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# An Ontological Analysis of Reference in Health Record Statements

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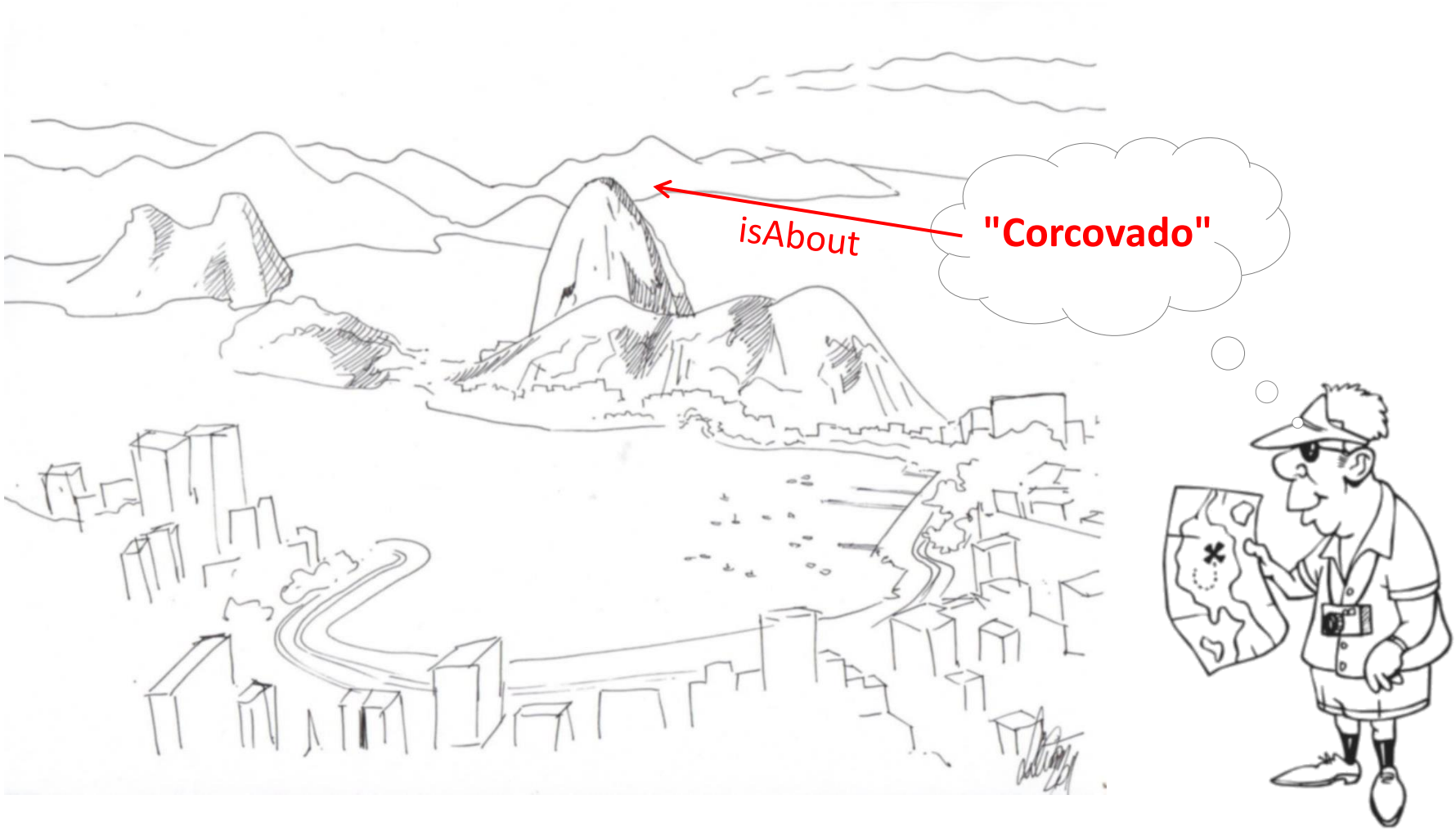
# Correct reference?



# Correct reference?

Alcoholic Hepatitis

"Viral Hepatitis (?)"

