dbai
Databases and Artificial Intelligence Group

# Research Unit for Databases and Artificial Intelligence (DBAI)

TU Wien, Institute of Logic and Computation

*Presentation by: Lucas Kletzander*

# Overview

Our research is located at the interface between **Theoretical Computer Science**, **Database Theory**, and **Artificial Intelligence.**

- Database Query Languages
- Information Integration
- Data Management
- Semantic Web
- Description Logics
- Ontology-based Data Access
- Formal Argumentation
- Belief Change
- Computational Social Choice
- Answer-set Programming
- Automated Timetabling and Scheduling
- …


Stefan Woltran


Reinhard Pichler


Nysret Musliu


Emanuel Sallinger


Georg Gottlob


Matthias Lanzinger


Mantas Simkus


Katja Hose

… and many many more!

dbai
Databases and Artificial Intelligence Group

# WWTF Project: Decompose and Conquer – Fast Query Processing via Decomposition

**Observation:**

- Database Management Systems (DBMSs) struggle with large queries
- Main problem: explosion of intermediate results
- Automatically generated queries (e.g., by Business Intelligence tools) may be large
- Most queries have simple structure – but this is not exploited by DBMSs

**Solution:**

- Efficient algorithms based on query decomposition exist
- So far, decomposition-based query evaluation only used in research prototypes
- Our goal: full integration of decomposition-based query evaluation into common DBMSs

**Application Perspective to AI-Problems:**

- On logical level: Conjunctive queries = Constraint Satisfaction Problems

dbai
Databases and Artificial Intelligence Group

# Computational Social Choice (COMSOC)

*Computational analysis of preference aggregation and collective decision making*

A discipline in the intersection of artificial intelligence, (theoretical) computer science, economics, and political science

**Typical methods in COMSOC:**

- Computational complexity analysis
- Algorithmic tools (approximation algorithms, fixed-parameter algorithms, …)
- Axiomatic analysis (properties of aggregation methods)
- Numerical simulations (with real-world preference data)

dbai
Databases and Artificial Intelligence Group

TU WIEN Informatics

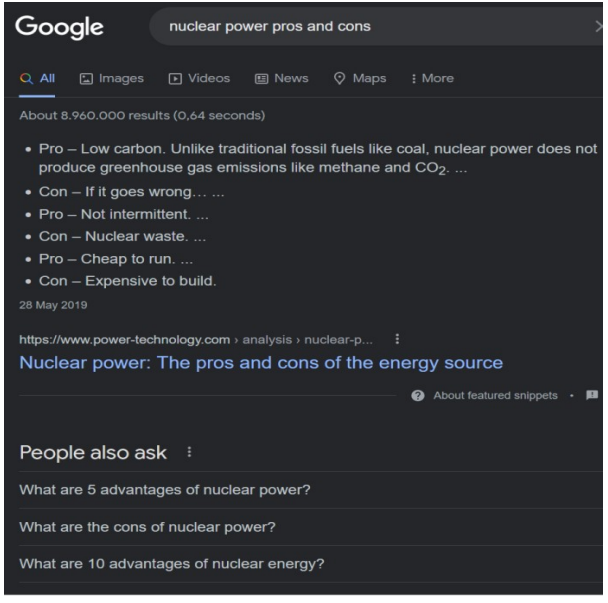
dbai Databases and Artificial Intelligence Group

