The Most Probable Explanation for Probabilistic Logic Programs with Annotated Disjunctions

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(Nancy, France)

0.6 0.3 0.1

0.5 0.1 0.4

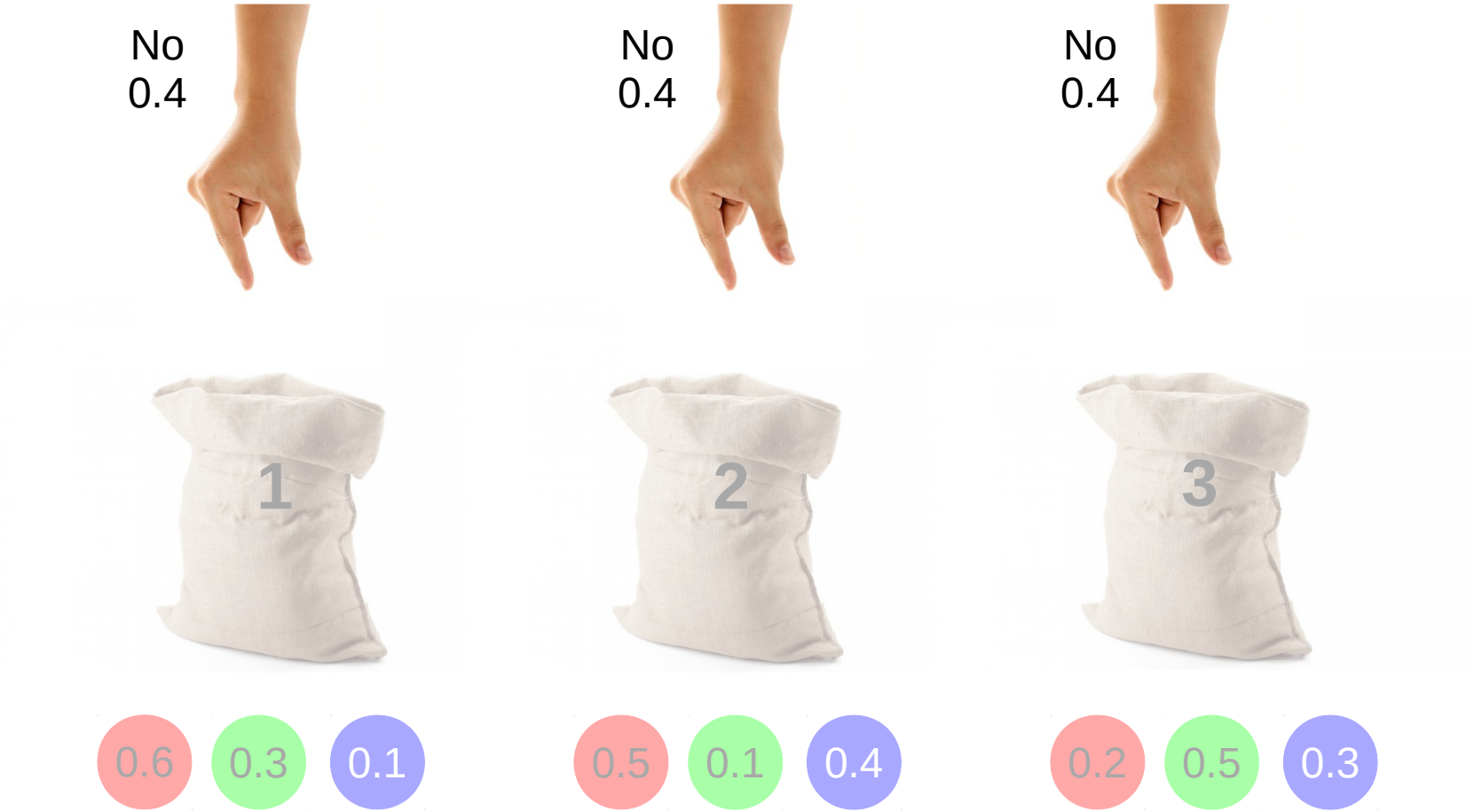
0.2 0.5 0.3

Yes/No
0.6/0.4

Yes/No
0.6/0.4

Yes/No
0.6/0.4

What is most probable to happen?



What is most probable to happen?

What is most probable to happen

knowing the player always picks?

What is most probable to happen

knowing the player always picks?

