Use Cases for Imperfect Knowledge in Health Informatics

William Van Woensel

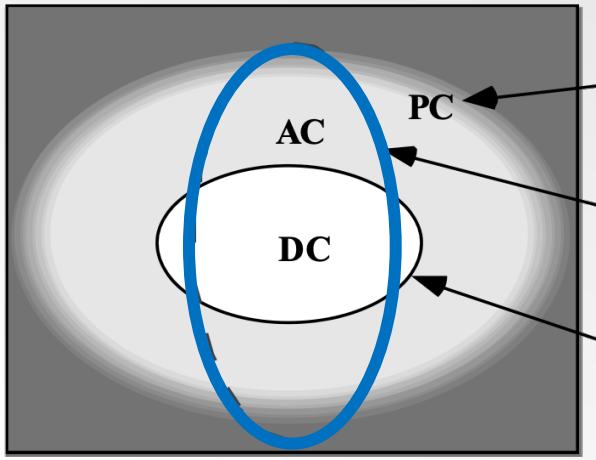
Syed Sibte Raza Abidi, Samina Abidi, Hossein Mohammedhassanzadeh

Varian: Chad Armstrong, Malavan Rajaratnam, Vaibhav Gupta

First International Workshop on Representing and Reasoning with Imperfect knowledge
May 3 2022

Use case: Expanding Closure of Medical KG

- Expand Closure of Medical Knowledge Graphs (KG) [1]
  - *Plausible inferencing:* does not guarantee correctness
    - Probabilistic, abductive, inductive, analogical, ..
  - Expanding *deductive closure* to *acceptable closure*
    - Knowledge is partially incomplete & incorrect



- Multi-Strategy Semantic Inferencing [2]
  - Based on Multi-Strategy, Tutor-based Learning (Tecuci [1])
  - **Justification Trees** are presented as answer to a query
    - Integrate deductive closure with plausible inferences for answer

➢Explain supporting (plausible) inferences to domain expert

➢Tutor paradigm: create AC by generalizing trees & validation by tutor

Explanation-based generalization

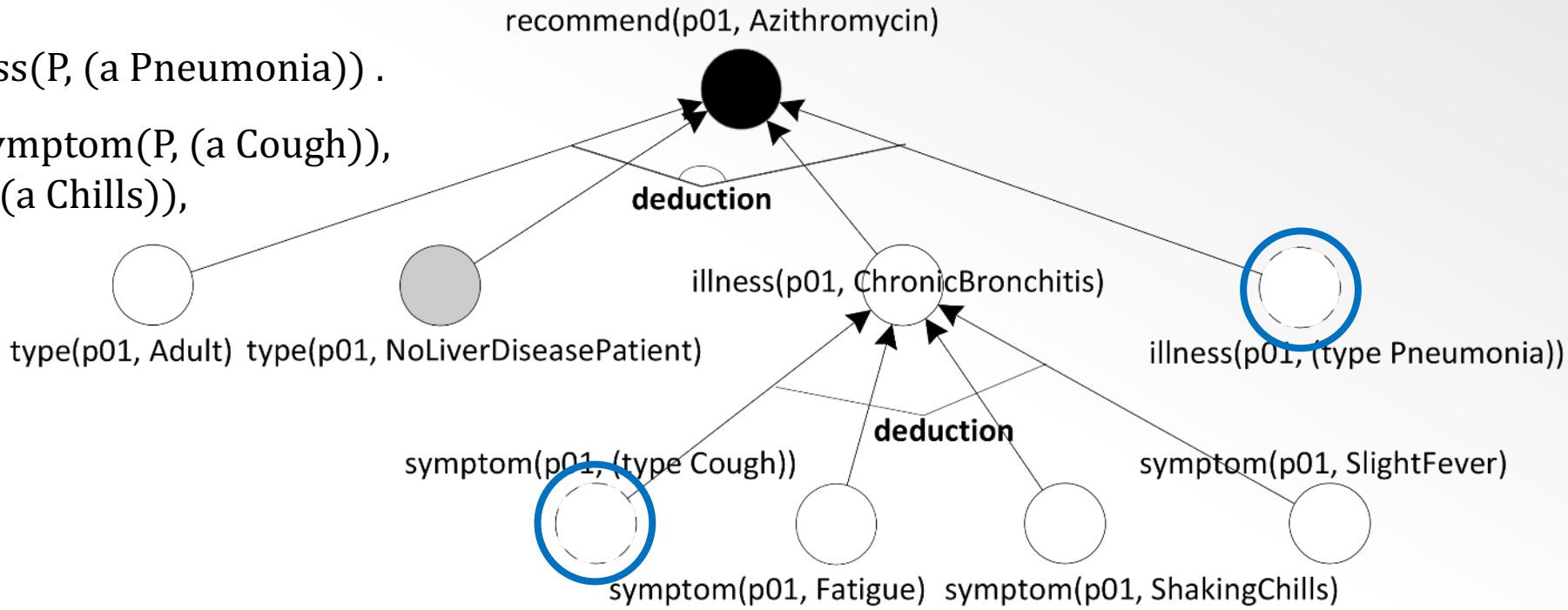
- Step 1: generate deductive justification for queries
  - Implemented via *backward chaining*