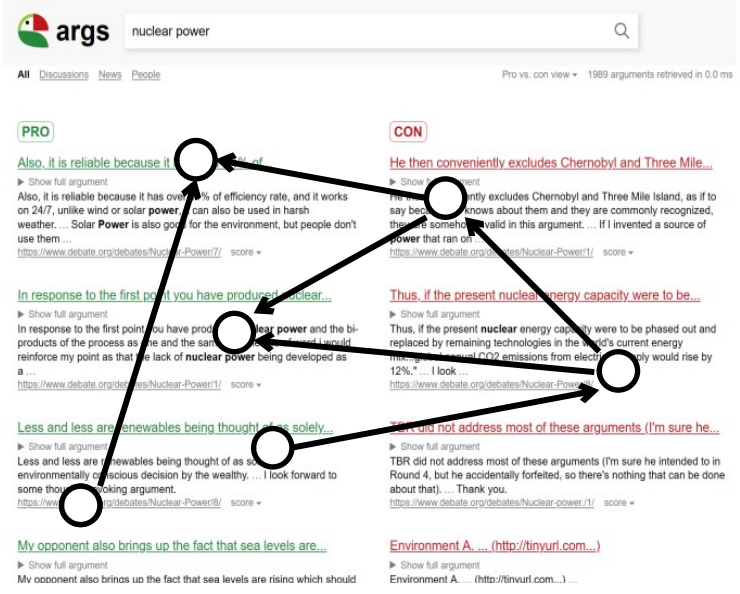
WWTF

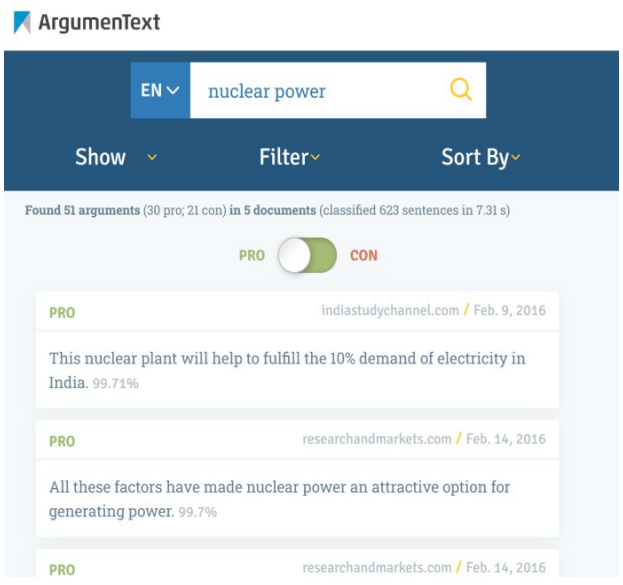
FWF Der Wissenschaftsfonds.

# Computational Argumentation

- Resolve inconsistencies
- Explainability
- Exploit structure to reason **fast**



# Homomorphism Counting as a Foundation for Graph Problems

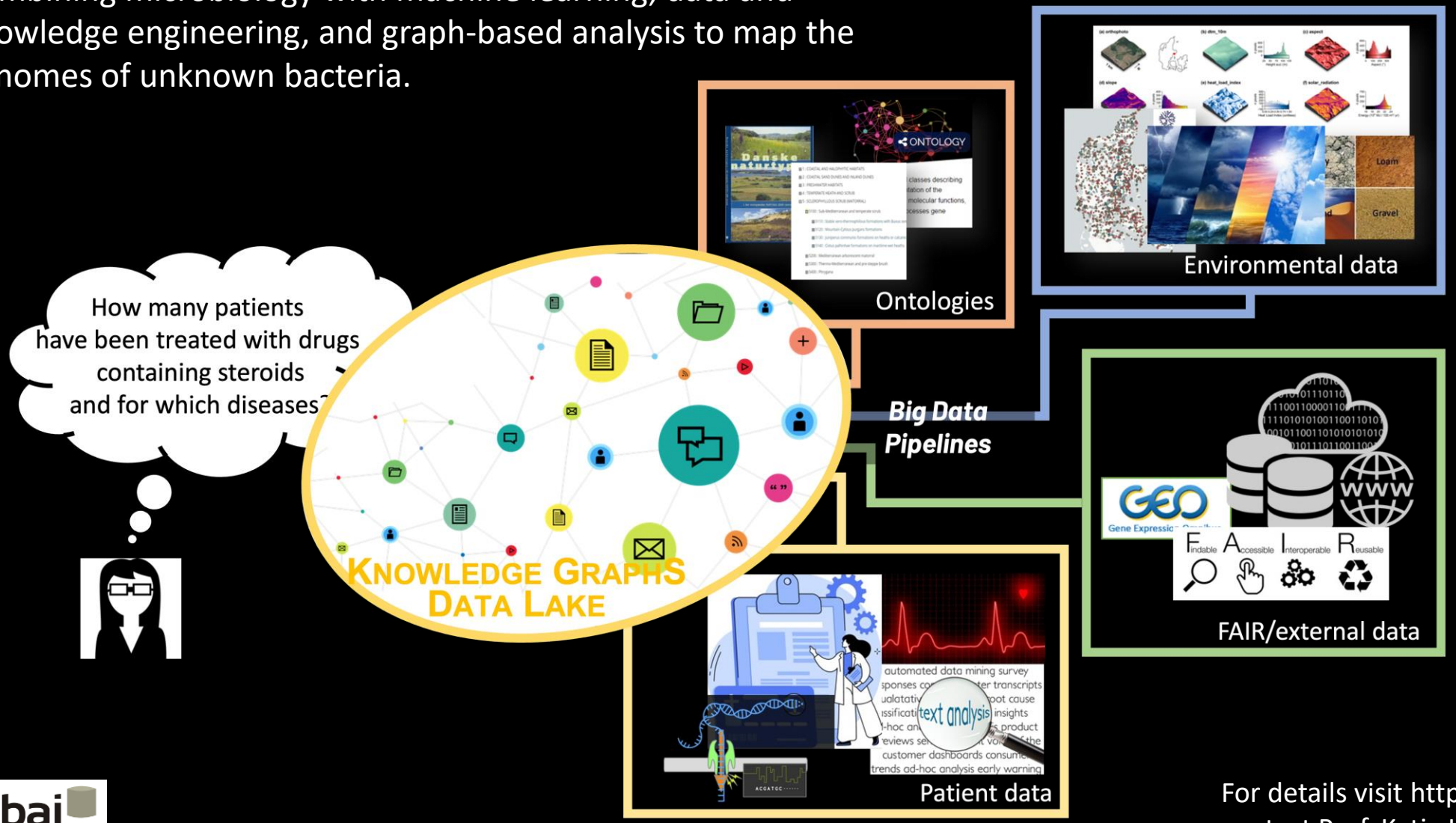
- Homomorphism counts reveal deep connections between (parameterised) complexity theory, model theory, logic, and graph machine learning.

