

Grafos de Conhecimento e seu Potencial para Aplicações de Inteligência Artificial

João Paulo A. Almeida

jpalmeyda@ieee.org

Núcleo de Estudos em Modelagem Conceitual & Ontologias (NEMO)
Universidade Federal do Espírito Santo



<https://creativecommons.org/licenses/by/4.0/>

Agenda

- Cenário atual (diagnóstico e requisitos)
- Grafos de conhecimento e ontologias
 - “a little semantics goes a long way”
- Sinergia com Large Language Models (LLMs)
 - Exemplo: interações medicamentosas

Cenário atual: as duas torres (Frank van Harmelen)



<https://www.slideshare.net/slideshow/systems-that-learn-and-reason-frank-van-harmelen/267008886>

THIS IS YOUR MACHINE LEARNING SYSTEM?

YUP! YOU POUR THE DATA INTO THIS BIG PILE OF LINEAR ALGEBRA, THEN COLLECT THE ANSWERS ON THE OTHER SIDE.

WHAT IF THE ANSWERS ARE WRONG?

JUST STIR THE PILE UNTIL THEY START LOOKING RIGHT.



Randall Munroe

<https://xkcd.com/1838>

Cenário atual: a torre de IA estatística

- Ganhos das abordagens de “aprendizado de máquina” com a escala
 - Large Language Models (LLMs) / IA “generativa”
 - Modelos pré-treinados
- Avanços em processamento de linguagem natural sem precedentes
 - Com aplicações para recuperação de informação, verbalização, tradução

Cenário atual: a torre de IA estatística

- Problemas persistentes de confiabilidade, “explanabilidade”
 - Confiabilidade: “alucinação”
 - Explanabilidade: “caixa preta”
 - Custo computacional do treinamento, inviabiliza retreinamento frente a novas informações
 - Dificuldade de obter escala em aplicações em domínios especializados
 - Dados em organizações
 - “Você não tem dados suficientes” (“Data hunger”)

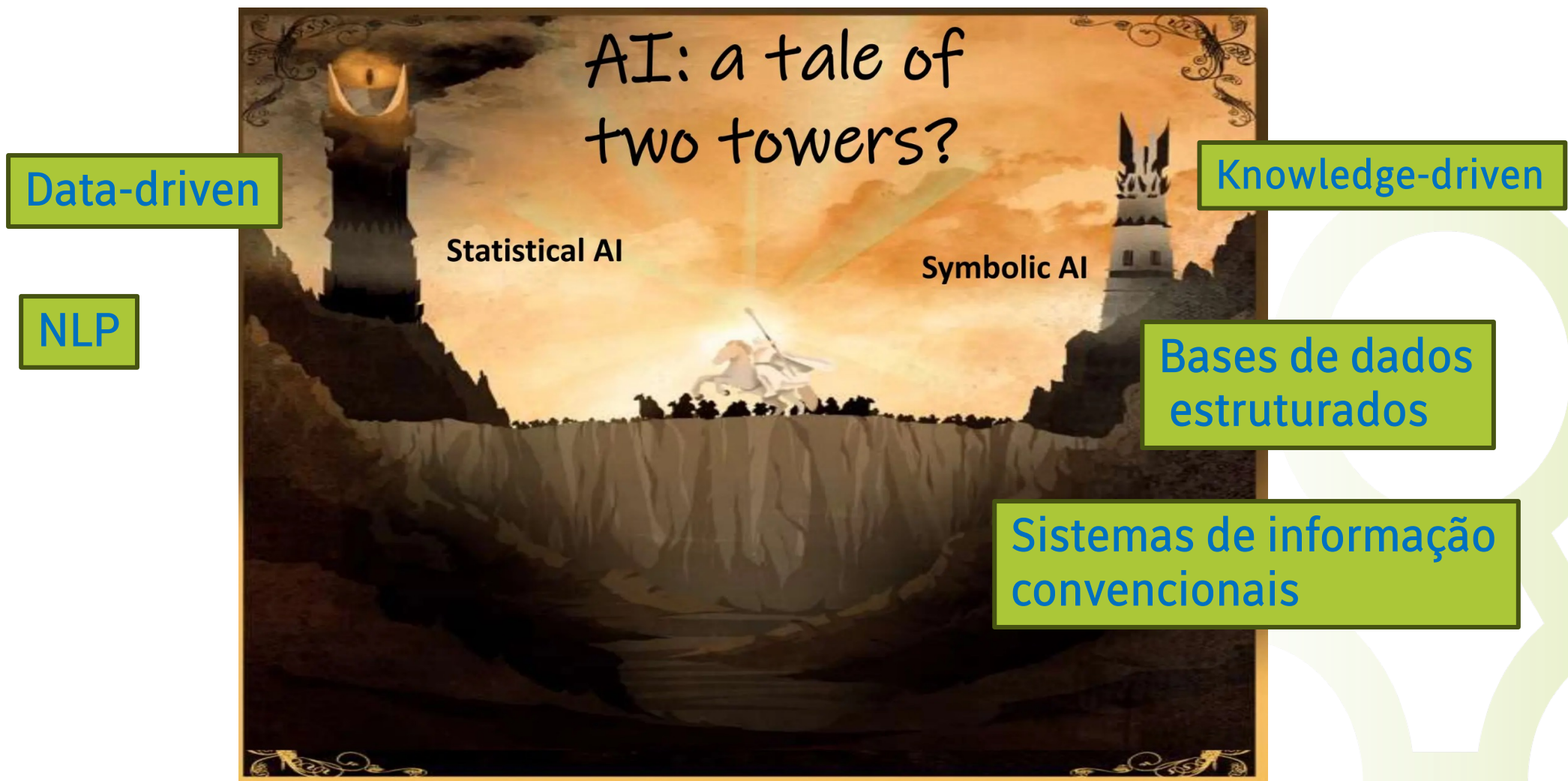
Cenário atual: a torre de IA simbólica

- Respostas baseada no que está declarado explicitamente (também com raciocínio lógico)
- Custo humano alto
 - Curadoria explícita de regras
 - Curadoria explícita de identificadores de entidades relevantes
 - Curadoria de dados em bases de conhecimento
- Dificuldade com processamento de linguagem natural
 - Rigidez dos identificadores