Query: **recommend(p01, Azithromycin)**

recommend(P, Azithromycin) :– type(P, Adult),
type(P, NoLiverDisease),
illness(P, ChronicBronchitis), illness(P, (a Pneumonia)) .

illness(P, ChronicBronchitis) :– symptom(P, (a Cough)),
symptom(P, Fatigue), symptom(P, (a Chills)),
symptom(P, SlightFever) .

Initial Justification Tree:



Query instance | Resolvable premise | Missing premise | OWL-inferred premise

Analogy-based Reasoning

- Two entities similar in one aspect, are **likely** similar in another
  - Transfer knowledge from *well-known* entity to *lesser-known* one
- Plausible analogical rules:

illness(P, (type Pneumonia)) :~ type(P, ReducedImmunityPatient), symptom(P, (type ShortnessOfBreath)), symptom(P, (type Fever)), symptom(P, ShakingChills)

I.e., **if** two patients have *reduced immunity*, share a particular kind of *shortness of breath* & *fever*, and have *shaking chills* **then** they will likely share the same kind of *pneumonia*

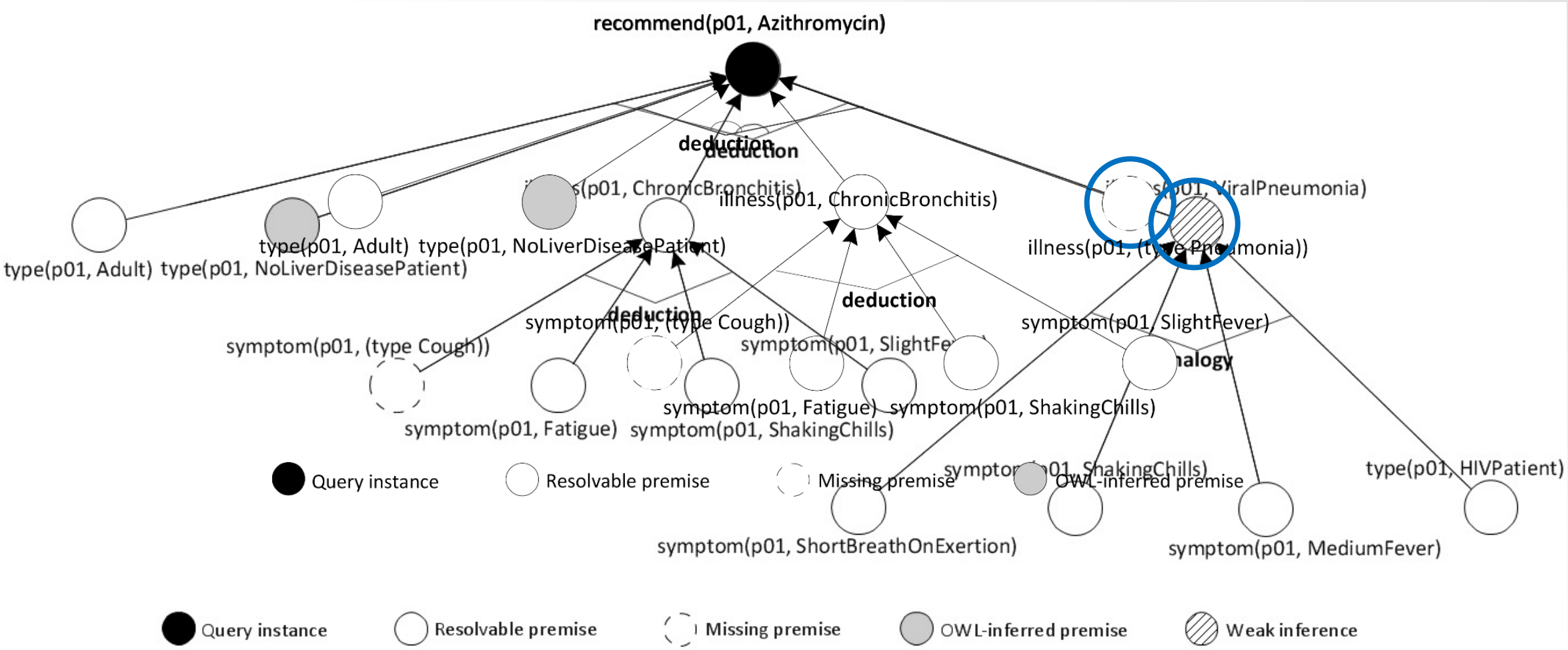
cds:p07 rdf:type *cds:OrganTransplantPatient ;* cds:symptom *cds:ShortBreathOnExertion;*

