TECHNISCHE UNIVERSITÄT DRESDEN

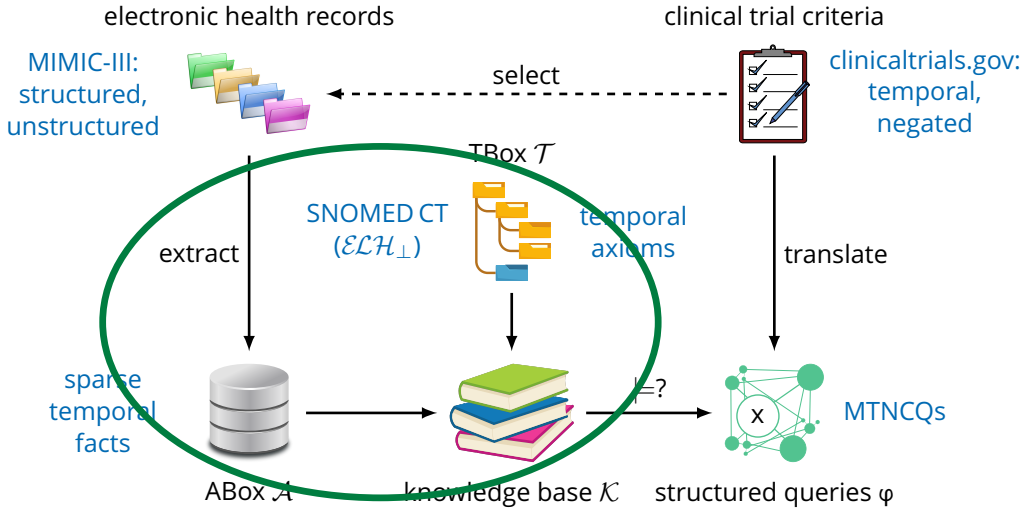
Stefan Borgwardt, Walter Forkel, Alisa Kovtunova

Institute of Theoretical Computer Science, Chair of Automata Theory

Finding New Diamonds: Temporal Minimal-World Query Answering over Sparse ABoxes

Bozen-Bolzano, 17th September 2019

Motivation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clinical trial criteria
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clinicaltrials.gov: temporal, negated
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SNOMED CT ($\mathcal{ELH}_\perp$)
temporal axioms
extract
translate
sparse temporal facts
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MTNCQs
ABox $\mathcal{A}$
knowledge base $\mathcal{K}$
structured queries φ

