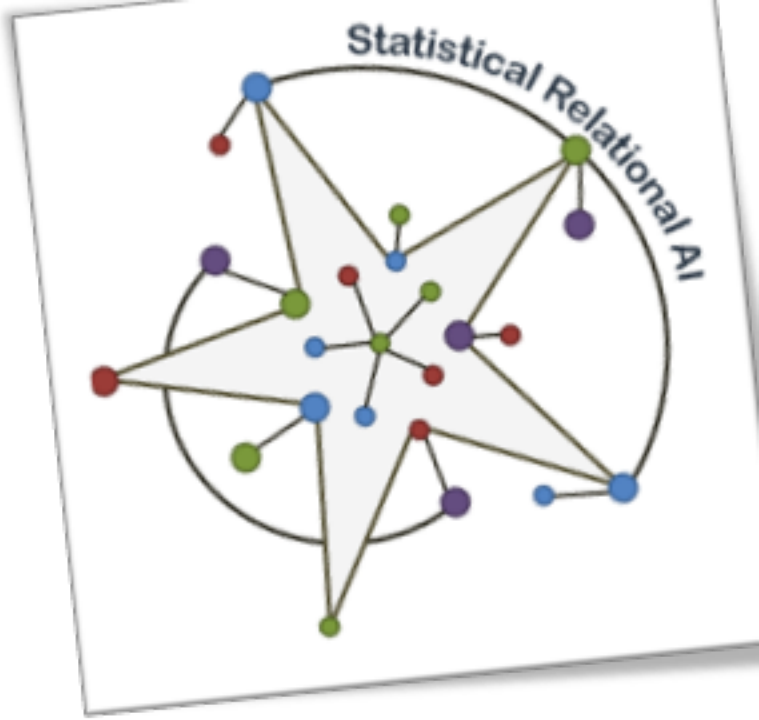
StarAI

Semantics and Symmetries in Exact Lifted Inference



Tutorial ECAI 2020

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Agenda

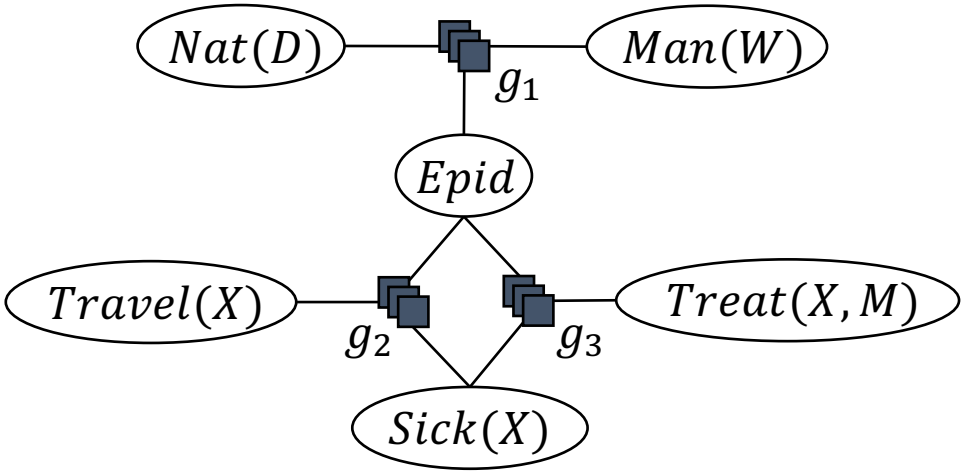
- Probabilistic relational models (PRMs) [Ralf]
- Exact Symmetries and Changing Domains in static PRMs [Tanya]
- Stable inference over time in dynamic PRMs [Marcel]
- Summary [Tanya]