"patient with **possible viral hepatitis**"
*(has alcoholic hepatitis)*

"patient scheduled for **heart transplant**"
*(dies before operation)*

"**planned pregnancy**"
*(unfortunately never gets pregnant)*

"omeprazol given to prevent **gastric ulcer**"
*(works, therefore patient won't get an ulcer)*

"patient **drinks socially**"
*(in fact a heavy drinker)*

"patient reports **severe back pain**"
*(patient simulates)*

"patient denied **hemodialysis**"
*(survives without hemodialysis)*

"father **died from myocardial infarction**"
*(died from ruptured aneurysm, son did not remember)*

Non-referring expressions in health records

# Adjectival modifiers in diagnostic statements

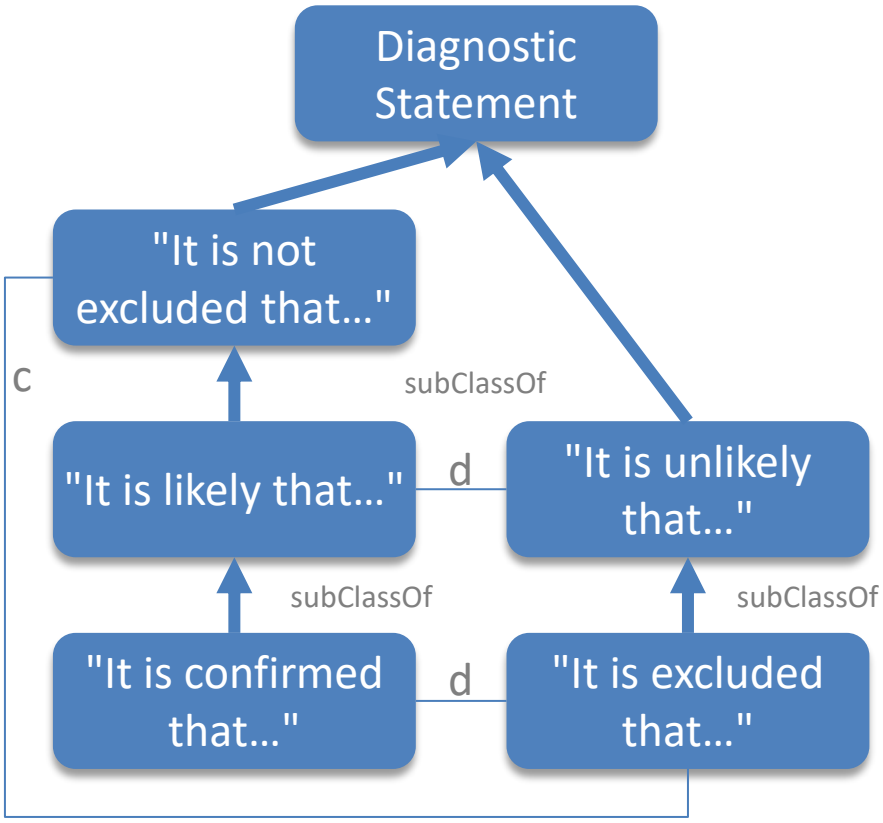
- "It is unlikely that the patient has hepatitis B"
- "It is confirmed that the patient has hepatitis B"
- "It is excluded that the patient has hepatitis B"

# Goal

- Develop appropriate OWL-DL patterns that allow for expressing reference with different (qualitative) gradings of certainty
- Create a gold standard of examples of commonly agreed plausible inferences
- Validate the ontology patterns by comparing machine inferences to gold standard using DL reasoner (HermiT)

