactics of distraction in argumentation which are most often fallacious but still effective. Most of

them, including threats (argumentum ad baculum), fear or pity are classified as **emotional appeals**. Such peripheral means of persuasion seems to be extremely difficult for formal modeling, as they refer to the emotions which rely on unpredictable factors. In this section, we describe a formal model which addresses this challenge, i.e. the model of persuasive negotiation proposed by S. Ramchurn, N. Jennings and C. Sierra (2003).

Negotiation is understood as an exchange of proposals and counter proposals between a proponent and an opponent until either a mutually acceptable agreement is reached or one of the parties withdraws. **Persuasive negotiation** is a negotiation where proposals are supported by rhetorical arguments (threats, rewards or appeals). Their model consists of the following items:

- $i, j, ... \in Agt$ is a set of agents
- $A = \mathrm{I} \cup \mathrm{EA}$ is a set of **actions** available where
  - $ai_1, ai_2, \ldots \in \mathrm{I}$ are illocutionary acts, i.e. utterances or speech acts (Searle 1969)
  - $ae_1, ae_2, \ldots \in \mathrm{EA}$ are environment actions, i.e. performed on the environment of the agents
- S: $B^{Agt} \times \mathrm{W}$ is a set of **world states** where
  - B^{Agt}: $B^{i_1} B^{i_2} \times \ldots \times B^{i_{|Agt|}}$ is a set of possible mental states of all agents, where B^{i_n} is a mental state of an agent i_n
  - $\omega, \omega', \omega'', \ldots \in \mathrm{W}$ is a set of fully observable environmental states
- agents can make various **evaluations**:
  - $V^i : S \rightarrow [0, 1]$ is an evaluation function that indicates the desirability of a particular **state** assigned by an agent i
  - $EV^i : S \times A \rightarrow [0, 1]$ is an expected value of an **action**(s) to an agent in a given state
  - $T : Agt \times Agt \rightarrow [0, 1]$ is the **trust** between agents, i.e. the value of one agent assigned by the other; it has a value between 0 (no trust) and 1 (absolute trust)
- $p_1, p_2, \ldots \in \mathrm{P}$ are **proposals** exchanged in the negotiations; they suggest to perform some actions by a proponent and an opponent, defined as $p = (a^i, a^j)$, where $p \in \mathrm{P}$, $a^i \subseteq A$, $a^j \subseteq A$, and $i, j \in Agt$.

Among illocutionary acts, we can distinguish acts specific for negotiations and those specific for persuasion. The negotiation illocutions (I_{neg}) for a proposal $p \in \mathrm{P}$ are: $propose(i, j, p)$, $accept(i, j, p)$ and $reject(i, j, p)$. The **persuasive illocutions** specific to persuasive negotiations (I_{pers}) are: $threaten(i, j, p, th)$, $reward(i, j, p, rw)$, and $appeal(i, j, p, m)$ where $i \in Agt$ is a sender, $j \in Agt$ is a hearer, $th, rw \in A$ and $\mathrm{m} \in \mathrm{I}$. For example, an agent i can send to an agent j a proposal p which is a verbal threat th

to remove a privilege, a promise rw to give a bribe of 100 000 dollars or an appeal m to assert the mental state of the sender, i.e. m is $assert$(b) where b $\in B^i$.

What is interesting, in this model threats and rewards can be understood broader, i.e. as any kind of actions. If it is the illocutionary action as discussed above, the argument is **verbal**, e.g. while saying "I will kill you". If it is the environmental action, the argument becomes **nonverbal**, e.g. when threatening by showing a knife. An appeal is a slightly different type of rhetorical argument. It cannot be any action – it is always an illocution. The item being appealed to is a hearers belief about the state of the world. A sender may appeal to beliefs about a past promise, common practice or the hearers possible preferences and goals.

Each action a has pre-conditions that must be true before the action can be executed ($pre(a)$) and post-conditions that follow from its execution ($post(a)$). One of the important characteristics of the persuasive illocutions is that the sender anticipates what the hearer believes rather than is interested in the logical defeasibility or truth of the statements. The primary **precondition** for a persuasive illocution $\iota \in \mathrm{I}_{pers}$ to be sent is that the persuader i prefers the execution of the proposal in ι to its current state, i.e., for each $p \in \mathrm{P}$, $\{EV^i(s,p) > V^i(s)\} \subseteq pre(propose(i,j,p))$. The **post-condition** is that the hearer j believes that i prefers the proposal to be executed rather than staying in its current state s, i.e., $\{B^j(B^i(EV^i(s,p) > > V^i(s)))\} \subseteq post(propose(i,j,p))$.

The interesting part of this model is the attempt to **represent rhetorical means** in terms of specification of their pre- and post-conditions. Let $i,j \in Agt, th \in A$, $s \in S$, $p \in \mathrm{P}$. If $\iota = threaten(i,j,p,th)$, then:

1. the preconditions $pre(\iota)$ are:
   (a) $B^i(V^j(s) > EV^j(s,p))$ – a sender i must believe that a hearer j prefers a current state s than the execution of a proposal p,
   (b) $B^i(V^j(s) > EV^j(s,th))$ – i should believe that j can be threatened, i.e. that j prefers the current state than the execution of the threat,
   (c) $B^i(V^j(\delta(s,p)) > V^j(\delta(s,th))$, where $\delta(s,a) = s'$ (for $a \in \mathrm{A}$) is a transition between world states caused by an action a; the condition means that i must believe that the state after the execution of the proposal is more preferred by j than the state obtained after the threat,
2. the post-condition $post(\iota)$ is:
   (a) $B^j(B^i(V^j(s) > V^j(\delta(s,th))))$ – j believes that the persuader i believes that the current state is more preferred by j than the state achieved after the execution of the threat.