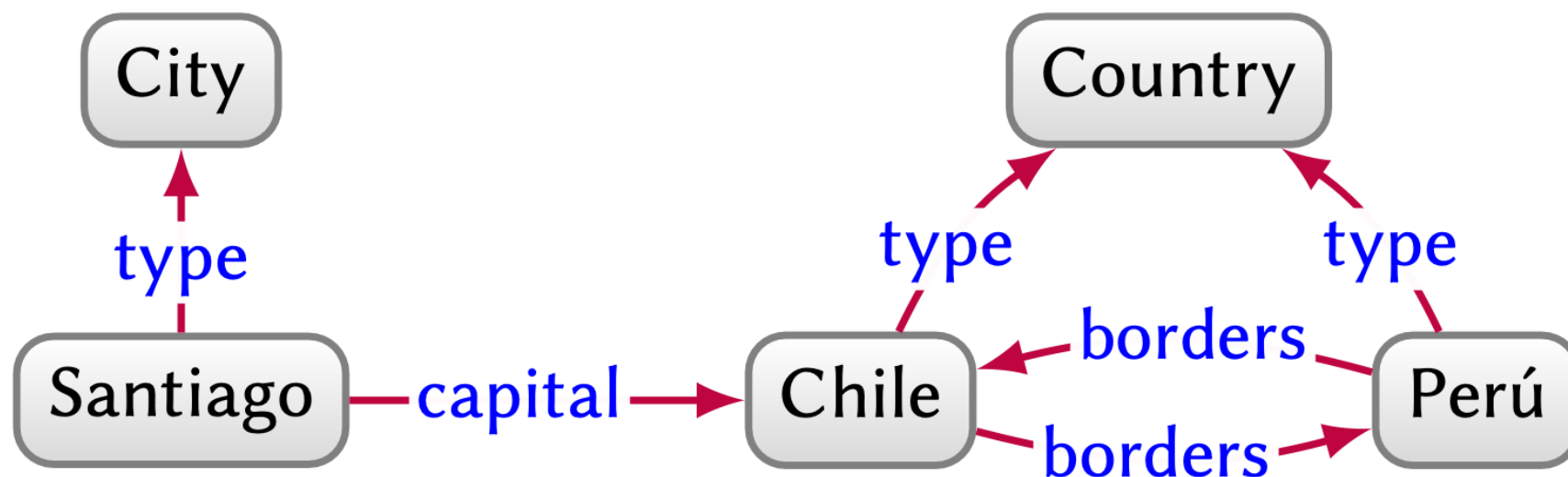
O que queremos?

- Sistemas confiáveis, que expliquem suas decisões (por exemplo citando fontes científicas), e que apoiem os humanos em suas tarefas
- Capazes de interagir através de linguagem
- Fidedignos à realidade (aos fatos que importam)
- Se eu pergunto: existe interação medicamentosa entre fluconazol e amoxicilina... me importo com o resultado!

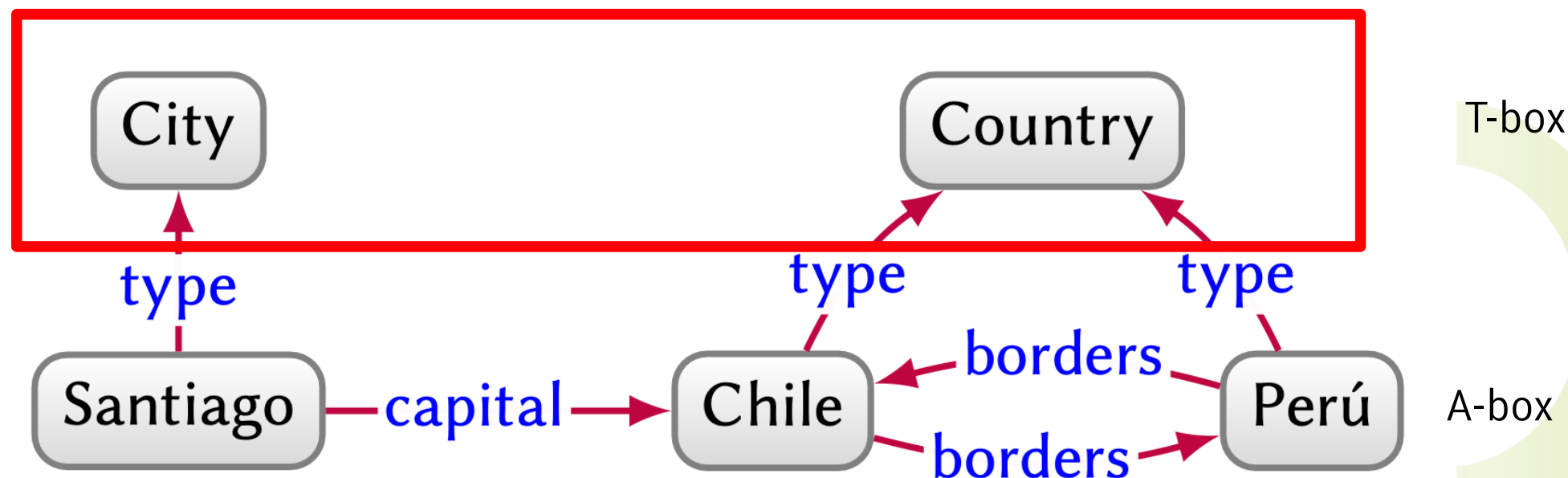
Combinando as forças das duas torres (Frank van Harmelen)



O que é um grafo de conhecimento?



O que é um grafo de conhecimento? (incluindo classes)



Exemplo de Grafo de Conhecimento: Wikidata

- Independente de domínio, estrutura por trás da Wikipedia

 WIKIDATA	Special page																		
Main page Community portal Project chat Create a new Item Recent changes Random Item Query Service Nearby Help Donate	Statistics <table><tr><th colspan="2">Page statistics</th></tr><tr><td>Content pages</td><td>113,988,305</td></tr><tr><td>Pages (All pages in the wiki, including talk pages, redirects, etc.)</td><td>119,114,068</td></tr><tr><th colspan="2">Edit statistics</th></tr><tr><td>Page edits since Wikidata was set up</td><td>2,261,414,291</td></tr><tr><td>Average edits per page</td><td>18.99</td></tr><tr><th colspan="2">User statistics</th></tr><tr><td>Registered users (list of members)</td><td>6,682,966</td></tr><tr><td>Active users (list of members) (Users who have performed an action in the last 30 days)</td><td>23,854</td></tr></table>	Page statistics		Content pages	113,988,305	Pages (All pages in the wiki, including talk pages, redirects, etc.)	119,114,068	Edit statistics		Page edits since Wikidata was set up	2,261,414,291	Average edits per page	18.99	User statistics		Registered users (list of members)	6,682,966	Active users (list of members) (Users who have performed an action in the last 30 days)	23,854
Page statistics																			
Content pages	113,988,305																		
Pages (All pages in the wiki, including talk pages, redirects, etc.)	119,114,068																		
Edit statistics																			
Page edits since Wikidata was set up	2,261,414,291																		
Average edits per page	18.99																		
User statistics																			
Registered users (list of members)	6,682,966																		
Active users (list of members) (Users who have performed an action in the last 30 days)	23,854																		
Lexicographical data Create a new Lexeme Recent changes Random Lexeme																			



Item

[Discussion](#)

[Read](#)

[View history](#)



Earth (Q2)



third planet from the Sun in the Solar System

Planet Earth | World | Gaia | Sol III

[In more languages](#)

Statements

instance of



terrestrial planet

[0 references](#)



inner planet of the Solar System

follows

[Venus](#)

followed by

[Mars](#)

