

Geospatial Artificial Intelligence – ein Blick in die Zukunft der Geoinformatik?

Johannes Scholz



johannes.scholz@plus.ac.at



www.zgis.at | | www.plus.ac.at/geoinformatik | | www.johannesscholz.net



@Joe_GISc



@Joe_GISc@mastodon.online

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Motivation & Background

The data deluge

Miller, H. J., & Goodchild, M. F. (2015). Data-driven Geography.
GeoJournal, 80(4), 449-461.



Data Deluge and Artificial Intelligence?

Artificial Intelligence (AI) is:

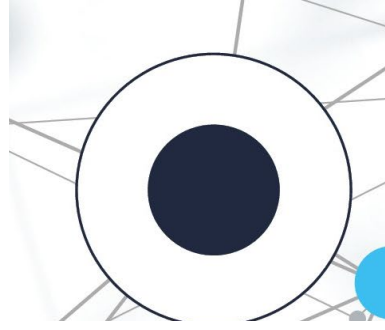
*“a system's ability to correctly **interpret external data**, to **learn from such data**, and to use those learnings to **achieve specific goals** and tasks **through flexible adaptation**.”*

(Kaplan & Haenlein 2019)

Data Deluge and Artificial Intelligence?

VOL. LIX. NO. 236.]

[October, 1950



Alan Turing publish a revolutionary paper in 1950

- **"Computing Machinery and Intelligence"**
- Postulation: we are able to develop Computers that think autonomously

Term "AI" was "invented" 1956 at a workshop at Dartmouth College (McCarthy 1956)

Walter Pitts and Warren McCulloch develop **1943(!)** an early prototype of Neural Networks

MIND
A QUARTERLY REVIEW
OF
PSYCHOLOGY AND PHILOSOPHY

I.—COMPUTING MACHINERY AND INTELLIGENCE
BY A. M. TURING

1. *The Imitation Game.*

I PROPOSE to consider the question, 'Can machines think?' This should begin with definitions of the meaning of the terms 'machine' and 'think'. The definitions might be framed so as to reflect so far as possible the normal use of the words, but this attitude is dangerous. If the meaning of the words 'machine' and 'think' are to be found by examining how they are commonly used it is difficult to escape the

AI History

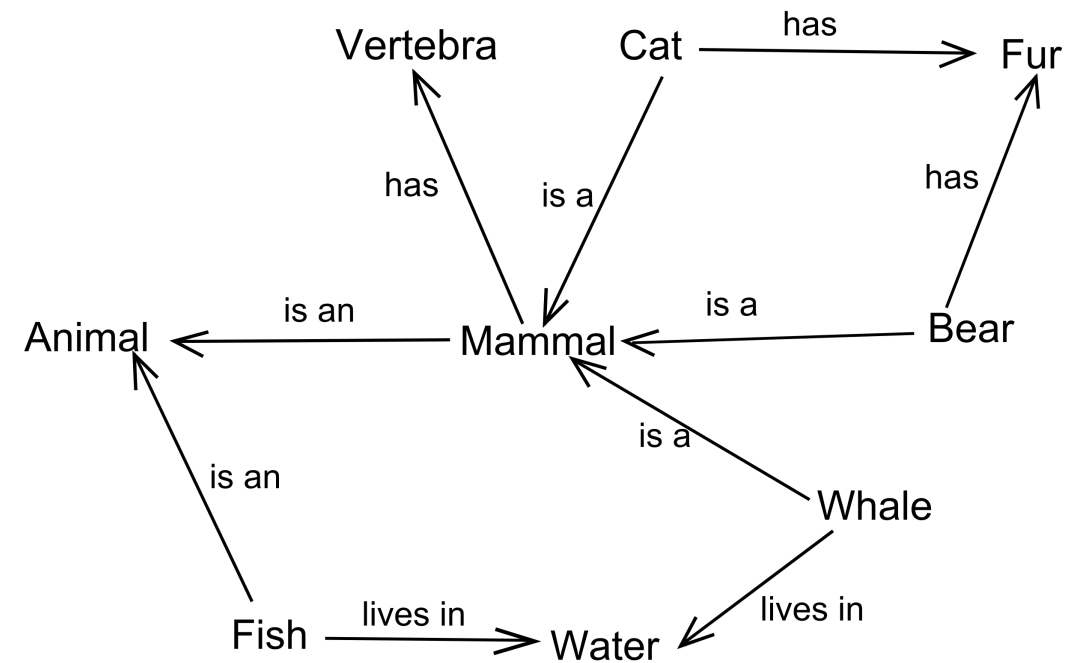
Early Optimism

- Solution of algebraic problems
- Solution of geometric theorems
- Language (incl. semantics)