The Most Probable Explanation

- Useful for
  - Medical Diagnostics
  - Computer Systems Diagnostics
  - Scheduling
  - etc.
- Typical task in SRL and PGM

Outline

- ProbLog programs with Annotated Disjunctions
- MPE of ProbLog programs
- Encodings of Annotated Disjunctions
- Evaluation

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ProbLog*

```
0.6::red(b1).      win:- red(b1), red(b2).
0.2::red(b2).      win:- red(b2), red(b3).
0.7::red(b3).      win:- red(b1), red(b3).
```


* http://dtai.cs.kuleuven.be/problog/

Possible Worlds

0.6::red(b1). win:- red(b1), red(b2).
0.2::red(b2). win:- red(b2), red(b3).
0.7::red(b3). win:- red(b1), red(b3).

poss. world	r_1	r_2	r_3	win	$\mathrm{P}(r_1)$	$\mathrm{P}(r_2)$	$\mathrm{P}(r_3)$	$\mathrm{P}(\omega_i)$
ω_1	T	T	T	T	0.6	0.2	0.7	0.084
ω_2	T	T	F	T	0.6	0.2	0.3	0.036
ω_3	T	F	T	T	0.6	0.8	0.7	0.336
ω_4	T	F	F	F	0.6	0.8	0.3	0.144
ω_5	F	T	T	T	0.4	0.2	0.7	0.056
ω_6	F	T	F	F	0.4	0.2	0.3	0.024
ω_7	F	F	T	F	0.4	0.8	0.7	0.224
ω_8	F	F	F	F	0.4	0.8	0.3	0.096

Probabilistic Facts

Yes/No
0.6/0.4

Can express

Cannot express

Probabilistic Facts

Yes/No
0.6/0.4

Can express

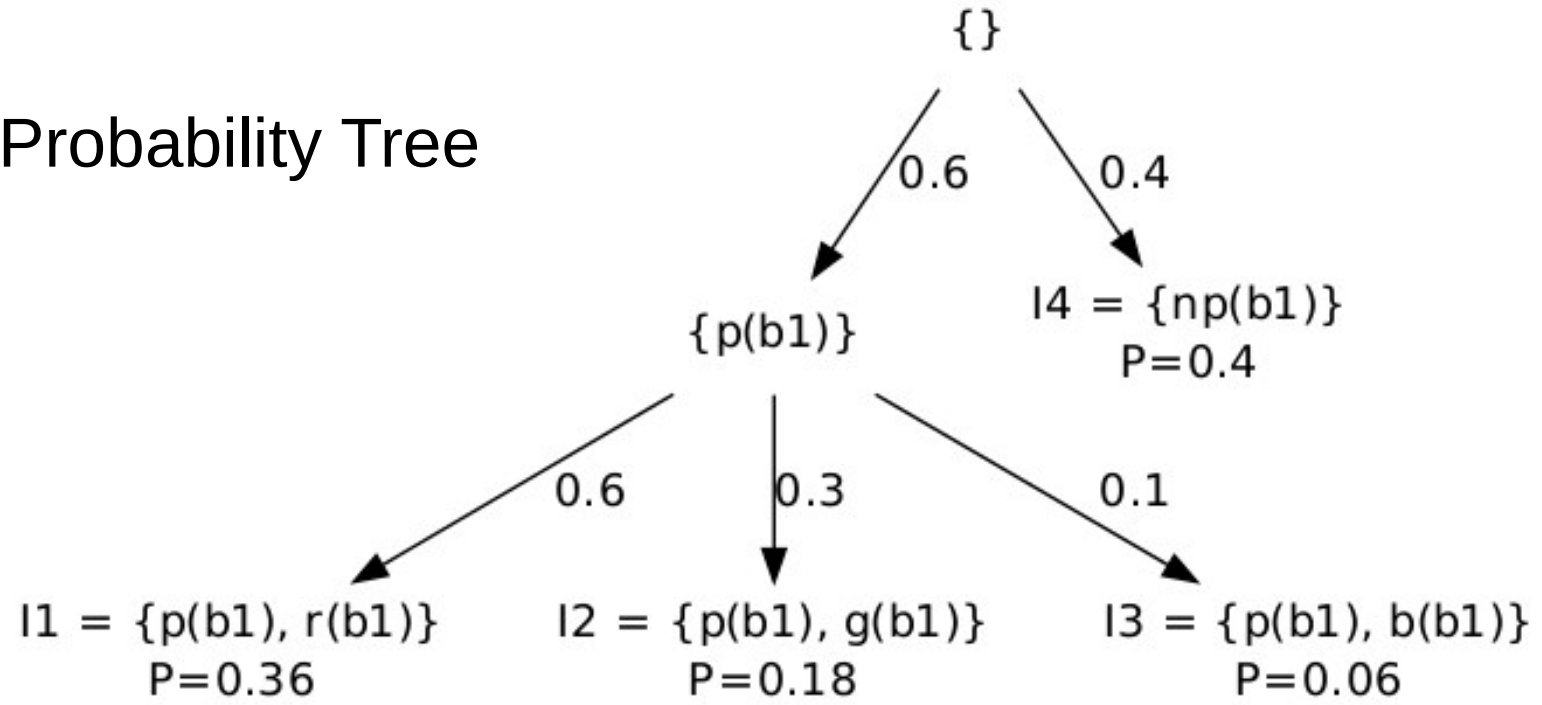
Cannot express
but annotated disjunctions can

