AI-Supported Smart City: Quo Vadis?

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Contents

1 – Introduction

- Recent trends
- Application domains
- Points of view

Recent Trends from 2000

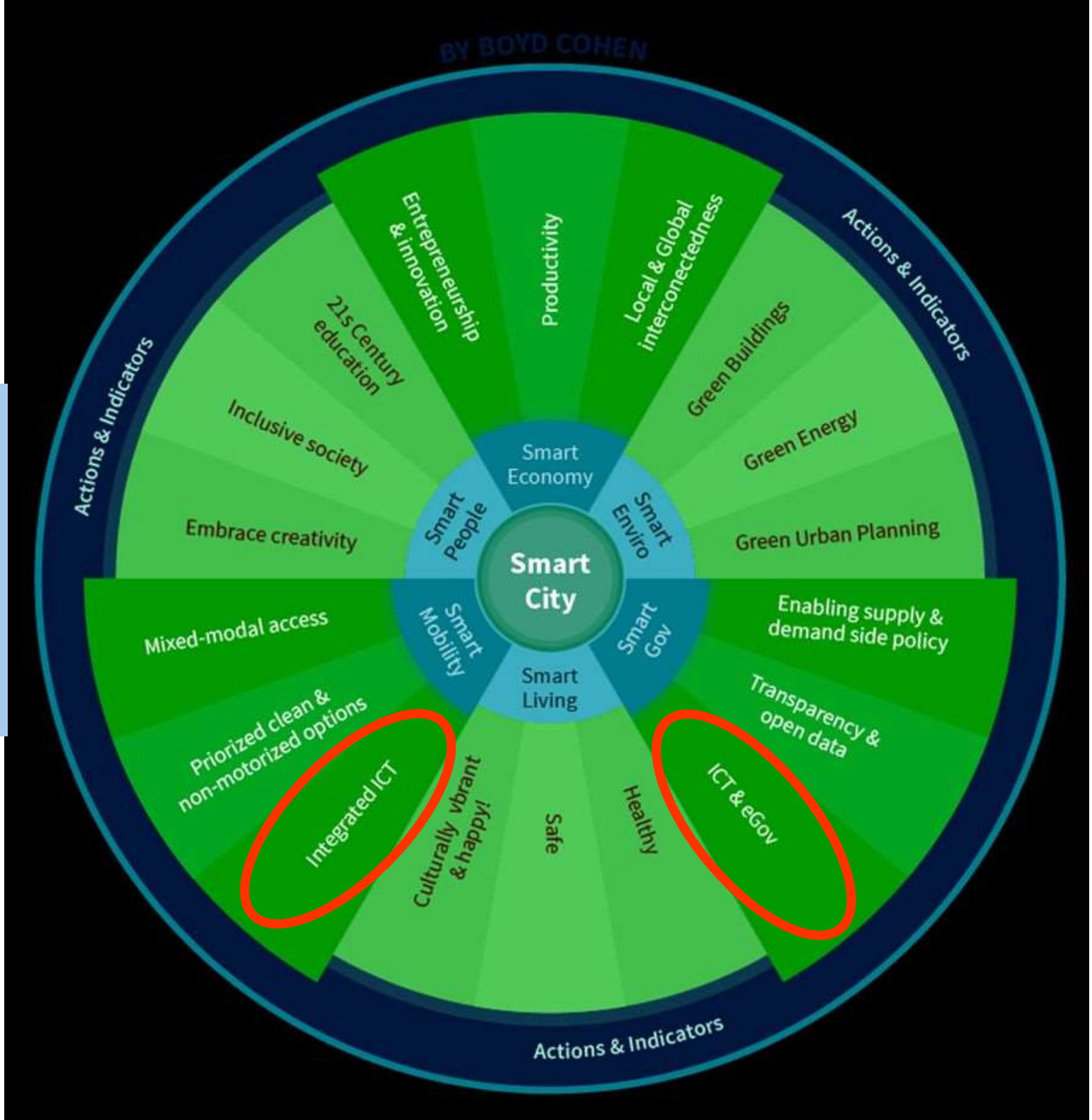
Evolution of human needs

- ↗Environment
- ↗ Social links
- ↗ Participation

Evolution of ICT

- ↗ Sensors
- ↗Telco, smartphones
- ↗ Cloud computing
- ↗ AI and Gen-AI
- ↗ Digital Twins