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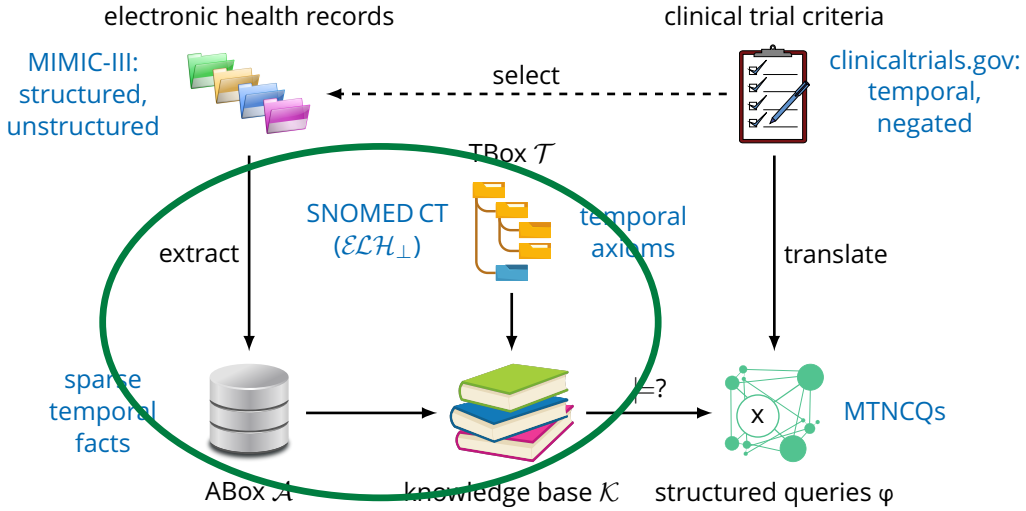
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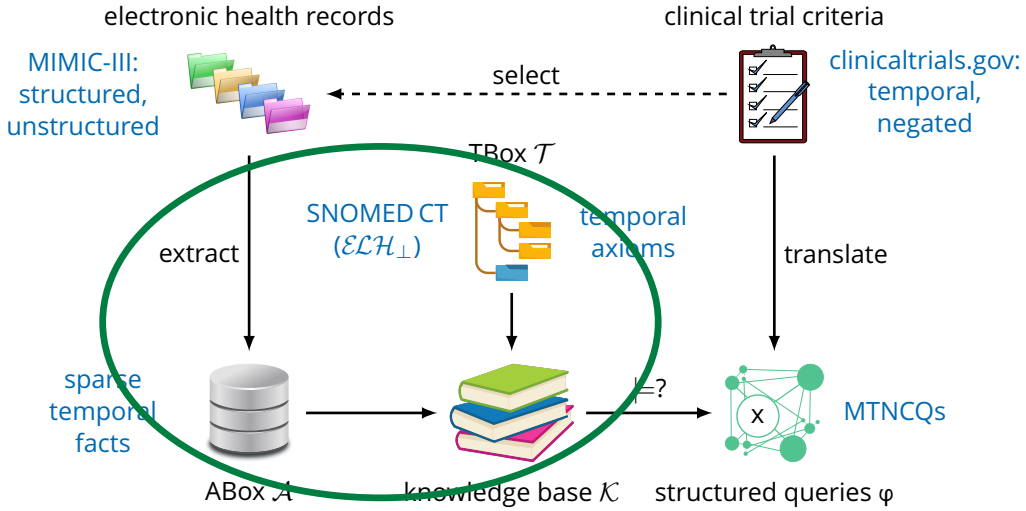
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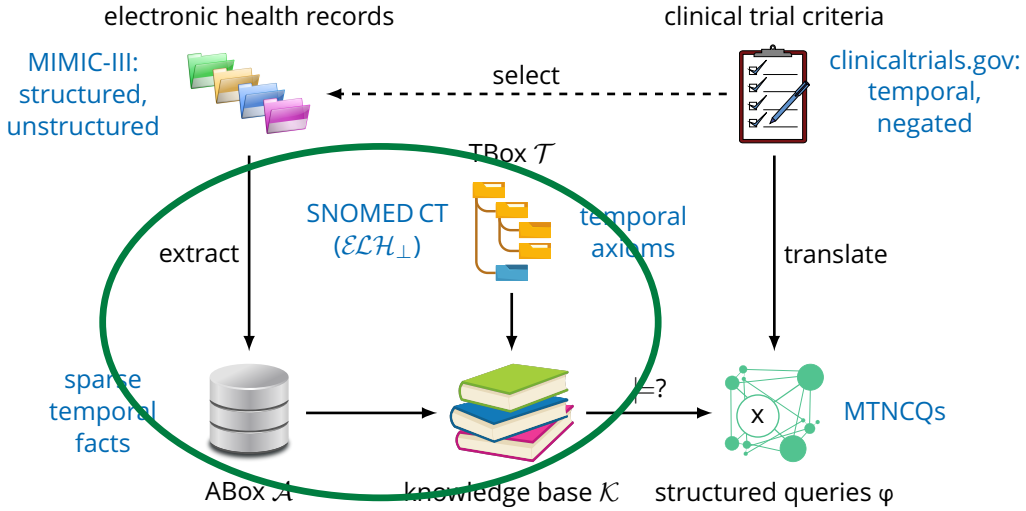
