A Model for Computer Reasoning Under Uncertainty

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Acknowledgements

- Jonathan Vessey

- John Fox
- Paul Krause
- Philip Parsons

- Anthony Long
- Carol Marchant
- William Button

Acknowledgements

- A Peter Johnson
  - For having given me the inspiration and confidence to redirect my career into chemical information research

Outline

- How do people make decisions and predictions?
- Basic issues in absolute reasoning - the Logic of Argumentation
- An introduction to our model
- Relative reasoning

How do people reason?

- Arguments For
- Arguments Against
- Undercutting arguments

Is it going to rain?

- “It is going dark. I think it is going to rain.”

Is it going to rain?

- “It is going dark. I think it is going to rain.”
- “It is late in the day. It always goes dark in the evening!”

Numbers or hunches?

- Proven evidence
- Quantitative evidence
- Qualitative evidence

- Numerical probability
  - Laws of chance
- Epistemic probability
  - Past experience

Structure of an argument

- If [grounds] is/are [threshold] then [proposition] is [force]

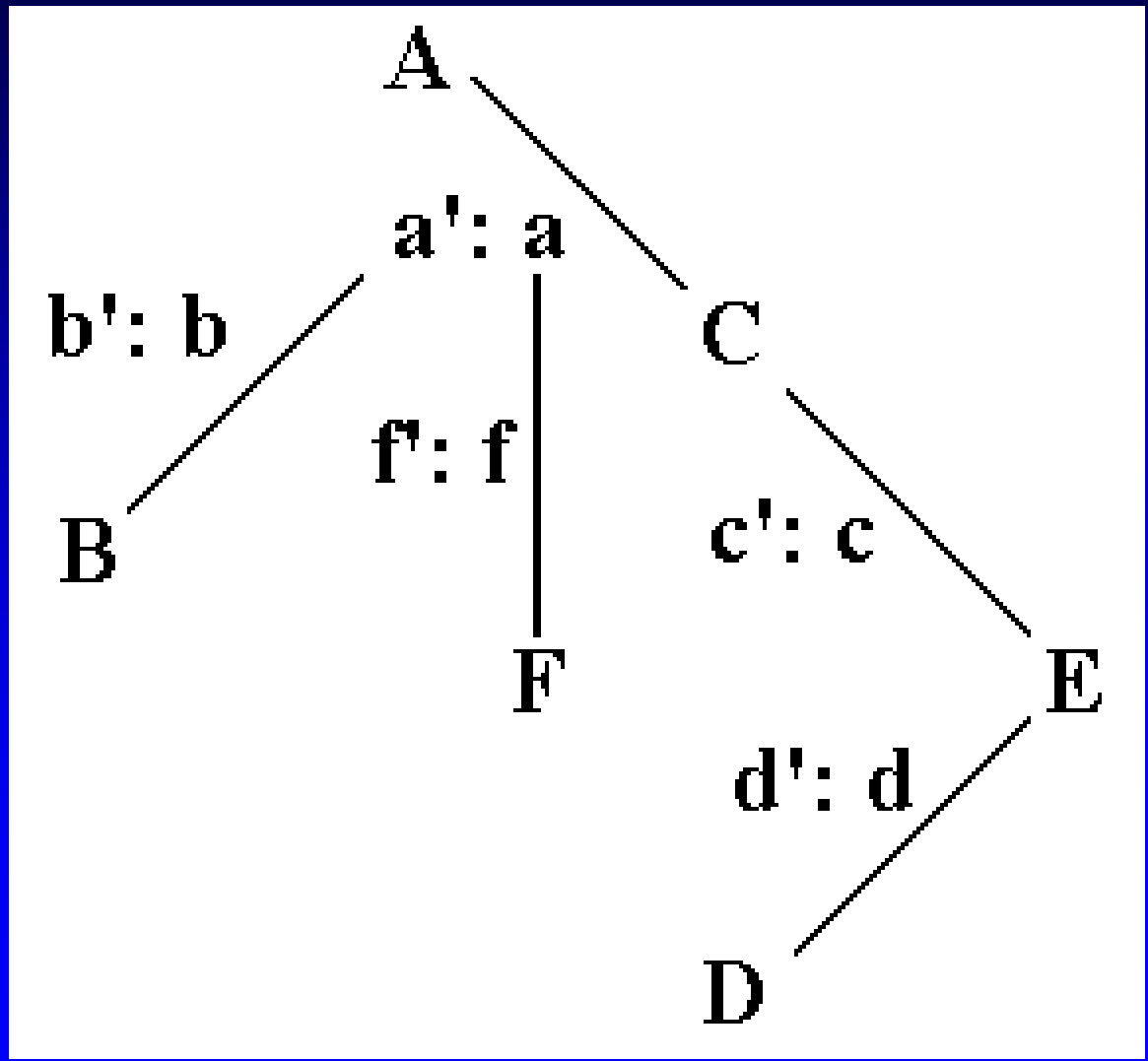
Structure of an argument

- If [grounds] is/are [threshold] then [proposition] is [force]
- If falling_rain is ‘certain’ then we_will_get_wet is ‘probable’

Summary

- People make decisions by weighing the arguments For and Against
- They appear to construct trees of arguments leading to a conclusion
- They use concepts like undercutting
- Undercutting and negation are areas where humans tend to make errors

A reasoning tree



Logic of Argumentation

- Arguments For
- Arguments Against
- Weigh the arguments For and Against

- An argument For has no implications for the case Against, and *vice versa*
- Contradiction is a valid state

How many ways can something be undecided?

- Equivocal
  - Equal balance of arguments
- Contradicted
  - Proof For and Against
- Open
  - No germane information
- Undefined
  - The question has not been asked

Polar and non-polar terms

- Probable
  - argument For = ‘probable’
  - argument Against = ‘open’
- Equivocal
  - argument For = ‘equivocal’
  - argument Against = ‘equivocal’

Hazards of negation

- Probable
  - relates to the case For
- Improbable