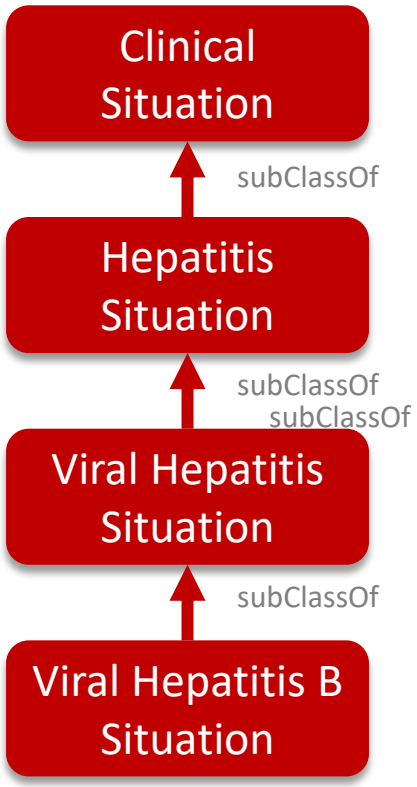
# Example

Diagnostic statement: “The diagnosis of the condition X is confirmed / likely / not excluded / unlikely / excluded.”




duality (d) , complement (c)

is about situation




situation X ≡ episode with X

# Plausible inferences

| | | **Being said to have hepatitis (H) / viral hepatitis (vH) / viral hepatitis B (vHB) is…** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Precondition: | | confirmed | | | likely | | | not excluded | | | unlikely | | | excluded | | |
| Entailment: | | H | vH | vHB | H | vH | vHB | H | vH | vHB | H | vH | vHB | H | vH | vHB |
| confirmed | H | x | x | x | | | | | | | | | | | | |
| | vH | | x | x | | | | | | | | | | | | |
| | vHB | | | x | | | | | | | | | | | | |
| likely | H | x | x | x | x | x | x | | | | | | | | | |
| | vH | | x | x | | x | x | | | | | | | | | |
| | vHB | | | x | | | x | | | | | | | | | |
| not excluded | H | x | x | x | x | x | x | x | x | x | | | | | | |
| | vH | | x | x | | x | x | | x | x | | | | | | |
| | vHB | | | x | | | x | | | x | | | | | | |
| unlikely | H | | | | | | | | | | x | | | x | | |
| | vH | | | | | | | | | | x | x | | x | x | |
| | vHB | | | | | | | | | | x | x | x | x | x | x |
| excluded | H | | | | | | | | | | | | | x | | |
| | vH | | | | | | | | | | | | | x | x | |
| | vHB | | | | | | | | | | | | | x | x | x |

# Five OWL patterns

- *"Existential"* (using OWL existential restrictions)
- *"Universal"* (using OWL universal restrictions)
- *"Punning"* (using the same OWL entities as classes and individuals)
- *"Two-Level"* (introducing universals as A-Box inhabitants)
- *"Query"* (expressing reference as SPARQL queries on OWL models)

# Five OWL patterns

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- *"Query"* (expressing reference as SPARQL queries on OWL models)

# OWL pattern "Existential"

*BeingSaidToHaveXisConfirmed* equivalentTo
*DiagnosticStatement* and (**hasCertainty** only *isConfirmed*)
and (**isAboutSituation** some *Xsituation*)

*BeingSaidToHaveXisLikely* equivalentTo
*DiagnosticStatement* and (**hasCertainty** only *isLikely*)
and (**isAboutSituation** some *Xsituation*)

*BeingSaidToHaveXisNotExcluded* equivalentTo
*DiagnosticStatement* and (**hasCertainty** only *IsNotExcluded*)
and (**isAboutSituation** some *Xsituation*)

*BeingSaidToHaveXisUnlikely* equivalentTo
*DiagnosticStatement* and
(**hasCertainty** only *isLikely*) and
(**isAboutSituation** some (*ClinicalSituation* and not *Xsituation*))

*BeingSaidToHaveXisExcluded* equivalentTo
*DiagnosticStatement* and
(**hasCertainty** only *isConfirmed*) and
(**isAboutSituation** some (*ClinicalSituation* and not *Xsituation*))