Example Results:

- When exactly is it feasible to count patterns in directed graphs? How does orientation in patterns affect the complexity of counting problems?
- What functions can Graph Neural Networks learn? We are able to give a precise characterisation.
- Important point: closely related methods despite work in widely different areas.

# Illuminating microbial dark matter through data science

Combining microbiology with machine learning, data and knowledge engineering, and graph-based analysis to map the genomes of unknown bacteria.




Partners

AALBORG UNIVERSITY

Funding

VILLUM FONDEN

TU WIEN dbai Databases and Artificial Intelligence Group

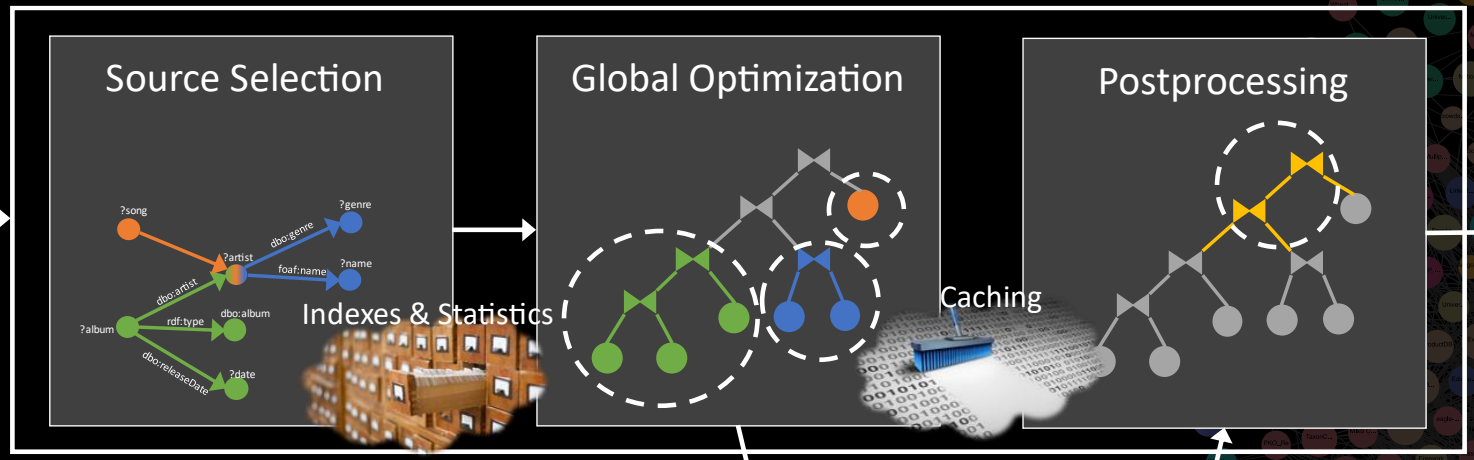
For details visit https://darkmatter.aau.dk/ or contact Prof. Katja Hose