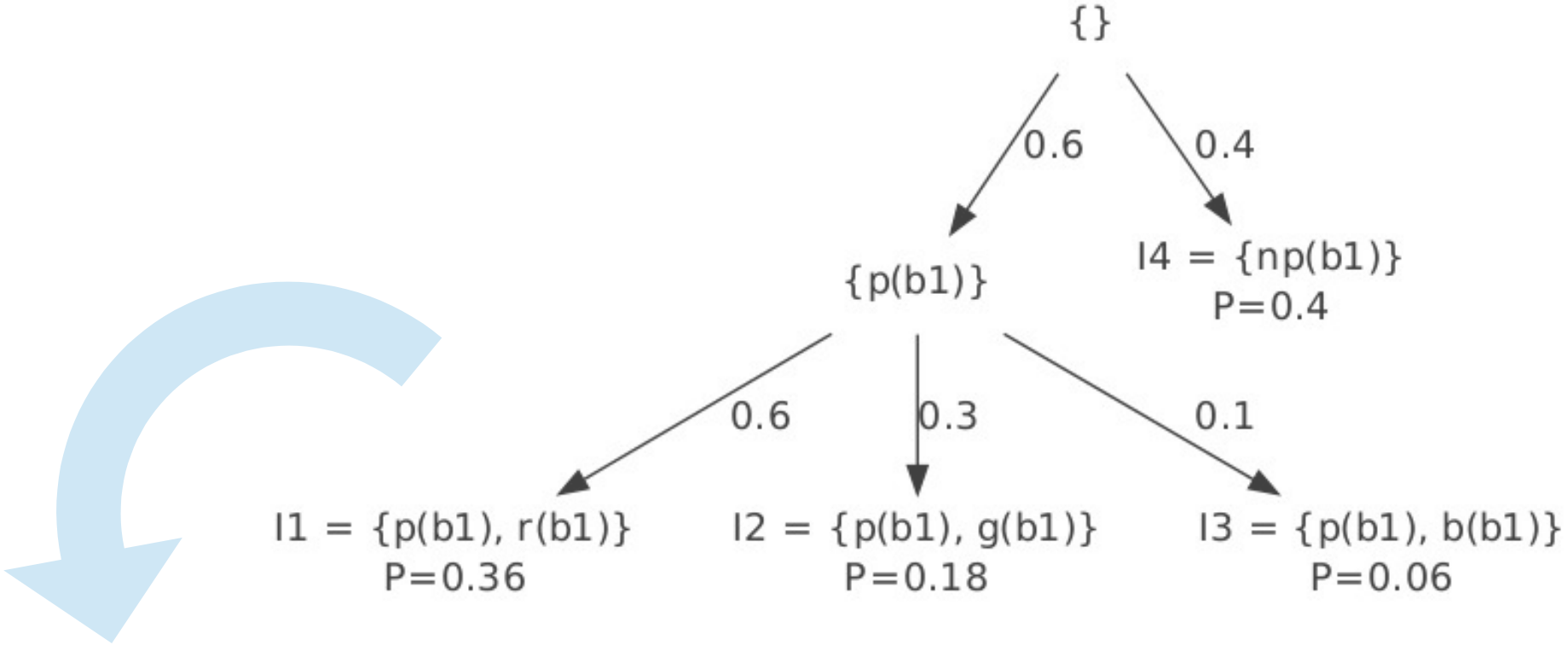
Logic Programs with Annotated Disjunctions

$0.6 :: pick(b1); 0.4 :: no\_pick(b1)$ <- $true.$

$0.6 :: red(b1); 0.3 :: green(b1); 0.1 :: blue(b1)$ <- $pick(b1).$

Probability Tree





Selection:	Interpretation	Probability $P(\sigma_i)$
σ_1	$I1 = \{\texttt{pick(b1)}, \texttt{red(b1)}\}$	0.36
σ_2	$I2 = \{\texttt{pick(b1)}, \texttt{green(b1)}\}$	0.18
σ_3	$I3 = \{\texttt{pick(b1)}, \texttt{blue(b1)}\}$	0.06
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ProbLog

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```

poss. world	r_1	r_2	r_3	win	$\mathrm{P}(r_1)$	$\mathrm{P}(r_2)$	$\mathrm{P}(r_3)$	$\mathrm{P}(\omega_i)$
ω_1	T	T	T	T	0.6	0.2	0.7	0.084
ω_2	T	T	F	T	0.6	0.2	0.3	0.036
ω_3	T	F	T	T	0.6	0.8	0.7	0.336
ω_4	T	F	F	F	0.6	0.8	0.3	0.144
ω_5	F	T	T	T	0.4	0.2	0.7	0.056
ω_6	F	T	F	F	0.4	0.2	0.3	0.024
ω_7	F	F	T	F	0.4	0.8	0.7	0.224
ω_8	F	F	F	F	0.4	0.8	0.3	0.096

