Joint Conference
ICBO - ONTOBRAS
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Towards principles of ontology-based annotation of clinical narratives

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Med Uni Graz

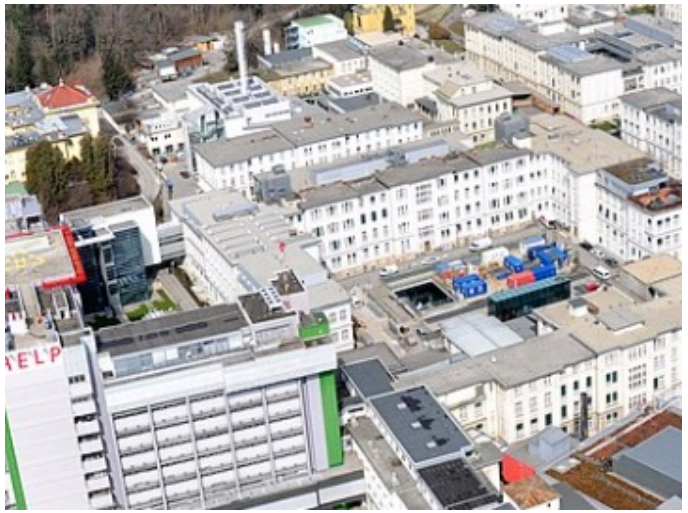
averbis
text analytics

MANCHESTER 1824
The University of Manchester

Most information in health records is “locked”in narratives

… in the local languages / sociolects

Porto Alegre
Brazil



Graz
Austria

Paciente G1PO, IG de 38 sem 4 dia(s), TS A+, interna por bolsa roita há mais de 18hs, recebendo penicilina. Evolui para Parto Eutócico com episiotomia em 27/06/2007 22:24 hs. Nasce RN APGAR 10/10, MASC, 3060 G. Exames: Toxo IGG e IGM neg VDRL neg EQU neg UROC: ausência de crescimento bacteriano. Hemograma 198mil plaq; Hb 13,1; LT 12,5 (75% seg) Em condições de alta, amamentando, útero contraído, lóquios fisiológico, sinais vitais estáveis, FO com bom aspecto. Recebe as orientações abaixo. ORIENTAÇÕES NA ALTA: # AMAMENTAÇÃO EXCLUSIVA POR 6 MESES; # TOMAR AS MEDICAÇÕES PRESCRITAS (SULFATO FERROSO 300MG 3X/DIA POR 90 DIAS, LONGE DAS REFISÇÕES, COM SUCO DE LARANJA; PARACETAMOL 750 MG 6/6HS SE DOR); # ORIENTO ANTICONCEPÇÃO; # RETORNAR À EMERGÊNCIA DESTE HOSPITAL SE FEBRE, SANGRAMENTO AUMENTADO OU OUTRAS INTERCORRÊNCIAS. # NÃO É NECESSÁRIO RETIRAR OS PONTOS. # LAVAR FO 3X/DIA COM ÁGUA E SABÃO DE GLICERINA.

* Anamnese und klinische Symptomatik
Stat. Übernahme vom LKH Fürstenfeld wegen neuerlicher Dyspnoe bei bek. dil. CMP u hochgr. MINS zur CA und Mitraclip /erztransplant Evaluierung. Bei dem Patienten besteht der St.p. 2x Simdax Therapie im Okt 2013.
* Physikalischer Status
48 jähr.Patient, deutl. reduz. AZ, normaler EZ. Cor: Ht rh, nc, Systolikum mit p.max. über dem Erbschen Punkt mit Fortleitung in die Axila
Pulmo: VA bds., feuchte RGs re>li
Abdomen: BD weich, kein DS
Extremitäten: ausgeprägte Knöchelödeme bds.
Herr DI Max Mustermann wurde aufgrund einer neuerlichen Dyspnoesymptomatik bei bek. dilat. CMP und hochgrad. MINS zur weiteren Evaluierung stat. vom LKH Fürstenfeld übernommen.

