Argumentation in Multi-agent Systems

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Outline

Part I
What one can argue about

Part II
How to argue

Part I

What one can argue about

Introduction

- Theory of Argumentation
  - Rich, interdisciplinary area of research
    - Philosophy
    - Communication studies
    - Linguistics
    - Psychology
  - Theoretical and practical branches
    - Artificial Intelligence
    - Computer Science

Introduction

- Theory of Argumentation
  - Applications
    - Specifying semantics to logic programs
    - Natural textual generation
    - Supporting legal reasoning
    - Decision-support for multi-party human decision-making
    - Conflict resolution
  - Interest in MAS Community
    - Autonomous agent reasoning
    - Multi-agent interaction

Introduction

- Events
  - ArgMAS@AAMAS
    - 2004-2009
  - Computational Models of Argument (COMMA)
    - 2006, 2008
- New Book
  - "Argumentation in Artificial Intelligence"
  - Edited by I. Rahwan and G. R. Simari
- New Journal
  - "Argument & Computation"
  - Editors: Chris Reed, Floriana Grasso, Iyad Rahwan and Guillermo R. Simari

Definition

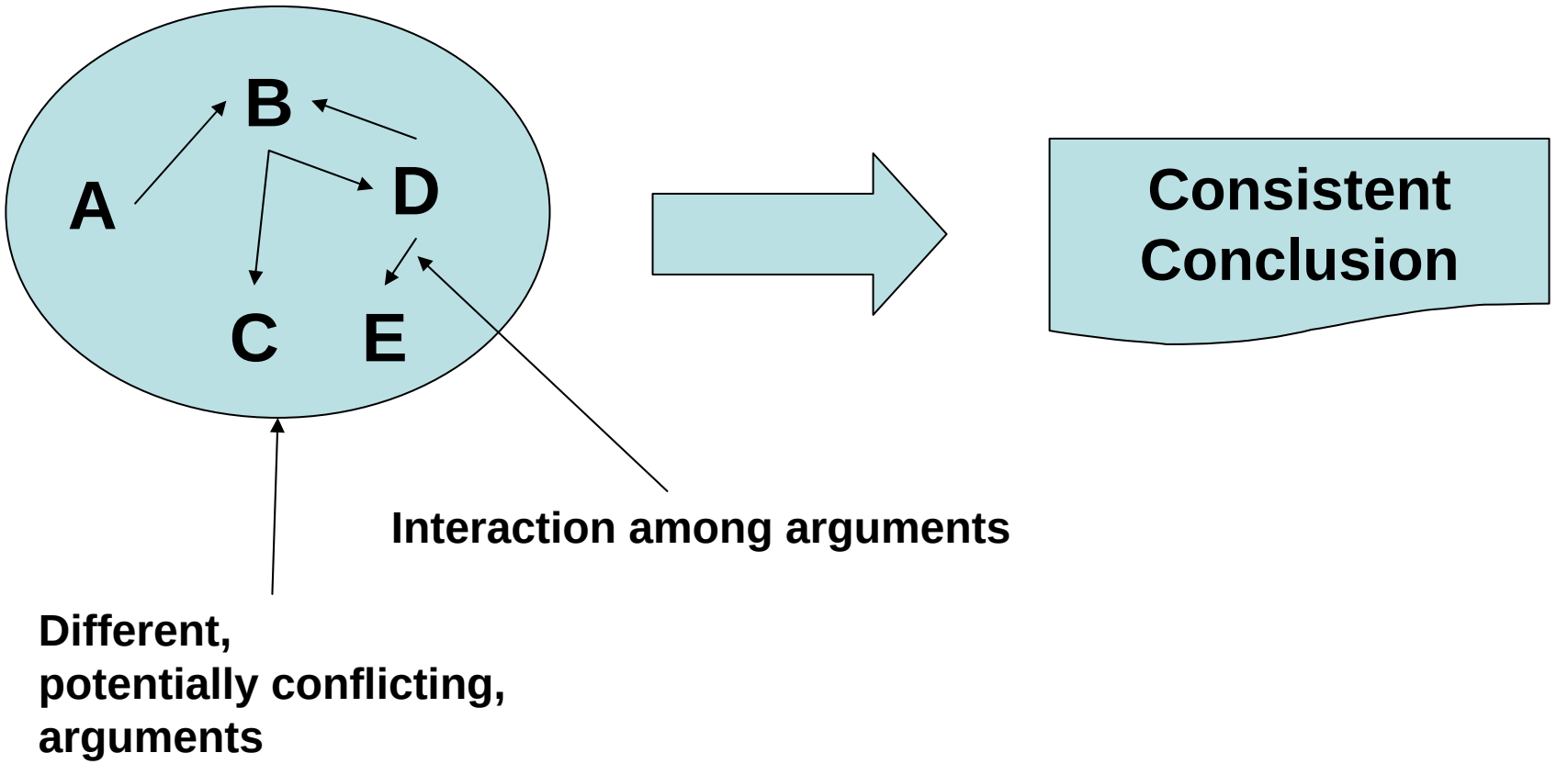
Argumentation is a verbal and social activity of reason aimed at increasing (or decreasing) the acceptability of a **controversial standpoint** for the listener or reader, by putting forward a constellation of propositions intended to **justify** (or **refute**) the standpoint before a rational judge.

