Deterministic Decomposable Circuits for Safe Queries

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Tuple-independent databases (TID)

- Probabilistic databases: model uncertainty about data
- Simplest model: tuple-independent databases (TID)
  - A relational database D
  - A probability valuation π mapping each fact of D into $[0, 1]$
- Semantics of a TID (D, π): a probability distribution on 2^D:
  - Each fact $F \in D$ is either present or absent with probability $\pi(F)$
  - Assume independence across facts

$\rightarrow$ For $D' \subseteq D$, $\Pr(D') = (\prod_{F \in D'} \pi(F)) \times (\prod_{F \in D \setminus D'} (1 - \pi(F)))$

Tuple-independent databases (TID)

$D =$

S	
a	a
b	c

Tuple-independent databases (TID)

$(D, \pi) =$

S		
a	a	.5
b	c	.2

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S		
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$.5 \times .2$

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$(1 - .5) \times (1 - .2)$

S

Tuple-independent databases (TID)

$(D, \pi) =$

S		
a	a	.5
b	c	.2

$q = \exists x\, y\; S(x, y) \land x \neq y$

$.5 \times .2$

S	
a	a
b	c

$.5 \times (1 - .2)$

S	
a	a

$(1 - .5) \times .2$

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$\Pr(D \models q) =$

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S	
a	a
b	c

✓

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S	
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✗

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S	
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✗

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S	
b	c

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✔

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✘

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(In the rest of this talk, we will asume PTIME $\neq$ **#P**)

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- Inclusion-Exclusion

→ $\Pr(q_1 \wedge q_2 \wedge q_3) = \Pr(q_1) + \Pr(q_2) + \Pr(q_3) - \Pr(q_1 \vee q_2) - \Pr(q_1 \vee q_3) - \Pr(q_2 \vee q_3) + \Pr(q_1 \vee q_2 \vee q_3)$

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This works for any safe query!

Alternative Approach

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Does this work for all the safe queries?

Question

Independence $+$ **Inclusion-exclusion**

$$\stackrel{?}{=}$$

Independence $+$ **mut.-exclusiveness**

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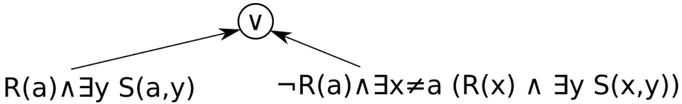
Example: independence + mutually-exclusiveness

$\exists x,y\ (R(x) \wedge S(x,y))$

Example: independence + mutually-exclusiveness



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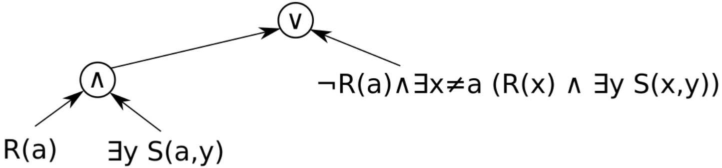

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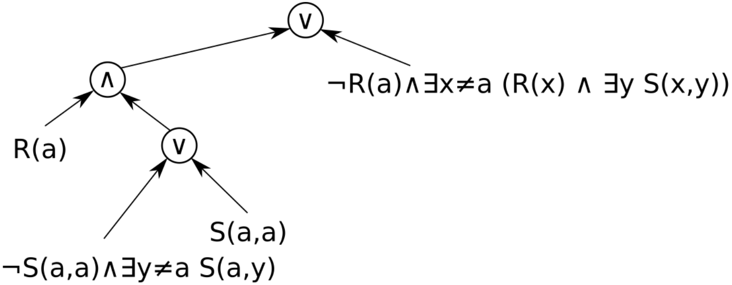

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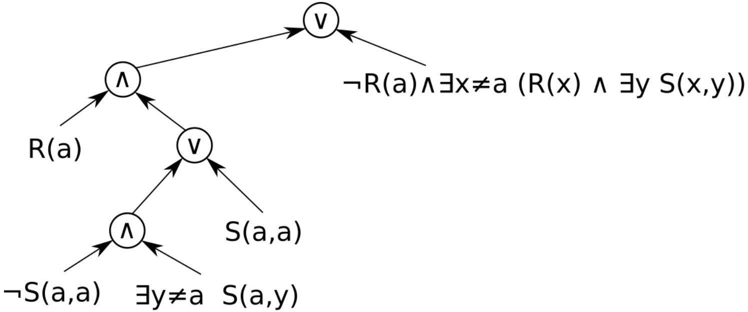

