Basic influence diagrams and the liberal stable semantics

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Argumentation for decision theory (motivation)

1. criticism made to decision theory: **requires perfect problem representations** (decision tables, probability distributions and utility functions)
2. idea: **use argumentation to get such representations**

The paper's contribution

We propose

- basic influence diagrams: simple graphical tool for describing DM problems (decisions, uncertainties, beliefs, goals and conflicts)
- direct mapping from basic influence diagrams onto assumption-based argumentation
- liberal stable semantics as **a way to generate decision tables**
- study relationship with existing semantics (admissible, naive, stable...)

Decision tables

Definition: lines = decisions, columns = scenarios, cells = consequences. Example:

.	$s_1 = \{rains\}$	$s_2 = \{sunny\}$
$d_1 = \{umbrella\}$	$\{dry, loaded\}$	$\{dry, loaded\}$
$d_2 = \{\neg umbrella\}$	$\{\neg dry, \neg loaded\}$	$\{dry, \neg loaded\}$

Figure: Decision table for going out.

References

- S. French. **Decision theory: an introduction to the mathematics of rationality**. Ellis Horwood, 1987.
- L. Amgoud and H. Prade. **Using arguments for making decisions: A possibilistic logic approach**. 20th Conference of Uncertainty in AI, 2004.

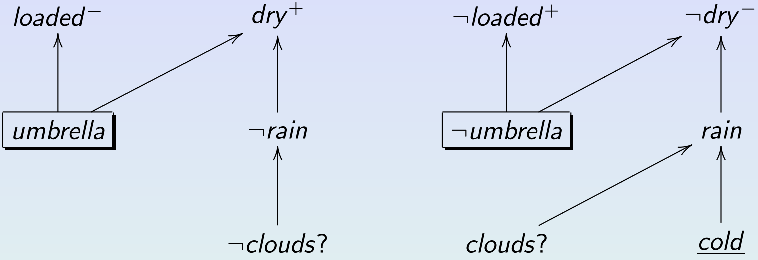
Approach based on argumentation

1. represent knowledge - **basic influence diagrams**
2. computational model - **assumption-based argumentation**
3. resolve - **liberal stable semantics**

References

- R.A. Howard and J.E. Matheson. **Influence diagrams**. *Readings on the Principles and Applications of Decision Analysis*, II:721–762, 2006.
- M. Morge and P. Mancarella. **The hedgehog and the fox. An argumentation-based decision support system**. *4th International Workshop on Argumentation in Multi-Agent Systems*, 2007.
- P.M. Dung, R.A. Kowalski and F. Toni. **Dialectic Proof Procedures for Assumption-Based, Admissible Argumentation**. *Artificial Intelligence*, 170(2):114–159, 2006.

Basic influence diagrams



if *umbrella* then *loaded*
if *umbrella* then *dry*
if ¬*rain* then *dry*
if ¬*umbrella* then ¬*loaded*
if ¬*umbrella* and *rain* then ¬*dry*
if ¬*clouds* then ¬*rain*
if *clouds* and *cold* then *rain*
cold

Equivalent assumption based argumentation framework

- **nodes** (decisions, goals and beliefs) are language $\mathcal{L} = \{umbrella, loaded, \neg clouds, \ldots\}$
- **arcs** are inference rules $\mathcal{R} = \{\frac{umbrella}{loaded}, \frac{clouds, cold}{rain}, \ldots\}$
- **leaves** (decisions and ?-beliefs) are assumptions $\mathcal{A} = \{umbrella, \neg umbrella, clouds, \neg clouds\}$
- **negations** (p vs. $\neg p$) are contrary relation $\mathcal{C} \subseteq 2^{\mathcal{A}} \times \mathcal{L}$

Reference

- P.M. Dung, R.A. Kowalski and F. Toni. **Dialectic Proof Procedures for Assumption-Based, Admissible Argumentation**. *Artificial Intelligence*, 170(2):114–159, 2006.

How is rationality defined ?

Consequences of decisions must be 'rational outcomes' $O \subseteq \mathcal{L}$:

- not the case that $p \in O$ and $\neg p \in O$ (**consistency**)
- either $p \in O$ or $\neg p \in O$ (**decidedness**)
- exists assumptions A such that $O = O(A) = \{p \in \mathcal{L}, A \vdash p\}$ (**closure under dependency rules**)

The set of assumptions A is rational iff $O(A)$ is a rational outcome.