# RelWeb: A reliable Web of Data

Keeping past and current versions of knowledge graphs on the Web accessible and queryable despite server failures and knowledge evolution.

SPARQL Query

```
SELECT DISTINCT * WHERE {
 ?album dbo: artist ?artist .
 ?album rdf:type dbo:album .
 ?album dbo:releaseDate ?date .
 ?artist dbo:genre ?genre .
 ?artist foaf:name ?name .
 ?song dbo: writer ?artist
}
```




Federation Engine

Query Result

{?album=A_Night_at_the_Opera_(Queen_song),
?artist=dbr:Queen_(band),
?date="1975-11-21",
?genre=dbr:Rock_music,
?name="Queen"@en,
?song=dbr:Bohemian_Rhapsody},
...

Source engines

Local Optimization & Execution

Knowledge becomes outdated and unavailable over time.

Provenance for data and queries is essential to generate trust.

Partners

AALBORG UNIVERSITY

WU WIRTSCHAFTS UNIVERSITÄT WIEN VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS

GHENT UNIVERSITY

Inria


Funding

INDEPENDENT RESEARCH FUND DENMARK


For details visit https://relweb.cs.aau.dk/ or contact Prof. Katja Hose

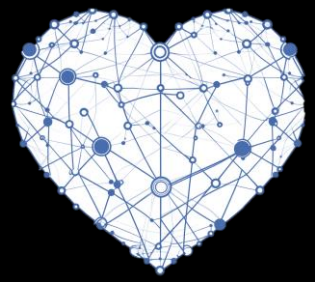
TU WIEN dbai Databases and Artificial Intelligence Group

# Virtual twins for personalized health data management

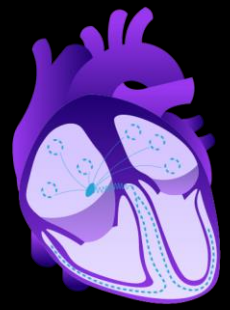
TARGET

Accelerating translational research for the personalised management of the AF-related stroke pathway

Atrial fibrillation and AF-related stroke

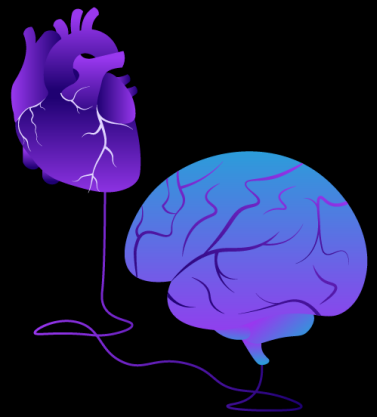


Graph-driven data integration, semantic harmonization, data quality, sharing, and analysis