cds:symptom *cds:MediumFever ;* cds:symptom *cds:ShakingChills ;* **cds:illness cds:ViralPneumonia**

cds:p01 rdf:type *cds:HIVPatient ;* cds:symptom *cds:ShortBreathOnExertion;*

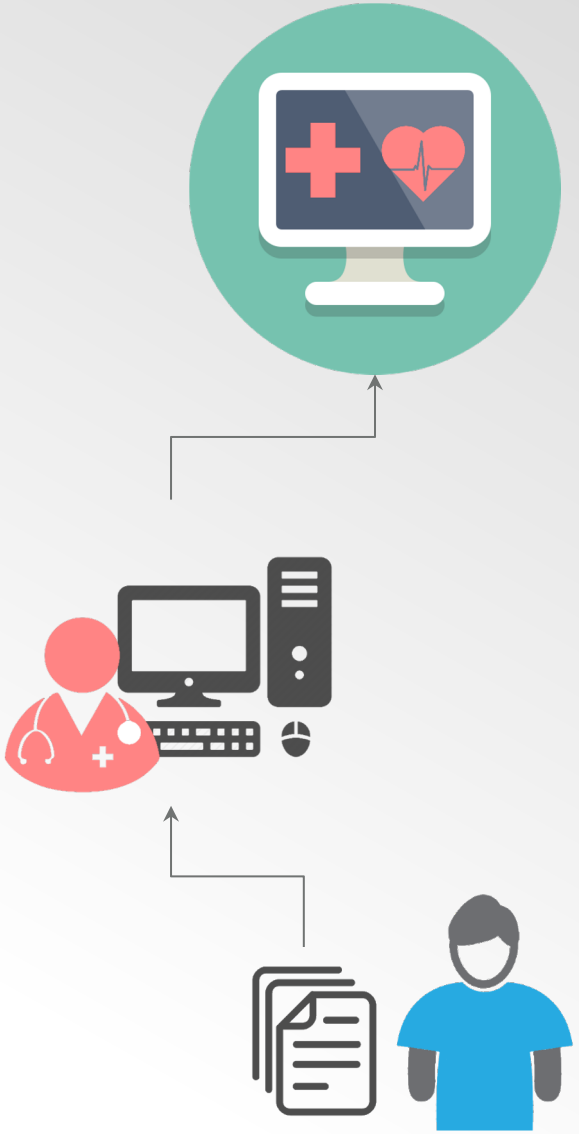
cds:symptom *cds:MediumFever ;* cds:symptom *cds:ShakingChills* ➔ cds:symptom **cds:ViralPneumonia**