[1 reference](#)

part of



Earth-Moon system

[0 references](#)

[Main page](#)

[Community portal](#)

[Project chat](#)

[Create a new Item](#)

[Recent changes](#)

[Random Item](#)

[Query Service](#)

[Nearby](#)

[Help](#)

[Donate](#)

[Lexicographical data](#)

[Create a new Lexeme](#)

[Recent changes](#)

[Random Lexeme](#)

[Tools](#)

[What links here](#)

[Related changes](#)

[Special pages](#)

[Permanent link](#)

[Page information](#)

[Concept URI](#)

[Cite this page](#)

[Get shortened URL](#)

[Download QR code](#)

Princípios básicos

- Representação de entidades através de nós
- Representação de relações através de arcos
- Tipos podem ser usados para construir árvores taxonômicas
- Tipos de arcos restringem possíveis relações
- Identificação única dos nós, tipos de nós, arcos, tipos de arcos
- Consultas por padrões
- Combinado com princípios FAIR:
 - Findable, Accessible, Interoperable, Reusable
 - Incluindo licenças explícitas dos dados

Taxonomies

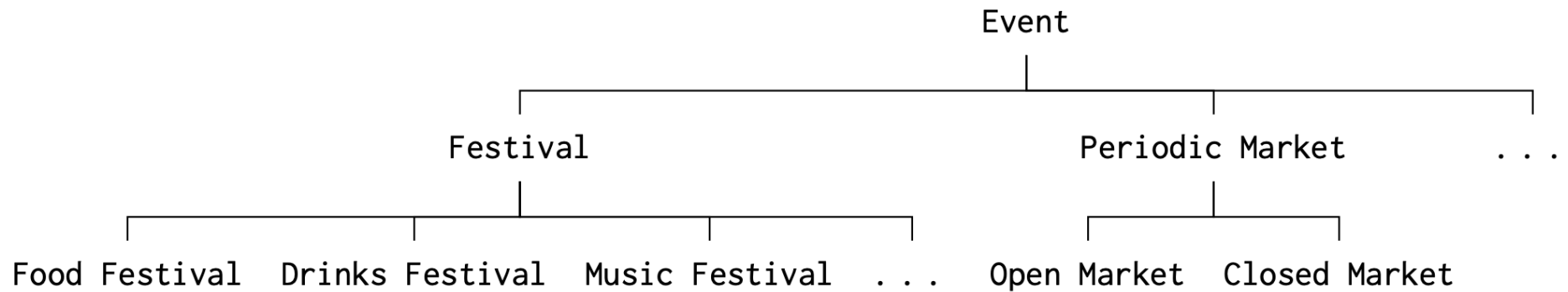
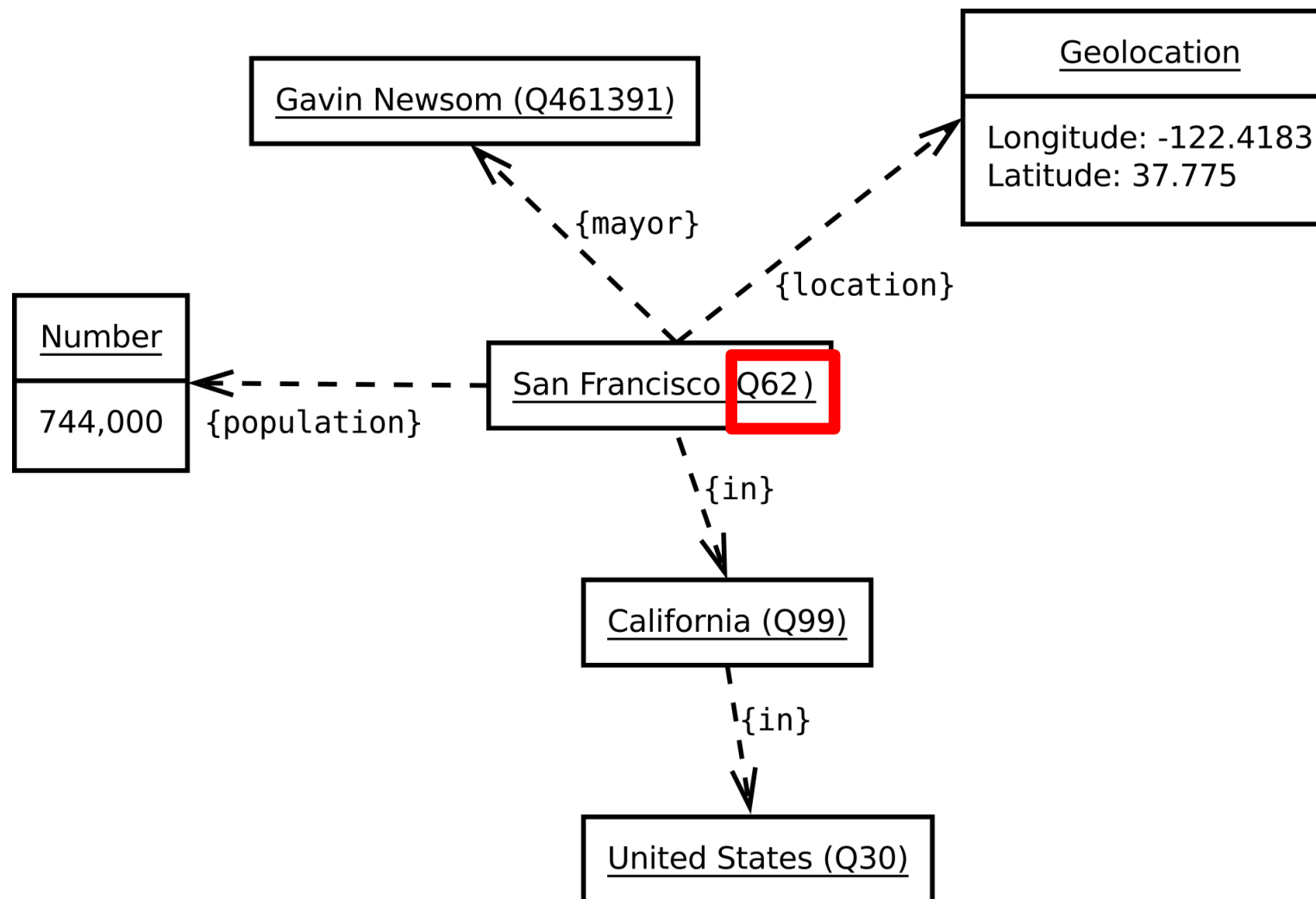