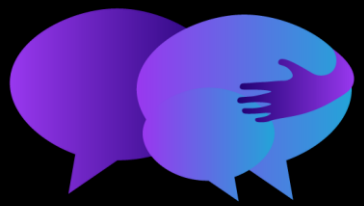


Virtual twins in healthcare

AI-powered real-time monitoring



Risk assessment



Patients and stakeholder engagement

Partners

Funding

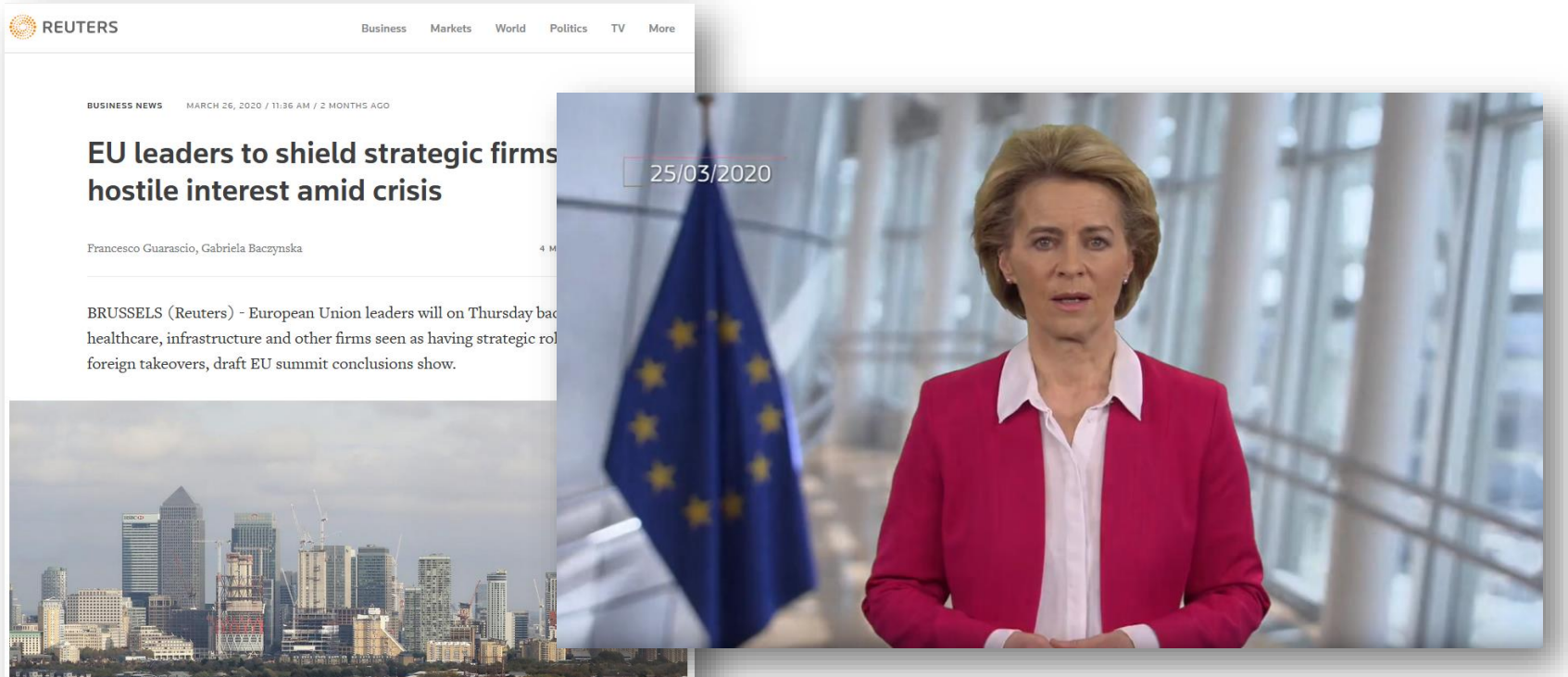
Co-funded by the European Union

For details visit https://target-horizon.eu/ or contact Prof. Katja Hose

# Knowledge Graph-based AI for Shielding Strategic Companies in Crises

Together with the Central Bank of Italy and Oxford University, TU Wien has been developing solutions to preventing hostile takeovers of strategically relevant companies (such as **health, energy, or public infrastructure** sector companies) in crises. Our AI system is based on a Knowledge Graph that represents both the complex domain knowledge, as well as can explain decisions, thus creating trust. It is part of a larger initiative on financial and economic Knowledge Graphs.

More info: https://kg.dbai.tuwien.ac.at/covid-19-economic-kg/ or contact Prof. Emanuel Sallinger.