ProbLog

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0.6::red(b1).      win:- red(b1), red(b2).
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poss. world	r_1	r_2	r_3	win	$P(r_1)$	$P(r_2)$	$P(r_3)$	$P(\omega_i)$
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ω_8	F	F	F	F	0.4	0.8	0.3	0.096

Logic Programs with Annotated Disjunctions

$0.6 :: pick(b1); 0.4 :: no\_pick(b1)$ <- $true.$

$0.6 :: red(b1); 0.3 :: green(b1); 0.1 :: blue(b1)$ <- $pick(b1).$

Selection:	Interpretation	Probability $P(\sigma_i)$
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σ_2	$I2 = \{$`pick(b1)`, `green(b1)`$\}$	0.18
σ_3	$I3 = \{$`pick(b1)`, `blue(b1)`$\}$	0.06
σ_4	$I4 = \{$`no_pick(b1)`$\}$	0.4

Logic Programs with Annotated Disjunctions

$0.6 :: pick(b1); 0.4 :: no\_pick(b1)$ <- $true.$

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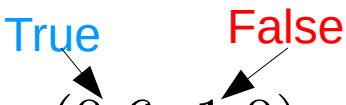
ProbLog Encoding of ADs

- ADs converted to Facts and Rules.
- Negation retains the mutual exclusiveness.
- Incorrect for MPE.

Weighted CNF Encoding of ADs

- Surrogate Probabilistic Facts
- Rules
- Constraints
  (based on cProbLog implementation)
- Retains the AD semantics regardless the task.

Weighted CNF Encoding of ADs



(0.6, 1.0)::spf(1, red(b1), 1).
(0.3, 1.0)::spf(1, green(b1), 2).
(0.1, 1.0)::spf(1, blue(b1), 3).
red(b1):- pick(b1), spf(1, red(b1), 1).
green(b1):- pick(b1), spf(1, green(b1), 2).
blue(b1):- pick(b1), spf(1, blue(b1), 3).

(0.6, 1.0)::spf(2, pick(b1), 1).
(0.4, 1.0)::spf(2, no_pick(b1), 2).
pick(b1):- spf(2, pick(b1), 1).
no_pick(b1):- spf(2, no_pick(b1), 2).

...

… and Constraints in CNF (to retain the mutual exclusiveness)

$$(\neg \texttt{spf}(1, \texttt{red}(\texttt{b1}), 1) \vee \neg \texttt{spf}(1, \texttt{green}(\texttt{b1}), 2)) \wedge$$
$$(\neg \texttt{spf}(1, \texttt{red}(\texttt{b1}), 1) \vee \neg \texttt{spf}(1, \texttt{blue}(\texttt{b1}), 3)) \wedge$$
$$(\neg \texttt{spf}(1, \texttt{green}(\texttt{b1}), 2) \vee \neg \texttt{spf}(1, \texttt{blue}(\texttt{b1}), 3))$$
$$\text{pick}(\text{b1}) \leftrightarrow (\texttt{spf}(1, \texttt{red}(\texttt{b1}), 1) \vee \texttt{spf}(1, \texttt{green}(\texttt{b1}), 2) \vee \texttt{spf}(1, \texttt{blue}(\texttt{b1}), 3))$$
$$\neg \texttt{spf}(2, \texttt{pick}(\texttt{b1}), 1) \vee \neg \texttt{spf}(2, \texttt{no\_pick}(\texttt{b1}), 2)$$
$$\text{spf}(2,\ \text{pick}(\text{b1}),\ 1) \vee \texttt{spf}(2, \texttt{no\_pick}(\texttt{b1}), 2)$$

Possible Worlds of the WMC Encoding

	spf(1,r,1)	spf(1,g,2)	spf(1,b,3)	spf(2,p,1)	spf(2,np,2)	r	g	b	p	np	$P(\omega_i)$
ω_1	T	F	F	T	F	T	F	F	T	F	0.36
ω_2	F	T	F	T	F	F	T	F	T	F	0.18
ω_3	F	F	T	T	F	F	F	T	T	F	0.06
ω_4	F	F	F	F	T	F	F	F	F	T	0.40

Possible Worlds of the WMC Encoding

	spf(1,r,1)	spf(1,g,2)	spf(1,b,3)	spf(2,p,1)	spf(2,np,2)	r	g	b	p	np	$P(\omega_i)$
ω_1	T	F	F	T	F	T	F	F	T	F	0.36
ω_2	F	T	F	T	F	F	T	F	T	F	0.18
ω_3	F	F	T	T	F	F	F	T	T	F	0.06
ω_4	F	F	F	F	T	F	F	F	F	T	0.40

1:1 correspondence

Selection:	Interpretation	Probability $P(\sigma_i)$
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Possible Worlds of the WMC Encoding

