

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

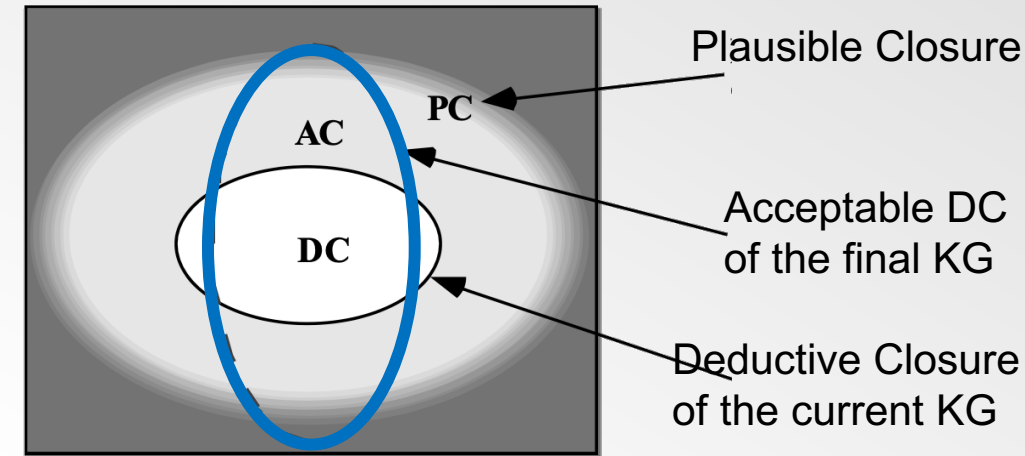
First International Workshop on Representing and Reasoning with Imperfect knowledge
May 3 2022



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 [1]

- Based on Multi-Strategy, Tutor-based Learning (Tecuci [2])
- **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

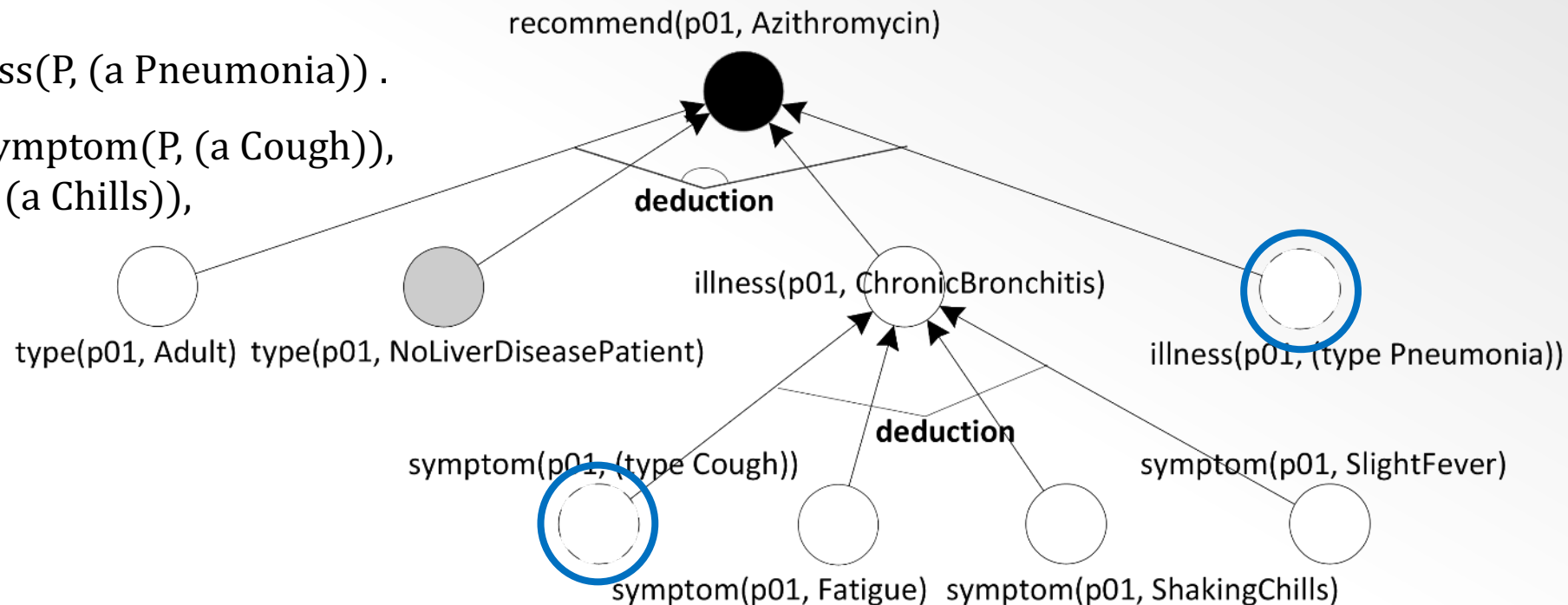
- Step 1: generate deductive justification for queries
 - Implemented via *backward chaining*