# Entailments of "Existential"

| | | **Being said to have hepatitis (H) / viral hepatitis (vH) / viral hepatitis B (vHB) is…** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Precondition: | | confirmed | | | likely | | | not excluded | | | unlikely | | | excluded | | |
| Entailment: | | H | vH | vHB | H | vH | vHB | H | vH | vHB | H | vH | vHB | H | vH | vHB |
| confirmed | H | x | x | x | | | | | | | | | | | | |
| | vH | | x | x | | | | | | | | | | | | |
| | vHB | | | x | | | | | | | | | | | | |
| likely | H | x | x | x | x | x | x | | | | | | | | | |
| | vH | | x | x | | x | x | | | | | | | | | |
| | vHB | | | x | | | x | | | | | | | | | |
| not excluded | H | x | x | x | x | x | x | x | x | x | | | | | | |
| | vH | | x | x | | x | x | | x | x | | | | | | |
| | vHB | | | x | | | x | | | x | | | | | | |
| unlikely | H | | | | | | | | | | x | | | x | | |
| | vH | | | | | | | | | | x | x | | x | x | |
| | vHB | | | | | | | | | | x | x | x | x | x | x |
| excluded | H | | | | | | | | | | | | | x | | |
| | vH | | | | | | | | | | | | | x | x | |
| | vHB | | | | | | | | | | | | | x | x | x |

# Problem with "Existential" pattern

- Existential import: for each statement about X there is
  - some instance of *XSituation* , or
  - some instance of '*Clinical Situation* and not *XSituation*'
- Conflicting statements would produce logical contradictions
- Solution: universal quantifier ("only") instead of existential quantifier ("some")
- "**isAboutSituation** only *SituationX"* → in case there a reference exists, then it is of the type *SituationX*

# OWL pattern "Universal"

*BeingSaidToHaveXisConfirmed* equivalentTo
*DiagnosticStatement* and (**hasCertainty** only *isConfirmed*)
and (**isAboutSituation** only *Xsituation*)

*BeingSaidToHaveXisLikely* equivalentTo
*DiagnosticStatement* and (**hasCertainty** only *isLikely*)
and (**isAboutSituation** only *Xsituation*)

*BeingSaidToHaveXisNotExcluded* equivalentTo
*DiagnosticStatement* and (**hasCertainty** only *IsNotExcluded*)
and (**isAboutSituation** only *Xsituation*)

*BeingSaidToHaveXisUnlikely* equivalentTo
*DiagnosticStatement* and
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(**isAboutSituation** only (*ClinicalSituation* and not *Xsituation*))

*BeingSaidToHaveXisExcluded* equivalentTo
*DiagnosticStatement* and
(**hasCertainty** only *isConfirmed*) and
(**isAboutSituation** only (*ClinicalSituation* and not *Xsituation*))

# Entailments of "Universal"

| | | **Being said to have hepatitis (H) / viral hepatitis (vH) / viral hepatitis B (vHB) is…** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Precondition: | | confirmed | | | likely | | | not excluded | | | unlikely | | | excluded | | |
| Entailment: | | H | vH | vHB | H | vH | vHB | H | vH | vHB | H | vH | vHB | H | vH | vHB |
| confirmed | H | x | x | x | | | | | | | | | | | | |
| | vH | | x | x | | | | | | | | | | | | |
| | vHB | | | x | | | | | | | | | | | | |
| likely | H | x | x | x | x | x | x | | | | | | | | | |
| | vH | | x | x | | x | x | | | | | | | | | |
| | vHB | | | x | | | x | | | | | | | | | |
| not excluded | H | x | x | x | x | x | x | x | x | x | | | | | | |
| | vH | | x | x | | x | x | | x | x | | | | | | |
| | vHB | | | x | | | x | | | x | | | | | | |
| unlikely | H | | | | | | | | | | x | | | x | | |
| | vH | | | | | | | | | | x | x | | x | x | |
| | vHB | | | | | | | | | | x | x | x | x | x | x |
| excluded | H | | | | | | | | | | | | | x | | |
| | vH | | | | | | | | | | | | | x | x | |
| | vHB | | | | | | | | | | | | | x | x | x |

# Problem with "Universal" pattern

"**isAboutSituation** only *SituationX*" ≡
*not* (**isAboutSituation** some (not *SituationX*)

- contradicts ground axiom of IAO
- Known issues with this kind of statements in DL → unexpected entailments (probably not relevant here (due to strict range restriction of the **isAboutSituation** relation), but doubts persist
- Expression is still "about" something, viz. the type SituationXType