Trust me it's correct

	spf(1,r,1)	spf(1,g,2)	spf(1,b,3)	spf(2,p,1)	spf(2,np,2)	r	g	b	p	np	$P(\omega_i)$
ω_1	T	F	F	T	F	T	F	F	T	F	0.36
ω_2	F	T	F	T	F	F	T	F	T	F	0.18
ω_3	F	F	T	T	F	F	F	T	T	F	0.06
ω_4	F	F	F	F	T	F	F	F	F	T	0.40

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Possible Worlds and MPE

	spf(1,r,1)	spf(1,g,2)	spf(1,b,3)	spf(2,p,1)	spf(2,np,2)	r	g	b	p	np	$P(\omega_i)$
ω_1	T	F	F	T	F	T	F	F	T	F	0.36
ω_2	F	T	F	T	F	F	T	F	T	F	0.18
ω_3	F	F	T	T	F	F	F	T	T	F	0.06
ω_4	F	F	F	F	T	F	F	F	F	T	0.40

Selection:	Interpretation	Probability $P(\sigma_i)$
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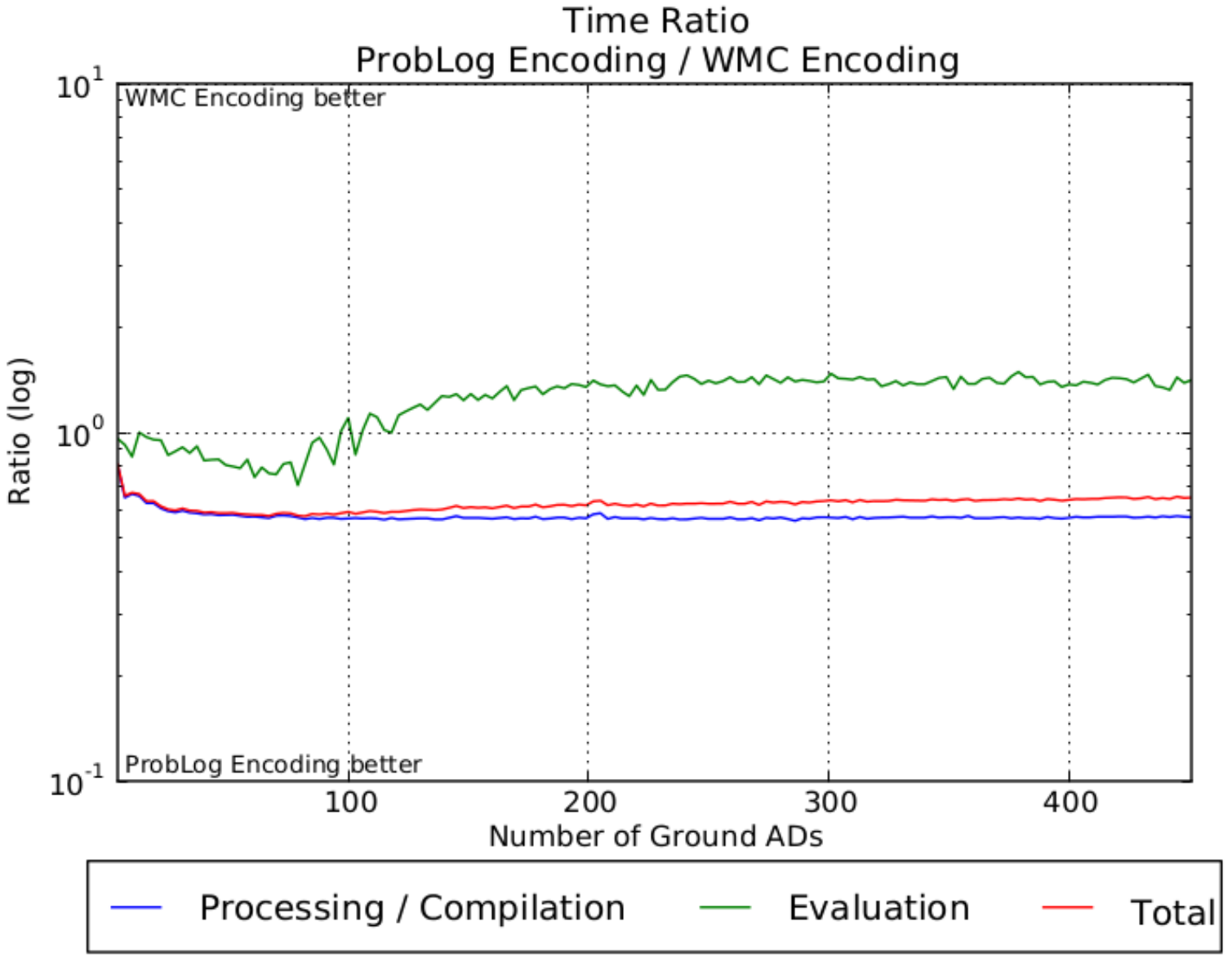
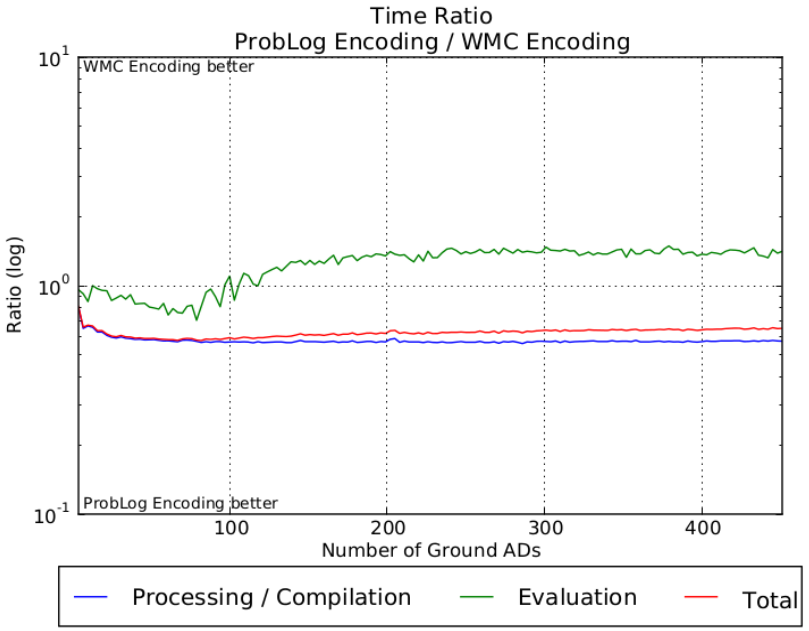
`people.cs.kuleuven.be/~dimitar.shterionov/mpe`

