

# The Epistemic and Practical Reasoner

## an implementation of argument-based practical reasoning

Wietske Visser

Seminar AI, 21 April 2008

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# Argument-based reasoning (1)

- ▶ a type of *defeasible reasoning*
  - ▶ synonyms: nonmonotonic / commonsense reasoning
  - ▶ can deal with inconsistent or incomplete belief bases
  - ▶ inferences are not certain, but can be made provided that there is no information to the contrary that defeats them

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# Argument-based reasoning (1)

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  - ▶ synonyms: nonmonotonic / commonsense reasoning
  - ▶ can deal with inconsistent or incomplete belief bases
  - ▶ inferences are not certain, but can be made provided that there is no information to the contrary that defeats them
- ▶ based on arguments that may contradict each other
  - ▶ e.g. conflicting conclusions (rebuttal)

Tweety is a bird    birds can fly  
Tweety can fly

Tweety is a penguin    penguins cannot fly  
Tweety cannot fly

# Argument-based reasoning (2)

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- ▶ difference between arguments and classical proofs
  - ▶ classical logic
    - ▶ about the truth of a proposition
    - ▶ single proof is sufficient
  - ▶ defeasible logic
    - ▶ about having more justification for a proposition than against it
    - ▶ interaction between multiple arguments

# Argument-based reasoning (3)

## Abstract argumentation framework (Dung)

- ▶ set of arguments with defeat relation
- ▶ abstract: internal structure of arguments and definition of defeat are not specified
- ▶ semantics define extensions with justified arguments
  - ▶ sceptical grounded semantics
  - ▶ credulous preferred semantics
- ▶ argument games determine the status of individual arguments according to certain semantics
  - ▶ G-game (sceptical)
  - ▶ P-game (credulous)

# Argument-based reasoning (4)

## Sceptical vs. credulous reasoning

- ▶ consider two arguments of equal strength:
  - ▶ Nixon is a pacifist, because Nixon is a Quaker and Quakers are pacifists
  - ▶ Nixon is not a pacifist, because Nixon is a Republican and Republicans are not pacifists
- ▶ they defeat each other
- ▶ neither conclusion is *sceptically justified*
- ▶ either conclusion is *credulously defensible*
- ▶ context determines which kind of reasoning is more rational

# Practical reasoning

- ▶ reasoning about goals, desires and actions
- ▶ choose between different options to achieve a goal
  - ▶ one that also achieves another goal
  - ▶ or that at least does not prevent too many goals from being achieved. . .
- ▶ highly dependent on epistemic reasoning (reasoning about knowledge or beliefs)
- ▶ own set of properties and problems
- ▶ focus here on determining which desires can be defeasibly inferred from a belief base

# Research question and method (1)

Three topics concerning argument-based practical reasoning are chosen to focus on:

- ▶ combination of epistemic and practical reasoning: e-p-semantics (Prakken)
- ▶ the practical syllogism (Bench-Capon and Prakken)
- ▶ accrual of arguments (Prakken, Bench-Capon and Prakken)

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# Research question and method (1)

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- ▶ combination of epistemic and practical reasoning: e-p-semantics (Prakken)
- ▶ the practical syllogism (Bench-Capon and Prakken)
- ▶ accrual of arguments (Prakken, Bench-Capon and Prakken)

Research question:

- ▶ Are these theories correct and completely specified?
- ▶ If not, what changes and additions are needed to make them better or more complete?

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# Research question and method (2)

Two reasons for implementing a theory

- ▶ test for correctness and completeness of the theory
  - ▶ theory must be completely specified
  - ▶ examples can be verified
- ▶ prototype for applications
  - ▶ an intelligent agent reasoning about goals and actions

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# E-p-semantics (1)

## Combining epistemic and practical reasoning

In certain contexts, reasoning about beliefs is sceptical while reasoning about action is credulous.

- ▶ practical example:
  - ▶ I want to take bus 42, because I want to be at the station and bus 42 will take me there
  - ▶ I want to cycle to the station, because I want to be at the station and cycling to it will take me there
- ▶ epistemic example:
  - ▶ bus 42 does not ride today, because a bus strike was announced in the papers yesterday
  - ▶ bus 42 does ride today, because I saw one passing this morning
- ▶ credulous practical reasoning and sceptical epistemic reasoning are *interleaved*

# E-p-semantics (2)

## Combining epistemic and practical reasoning

### Formalisation

- ▶ distinction between epistemic and practical arguments
- ▶ new semantics: e-p-semantics
  - ▶ combination of grounded semantics for epistemic arguments and preferred semantics for practical arguments
- ▶ new argument game: GP-game
  - ▶ combination of G-game rules for epistemic arguments and P-game rules for practical arguments

# The practical syllogism (1)

If action  $a$  causes state  $b$ , and I have the goal to be in state  $b$ , then it is rational for me to wish to do  $a$ .

