A Model for Computer Reasoning Under Uncertainty

Dr. Philip N. Judson
LHASA Ltd., Leeds UK
judson@dircon.co.uk
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 = \( \text{Max}\{F_a, F_b, F_c, \ldots\} \)

Aggregate Force Against = \( \text{Max}\{F_d, F_e, F_f, \ldots\} \)

where \( \text{Max} \) 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

- “0.4” 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

Absolute Reasoning

Relative Reasoning

▶️

▶️

▶️

▶️

▶️

▶️
Incomplete Domain
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.
References