Clinical language: compact, sloppy, contextualised

- Works well for expert-to-expert communication

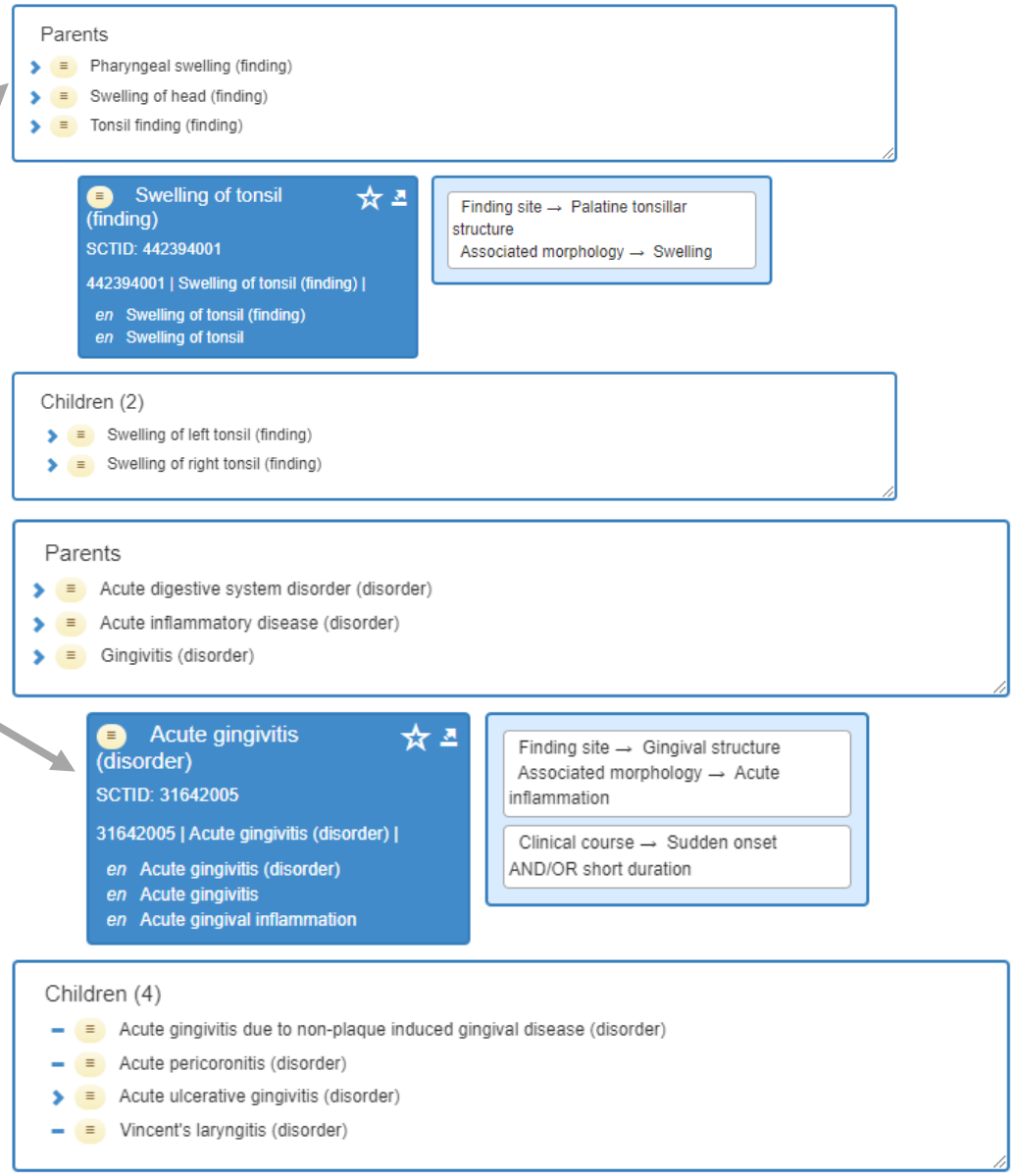
Phenomenon	Example	Elucidation
Telegram style	“left PICA stroke, presented to ED after fall”	Incomplete sentences, sketchy style
Colloquialisms	“pothole sign”, “snorkel”	Milieu-specific sub-languages
Ad-hoc abbreviations	“infiltr”	Truncation (“infiltrated mucosa”)
Ambiguous short forms	“RTA”	“Road traffic accident”, “Renal-tubular acidosis”
Short forms of regional or local scope	“LDS Hospital” “St. p.”	“Latter-Day-Saints Hospital” (and not “Leak Detection System”) “Status post” = “History of”
Conventionalized Latin abbreviations	“V mors can dig V dext”	“Vulnus morsum canis digiti quinti dextri” (in some European languages)
Numeric codes	“45, 46 with crowns”, “VI palsy”, “2-2-2”,	Tooth numbers, cranial nerves, dose frequencies
Spelling errors, typos	“Diabtes”, “Astra-Seneca”, “Hipotireose”,	accidental (quick typing) or systematic (e.g. 2nd language speakers)
Spelling variants	“Esophagus”, “Oesophagus”	e.g. American vs. British English
Single noun compounds	“Ibuprofenintoxikation”	Non-lexicalized long words (in languages such as German, Swedish)
Anaphora	(i) “adenoCa rect pN+MX G2 (...). tumor excised in toto” (ii) “no blood in stomach (...). mult mucosal erosions ”	(i) “Tumor” coreferential to adenocarcinom described in left context (ii) “mucosal erosions” refined to “erosions of gastric mucosa”
Negations	“No evidence of pneumonia” “Pulmones: nihil”, “metastasenfrei”	non-standard, jargon-like
Epistemic contexts	“susp MI, DD lung embolism”	suspected diagnosis, differential diagnosis
Temporal contexts	“h/o Covid-19”, “Streptokokkenangina 06/16”	“history of” Coarse-grained references to dates (mm/yy)
Other contexts	(i) father: pancreas ca” (ii) “refrained from resuscitation”	(i) family history (ii) plans not executed

- Major interoperability bottleneck for machine processing

Desideratum: making unstructured health record data interoperable

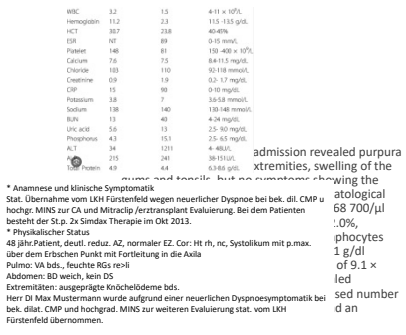
- Using international standards
- Rooted in Applied Ontology principles
- Information extraction via NLP
  (Natural language processing)

Physical examination on admission revealed purpura of the upper and lower extremities, **swelling of the gums and tonsils**, but no symptoms showing the complication of myasthenia gravis. Hematological tests revealed leucocytosis: WBC count 68 700/µl (blasts 11.5%, myelocytes 0.5%, bands 2.0%, segments 16.0%, monocytes 65.5%, lymphocytes 4.0%, atypical lymphocytes 0.5%), Hb 7.1 g/dl (reticulocytes 12%) and a platelet count of 9.1 × 104/µl. A bone marrow aspiration revealed hypercelllar bone marrow with a decreased number of erythroblasts and megakaryocytes and an increased number of monoblasts



SNOMED CT large clinical ontology
(350k concepts, > 1M English terms)

Clinical knowledge graph as canonical content representations



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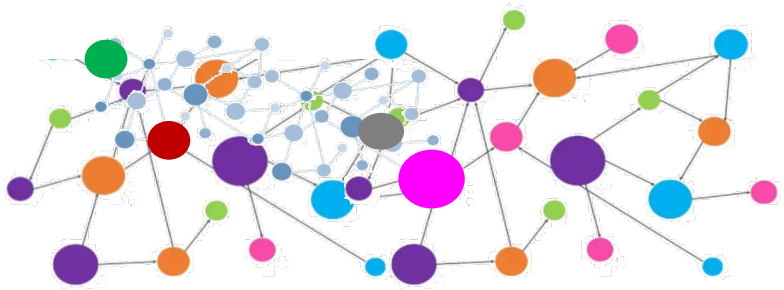
Heterogeneous clinical data

NLP

Tools & resources

„Models of meaning“* SNOMED CT

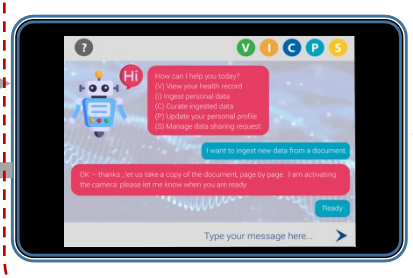
„Models of use“* HL7® FHIR®



Standardised and contextualised data

raw

curated



Health data curators

Curation platform

- Primary use:
  - Document Retrieval
  - Question Answering
  - Content summarization
  - Information extraction
  - Input for decision support
  - Data visualization, navigation