1958, H. A. Simon and Allen Newell: "**within ten years** a digital computer will be the world's chess champion" and "within ten years a digital computer will discover and prove an important new mathematical theorem."

1965, H. A. Simon: "machines will be capable, **within twenty years**, of doing any work a man can do."

1967, Marvin Minsky: "**Within a generation** ... the problem of creating 'artificial intelligence' will substantially be solved."



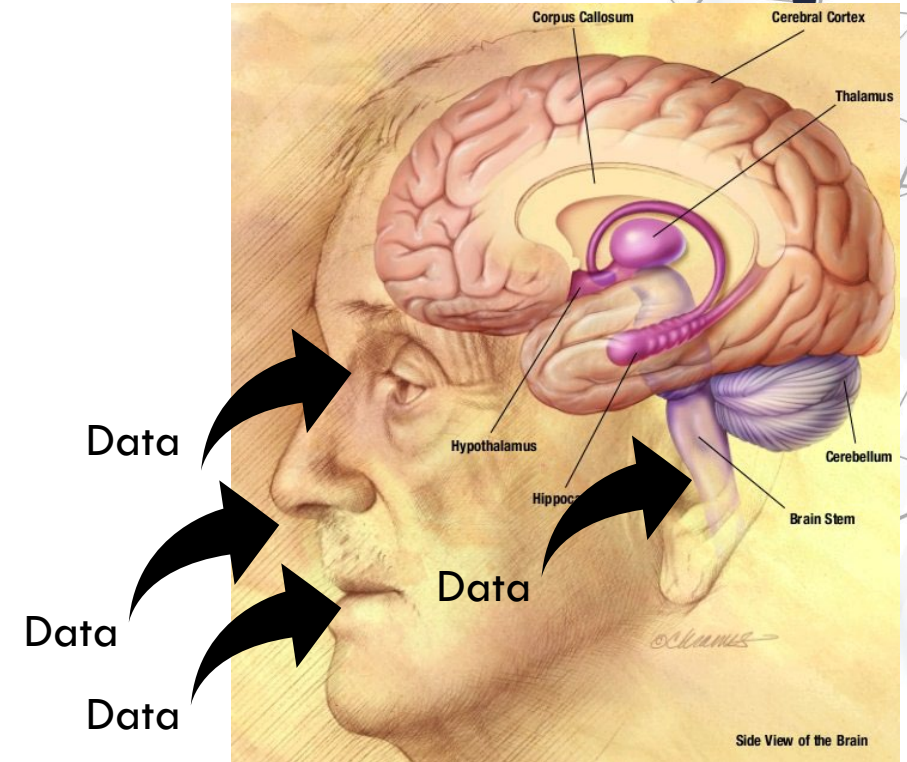
AI History

AI Winter (until 1980ies)

- Computational power was not sufficient
- Not able to build up „intelligence“ and solve real-world problems
- ...

AI Transition to „learning phase“

- First learning (processing of data) then intelligence



AI History





GeoAI Basics

Geospatial Artificial Intelligence

“**GeoAI** can be regarded as a study subject to **develop intelligent computer programs** to mimic the processes of **human perception, spatial reasoning, and discovery** about **geographical phenomena** and **dynamics**

- to advance our knowledge,
- to solve problems in human environmental systems and their interactions,
- with a focus on spatial contexts and roots in geography or GIScience.” (Gao, 2021)

Spatially explicit models incorporating spatial contexts (Yan et al., 2018) can **outperform traditional nonspatial AI** models in many tasks:

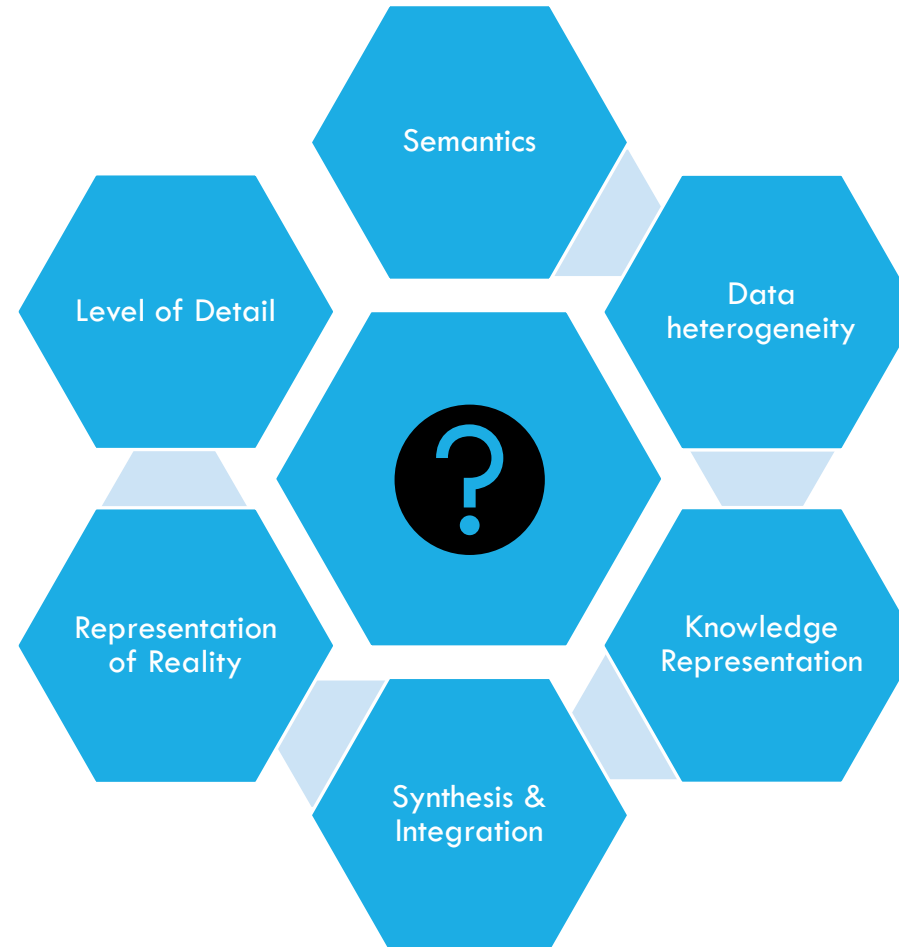
- image classification,
- geographic knowledge graph summarization (Yan et al., 2019),
- and geographic question-answering problems (Mai et al., 2019).

GeoAI – Additional Questions?

Questions that may surface when:


- Representing
- Manipulating
- Storing
- Analyzing, and
- Visualizing

Geographic Data ...!



GeoAI & Spatial Analysis

Has a three-folded nature:

- Data driven 
- Knowledge Driven
- Geospatial Application Domains

Knowledge Driven GeoAI

Ontology:

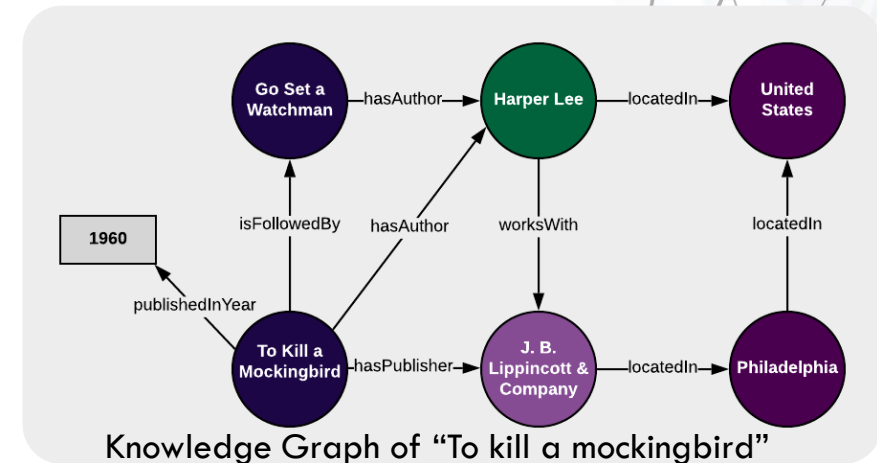
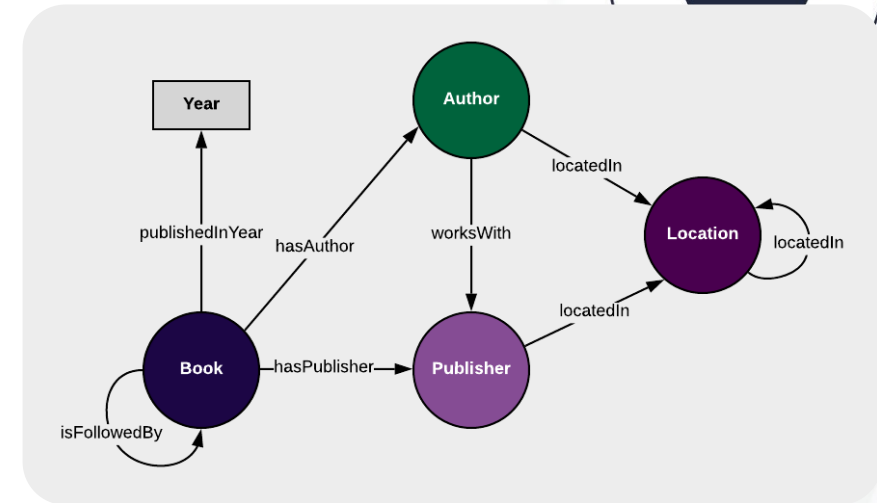
- Description of the concepts and their relations existing in a Universe of Discourse (Uschold & Gruninger, 1996)
- Definitions of a shared vocabulary

(Geo)Knowledge Graph (GeoKG) (Paulheim, 2017):

- mainly describes real world entities and their interrelations, organized in a graph,
- defines possible classes and relations of entities in a schema

Ontology + (Geo)Data = (Geo)Knowledge Graph

- Graphs are supported by **Semantic Web approaches** and contemporary **NoSQL databases**
- In comparison to OWL-Ontologies and Reasoners the **reasoning speed is significantly higher** (see Lampoltshammer & Wiegand 2015)