- ▶ very natural way to reason about action
- ▶ abductive ('backwards') inference
- ▶ goes back as far as Aristotle
- ▶ need to consider negative side-effects of the action
  - ▶  $a$  might also cause unwanted state  $b'$
- ▶ need to consider alternatives for achieving the goal
  - ▶ state  $b$  might also be realised by action  $a'$

# The practical syllogism (2)

## Formalisation

- ▶ modal operator  $D$  standing for desire
- ▶ two new inference rules
  - ▶ positive practical syllogism:  
 $a$  causes  $b$ , I want  $b$ , so I want  $a$
  - ▶ negative practical syllogism:  
 $a$  prevents  $b$ , I want  $b$ , so I do not want  $a$
- ▶ alternative defeat
  - ▶  $a_1$  causes  $b$ , I want  $b$ , so I want  $a_1$
  - ▶  $a_2$  causes  $b$ , I want  $b$ , so I want  $a_2$
  - ▶ not rational to want both, so they defeat each other

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# Accrual of arguments (1)

Accrual of arguments: 'add up' multiple arguments with the same conclusion.

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Accrual of arguments: 'add up' multiple arguments with the same conclusion.

- ▶ an accrual might be stronger than its elements
  - ▶ A: I want to be fit, jogging will get me fit, so I want to go jogging
  - ▶ B: I want to loose weight, jogging will help me loose weight, so I want to go jogging
  - ▶ C: I do not want to be wet, it is raining, jogging in the rain will get me wet, so I do not want to go jogging
  - ▶ suppose C is stronger than either A or B, but A and B together are stronger than C

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# Accrual of arguments (2)

- ▶ an accrual might be weaker than its elements
  - ▶ A: I want to be fit, jogging will get me fit, so I want to go jogging
  - ▶ B: I do not want to be hot, it is hot outside, jogging in the heat will get me hot, so I do not want to go jogging
  - ▶ C: I do not want to be wet, it is raining, jogging in the rain will get me wet, so I do not want to go jogging
  - ▶ suppose A is weaker than either B or C, but B and C together are weaker than A

# Accrual of arguments (3)

## Three principles of accrual

- ▶ accruals can be stronger or weaker than their elements: strength cannot be calculated from the strengths of the elements
- ▶ only the largest possible accrual may be used
- ▶ flawed arguments may not accrue

## Formalisation

- ▶ accrual inference rule
- ▶ rebuttal only between accrual arguments
- ▶ accrual undercut: an accrual undercutter  $A$  undercuts an accrual  $B$  if  $B$ 's elements are a proper subset of  $A$ 's elements

# Accrual of arguments (4)

Difficulty: strength of accruals

- ▶ in first theory completely unspecified
- ▶ second theory: based on goals reached and prevented if the argument's final desire is carried out

Problems:

- ▶ applies only to practical arguments, not epistemic ones
- ▶ combination with degree of belief and rule strength
- ▶ set of prevented goals may be defined outside the argument
- ▶ ordering of sets of goals is only partial (there may be infinitely many goals)
- ▶ the ordering must be defined somewhere

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# The language

- ▶ propositional modal logic
- ▶ non-nested modality D standing for desire
- ▶ facts and rules
- ▶ two types: epistemic and practical
- ▶ strength between 0 and 1
- ▶ examples:

```
r1: canFly <- bird 0.8.  
~canFly <- penguin 0.7.  
~r1 <- penguin 0.9.  
penguin.  
bird <- penguin.
```

```
r1: beAtStation <- takeBus42.  
r2: beAtStation <- cycleToStation.  
DbeAtStation.  
~r1 <- busStrike.  
busStrike.  
~busStrike.
```

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# The structure of arguments

- ▶ trees of chained defeasible inferences
- ▶ one conclusion, zero or more subarguments
- ▶ two types: epistemic and practical
- ▶ no circular arguments
- ▶ example:

$$\frac{\frac{\text{penguin}}{\text{bird}} \text{ FF} \quad \frac{\text{bird} \leftarrow \text{penguin}}{\text{canFly}} \text{ RA}}{\text{canFly}} \text{ RA} \quad \frac{\text{canFly} \leftarrow \text{bird}}{\text{canFly}} \text{ RA}$$

# Inference schemes (1)

Inferences are instantiations of inference schemes.