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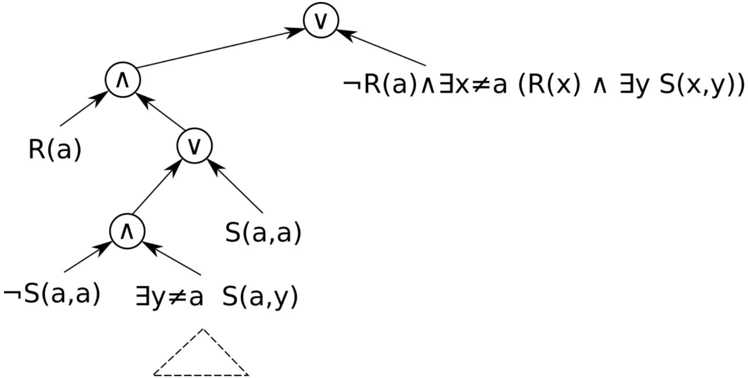

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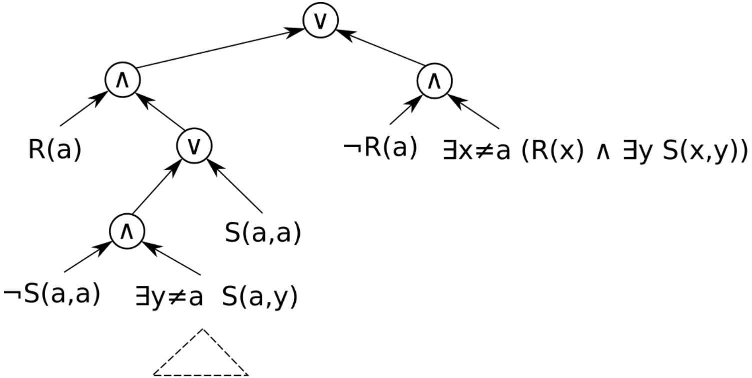

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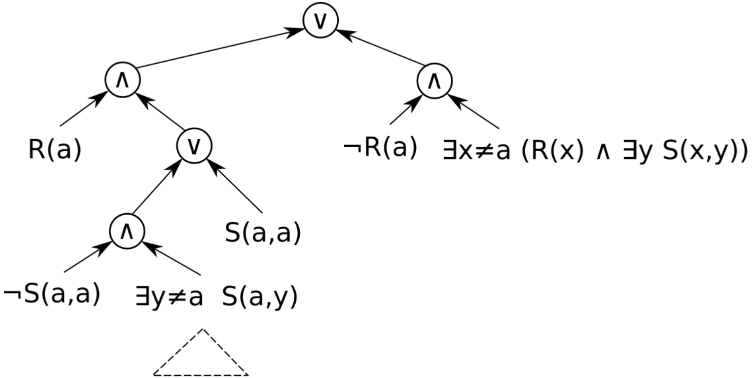

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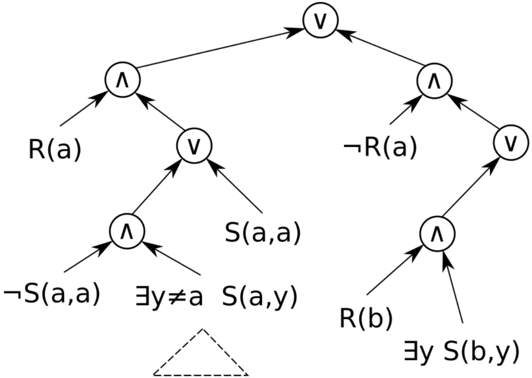

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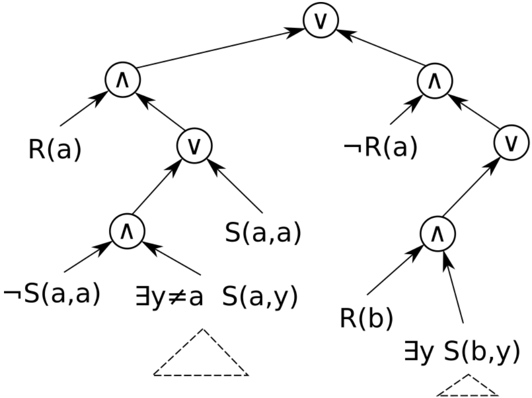

