Dominant decisions by argumentation agents

Paul Matt Francesca Toni Juan Vaccari

Department of Computing
Imperial College London
United Kingdom

Sixth International Workshop on
Argumentation in Multi-Agent Systems (ArgMAS 2009)
May 12, 2009
Europa Congress Center - Budapest, Hungary

Outline

- Motivation: ranking items in e-marketplaces
- Decision-making problem formalisation + dominance
- Solution 1: Assumption-based argumentation
  - Admissibility $\equiv$ dominance
- Limits of admissibility
- Solution 2: degrees of admissibility
- Solution 3: relative value of a decision
- Application to satellite earth observation
- Conclusions

Motivation: ranking items in e-marketplaces

- a buyer wants to purchase an item (e.g. camera on eBay)
- each item is described by a set of technical features (e.g. zoom, etc.)
- the buyer is not an expert on the area, does not know how to choose
- we want to support buyers in this kind of context

Decision-making problem formalisation

- given
  - a collection D of $n \geq 2$ possible items
    - Canon
    - Leica
    - Sony
  - a set F of technical features
    - digital, reflex
    - zoom, fixed lens
    - small
  - a set G of goals/benefits to achieve
    - light
    - high resolution
  - some logical (expert) knowledge B ("beliefs") that links items to features and features to goals
  - and weights $w(g_i) > 0$ representing the importance of goals
- we want to choose a "best" item

Beliefs and dominance

- we assume that B can be represented by rules like
  - canon $\longrightarrow$ reflex canon $\longrightarrow$ small (D $\longrightarrow$ F)
  - leica $\longrightarrow$ small (D $\longrightarrow$ F)
  - small $\longrightarrow$ light (F $\longrightarrow$ G)
  - digital $\longrightarrow$ light (F $\longrightarrow$ G)
  - reflex $\longrightarrow$ high resolution (F $\longrightarrow$ G)
- conclusions can be derived from B using modus ponens ($\vdash$)
- def. d is *dominant* iff $\gamma(d) \supseteq \gamma(d')$ for every $d' \neq d$, where $\gamma(d)$ denotes the set of goals satisfied by item d

$$\gamma(d) = \{g \in G | B \cup \{d\} \vdash g\}$$

- γ(canon) = {light, high resolution}
- γ(leica) = {light}
- γ(sony) = {}
- canon is dominant

Argumentation: Why?

- assume each item is defended by a seller
- sellers argue with each another
- seller of x can attack seller of y with an argument of the type "x satisfies goal g and y presumably doesn't"
- then seller y may counter-attack seller of x by saying "you are wrong, y also satisfies g"
- each seller argues with all the others about all goals satisfied by his item
- the "winner(s)" are those that counter-attack every attack... hence idea of using admissibility
- an adequate argumentation framework equipped with semantics of admissibility can emulate this competition between sellers and help the buyer choose an item

Assumption-based argumentation

- An *ABA framework* is a quadruple $\langle \mathcal{L}, \mathcal{R}, \mathcal{A}, \mathcal{C} \rangle$ where
  - $\mathcal{L}$ is a set of sentences, referred to as *language*
  - $\mathcal{R}$ is a set of *(inference) rules* of the form $\frac{p_1,\ldots,p_n}{q}$ for $n \geq 0$, where $p_1, \ldots, p_n \in \mathcal{L}$ are called the premises and $q \in \mathcal{L}$ are called the conclusion of the rule
  - $\mathcal{A} \subseteq \mathcal{L}$, referred to as the set of *assumptions*
  - $\mathcal{C} : \mathcal{A} \rightarrow \mathcal{L}$, referred to as the *contrary* mapping.
- Given any two sets of assumptions A and B, we say that A *attacks* B if and only if there exists an argument based on (a subset of) A whose conclusion q is the contrary of an assumption contained in B.
- A is conflict free iff A does not attack itself
- A is admissible iff A is conflict-free and A attacks every set of assumptions B that attacks A

Solution 1: Mapping onto ABA

- $\mathcal{L}$ contains the following sentences:
  - f^d, standing for "item d has feature f" (e.g., f^d)
  - g^d, standing for "benefit or sub-goal g is provided by item d"
  - $M(\neg g^d)$, standing for "item d presumably cannot provide benefit g"
  - $\neg d$, standing for "the user should not choose item d"
- the assumptions and contrary mapping

$$\mathcal{A} = D \cup \{M(\neg g^d) \mid (g, d) \in G \times D\}$$

$$\mathcal{C}(a) = \begin{cases} \neg d \text{ if } a = d \\ g^d \text{ if } a = M(\neg g^d) \end{cases}$$