ProbLog vs Weighted CNF Encoding - Time

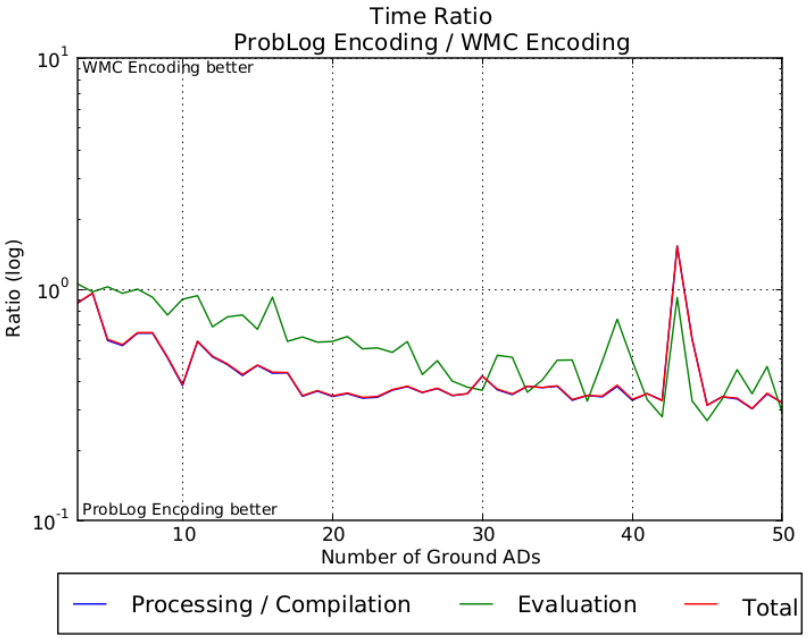
Balls



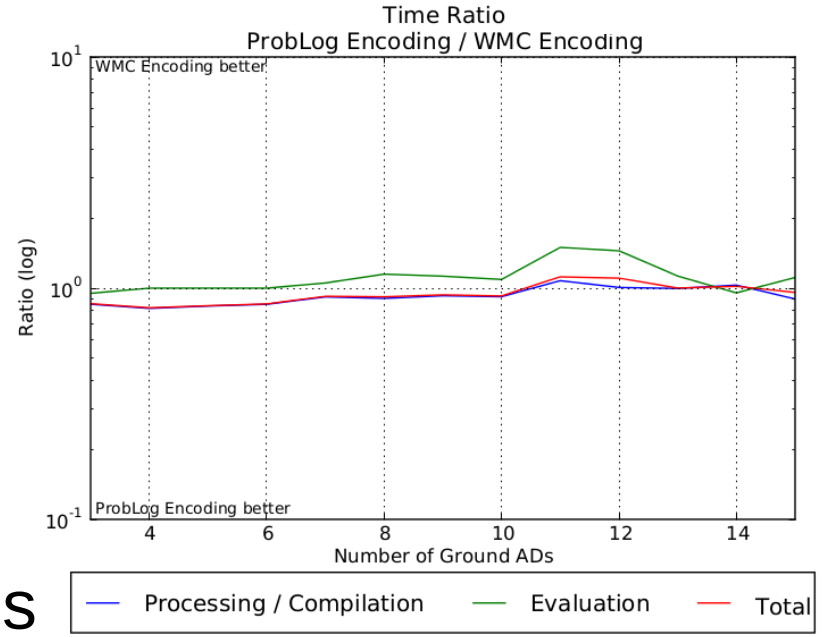
ProbLog vs Weighted CNF Encoding - Time



Balls

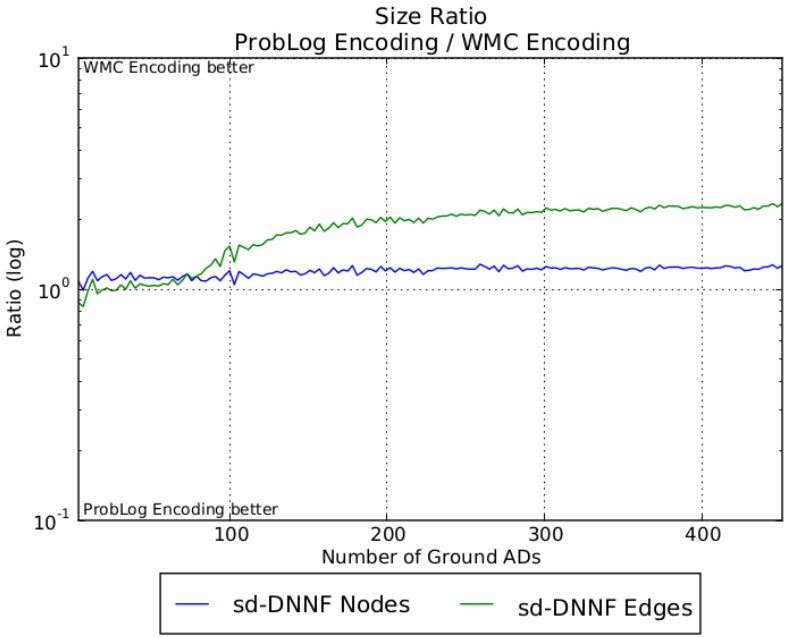


Growing Negated Body