Problem statement: find exactly ALL rational opinions.

Which semantics to use ?

A set of assumptions $A \subseteq \mathcal{A}$ is deemed

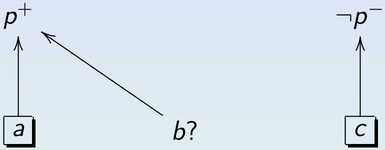
- *conflict-free* iff A does not attack itself
- *naive* iff A is maximally conflict-free
- *admissible* iff A is conflict-free and A attacks every set of assumptions B that attacks A
- *stable* iff A is conflict-free and attacks every set it does not include
- *semi-stable* iff A is complete where $\{A\} \cup \{B | A \textit{ attacks } B\}$ is maximal
- $+$ *preferred, complete and ideal...*

References

- P.M. Dung. **On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, log programming, and n-person games**. *Artificial Intelligence*, 77(2):321–257, 1995.
- P.M. Dung, R.A. Kowalski and F. Toni. **Dialectic Proof Procedures for Assumption-Based, Admissible Argumentation**. *Artificial Intelligence*, 170(2):114–159, 2006.
- M. Caminada. **Semi-stable semantics**. *1st International Conference on Computational Models of Arguments*, 2006.

Let us try with a small example...

Consider the following basic influence diagram and influence rules



if a and b then p
if c then ¬p

The rational opinions are $A = \{c\}$, $\{a, b\}$, $\{a, c\}$ and $\{b, c\}$.

Surprising solutions !

- $\{\}$ is conflict-free but not rational
- $\{c\}$ is not naive but is rational
- $\{\}$ is admissible but not rational
- $\{c\}$ is not stable but is rational
- $\{c\}$ is not semi-stable but is rational
- $\{c\}$ is not preferred but is rational
- $\{c\}$ is not complete but is rational
- $\{a, c\}$ is not grounded but is rational
- $\{\}$ is ideal but not rational

New semantics ?

The liberal stable semantics

Definition:

- Abstract argumentation: $S \subseteq Arg$ is liberal stable iff S is conflict-free and attacks a maximal set of arguments.
- Assumption-based argumentation: $A \subseteq \mathcal{A}$ is conflict-free and attacks a maximal set of sets of assumptions.

Properties (in symmetric assumption-based frameworks):

- Every stable set is liberal stable and every liberal stable set is conflict-free and admissible.
- Under extensible frameworks: every naive, stable or preferred set is liberal stable and every liberal stable set is conflict-free and admissible.

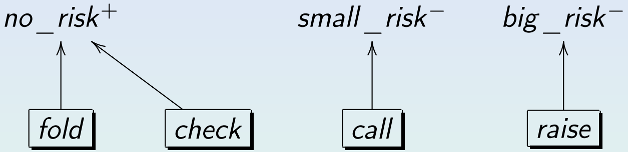
How good is the semantics ?

In the previous example, works perfectly. More generally...

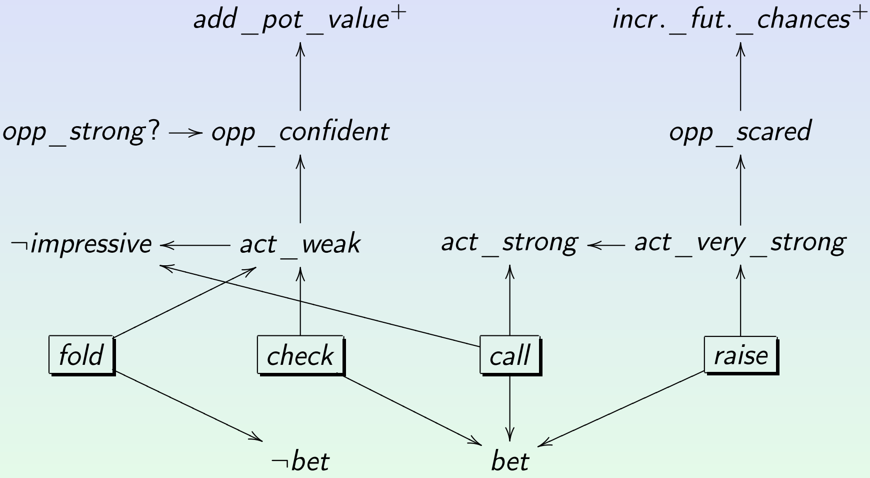
- **Theorem 1**: All rational solutions are liberal stable.
- **Theorem 2**: If every naive opinion is decided, then every liberal stable solution is rational.