- the inference rules $\mathcal{R}$ consist of all the rules of the form
  - $\frac{d}{f^d}$ if $d \rightarrow f \in B$, for $d \in D$ and $f \in F$
  - $\frac{f_1^d, \ldots, f_n^d, sg_1^d, \ldots, sg_m^d}{g^d}$ if $f_1, \ldots, f_n, sg_1, \ldots, sg_m \rightarrow g \in B$, for $f_i \in F$, $sg_j \in SG$, $g \in SG \cup G$
  - $\frac{g^{d'}, M(\neg g^d)}{\neg d}$ for every benefit $g \in G$ and pair of distinct items $d, d' \in D$

Theorem - Dominance & Admissibility

- **theorem**: d is dominant iff $\{d\}$ is admissible (see proof in paper)
- d is *dominant* iff $\gamma(d) \supseteq \gamma(d')$ for every $d' \neq d$, where $\gamma(d)$ denotes the set of goals satisfied by item d

$$\gamma(d) = \{g \in G | B \cup \{d\} \vdash g\}$$

Limits of admissibility

- there may not exist any dominant/admissible items (no purchase)
  (e.g., $\gamma(d) = \{g_1, g_2\}$ $\gamma(d') = \{g_2, g_3\}$)
- makes no use of buyer's preference (crude ranking of items)
  (e.g., $\gamma(d) = \{g_1, g_2, g_3\}$ $\gamma(d') = \{g_4\}$,
  $w(g_1) = 1, w(g_2) = 1, w(g_3) = 1, w(g_4) = 20$)

Solution 2: degrees of admissibility

- def: degree of admissibility α of a conflict-free set of arguments A is
  - 1 if A is not attacked,
  - the fraction of attacking arguments it counter-attacks, and
  - 0 if A is not conflict-free
- example: degrees of admissibility for leica:
  - $\gamma(\text{canon}) = \{\text{light, high resolution}\}$
  - $\gamma(\text{leica}) = \{\text{light}\}$
  - canon attacks leica with two arguments since it satisfies both goals and presumably leica does not.
  - leica counter-attacks one of them (regarding light goal)
  - $\alpha(\mathit{leica}) = \frac{1}{2}$

Solution 2: degrees of admissibility (cont)

- degrees of admissibility

$$\alpha(\{d\}) = \begin{cases} 1 \text{ if } T - T_d = 0 \\ \frac{\sum_{g \in G} T_{d,g} * (T_g - T_{d,g})}{T - T_d} \text{ otherwise} \end{cases}$$

where $T_{d,g}$ is 1 if d satisfies g and 0 otherwise, T_g the number of decisions satisfying g, T_d the number of goals satisfied by d, T the sum of T_g over all goals

Solution 3: Relative value of a decision

- Generalisation taking into account weights of goals

$$\alpha(d) = \frac{\sum_{g \in G} w(g) * T_{d,g} * (T_g - T_{d,g})}{\sum_{g \in G} w(g) * (T_g - T_{d,g})}$$

where $T_{d,g}$ is 1 if d satisfies g and 0 otherwise, T_g the number of decisions satisfying g, T_d the number of goals satisfied by d, T the sum of T_g over all goals

Application to satellite earth observation

- Implementation in an e-marketplace application: selection of *earth observation* images generated by satellites.
- Earth Observation
  - environmental monitoring
  - meteorology
  - maps making
- Satellites with different characteristics (type of sensors, types of orbits, etc.)
- Pecularities of the images needed by users
- Concrete problem: selecting satellite images to monitor oil spills
- business knowledge provided by GMV Aerospace & Defence, and implemented in the context of ArguGRID project
- Implementation of solutions with admissibility and degrees of admissibility for a knowledge base including several satellites, sensors, and goals.

Conclusions

- Characterisation of link between admissibility semantics and decision principle (dominance)
- New argumentation semantics (degrees of admissibility) useful for decision making (under strict certainty)
- Decision formula obtained from solution 3 using weights
- Concrete application: earth observation