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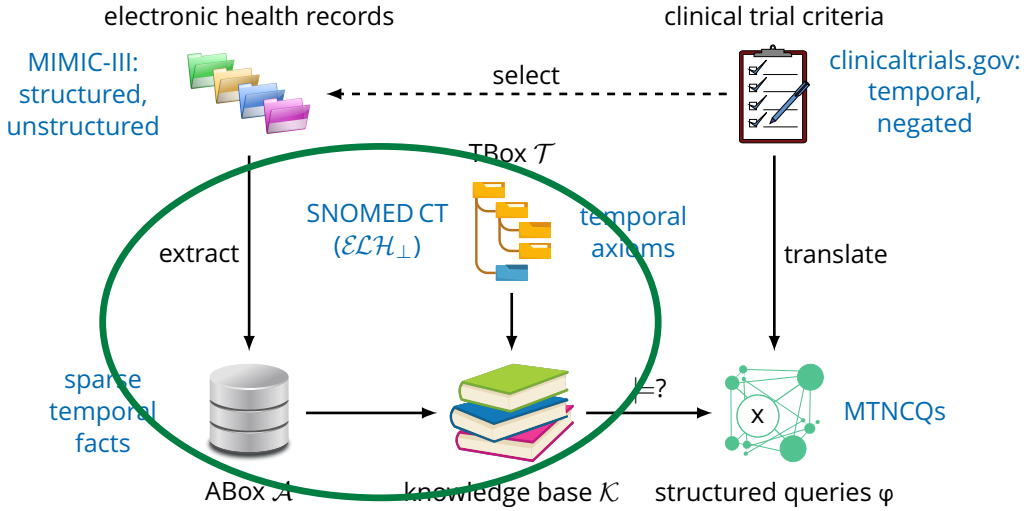
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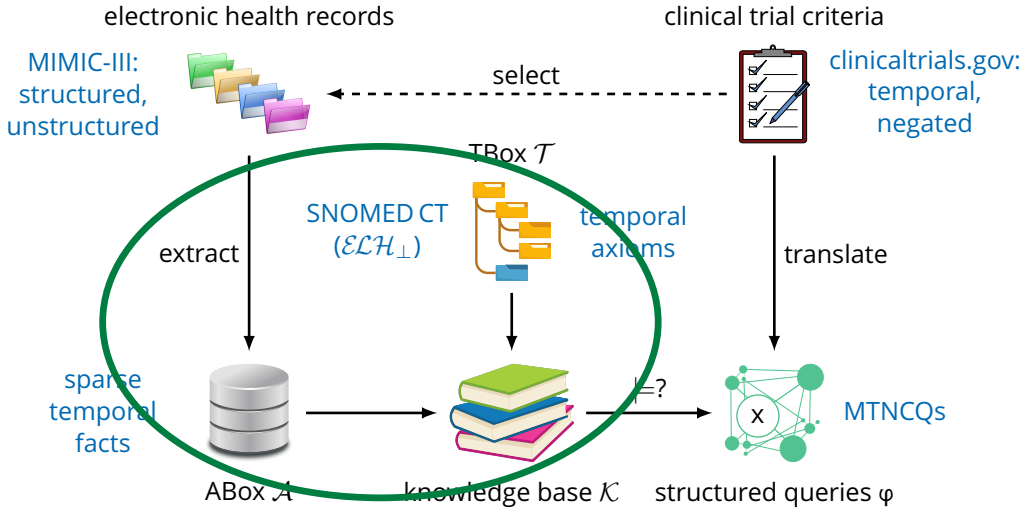
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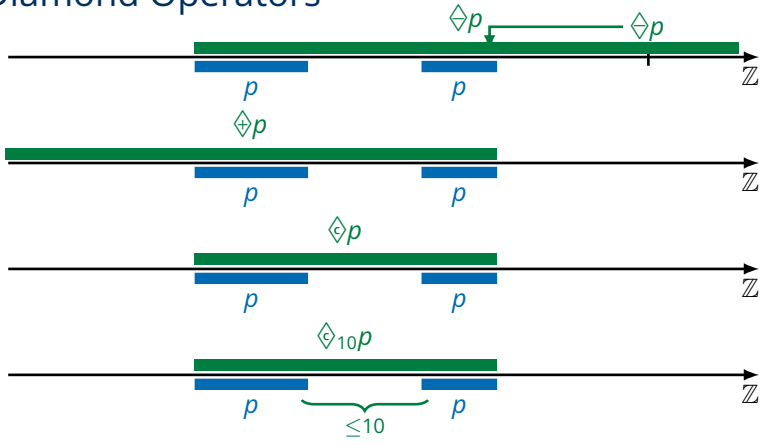
Metric Diamond Operators