Knowledge Driven GeoAI

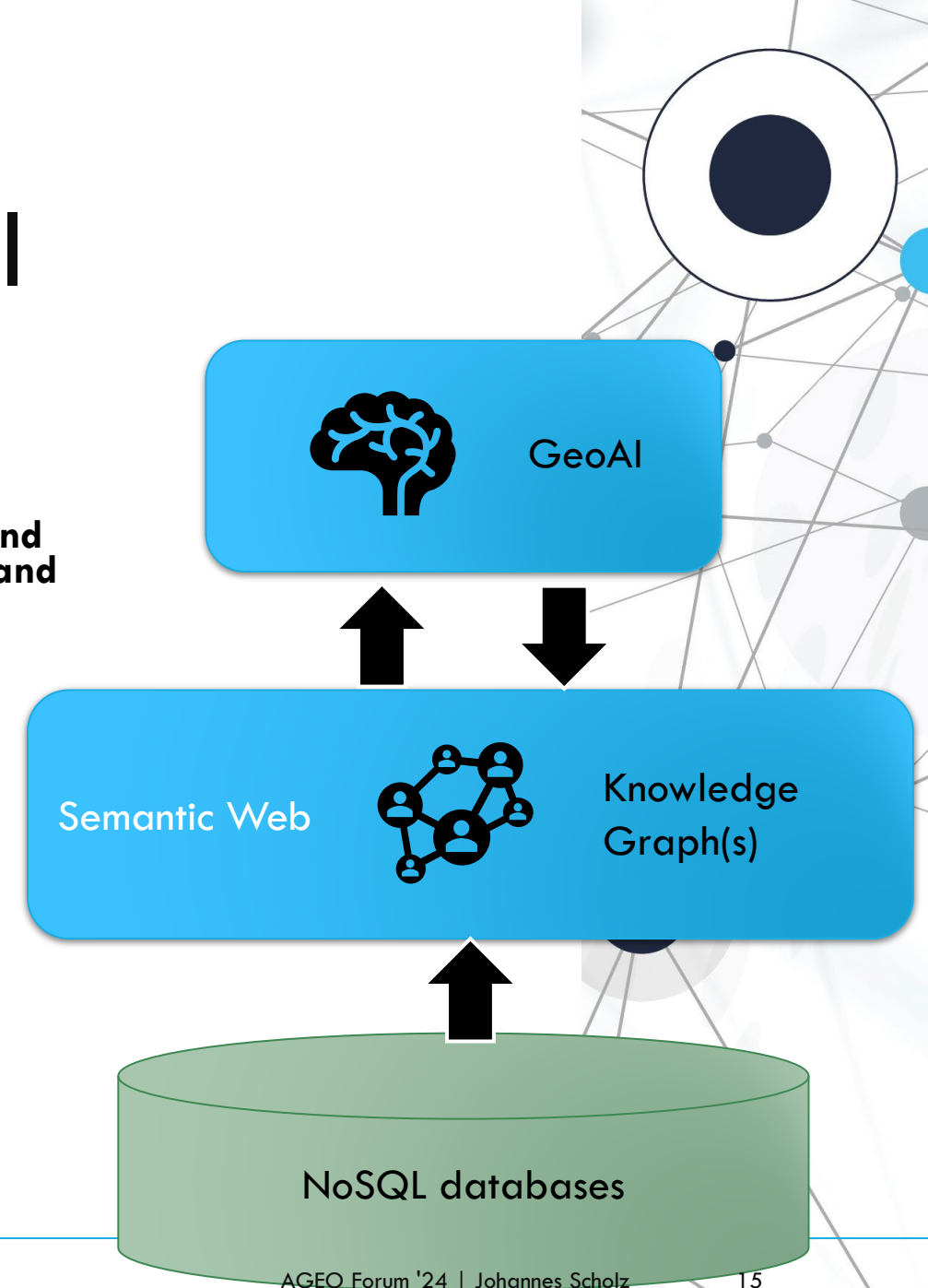
“Can GeoAI algorithms be fueled by GeoKGs?”

Can GeoAI algorithms utilize the inherent dimensions – Space/Time and GeoSemantics – of GeoKGs, to accurately model spatial phenomena and contribute to their explainability?”

Why?

- Knowledge graphs are understood by both humans and machines
 - Serve foundation for artificial intelligence (Semantic AI)
 - Facilitate applications such as geospatial data integration and knowledge discovery
- Spatial Linked Open Data cloud
 - Open-source cross-domain knowledge graph
 - Essential for describing events, people, and objects
- Geographic Question Answering (e.g. Mai et al. 2020):
 - Semantically enriched contextual data necessary
 - Data synthesis(!)