The preconditions of the threat are true in the example given in Figure 2a. The figure describes not the reality, but the beliefs of the proponent i about preferences of the audience j. The arrows represent the actions which can be proposals or rhetorical arguments. The numbers show evaluation assigned by the audience j to the states (number placed inside the circle in the figure) or to the actions performed (number placed on the arrows). The precondition (1a) is true since the current state s is evaluated as 0.5, and the execution of the action p is evaluated as 0.2 and, obviously, $0.5 > 0.2$. The precondition (1b) is true since j evaluates the current state s as 0.5 and the execution of the threat th as 0.4 and $0.5 > 0.4$. The last precondition (1c) is true since $\delta(s, p)$, i.e. the state reached from the current state after the execution of the proposal, is evaluated as 0.6 and $\delta(s, th)$, i.e. the state reached from the current state after execution of the threat, is evaluated as 0.3 and $0.6 > 0.3$. Intuitively, the preconditions mean that the persuader thinks that even though the audience doesn't want the proposal to be executed ($0.5 > 0.2$) and doesn't want the threat to be performed ($0.5 > 0.4$), the audience still prefers to end up in the state reached after the proposal ($\delta(s, p) = 0.6$) than in the state reached after the threat ($\delta(s, th) = 0.3$).

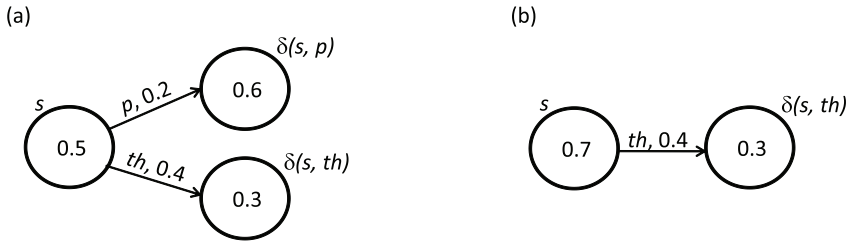

Figure 2. (a) The threat *th*'s preconditions: persuader's beliefs about audience's preferences on states and actions; (b) the threat *th*'s post-condition: the audience's opinion about the persuader's beliefs about preferences of the audience

The post-condition following execution of the threat is illustrated by Figure 2b. This time, the figure shows what the audience thinks about the beliefs of the proponent with respect to the audience's preferences. That is, the audience is convinced that the proponent believes that the current state is evaluated by the audience higher (0.7) than the state reached after the execution of the threat (0.3). Intuitively, the post-condition means that the audience assumes that the persuader believes that the audience doesn't want the threat to be executed ($0.7 > 0.3$).

Let $i, j \in Agt, rw \in A$, $s \in S$, $p \in$ P. If $\iota = reward(i, j, p, rw)$, then:

1. the preconditions $pre(\iota)$ are:
   (a) $B^i(EV^j(s,p) < V^j(s) < EV^j(\delta(s,p), rw))$ – a sender i should believe that the execution of a proposal is less preferred by j than the current state, and the current state is less preferred by j than the execution of the reward following the proposal,
   (b) $B^i(V^j(\delta(s,p)) < V^j(\delta(\delta(s,p), rw)))$ – i must believe that the state reached after the execution of the proposal is less preferred by j than the state reached after the execution of the reward (which followed the proposal),
2. the post-conditions $post(\iota)$ are:
   (a) $B^j(B^i(V^j(\delta(s,p)) < V^j(\delta(\delta(s,p), rw))))$ – j believes that the second precondition is fulfilled,
   (b) $B^j(B^i(V^j(s) > V^j(\delta(s,p))))$ – j believes that i thinks that the current state is more preferred by j than the state reached after the execution of the proposal.

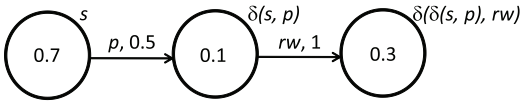

Figure 3. Reward *rw*'s preconditions: persuader's beliefs about audience's preferences on states and actions

The preconditions of the reward are true in the example illustrated by Figure 3. The figure depicts the beliefs of the proponent i. The precondition (1a) is true since: (i) the current state is evaluated as 0.7, (ii) the execution of the proposal is evaluated as 0.5, (iii) the execution of the reward after the proposal is evaluated as 1, and (iv) $0.5 < 0.7 < 1$. The precondition (1b) is true since the state reached after execution of the proposal is evaluated as 0.1 and the state reached after execution of two actions (first – the proposal and then – the reward) is evaluated as 0.3 and $0.1 < 0.3$. Observe that in such an example, even though the audience was rewarded it will end up in the state less preferred by that audience (0.3) than the state from where it begins (0.7). This model assumes that an audience feels rewarded by an action (rw) itself and not by a state reached after this action ($\delta(s, rw)$). This means that a briber thinks that I will feel rewarded by the action of giving me 100 000 dollars and not by the state in which I will be after this bribe, i.e. the state where I have 100 000 dollars. This could seem counterintuitive in some cases.