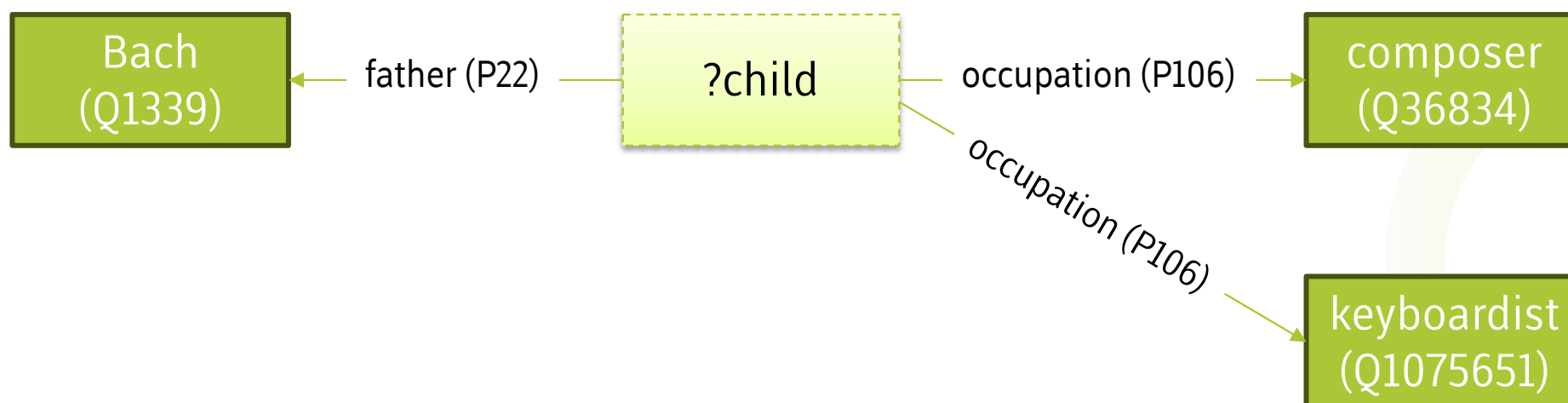
Fig. 11. Example class hierarchy for Event

Identificação única de nós



<https://www.wikidata.org/wiki/Wikidata:Introduction#>

Consulta por padrões





```
1 SELECT ?child ?childLabel
2 WHERE
3 {
4   ?child wdt:P22 wd:Q1339;    # child whose father is Bach
5         wdt:P106 wd:Q36834;    # occupation composer
6         wdt:P106/wdt:P279+ wd:Q1075651. # occupation keyboardist or specialization
7 SERVICE wikibase:label { bd:serviceParam wikibase:language "[AUTO_LANGUAGE]"; }
8 }
```

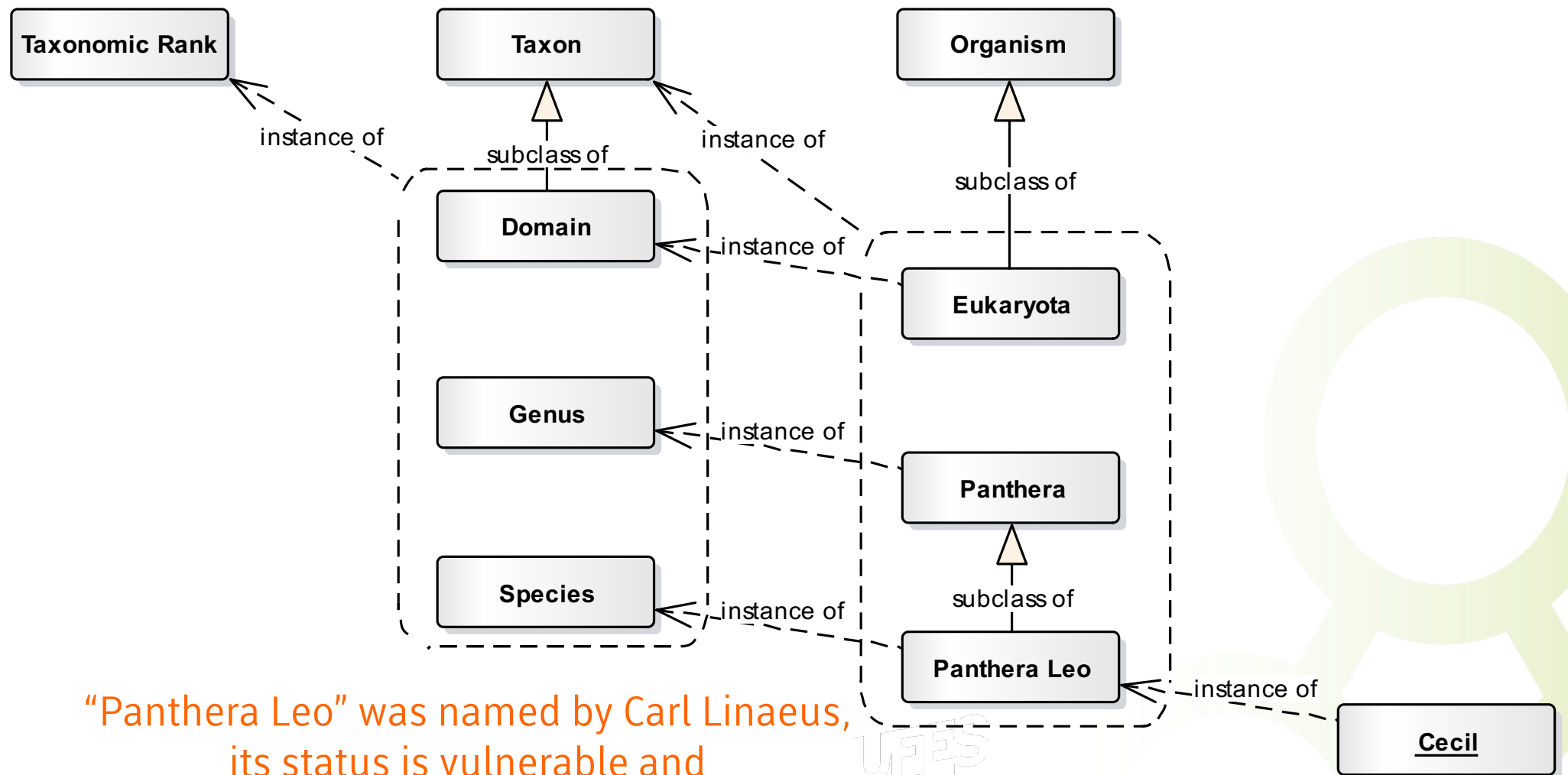
child	childLabel
Q106641	Johann Christian Bach
Q107277	Wilhelm Friedemann Bach
Q710996	Gottfried Heinrich Bach
Q57225	Johann Christoph Friedrich Bach
Q107277	Wilhelm Friedemann Bach
Q470198	Johann Gottfried Bernhard Bach

