Modeling Persuasiveness: change of uncertainty through agents' interactions

K. Budzyńska[1] M. Kacprzak[2] Paweł P. Rembelski[3]

[1] Institute of Philosophy, Cardinal Stefan Wyszynski University in Warsaw, Poland

[2] Faculty of Computer Science, Bialystok University of Technology, Poland

[3] Faculty of Computer Science, Polish-Japanese Institute of Information Technology

Conference on Computational Models of Argument
Toulouse, May 28 - 30, 2008

Outline

PERSEUS

Outline

1. PERSEUS Project
2. Strength and dynamics of persuasion
   - Example
   - Formal models
3. Formalization
   - Syntax and semantics
   - Axiomatization
4. Investigation of the persuasion systems

PERSEUS

PERsuasiveness: **S**tudies on the **E**ffective **U**se of argument**S**

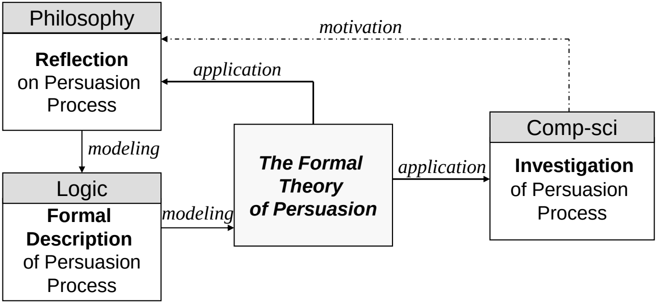

Figure: *The Perseus Project and the Formal Theory of Persuasion.*

The notion of persuasion

Definition (Walton and Krabbe)

- Persuasion dialogue - dialogue of which initial situation is a **conflict of opinion** and the aim is to resolve this conflict by verbal means and thereby influence the **change of agents' beliefs**

The **aspects** of persuasion we want to model:

1. **Persuasiveness** - a *degree of changes* in the agent's beliefs induced by the persuasion
2. **Dynamics of persuasion** - *tracking changes* in the belief state of an agent at *any intermediate stage* of the persuasion

PERSEUS

The **aim** of our theory

Investigation into **properties of persuasion systems** based on existing theories (instead of developing and implementing arguing agents or determining their architecture and specification)

1. **Logic** allowing to express such properties of multi-agent systems
2. **Software system** allowing to examine selected multi-agent systems

PERSEUS

Outline

PERSEUS

Outline

- Ann and Paul discuss where John is spending his summer holidays this year.
- Ann allows scenarios in which John is in Italy, Spain or Peru.
- Paul wants to convince her that John is in Alaska.

Figure: Before the persuasion

- *Paul*: Last time I met John in a restaurant he told me about great discounts for vacation in Alaska.
- *Ann*: Hm, Alaska - I really dont know. But it could be interesting...

Figure: An argument a_1

- *Paul*: You know that John likes original places.
- *Ann*: Yes, you are right. He wouldn't choose Italy or Spain - it would be too trivial for him.

Figure: An argument a_2

- *Paul*: Do you know that he spent whole month in Peru last year?
- *Ann*: Really? He wouldn't visit the same place twice!

Figure: An argument a_3

PERSEUS

Assumptions

the thesis T: "John spends his summer holidays in Alaska"

1. START: Ann is absolutely sure that **T is false**
2. intermediate stages: **each successive argument increases her certainty** that T is true
3. END: after a_3 Ann is absolutely sure that **T is true**

Outline

Motivation

The **formal tool** that allows to:

1. express **persuasiveness**, i.e. a *degree of changes* in Ann's beliefs
   - in what degree Ann is convinced of T after the given argumentation
   - one argumentation may be more persuasive than the other one
2. **track the changes** in her belief state at *any intermediate stage* of the persuasion
   - how Ann reacts after each successive argument
   - the changes in her beliefs after a_1, then after a_2 and finally after a_3