What is Argumentation good for?

- Argumentation can be used for
  - Theoretical reasoning
    - About what to believe
  - Practical reasoning
    - About what to do

- Activity of reason
  - Evaluation by a rational judge
    - System that defines the reasonableness of these proposition
      - According to **some criteria**

What is Argumentation good for?



What is Argumentation good for?

- Two main sorts problems encountered in MAS
  - Forming and revising believes and decision
    - Forming beliefs and decisions on the basis of
      - Incomplete, conflicting and uncertain information
  - Rational interaction
    - Structuring dialogue among participants
      - Potentially conflicting viewpoints

Argumentation for Reasoning in Autonomous Agents

- Argumentation for Belief Revision
  - Problem
    - Maintenance and updating agent's beliefs in a dynamic environment
    - Perceptual information X Its view of the world
  - Nonmonotonic reasoning formalisms
    - Specify efficient ways to update beliefs
  - Argumentation-based frameworks
    - View the problem of nonmonotonic reasoning as a
      - Process in which arguments for and against certain conclusions are constructed and compared
    - Various argument-based frameworks has been proposed in the last 20 or so years

Argumentation for Reasoning in Autonomous Agents

- Argumentation for Belief Revision
  - Incorporation of argument-based frameworks into *situated* autonomous agent reasoning
    - Opportunity to be pursued
  - Challenges
    - Representation of the environment
    - Mechanism for integration perceptual information into belief-update mechanism
    - Updating beliefs in a timely fashion

Argumentation for Reasoning in Autonomous Agents

- Argumentation for Deliberation and Means-end Reasoning
  - Agents: two additional tasks
    - Deliberation
    - Means-end reasoning

Argumentation as a means for choosing goals

Argumentation has also been used for planning

Question: Will argumentation offer real advances over existing planning algorithms?

  - More generally
    - Argumentation provides a frameworks for making decisions
      - Beliefs
      - Goals
      - Actions

Argumentation for Agent Communication

- MAS
  - Agents need to communicate
    - Individual aims
    - Collective aims
- Argumentation
  - Improve expressivity
  - Benefits
    - Efficiency
      - Agents reveal relevant pieces of information
    - Verifiable semantics
      - Agent's ability to justify their claims
    - Protocols more flexible
      - Mechanisms based on commitments

Argumentation for Agent Communication

- Challenges on communication by means of argumentation
  - Integration with agents' reasoning
  - Validation of provable desirable properties of these protocols
  - Communication among potentially heterogeneous agents
    - Argument interagent format

Argumentation for Agent Communication

- Efficiency of Argumentation
  - Argumentation make communication more efficient
    - Allows agents to reveal relevant pieces of information when it needed during a conversation
    - Evidence ??
  - Argumentation → computational and communication overload
  - Karunatillake and Jennings
    - “Is it worth arguing?”
      - Argumentation turns out to be effective when the number of resource involved in the task allocation problem remains rather limited

Argumentation for Agent Communication

- Flexibility of Communication
  - Studying different types of dialogues
    - Dialogue-games
      - Influential in AI and MAS
      - Means for specifying protocols
      - Roots in the philosophy of argumentation
  - Dialogue-game protocol
    - Commencement rules
    - Combination rules
    - Commitment rules
    - Termination rules