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

Initial Justification Tree:

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) .



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*

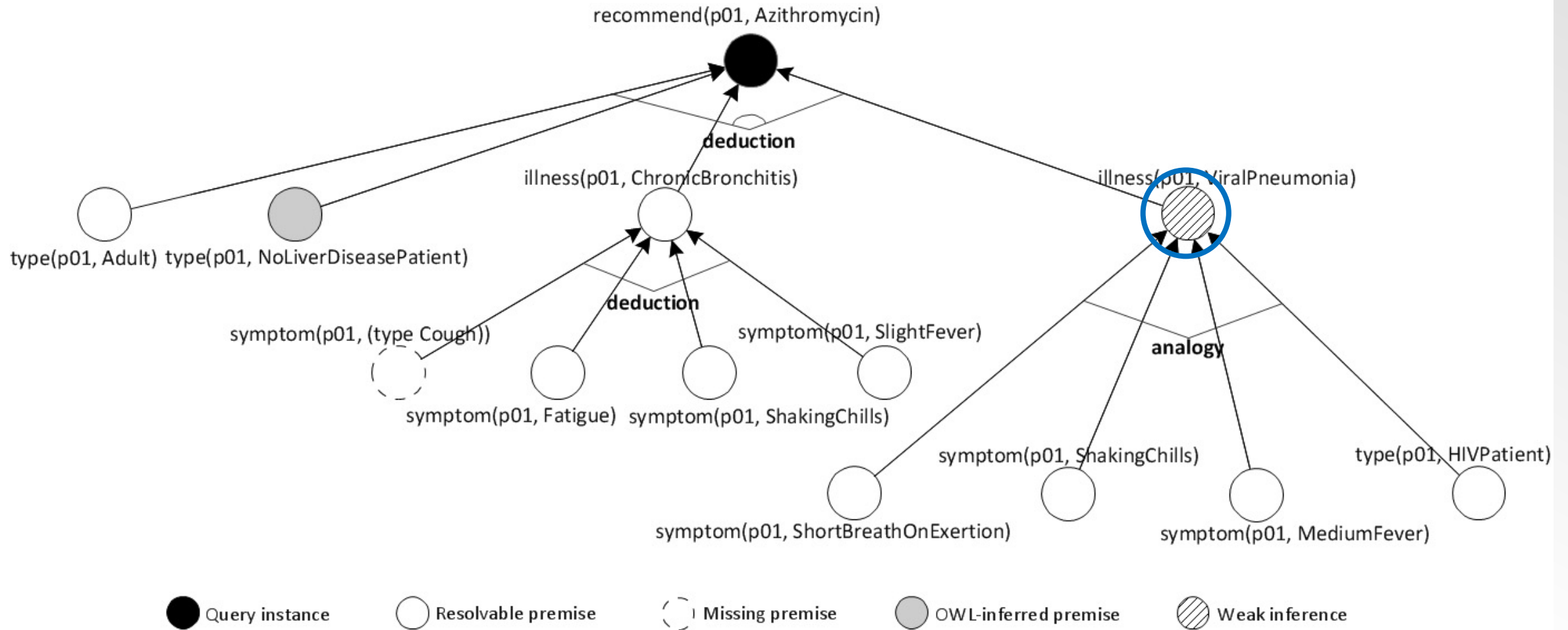
cds:p07 `rdf:type cds:OrganTransplantPatient ; cds:symptom cds:ShortBreathOnExertion;`