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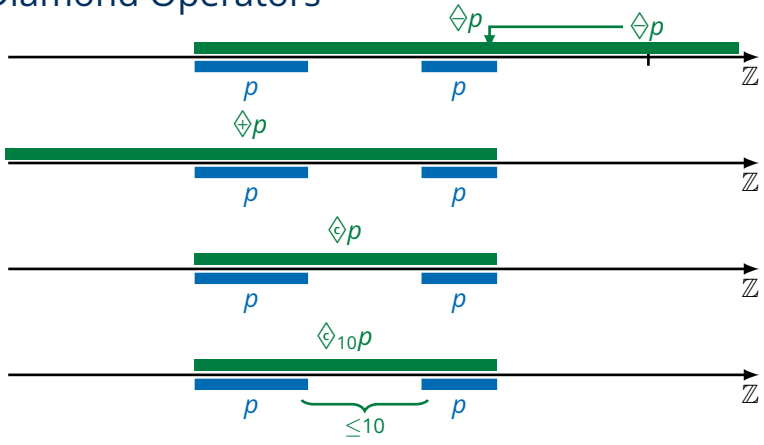

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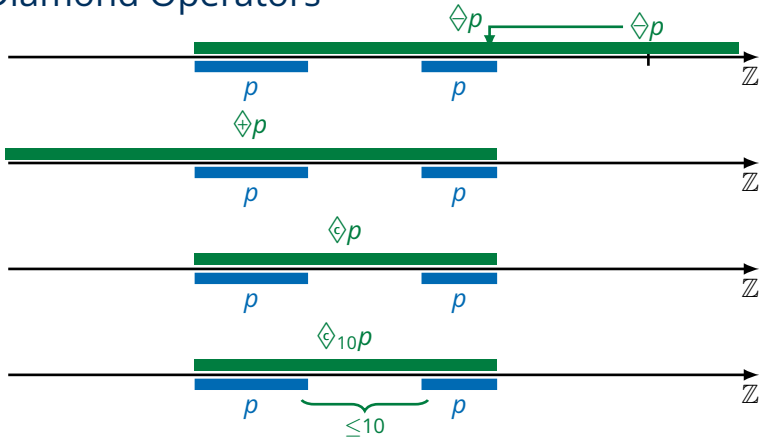

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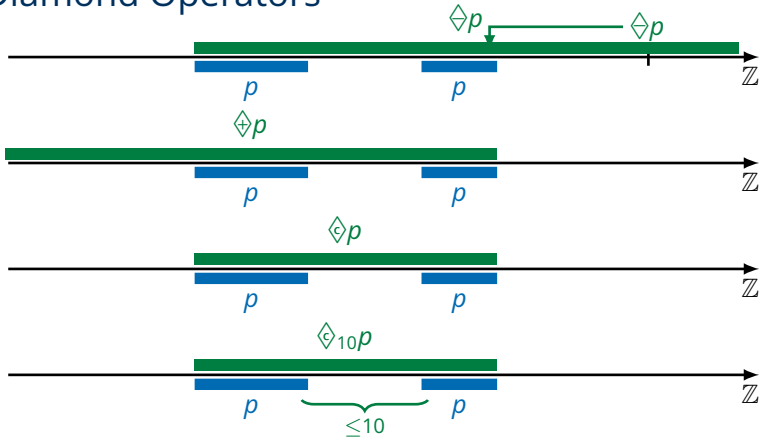

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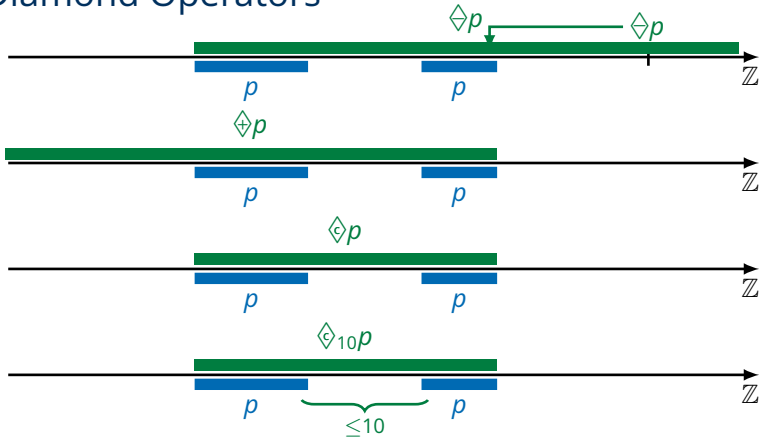