- Flexibility of Communication

Dialogue Type	*Dialogue Goal*	*Initial situation*
Persuasion	resolution of conflict	conflict of opinion
Negotiation	making a deal	conflict of interest
Deliberation	reaching a decision	need for action
Information seeking	exchange of information	personal ignorance
Inquiry	growth of knowledge	general ignorance

Argumentation for Agent Communication

- Flexibility of Communication
  - Advantages of dialogue-games
    - They offer an intuitive approach to defining protocols
    - They naturally lend themselves to argumentation-theoretic analysis
    - Good compromise between the strict rule-governed nature of many implemented agent systems
    - Greater expressiveness envisioned by generic agent communication languages
  - Challenges
    - Find the good degree of flexibility
    - Reduce the autonomy of agents to prove interesting properties X allow agents to exchange arguments in a way that is deemed “natural” and flexible

Argumentation for Agent Communication

- Integration of Argumentation and Reasoning
  - Argumentation
    - Agents reasoning + structure communication
      - Can naturally provide a means for integrating communication with reasoning in a unified framework
  - ***A1: Can you please give me a nail?***
  - ***A2: Sorry, I need it for hanging a mirror.***
  - ***A1: But you can use a screw and a screw driver to hang a mirror! And if you ask me, I can provide you with these.***
  - ***A2: Really? I guess in that case, I do not need the nail. Here you go.***
  - ***A1: Thanks.***

Argumentation for Agent Communication

- Integration of Argumentation and Reasoning
  - Reasoning and Planning
    - Argumentation used by agents to form beliefs about the environment
    - Generate plans for achieving their goals
  - Generating Utterances
    - Argumentation used to generate arguments for utterances and arguments
  - Evaluating Incoming Communication
    - Argumentation-based belief-revision
  - Communication Structuring
    - Argumentation-based protocols
      - Argumentation schemes for reasoning about resources and plans

Argumentation for Agent Communication

- Integration of Argumentation and Reasoning
  - Argumentation schemes
    - Capture stereotypical patterns of reasoning
    - Associated with a set of *critical questions*
  - Important issue on the boundary between communication and internal reasoning
    - Argumentation dialogue strategies
  - Effects of a specific set of agents attitudes on dialogue outcomes
    - Confident agent
      - Happy to asset statements for which it has an argument
    - Careful agent
      - Makes assertions only after going through its whole knowledge base and making sure it has not arguments against it

Argumentation for Agent Communication

- Properties of Protocols
  - Growing number of dialogue protocols
    - Need to understand the properties of such protocols
    - Without this knowledge
      - No basis for choosing between them
      - Assessing whether they are adequate for a given purpose
  - Two recent developments in this area
    - The methodology adopted so far seems a rather unsatisfactory approach
      - Much more use would be to have a meta-theory of protocols
    - In order to assess the quality of a protocol
      - It is important to distinguish what is inherent to the problem itself

Argumentation for Agent Communication

- Argument Interchange Format
  - Major barrier to the development and practical deployment of argumentation systems
    - Lack of a shared, agreed notation for an “interchange format” for argument and argumentation
  - Recently proposed
    - Argument Interchange Format (AIF)
      - Represents a consensus “abstract model”
      - It can be extended to capture a variety of argumentation formalisms and schemes