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

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

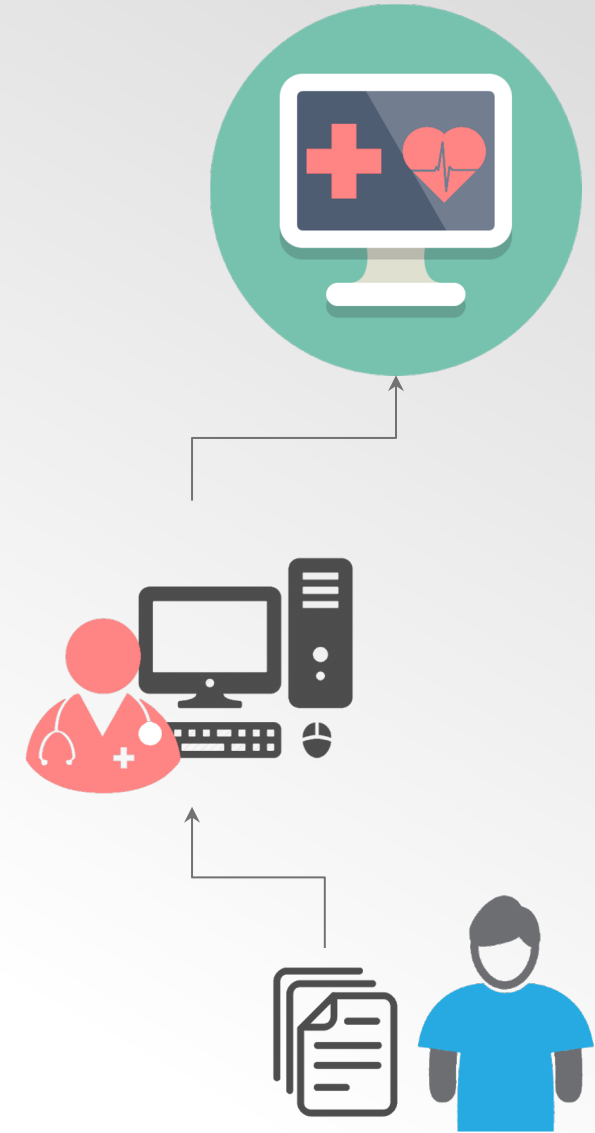
`cds:symptom cds:MediumFever ; cds:symptom cds:ShakingChills → cds:symptom cds:ViralPneumonia`