TU Wien:

TU Wien Informatics

TU Wien | Knowledge Graph Lab

dbai Database and Artificial Intelligence Group

Partners:

Banca d'Italia Eurosistema

University of Oxford

Politecnico di Milano

Funding:

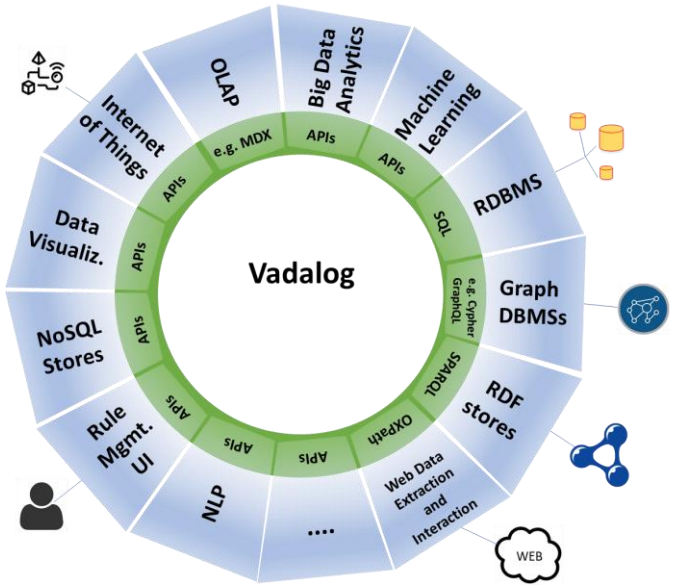
WWTF Vienna Science and Technology Fund

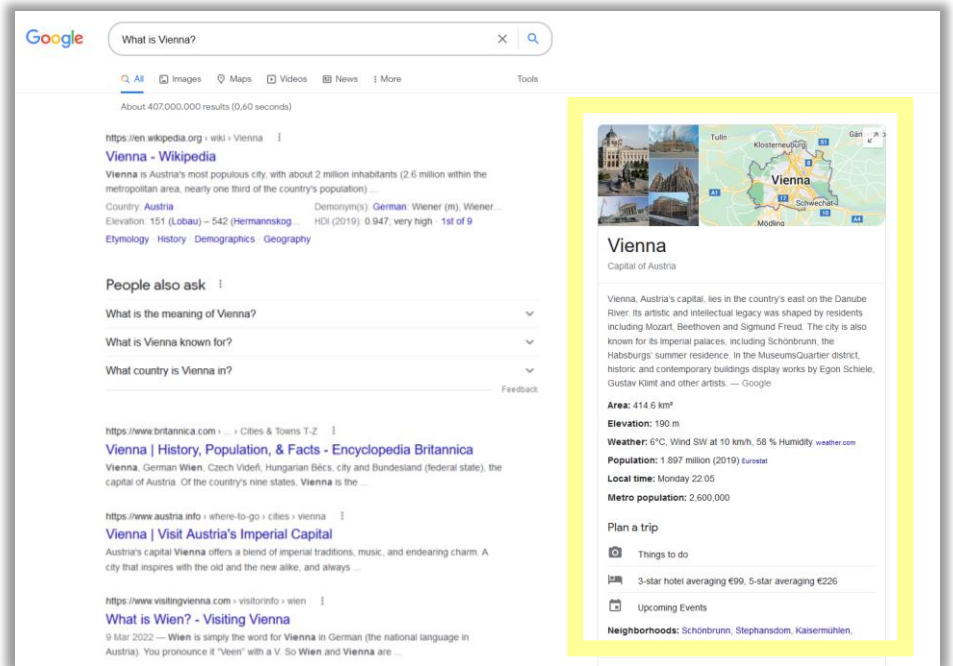
Vienna Research Groups

# Scalable Reasoning in Knowledge Graphs

In a 1,6m€ WWTF VRG grant, TU Wien is researching the foundations of the next generation of Knowledge Graph-based AI systems. Everyone of us has come in contact with Knowledge Graphs: whenever we ask a query on a search engine, we do not only get answers from websites, but also get information from the Knowledge Graph (highlighted in yellow below). Beyond search engines, Knowledge Graphs power many AI innovations through their ability to scalably reason over data. Yet this power is still very limited. The goal of this project is both to build the theoretical foundations, as well as to bring them to practice.

More info: https://kg.dbai.tuwien.ac.at/ or contact Prof. Emanuel Sallinger.