Concluding Remarks

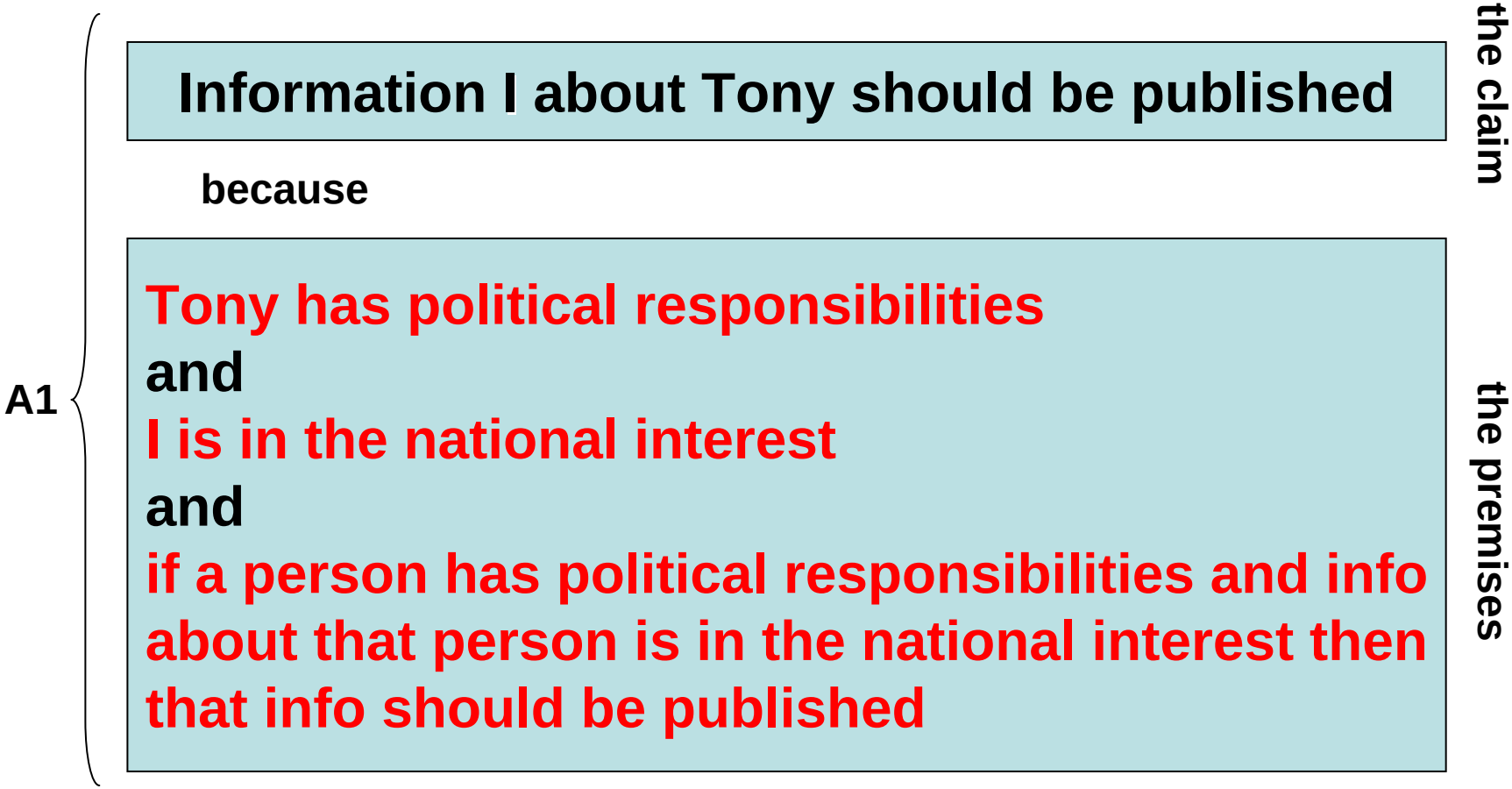
- Argumentation theory
  - Concerned with the study of rational human reasoning and dialogue
  - Ideal resource for techniques, results and intuitions for
    - Multi-agent reasoning and communication
  - We need to integration argumentation systems into the reasoning process of agents
  - We need to understand better how to design argumentation-based agents interactions so that they achieve the things we want
  - We need to be able to show the effectiveness of argumentation-based interactions

Part II

How to argue

What is an Argument?

- A set of premises offered in support of a conclusion /claim



What is Argumentation?

- The process whereby arguments are constructed, exchanged and evaluated in light of their interactions with other arguments

A1 (publish info about Tony because political responsibilities...)

A2 (Tony does not have political responsibilities because Tony resigned from parliament and if a person resigns...)

A3 (Tony does have political responsibilities because he is now middle east envoy and if a person is...)