Let $i, j \in Agt$, $m \in \mathrm{I}$, $s \in S$, $p \in \mathrm{P}$. If $\iota = appeal(i, j, p, m)$, then:

1. the preconditions $pre(\iota)$ are:
   (a) $B^i(EV^j(s, m) > V^j(s) > EV^j(s, p))$ – the sender i must believe that appeal is more preferred by j than the current state and the current state is more preferred by j than the execution of the proposal,
   (b) $B^i(V^j(\delta(s, p)) < V^j(\delta(\delta(s, m), p)))$ – i should believe that the state reached after the execution of the proposal is less preferred by j than the state reached after the execution of two actions: first the appeal and then the proposal,
2. the post-conditions $post(\iota)$ are:
   (a) $B^j(B^i(V^j(\delta(s, p)) < V^j(\delta(s, m))))$ – j believes that the persuader i thinks that the state reached after the execution of the proposal is less preferred by j than the state reached after the execution of the appeal,
   (b) $B^j(B^i(V^j(s) > V^j(\delta(s, p))))$ – j believes that i thinks that the current state is more preferred by j than the state reached after the execution of the proposal.

To the best of authors knowledge, this is the only model formally representing the rhetorical techniques such as threat and reward that are extremely common in the social practice. However, when we describe peripheral factors it would be worth to include into the model the distinction between central and peripheral route to persuasion. According to ELM, the peripheral factors such as threat influence a given audience differently depending on which route is activated for this audience. This would give a more adequate representation of that type of persuasive tools.

Observe that in this model, the goal of the persuasion is an act of choosing the proposal offered in negotiation. The nature of arguments which aim to change acts in order to achieve a given goal is specified in the next section.

4. Beliefs and behavior

Psychological models emphasize the difference between argumentation aiming to change beliefs and argumentation aiming to change behaviors (acts, actions). As a result, these two kinds of arguments should have different formal representation. In logic this issue was recognized as the distinction between theoretical reasoning and **practical reasoning**. The practical reasoning is a reasoning about what *should be done* according to some crite-

rion such as moral, financial, health or pleasurable criterion. However, the issue how to adequately represent reasoning about actions appeared to be much more controversial or not obvious.

This type of reasoning is discussed in a model proposed by K. Atkinson, T. Bench-Capon and P. McBurney (Atkinson, Bench-Capon & McBurney 2003, Atkinson 2005). They consider arguments in which one agent persuades another to adopt a course of action. The reasons for the choice of action are the possibility of achieving some goal and promoting some values. The proposed model consists of the following items:

- $a, a_1, a_2, \ldots \in A$ – a finite set of actions
- $p, q, r, \ldots \in V_0$ – a finite set of propositions
- $s, s_1, s_2, \ldots \in S$ – a finite set of states; each element of S is an assignment of a truth value $\{T, F\}$ to every element of V_0
- $g, g_1, g_2, \ldots \in G$ – a finite set of goals that are propositional formulas
- $v, w, \ldots \in V$ – a finite set of values
- $value$ – a function mapping each element of G to a pair $\langle v, sign \rangle$, where $v \in V$ and $sign \in \{+, =, -\}$
- $apply$ – a ternary relation on $A \times S \times S$ with $apply(a, s_1, s_2)$ to be read as: "Performing action a in state s_1 results in state s_2".

Imagine that Kasia wants to see Magda before Magda leaves London at 4.30. Kasia thinks: "I have to be in London at 4.15, so I should catch the 2.30 train". Traditionally, this type of cognitive process was treated as practical reasoning. One of the first approach was to treat the practical reasonings similarly to the deductive theoretical reasonings, i.e. as **practical syllogisms**: "I'm to be in London at 4.15" and "If I catch the 2.30 train, I'll be in London at 4.15" therefore "I'll catch the 2.30 train". As a result, this process has the following representation:

P1: An agent wants to achieve g
P2: If a is done, g is achieved
T: a will (should) be done

where g is being in London at 4.15, a is catching the 2.30 train, P1, P2 are the premises and T is the claim of the reasoning. This representation is criticized since the conclusion is weakly supported by the premises. The following observations are made:

1. the reasoning has not a form of deduction, but of abduction, i.e. β, $\alpha \rightarrow \beta$ therefore α,
2. execution of action a typically excludes execution of other action a_1 which could have other result g_1 even more desirable than g, e.g. a_1 could be staying at home and g_1 is watching a movie with a boyfriend,

3. execution of action a typically has a number of results: $g_1, g_2, \ldots$; some could be undesirable so that it will lead us to abandon the goal g, e.g. g_1 is canceling the meeting with a friend, g_2 – travel sickness, etc.

These observations lead to the conclusion that the representation of practical argument must take into account the **alternative actions and the alternative goals** that an agent may have. Thus, Searle proposes to represent this kind of arguments in the following manner (Searle 2001):

P1: An agent wants, all things considered, to achieve g
P2: The best way, all things considered, to achieve g is to do a
T: An agent will (should) do a

There are two weak points of this model: the notion "best" and "all things considered". The criticism of the first point is based on the Searle's observation that the preference ordering and utility function (which are typically used to model the notion of "best") are rather the product and not the input for practical reasoning. The criticism of the second point refers to limitation of reasoning resources and imperfection of information.

The other account associates the practical reasoning with the **critical questions**. Walton proposes to represent these arguments in the following manner:

P1: An agent wants to achieve g
P2: If a is done, g is achieved
T: a should be done
Q1: Are there alternative ways of realizing g?
Q2: Is it possible to do a?
Q3: Does an agent have goals other than g which should be taken into account?
Q4: Are there other consequences of doing a which should be taken into account?

where Q1-Q4 are critical questions.

