Capita Selecta AI - Probabilistic Programming
Inference for SRL

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Probabilistic Inference Using Weighted Model Counting

1.1 PGM to CNF

1.1.1 ENC 1

Our ENC1 encoding for the Cancer Bayesian network can be found in appendix 4.1.

1.1.2 ENC 2

Our ENC2 encoding for the Cancer Bayesian network can be found in appendix 4.2.

1.2 SRL to CNF

1.2.1 Encoding of Monty Hall as CNF

An encoding of problog programs can be generated by our program as follows:

```
python3 scripts/inference.py --problog files/problog/monty_hall.pl
```

The CNF will be shown using the program's predicates. A version of the CNF in dimacs format will be shown as well. See `README.MD` for more information.

Our CNF encoding for the given Monty Hall ProbLog program is:

$$
\begin{aligned}
&\wedge(open\_door(2) \vee prize(2) \vee prize(3) \vee \neg p\_open\_door(2)\_0)\\
&\wedge(open\_door(2) \vee prize(2) \vee \neg prize(3))\\
&\wedge(\neg open\_door(2) \vee \neg prize(2) \vee \neg prize(2))\\
&\wedge(\neg open\_door(2) \vee \neg prize(2) \vee prize(3))\\
&\wedge(\neg open\_door(2) \vee \neg prize(3) \vee \neg prize(2))\\
&\wedge(\neg open\_door(2) \vee \neg prize(3) \vee prize(3))\\
&\wedge(\neg open\_door(2) \vee p\_open\_door(2)\_0 \vee \neg prize(2))\\
&\wedge(\neg open\_door(2) \vee p\_open\_door(2)\_0 \vee prize(3))\\
&\wedge(open\_door(3) \vee prize(2) \vee prize(3) \vee \neg p\_open\_door(3)\_0)\\
&\wedge(open\_door(3) \vee prize(3) \vee \neg prize(2))\\
&\wedge(\neg open\_door(3) \vee \neg prize(2) \vee \neg prize(3))\\
&\wedge(\neg open\_door(3) \vee \neg prize(2) \vee prize(2))\\
&\wedge(\neg open\_door(3) \vee \neg prize(3) \vee \neg prize(3))\\
&\wedge(\neg open\_door(3) \vee \neg prize(3) \vee prize(2))\\
&\wedge(\neg open\_door(3) \vee p\_open\_door(3)\_0 \vee \neg prize(3))\\
&\wedge(\neg open\_door(3) \vee p\_open\_door(3)\_0 \vee prize(2))\\
&\wedge(win\_keep \vee \neg prize(1))\\
&\wedge(\neg win\_keep \vee prize(1))\\
&\wedge(win\_switch \vee \neg prize(2) \vee open\_door(2))\\
&\wedge(win\_switch \vee \neg prize(3) \vee open\_door(3))\\
&\wedge(\neg win\_switch \vee prize(2) \vee prize(3))\\
&\wedge(\neg win\_switch \vee prize(2) \vee \neg open\_door(3))\\
&\wedge(\neg win\_switch \vee \neg open\_door(2) \vee prize(3))\\
&\wedge(\neg win\_switch \vee \neg open\_door(2) \vee \neg open\_door(3))\\
&\wedge(\neg prize(1) \vee \neg prize(2))\\
&\wedge(\neg prize(1) \vee \neg prize(3))\\
&\wedge(\neg prize(2) \vee \neg prize(3))\\
&\wedge(prize(1) \vee prize(2) \vee prize(3))
\end{aligned}
$$

Weights:

$W(p\_open\_door(2)\_0) = 0.5$

$W(p\_open\_door(3)\_0) = 0.5$

$W(select\_door(1)) = 1.00$

$W(prize(1)) = 0.33$

$W(prize(2)) = 0.33$

$W(prize(3)) = 0.33$

$W(open\_door(2)) = 1.00$

$W(open\_door(3)) = 1.00$

$W(win\_keep) = 1.00$

$W(win\_switch) = 1.00$

1.3 Weighted Model Counting

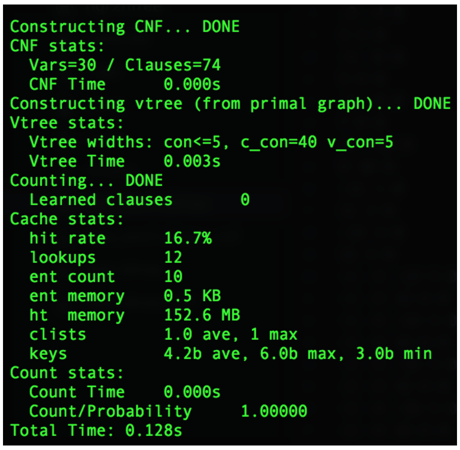
1.3.1 Weighted model counters on above CNFs

We will use MiniC2D and Cachet as WMC counters.