Query

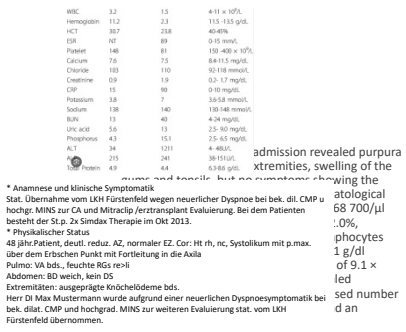
aggregated knowledge graph

Query

- Secondary use:
  - Retrospective research
  - Patient recruiting
  - Training of predictive models
  - Training of decision support systems
  - Quality improvement

* A. L. Rector, R. Qamar, T. Marley, Binding ontologies and coding systems to electronic health records and messages, Applied Ontology 4 (2009) 51–69.

Natural Language Processing : clinical narratives → knowledge graphs



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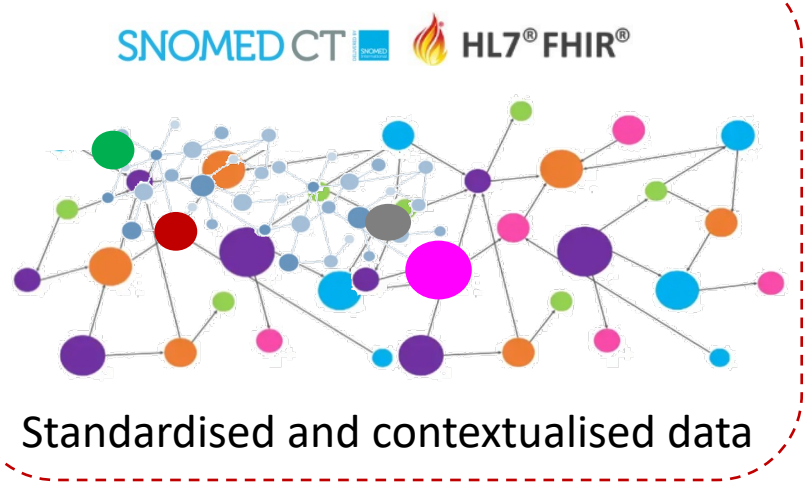
Heterogeneous clinical data

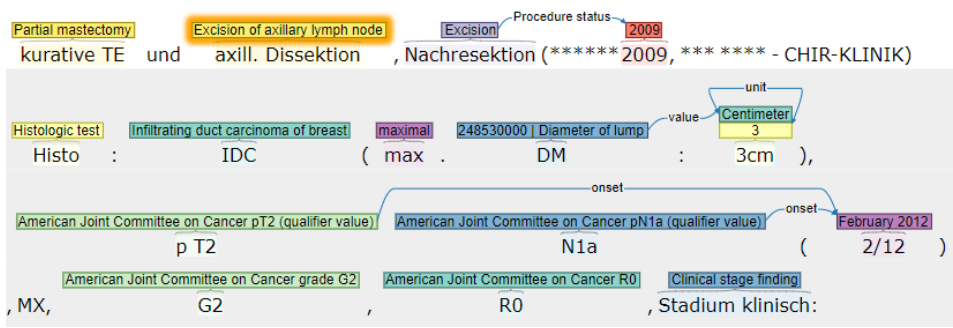
NLP

Tools & resources



Standardised and contextualised data

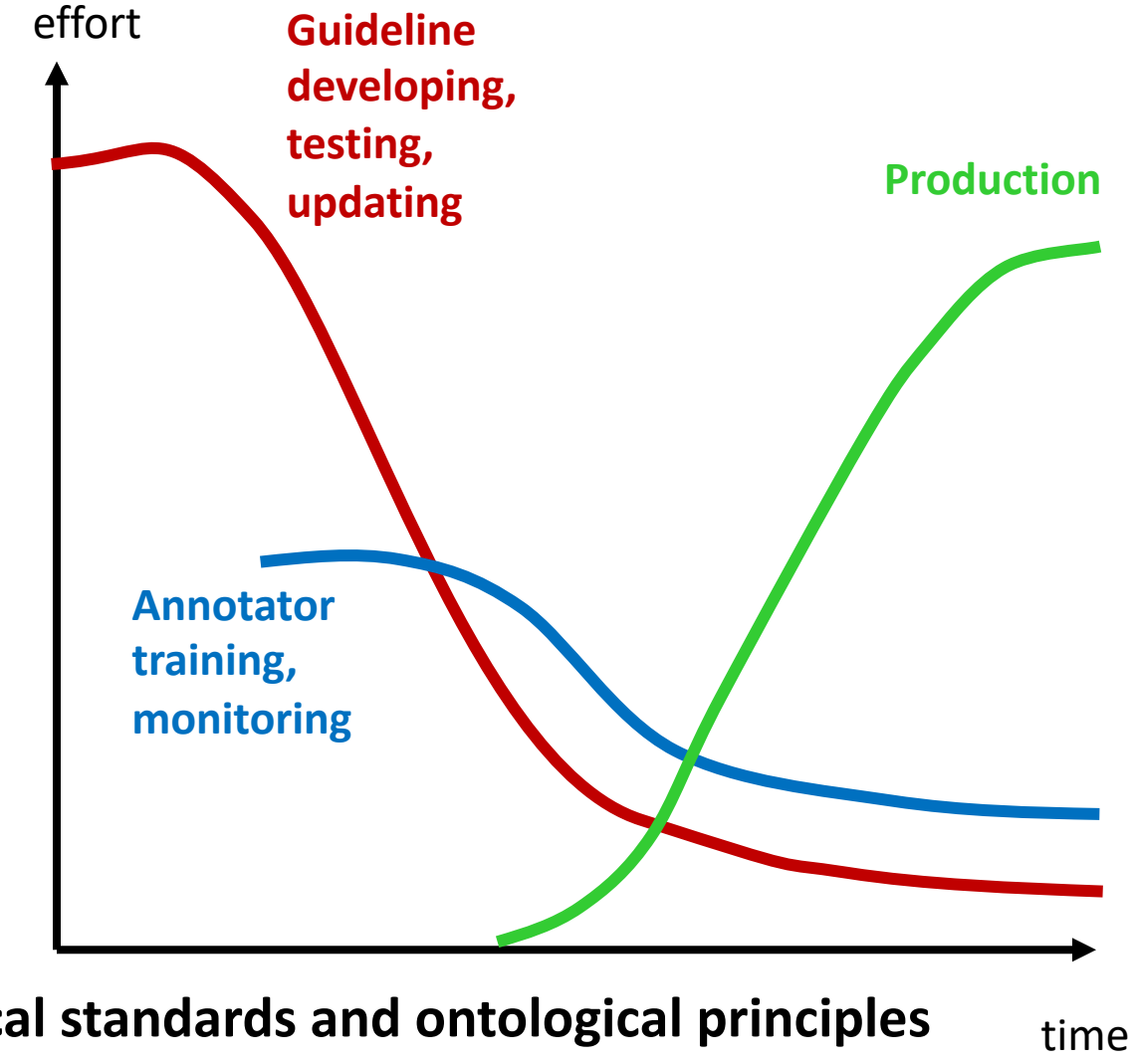
- NLP methods
  - Classical pipelines (sequential processing steps), rules, lexicons
  - End-to-end approaches: single architecture directly maps input text to the desired output: Deep learning, large language models
- **Annotated clinical corpora: central resource**
  - Training, model fine-tuning
  - Benchmarking of NLP systems