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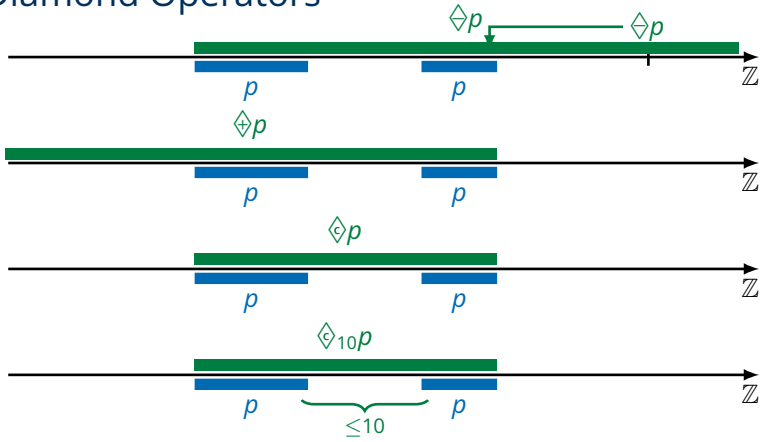

- can be seen as closure operators $2^{\mathbb{Z}} \to 2^{\mathbb{Z}}$
- $\{\Diamond_1, \Diamond_2, \ldots, \Diamond, \Diamond, \Diamond, \Diamond\}$ is closed under pointwise $\cap, \cup, \circ$

A Temporal Description Logic

based on (Gutiérrez-Basulto, Jung, and Kontchakov 2016)

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$$\Diamond A \sqsubseteq B,\ A_1 \sqcap A_2 \sqsubseteq B,\ \Diamond r \sqsubseteq s,\ \Diamond A \sqsubseteq \exists r.B,\ \exists r.A \sqsubseteq B, \quad A(a,i),\ r(a,b,i)$$

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$\Diamond = \Diamond$

Translation into first-order logic:

$$\forall x, t, t'.\, A(x,t') \wedge (t' \leq t) \rightarrow \exists y.\, r(x,y,t) \wedge B(y,t)$$

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Theorem

Entailment in $\mathcal{TELH}_\bot^{\Diamond,\text{lhs}}$ is P-complete.

(Some) Completion Rules

$$\frac{\Diamond_{\star} A_1 \sqsubseteq A_2 \qquad \Diamond_{\bullet} A_2 \sqsubseteq A_3}{(\Diamond_{\bullet} \circ \Diamond_{\star}) A_1 \sqsubseteq A_3} \qquad \frac{\Diamond_{\star} A \sqsubseteq A_1 \qquad \Diamond_{\bullet} A \sqsubseteq A_2 \qquad A_1 \sqcap A_2 \sqsubseteq B}{(\Diamond_{\star} \cap \Diamond_{\bullet}) A \sqsubseteq B}$$

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(only for representative time points i)

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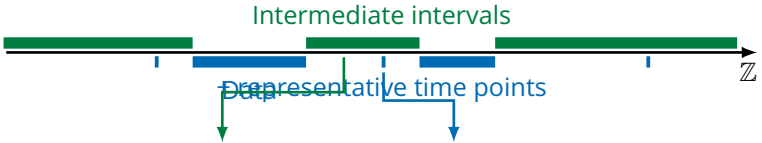