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

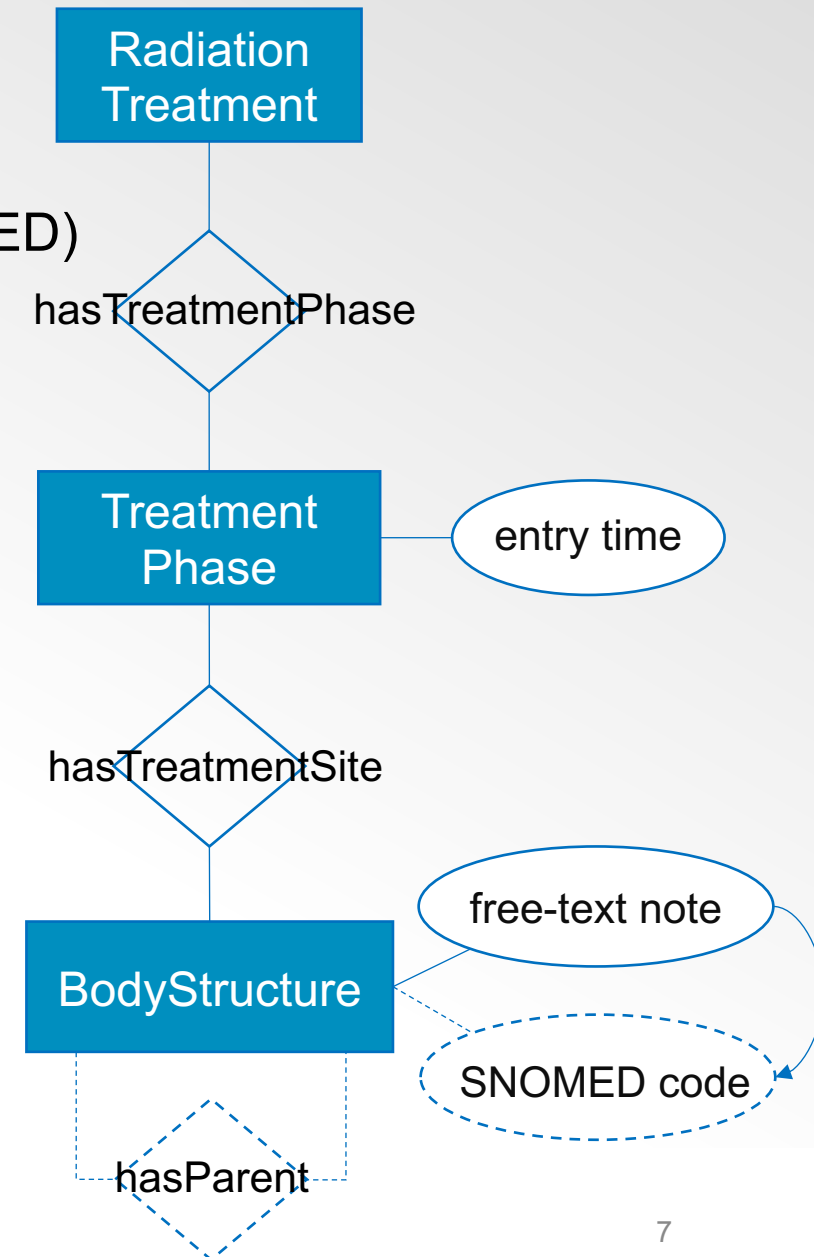
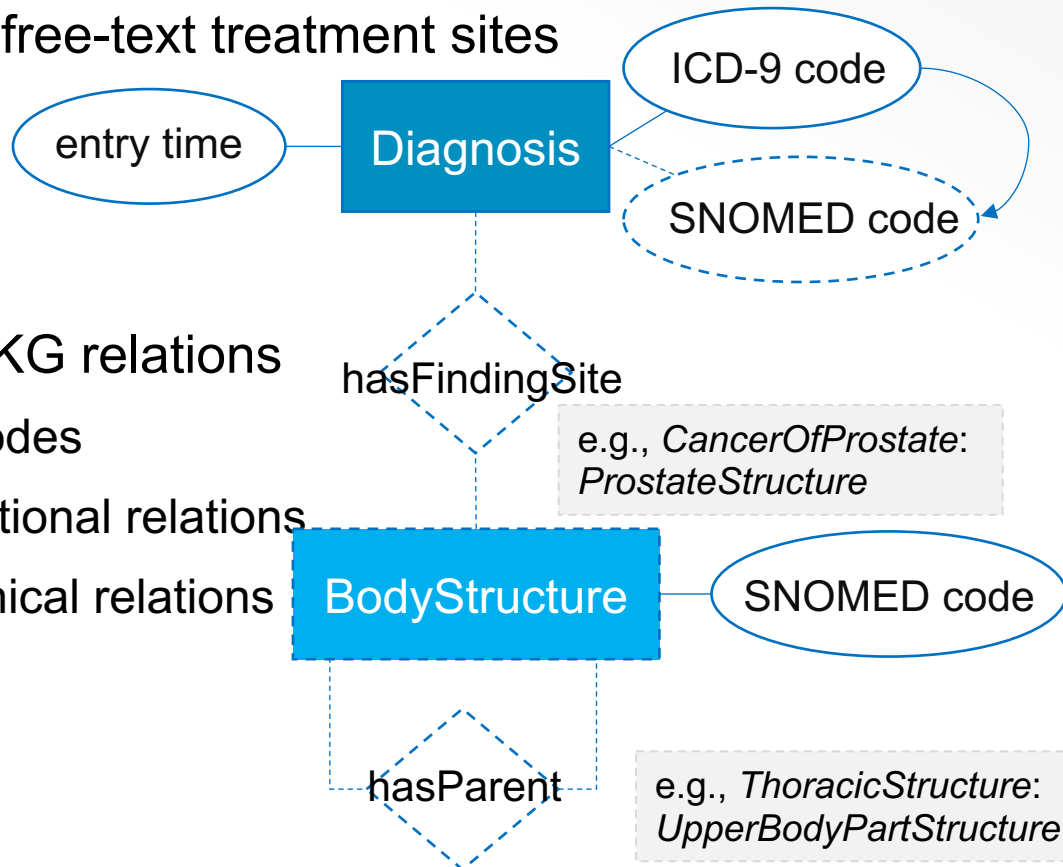
- Enrich with medical KG relations