Semantics of a PRM

Also holds for MLNs

- Joint probability distribution P_G by grounding

$$P_G = \frac{1}{Z} \prod_{f \in gr(G)} f$$



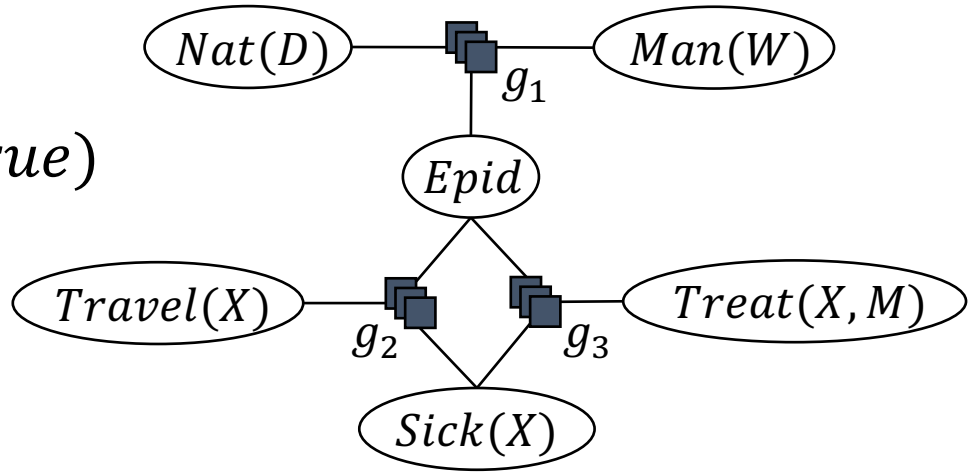
$$Z = \sum_{v \in r(rv(gr(G)))} \prod_{f \in gr(G)} f_i(\pi_{rv(f_i)}(v))$$

$\pi_{variables}(v)$ = projection of v onto $variables$

Queries

- Marginal distribution
  - $P(Sick(eve))$
  - $P(Travel(eve,)\ Treat(eve, m_1))$
- Conditional distribution
  - $P(Sick(eve)|Epid)$
  - $P(Epid|Sick(eve) = true)$
- Assignment queries
  - MPE
  - MAP

Avoid groundings!



Lifted Variable Elimination (LVE) among others

Exact Symmetries

- Together with grounding semantics

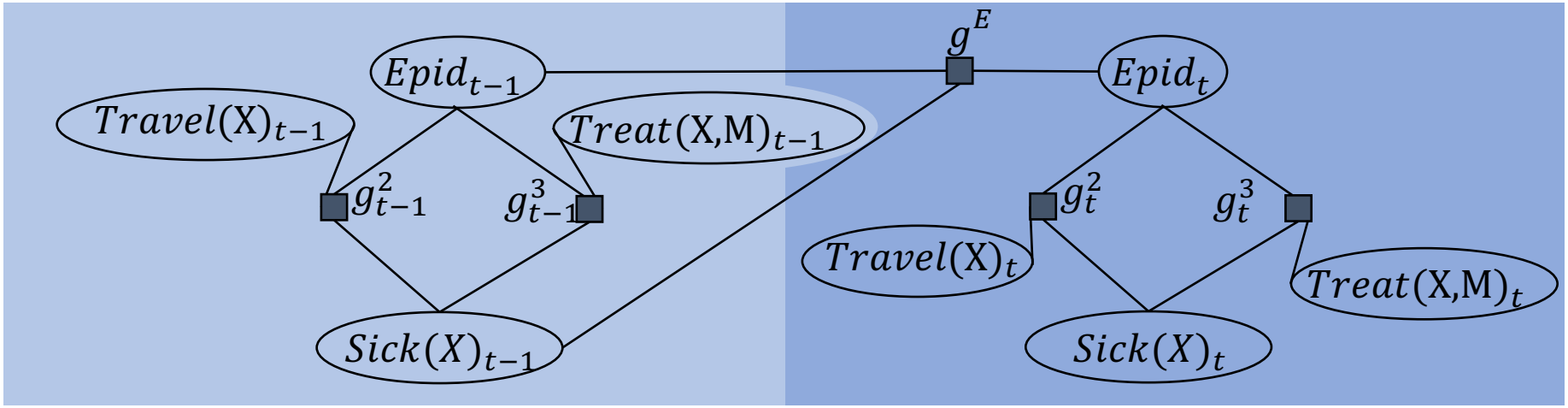
- Tractability of query answering problem
  - Polynomial w.r.t. domain sizes
- Colour passing for exact compression of models
  - Equivalence between ground and lifted model
- Symmetric evidence for lifted evidence handling
  - Only so many values observable
- Lifted queries for lifted query answering
  - Indistinguishable query terms