Plausible Justification Tree



Use Case: Plausibly Infer Missing EMR Data

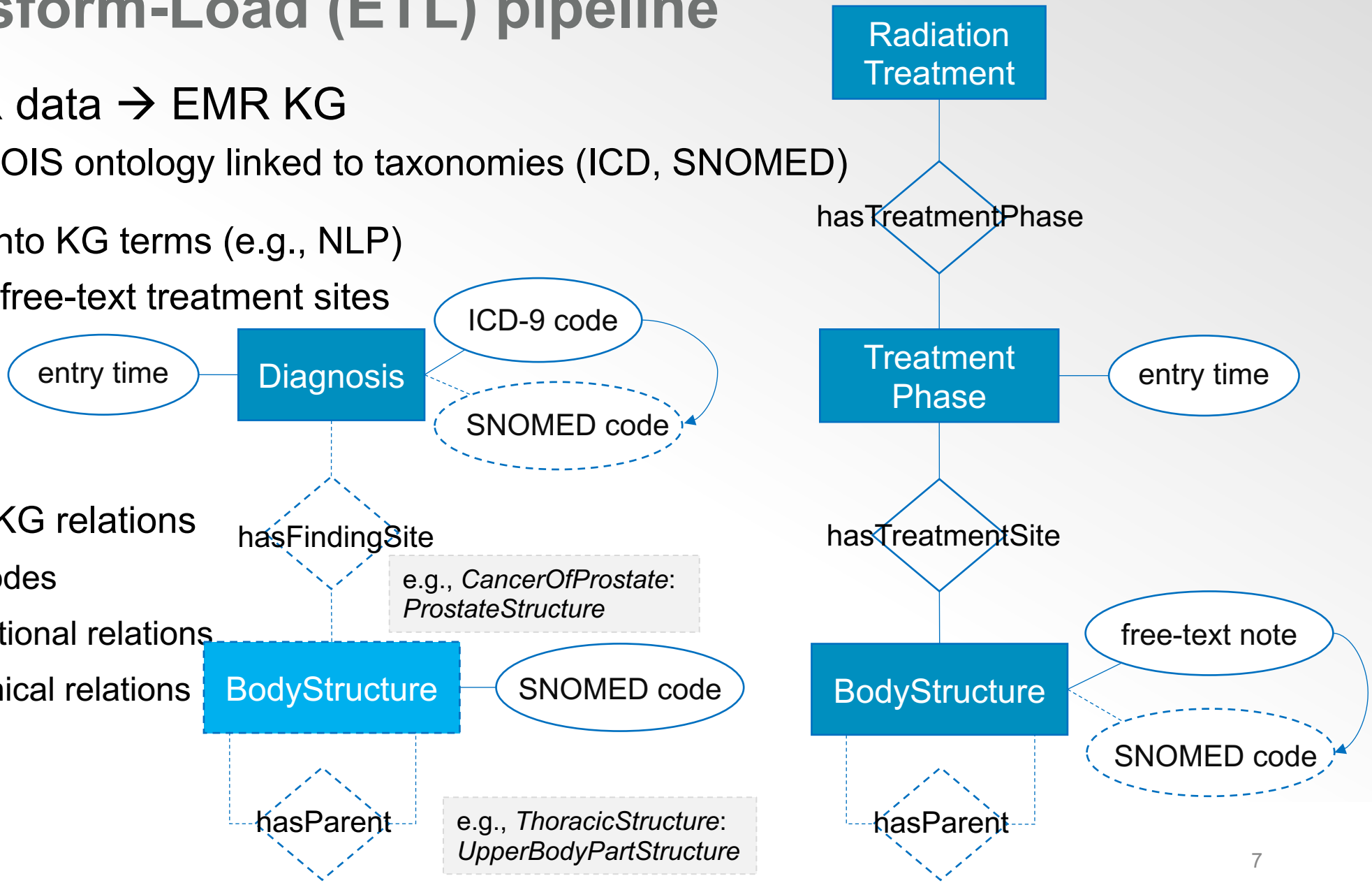
- EMR often show incomplete picture
  - Fragmented and disconnected EMR [3]
    - Different vendors: Telus, QHR, Nightingale, Practimax, Accuro, ..
  - Data input problem from clinician end [3]
    - Hugely increased workloads and burnout using EMR
- Varian Aria Oncology Information System
  - Missing causal associations between diagnoses, treatments
    - It was possible to enter this data in UI but not mandatory (mostly missing)
  - No training data for ML methods
- ➢ Use plausible reasoning over medical KG [4]
  - Leverage medical taxonomies (SNOMED-CT, ICD)
  - Plausibly infer causal relations between diagnoses, treatment