MiniC2D

MiniC2D needs to use the $-W$ option to do weighted model counting.

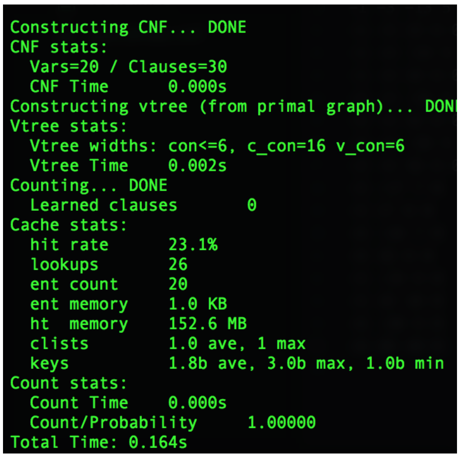
- ENC1:



```
Constructing CNF... DONE
CNF stats:
  Vars=30 / Clauses=74
  CNF Time      0.000s
Constructing vtree (from primal graph)... DONE
Vtree stats:
  Vtree widths: con<=5, c_con=40 v_con=5
  Vtree Time    0.003s
Counting... DONE
  Learned clauses       0
Cache stats:
  hit rate      16.7%
  lookups       12
  ent count     10
  ent memory    0.5 KB
  ht  memory    152.6 MB
  clists        1.0 ave, 1 max
  keys          4.2b ave, 6.0b max, 3.0b min
Count stats:
  Count Time    0.000s
  Count/Probability     1.00000
Total Time: 0.128s
```

Figure 1.1: Grounded problog cnf

- ENC2:



```
Constructing CNF... DONE
CNF stats:
  Vars=20 / Clauses=30
  CNF Time      0.000s
Constructing vtree (from primal graph)... DON
Vtree stats:
  Vtree widths: con<=6, c_con=16 v_con=6
  Vtree Time    0.002s
Counting... DONE
  Learned clauses       0
Cache stats:
  hit rate      23.1%
  lookups       26
  ent count     20
  ent memory    1.0 KB
  ht  memory    152.6 MB
  clists        1.0 ave, 1 max
  keys          1.8b ave, 3.0b max, 1.0b min
Count stats:
  Count Time    0.000s
  Count/Probability     1.00000
Total Time: 0.164s
```

Figure 1.2: Grounded problog cnf

- Monty hall:

```
Constructing CNF... DONE
CNF stats:
  Vars=10 / Clauses=26
  CNF Time      0.000s
Constructing vtree (from primal graph)... DONE
Vtree stats:
  Vtree widths: con<=4, c_con=22 v_con=4
  Vtree Time    0.002s
Counting... DONE
  Learned clauses       0
Cache stats:
  hit rate      20.0%
  lookups       5
  ent count     4
  ent memory    0.2 KB
  ht  memory    152.6 MB
  clists        1.0 ave, 1 max
  keys          3.2b ave, 4.0b max, 3.0b min
Count stats:
  Count Time    0.000s
  Count         1.00000000
Total Time: 0.116s
```

Figure 1.3: Grounded problog cnf

-

Cachet

- ENC1:

```
Number of total components              11
Number of split components              2
Number of non-split components          5
Number of SAT residual formula          12
Number of trivial components            0
Number of changed components            0
Number of adjusted components           0
First component split level             1

Number of Decisions                     11
Max Decision Level                      5
Number of Variables                     30
Original Num Clauses                    74
Original Num Literals                   172
Added Conflict Clauses                  0
Added Conflict Literals                 0
Deleted Unrelevant clauses              0
Deleted Unrelevant literals             0
Number of Implications                  124
Total Run Time                          0.018895

Satisfying probability                  8.72319e-08
Number of solutions                     93.6645
```

Figure 1.4: Grounded problog cnf

- ENC2:

```
Number of total components          11
Number of split components          2
Number of non-split components      5
Number of SAT residual formula      12
Number of trivial components        0
Number of changed components        0
Number of adjusted components       0
First component split level         1

Number of Decisions                 11
Max Decision Level                  5
Number of Variables                 20
Original Num Clauses                30
Original Num Literals               84
Added Conflict Clauses              0
Added Conflict Literals             0
Deleted Unrelevant clauses          0
Deleted Unrelevant literals         0
Number of Implications              72
Total Run Time                      0.017282

Satisfying probability              1
Number of solutions                 1.04858e+06
```

Figure 1.5: Grounded problog cnf

- Monty Hall:

For ENC1 we see that with Cachet we get a satisfying probability of almost 0. This is due to the fact that with ENC1 all our negative literals have a weight of 1, while Cachet expects that a literal + its negation = 1.