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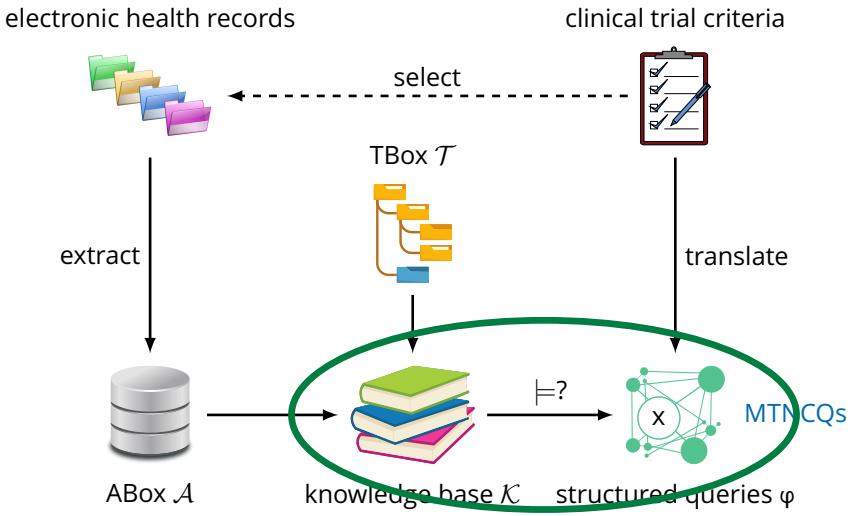
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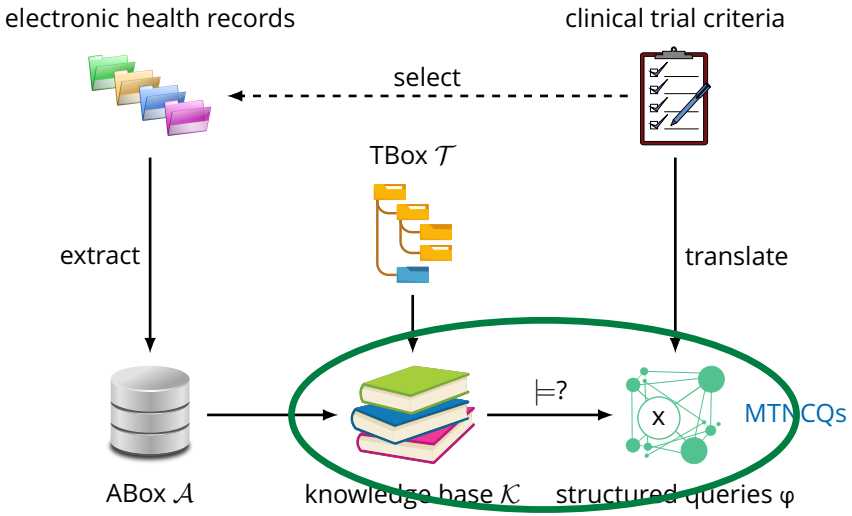
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Metric Temporal Conjunctive Queries with Negation (MTNCQs)

"Diagnosis of Rheumatoid Arthritis (RA)
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negative information is rarely entailed $\rightsquigarrow$ use "negation by failure"

Minimal-World Semantics

(Borgwardt and Forkel 2019)

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Knowledge base $\mathcal{K}$:

$$\text{DiabetesPatient} \equiv \exists \text{diagnosis}.\text{Diabetes}$$

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$$\text{DiabetesType1} \sqsubseteq \text{Diabetes}$$

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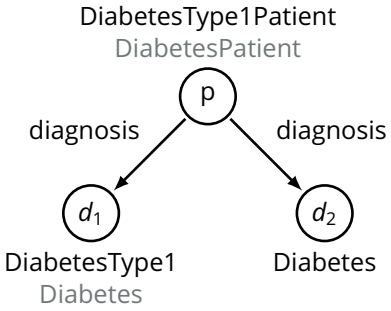

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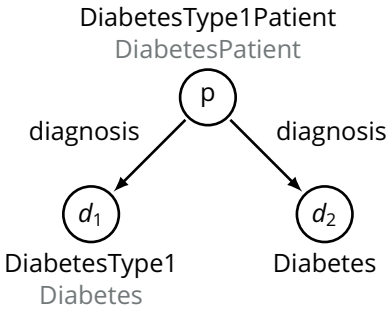

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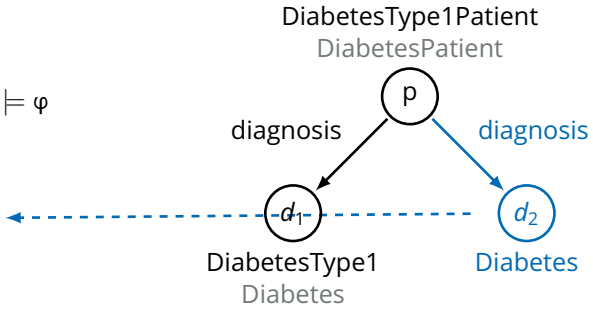
Patient p has a diagnosis with Diabetes that is not DiabetesType1.



