

The Predictive Power of Heuristic Portfolios in Human Syllogistic Reasoning

Nicolas Riestern, Daniel Brand, Marco Ragni

Cognitive Computation Lab, Department of Computer Science, University of Freiburg



Syllogistic Reasoning

All sharks are fish.
No orcas are sharks.
What, if anything, follows?

- Two premises featuring a common middle term (sharks)
- Four quantifiers:
All (A), Some (I), Some ... not (O), None (E)
- Four figures defining the arrangement of terms
- Nine possible conclusions combining non-end terms:
4 quantifiers x 2 directions and "No Valid Conclusion"
- Experimental setting asks participants for valid conclusion
- Cognitive models aim at approximating the mental processes leading to the conclusion

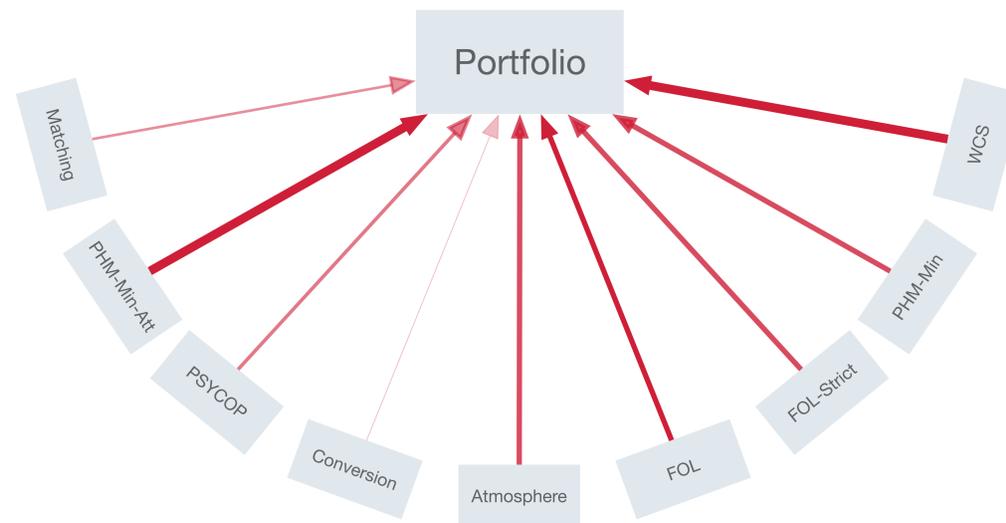
State of the Art

- At least 12 existing theoretical accounts [1]
- Problem: Lack of standardized evaluation
- Multiple goals (interpretability vs. performance)
- Different conceptual methods (logics vs. statistics)
- Variety of experimental settings (verification vs. generation)

→ Many models give accounts for single phenomena only. Lack of unified models.

References

- [1] Khemlani, S., & Johnson-Laird, P. N. (2012). Theories of the syllogism: A meta-analysis. *Psychological Bulletin*, 138(3), 427-457.
- [2] Freund, Y. (1995). Boosting a weak learning algorithm by majority. *Information and Computation*, 121(2), 256-285.
- [3] Gomes, C. P., & Selman, B. (2001). Algorithm portfolios. *Artificial Intelligence*, 126(1-2), 43-62.



Portfolio Meta-Model

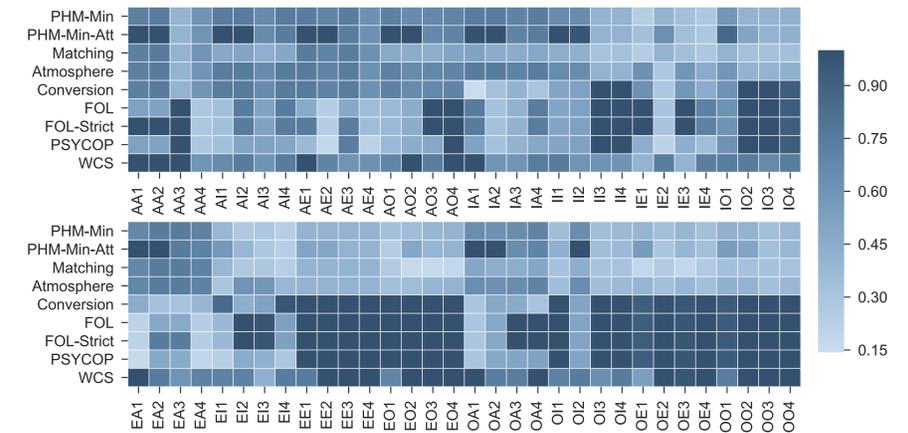
- Meta-Model composed of different submodels
 - Inspired from machine learning [2] and algorithm selection [3]
 - Weights assigned based on individual model performance
 - Metric used: Mean Reciprocal Rank (MRR)
 - Different weights per task, i.e., per syllogism
- Exploits strengths and avoids weaknesses of individual models

Mean Reciprocal Rank (MRR)

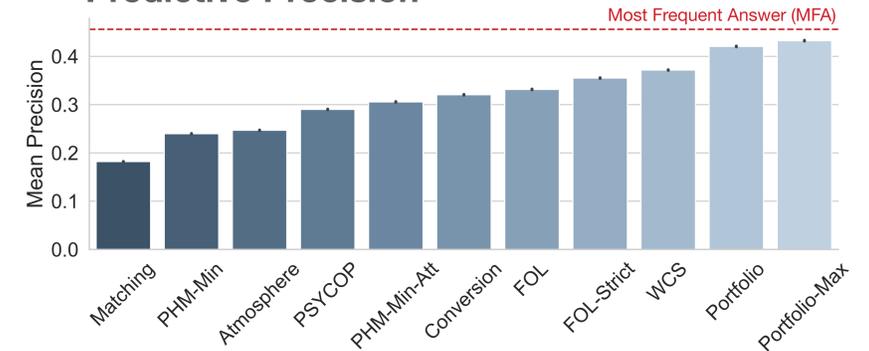
$$MRR_M(A_s) = \frac{1}{|P_M(s)|} \sum_{p \in P_M(s)} \frac{1}{r(p, A_s)}$$

M : Model
 s : Syllogism
 A_s : Response distribution for syllogism s
 $P_M(s)$: Response set of model M for syllogism s
 $r(p, A_s)$: Rank of response p in the distribution A_s

Portfolio Weights



Predictive Precision



Conclusions

Portfolio Applications

- Research tool in cognitive modeling
- Outperforms the state of the art in predicting syllogistic reasoning

Insight into Individual Strategies

- Portfolio weights as indication of heuristic qualities
- Can be optimised for individuals to obtain personalised strategies
- Illustrates similarities between different approaches (e.g., logics)

Performance Convergence

- MFA upper bound almost reached
- Improvement beyond MFA only possible when modeling individuals



riestern@cs.uni-freiburg.de
<https://www.cc.uni-freiburg.de>
 nriesterer

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