1.3.2 Difference between the selected WMCs

MiniC2D Vs Cachet

MiniC2D and Cachet are both weighted model counters but how they do this is quite different. MiniC2D is a top down compiler that compiles CNFs into a SDD which results in a faster system but it also uses less space while Cachet is an algorithm that uses formula caching together with clause learning and component analysis. MiniC2D needs vtrees to be able to compile the CNFs into an SDD. TThey, however, both use things from the SAT literature. They both use clause learning and component caching as to be able to reuse components that later appear again in the search. Cachet on the other hand also uses some other things from SAT literature like an explicit on the fly calculation of connected components. This is different in MiniC2D as it uses a vtree to identify disconnected CNF components. [1] [2]

1.3.3 Overview of computational requirements

All the tests can be found in the test folder. We used our scripts to create the dimac files. The input files for our enc1 and enc2 converter ard ".dsc" files which can be found at `http://www.bnlearn.com/bnrepository/discrete-small.html#cancer`.

Test 1: Cancer network

Table 1.1: My caption

	ENC1			ENC2		
	Prob	**Memory**	**Runtime**	**Prob**	**Memory**	**Runtime**
Minic2d	1.0	0.2 KB	0.155s	1.0	1.0 KB	0.000s
Cachet	val1	val2	a	b	val3	val4

Test 2: asia network

Table 1.2: My caption

	ENC1			ENC2		
	Prob	**Memory**	**Runtime**	**Prob**	**Memory**	**Runtime**
Minic2d	1.0	0.9 KB	0.145s	1.0	2.0 KB	0.139s
Cachet	val1	val2	a	b	val3	val4

Test 3: sachs network

Table 1.3: My caption

	ENC1			ENC2		
	Prob	**Memory**	**Runtime**	**Prob**	**Memory**	**Runtime**
Minic2d	0.99707	14.3 KB	0.184s	1.0	14.5 KB	0.154s
Cachet	val1	val2	a	b	val3	val4

Test 4: earthquake network

Table 1.4: My caption

	ENC1			ENC2		
	Prob	**Memory**	**Runtime**	**Prob**	**Memory**	**Runtime**
Minic2d	1.0	0.6 KB	0.137s	1.0	1.0 KB	0.153s
Cachet	val1	val2	a	b	val3	val4

Test 5: survey network

Table 1.5: My caption

	ENC1			ENC2		
	Prob	**Memory**	**Runtime**	**Prob**	**Memory**	**Runtime**
Minic2d	1.0	1.6 KB	0.125s	1.0	2.0 KB	0.125s
Cachet	val1	val2	a	b	val3	val4

Test 6: alarm network

Table 1.6: My caption

	ENC1			ENC2		
	Prob	**Memory**	**Runtime**	**Prob**	**Memory**	**Runtime**
Minic2d	1.0	959.7KB KB	0.268s	1.0	139KB	0.095s
Cachet	val1	val2	a	b	val3	val4

Test 6: andes network

Table 1.7: My caption

	ENC1			ENC2		
	Prob	**Memory**	**Runtime**	**Prob**	**Memory**	**Runtime**
Minic2d	1.0	2.7GB	122.78s	1.0	139.8MB	6.086s
Cachet	val1	val2	a	b	val3	val4

1.4 Knowledge compilation

Vtree with the most compact circuit

During our tests

Pattern for a good vtree

As a vtree is a binary tree, which means that a good vtree is compact. We want thus a vtree that is shallow.

Build an Inference Engine

2.0.1 Implementation

We have implemented the pipeline using python. Information about it can be found in `README.MD`.

2.0.2 Pipeline with previous tasks

Cancer Bayesian network

- Probability:
- Total runtime:
- Runtime of the separate parts:
- Number of variables in CNF:
- Number of lines in CNF:
- Depth of vtree:
- Number of edges and nodes in the circuit:

Monty Hall

- Probability:
- Total runtime:
- Runtime of the separate parts:
- Number of variables in CNF:
- Number of lines in CNF:
- Depth of vtree:
- Number of edges and nodes in the circuit:

2.0.3 Pipeline on Bayesian learning example

DAS NEN DIKKE VETTE TODO

- Probability:
- Total runtime:
- Runtime of the separate parts:
- Number of variables in CNF:
- Number of lines in CNF:
- Depth of vtree:
- Number of edges and nodes in the circuit:

2.0.4 Pipeline on alarm Bayesian network

GOD DAMN IT STOM VAK HOE MOETEN WIJ DIT IN 50 UUR DOEN? PROCESS WORDT GEWOON GEKILLED OMDAT DIE CNF GIGANTISCH GROOT WORDT.

