

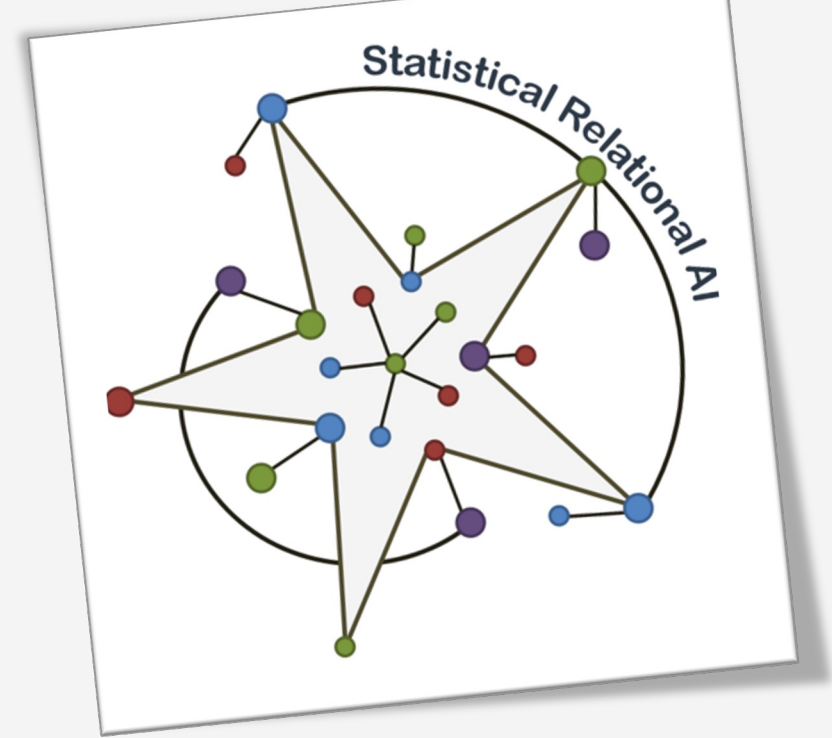
# Statistical Relational AI

## Exploiting Symmetries

Tanya Braun, University of Münster

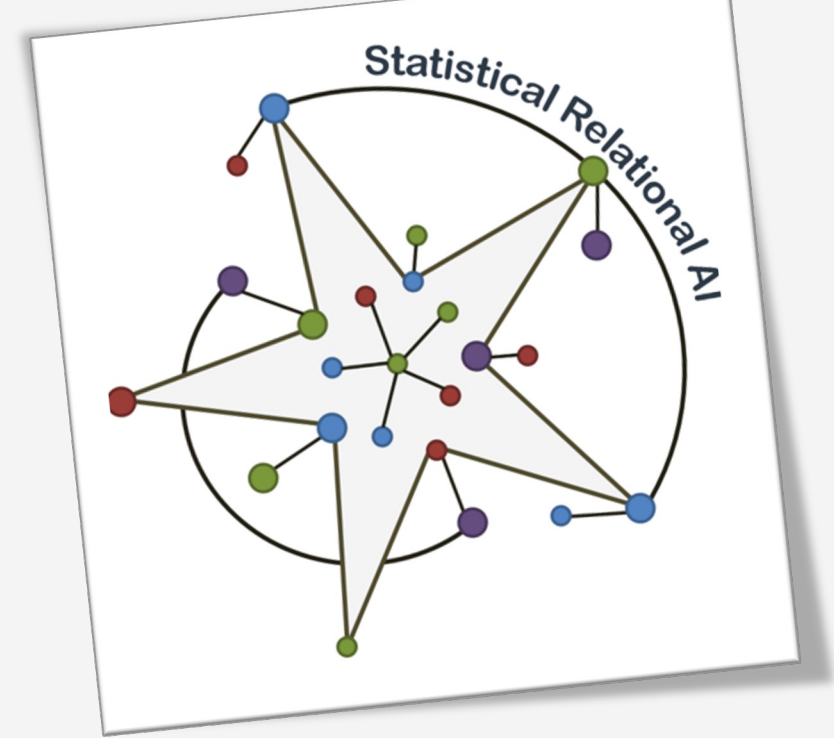
Marcel Gehrke, University of Lübeck

Marco Wilhelm, TU Dortmund University