Document annotation – knowledge acquisition bottleneck

- Requirements
  - Domain expertise
  - Extensive training
  - Motivation
- Problems
  - Inter-annotator variability
  - Annotation fatigue
  - Ambiguities
  - Time constraints
- Success factors:
  - Good tooling
  - Repeated training sessions
  - Adjudication between annotators
  - Quality checks (inter-annotator agreement)
  - Good communication channels
  - **Rigorous annotation guidelines based on clinical standards and ontological principles**

medical students



Annotation guideline browser, annotation tool

Annotation guideline for semantic annotations of clinical narratives based on SNOMED CT and FHIR

Stefan Schulz[1,2], Akhila Naz Kuppassery[1], Alexander Beger[1], Sareh Aghaei[1], Daniel Dür[1], Larissa Hammer[1], Kristian Kankainen[3], Markus Kreuzthaler[1], NN, NN...

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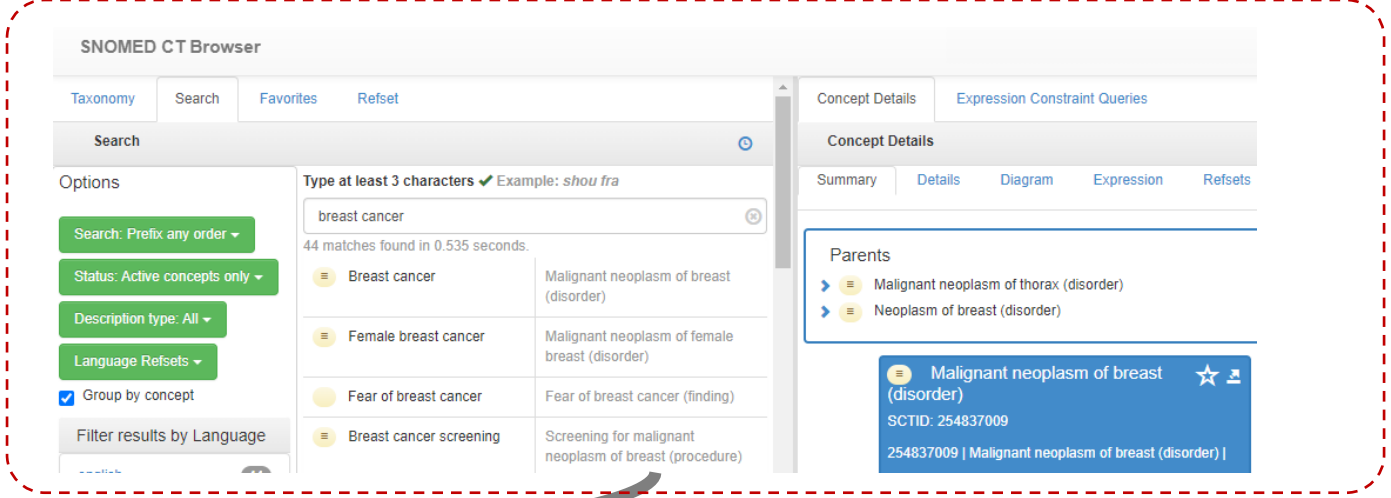
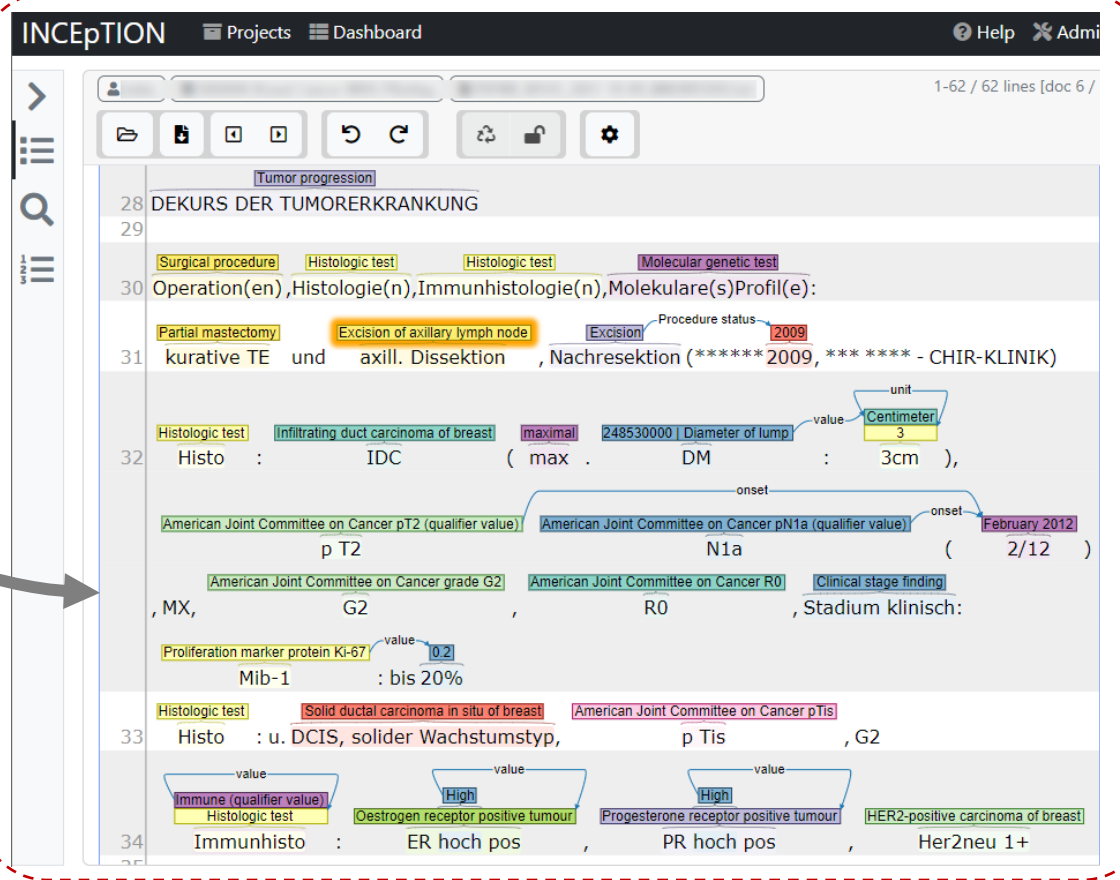
Version 2023-06-14

