# Fast Reduction of Ground Markov Logic Networks

Shavlik & Natarajan, IJCAI 2009

#### Markov Logic Networks

Weighted logic

1.5 
$$\forall x \ Smokes(x) \Rightarrow Cancer(x)$$
  
1.1  $\forall x, y \ Friends(x, y) \Rightarrow \left(Smokes(x) \Leftrightarrow Smokes(y)\right)$ 

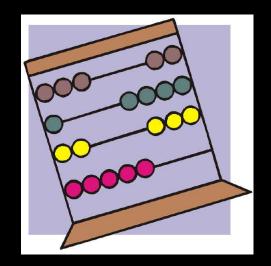
$$P(x) = \frac{1}{Z} \exp \left( \sum_{i} w_{i} n_{i}(x) \right)$$
Weight of formula *i*
No. of true groundings of formula *i* in *x*

- Standard approach
  - 1) Assume finite number of constants
  - 2) Create all possible groundings
  - 3) Perform statistical inference (often via sampling)

## Counting Satisfied Groundings

Typically lots of redundancy in FOL sentences

$$\forall x, y, z \quad p(x) \land q(x, y, z) \land r(z) \rightarrow w(x, y, z)$$



If p(John) = false, then formula = true for all Y and Z values

# Factoring Out the Evidence



Let A = weighted sum of formula satisfied by evidence

Let B<sub>i</sub> = weighted sum of formula in world i **not** satisfied by evidence

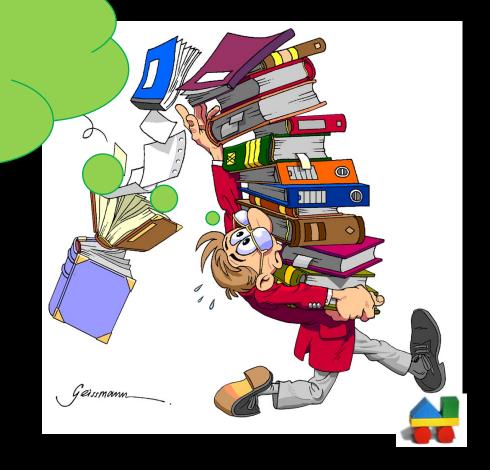
$$e \stackrel{\text{Bi Bi}}{=}$$

$$i) = \frac{\text{A + B1}}{\text{A + B1}} = \frac{\text{An+ Bn}}{\text{An+ Bn}}$$

Prob(world i) = 
$$e^{A} \stackrel{B1}{\leftarrow} + ... + e^{An+Bn}$$

Efficiently factor out those formula groundings that evidence satisfies

Can potentially eliminate the need for approximate inference



### Worked Example

 $\forall$  x, y, z GradStudent(x)  $\land$  Prof(y)  $\land$  Prof(z)  $\land$  TA(x, z)  $\land$  SameGroup(y, z)  $\rightarrow$  AdvisedBy(x, y)

10,000	People at some school The Evidence	е
2000	Graduate students	
1000	Professors	
1000	TAs	
500	Pairs of professors in the same group	

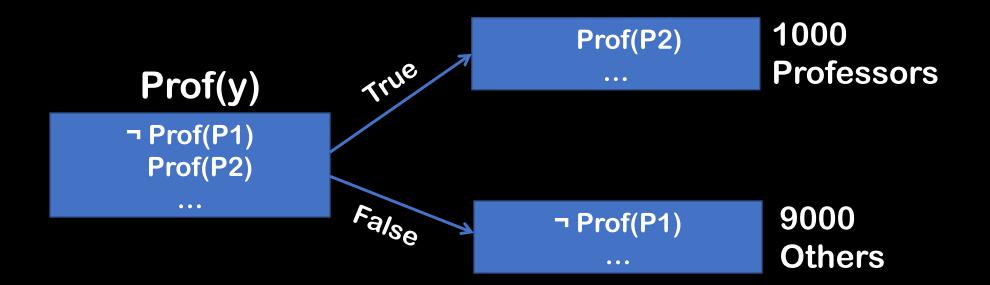
Total Num of Groundings =  $|x| \times |y| \times |z| = 10^{12}$ 