  - relates to the case Against
- Not probable
  - relates to the case For

Set For used in DfW and METEOR

- contradicted
- certain
- probable
- plausible
- equivocal
- open
- undefined

Set Against used in DfW and METEOR

- contradicted
- impossible
- improbable
- doubted
- equivocal
- open
- undefined

Inclusive and exclusive terms

- Inclusive
  - certain, probable, plausible, impossible, improbable, doubted
- Exclusive
  - contradicted, equivocal, open, undefined

Summary

- Different kinds of forces of arguments can support the case For or the case Against, or both
- There are two stages in reaching a conclusion about the likelihood of something
  - (1) Aggregate the arguments For and the arguments Against
  - (2) Resolve the cases For and Against

Combining arguments For or Against

- If there is an argument for something being ‘probable’ and one for it being ‘plausible’, does that make it more than ‘probable’?

- If there are three reasons to believe that something is ‘plausible’, does that make it more likely than ‘plausible’?

Combining arguments For or Against

- In our implementation of the model multiple arguments are not additive - the level of belief in the case For something is the level of belief conferred by the strongest argument

Combining arguments For or Against

Aggregate Force For = Max{F_a, F_b, F_c, …}

Aggregate Force Against = Max{F_d, F_e, F_f, …}

where Max returns the value of the force highest in an ordered list

Combining the cases For and Against

Tension = Resolve[For, Against]

where the value returned by Resolve is determined from a matrix containing the sets of terms For and Against

Examples from the resolution matrix

certain vs impossible -> contradicted

probable vs improbable -> equivocal

probable vs doubted -> plausible

plausible vs doubted -> equivocal

Mixing quantitative probability of chance with qualitative terms

- Include the numbers 0 to 1 in the terms supporting the case For
- Apply arithmetic of probability to aggregate terms falling in this range

Mixing quantitative probability of chance with qualitative terms

- “O.4” with “0.3” gives “0.58”
- “0.4” with “certain” can give “certain”
- “0.4” with “improbable” can give “improbable”
- “0.4” with “equivocal” can give “equivocal”