Atkinson, Bench-Capon and McBurney propose to **modify this model** criticizing Walton's account. First they say that the notion of a goal is ambiguous. Observe that catching the 2.30 train which arrives in London at 4.15 may be justified by different reasons: (1) direct consequences of the action, e.g. Kasia needs to be in London before 4.30, i.e., before Magda leaves (e.g. at 4.15) – in this case g is being in London before 4.30, (2) a state of affairs that follows from the action, e.g. Kasia wants to see Magda before she leaves – in this case g is seeing Magda before she leaves London, (3) an underlying social value which an agent hope to promote by the action, e.g. friend-

ship requires that Kasia meets with Magda before she leaves – in this case g is promoting friendship with Magda. Thus, they propose that the first premise should have the following representation:

P1: An agent wants to achieve a state s to bring about g which promotes a value v

Such representation influences the structure of the critical questions Q1, Q3 and Q4. That is, they should be extended in the following manner:

Q1a: Are there alternative ways of realizing the same consequences?
Q1b: Are there alternative ways of realizing the same goal?
Q1c: Are there alternative ways of promoting the same values?

Q3a: Would doing a promote some other value?
Q3b: Does doing a preclude some other actions which would promote some other value?

Q4a: Does doing a have a side effect which demotes the value v?
Q4b: Does doing a have a side effect which demotes some other value?

Secondly, they criticize the premise P2 since it is assumed to be representing what an agent knows or reasonably believes. Finally, they suggest the following model of the practical reasoning:

In the current situation s_1
Performing action a
Will result in the new situation s_2.
g is true in s_2.
The truth of g promotes some value v.

and they add more critical questions into the model:

Q5: Are the circumstances such that doing a will bring about g?
Q6: Does g promote v?
Q7: Is g possible?

Each of this question should be further extended. The question Q5 has four variants: (Q5a) whether the believed circumstances are possible, (Q5b) whether the believed circumstances are true, (Q5c) assuming both of these, whether the action has the stated consequences, (Q5d) assuming all of these, whether the action will bring about the desired goal. The critical question Q6 has two variants: (Q6a) whether g does realize the value intended, (Q6b) whether the value proposed is indeed a legitimate value. Finally, the critical question Q7 has two variants: (Q7a) whether the situation s_2 believed by an agent to result from doing a is a possible state of affairs,

(Q7b) whether the particular aspects of s_2 represented by g are possible. All these critical questions correspond to different attacks that could be formulated against a given practical reasoning.

Notice that four statements must hold for this representation to be valid:

Statement 1: s_1 is the case.
Statement 2: $apply(a, s_1, s_2) \in apply$.
Statement 3: $s_2 \models g$ (g is true in state s_2).
Statement 4: $value(g) = \langle v, + \rangle$.

In this section we discussed how to persuade to perform some action in order to achieve a goal. In the next section, we will show the model where we represent persuasion's goals instead of agent's (action's) goals. Together with the notion of the persuasion's result they allow to characterize the notion of success of the persuasion.

5. Success: goals and result

The essential feature of persuasion is that it is always performed to achieve a goal (changing somebody's mind or action). In the informal model of coalescent argumentation, Michael Gilbert assumes that all persuasive arguments have two levels of goals (Gilbert 1997). The macro level has so-called **face goals** of the interaction and the maintenance of the relationship between the agents. They may involve e.g. some version of Gricean maxims of cooperation. At the micro level there are the **task goals** which refer to the specific desired effect that started the argumentation. Imagine that a man meets a woman at a dinner and starts the discussion about some movie. His task goal may be to pick her up, while face goal may be to share opinions about the movie. Recognizing the goals of the agents is the first step to achieve a success in coalescent argumentation.

The formal model which captures the aspects of persuasion's goal, result and success is a model proposed by M. Tokarz (1985, 1987). The model is based on the following assumptions: (a) a persuasive act starts with sending some message, (b) the act is always performed in some situation, (c) the act is able to (at least potentially) change that situation, (d) the persuasion is executed with such *goal*, i.e. to change the situation given into the direction planned and favorable for the sender, (e) the real change (*result*) induced by sending the message might not be the change planned, i.e. the persuasive act might be *unsuccessful*.

Let $\mathcal{L} = \mathcal{L}_s \cup \mathcal{L}_e$ be a **language**, where $\mathcal{L}_s$ is a set of sentences which describe situations and $\mathcal{L}_e$ is a set of other meaningful expressions. A situation expressed by a sentence $\alpha \in \mathcal{L}_s$ is called objective of that sentence.

The **pragmatic model** is a structure:

$$\mathcal{M} = (\mathcal{S}, O, R)$$

where:

- $\mathcal{S} = (S, \leq)$ is a pair in which
  - S is a **set of situations**,
  - $\leq$ is a binary relation on $S \times S$ and for $s_1, s_2 \in S$ if $s_1 \leq s_2$, we say that s_1 is a **part** of s_2,
- $O : S \longrightarrow S^{\mathcal{L}_s}$ is a function which for each situation (state) assigns to each sentence $\alpha \in \mathcal{L}_s$ an **objective** of α (i.e. a state),
- $R : S \longrightarrow S^{\mathcal{L}}$ is a function which for each situation (state) assigns to each $\alpha \in \mathcal{L}$ (to a sentence describing situation or other expression) a **result** of α (i.e. a state).

The model assumes two types of pragmatic functions of messages. When an agent utters a sentence $\alpha \in \mathcal{L}_s$ in a situation s_1 then α *describes* some situation s_2 (i.e. $s_2 = O(s_1, \alpha)$) and α *creates* some situation s_3 (i.e. $s_3 = R(s_1, \alpha)$). This means that s_2 is an objective of α and s_3 is its result.