NON-GRADED DOXASTIC LOGIC

Expressiveness

The **degrees of belief** of an agent with respect to a thesis T:

1. $B(\neg\ T)$ - a negative belief
   - the agent believes T is false
2. $N(T)$ - a neutral belief
   - the agent is not sure if T is true or false
   - $N(T)$ wtw $\neg B(T) \wedge \neg B(\neg\ T)$
3. $B(T)$ - a positive belief
   - the agent believes T is true

Dynamics in non-graded logic

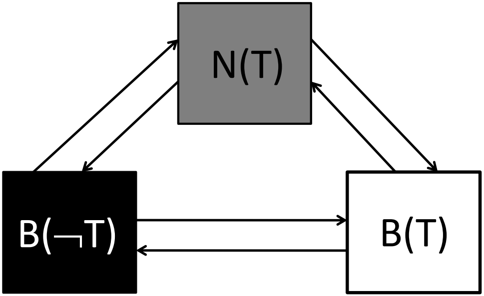

Figure: Dynamics of persuasion

The "Alaska" example

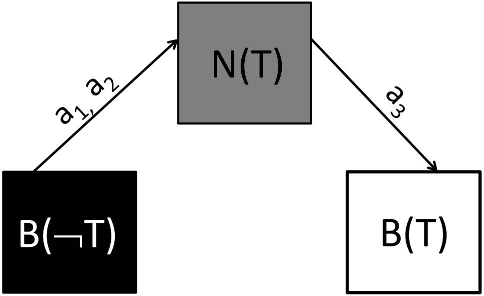

Figure: The change of beliefs induced by Paul's argumentation

GRADED BELIEFS

Expressiveness

If we wanted to describe **three types of uncertainty**, our model should include five belief states:

1. 0 - absolutely negative beliefs
2. $\frac{1}{4}$ - **rather negative** beliefs
3. $\frac{1}{2}$ - **"fifty-fifty"**
4. $\frac{3}{4}$ - **rather positive** beliefs
5. 1 - absolutely positive beliefs

PERSEUS

Dynamics in the model of graded beliefs

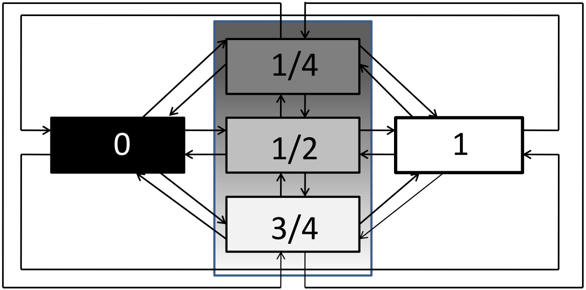

Figure: Dynamics of persuasion

The "Alaska" example

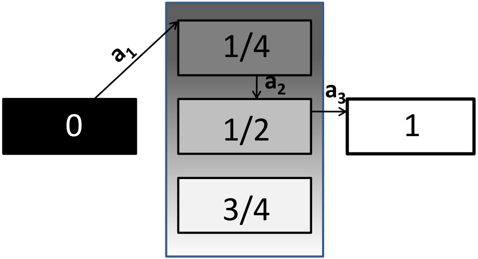

Figure: The change of beliefs induced by Paul's argumentation

The extension

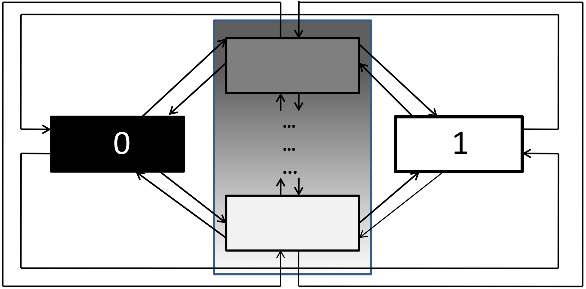

Figure: The extension of the model of beliefs' change

Outline

1. PERSEUS Project
2. Strength and dynamics of persuasion
   - Example
   - Formal models
3. Formalization
   - Syntax and semantics
   - Axiomatization
4. Investigation of the persuasion systems

GRADED BELIEFS

Inspiration

Logic of graded modalities:
Wiebe van der Hoek, Modalities for reasoning about knowledge and quantities, Amsterdam, 1992

Basic doxastic formula

The basic formula we use for expressing *uncertainty* is:

$$M!_j^{d_1, d_2}\ \mathrm{T}$$

where d_1, d_2 are natural numbers.