- Probability:
- Total runtime:
- Runtime of the separate parts:
- Number of variables in CNF:
- Number of lines in CNF:
- Depth of vtree:
- Number of edges and nodes in the circuit:

Parameter Learning

learning

Appendix

4.1 ENC1

Indicator clauses:

$$\begin{gathered}
(\neg\, \lambda_{PollutionLow} \vee \neg\, \lambda_{PollutionHigh}) \wedge (\lambda_{PollutionLow} \vee \lambda_{PollutionHigh}) \wedge (\neg \\
\lambda_{SmokerTrue} \vee \neg\, \lambda_{SmokerFalse}) \wedge (\lambda_{SmokerTrue} \vee \lambda_{SmokerFalse}) \wedge (\neg \\
\lambda_{CancerTrue} \vee \neg\, \lambda_{CancerFalse}) \wedge (\lambda_{CancerTrue} \vee \lambda_{CancerFalse}) \wedge (\neg \\
\lambda_{XrayPositive} \vee \neg\, \lambda_{XrayNegative}) \wedge (\lambda_{XrayPositive} \vee \lambda_{XrayNegative}) \wedge (\neg \\
\lambda_{DyspnoeaTrue} \vee \neg\, \lambda_{DyspnoeaFalse}) \wedge (\lambda_{DyspnoeaTrue} \vee \lambda_{DyspnoeaFalse})
\end{gathered}$$

Parameter clauses:

$$\begin{gathered}
(\neg\, \lambda_{PollutionLow} \vee \theta_{PollutionLow}) \wedge (\lambda_{PollutionLow} \vee \neg\, \theta_{PollutionLow}) \wedge (\neg \\
\lambda_{PollutionHigh} \vee \theta_{PollutionHigh}) \wedge (\lambda_{PollutionHigh} \vee \neg\, \theta_{PollutionHigh}) \wedge (\neg \\
\lambda_{SmokerTrue} \vee \theta_{SmokerTrue}) \wedge (\lambda_{SmokerTrue} \vee \neg\, \theta_{SmokerTrue}) \wedge (\neg \\
\lambda_{SmokerFalse} \vee \theta_{SmokerFalse}) \wedge (\lambda_{SmokerFalse} \vee \neg\, \theta_{SmokerFalse}) \wedge (\neg \\
\lambda_{PollutionLow} \vee \neg\, \lambda_{SmokerTrue} \vee \neg\, \lambda_{CancerTrue} \vee \\
\theta_{CancerTrue|PollutionLow,SmokerTrue}) \wedge (\lambda_{PollutionLow} \vee \neg \\
\theta_{CancerTrue|PollutionLow,SmokerTrue}) \wedge (\lambda_{SmokerTrue} \vee \neg \\
\theta_{CancerTrue|PollutionLow,SmokerTrue}) \wedge (\lambda_{CancerTrue} \vee \neg \\
\theta_{CancerTrue|PollutionLow,SmokerTrue}) \wedge (\neg\, \lambda_{PollutionLow} \vee \neg\, \lambda_{SmokerTrue} \vee \neg \\
\lambda_{CancerFalse} \vee \theta_{CancerFalse|PollutionLow,SmokerTrue}) \wedge (\lambda_{PollutionLow} \vee \neg \\
\theta_{CancerFalse|PollutionLow,SmokerTrue}) \wedge (\lambda_{SmokerTrue} \vee \neg \\
\theta_{CancerFalse|PollutionLow,SmokerTrue}) \wedge (\lambda_{CancerFalse} \vee \neg \\
\theta_{CancerFalse|PollutionLow,SmokerTrue}) \wedge (\neg\, \lambda_{PollutionLow} \vee \neg\, \lambda_{SmokerFalse} \vee \neg \\
\lambda_{CancerTrue} \vee \theta_{CancerTrue|PollutionLow,SmokerFalse}) \wedge (\lambda_{PollutionLow} \vee \neg \\
\theta_{CancerTrue|PollutionLow,SmokerFalse}) \wedge (\lambda_{SmokerFalse} \vee \neg \\
\theta_{CancerTrue|PollutionLow,SmokerFalse}) \wedge (\lambda_{CancerTrue} \vee \neg \\
\theta_{CancerTrue|PollutionLow,SmokerFalse}) \wedge (\neg\, \lambda_{PollutionLow} \vee \neg\, \lambda_{SmokerFalse} \vee \neg \\
\lambda_{CancerFalse} \vee \theta_{CancerFalse|PollutionLow,SmokerFalse}) \wedge (\lambda_{PollutionLow} \vee \neg \\
\theta_{CancerFalse|PollutionLow,SmokerFalse}) \wedge (\lambda_{SmokerFalse} \vee \neg \\
\theta_{CancerFalse|PollutionLow,SmokerFalse}) \wedge (\lambda_{CancerFalse} \vee \neg \\
\theta_{CancerFalse|PollutionLow,SmokerFalse}) \wedge (\neg\, \lambda_{PollutionHigh} \vee \neg\, \lambda_{SmokerTrue} \vee \neg \\
\lambda_{CancerTrue} \vee \theta_{CancerTrue|PollutionHigh,SmokerTrue}) \wedge (\lambda_{PollutionHigh} \vee \neg \\
\theta_{CancerTrue|PollutionHigh,SmokerTrue}) \wedge (\lambda_{SmokerTrue} \vee \neg \\
\theta_{CancerTrue|PollutionHigh,SmokerTrue}) \wedge (\lambda_{CancerTrue} \vee \neg \\
\theta_{CancerTrue|PollutionHigh,SmokerTrue}) \wedge (\neg\, \lambda_{PollutionHigh} \vee \neg\, \lambda_{SmokerTrue} \vee \neg \\
\lambda_{CancerFalse} \vee \theta_{CancerFalse|PollutionHigh,SmokerTrue}) \wedge (\lambda_{PollutionHigh} \vee \neg
\end{gathered}$$