Agents and Arguments

- 1) Arguments
  - Proofs of claims in underlying logic
- 2) Interactions between arguments are defined
- 3) Evaluate winning arguments in argument graph

- $\Rightarrow$ claims represent beliefs, goals and actions

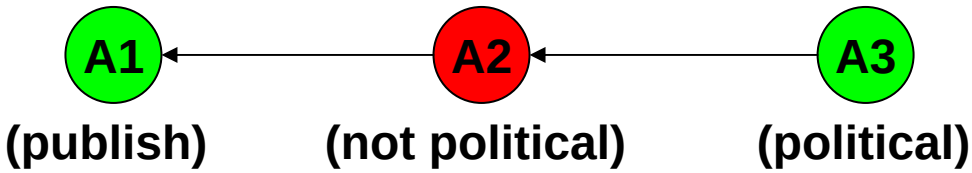
- Inherently dialectical nature of argumentation theory provide principled ways in which to structure exchange of, and reasoning about arguments for proposals/statements between human/automated agents
  - (e.g. in persuasion, negotiation, deliberation dialogues)

Agents and Arguments

- Negotiation dialogue between a buyer and seller of cars:
  - ***Seller (Offer: Renault)***
  - ***Buyer (Reject: Renault)***
  - ***Seller (Why?)***
  - ***Buyer (Argue: Renault is French, and French cars are unsafe)***
  - ***Seller (Argue: Renaults are not unsafe as have been awarded safest car in Europe by EU)***
  - ***Buyer (Accept)***
- Exchange of arguments provides for agreements that would not be reached in simple handshaking protocols

Dung's Abstract Argumentation framework

- **Definition 1.** *An argumentation framework is a pair* $Ar = (Ar, def)$ *where Ar is a set of arguments and* $def \subseteq Ar \times Ar$ *. We say that A defeats B iff* $(A, B) \in def$ *.*
  - "*Calculus of opposition*" applied to determine winning arguments

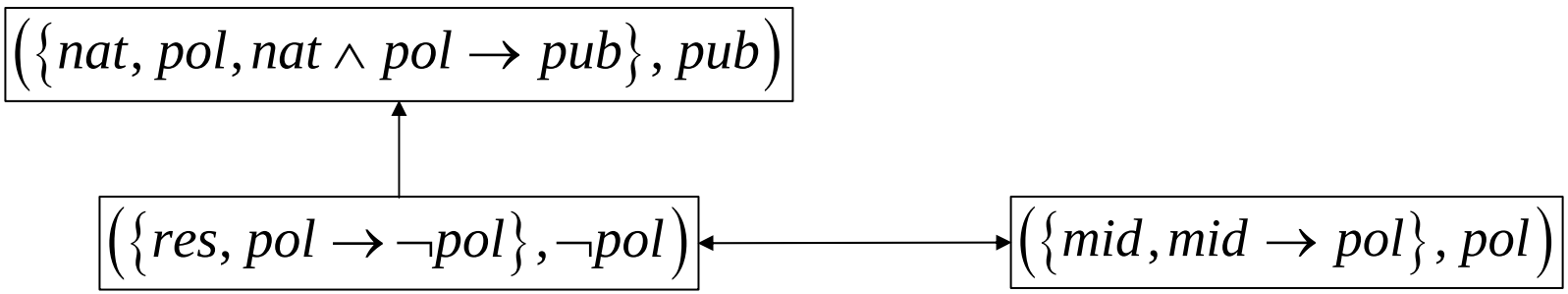


- (Ar, def) abstracts from underlying logic based definition of Ar and def
  - Ar = proofs of conclusions (claims)
  - def = logic specific definition of conflict