## TU Wien:

TU WIEN Informatics

TU WIEN | Knowledge Graph Lab

dbai Database and Artificial Intelligence Group

## Partners:

University of Oxford · Meltwater Outside Insight · Banca d'Italia · Stanford University · ENS École Normale Supérieure · JKU Johannes Kepler University Linz · University of California San Diego · University of California Los Angeles · The University of Edinburgh · Politecnico di Milano

## Funding:

WWTF Vienna Science and Technology Fund

Vienna Research Groups

# FWF Project HYPAR: Hybrid Parameterized Problem Solving in Practice

**Observation:**
Problem solving in AI suffers from "strictly" following structure

**Solution:**

- Focus on *hybrid algorithms* where solving is "weakly" guided by structure

⇝ benefit from the interplay between structure- guidance and *dynamic search space exploration*

**Partner:**

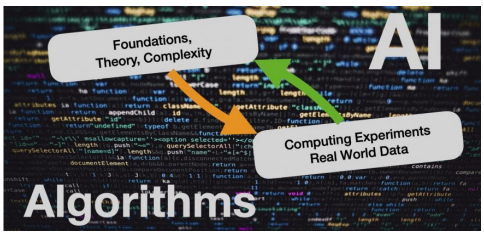
Torsten Schaub, University of Potsdam, Germany

# WWTF Project RevealAI: Revealing and Utilizing the Hidden Structure for Solving Hard Problems in AI

**Observation:**
The "structure" of instances is not obvious and oftentimes hidden.

**Solution:**

- Design novel and *more robust* algorithms revealing structure
- Utilize theoretical findings for tackling problems in AI




**Partner:**
Algorithms and Complexity Group, TU Wien

TU WIEN Informatics

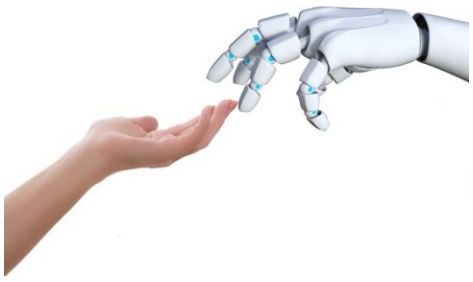
dbai Databases and Artificial Intelligence Group

Christian Doppler Forschungsgesellschaft

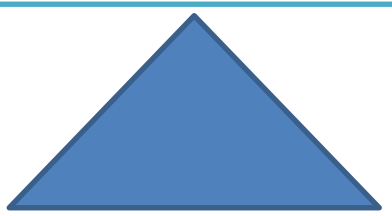
Bundesministerium für Digitalisierung und Wirtschaftsstandort

# Christian Doppler Laboratory for Artificial Intelligence and Optimization for Planning and Scheduling

## Contribution: Innovative hybrid algorithms



*Artificial Intelligence:*
*Problem Solving, Machine Learning…*



*Methods of Logic*

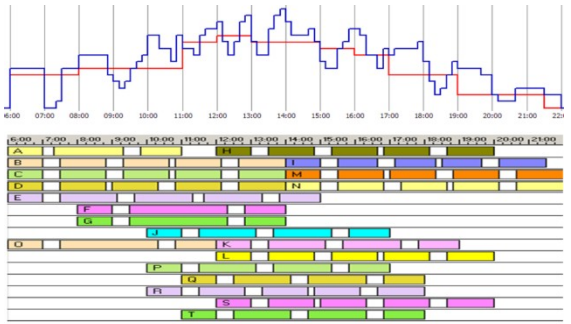
$$S_{i,d,t} \leftrightarrow \bigwedge_{x=1}^{sl_t} U_{i,d,x} \bigwedge_{y=sl_t}^{sl_{max}} \neg U_{i,d,y}$$