$\theta_{CancerFalse|PollutionHigh,SmokerTrue}) \wedge (\lambda_{SmokerTrue} \vee \neg \theta_{CancerFalse|PollutionHigh,SmokerTrue}) \wedge (\lambda_{CancerFalse} \vee \neg \theta_{CancerFalse|PollutionHigh,SmokerTrue}) \wedge (\neg \lambda_{PollutionHigh} \vee \neg \lambda_{SmokerFalse} \vee \neg \lambda_{CancerTrue} \vee \theta_{CancerTrue|PollutionHigh,SmokerFalse}) \wedge (\lambda_{PollutionHigh} \vee \neg \theta_{CancerTrue|PollutionHigh,SmokerFalse}) \wedge (\lambda_{SmokerFalse} \vee \neg \theta_{CancerTrue|PollutionHigh,SmokerFalse}) \wedge (\lambda_{CancerTrue} \vee \neg \theta_{CancerTrue|PollutionHigh,SmokerFalse}) \wedge (\neg \lambda_{PollutionHigh} \vee \neg \lambda_{SmokerFalse} \vee \neg \lambda_{CancerFalse} \vee \theta_{CancerFalse|PollutionHigh,SmokerFalse}) \wedge (\lambda_{PollutionHigh} \vee \neg \theta_{CancerFalse|PollutionHigh,SmokerFalse}) \wedge (\lambda_{SmokerFalse} \vee \neg \theta_{CancerFalse|PollutionHigh,SmokerFalse}) \wedge (\lambda_{CancerFalse} \vee \neg \theta_{CancerFalse|PollutionHigh,SmokerFalse}) \wedge (\neg \lambda_{CancerTrue} \vee \neg \lambda_{XrayPositive} \vee \theta_{XrayPositive|CancerTrue}) \wedge (\lambda_{CancerTrue} \vee \neg \theta_{XrayPositive|CancerTrue}) \wedge (\lambda_{XrayPositive} \vee \neg \theta_{XrayPositive|CancerTrue}) \wedge (\neg \lambda_{CancerTrue} \vee \neg \lambda_{XrayNegative} \vee \theta_{XrayNegative|CancerTrue}) \wedge (\lambda_{CancerTrue} \vee \neg \theta_{XrayNegative|CancerTrue}) \wedge (\lambda_{XrayNegative} \vee \neg \theta_{XrayNegative|CancerTrue}) \wedge (\neg \lambda_{CancerFalse} \vee \neg \lambda_{XrayPositive} \vee \theta_{XrayPositive|CancerFalse}) \wedge (\lambda_{CancerFalse} \vee \neg \theta_{XrayPositive|CancerFalse}) \wedge (\lambda_{XrayPositive} \vee \neg \theta_{XrayPositive|CancerFalse}) \wedge (\neg \lambda_{CancerFalse} \vee \neg \lambda_{XrayNegative} \vee \theta_{XrayNegative|CancerFalse}) \wedge (\lambda_{CancerFalse} \vee \neg \theta_{XrayNegative|CancerFalse}) \wedge (\lambda_{XrayNegative} \vee \neg \theta_{XrayNegative|CancerFalse}) \wedge (\neg \lambda_{CancerTrue} \vee \neg \lambda_{DyspnoeaTrue} \vee \theta_{DyspnoeaTrue|CancerTrue}) \wedge (\lambda_{CancerTrue} \vee \neg \theta_{DyspnoeaTrue|CancerTrue}) \wedge (\lambda_{DyspnoeaTrue} \vee \neg \theta_{DyspnoeaTrue|CancerTrue}) \wedge (\neg \lambda_{CancerTrue} \vee \neg \lambda_{DyspnoeaFalse} \vee \theta_{DyspnoeaFalse|CancerTrue}) \wedge (\lambda_{CancerTrue} \vee \neg \theta_{DyspnoeaFalse|CancerTrue}) \wedge (\lambda_{DyspnoeaFalse} \vee \neg \theta_{DyspnoeaFalse|CancerTrue}) \wedge (\neg \lambda_{CancerFalse} \vee \neg \lambda_{DyspnoeaTrue} \vee \theta_{DyspnoeaTrue|CancerFalse}) \wedge (\lambda_{CancerFalse} \vee \neg \theta_{DyspnoeaTrue|CancerFalse}) \wedge (\lambda_{DyspnoeaTrue} \vee \neg \theta_{DyspnoeaTrue|CancerFalse}) \wedge (\neg \lambda_{CancerFalse} \vee \neg \lambda_{DyspnoeaFalse} \vee \theta_{DyspnoeaFalse|CancerFalse}) \wedge (\lambda_{CancerFalse} \vee \neg \theta_{DyspnoeaFalse|CancerFalse}) \wedge (\lambda_{DyspnoeaFalse} \vee \neg \theta_{DyspnoeaFalse|CancerFalse})$