WIKIDATA QUERY SERVICE
NO ESPRITO SANTO

<https://w.wiki/BaHD>

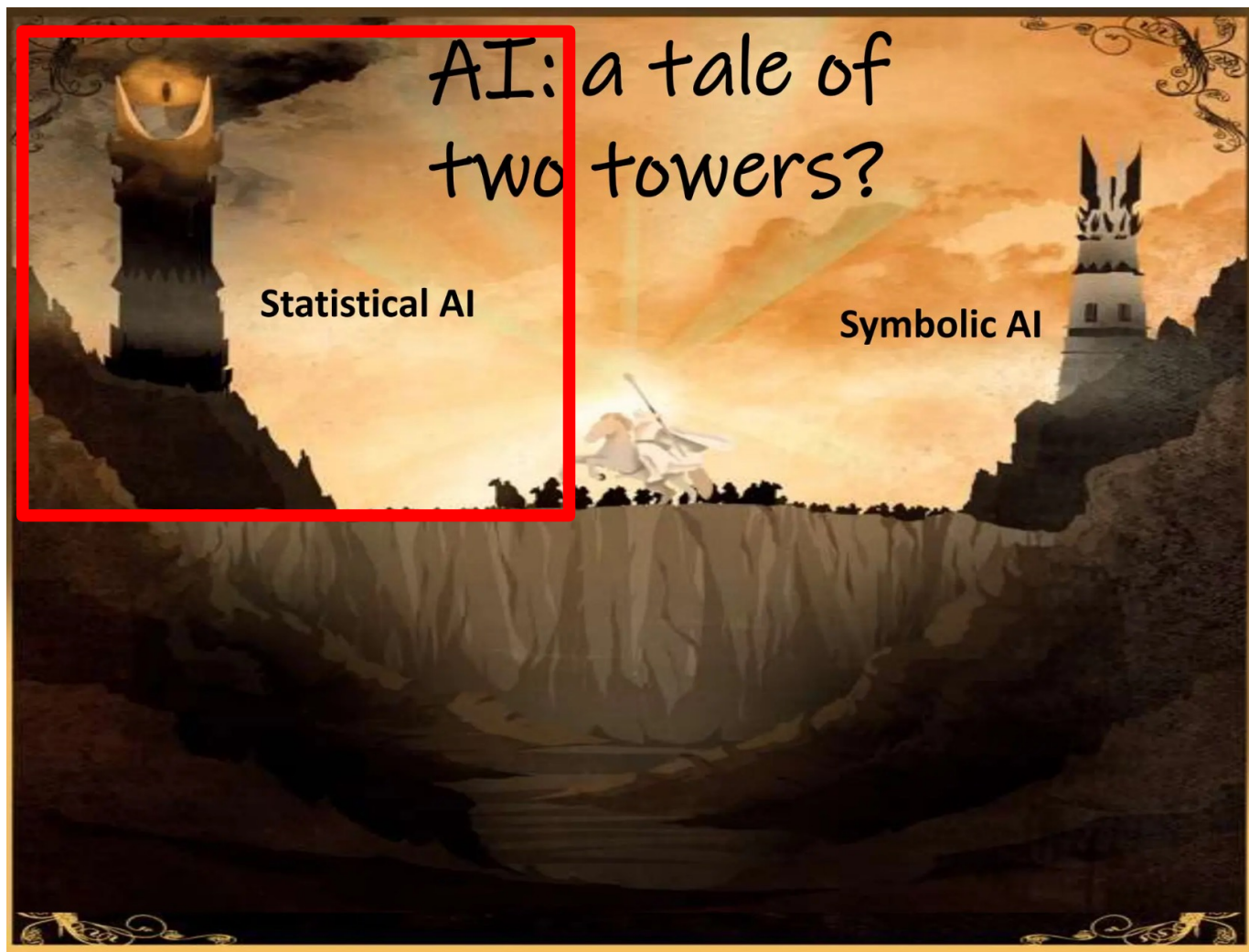
Construtos

- Classificação
 - Tipos, classes, categorias
- Estruturas taxonômicas
 - é-um
- Instanciação
 - é-instância-de
- Atributos
 - qualidades
- Relacionamentos
- Relações todo-parte
- Tipos de tipos



"Panthera Leo" was named by Carl Linnaeus,
its status is vulnerable and
all its instances are warmblooded

Cenário atual: as duas torres (Frank van Harmelen)



Exemplo: interações medicamentosas

ChatGPT 4o >



Any drug interactions between Pentobarbital and Acetaminophen?



There are no significant drug interactions between pentobarbital and acetaminophen.

Pentobarbital is a barbiturate, primarily used as a sedative or anticonvulsant, while acetaminophen is a non-opioid analgesic and antipyretic. They work through different mechanisms and do not generally affect each other's metabolism.

However, combining pentobarbital with other medications that depress the central nervous system (CNS) can enhance sedative effects, so caution is advised. Always consult with a healthcare professional before using these medications together, especially if other medications or conditions are involved.



About: DDI between Pentobarbital and Acetaminophen - Barbiturates may increase the metabolism of Acetaminophen. This may 1) diminish the effect of acetaminophen; and 2) increase the risk of liver damage. [drugbank_resource:DB00312_DB00316] [Goto](#) [Sponge](#) [NotDistinct](#) [Permalink](#)

An Entity of Type : http://bio2rdf.org/drugbank_vocabulary:Resource, within Data Space : bio2rdf.org associated with source [document\(s\)](#)

Type: [New Facet based on Instances of this Class](#)

Attributes

[rdf:type](#)

Values

[drug-drug_interaction \[drugbank_vocabulary:Drug-Drug-Interaction\]](#)
[drugbank_resource \[drugbank_vocabulary:Resource\]](#)

[rdfs:label](#)

DDI between Pentobarbital and Acetaminophen - Barbiturates may increase the metabolism of Acetaminophen. This may 1) diminish the effect of acetaminophen; and 2) increase the risk of liver damage. [drugbank_resource:DB00312_DB00316]

[dcterms:title](#)

DDI between Pentobarbital and Acetaminophen - Barbiturates may increase the metabolism of Acetaminophen. This may 1) diminish the effect of acetaminophen; and 2) increase the risk of liver damage.

[dcterms:identifier](#)

drugbank_resource:DB00312_DB00316

[void:inDataset](#)

http://bio2rdf.org/drugbank_resource:bio2rdf.dataset.drugbank.R3

[Bio2RDF identifier](#)

DB00312_DB00316

[Bio2RDF namespace](#)

drugbank_resource

[Bio2RDF uri](#)

http://bio2rdf.org/drugbank_resource:DB00312_DB00316

is [ddi_interactor_in ...di-interactor-in](#) of [Pentobarbital \[drugbank:DB00312\]](#)
[Acetaminophen \[drugbank:DB00316\]](#)

Barbiturates may increase the metabolism of Acetaminophen. This may 1) diminish the effect of acetaminophen; and 2) increase the risk of liver damage.

https://bio2rdf.org/drugbank_resource:DB00312_DB00316

Exemplo: usando os nomes comerciais...