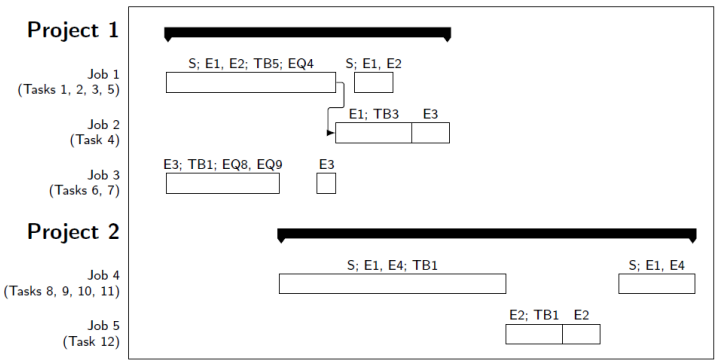
*Mathematical Optimization*

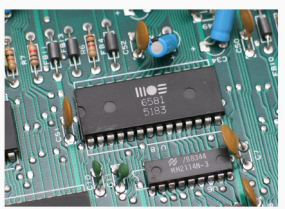
$$\begin{aligned} minimize\ f = \quad & 30 * \sum_{\substack{s\in S \\ k\in K \\ d\in\{1\ldots7\}}} C_{skd}^{S1} \\ & +15 * \sum_{\substack{n\in N \\ s\in S \\ d\in\{1\ldots7\}}} (C_{nsd}^{S2a} + C_{nsd}^{S2b}) \\ & +30 * \sum_{\substack{n\in N \\ d\in\{1\ldots7\}}} (C_{nd}^{S2c} + C_{nd}^{S2d}) \end{aligned}$$

# CD-Lab: Industrial applications

Automated Planning and Scheduling: Production Planning and Scheduling, Personnel Planning, Test Laboratory Scheduling…

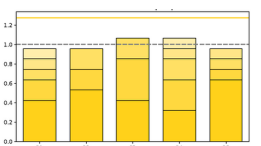


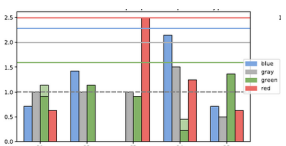


https://commons.wikimedia.org/wiki/File:MOS6581_chtaube061229.jpg, Christian Taube
CC BY-SA 2.5

https://commons.wikimedia.org/wiki/File:Reflow_oven.jpg, Nelatan
CC BY-SA 3.0

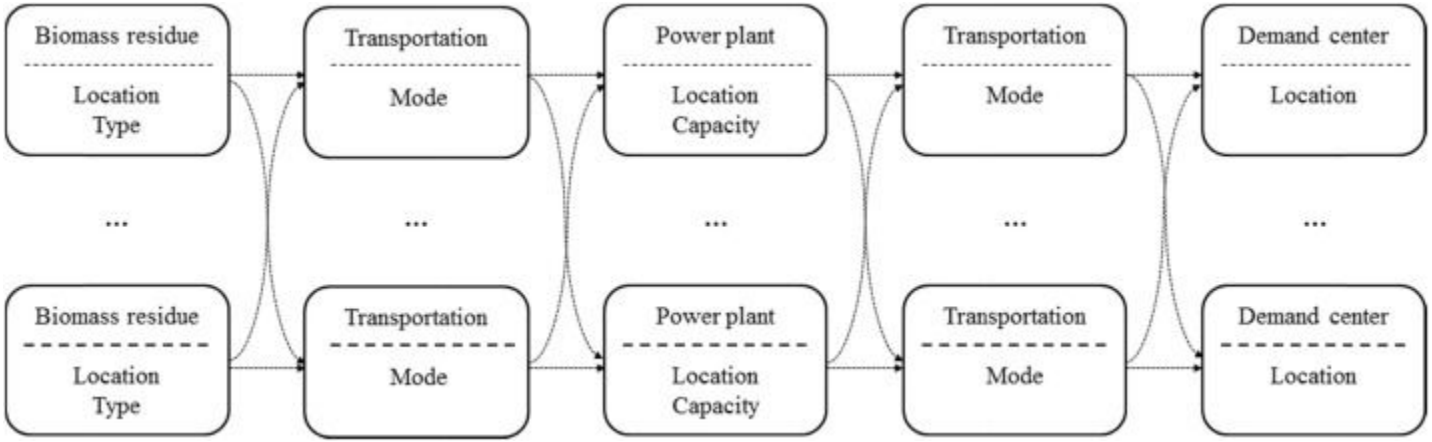




Partners:

# Optimization methods for the design of reverse logistics network

- Exact methods and heuristics




Paulo, H., Azcue, X., Barbosa-Póvoa, A. P., & Relvas, S. (2015). Supply chain optimization of residual forestry biomass for bioenergy production: The case study of Portugal. Biomass and Bioenergy, 83, 245-256.