Weights:

W($\lambda_{PollutionLow}$) = 1.00
W($\neg\lambda_{PollutionLow}$) = 1.00
W($\lambda_{PollutionHigh}$) = 1.00
W($\neg\lambda_{PollutionHigh}$) = 1.00
W($\lambda_{SmokerTrue}$) = 1.00
W($\neg\lambda_{SmokerTrue}$) = 1.00
W($\lambda_{SmokerFalse}$) = 1.00
W($\neg\lambda_{SmokerFalse}$) = 1.00
W($\lambda_{CancerTrue}$) = 1.00
W($\neg\lambda_{CancerTrue}$) = 1.00
W($\lambda_{CancerFalse}$) = 1.00
W($\neg\lambda_{CancerFalse}$) = 1.00
W($\lambda_{XrayPositive}$) = 1.00
W($\neg\lambda_{XrayPositive}$) = 1.00
W($\lambda_{XrayNegative}$) = 1.00
W($\neg\lambda_{XrayNegative}$) = 1.00
W($\lambda_{DyspnoeaTrue}$) = 1.00
W($\neg\lambda_{DyspnoeaTrue}$) = 1.00
W($\lambda_{DyspnoeaFalse}$) = 1.00
W($\neg\lambda_{DyspnoeaFalse}$) = 1.00

W($\theta_{PollutionLow}$) = 0.90
W($\neg\theta_{PollutionLow}$) = 1.00
W($\theta_{PollutionHigh}$) = 0.10
W($\neg\theta_{PollutionHigh}$) = 1.00
W($\theta_{SmokerTrue}$) = 0.30
W($\neg\theta_{SmokerTrue}$) = 1.00
W($\theta_{SmokerFalse}$) = 0.70
W($\neg\theta_{SmokerFalse}$) = 1.00
W($\theta_{CancerTrue|PollutionLow,SmokerTrue}$) = 0.03
W($\neg\theta_{CancerTrue|PollutionLow,SmokerTrue}$) = 1.00
W($\theta_{CancerFalse|PollutionLow,SmokerTrue}$) = 0.97
W($\neg\theta_{CancerFalse|PollutionLow,SmokerTrue}$) = 1.00
W($\theta_{CancerTrue|PollutionLow,SmokerFalse}$) = 0.00
W($\neg\theta_{CancerTrue|PollutionLow,SmokerFalse}$) = 1.00
W($\theta_{CancerFalse|PollutionLow,SmokerFalse}$) = 1.00
W($\neg\theta_{CancerFalse|PollutionLow,SmokerFalse}$) = 1.00
W($\theta_{CancerTrue|PollutionHigh,SmokerTrue}$) = 0.05
W($\neg\theta_{CancerTrue|PollutionHigh,SmokerTrue}$) = 1.00
W($\theta_{CancerFalse|PollutionHigh,SmokerTrue}$) = 0.95
W($\neg\theta_{CancerFalse|PollutionHigh,SmokerTrue}$) = 1.00
W($\theta_{CancerTrue|PollutionHigh,SmokerFalse}$) = 0.02
W($\neg\theta_{CancerTrue|PollutionHigh,SmokerFalse}$) = 1.00
W($\theta_{CancerFalse|PollutionHigh,SmokerFalse}$) = 0.98
W($\neg\theta_{CancerFalse|PollutionHigh,SmokerFalse}$) = 1.00
W($\theta_{XrayPositive|CancerTrue}$) = 0.90
W($\neg\theta_{XrayPositive|CancerTrue}$) = 1.00
W($\theta_{XrayNegative|CancerTrue}$) = 0.10
W($\neg\theta_{XrayNegative|CancerTrue}$) = 1.00
W($\theta_{XrayPositive|CancerFalse}$) = 0.20
W($\neg\theta_{XrayPositive|CancerFalse}$) = 1.00
W($\theta_{XrayNegative|CancerFalse}$) = 0.80
W($\neg\theta_{XrayNegative|CancerFalse}$) = 1.00
W($\theta_{DyspnoeaTrue|CancerTrue}$) = 0.65
W($\neg\theta_{DyspnoeaTrue|CancerTrue}$) = 1.00
W($\theta_{DyspnoeaFalse|CancerTrue}$) = 0.35
W($\neg\theta_{DyspnoeaFalse|CancerTrue}$) = 1.00
W($\theta_{DyspnoeaTrue|CancerFalse}$) = 0.30
W($\neg\theta_{DyspnoeaTrue|CancerFalse}$) = 1.00
W($\theta_{DyspnoeaFalse|CancerFalse}$) = 0.70
W($\neg\theta_{DyspnoeaFalse|CancerFalse}$) = 1.00