Guests are welcome! Feel free to drop comments.
E-mail contact: stefan.schulz@medunigraz.at

In progress: consolidation of practical content for insertion into AIDAVA D4.2

https://bit.ly/3X4McGC





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General annotation principles

- Semantic annotation only (no POS, syntactic relations etc.)
- Annotation at two levels
  - Text spans (“entities”) with codes and literals
  - Binary relations with user-friendly predicates (hide complexity from annotators): (i) semantic relations (ii) co-reference annotations
- Annotation vocabularies linked to ontology-based standards
  - SNOMED CT, FHIR, HPO, RxNorm …
  - multilingual, well-curated, free, ontology-based, compositional (post-coordination)
- Annotation vocabulary determines
  - Annotation spans (subword to multiword): longest match preference
  - Granularity and scope
- Close-to-text annotation
  - no interpretation by annotators

Specific annotation principles (SNOMED CT + FHIR annotation)

- "Core" hierarchies:
  - *Clinical finding*, *Event*, *Observable entity*, *Pharmaceutical / biologic product*, *Procedure*, *Specimen*
  - High proportion of fully defined concepts
- "Supportive" hierarchies
  - *Substance*, *Organism*, *Body structure*, *Physical object, Qualifier*
  - Primitive concepts
  - HL7-FHIR values sets mapped to SNOMED concepts
- Annotation predicates (binary relations) link "core" concepts to "supportive" concepts, grounded in
  - SNOMED CT object properties or chains thereof,
  - Relational chains of FHIR elements
  - both

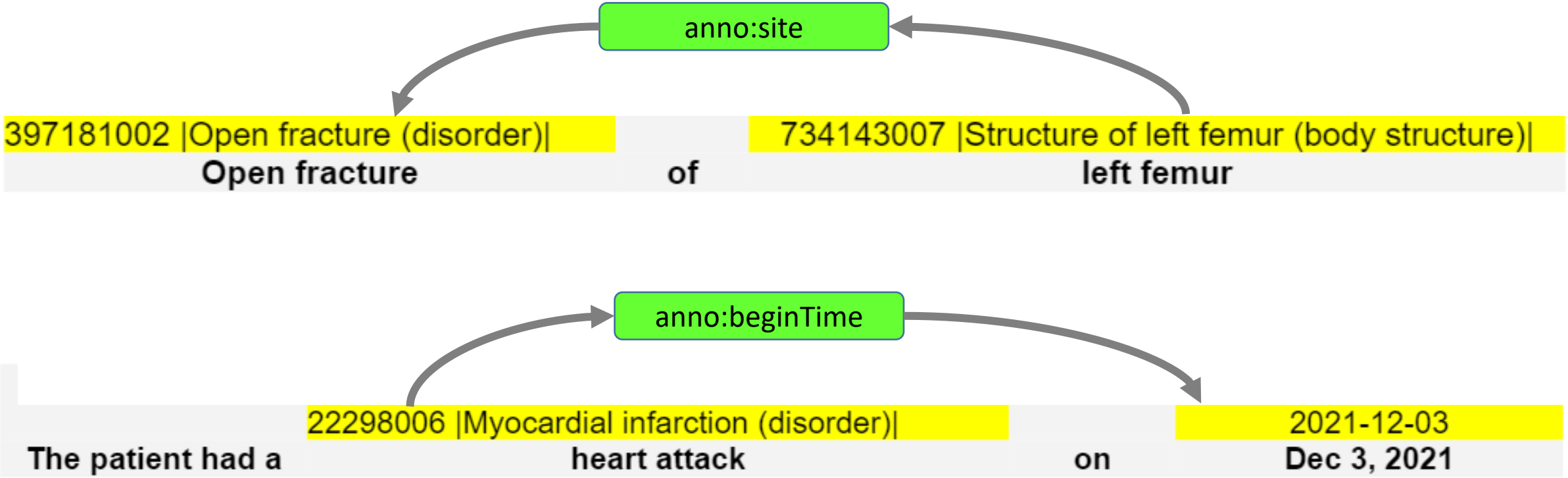
Relation annotation vocabulary based on SNOMED CT and FHIR

- Close-to-user predicates
- Mapped to relations or relation chains in underlying standards

anno:	Domain	Target path	Range
site	‘sct:Clinical finding’	[a]‘sct:Finding site’ [b] INV(fhir:Condition.code) || fhir:Condition.body	‘sct:Body structure’
site	‘sct:Procedure’	[a]‘sct:Procedure - Direct’ [b] INV(fhir:Procedure.code) || fhir:Procedure.body	‘sct:Body structure’
inFamily	‘sct:Clinical finding’	[b] INV(fhir:FamilyMemberHistory.condition) || fhir:FamilyMemberHistory.relationship [a] INV(‘sct:Associated finding’) || ‘sct:Subject relationship context’	‘sct:Person’
verification status	‘sct:Clinical finding’	[b] INV(fhir:Condition.code) || fhir:Condition.verificationStatus [a] INV(‘sct:Associated finding’) || ‘sct:Finding context’	‘sct:| Qualifier value’ (cf. Tab. 1)