Changing Domains

- Invariant models
  - Models where query answers are independent from specific domain sizes
- Increasing domains
  - Adapting weights to avoid extreme behaviour
    - Domain-size aware models
- Unknown domains
  - Set of or distribution over universes
  - New types of queries
    - Up and including form of model checking

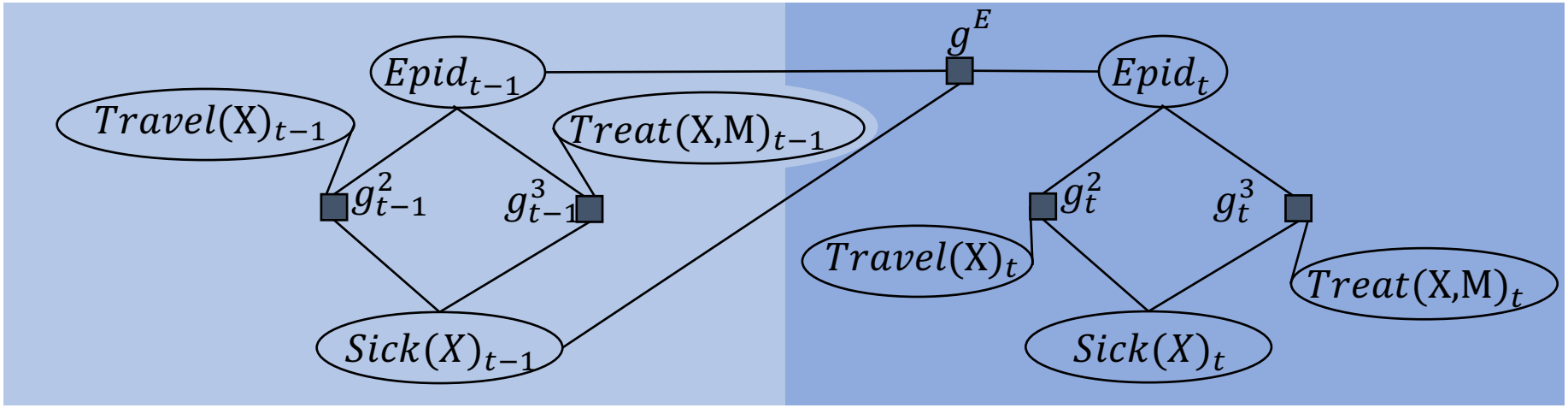
Dynamic PRMs

- Marginal distribution query: $P\left(A_\pi^i \,\middle|\, E_{0:t}\right)$ w.r.t. the model:
  - Hindsight: $\pi < t$ (Was there an epidemic $t - \pi$ days ago?)
  - Filtering: $\pi = t$ (Is there an currently an epidemic?)
  - Prediction: $\pi > t$ (Is there an epidemic in $\pi - t$ days?)
- MPE, MAP on temporal sequence