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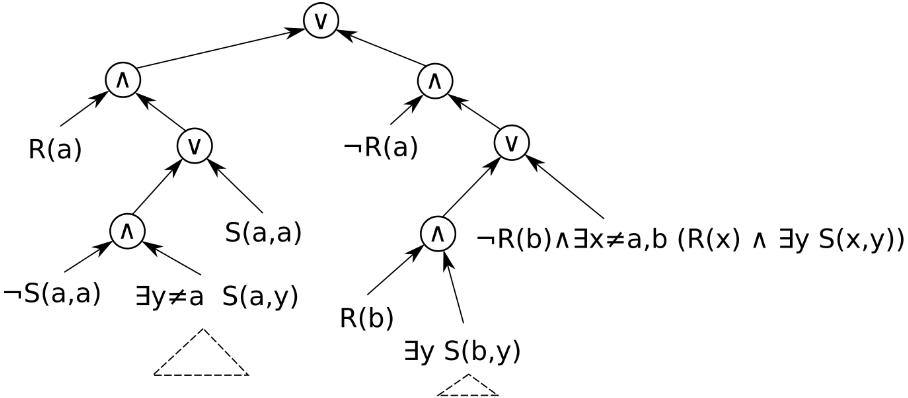

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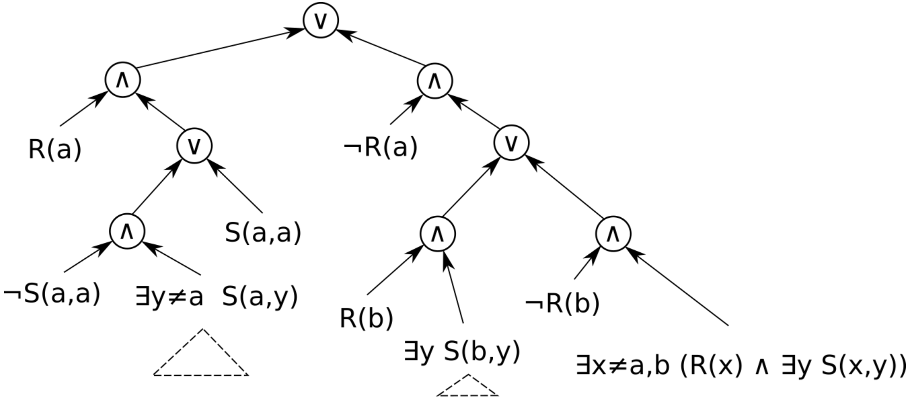

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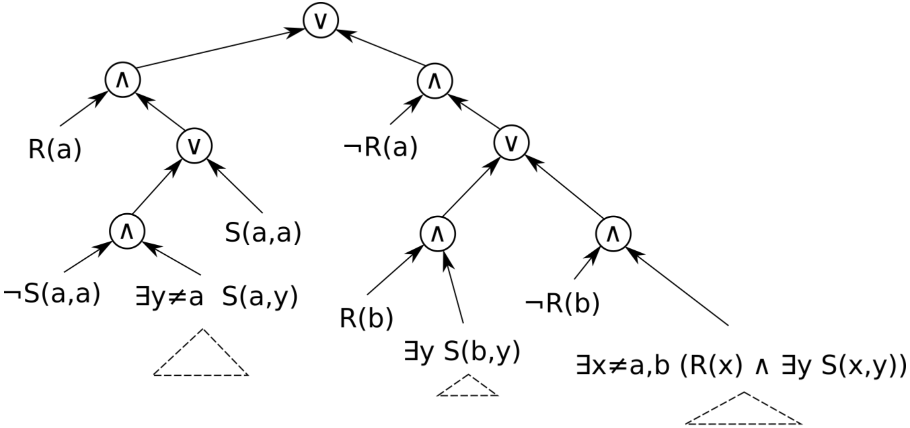