- 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

- Identify related EMR concepts for similarity analysis

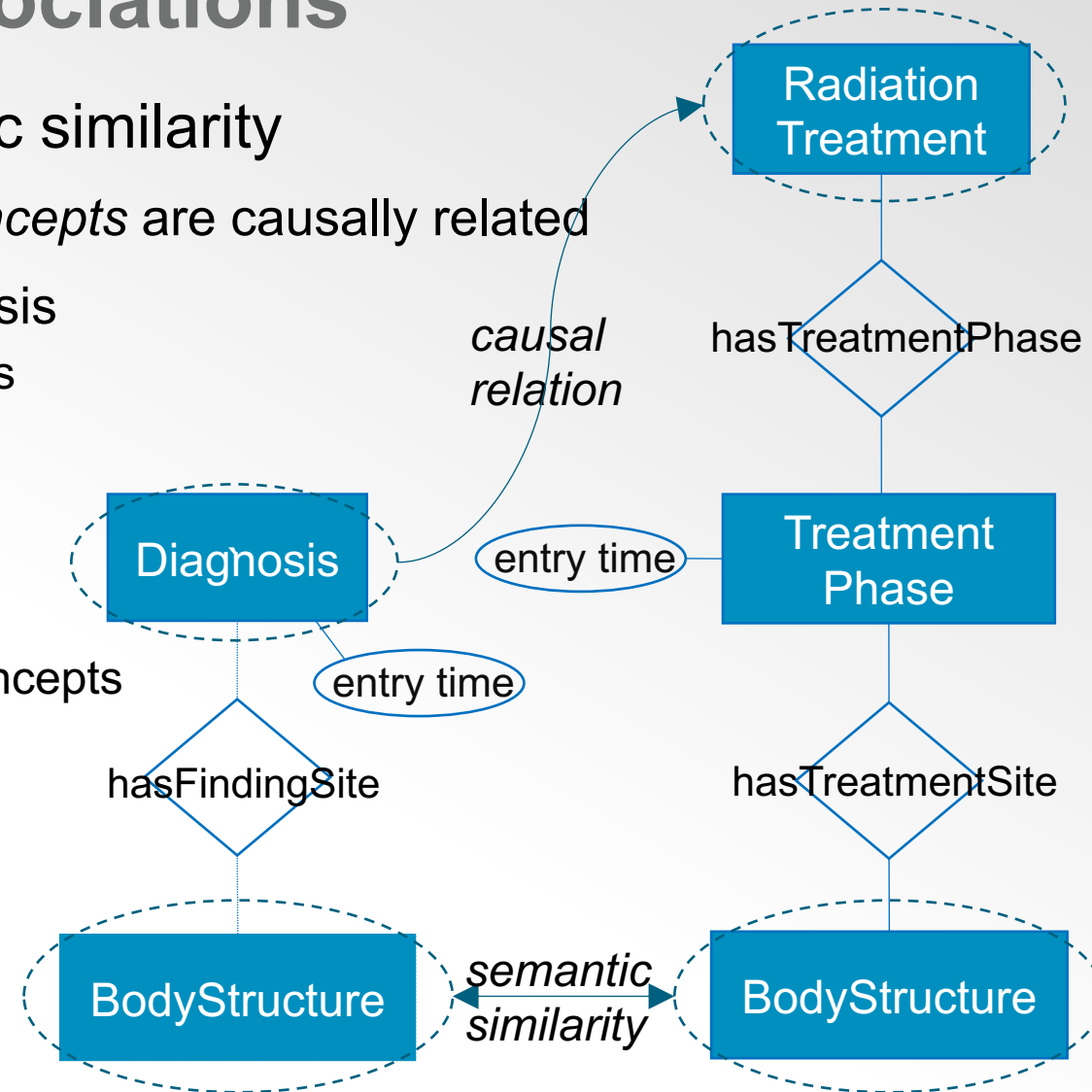
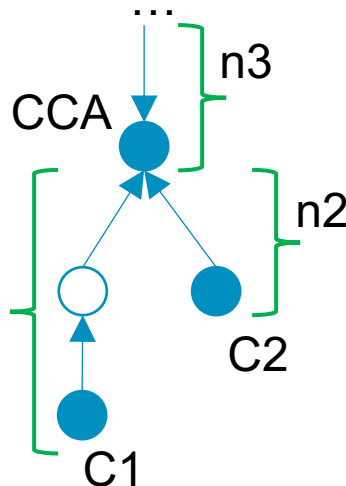
- In EMR KG, concepts have associated body structures