A **persuasive act** is an intentional sentence expressed in intentional language which is a product of the language $\mathcal{L}$ (a set of all sentences) and the language $\mathcal{L}_s$ (a set of "descriptive" sentences):

$$(\alpha, \beta) \in \mathcal{L} \times \mathcal{L}_s$$

where α is understood as a message uttered and β is the sentence describing the goal of uttering α.[2]

In such specified model, various phenomena characteristic for persuasion can be described. We say that a persuasive act (α, β) is **successful** in a situation s in the model $\mathcal{M}$, if $O(s, \beta) \leq R(s, \alpha)$. It means that the success of persuasion (α, β) depends on the relation between its goal $O(s, \beta)$ and its result actually achieved $R(s, \alpha)$. More specifically, the goal must be a part of the result. We can interpret relation $\leq$ in terms of persuader's preferences. Then, we would say that in successful persuasion the goal must be at least as good or as much preferred by a persuader as the result. In

[2] In this model, the first element of persuasive act can consist of the sequence of utterances, where a utterance is defined as $(\alpha, s) \in \mathcal{L} \times S$. However, for the clarity of the review we limit the persuasion to sending a single message.

other words, a persuasion ends with success when its goal (or even more) is achieved. Imagine that Kasia wants to persuade Magda to lend her 100 dollars. Kasia will be successful when Magda gives her 200 dollars (if, of course, Kasia would prefer to have more money). In this example, α could be the expression "Please lend me 100 dollars", β – "Magda lends Kasia 100 dollars", $O(s, \beta)$ is a situation when Magda lends Kasia 100 dollars and $R(s, \alpha)$ is a situation when Magda lends Kasia 200 dollars.

Observe that better and worse success can be expressed in that model. Say that $s_1 < s_2 < s_3 < s_4$ is a persuader's preference relation on the set of situations S and s_2 is her minimal goal. The more successful a persuasive act in a situation s is, the higher in this preference relation a result R(s, α) is. For example, if Kasia's preference relation is: 0 dollars $< \ldots <$ 100 dollars $< \ldots <$ 1000 dollars, and 100 dollars is a minimal loan Kasia is interested in, then a persuasive act (α_1, β) resulting with 200 dollars is more successful than a persuasive act (α_2, β) resulting with 100 dollars.

Moreover, we say that the goal $\beta \in \mathcal{L}_s$ is **achievable** in a situation s in the model $\mathcal{M}$, if there is a successful persuasion (α, β) in that situation s. This notion allows to specify two types of failure in persuasion. We make a tactical mistake when the goal was achievable however we failed to achieve it. While we make a genetic mistake when we didn't achieve the goal but it was not achievable anyway, so it was pointless to start the persuasion.

In the work (Tokarz 2006), Tokarz discusses the other notion of a persuasion goal. $Z(\alpha)$ is a persuasive meaning of a message α, i.e. publicly "announced" goal of sending a message. It may be the case that a persuader declares different goal with a message (**suggested** goal) than the **real** goal that he wants to achieve, i.e. for persuasion (α, β) it may be that $Z(\alpha) \neq O(\beta)$. For example, when a man asks a woman how does she find some movie (α), then the suggested goal is to know her opinion on the movie (Z(α)) while his real goal is to pick her up ($O(\beta)$). It corresponds to the macro and micro levels of argumentation considered in Gilbert's account. The suggested goal can be treated as face goal, while the real goal – as task goal.

Tokarz shows how this distinction allows to express two types of strategies described in psychological models: $foot - in - the - door$ (FITD) and $door - in - the - face$ (DITF). The strategy FITD makes use of the psychological mechanism of consequence. In order to achieve something bigger (100 dollars), first we try to achieve something small (10 dollars). Since people tend to be consequent in decision-making process, the first "small" decision gives a big chance that a persuasion's audience repeat the analogous decision in the "bigger" case. In an experiment (Freedman & Fraser 1966), one group of people were asked to put in their garden an ugly sign advising

to drive carefully. Almost nobody agreed on it. The other group was first asked to put a small sign in their window. After they agreed, they were asked to put the ugly sign in their garden. The most of the subjects in that group agreed to do it. Tokarz proposes to describe this strategy in the following way: $(\alpha, \beta) \in$ FITD iff $Z(\alpha) < O(\beta)$, i.e. the goal suggested is smaller than the real goal of persuasion. The other strategy, i.e. $door - in - the - face$, makes use of the psychological mechanism of reciprocation, i.e. people's tendency to return a favor. To achieve something smaller (100 dollars), first we suggest that we want something much bigger (e.g. 1000 dollars). The rejection of that request may cause a discomfort felt by a persuasion's hearer what in turn will make him prone to accepting the second, smaller request. Formally speaking, $(\alpha, \beta) \in$ DITF iff $Z(\alpha) > O(\beta)$.

In this section we described different types of persuasion goals and specified the "degrees" of preferring its results. In the next section we will show how the degrees of beliefs can be changed by verbal or nonverbal persuasive arguments.

6. Persuasiveness and nonverbal arguments

In his work (Blair 1992), Anthony Blair emphasizes that an argumentation aims to move the audience beliefs from the lower level of **certainty** (e.g. from $\frac{1}{4}$) to the higher one (e.g. to $\frac{3}{4}$). In this section, we introduce the notion of persuasiveness understood as the degree of audiences' belief generated by the persuasion (Budzyńska, Kacprzak & Rembelski 2008). Furthermore, in this section we want to address the aspect of nonverbal means of persuasion. The theory of **visual arguments** by Leo Groarke (e.g. Groarke 2007) shows that different components of argumentation may be expressed via other cues than the verbal ones, e.g., the photography or drawings can play the role of arguments. Nonverbal (visual) means of persuasion can be expressed in the model of persuasive acts (Section 5) as well as in the model of persuasive negotiation (Section 3). The first model assumes that a message remains the same no matter whether it is said (e.g. uttering "Get out") or executed without words (e.g. pointing a finger at a door). In the second model, threats and rewards were allowed to be performed by illocutions (verbal actions) or environmental actions (nonverbal ones).