Propositional Classical Logic Example

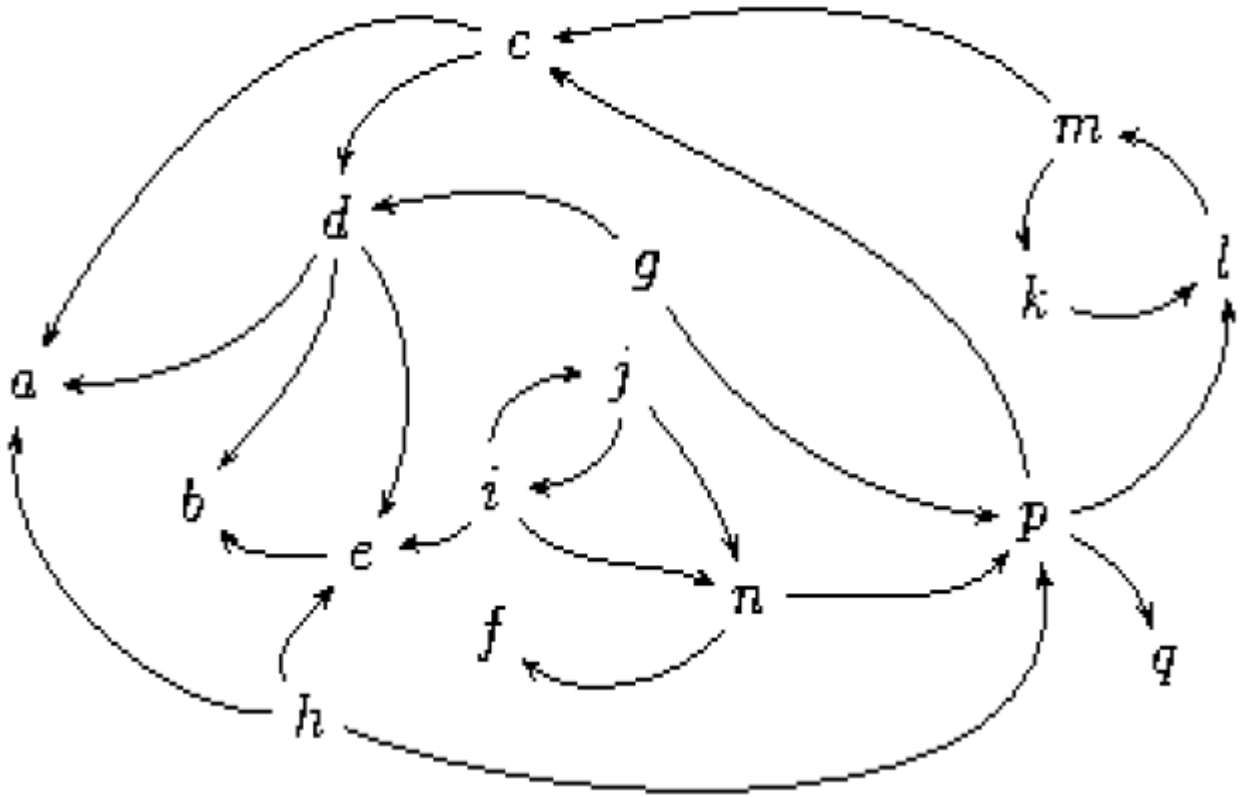
- Δ is a set of propositional classical logic formulae
- Ar = { (H,h) | H is consistent,
  H $\rightarrow$ h,
  H is minimal }
- (H1,h1) and (H2,h2) *rebut* attack each other iff $h1 \equiv \neg h2$
  - attack one of the **conclusions** of the other argument
- (H1,h1) *undercut* attacks (H2,h2) iff $h1 \equiv \neg h$ for some $h \in h2$
  - attack the **reasons** of the other argument

$$\Delta = \{nat, pol, nat \wedge p \rightarrow pub, \quad res, res \rightarrow \neg pol, \quad mid, mid \rightarrow pol\}$$



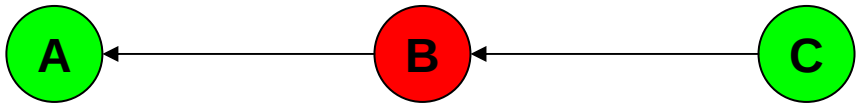
Argumentation Semantics

- AF = (Ar, def)