Example 1: “Two level” annotation

1. Text spans, annotated with codes or literals
2. Linkage of text spans by binary predicates



Example 2: Deep annotation

Annotations exploit the whole depth of the annotation vocabulary

No “entity-type” annotation

1223620100011910 3 |Conjunctivitis of right eye (disorder)|
Unilateral conjunctivitis right

Not:

Disorder
Unilateral conjunctivitis right

Example 3: Flexible annotation spans / longest match principle

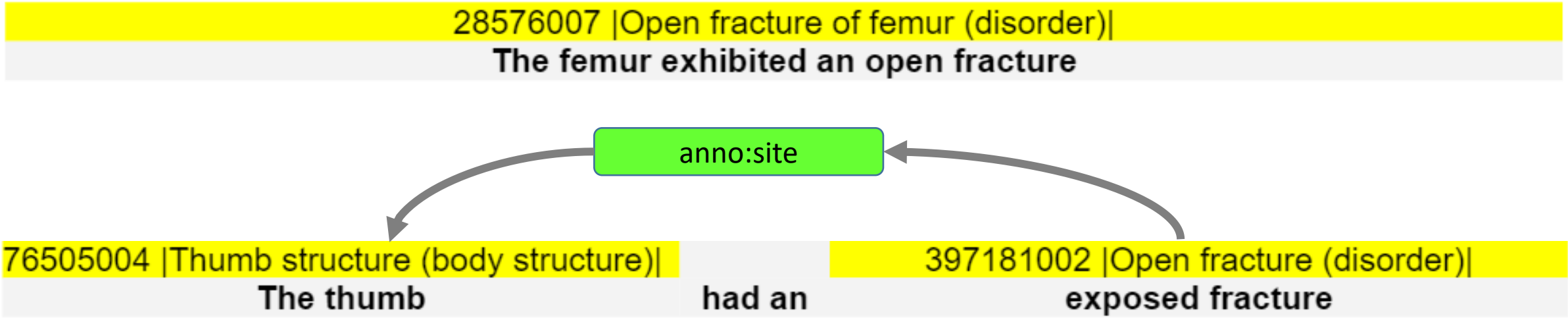
- Annotations spans determined by annotation vocabulary
- Preference given to longest match (precoordinated concepts)
- No determination of spans by NER before annotation

28576007 |Open fracture of femur (disorder)|

The femur exhibited an open fracture

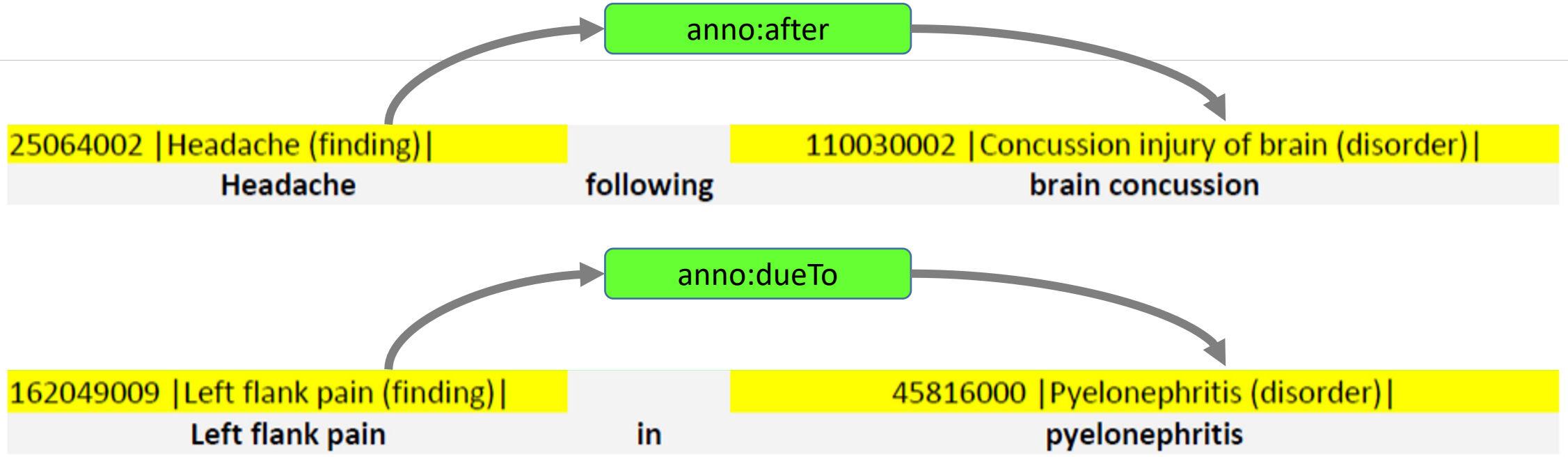
Example 3: Flexible annotation spans / longest match principle

- Annotations spans determined by annotation vocabulary
- Preference given to longest match (precoordinated concepts)
- No determination of spans by NER before annotation



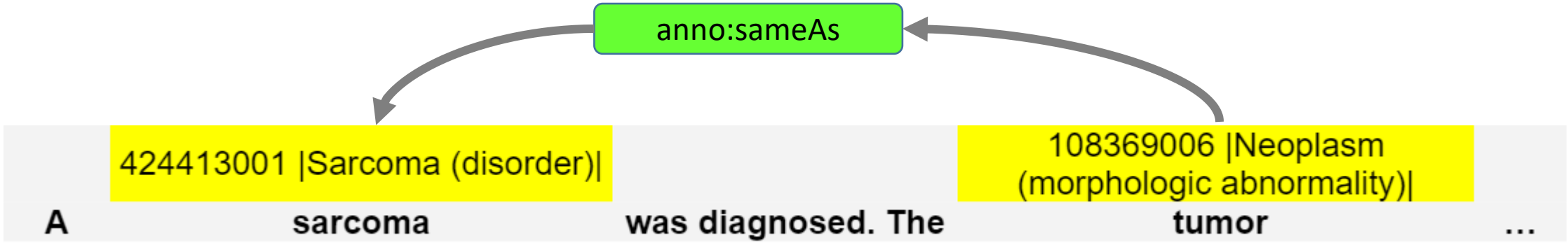
Example 4: Close-to-text: no interpretation of content