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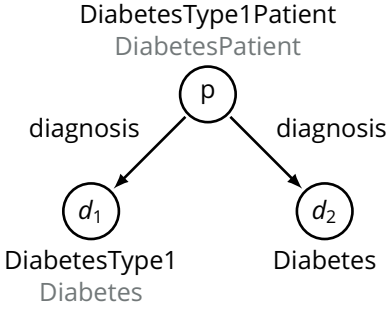

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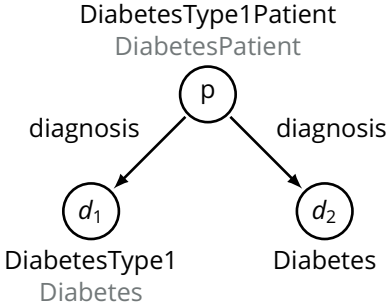
Minimal-world semantics:
use $\mathcal{I}_\mathcal{K} \models \varphi$ instead of $\mathcal{K} \models \varphi$



Temporal Minimal-World Semantics

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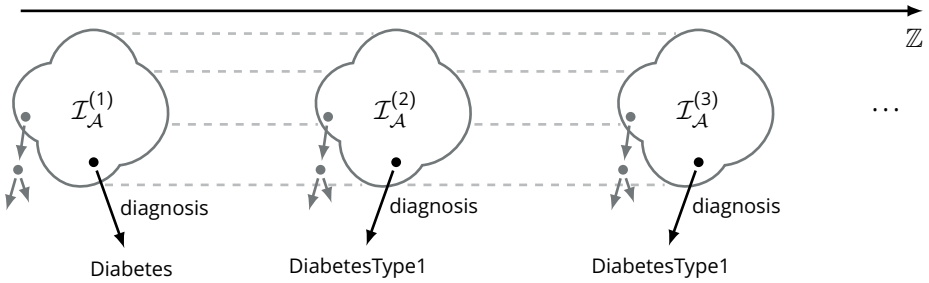
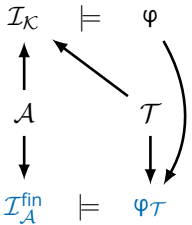


Combined Rewriting

$\mathcal{I}_\mathcal{K}$ can be infinite!



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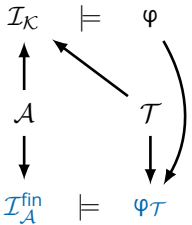

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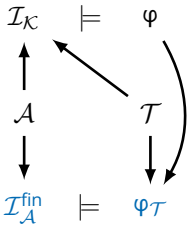

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- rewriting temporal operators into FOL:

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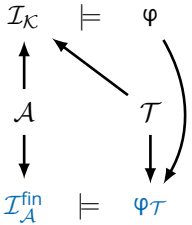

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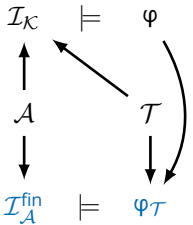

Theorem

In $\mathcal{TELH}_\bot^{\Diamond,\text{lhs}}$, entailment of rooted MTNCQs is ExpSpace-complete, and P-complete in data complexity.

It’s Not That Easy

Queries can distinguish more time points!

$\square_{[A,B]}$ sum of all numbers in φ (∞ does not count)

It’s Not That Easy

Queries can distinguish more time points!

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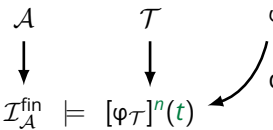
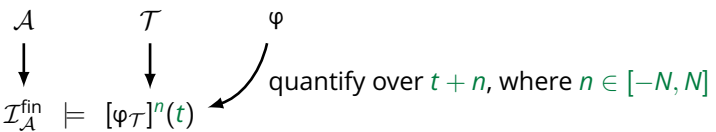


quantify over $t + n$, where $n \in [-N, N]$

It's Not That Easy

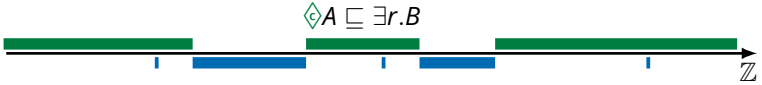
Queries can distinguish more time points!



N, and therefore $\varphi_{\mathcal{T}}$, is exponentially large. Model checking in FOL is in PSPACE.