- Intuitively: in exactly d_1 doxastic alternatives the thesis T is true among d_2 doxastic alternatives the agent j considers as possible.
- We say that j believes T with degree $\frac{d_1}{d_2}$.

PERSEUS

The "Alaska" example

$\mathcal{M}, s_1 \models M!^{0,3}_{aud}T$ since exactly 0 states satisfy T among 3 accessible states considered by the audience

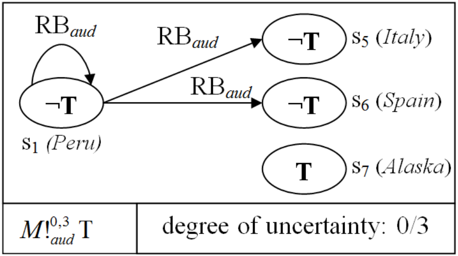

Figure: Uncertainty of Ann about the place where John is spending holidays.

Graded modalities

Other doxastic operators

- $M_i^d \alpha$ - agent *i* considers more than *d* accessible worlds verifying α
- $B_i^d \alpha$ - agent *i* reckons with at most *d* exceptions for α
- $M!_i^d \alpha$ - agent *i* considers exactly *d* accessible worlds verifying α

PERSEUS

CHANGE OF GRADED BELIEFS

Inspiration

Dynamic logic:
D. Harel, D. Kozen, and J. Tiuryn, Dynamic Logic, MIT Press, 2000.

Algorithmic logic:
G. Mirkowska and A. Salwicki. Algorithmic Logic, Polish Scientific Publishers, Warsaw, 1987.

Basic formula

The basic formula which expresses the *change* of uncertainty is:

$$\Diamond(i : P)M!_j^{d_1,d_2}\, \mathrm{T}$$

Intuitively: after execution of a sequence of arguments P performed by i it is possible that j will believe T with degree $\frac{d_1}{d_2}$.

The "Alaska" example

$$\mathcal{M}, s_1 \models \Diamond(prop : a_1; a_2; a_3)M!^{1,1}_{aud}T$$

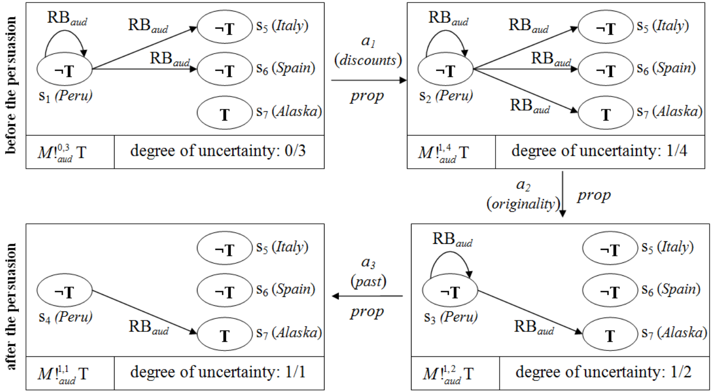

Figure: The change of Ann's uncertainty during the persuasion.

Outline

Syntax

The set F 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 is a propositional variable, d is a natural number, P is a program scheme, $i \in \{1, \ldots, n\}$ is a name of an agent.