- Only annotate what is explicitly stated, not what might be medically plausible



Example 5: Coreference annotations

- Nominal anaphora



From text to canonical representation

Text

Words
phrases
numeric expressions

Anntotations

Codes for classes
Annotation predicates
literals

Knowledge graph

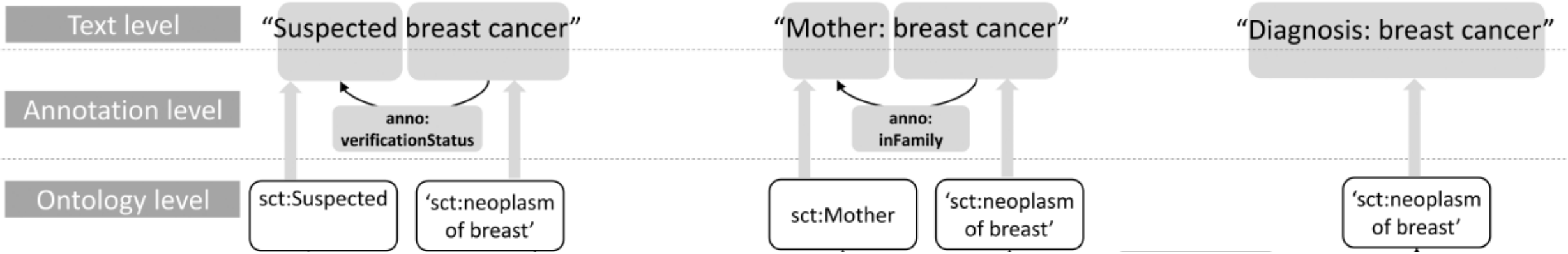
Semantic interpretations
Classes vs. Individuals
“Isosemantic” reporesentations
(e;g; SNOMED only vs. SNOMED + FHIR)

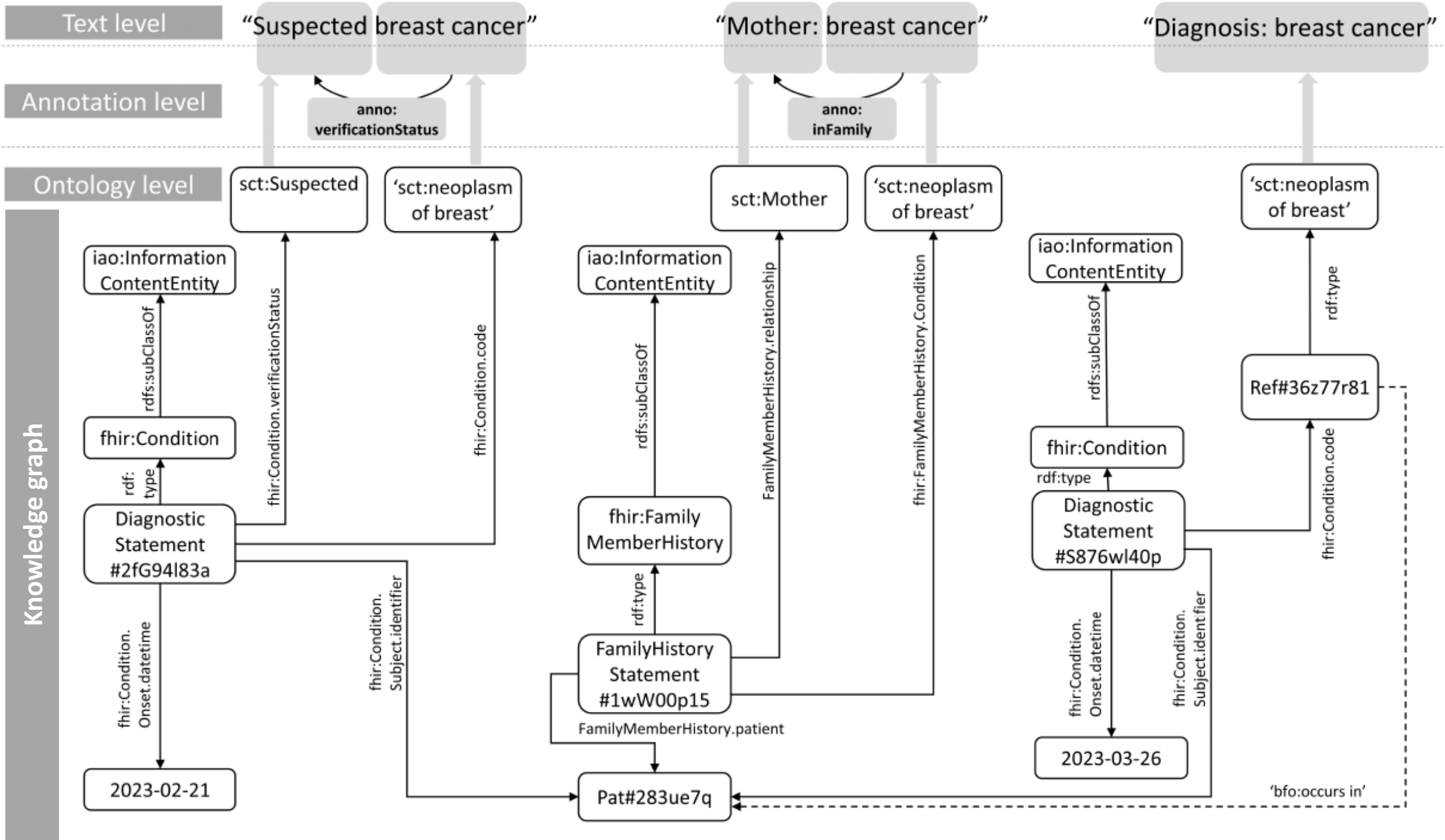
Text level

“Suspected breast cancer”

“Mother: breast cancer”

“Diagnosis: breast cancer”