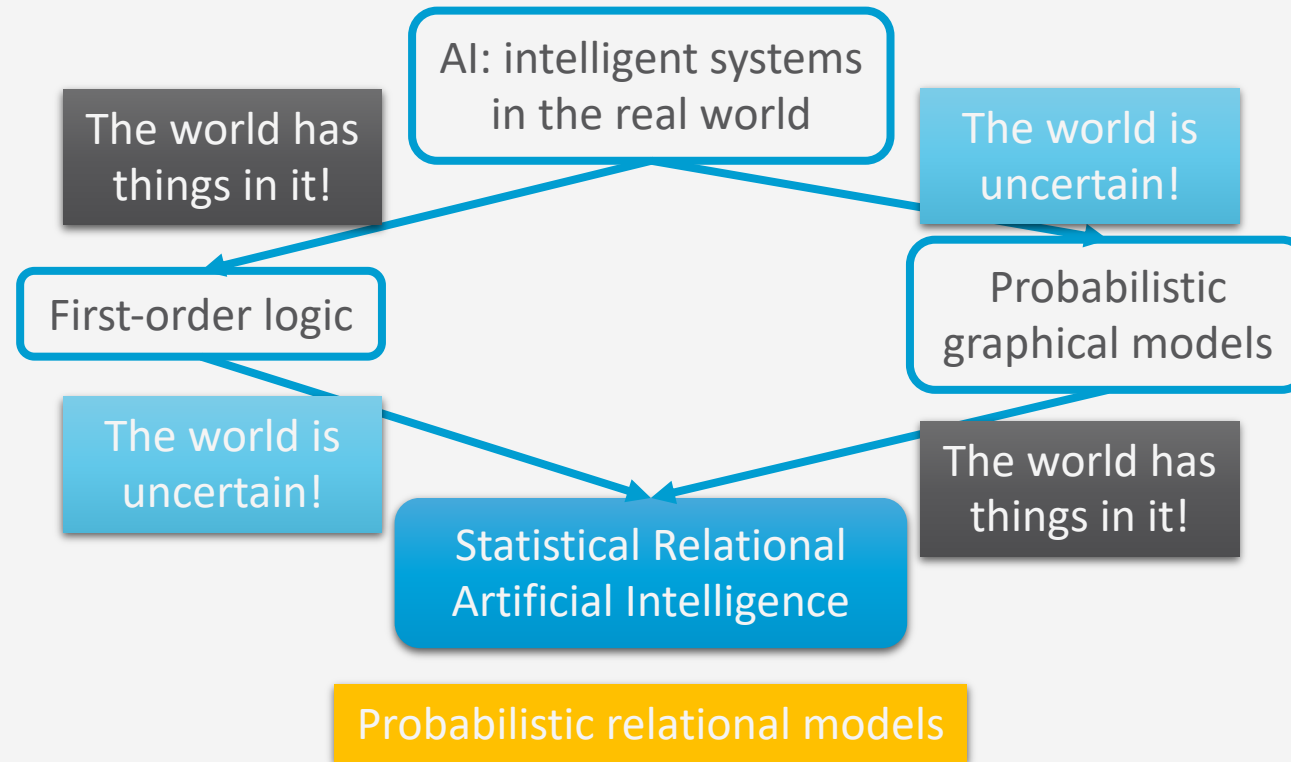


## Agenda

1. Introduction [Tanya]
2. Exploiting Symmetries in Probabilistic Graphical Models [Marcel]
3. Exploiting Symmetries in Conditional Knowledge Bases [Marco]
4. Summary [Tanya]