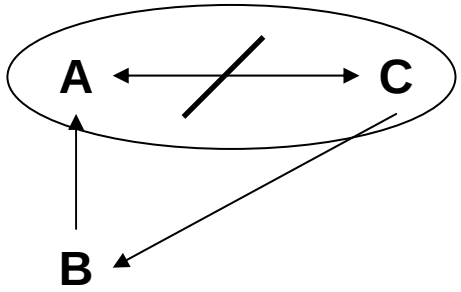


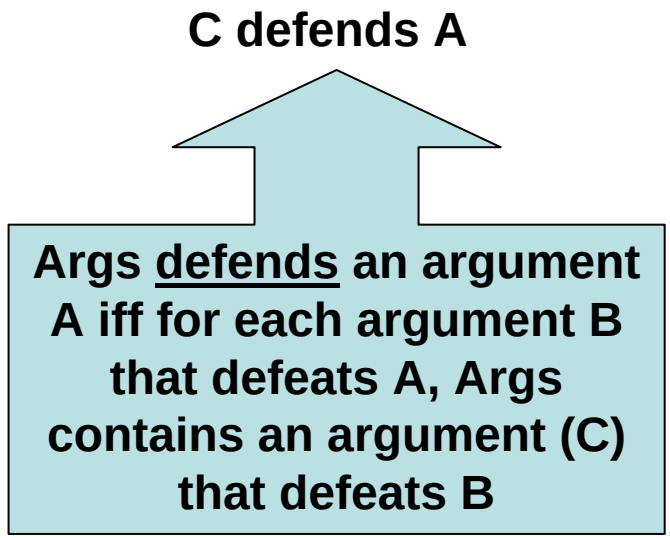
- What are the justified / rejected / undecided arguments?

Dung's Calculus of Opposition



- S =





- Let AF = (Args, Attack) and $S \subseteq Args$
- $A \in Args$ **is acceptable** w.r.t. S iff $\forall B \in Args \quad s.t. \quad (B, A) \in Attack$

$$\exists C \in S \quad s.t. \quad (C, B) \in Attack$$

- Intuitively, in defending an argument A, any C that I use to defend A against an attack by some B must not conflict with A and must itself be defendable against any attack

Some definitions

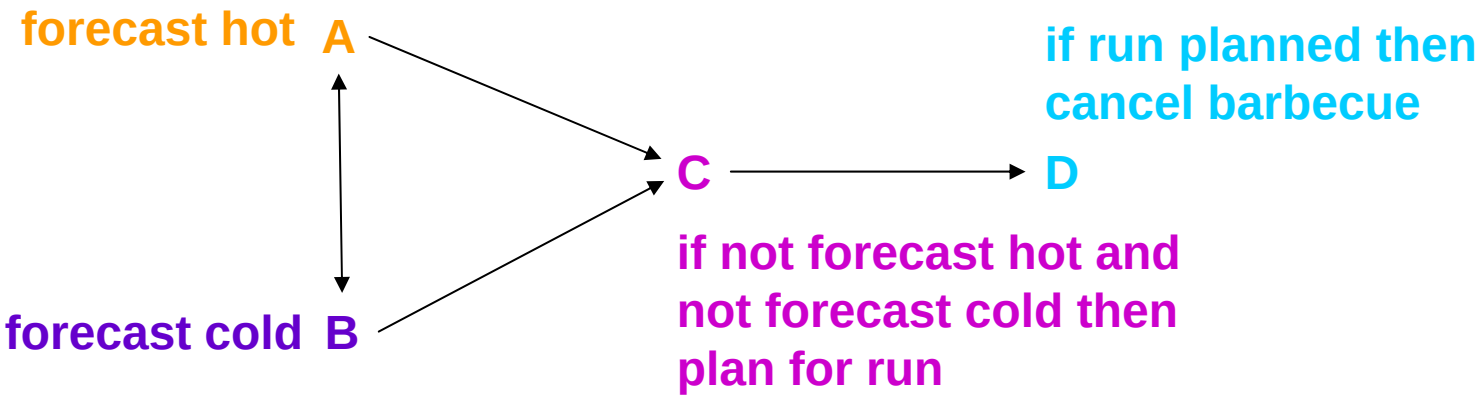
- **Definition 2.** A set S of arguments is said to be ***conflict-free*** if there are no arguments A, B in S such that A attacks B.

- **Definition 3.**
  - (1) An argument $A \in Args$ is ***acceptable*** with respect to a set S of arguments iff for each argument $B \in Args$: if B attacks A then B is attacked by S.
  - (2) A conflict-free set of arguments S is ***admissible*** iff each argument in S is acceptable w.r.t. S.