4.2 ENC2

Indicator clauses

$(\neg\ \lambda_{PollutionLow} \lor \neg\ \lambda_{PollutionHigh}) \land (\lambda_{PollutionLow} \lor \lambda_{PollutionHigh}) \land (\neg\ \lambda_{SmokerTrue} \lor \neg\ \lambda_{SmokerFalse}) \land (\lambda_{SmokerTrue} \lor \lambda_{SmokerFalse}) \land (\neg$

$\lambda_{CancerTrue} \vee \neg\, \lambda_{CancerFalse}) \wedge (\lambda_{CancerTrue} \vee \lambda_{CancerFalse}) \wedge (\neg\, \lambda_{XrayPositive} \vee \neg\, \lambda_{XrayNegative}) \wedge (\lambda_{XrayPositive} \vee \lambda_{XrayNegative}) \wedge (\neg\, \lambda_{DyspnoeaTrue} \vee \neg\, \lambda_{DyspnoeaFalse}) \wedge (\lambda_{DyspnoeaTrue} \vee \lambda_{DyspnoeaFalse})$

Parameter clauses

$$(\neg\, \rho_{PollutionLow} \vee \lambda_{PollutionLow}) \wedge (\rho_{PollutionLow} \vee \lambda_{PollutionHigh}) \wedge (\neg\, \rho_{SmokerTrue} \vee \lambda_{SmokerTrue}) \wedge (\rho_{SmokerTrue} \vee \lambda_{SmokerFalse}) \wedge (\neg\, \lambda_{PollutionLow} \vee \neg\, \lambda_{SmokerTrue} \vee \neg\, \rho_{CancerTrue|PollutionLow,SmokerTrue} \vee \lambda_{CancerTrue}) \wedge (\neg\, \lambda_{PollutionLow} \vee \neg\, \lambda_{SmokerTrue} \vee \rho_{CancerTrue|PollutionLow,SmokerTrue} \vee \lambda_{CancerFalse}) \wedge (\neg\, \lambda_{PollutionLow} \vee \neg\, \lambda_{SmokerFalse} \vee \neg\, \rho_{CancerTrue|PollutionLow,SmokerFalse} \vee \lambda_{CancerTrue}) \wedge (\neg\, \lambda_{PollutionLow} \vee \neg\, \lambda_{SmokerFalse} \vee \rho_{CancerTrue|PollutionLow,SmokerFalse} \vee \lambda_{CancerFalse}) \wedge (\neg\, \lambda_{PollutionHigh} \vee \neg\, \lambda_{SmokerTrue} \vee \neg\, \rho_{CancerTrue|PollutionHigh,SmokerTrue} \vee \lambda_{CancerTrue}) \wedge (\neg\, \lambda_{PollutionHigh} \vee \neg\, \lambda_{SmokerTrue} \vee \rho_{CancerTrue|PollutionHigh,SmokerTrue} \vee \lambda_{CancerFalse}) \wedge (\neg\, \lambda_{PollutionHigh} \vee \neg\, \lambda_{SmokerFalse} \vee \neg\, \rho_{CancerTrue|PollutionHigh,SmokerFalse} \vee \lambda_{CancerTrue}) \wedge (\neg\, \lambda_{PollutionHigh} \vee \neg\, \lambda_{SmokerFalse} \vee \rho_{CancerTrue|PollutionHigh,SmokerFalse} \vee \lambda_{CancerFalse}) \wedge (\neg\, \lambda_{CancerTrue} \vee \neg\, \rho_{XrayPositive|CancerTrue} \vee \lambda_{XrayPositive}) \wedge (\neg\, \lambda_{CancerTrue} \vee \rho_{XrayPositive|CancerTrue} \vee \lambda_{XrayNegative}) \wedge (\neg\, \lambda_{CancerFalse} \vee \neg\, \rho_{XrayPositive|CancerFalse} \vee \lambda_{XrayPositive}) \wedge (\neg\, \lambda_{CancerFalse} \vee \rho_{XrayPositive|CancerFalse} \vee \lambda_{XrayNegative}) \wedge (\neg\, \lambda_{CancerTrue} \vee \neg\, \rho_{DyspnoeaTrue|CancerTrue} \vee \lambda_{DyspnoeaTrue}) \wedge (\neg\, \lambda_{CancerTrue} \vee \rho_{DyspnoeaTrue|CancerTrue} \vee \lambda_{DyspnoeaFalse}) \wedge (\neg\, \lambda_{CancerFalse} \vee \neg\, \rho_{DyspnoeaTrue|CancerFalse} \vee \lambda_{DyspnoeaTrue}) \wedge (\neg\, \lambda_{CancerFalse} \vee \rho_{DyspnoeaTrue|CancerFalse} \vee \lambda_{DyspnoeaFalse})$$