# Statistical Relational Artificial Intelligence (StaRAI)

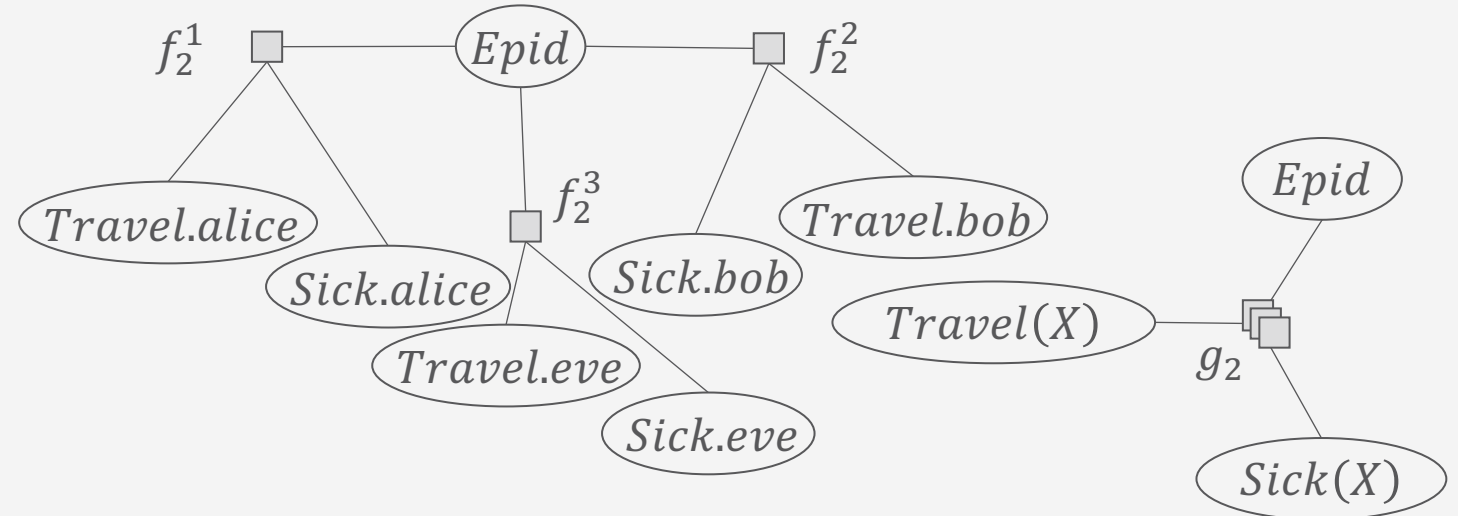


## Exploiting Symmetries

- Exchangeable random variables in the full joint probability distribution
  - Inference using representatives
  - Tractability in terms of domain sizes

$$\begin{aligned}
 &(\mathbf{10}, \text{Presents}(\text{alice}, p_1, \text{ijcai}) \Rightarrow \text{Attends}(\text{alice}, \text{ijcai})) \\
 &(\mathbf{10}, \text{Presents}(\text{alice}, p_1, \text{kr}) \Rightarrow \text{Attends}(\text{alice}, \text{kr})) \\
 &(\mathbf{10}, \text{Presents}(\text{alice}, p_2, \text{ijcai}) \Rightarrow \text{Attends}(\text{alice}, \text{ijcai})) \\
 &(\mathbf{10}, \text{Presents}(\text{alice}, p_2, \text{kr}) \Rightarrow \text{Attends}(\text{alice}, \text{kr}))
 \end{aligned}$$