Dung's Acceptability Semantics

- Let AF = (Args, Attack) and let S be a conflict free subset of Args. Then:
  - S is a ***complete extension*** iff every argument acceptable w.r.t. S is in S
  - S is the ***grounded extension*** iff it is the smallest complete extension
  - S is a ***preferred extension*** iff it is a maximal complete extension
  - S is a ***stable extension*** iff every argument not in S is attacked by an argument in S

Example

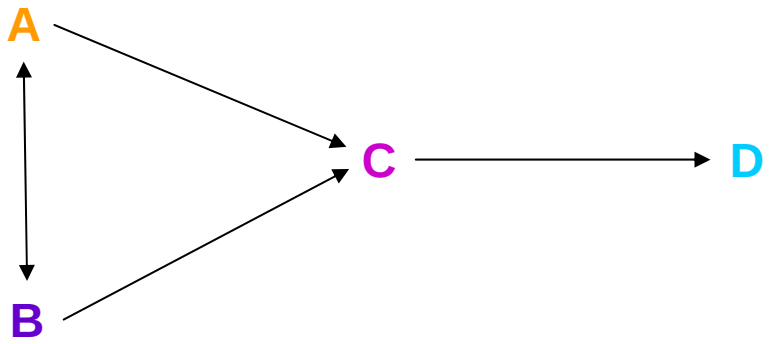


- {}, {A}, {A,D}, {B,D} are admissible
- {C} and {A,C} are not admissible
- {A} is not complete
- {}, {A,D}, {B,D} are complete extensions
- {} is the smallest complete (grounded) extension
- {A,D} and {B,D} are the preferred (and stable) extensions

Example

- X is a **credulously** justified argument under the semantics E if X is in ***at least one*** E extensions
- X is a **sceptically** justified argument under the semantics E if X is in ***all*** E extensions

- X is a **rejected** argument under the semantics E if X is not in any E extension
- X is an ***undecided*** argument under the semantics E if X is in at least one, but not all E extensions



{A,D} and {B,D} are *preferred* and so A,B,D are *credulously* justified and D is sceptically justified

{} is grounded and so no argument is *sceptically* justified

A Dialectical Game for Grounded Semantics

- Is argument A element of the grounded extension?
  - proponent states A
  - opponent and proponent then take turns, in which they
  - state an argument that defeats the previous argument
  - proponent is not allowed to repeat any previous argument
  - a player wins iff the other player cannot move
- Argument A is in the grounded extension iff proponent has winning strategy for A

A Dialectical Game for Admissibility

- Is argument A element of an admissible set?
  - proponent states A
  - opponent and proponent then take turns; the opponent each time states an argument that defeats one of the previous arguments of the proponent; the proponent each time states an argument that defeats the immediately preceding argument of the opponent
  - the proponent may repeat its own moves, but not the moves of the opponent; the opponent may repeat the proponent's moves but not its own moves
  - proponent wins iff opponent cannot move; opponent wins iff proponent cannot move or if opponent is able to repeat proponent's move
- A is in admissible set iff proponent has winning strategy

Argumentation Schemes

- Argumentation Scheme
  - *Major premise: Source E is an expert in the subject domain S containing proposition A.*
  - *Minor premise: E asserts that proposition A in domain S is true.*
  - *Conclusion: A may plausibly be taken as true.*
- Critical Questions
  - **CQ1:** How credible is E as an expert source?
  - **CQ2:** Is E an expert in the field that A is in?
  - **CQ3:** Does E's testimony imply A?
  - **CQ4:** Is E reliable?
  - **CQ5:** Is A consistent with the testimony of other experts?
  - **CQ6:** Is A supported by evidence?

Argumentation Schemes

- Three categories of critical questions
  - Used to question whether a **premise** of a scheme **holds**
    - e.g. CQ2 and CQ3
  - Used to recognize **exceptions** to the use of the scheme
    - e.g. CQ4 and CQ5
  - Used to question the **assumptions** used in the scheme
    - e.g. CQ1 and CQ6

References

- L. Amgoud and C. Cayrol. A reasoning model based on the production of acceptable arguments. Annals of Mathematics and Artificial Intelligence, 34(1-3):197 215, 2002.
- M.W.A. Caminada. An Introduction to Formal Argumentation. Presentation Luxembourg 2008.
- P. M. Dung. On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games. Artificial Intelligence, 77:321 357, 1995
- N. Maudet, S. Parsons and I. Rahwan (2007). Argumentation in Multi-Agent Systems: Context and Recent Developments. In Proceedings of the ArgMAS 2006, LNCS, Volume 4766, Springer, pages 35-52.
- S. Modgil and L. Armgoud. Agents and Arguments. EASSS 2008.

Questions?

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