ChatGPT 4o >



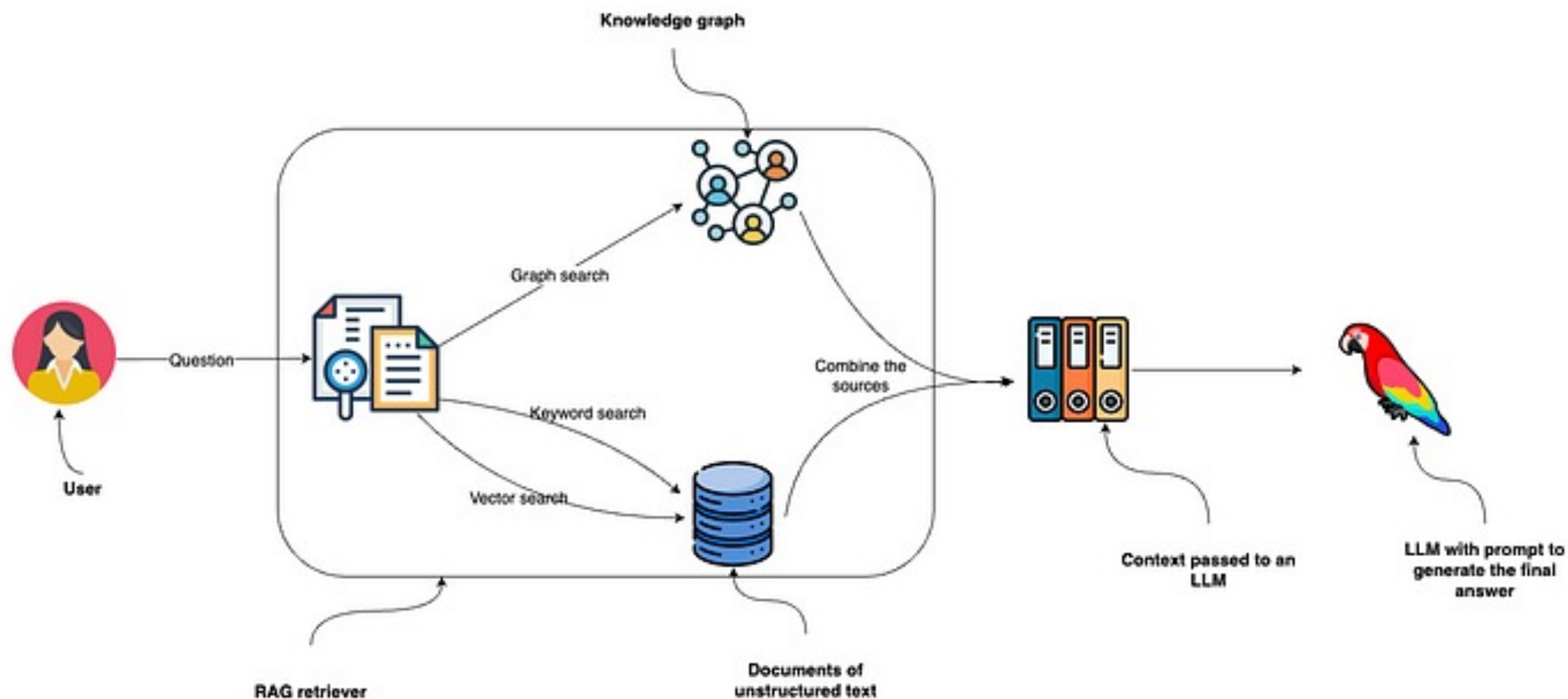
Any drug interactions between Nembutal and Tylenol?



Nembutal (pentobarbital) and Tylenol (acetaminophen) do not have a direct drug interaction. However, caution is still needed when using them together:

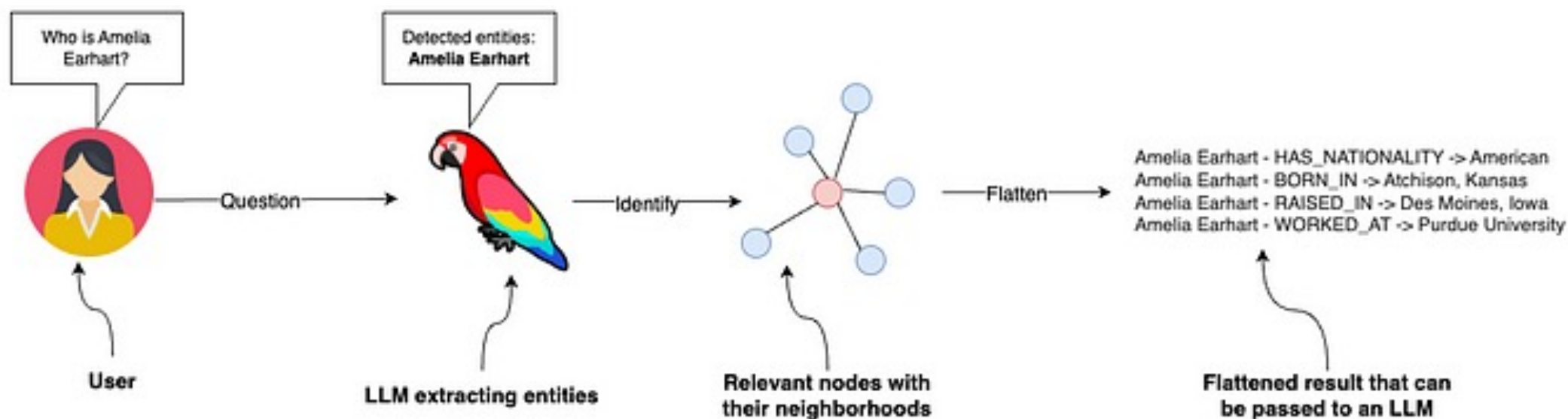
1. **Central Nervous System (CNS) Effects:** Nembutal is a barbiturate that acts as a sedative and can cause CNS depression. When taken with other medications that may have sedative properties or affect the liver, like acetaminophen, there could be an increased risk of drowsiness or sedation.
2. **Liver Considerations:** Tylenol is metabolized by the liver, and combining it with barbiturates like Nembutal, which can also affect liver enzymes, may increase the risk of liver toxicity, especially at higher doses or with chronic use.

Graph Retrieval Augmented Generation



<https://blog.langchain.dev/enhancing-rag-based-applications-accuracy-by-constructing-and-leveraging-knowledge-graphs/>

Usando LLMs para consultas a grafos de conhecimento



<https://blog.langchain.dev/enhancing-rag-based-applications-accuracy-by-constructing-and-leveraging-knowledge-graphs/>

Exemplo: OpenAI embeddings + DrugBank + ChatGPT



The DrugBank Open Data datasets are public domain datasets that can be used freely in your application or project (including commercial use). It is released under a [Creative Common's CC0 International License](#).

To the extent possible under law, the person who associated CC0 with the DrugBank Open Data has waived all copyright and related or neighboring rights to the DrugBank Open Data. This work is published from: Canada.