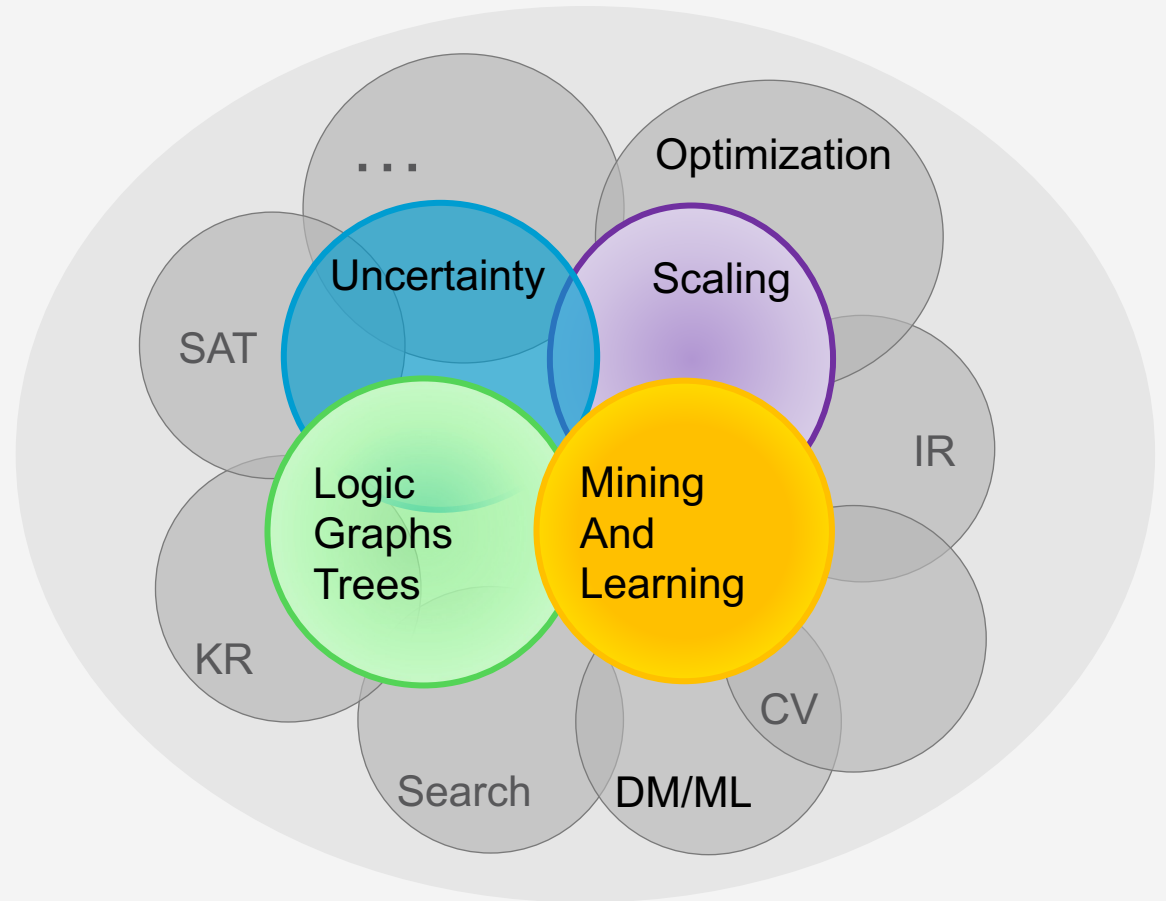
$$\mathbf{10} \text{ Presents}(X, P, C) \Rightarrow \text{Attends}(X, C)$$



# The Larger Scope

## Statistical Relational Learning & AI

- Study and design
  - intelligent agents
  - that reason about and
  - act in noisy worlds
  - composed of objects and relations among the objects



## Some Things We Did Not Talk About Today: More on Lifted Inference

- Approximate inference, e.g.,
  - Lifted belief propagation [Ahmadi et al. 13]
  - Lifted importance sampling [Gogate et al. 12]
  - Lifted MCMC [Niepert 12]
- Lifted evidence [Van den Broeck & Davis 12]
- Lifted queries [B & Möller 18]
- Assignment queries: Lifted inference for MPE [de Salvo Braz et al. 06, Apsel & Brafman 12, B & Möller 19] and MAP queries [B 20]
- Continuous inference [Choi et al. 10, Hartwig et al. 23]
- Lifted variational inference in hybrid models [Choi & Amir 12]

Plus, learning of relational models:  
e.g., boosted relational learning  
[Natarajan et al. 12]

# Some Things We Did Not Talk About Today:

## Decision Making

- Models:
  - Decision-theoretic ProbLog [Van den Broeck et al. 10]
  - First-order (partially observable) Markov decision processes (FO (PO)MDPs) [Boutelier et al. 01]
  - Markov logic decision networks [Nath & Domingos 09]
  - (Temporal) decision parfactor models [Gehrke et al. 19b, c]
  - Lifting the agent set in decentralised POMDPs (multi-agent setting) [B et al. 22]
- Solution methods:
  - Symbolic dynamic programming for FO POMDPs [Sanner & Kersting 10]
  - L(D)JT for decision parfactor models [Gehrke et al. 19b, c]

## Some Things We Did Not Talk About Today: Description Logics / Infinite Domains

- Probabilistic Description Logics, e.g.:
  - Tractable Probabilistic DLs [1]
  - Expressive Probabilistic DLs [2]
- Maximum Entropy and Infinite Domains:
  - Entropy Limit Approach [3]
  - Maximum Entropy Approach [4]
  - Entropy Limit Conjecture [5]
- Maximum Entropy and Description Logics:
  - Probabilistic DL ALCP [6]
  - Probabilistic DL ALC<sup>ME</sup> [7]