Extract-Transform-Load (ETL) pipeline

- **Transform**: EMR data → EMR KG
  - ❑ *Oncology EMR*: OIS ontology linked to taxonomies (ICD, SNOMED)
- Transform free-text into KG terms (e.g., NLP)
  - ❑ *Oncology EMR*: free-text treatment sites
- Enrich with medical KG relations
  - Map terminology codes
  - Enrich with associational relations
  - Enrich with hierarchical relations

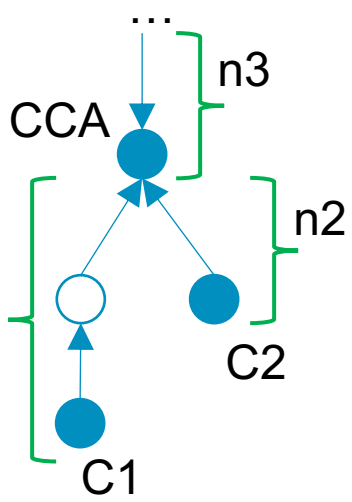
SNOMED-CT

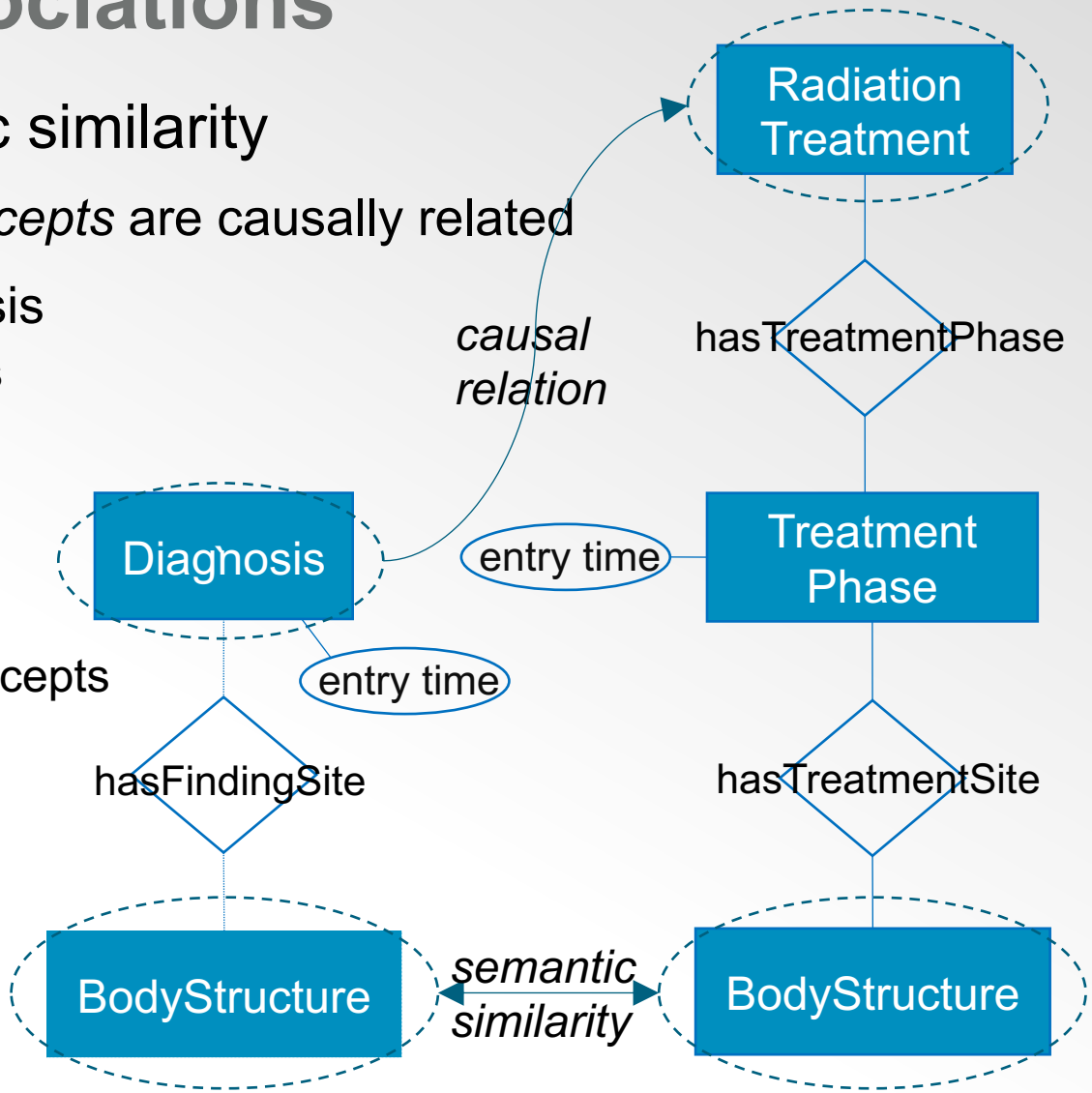


Plausible Metrics for Causal Associations

- Plausible inference pattern based on semantic similarity
  - If some *related concepts* are similar, then *target concepts* are causally related

1) Identify related EMR concepts for similarity analysis
   - In EMR KG, concepts have associated body structures
2) Apply semantic similarity on related concepts
   - Wu-Palmer [5]: 2 x n3 / (n1 + n2 + (2 x n3))
   - ❖ CD = distance between two concepts and their CCA
   - ❖ Same CD for lower concepts is better than higher concepts





Conclusions

- Two HI use cases for plausible reasoning
  - PhD project: use justification trees to integrate deductive & plausible reasoning
    - Explaining to domain expert why system offers certain answers
  - Industry project: leverage EMR KG & plausible reasoning to solve problem