Text level
Annotation level
Ontology level
“Suspected breast cancer”
“Mother: breast cancer”
“Diagnosis: breast cancer”
anno: verificationStatus
anno: inFamily
sct:Suspected
‘sct:neoplasm of breast’
sct:Mother
‘sct:neoplasm of breast’
‘sct:neoplasm of breast’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sct:Mother
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‘sct:neoplasm of breast’
iao:Information ContentEntity
iao:Information ContentEntity
iao:Information ContentEntity
rdfs:subClassOf
fhir:Condition.verificationStatus
fhir:Condition.code
rdfs:subClassOf
FamilyMemberHistory.relationship
fhir:FamilyMemberHistory.Condition
rdfs:subClassOf
rdf:type
fhir:Condition
rdf: type
fhir:Family MemberHistory
fhir:Condition
rdf:type
Ref#36z77r81
Diagnostic Statement #2fG94l83a
rdf:type
FamilyHistory Statement #1wW00p15
Diagnostic Statement #S876wl40p
fhir:Condition. Onset.datetime
fhir:Condition. Subject.identifier
FamilyMemberHistory.patient
fhir:Condition. Onset.datetime
fhir:Condition. Subject.identifier
fhir:Condition.code
2023-02-21
Pat#283ue7q
2023-03-26
‘bfo:occurs in’

Conclusion and outlook

- Annotated corpora are essential for training and benchmarking NLP tools, particularly in the current era of deep learning and large language models
- Semantic resources / ontologz-based standards are crucial:
  - Ontologies (description of entity types): Definitions / Axioms
  - Terminologies (description of natural language): labels, synonyms
  - Information Models (Instance-level templates, link to ontologies and values)
- Clinical free text annotation is a huge and challenging task. Facilitated by
  - Pre-annotations using existing NLP annotators
  - Simple, intuitive set of predicates that map to more complex graph structures in the background
- Adherence to detailed guideline principles
  - might take a long journey
  - Indispensable for high agreement between annotators → canonical clinical content representations

Contact: Stefan Schulz

stefan.schulz@medunigraz.at

http://purl.org/steschu

Comment on our annotation guideline:

https://bit.ly/3X4McGC

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- Grant 101057062 “AIDAVA” (funder: the European Commission, HORIZON-HLTH-2021,
- Grant “Assembling the Data Jigsaw: Powering Robust Research on the Causes, Determinants and Outcomes of MSK Disease” (funder: The Nuffield Foundation)
- Grant EP/V047949/1 “Integrating hospital outpatient letters into the healthcare data space” (funder: UKRI/EPSRC).

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In progress: consolidation of practical content for insertion into AIDAVA D4.2

Semantic equivalences

Clinical Summary > **Condition**

HL7 FHIR Release 4

Condition
- verificationStatus
- code: 390926006 |Suspected gallstones (situation)|
- bodySite

Condition
- verificationStatus: unconfirmed
- code: 235919008 |Gallbladder calculus (disorder)|
- bodySite

Condition
- verificationStatus: unconfirmed
- code: 313413008 |Calculus finding (finding)|
- bodySite: 3578005 |Structure of body of gallbladder (body structure)|

Condition
- verificationStatus: unconfirmed
- code: 56381008 |Calculus (morphologic abnormality)|
- bodySite: 3578005 |Structure of body of gallbladder (body structure)|

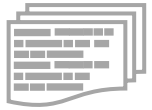
Condition
- verificationStatus
- code
- bodySite

```
EquivalentClasses(
    :41769001 |Disease suspected (situation)|
    ObjectIntersectionOf(
        :444433005 |Suspected clinical finding (situation)|
        ObjectSomeValuesFrom(
            :609096000 |Role group (attribute)|
            ObjectIntersectionOf(ObjectSomeValuesFrom(
                :246090004 |Associated finding (attribute)| :64572001 |Disease (disorder)|)
            ObjectSomeValuesFrom(:408729009 |Finding context (attribute)| :415684004 |Suspected (qualifier value)|)
            ObjectSomeValuesFrom( :408731000 |Temporal context (attribute)| :410512000 |Current or specified time (qualifier value)|)
            ObjectSomeValuesFrom( :408732007 |Subject relationship context (attribute)| :410604004 |Subject of record (person)| )))))
```

Open issue: Identity management

t_1 

Biopsy

t_2 

Imaging

t_3 

Operation

t_4 

126926005 |Neoplasm of breast (disorder)|

rdf:type

NoB34u73axn4us

owl:sameAs

254837009 |Malignant neoplasm of breast (disorder)|

rdf:type

MoBkj88935elp

owl:sameAs

278054005 |Lobular carcinoma of breast (disorder)|

rdf:type

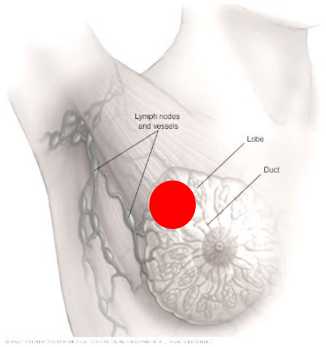
LCBrrp009g65t

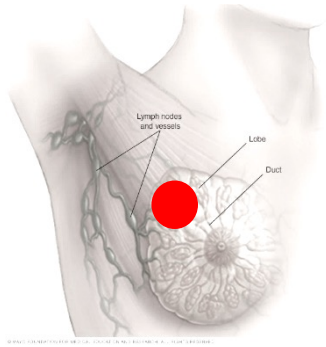
owl:sameAs

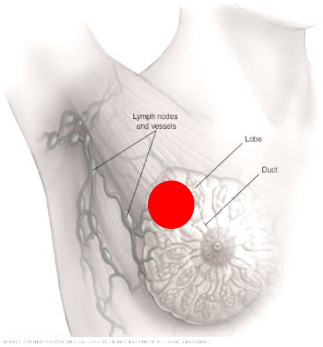
713609000 |Invasive carcinoma of breast (disorder)| AND 278054005 |Lobular carcinoma of breast (disorder)|

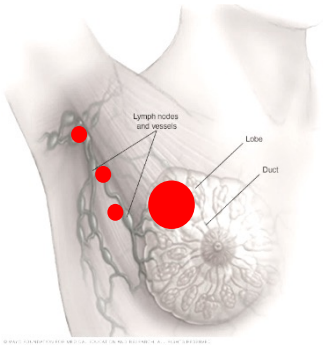
rdf:type

ILCB4tz5pplkll









Lobular carcinoma of breast

Invasive Lobular carcinoma of breast