Decidedness of naive opinion is a very natural requirement.

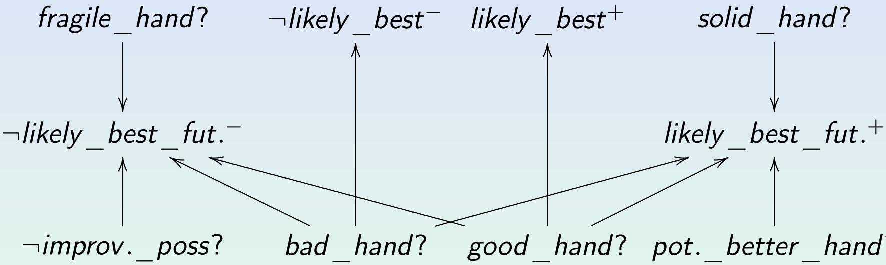
Application to Poker: risk / movement ♣



Application to Poker: psychological effects ♠



Application to Poker: hand strength dynamics ◇



Result obtained ♡

.	$s_1 \vee s_7$	$s_2 \vee s_8$	$s_3 \vee s_9$
d_1	NR^+, APV^+, UB^-, UBF^-	NR^+, APV^+, UB^-, UBF^-	NR^+, APV^+, LB^+, LBF^+
d_2	NR^+, APV^+, UB^-, UBF^-	NR^+, APV^+, UB^-, UBF^-	NR^+, APV^+, LB^+, LBF^+
d_3	SR^-, APV^+, UB^-, UBF^-	SR^-, UB^-, UBF^-	SR^-, APV^+, LB^+, LBF^+
d_4	$BR^-, APV^+, IFC^+, UB^-, UBF^-$	BR^-, IFC^+, UB^-, UBF^-	$BR^-, APV^+, IFC^+, LB^+, LBF^+$

.	$s_4 \vee s_{10}$	$s_5 \vee s_{13}$	$s_6 \vee s_{14}$
d_1	NR^+, APV^+, LB^+, LBF^+	NR^+, APV^+, UB^-, LBF^+	NR^+, APV^+, UB^-, LBF^+
d_2	NR^+, APV^+, LB^+, LBF^+	NR^+, APV^+, UB^-, LBF^+	NR^+, APV^+, UB^-, LBF^+
d_3	SR^-, LB^+, LBF^+	SR^-, APV^+, UB^-, LBF^+	SR^-, UB^-, LBF^+
d_4	BR^-, IFC^+, LB^+, LBF^+	$BR^-, APV^+, IFC^+, UB^-, LBF^+$	BR^-, IFC^+, UB^-, LBF^+

.	$s_{11} \vee s_{15}$	$s_{12} \vee s_{16}$
d_1	NR^+, APV^+, LB^+, UBF^-	NR^+, APV^+, LB^+, UBF^-
d_2	NR^+, APV^+, LB^+, UBF^-	NR^+, APV^+, LB^+, UBF^-
d_3	SR^-, APV^+, LB^+, UBF^-	SR^-, LB^+, UBF^-
d_4	$BR^-, APV^+, IFC^+, LB^+, UBF^-$	BR^-, IFC^+, LB^+, UBF^-

Figure: Compact decision table for playing a hand.

$s_1 = \{bad\_hand, solid\_hand, no\_improvement\_possible, opponent\_strong\}$
$s_7 = \{bad\_hand, fragile\_hand, no\_improvement\_possible, opponent\_strong\}$

...

Summary and conclusion

- introduced basic influence diagrams for knowledge representation in decision making
- use simple mapping onto assumption-based argumentation
- rationality obtained via new semantics of liberal stability
- liberal stable solutions provide qualitative decision tables