Weights

$W(\lambda_{PollutionLow}) = 1.00$
$W(\neg\, \lambda_{PollutionLow}) = 1.00$
$W(\lambda_{PollutionHigh}) = 1.00$
$W(\neg\, \lambda_{PollutionHigh}) = 1.00$
$W(\lambda_{SmokerTrue}) = 1.00$
$W(\neg\, \lambda_{SmokerTrue}) = 1.00$
$W(\lambda_{SmokerFalse}) = 1.00$
$W(\neg\, \lambda_{SmokerFalse}) = 1.00$
$W(\lambda_{CancerTrue}) = 1.00$
$W(\neg\, \lambda_{CancerTrue}) = 1.00$
$W(\lambda_{CancerFalse}) = 1.00$
$W(\neg\, \lambda_{CancerFalse}) = 1.00$
$W(\lambda_{XrayPositive}) = 1.00$
$W(\neg\, \lambda_{XrayPositive}) = 1.00$
$W(\lambda_{XrayNegative}) = 1.00$
$W(\neg\, \lambda_{XrayNegative}) = 1.00$
$W(\lambda_{DyspnoeaTrue}) = 1.00$
$W(\neg\, \lambda_{DyspnoeaTrue}) = 1.00$
$W(\lambda_{DyspnoeaFalse}) = 1.00$
$W(\neg\, \lambda_{DyspnoeaFalse}) = 1.00$
$W(\rho_{PollutionLow}) = 0.90$
$W(\neg\, \rho_{PollutionLow}) = 0.10$

$\mathrm{W}(\rho_{SmokerTrue}) = 0.30$
$\mathrm{W}(\neg\ \rho_{SmokerTrue}) = 0.70$
$\mathrm{W}(\rho_{CancerTrue|PollutionLow,SmokerTrue}) = 0.03$
$\mathrm{W}(\neg\ \rho_{CancerTrue|PollutionLow,SmokerTrue}) = 0.97$
$\mathrm{W}(\rho_{CancerTrue|PollutionLow,SmokerFalse}) = 0.00$
$\mathrm{W}(\neg\ \rho_{CancerTrue|PollutionLow,SmokerFalse}) = 1.00$
$\mathrm{W}(\rho_{CancerTrue|PollutionHigh,SmokerTrue}) = 0.05$
$\mathrm{W}(\neg\ \rho_{CancerTrue|PollutionHigh,SmokerTrue}) = 0.95$
$\mathrm{W}(\rho_{CancerTrue|PollutionHigh,SmokerFalse}) = 0.02$
$\mathrm{W}(\neg\ \rho_{CancerTrue|PollutionHigh,SmokerFalse}) = 0.98$
$\mathrm{W}(\rho_{XrayPositive|CancerTrue}) = 0.90$
$\mathrm{W}(\neg\ \rho_{XrayPositive|CancerTrue}) = 0.10$
$\mathrm{W}(\rho_{XrayPositive|CancerFalse}) = 0.20$
$\mathrm{W}(\neg\ \rho_{XrayPositive|CancerFalse}) = 0.80$
$\mathrm{W}(\rho_{DyspnoeaTrue|CancerTrue}) = 0.65$
$\mathrm{W}(\neg\ \rho_{DyspnoeaTrue|CancerTrue}) = 0.35$
$\mathrm{W}(\rho_{DyspnoeaTrue|CancerFalse}) = 0.30$
$\mathrm{W}(\neg\ \rho_{DyspnoeaTrue|CancerFalse}) = 0.70$

Bibliography

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