>> (Geo)Knowledge Graphs can serve that functionality



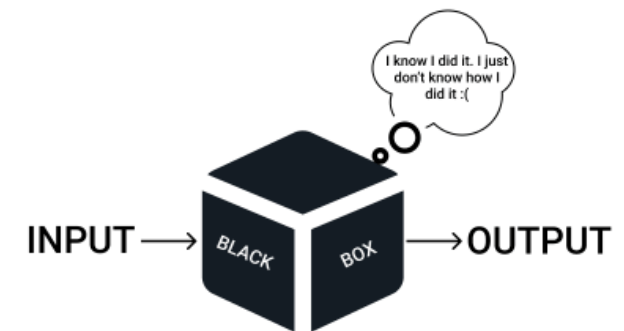
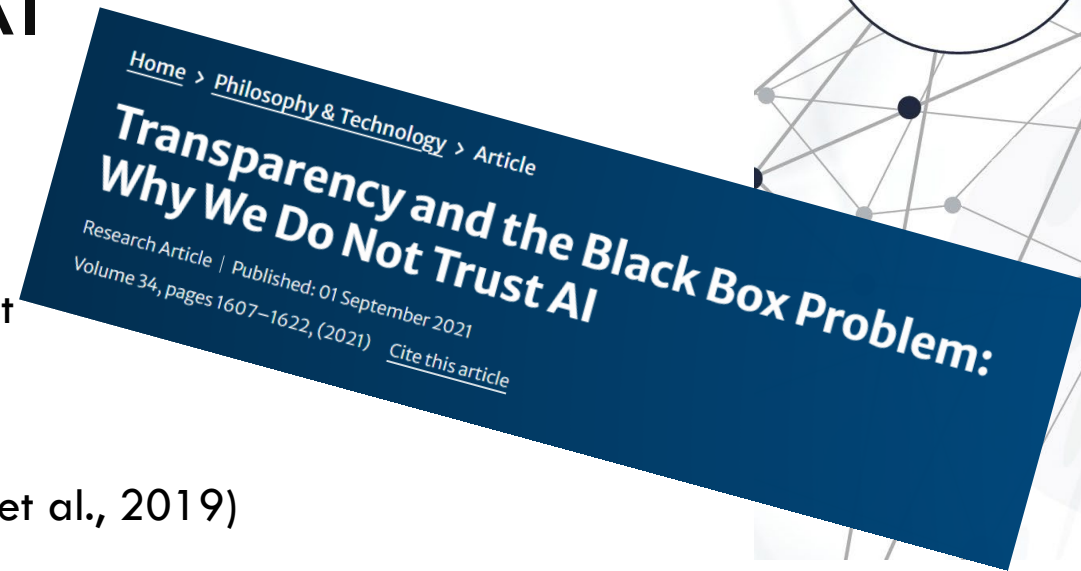
Knowledge Driven GeoAI

Verdict:

- Black Box Problem of AI – lack of understanding erodes trust

Approach: Causal Modeling & Inferencing

- Causal inferencing helps to achieve Explainable AI (Rueden et al., 2019)
 - Represents causal relationships of a system
 - Relies on expert knowledge & observational data
- Prediction under distribution shift
- What-If Questions
- Modeling of **Causality with Graph(s)(!)**
- Causal relationships can be used to **improve model interpretability** (Roscher et al., 2020b; Miller, 2019) and help **to improve model performance** when **“small” data sets** are available





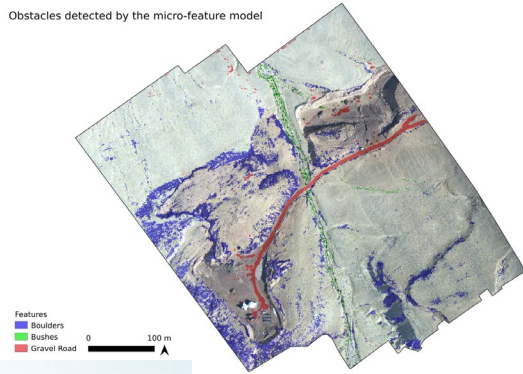
Selected Applications & Projects

Geospatial Application Domains & GeoAI

Detection of terrain features (Li and Hsu 2020, Prinz et al., 2022)