DATASET	DESCRIPTION	RELEASED ON	VERSION	SIZE	FORMAT	COMMAND	DOWNLOAD
DrugBank Vocabulary	DrugBank identifiers, names, and synonyms to permit easy linking and integration into any type of project.	2024-03-14	5.1.12	926 KB	CSV	Example	Download
DrugBank Structures	DrugBank structures, names, and synonyms to permit easy linking and integration into any type of project.	2024-03-14	5.1.12	4.29 MB	SDF	Example	Download

Agradecimentos a Renzo Leão (IC) e Profa. Veruska Zamborlini

Exemplo: OpenAI embeddings + DrugBank + ChatGPT

DrugBank ID,Accession Numbers,Common name,CAS,UNII,Synonyms,Standard InChI Key
DB00001,BTD00024 | BIOD00024,Lepirudin,138068-37-8,Y43GF64R34,"[Leu1, Thr2]-63-desulfohirudin |
Desulfatohirudin | Hirudin variant-1 | Lepirudin | Lepirudin recombinant | R-hirudin",
DB00002,BTD00071 | BIOD00071,Cetuximab,205923-56-4,PQX0D8J21J,Cetuximab | Cétuximab | Cetuximabum,
DB00003,BTD00001 | BIOD00001,Dornase alfa,143831-71-4,953A260A1Y,"Deoxyribonuclease (human clone 18-1 protein
moiety) | Dornasa alfa | Dornase alfa | Dornase alfa, recombinant | Dornase alpha | Recombinant
deoxyribonuclease (DNase)",
DB00004,BTD00084 | BIOD00084,Denileukin diftitox,173146-27-5,25E79B5CTM,Denileukin | Denileukin diftitox |
Interleukin-2/diphtheria toxin fusion protein,
DB00005,BTD00052 | BIOD00052,Etanercept,185243-69-0,OP401G70JC,Etanercept | etanercept-szss | etanercept-ykro
| Recombinant human TNF | rhu TNFR:Fc | rhu-TNFR:Fc | TNFR-Immunoadhesin,
DB00006,BTD00076 | EXPT03302 | BIOD00076 | DB02351,Bivalirudin,128270-60-0,TN9BEX005G,Bivalirudin |
Bivalirudina | Bivalirudinum,OIRCOABEOLEUMC-GEJPAHFPSA-N
DB04817,"",Metamizole,50567-35-6,934T64RMN,Dipyrone | Metamizol,VWZTYCIRDMTEY-UHFFFAOYSA-N

Exemplo: OpenAI embeddings + DrugBank + ChatGPT

DrugBank ID,Accession Numbers,Common name,CAS,UNII,Synonyms,Standard InChI Key
DB00001,BTD00024 | BIOD00024,Lepirudin,138068-37-8,Y43GF64R34,"[Leu1, Thr2]-63-des
Desulfatohirudin | Hirudin variant-1 | Lepirudin | Lepirudin recombinant | R-hirud
DB00002,BTD00071 | BIOD00071,Cetuximab,205923-56-4,PQX0D8J21J,Cetuximab | Cétuxima
DB00003,BTD00001 | BIOD00001,Dornase alfa,143831-71-4,953A260A1Y,"Deoxyribonucleas
moiety) | Dornasa alfa | Dornase alfa | Dornase alfa, recombinant | Dornase alpha
deoxyribonuclease (DNase)",
DB00004,BTD00084 | BIOD00084,Denileukin diftitox,173146-27-5,25E79B5CTM,Denileukin
Interleukin-2/diphtheria toxin fusion protein,
DB00005,BTD00052 | BIOD00052,Etanercept,185243-69-0,OP401G70JC,Etanercept | etaner
| Recombinant human TNF | rhu TNFR:Fc | rhu-TNFR:Fc | TNFR-Immunoadhesin,
DB00006,BTD00076 | EXPT03302 | BIOD00076 | DB02351,Bivalirudin,128270-60-0,TN9BEX0
Bivalirudina | Bivalirudinum,OIRCOABEOLEUMC-GEJPAHFPSA-N

DB04817,"",Metamizole,50567-35-6,934T64RMN",Dipyrone | Metamizol, VWZTYCIRDMTEY-UH

Adicionamos coluna
de embedding
usando "text-
embedding-3-large"

Passo 1: Gerar embeddings para os medicamentos

```
def get_embedding(text, model="text-embedding-3-large"):
    return client.embeddings.create(input = [text], model=model).data[0].embedding

df = pd.read_csv('drugbank_vocabulary.csv')

# Process the 'Synonyms' column to replace '/' with 'or'
df['Synonyms'] = df['Synonyms'].fillna('').apply(lambda x: x.replace('/', 'or'))

# Combine 'Common name' and 'Synonyms' columns
df['Combined'] = df['Common name'].fillna('') + ' or ' + df['Synonyms'].fillna('')

# Calculate embeddings for each row and store them in a new column
df['Embedding'] = df['Combined'].apply(lambda x: get_embedding(x))

# Save the DataFrame to a CSV file
output_file_path = 'indexed-vocab.csv'
df.to_csv(output_file_path, index=False)
```

Passo 2: Dados nomes de medicamentos, busca

```
term1 = get_embedding("Pentobarbital")
term2 = get_embedding("tylenol")
drug1=find_closest_embedding(df, term1)[0]
drug2=find_closest_embedding(df, term2)[0]
```

Importante para o exemplo: "tylenol" não ocorre no DrugBank que não tem nomes comerciais

Resposta do Passo 2:

```
drug1['DrugBank ID']=DB00312
drug1['DrugBank ID']=DB00316
```

Passo 3: Busca no grafo de conhecimento

Define the SPARQL query

```
query = """
PREFIX biovoc: <http://bio2rdf.org/bio2rdf_vocabulary:>
PREFIX dbvoc: <http://bio2rdf.org/drugbank_vocabulary:>
PREFIX dcterms: <http://purl.org/dc/terms/>
SELECT DISTINCT *
WHERE {
    <http://bio2rdf.org/drugbank:""+drug1['DrugBank ID']+" ">
        dbvoc:ddi-interactor-in ?interactionLink;
        biovoc:identifier ?drugIdentifier1.

    <http://bio2rdf.org/drugbank:""+drug2['DrugBank ID']+" ">
        dbvoc:ddi-interactor-in ?interactionLink;
        biovoc:identifier ?drugIdentifier2.

    ?interactionLink dcterms:title ?interactionDescription;
        biovoc:identifier ?interactionIDs.
}
"""
```

Resultado do Passo 3:

- http://bio2rdf.org/drugbank_resource:DB00312_DB00316
- DDI between Pentobarbital and Acetaminophen - Barbiturates may increase the metabolism of Acetaminophen. This may 1) diminish the effect of acetaminophen; and 2) increase the risk of liver damage.