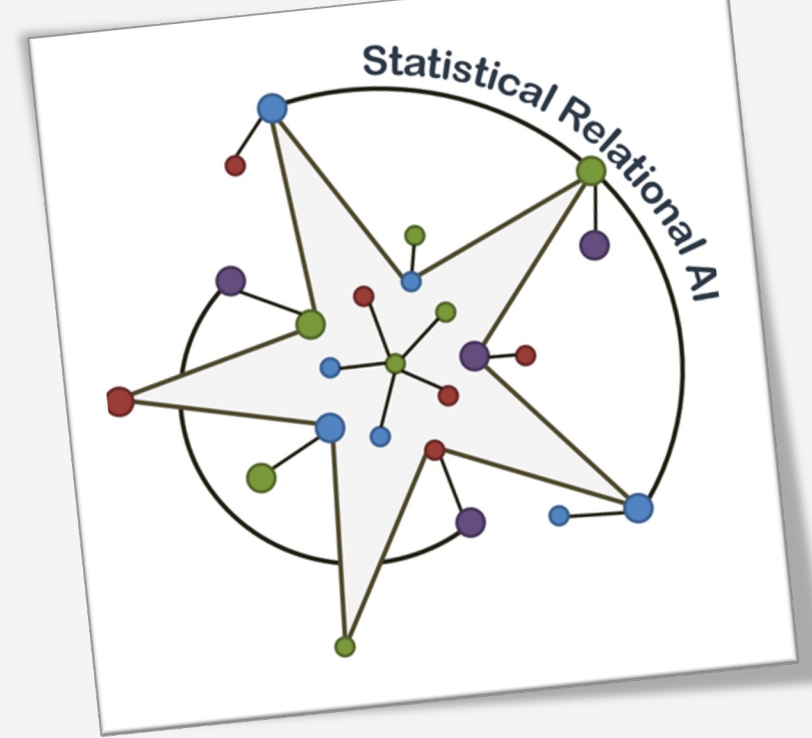


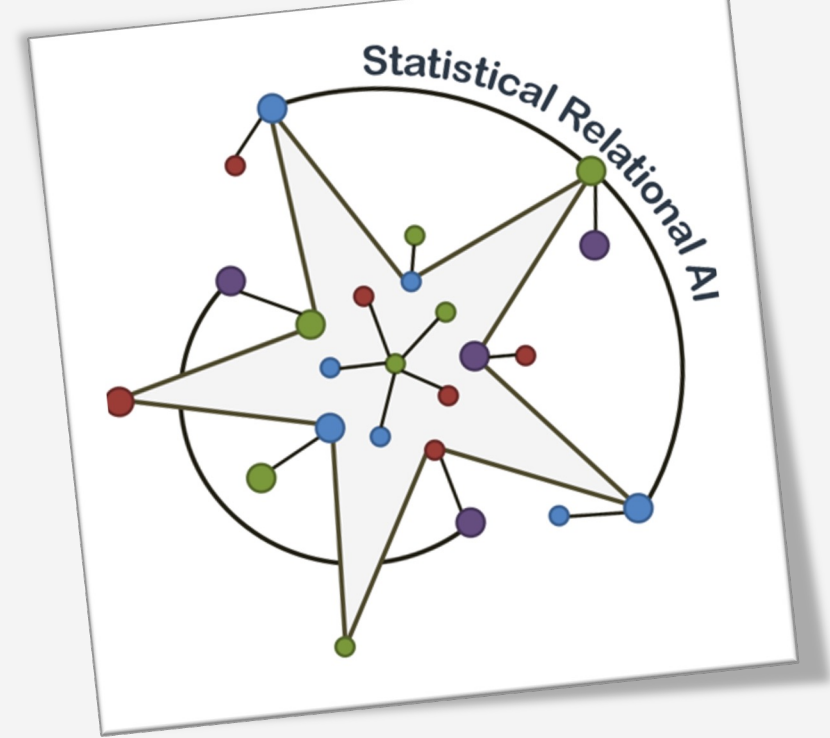
## What Else Is There To Do?

- Enhance lifting applicability, e.g., approximating symmetries
- Develop more robust learning algorithms
- Incorporate additional requirements such as
  - Privacy
  - Ethics
  - Explainability
  - Human-awareness
- And so much more...

Thank you!

- For slides, please go to (QR code goes to this address):  
<https://www.uni-muenster.de/Informatik.AGBraun/en/research/tutorials/kr-23.html>





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