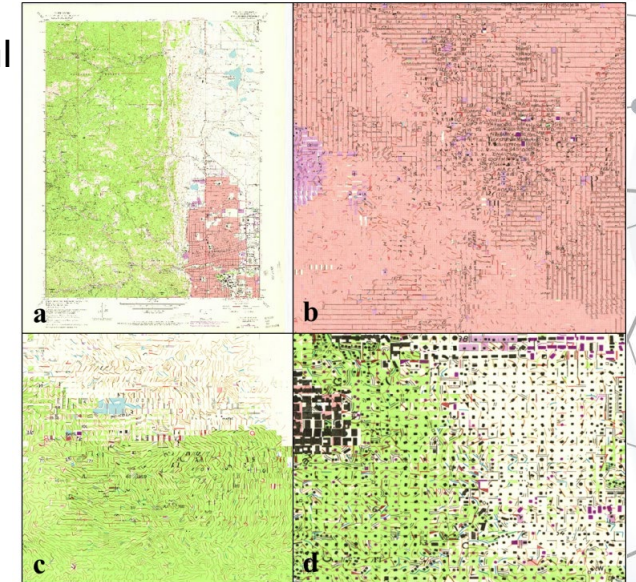
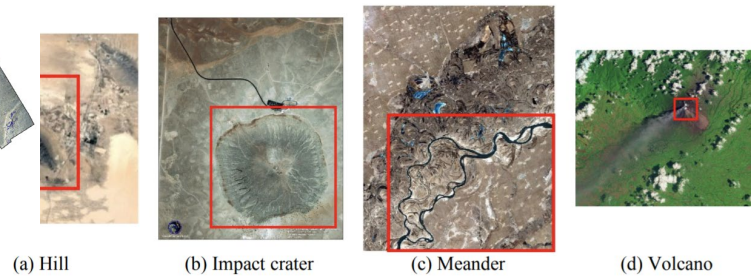


Obstacles detected by the micro-feature model



ÖSTERREICHISCHES WELTRAUM FORUM
AUSTRIAN SPACE FORUM

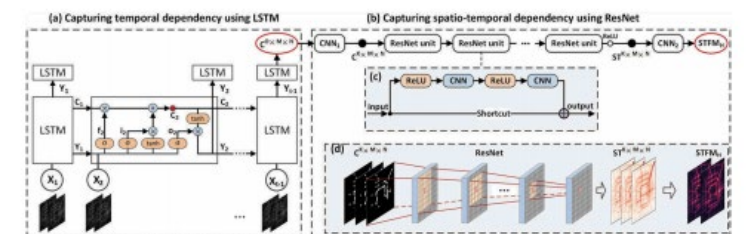
Information extraction from historical maps (Duan et al. 2020)



Building footprints (Xie et al. 2020)



Traffic forecasting (Ren et al. 2020)



Geospatial Application Domains & GeoAI @PLUS

ABM4EnergyTransition



Bundesministerium Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie

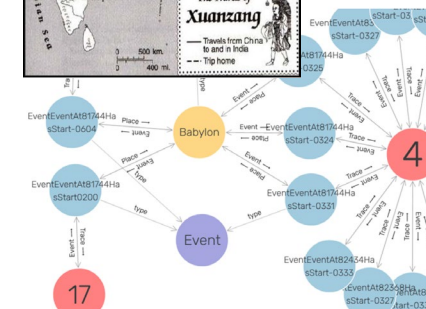
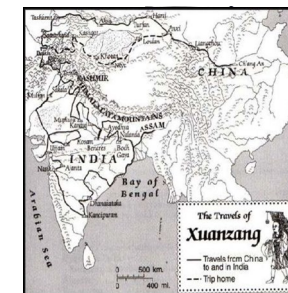


IGNITE

iKlimEt

CaGISc Rising Grant - GeoKGs for Digital Humanities

Travels of monk Xuanzang (629AD-645AD)