…or you can define the hierarchy differently

Absolute and relative reasoning

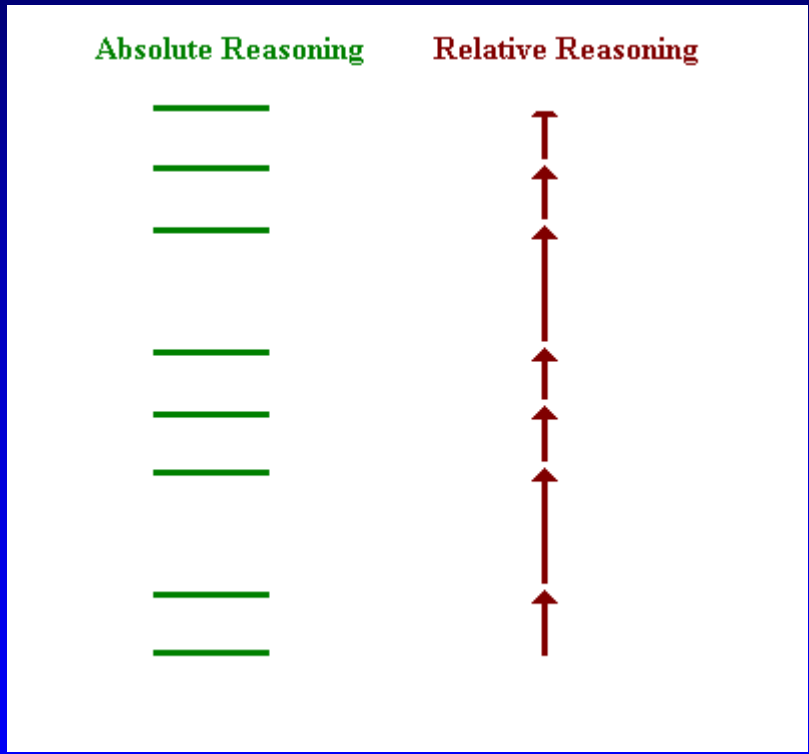
- “If A is certain then B is doubted”
- “C is more likely than D”

Absolute and relative reasoning

- A is probable
- B is probable
- C is doubted
- D is more likely than C

- Are A and B equally likely?
- Is D probable?

Complete Domain



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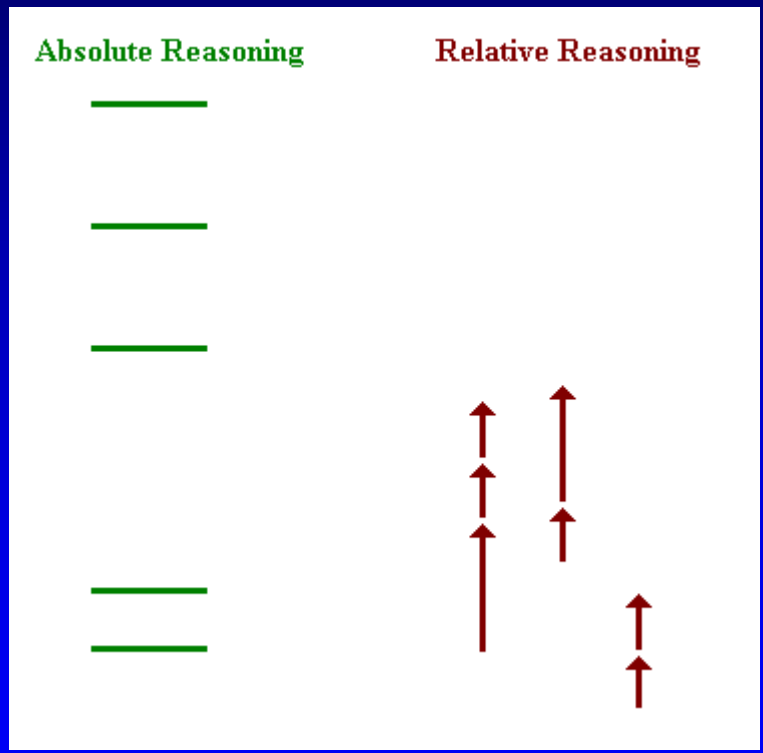

Absolute and relative reasoning

- In METEOR the two reasoning models operate independently
- Their conclusions are combined and reported together

Likelihood versus quantity

In METEOR we predict the likelihood that the product of a biotransformation will be seen, not the quantity of product or the reaction rate; we predict “the most likely metabolite”, not “the expected major metabolite”.

Conclusion

- In our model we have extended and tightened previous descriptions of the Logic of Argumentation
- The model supports mixed quantitative and qualitative measures of probability which can be stochastic or epistemic
- We have introduced and use a parallel universe of relative probability

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