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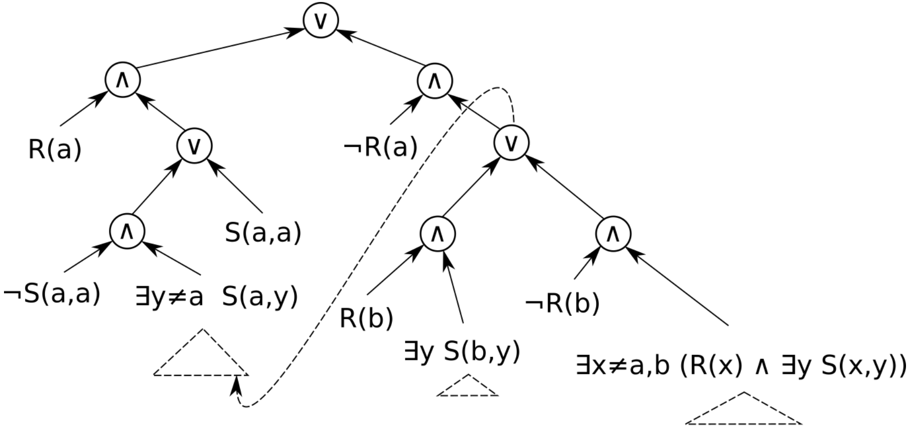

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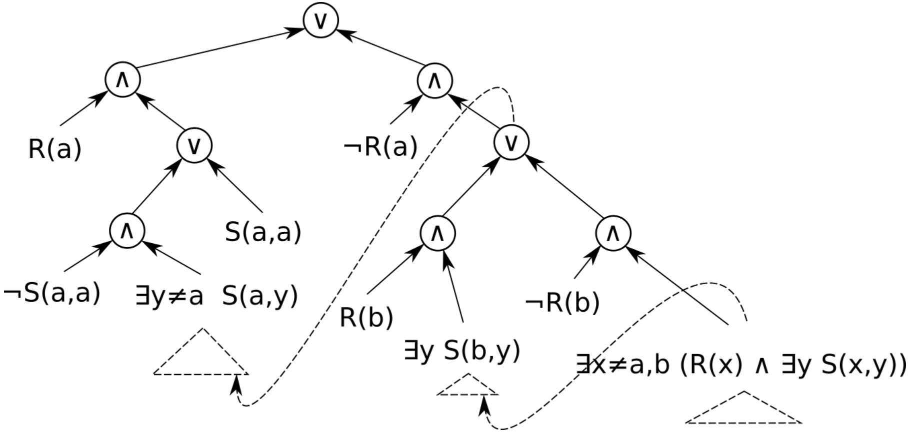
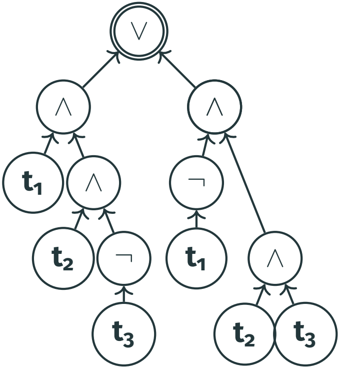


d-DNNF



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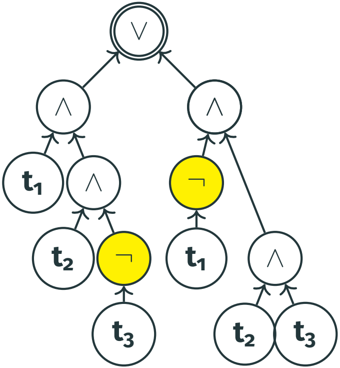
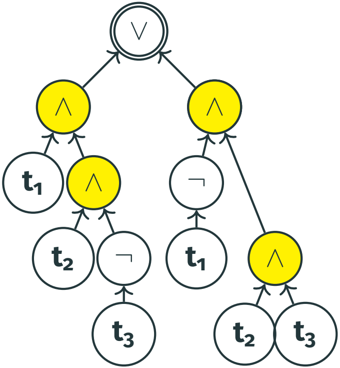


- Negation Normal Form: negations only applied to the leaves



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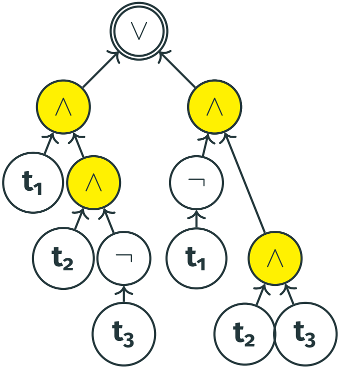