- ▶ from fact
- ▶ from rule
- ▶ rule application

$$\frac{\sim\text{canFly} \leftarrow \text{penguin} \quad \text{penguin}}{\sim\text{canFly}} \text{ RA}$$

- ▶ DKD

$$\frac{\text{Daction}}{\sim\text{D}\sim\text{action}} \text{ DKD}$$

# Inference schemes (2)

- ▶ positive practical syllogism

$$\frac{\text{state} \leftarrow \text{action, circumstance} \quad D\text{state} \quad \text{circumstance}}{D\text{action}} \text{ PPS}$$

- ▶ negative practical syllogism

$$\frac{\sim \text{state} \leftarrow \text{action, circumstance} \quad D\text{state} \quad \text{circumstance}}{\sim D\text{action}} \text{ NPS}$$

- ▶ accrual

$$\frac{a}{a} \text{ ACCR}$$

- ▶ accrual undercutter

# Strength of arguments

Simple arguments:

- ▶ weakest link
- ▶ last link

Accrual arguments:

- ▶ all equal
- ▶ strongest link
- ▶ number of promoted desires

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# Conflicts between arguments

Three types of conflict:

- ▶ rebuttal
- ▶ alternative
- ▶ accrual undercut

Argument  $A$  defeats argument  $B$  if

- ▶  $A$  rebuts  $B$  and  $A$  is at least as strong as  $B$ ; or
- ▶  $A$  accrual-undercuts  $B$ ; or
- ▶  $A$  is an alternative to  $B$  and  $A$  is at least as strong as  $B$ ;  
or
- ▶  $A$  defeats a subargument of  $B$

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# Argument games (2)

## A bit simplified

Move:

- ▶ identifier
- ▶ player: PRO or CON
- ▶ argument
- ▶ target

Game (general):

- ▶ sequence of moves
- ▶ PRO moves first: the main argument
- ▶ PRO and CON move in turn
- ▶ a move's argument defeats the target's argument
- ▶ a player wins if the other has no legal moves left
- ▶ if PRO wins, the main argument is justified

# Argument games (3)

## A bit simplified

G-game (sceptical):

- ▶ PRO may not repeat any arguments

P-game (credulous):

- ▶ PRO may not repeat CON's arguments
- ▶ CON may not repeat his own arguments

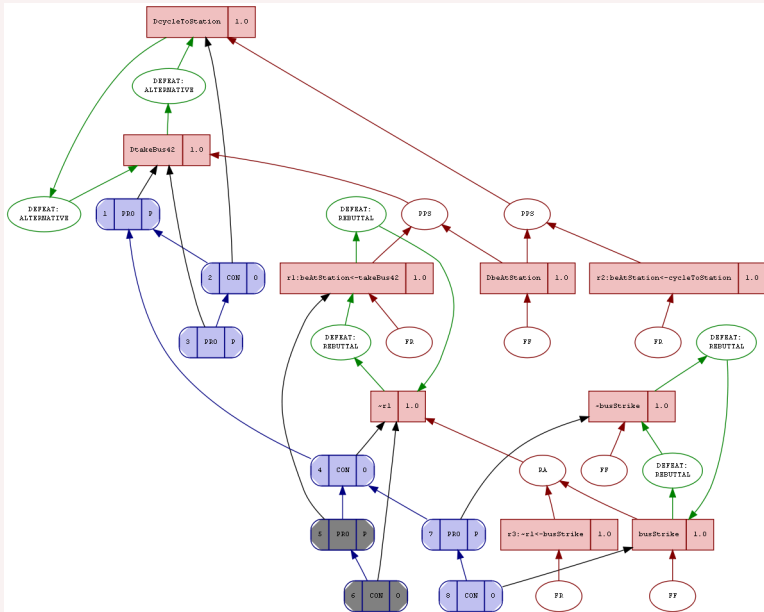
GP-game (sceptical epistemic and credulous practical):

- ▶ combination of G-game rules for epistemic arguments and P-game rules for practical arguments

# Argument games (4) - Example GP-game

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## Overview

- ▶ written in Java 6
- ▶ graphical user interface
- ▶ input: belief base, query and parameters
- ▶ arguments and an argument game are generated
- ▶ output: log, xml and graph

## Demonstration

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Recall the research question:

- ▶ Are the implemented theories correct and completely specified?
- ▶ If not, what changes and additions are needed to make them better or more complete?

# Results

Answer:

- ▶ e-p-semantics
  - ▶ fully specified
  - ▶ only minor errors in examples
- ▶ practical syllogism
  - ▶ inference schemes PPS and NPS fully specified
  - ▶ alternative defeat only defined for use with accrual
  - ▶ alternative definition was created straightforwardly
- ▶ accrual of arguments
  - ▶ inference schemes accrual and accrual undercutter fully specified
  - ▶ accrual can be made more efficient by adding a restriction
  - ▶ major problem: accrual strength
  - ▶ games can become very long

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# Further work

- ▶ accrual strength
  - ▶ radical change in the way strength is currently modelled
- ▶ more elaborate notion of undercut
- ▶ extension to first-order predicate logic
- ▶ other approaches to argument-based practical reasoning

# More information

Interested?

The Epistemic and Practical Reasoner and my thesis can be found on [www.wietskevisser.nl/research/epr](http://www.wietskevisser.nl/research/epr)

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