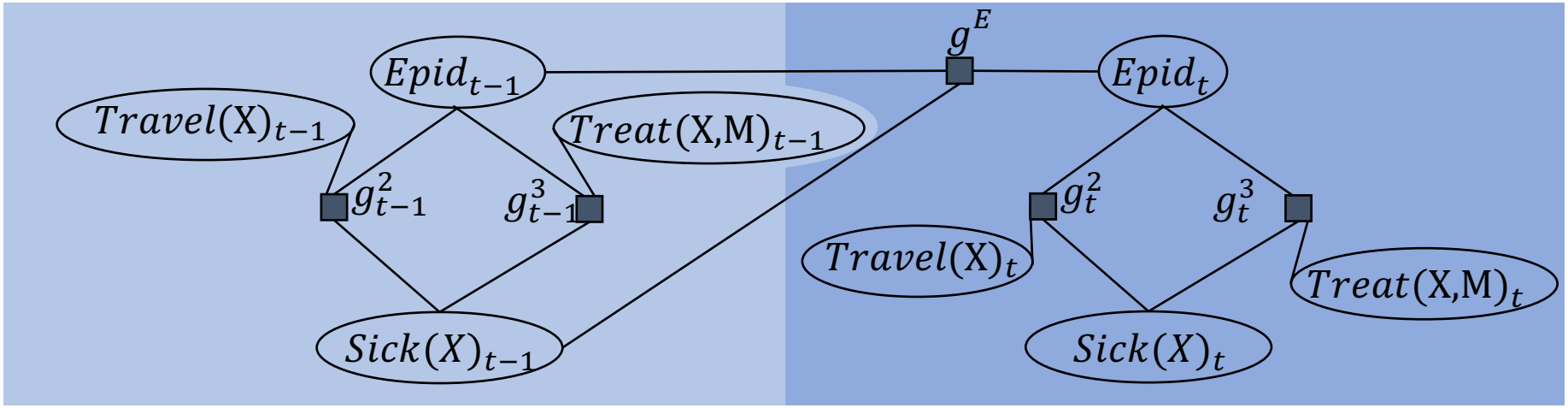
Reasoning over Time

- Unrolling of model infeasible
- Using interface variables to separate past from future
  - Helper structure called first-order junction tree



Keeping reasoning polynomial

- Evidence yielding a splintered model
- Taming effects of evidence by approximating symmetries to merge groups of parfactors
  - Error indefinitely bounded due to model behaviour applied with each passing timestep



The Finish Line

- Lifted inference
  - Use information about regular structures to speed up inference
  - Treat constants as indistinguishable as long as there is no evidence to the contrary
    - Another example: Exploration vs. exploitation in agents (Example by Kersting and Natarajan, 2015)
      - Exploring a house, after having opened one or two water taps in a kitchen, household robot can expect other water taps in kitchens to behave similarly
- *But there is so much more to do!*
  - Something we talked about today: unknown domains
  - Something we did not talk about: lifted decision making / first-order MDPs
    - Some work already exists e.g., Sanner and Kersting, 2010; Gehrke et al., 2019
    - Interaction beyond debugging

The End *

- Gehrke et al. (2019)
  Marcel Gehrke, Tanya Braun, Ralf Möller, Alexander Waschkau, Christoph Strumann, and Jost Steinhäuser: Lifted Maximum Expected Utility. In: *Artificial Intelligence in Health*, 2019.
- Kersting and Natarajan (2015)
  Kristian Kersting and Sriraam Natarajan: Statistical Relational Artificial Intelligence: From Distributions through Actions to Optimisation. *KI - Künstliche Intelligenz*, 29(4):363-368, 2015.
- Sanner and Kersting (2010)
  Scott Sanner and Kristian Kersting: Symbolic Dynamic Programming for First-order POMDPs. In: *AAAI-10 Proceedings of the 24th AAAI Conference on Artificial Intelligence*, 2010.

*PRMs are a true backbone of AI, and this tutorial emphasized only some central topics. We definitely did not cite all publications relevant to the whole field of PRMs here. We would like to thank all our colleagues for making their slides available (see some of the references to papers for respective credits). Slides or parts of it are almost always modified.