The example of the formal model which enables to describe *both* of those aspects is a **multimodal logic of actions and graded beliefs** $\mathcal{AG}_n$ proposed by K. Budzyńska and M. Kacprzak (see e.g. Budzyńska

& Kacprzak 2008, Budzyńska, Kacprzak & Rembelski 2008). We use and join elements of Algorithmic Logic (AL) (Mirkowska & Salwicki 1987), Dynamic Logic (DL) (Harel, Kozen & Tiuryn 2000) and Logic of Graded Modalities (LGM) (Hoek 1992). The logic $\mathcal{AG}_n$ can be applied for reasoning about persuasion process where the focus is on influencing beliefs or behavior of audience. This impact is caused by using both verbal and nonverbal means. Furthermore, it is not assumed that this process is initiated by conflict of opinion. The process does not terminate when all parties share one point of view about a thesis but when the audience believes the thesis with the degree which satisfies the proponent. Degrees of beliefs may be changed by provided arguments. It is assumed that arguments are **actions** which can modify environment and/or doxastic relations of agents. Consequently, the logic $\mathcal{AG}_n$ allows for modeling and analyzing persuasiveness of arguments. It can be applied for reasoning about what arguments can bring a success, expressing how the order of provided arguments induce a success or determining optimal sequences of arguments. However it does not deal with the problem of constructing and evaluating arguments and counterarguments as well as studying their correctness.

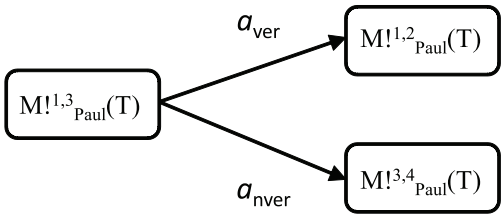

Figure 4. Different results of verbal and nonverbal arguments

To illustrate this approach take into account a scenario in which a dealer tries to convince Paul that a car is very safe and he should buy it. First of all observe that in this situation it is not important what the dealer really thinks about safety of the car and what he publicly declares. Moreover Paul doesn't want to persuade the dealer that it is not true that the car is safe. The focus is only on Paul's beliefs and decisions. **Degrees of agents' beliefs** are modeled by Kripke structure of possible worlds. Say that at the beginning of the persuasion Paul considers 3 possibilities (doxastic alternatives): (1) the car does not have an airbag, (2) the car has an airbag which prevents severe injuries in the case of accident, (3) the car has an airbag but it cannot prevent severe injuries in the case of accident. In only one of three doxastic alternatives it is true that the car is safe, so Paul believes the thesis with

a degree $\frac{1}{3}$ what is denoted by modal formula $M!^{1,3}_{Paul}(safe)$. The doxastic alternatives which an agent i subjectively assume to be true are determined by doxastic relation RB_i defined in the model of $\mathcal{AG}_n$ logic. So, initially Paul is doubtful about the thesis. Then, the dealer says "This car is safe since it has an airbag" (verbal argument denoted by a_{ver}). In consequence the degree of Paul's belief will rise to value $\frac{1}{2}$. This change is expressed by formula $\Diamond(a_{ver} : dealer)M!^{1,2}_{Paul}(safe)$. Instead of the utterance the dealer can show a film with a crash test (**nonverbal argument** denoted by a_{nver}). Now the result may be such that Paul believes the thesis with a degree $\frac{3}{4}$ and the formula $\Diamond(a_{nver} : dealer)M!^{3,4}_{Paul}(safe)$ holds (see Figure 4 where T means the thesis "car is safe"). In this manner we can compare verbal and nonverbal arguments and study their **persuasiveness**. In real life situation it is often the case that a customer buys a product although he is not absolutely sure that this product fulfills all his requirements. So, the dealer may finish the process of argumentation when Paul's belief about safety of the car reaches a degree $\frac{3}{4}$ since it is enough to make him buy the car. It is worth noticing that the arguments which can rise Paul's beliefs to a degree $\frac{3}{4}$ can exist while arguments which rise the beliefs to a degree 1 may not exist – Paul will never absolutely believe that the car is safe. Therefore if we assume that the proponent wins only when the point of view of an audience about the thesis is absolutely positive then such an argumentation would not have a chance to be successful.

Now we are ready to give formal syntax and semantics of the logic $\mathcal{AG}_n$. Let V_0 denote an at most enumerable set of *propositional variables* (also called *propositions*) and Π_0 an at most enumerable set of *program variables* (also called *atomic actions*). Propositional variables represent atomic assertions such as: "the car is safe", which can be either true or false. Further, program variables represent things happening. In the formalism they express giving *arguments*. In addition, we assume the boolean connectives: $\neg$, $\wedge$, $\vee$, $\rightarrow$, $\leftrightarrow$ and one program connective: ; which is a sequential composition operator. By means of this operator we compose *schemes of programs* which are defined as finite sequences of atomic actions: $a_1; a_2; \ldots; a_k$. Intuitively, the program $a_1; a_2$ for $a_1, a_2 \in \Pi_0$ means "Do a_1, then do a_2". We denote the set of all schemes of programs with Π. The last components of the language are modalities. We use modality M for reasoning about beliefs of individuals and modality $\Diamond$ for reasoning about actions they perform. Recall that intended interpretation of $M^d_i\alpha$ is that there are more than d states which are considered by an agent i and verify α. Whereas, a formula $\Diamond(i : P)\alpha$ says that after execution of a program P by an agent i a condition α may be true.