Passo 4: LLM verbaliza com o contexto da consulta ao grafo

```
messages = [  
    {"role": "system", "content": "You are a helpful assistant."  
    + " Take into account that: "+interactionDescription},  
  
    {"role": "user", "content": "Any drug interactions between  
    "+label1+" and "+label2+"?"}  
]  
  
# Generate the chat completion  
completion = client.chat.completions.create(  
    model="gpt-4o",  
    messages=messages  
)  
  
# Print the response  
print(completion.choices[0].message)
```

Resposta final enriquecida

Yes, there is a known drug interaction between pentobarbital and Tylenol (acetaminophen). Pentobarbital, a barbiturate, may increase the metabolism of acetaminophen. This interaction can potentially lead to two main effects:

1. **Diminished Effect of Acetaminophen:** The increased metabolism may reduce the efficacy of acetaminophen, making it less effective for relieving pain or reducing fever.
2. **Increased Risk of Liver Damage:** The enhanced metabolic activity can increase the production of toxic metabolites from acetaminophen, potentially leading to an increased risk of liver damage.

It's important to exercise caution when using these medications together and consult with a healthcare provider to ensure safe use. They might adjust the dosages or suggest alternative therapies to mitigate these risks.

Mais possibilidades

 Explore ▾ For Drug Discovery ▾ For Clinical Software ▾ For Academic Research 👤

Type your search... 🔍

Interactions Found

		SEVERITY ?	DESCRIPTION
Pentobarbital [Nembutal]	↔	Acetaminophen [Tylenol]	MAJOR The metabolism of Acetaminophen can be increased when combined with Pentobarbital.
EXTENDED DESCRIPTION	The subject drug is a strong CYP3A4 inducer and the affected drug is metabolized by CYP3A4. Concomitant administration will increase the metabolism of the affected drug, leading to decreased serum concentrations and reduced therapeutic effect. READ LESS		
REFERENCES	1. Zhou SF: Drugs behave as substrates, inhibitors and inducers of human cytochrome P450 3A4. Curr Drug Metab. 2008 May;9(4):310-22. [Article] 2. Lynch T, Price A: The effect of cytochrome P450 metabolism on drug response, interactions, and adverse effects. Am Fam Physician. 2007 Aug 1;76(3):391-6. [Article] 3. Klein K, Zanger UM: Pharmacogenomics of Cytochrome P450 3A4: Recent Progress Toward the "Missing Heritability" Problem. Front Genet. 2013 Feb 25;4:12. doi: 10.3389/fgene.2013.00012. eCollection 2013. [Article] 4. Drugs related to CYP3A4 [File] READ LESS		



[Main page](#)
[Community portal](#)
[Project chat](#)
[Create a new Item](#)
[Recent changes](#)
[Random Item](#)
[Query Service](#)
[Nearby](#)
[Help](#)
[Donate](#)

[Lexicographical data](#)
[Create a new Lexeme](#)
[Recent changes](#)
[Random Lexeme](#)

[Tools](#)
[What links here](#)
[Related changes](#)
[Special pages](#)
[Permanent link](#)
[Page information](#)
[Concept URI](#)
[Cite this page](#)
[Get shortened URL](#)

[English](#) Not logged in [Talk](#) [Contributions](#) [Create account](#) [Log in](#)

Item

[Discussion](#)

Read

[View history](#)

paracetamol (Q57055)

chemical compound with antipyretic and pain relieving properties

[edit](#)

p-acetylaminophenol | acetaminofen4-(acetylamino)phenol

| N-acetyl-p-aminophenol4-hydroxyacetanilide | N-(4-hydroxyphenyl)acetamide

| p-hydroxyacetanilide | p-acetaminophenol | p-acetamidophenol | 4'-hydroxyacetanilide

| p-hydroxy-acetanilid | p-hydroxyphenolacetamide | 4-acetamidophenol | acetaminophen

| p-(acetylamino)phenol | APAP | L484

[In more languages](#)

Statements

instance of



type of chemical
entity

[edit](#)

[0 references](#)

[+ add reference](#)

[+ add value](#)

subclass of



acetamides

[edit](#)

[0 references](#)

CosIng number	31569 edit ▶ 1 reference + add value
PesticideInfo chemical ID	PRI776 edit ▼ 0 references + add reference + add value
Nikkaji ID	J4.025H edit ▼ 0 references + add reference + add value
UM-BBD compound ID	c1405 edit ▼ 0 references + add reference + add value



ATC code



N02BE01



edit

▼ 1 reference

stated in	DrugBank
DrugBank ID	00316
	⚠
language of work or name	English
title	Acetamin ophen (English)
publication date	17 Novembe r 2015

+ add reference

+ add value

World Health Organisation
international non-proprietary
name numeric ID



626



edit

▼ 0 references

+ add reference

+ add value

Mainstream



Introduction:

In Q1 2025, SAP is planning to release the [knowledge graph engine](#) as a new capability for SAP HANA Cloud platform. This new multi-model engine allows businesses to connect and analyze information more effectively. SAP HANA Cloud will enable smarter applications and improve user experiences by using data stored in a graph to answer complex questions.

Knowledge graphs connect corporate knowledge, which makes them especially beneficial for powering large language models (LLMs) and generative AI capabilities. Developers can use business context to create applications that provide more precise and relevant answers, enhancing user interactions and improving business processes.

For many, the topic of knowledge graphs is new and exciting. I share below a brief introduction on the major concepts and how SAP plans for those concepts to materialize in SAP HANA Cloud.

Ontologies

An ontology is a guiding framework used to define at a higher level (i.e. classes, categories, groupings, etc.) the facts that occur in a domain and how those higher-level descriptions should relate to each other. Instead of focusing on the facts, an ontology regulates the resulting knowledge graph. For example, in the context of movies, an ontology could define the concept of "movies" and its attributes like title, director, genre, and release date, making the framework flexible and scalable for future data. Ontologies act as the blueprint for knowledge graphs, structuring and connecting data to allow deeper insights and reasoning.

<https://community.sap.com/t5/technology-blogs-by-sap/connecting-the-facts-sap-hana-cloud-s-knowledge-graph-engine-for-business/ba-p/13888597>

Conclusões

- Sinergia entre as torres **nas duas direções**
- Várias arquiteturas possíveis de combinação
 - LLMs como componente
 - Grafo de conhecimento como componente
- Melhora significativa de resultados especialmente em domínios especializados
- Requer grafos de conhecimento de alta qualidade
- Outros tipos de sinergia:
 - Uso de LLMs para auxiliar na manutenção de grafos de conhecimento
 - LLMs para escrever e explicar queries

NEMO

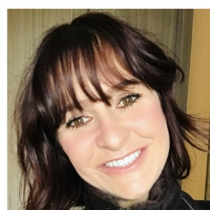
Núcleo de Estudos em Modelagem Conceitual e Ontologias



Camila



João Paulo



Monalessa



Ricardo (in memoriam)



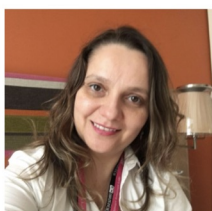
Veruska



Vitor



Giancarlo



Renata

MEMBROS SÊNIOR

- 18 anos de existência
- +600 publicações nacionais e internacionais
- +70 alunos formados (graduação e pós)
- +20 orientações em andamento

MEMBROS EXTERNOS



<https://nemo.inf.ufes.br>