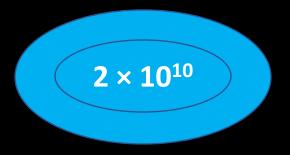
**10**<sup>12</sup>

GradStudent(x)  $\land$  Prof(y)  $\land$  Prof(z)  $\land$  TA(x,z)  $\land$  SameGroup(y,z)  $\rightarrow$  AdvisedBy(x,y) **FROG** keeps only these X values **GradStudent(P1)** 2000 **GradStudent(P3)** True **Grad Students GradStudent(x) GradStudent(P1)** ¬ GradStudent(P2) **GradStudent(P3)** ¬ GradStudent(P2) False 8000 ¬ GradStudent(P4) **Others** All these values for X satisfy the clause, regardless of Y and Z  $2 \times 10^{11}$ Instead of  $10^4$  values for X,

have 2 x 10<sup>3</sup>

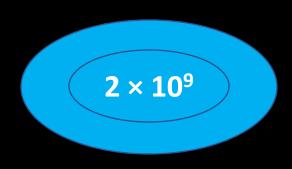
#### GradStudent(x) $\land$ Prof(y) $\land$ Prof(z) $\land$ TA(x,z) $\land$ SameGroup(y,z) $\rightarrow$ AdvisedBy(x,y)

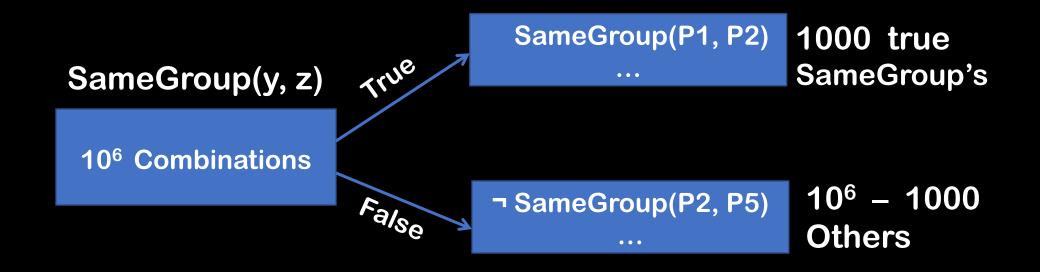




**GradStudent(x)**  $\land$  Prof(y)  $\land$  Prof(z)  $\land$  TA(x,z)  $\land$  SameGroup(y,z)  $\rightarrow$  AdvisedBy(x,y)

<<< Same as Prof(y) >>>

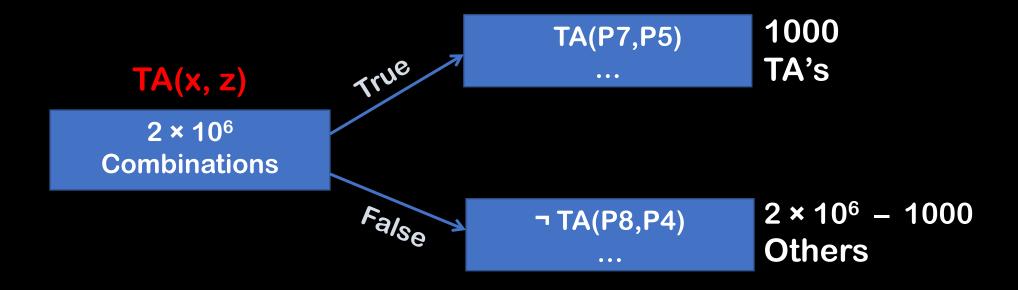


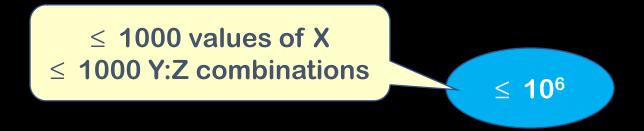


2000 values of X 1000 Y:Z combinations

2 × 10<sup>6</sup>

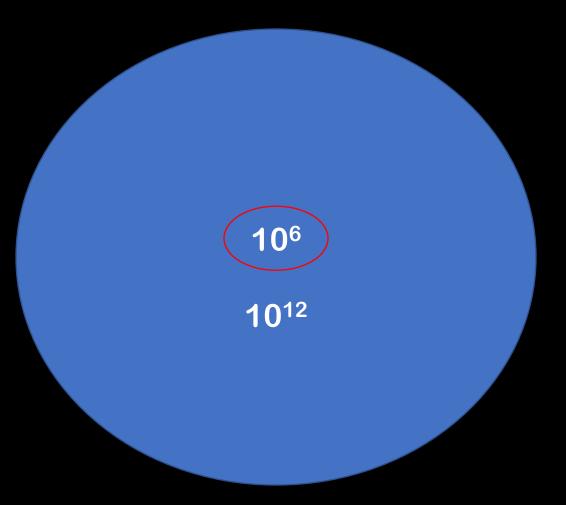
#### GradStudent(x) $\land$ Prof(y) $\land$ Prof(z) $\land$ TA(x,z) $\land$ SameGroup(y,z) $\rightarrow$ AdvisedBy(x,y)





Original number of groundings =  $10^{12}$ 

Final number of groundings ≤ 10<sup>6</sup>



## Sample Results: UWash-CSE