The set of all **well-formed expressions** of $\mathcal{AG}_n$ is given by the following Backus-Naur form (BNF):

$$\alpha ::= p|\neg\alpha|\alpha \vee \alpha|M_i^d\alpha|\Diamond(i:P)\alpha,$$

where $p \in V_0$ is a proposition, $d \in \mathbb{N}$ is a natural number, $P \in \Pi$ is a sequence of arguments (actions), $i \in Agt = \{1, \ldots, n\}$ is an agent.

Other boolean connectives are defined from $\neg$ and $\vee$ in a standard way. The necessity operator $\Box$ is the modal dual of the possibility operator $\Diamond$ and is defined as $\Box(i:P)\alpha \leftrightarrow \neg\Diamond(i:P)\neg\alpha$. We use $B_i^d\alpha$ as an abbreviation for $\neg M_i^d\neg\alpha$ – at most d states considered by i refute α. We use also $M!_i^d\alpha$ where $M!_i^0\alpha \Leftrightarrow B_i^0\neg\alpha$, $M!_i^d\alpha \Leftrightarrow M_i^{d-1}\alpha \wedge \neg M_i^d\alpha$, if $d > 0$. From the definition above, it is clear that $M!_i^d$ means "exactly d". The most important formula that we shall use in reasoning about the persuasion process is $M!_i^{d_1,d_2}\alpha$ which is an abbreviation for $M!_i^{d_1}\alpha \wedge M!_i^{d_2}true$. It should be read as "$i$ believes α with a degree $\frac{d_1}{d_2}$". Thereby, by a **degree of beliefs** of agents we mean the ratio of d_1 to d_2, i.e. the ratio of the number of states which are considered by an agent i and verify α to the number of all states which are considered by this agent. It is easy to observe that $0 \leq \frac{d_1}{d_2} \leq 1$. Intuitively, if an agent believes a thesis α with a degree 1 then he is absolutely sure that α holds while if he believes α with a degree 0 then he is absolutely certain α is false.

The semantics of the language is based on the notions of *valuation* and *interpretation*. A valuation is a function which assigns a logical value of "false" (denoted by **0**) or "true" (denoted by **1**) to every propositional variable at every state. An interpretation assigns to every program variable and to every agent a binary relation in the set of states S. Furthermore, we consider a doxastic function which assigns to every agent a binary relation which will give interpretation of the belief operator. The **model** is defined as follows.

Let Agt be a finite set of names of agents. By a semantic model we mean a Kripke structure $\mathcal{M} = (S, RB, I, v)$ where

- S is a non-empty set of states (the universe of the structure),
- RB is a doxastic function, $RB : Agt \longrightarrow 2^{S\times S}$,
- I is an interpretation of the program variables, $I : \Pi_0 \longrightarrow (Agt \longrightarrow 2^{S\times S})$, where for every $a \in \Pi_0$ and $i \in Agt$, the relation $I(a)(i)$ is serial, and $I(Id)(i) = \{(s,s) : s \in S\}$, where Id is a program constant which means identity,
- v is a function which assigns to every state a valuation of propositional variables $v : S \longrightarrow \{\mathbf{0}, \mathbf{1}\}^{V_0}$ and for every $s \in S$, $v(s)(true) = \mathbf{1}$, where $true$ is a propositional constant.

Function I can be extended in a simple way to define interpretation of any program scheme. Let $I_\Pi : \Pi \longrightarrow (Agt \longrightarrow 2^{S\times S})$ be a function defined by mutual induction on the structure of $P \in \Pi$ as follows:

- $I_\Pi(a)(i) = I(a)(i)$ for $a \in \Pi_0$ and $i \in Agt$,
- $I_\Pi(P_1; P_2)(i) = I_\Pi(P_1)(i) \circ I_\Pi(P_2)(i) =$
  $= \{(s, s') \in S \times S : \exists_{s''\in S}((s, s'') \in I_\Pi(P_1)(i)$ and $(s'', s') \in I_\Pi(P_2)(i))\}$
  for $P_1, P_2 \in \Pi$ and $i \in Agt$.

In other words, $(s, s') \in I_\Pi(P)(i)$ for $P = (a_1; \ldots; a_k)$ and $i \in Agt$ iff there exists a sequence of states $s_0, \ldots, s_k$ such that $(s_{j-1}, s_j) \in I(a_j)(i)$ for $j = 1, \ldots, k$. Intuitively, it means that the state s' can be achieved from the state s if the agent i performs actions $a_1, \ldots, a_k$ in order they appear.

The **semantics** of formulas of $\mathcal{AG}_n$ is defined below.

For a given structure $\mathcal{M} = (S, RB, I, v)$ and a given state $s \in S$ the boolean value of the formula α is denoted by $\mathcal{M}, s \models \alpha$ and is defined inductively as follows:

$\mathcal{M}, s \models p$ iff $v(s)(p) = \mathbf{1}$, for $p \in V_0$,
$\mathcal{M}, s \models \neg\alpha$ iff $\mathcal{M}, s \not\models \alpha$,
$\mathcal{M}, s \models \alpha \vee \beta$ iff $\mathcal{M}, s \models \alpha$ or $\mathcal{M}, s \models \beta$,
$\mathcal{M}, s \models M_i^d\alpha$ iff $|\{s' \in S : (s, s') \in RB(i)$ and $\mathcal{M}, s' \models \alpha\}| > d$, $d \in \mathbb{N}$,
$\mathcal{M}, s \models \Diamond(i : P)\alpha$ iff $\exists_{s'\in S}$ $((s, s') \in I_\Pi(P)(i)$ and $\mathcal{M}, s' \models \alpha)$.