- Apply semantic similarity on related concepts

- Wu-Palmer [5]: $2 \times n_3 / (n_1 + n_2 + (2 \times n_3))$

- ❖ CD = distance between two concepts and their CCA

- ❖ Same CD for lower concepts is better than higher concepts



Conclusions

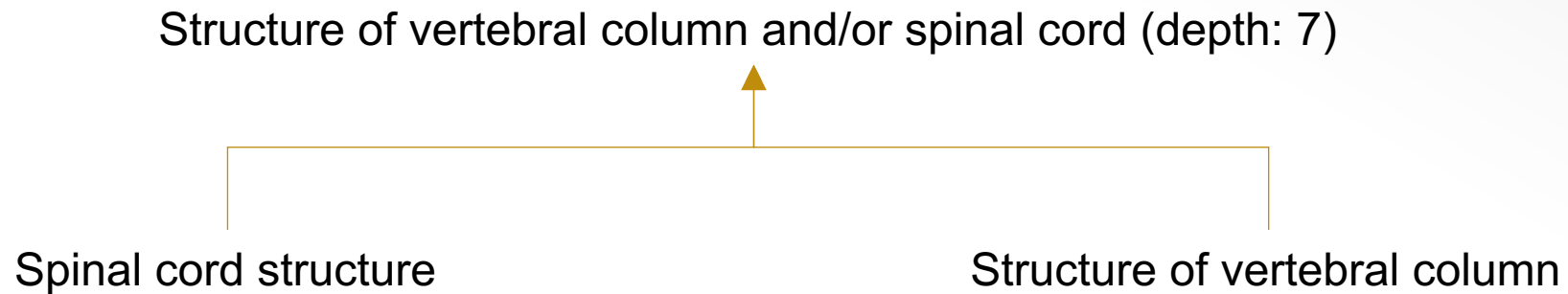
- Two HI use cases for plausible reasoning
 - PhD project: use justification trees to integrate deductive & plausible reasoning
 - Explaining to domain expert why system offers certain answers
 - Industry project: leverage EMR KG & plausible reasoning to solve problem
 - No large-scale dataset available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

Demo: Multi-Strategy Inferencing

<https://youtu.be/xDj6y0cCjAs>

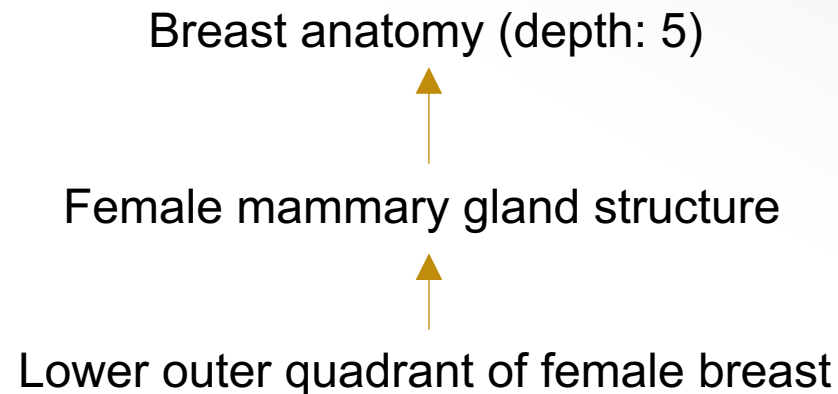
Missing EMR Data: Example Path (1)

- Treatment
 - **Site:** Structure of vertebral column ("T3-T6 SPINE")
- Diagnosis
 - **Type:** Secondary malignant neoplasm of brain and spinal cord
 - **Site:** Spinal cord structure (other: Brain structure)
- Similarity: 0.89
- Path:



Missing EMR Data: Example Path (2)

- Treatment
 - **Site:** Breast anatomy ("RT BREAST")
- Diagnosis
 - **Type:** Malignant neoplasm of lower-outer quadrant of female breast
 - **Site:** Lower outer quadrant of female breast
- Similarity: 0.86
- Path:



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).