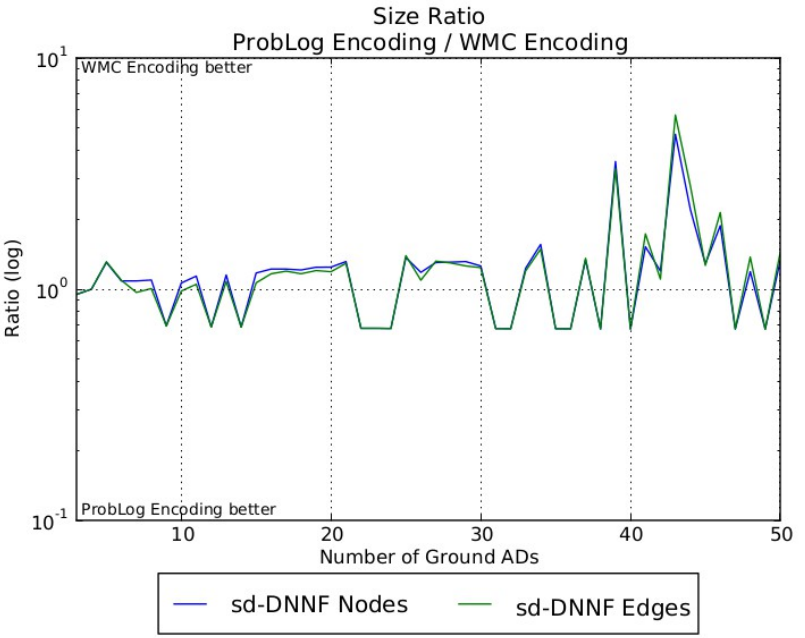


Growing Heads

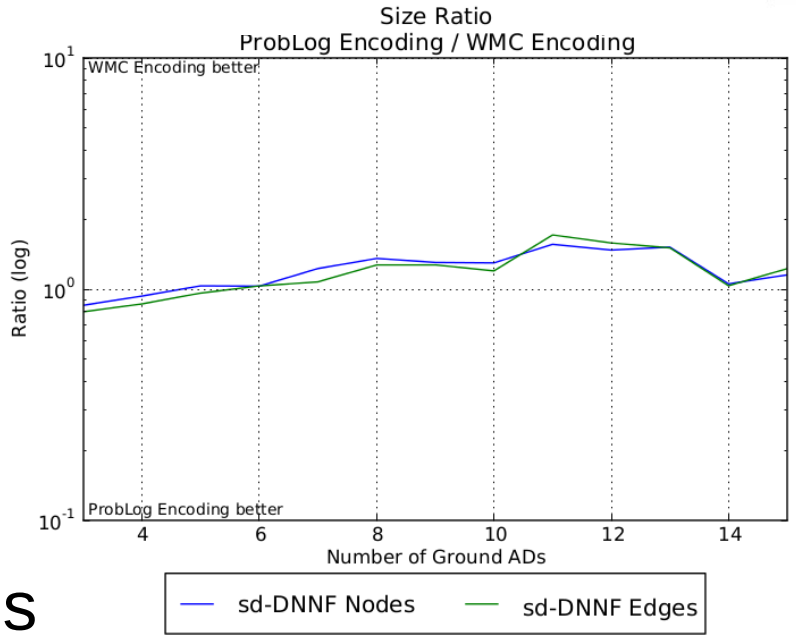
ProbLog vs Weighted CNF Encoding - Size



Balls



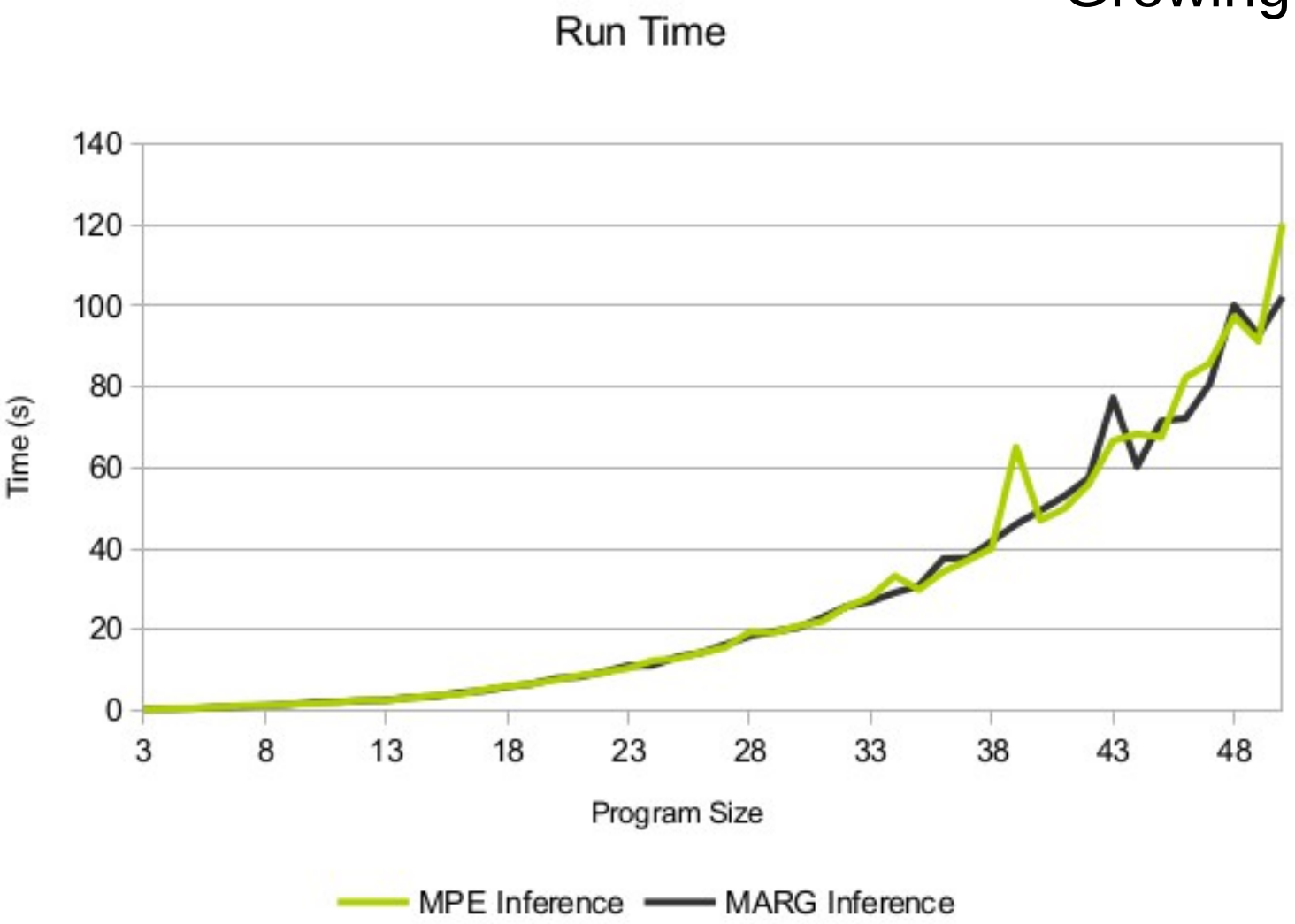
Growing Negated Body



Growing Heads

MPE - Time

Growing Negated Body



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Conclusions

- WMC encoding of Annotated Disjunctions
  - Constraints
  - Semantically correct
- (Efficient) MPE is possible
- Good performance

Thank you!
Merci!