We say that α is true in a model $\mathcal{M}$ at the state s if $\mathcal{M}, s \models \alpha$.

7. Conclusions

The purpose of our work was to present a brief survey of selected models for argumentation in which elements of persuasion are included and emphasized. In this article we tried to juxtapose models based on informal logic with more formal approaches. In conclusions we succinctly list what aspects of persuasion are considered in what proposals and what role they play in argumentation.

Let us start with the model for persuasion dialogs. They are strongly ingrained in the **game theory**. It is assumed that there are two parties in a **conflict** who play the role of a proponent and an opponent. The aim of the game is to resolve the conflict. In pure persuasion, every player tries to convince the adversary to accept his point of view. Thus, this approach allows for modeling systems in which agents need to establish common standpoint to execute joint actions or achieve a collective goal. The next feature of this

model is that it expresses different kinds of **interactions** between participants of the persuasion process. They are modeled by means of speech acts. Players of a game do not limit they utterances to claim a thesis and give arguments supporting them but also can concede, retract, ask questions. Another important element of the model are protocols. They determine stages of a persuasion dialog, i.e. define legal moves, possible requests, show how to create and evaluate arguments, etc. In fact, they form methods of **resolving a conflict**. Since it is a model of dialogs the conflict's resolution can be done only with the use of **verbal means**. Other tools are not considered. The last feature of the approach is that agents argue about the publicly declared **commitments** rather than beliefs. It is especially important in scenarios where a proponent, e.g. a car dealer, does not believe a thesis which he claims but he tries to defend it in order to obtain a desired result, e.g, to sell a car.

The second proposal we describe is a model of the persuasive negotiation. The most important feature of this model is that it takes into consideration arguments that **appeal to emotions**. Thereby in this approach we can reason about argumentations in which participants apply not only logical arguments but also arguments which refer to feelings such as fear, greed, desire etc. Moreover, arguments can be **illocutionary actions** or **environmental actions**. It means that arguments are verbally expressed or they change the world in which participants exist. Another feature is possibility of expressing **trust** between agents. It is the crucial element of persuasion since the result of this process depends not only on issue-relevant arguments but also on an agent who gives them. In many cases, a proponent who enjoys huge respect may accomplish much more than the most convincing reasons.

The main feature of the third approach is that it models a reasoning, the aim of which is to influence somebody's behavior and activity rather than beliefs. Thereby, it allows the formalization of elements of **practical reasoning**. Indeed, in many scenarios a persuader wants to make somebody do something and does not care about his beliefs. For example, Mary intends to convince her friend Paul to drive her to work. Assume Paul thinks that it is not a good idea since he is very busy now. Notice that in such a situation Mary will be satisfied when Paul gives her a lift even though he does not change his mind and still believes it was abuse of his courtesy. Furthermore, this model takes into consideration the **values** of actions and the goals of these actions. The goals that we consider in practical arguments may promote the different values such as friendship, convenience or low financial cost.

In the fourth approach the most important thing is the distinction between the **intended goal** of performing action and its **real result**. So, the model makes possible to reason about success of arguments and relation between an argument and circumstances in which it is provided. It is obvious that if somebody gives an argument, he may or may not be successful depending on a situation in which it is executed (e.g. when an audience is in a good mood or when it is nervous). Moreover, in this model two types of arguments' goals are distinguished: **suggested** (face) and **real** (task). The first one refers to those which performers publicly declare. The second goals are the real ones but possibly hidden. Awareness of these two types of goals is very helpful when we want to recognize and attack real reasons for which somebody believes something or acts in some way. The model also expresses two different **mistakes** that cause failure of a proponent: tactical and genetical. The tactical mistake consists in realization of wrong strategy. The genetical mistake points at specific situations in which no argument is effective.

The fifth approach is a formalization of persuasion process specified by two key elements: **grades** of beliefs and **actions** which can result in changes of these grades. It is the proposal where intermediate stages leading to a success can be modeled and signified by values. Application of beliefs' degrees allows for reasoning about **persuasiveness** of arguments, i.e., not only whether they can bring a success but also how big such a success is. Furthermore, it is assumed that an argument is effective when it causes that audience believes a thesis with a fixed degree which is not necessarily equal to the highest one. It means that in some situations persuasion finishes with success although audience is not absolutely sure that a thesis is true. Next, in this approach the change of a state of a system is a result of actions. Actions can model **verbal** and **nonverbal** arguments. Moreover, they can influence both beliefs or situations in which a persuasion is executed. Therefore, a proponent can make an audience modify the degree in which it believes the thesis or actions it wants to perform. The other important fact is that the **result** of persuasion may depend on (1) arguments, (2) proponent (especially his credibility), (3) audience. This means that the same arguments can bring different results depending on who is the audience or who is the persuader. The model also allows to show the difference in the effects of performing the same arguments in various **orders**.

The review shows that there is no uniform model of persuasion which captures all its elements. The problem of formalization of persuasive argumentation is difficult and ambitious since it is extremely hard to identify, capture and formally model some of its aspects. Although there is little work

on formal systems for persuasion, this field arouses big interest. Therefore the described approaches offer very valuable base which may give rise to the further research.

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