# OWL pattern "Two level"

*Type* subClassOf *owl:Thing*

*Particular* subClassOf *owl:Thing*

*Type* subClassOf **hasInstance** some *Particular*

*X* EquivalentTo **isInstanceOf** value **x_Type**

**x_Type** type Type and **hasInstance** only X

*X* subclassOf **isInstanceOf** value **x_Type**

every member of the class *X* is an instance of the type **x_Type**. The type **x_Type** has only instances that are members of the class *X*

**isAboutSituation** o **isSubtypeOf** subPropertyOf **isAboutSituation**

# OWL pattern "Two Level"

*BeingSaidToHaveXisConfirmed* equivalentTo
*DiagnosticStatement* and (**hasCertainty** only *isConfirmed*)
and (**isAboutSituation** value *XsituationType*)

*BeingSaidToHaveXisLikely* equivalentTo
*DiagnosticStatement* and (**hasCertainty** only *isLikely*)
and (**isAboutSituation** value *XsituationType*)

*BeingSaidToHaveXisNotExcluded* equivalentTo
*DiagnosticStatement* and (**hasCertainty** only *IsNotExcluded*)
and (**isAboutSituation** value *XsituationType*)

*BeingSaidToHaveXisUnlikely* equivalentTo
*DiagnosticStatement* and
(**hasCertainty** only *isUnlikely*) and
(**isAboutSituation** value *XsituationType*)

*BeingSaidToHaveXisExcluded* equivalentTo
*DiagnosticStatement* and
(**hasCertainty** only *isExcluded*) and
(**isAboutSituation** value *XsituationType*)

# Entailments of "Two Level"

| | | **Being said to have hepatitis (H) / viral hepatitis (vH) / viral hepatitis B (vHB) is…** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Precondition: | | confirmed | | | likely | | | not excluded | | | unlikely | | | excluded | | |
| Entailment: | | H | vH | vHB | H | vH | vHB | H | vH | vHB | H | vH | vHB | H | vH | vHB |
| confirmed | H | x | x | x | | | | | | | | | | | | |
| | vH | | x | x | | | | | | | | | | | | |
| | vHB | | | x | | | | | | | | | | | | |
| likely | H | x | x | x | x | x | x | | | | | | | | | |
| | vH | | x | x | | x | x | | | | | | | | | |
| | vHB | | | x | | | x | | | | | | | | | |
| not excluded | H | x | x | x | x | x | x | x | x | x | | | | | | |
| | vH | | x | x | | x | x | | x | x | | | | | | |
| | vHB | | | x | | | x | | | x | | | | | | |
| unlikely | H | | | | | | | | | | x | x | x | x | x | x |
| | vH | | | | | | | | | | | x | x | | x | x |
| | vHB | | | | | | | | | | | | x | | | x |
| excluded | H | | | | | | | | | | | | | x | x | x |
| | vH | | | | | | | | | | | | | | x | x |
| | vHB | | | | | | | | | | | | | | | x |

# Problem with "Two Level" pattern

- No inversions with negative statements
- The sentence "Hepatitis B excluded" is still a statement about the type Hepatitis, whereas it does not claim the existence of an instance of the type hepatitis
- Possible solution: combine "Universal" with "Two Level", but removing the axiom

**isAboutSituation** o **isSubtypeOf** subPropertyOf **isAboutSituation**

- Is there any practical usefulness of maintaining parallel, isomorphic hierarchies of OWL classes in the T-box and OWL types in the A-box ?

# Open issues / Outlook

- Related work from philosophy, e.g. dummy entities like "subfactuals" (Meinong)
- Relax assumptions of ontological realism
- Relation to alternative approaches of representing the content of health records, e.g. Referent tracking (Ceusters)
- Relation to other logics (higher-order, modal logics)
- Relation to models of probability
- Empirical assessment of computational behaviour (theoretically, OWL DL is NExpTime-complete)

# Thank you


Download sample ontologies from https://biotop.googlecode.com/svn/trunk/apps/FOIS2014/