Digital Humanities

Effects of Climate Change

Core Research Areas

ABM – GeoAI –
GeoKG –
Geosemantics

Energy Transition & Decarbonization

Military Information Systems

Digital Tourism

Logistics & Supply Chain

Data-Driven Tourism 4 Sustainability

Virtual Shepherd

TU Wien Informatics

MOVING LAYERS

VIEHFINDER



RegioWoodTrain



MEDLOK

iHCE TU Graz



Bundesministerium Landesverteidigung

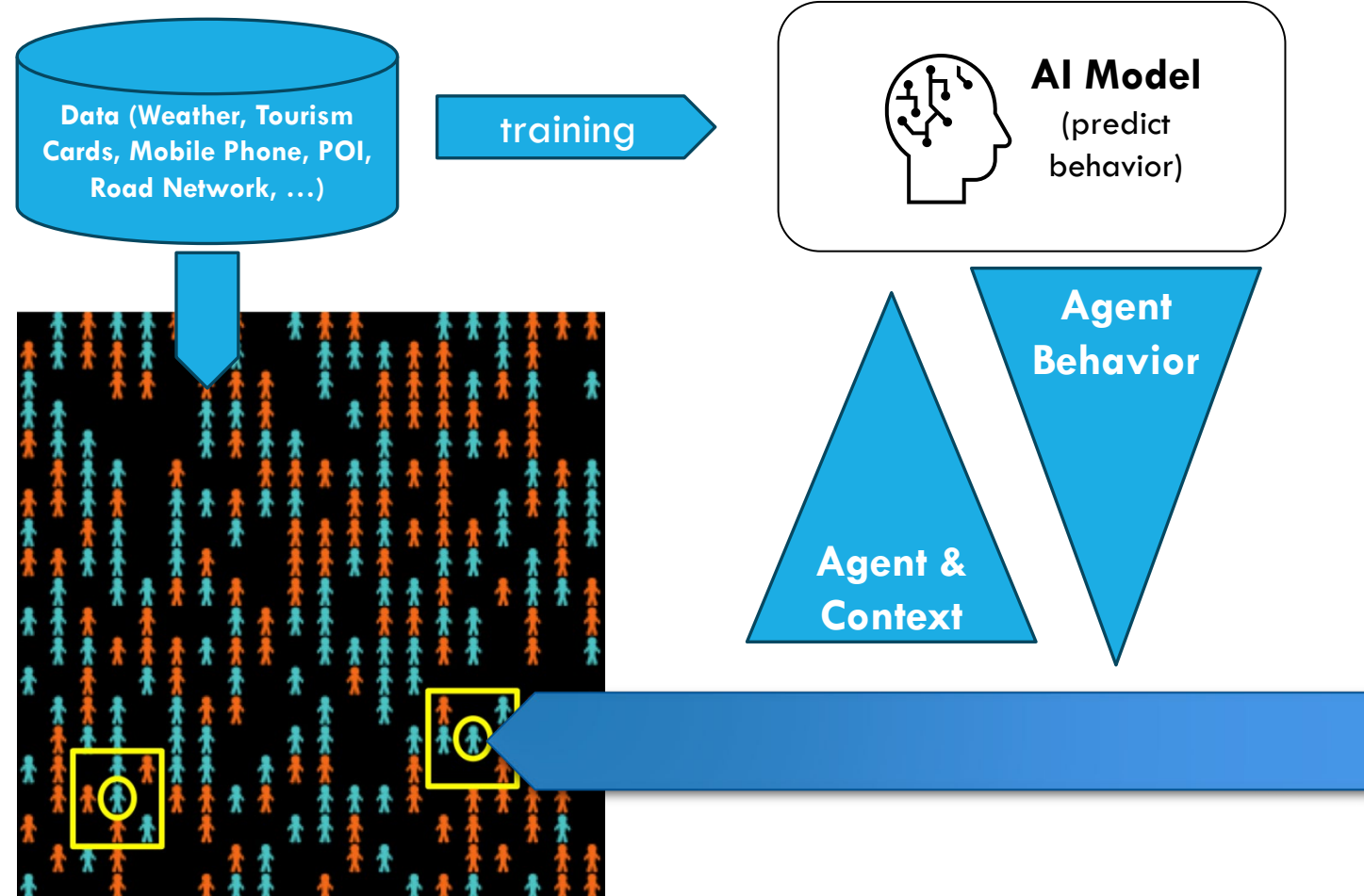
GeoCROW



Data-driven Tourism for Sustainability

■ Motivation

- Tourism sector seeks to understand visitor behavior to address issues like overtourism and congestion with “nudging”
- It aims to enhance overall customer experience by predicting tourists' preferences and destinations



Conclusion

GeoAI, GeoKGs and Geosemantics are closely related and of utmost interest for the GIScience community!

GeoAI, GeoKnowledge Graphs and Geosemantics (can) deliver the methodological advance to

- Make **significant contributions** to innovative **solutions of (applied) research questions** from **various scientific fields**
- Serve as **“glue” between different scientific fields** in **interdisciplinary contexts**

Help us understand spatial phenomena in the data-driven era!



Outlook

GeoAI is here to stay!

Stronger focus on ethical issues and explainability!

(Provocative) Questions:

Will we need a GIS engineer in the future?

Will GeoAI design our maps in the future?





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