Model

Definition

Let $Agt = \{1, 2, \ldots, n\}$ be a finite set 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,
- RB is a doxastic function, $RB : Agt \longrightarrow 2^{S \times S}$, where for every $i \in Agt$, the relation $RB(i)$ is serial, transitive and euclidean,
- 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,
- $v : S \longrightarrow \{\mathbf{0}, \mathbf{1}\}^{V_0}$ is a valuation function.

PERSEUS

Semantics

Definition

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:

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

Outline

PERSEUS

Inference rules

(Modus Ponens)

R1 $\frac{\alpha, \ \alpha\rightarrow\beta}{\beta}$

(Necessitation for graded beliefs)

R2 $\frac{\alpha}{B_i^0\alpha}$

(Necessitation for programs)

R3 $\frac{\alpha}{\Box(i:P)\alpha}$

Axioms

[A0] classical propositional tautologies
[A1] $M_i^{d+1}\alpha \rightarrow M_i^d\alpha$ (analogue of modal system K)
[A2] $B_i^0(\alpha \rightarrow \beta) \rightarrow (M_i^d\alpha \rightarrow M_i^d\beta)$
[A3] $M!_i^0(\alpha \wedge \beta) \rightarrow ((M!_i^{d_1}\alpha \wedge M!_i^{d_2}\beta) \rightarrow M!_i^{d_1+d_2}(\alpha \vee \beta))$
[A4] $M_i^d\alpha \rightarrow B_i^0 M_i^d\alpha$ (negative introspection)
[A5] $M_i^0 M_i^d\alpha \rightarrow M_i^d\alpha$ (positive introspection)
[A6] $M_i^0(\mathit{true})$ (consistency of beliefs)
[A7] $\Box(i:P)(\alpha \rightarrow \beta) \rightarrow (\Box(i:P)\alpha \rightarrow \Box(i:P)\beta)$
[A8] $\Box(i:P)(\alpha \wedge \beta) \leftrightarrow (\Box(i:P)\alpha \wedge \Box(i:P)\beta)$
[A9] $\Box(i:P_1;P_2)\alpha \leftrightarrow \Box(i:P_1)(\Box(i:P_2)\alpha)$
[A10] $\Box(i:P)\alpha \rightarrow \Diamond(i:P)\alpha$
[A11] $\Box(i:P)\mathit{true}$
[A12] $\Box(i:Id)\alpha \leftrightarrow \alpha$

Soundness and completeness

Theorem

$\mathcal{AG}_n$ is sound and complete with respect to $\mathcal{M}$.

The proof is based on the completeness results for normal modal logics with graded modalities, epistemic logics, and dynamic logics (the technique of the canonical models for classical modal logics).

Outline

PERSEUS

Research questions

We would like to learn about properties of the persuasion systems such as:

- "What chances has a persuader to influence a degree of others' beliefs about a given thesis?",
- "How significant will be such a change?",
- "Would rearrangement of arguments give better or worse effect?", etc.

Questions' grammar

Context-free grammar

$$\phi ::= \omega | \neg\phi | \phi \vee \phi | M_i^d \phi | \Diamond(i : P)\phi | M_i^? \omega | \Diamond(i :?)\omega$$

where ω is defined as follows

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

and $p \in V_0$, $d \in \mathbb{N}$, $i \in Agt$.