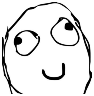

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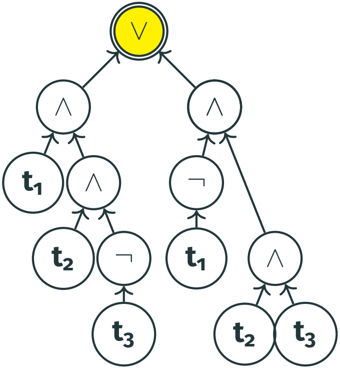

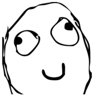

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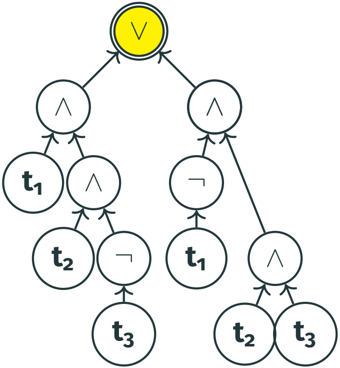

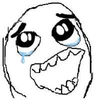

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  - → **#SAT** and **probability evaluation**

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- Independence + IE $\stackrel{?}{=}$ independence + mut.-exclusiveness

$\rightarrow$ We already have: safe UCQs $\supseteq$ UCQ(d-DNNF)

Conjecture

- UCQ $q \in$ **UCQ(d-DNNF)** $\equiv$ for every database D, we can compute in PTIME a d-DNNF representing the result
- **Question: tractable UCQs = safe UCQs $\stackrel{?}{=}$ UCQ(d-DNNF)**
- Independence + IE $\stackrel{?}{=}$ independence + mut.-exclusiveness

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$\rightarrow$ So the question is: safe UCQs $\subseteq$ UCQ(d-DNNF)?

- Asked by Dalvi, Jha and Suciu

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→ It is known that $\mathcal{H}$-queries $\subsetneq$ UCQ(**structured** d-DNNF)

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- We defined a notion of an $\mathcal{H}$-query q being nice, such that:

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- Maybe **safe UCQs** = **UCQ(d-D)**?

Conclusion

$$[(\exists x \exists y\, S_2(x,y) \wedge S_3(x,y)) \vee (\exists x \exists y\, S_4(x,y) \wedge S_5(x,y))] \wedge [(\exists x \exists y\, R(x) \wedge S_1(x,y)) \vee (\exists x \exists y\, S_3(x,y) \wedge S_4(x,y)) \vee (\exists x \exists y\, S_4(x,y) \wedge S_5(x,y))] \wedge [(\exists x \exists y\, R(x) \wedge S_1(x,y)) \vee (\exists x \exists y\, S_1(x,y) \wedge S_2(x,y)) \vee (\exists x \exists y\, S_3(x,y) \wedge S_4(x,y))] \wedge [(\exists x \exists y\, S_1(x,y) \wedge S_2(x,y)) \vee (\exists x \exists y\, S_2(x,y) \wedge S_3(x,y))] \wedge [(\exists x \exists y\, S_1(x,y) \wedge S_2(x,y)) \vee (\exists x \exists y\, S_5(x,y) \wedge T(y))] \wedge [(\exists x \exists y\, R(x) \wedge S_1(x,y)) \vee (\exists x \exists y\, S_5(x,y) \wedge T(y))] \wedge [(\exists x \exists y\, S_3(x,y) \wedge S_4(x,y)) \vee (\exists x \exists y\, S_5(x,y) \wedge T(y))] \wedge [(\exists x \exists y\, S_2(x,y) \wedge S_3(x,y)) \vee (\exists x \exists y\, S_3(x,y) \wedge S_4(x,y))] \wedge [(\exists x \exists y\, R(x) \wedge S_1(x,y)) \vee (\exists x \exists y\, S_2(x,y) \wedge S_3(x,y))] \wedge [(\exists x \exists y\, S_2(x,y) \wedge S_3(x,y)) \vee (\exists x \exists y\, S_5(x,y) \wedge T(y))] \wedge [(\exists x \exists y\, R(x) \wedge S_1(x,y)) \vee (\exists x \exists y\, S_1(x,y) \wedge S_2(x,y)) \vee (\exists x \exists y\, S_4(x,y) \wedge S_5(x,y))] \wedge [(\exists x \exists y\, S_4(x,y) \wedge S_5(x,y)) \vee (\exists x \exists y\, S_5(x,y) \wedge T(y))]$$

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This query is obviously in UCQ(d-D), but is it in UCQ(d-DNNF)?

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Thanks for your attention!