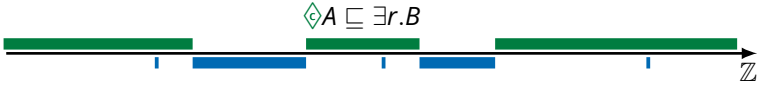
$\rightarrow$ EXPSPACE

Summary

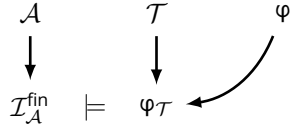


Entailment in $\mathcal{TELH}_{\perp}^{\Diamond,\mathsf{lhs}}$ over sparse data is P-complete.

Summary

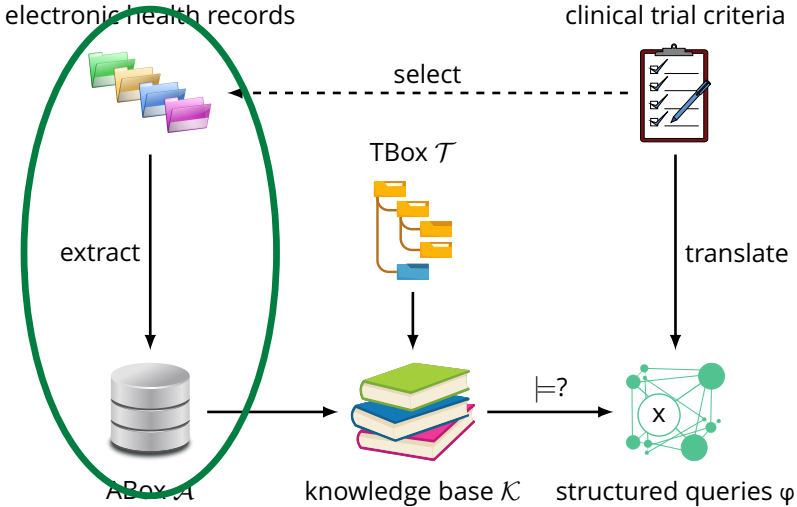


Entailment in $\mathcal{TELH}_{\bot}^{\Diamond,\mathsf{lhs}}$ over sparse data is P-complete.

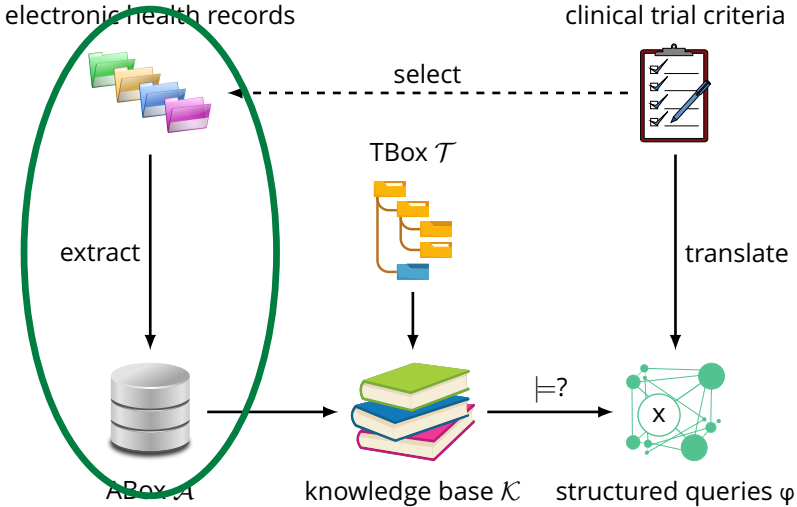


Answering MTNCQs in $\mathcal{TELH}_{\bot}^{\Diamond,\mathsf{lhs}}$ is P-complete in data complexity.

Outlook


electronic health records
clinical trial criteria
select
TBox $\mathcal{T}$
extract
translate
$\models$?
ABox $\mathcal{A}$
knowledge base $\mathcal{K}$
structured queries φ

Outlook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Thank you!

Borgwardt, Stefan and Walter Forkel (2019). “Closed-World Semantics for Conjunctive Queries with Negation over $\mathcal{ELH}_\bot$ Ontologies”. In: *Proc. JELIA'19*, pages 371–386.

Gutiérrez-Basulto, Víctor, Jean Christoph Jung, and Roman Kontchakov (2016). “Temporalized $\mathcal{EL}$ Ontologies for Accessing Temporal Data: Complexity of Atomic Queries”. In: *Proc. IJCAI'16*, pages 1102–1108.

Pictures from https://publicdomainvectors.org