PERSEUS

Examples of questions

Verification of a property

$$\mathcal{M}, s \models \Diamond(ag1 : a1; a2; a3)M!^{2,3}_{ag2}p$$

Question about the degree of beliefs

$$\mathcal{M}, s \models \Diamond(ag1 : a1; a2; a3)M!^{?,?}_{ag2}p$$

Question about arguments

$$\mathcal{M}, s \models \Diamond(ag1 : ?)M!^{2,3}_{ag2}p$$

PERSEUS

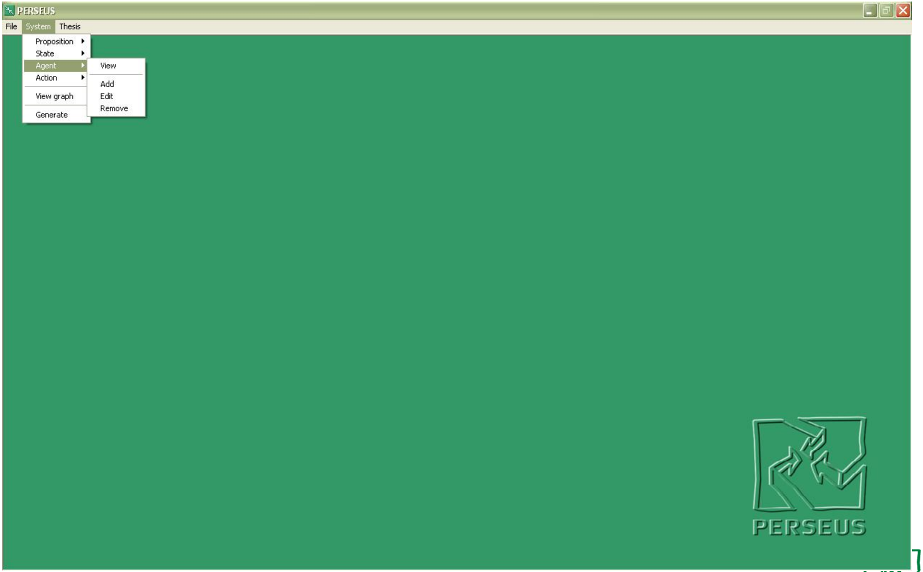

Figure: PERSEUS - the program window

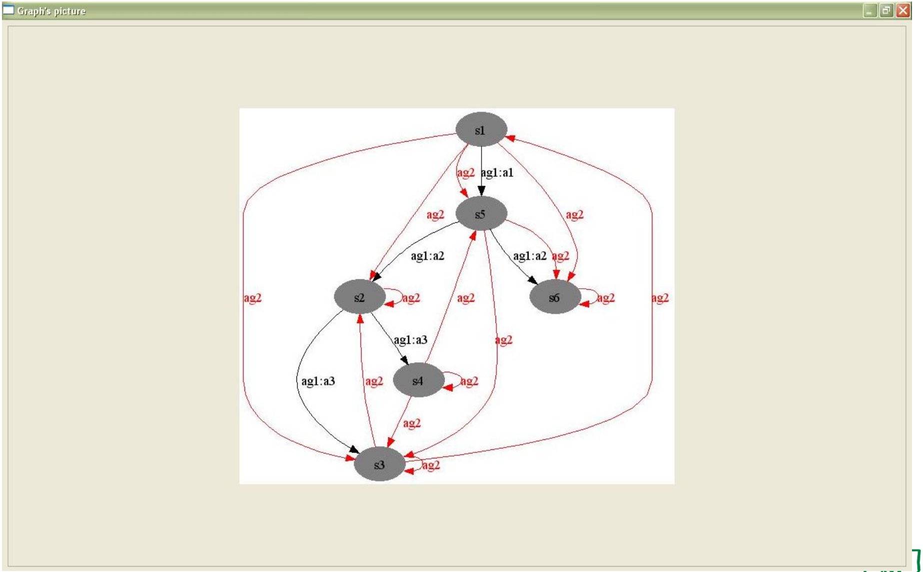

Figure: PERSEUS generates the graph of the model

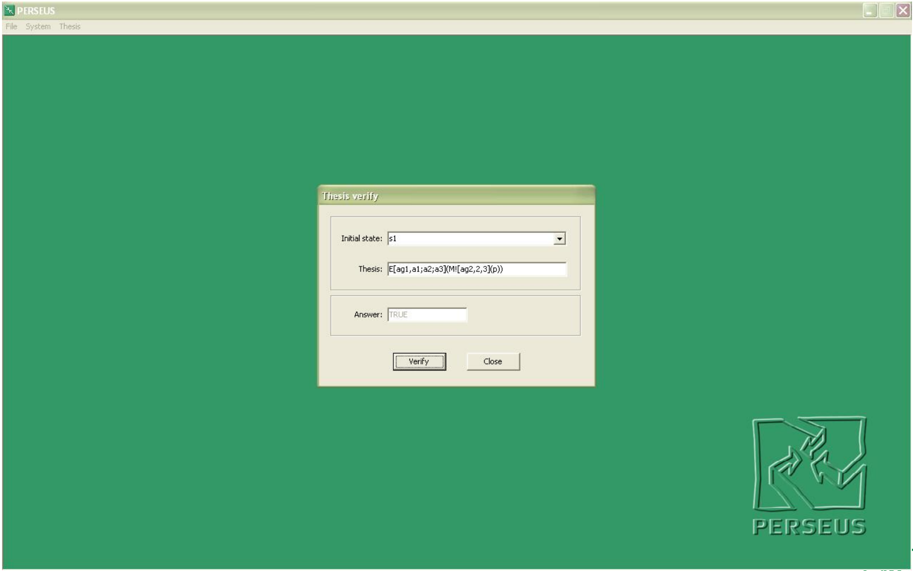

Figure: PERSEUS verifies the property

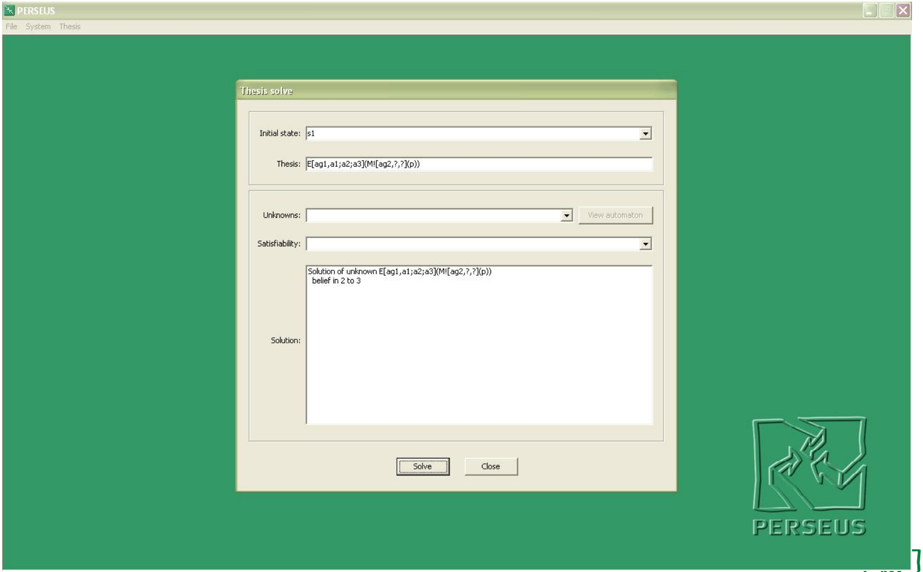

Figure: PERSEUS solves the question

Summary

- Formal model of persuasion including *dynamics* of this process and *uncertainty* of beliefs.
- Logic in which we can express the properties of persuasion.
- Investigation of persuasion systems.

PERSEUS

Thank you.

Figure: to be continued...

For Further Reading I

- K. Budzyńska and M. Kacprzak.
  A logic for reasoning about persuasion.
  Fundamenta Informaticae, IOS Press 85(2008).

- K. Budzyńska and M. Kacprzak and P. Rembelski
  Investigation into properties of persuasion systems.
  Proc. of Workshop on Logics for Agents and Mobility (LAM'08)
  2008.

- K. Budzyńska and M. Kacprzak
  Aristotle, Rhetoric and Probability.
  Proc. of 3rd Tokyo Conference on Argumentation, 2008.

- http://perseus.ovh.org/