    - No large-scale dataset available for statistical analysis

- See references for more on these use cases

Demo: Multi-Strategy Inferencing

References

[1] **Multi-Strategy Semantic Web Reasoning for Medical Knowledge Bases**. Van Woensel, W., Mohammadhassanzadeh, H., Abidi, S.R., Abidi, S.S.R.. In: International Workshop on Biomedical Data Mining, Modeling, and Semantic Integration (BDM2I2015). pp. 1–12. CEUR-WS.org, Bethlehem, Pennsylvania (2015).

[2] **Plausible Justification Trees: A Framework for Deep and Dynamic Integration of Learning Strategies**. Tecuci, G. In: Mach. Learn. 11, 237–261 (1993).

[3] **A Crisis in Healthcare: A Call to Action on Physician Burnout**. A. K. Jha, A. R. Iliff, et al. In: Massachusetts Medical Society, Massachusetts Health and Hospital Association, Harvard T.H. Chan School of Public Health, and Harvard Global Health Institute.

[4] **Using Knowledge Graphs to Plausibly Infer Missing Associations in EMR Data**. Van Woensel, W., Rajaratnam, M., Gupta, V., Armstrong, C., Abidi, S.S.R.: In: 31st European Medical Informatics Conference (2021)

[5] **Verbs semantics and lexical selection**. Wu, Z., Palmer, M. In: 32nd annual meeting on Association for Computational Linguistics. pp. 133–138. Association for Computational Linguistics (1994).