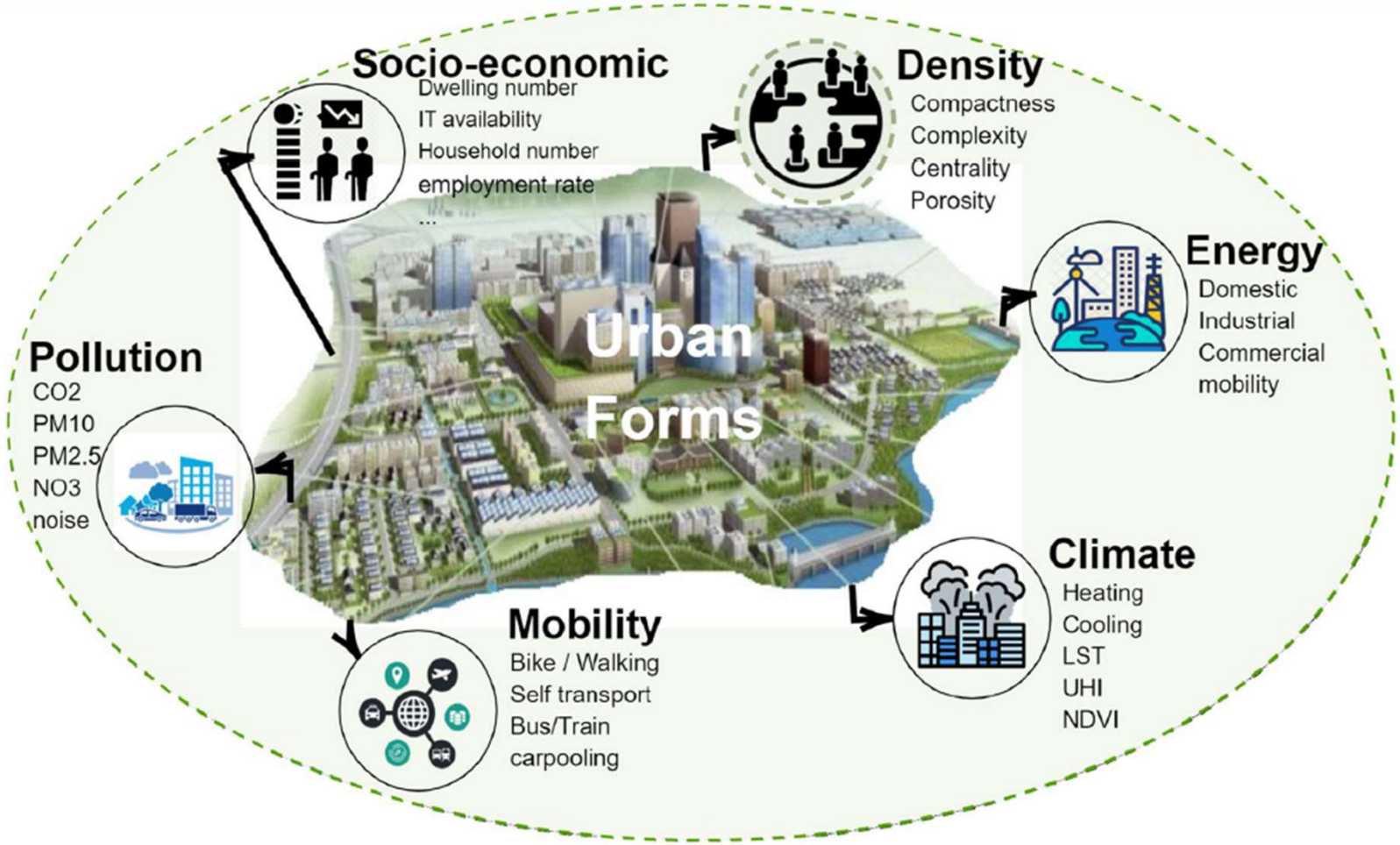
Boyd Cohen definition



Domains of applications in smart cities

- Energy consumption – Carbon-neutrality
- Building – heating – AC
- Mobility – electric mobility
- Energy
- Health
- Homeland security

Urban indicators



Stéphane Cédric Koumetio Tekouabou · El Bachir Diop · Rida Azmi · Jérôme Chenal
"Artificial Intelligence Based Methods for Smart and Sustainable Urban Planning: A Systematic Survey".
Archives of Computational Methods in Engineering, 2022

Two Possible Points of View

- How the evolution of technology affects human behavior?

- How the evolution of human needs influences the development in technologies?

2 – Context for AI

- Sensor-based systems – IoT
- Artificial intelligence – Gen-AI
- Geovisualization
- Citizen participation
- Security of systems
- Twin cities
- Etc.

Artificial Intelligence

- Definitions
  - 1 – a branch of computer science dealing with the simulation of intelligent behavior in computers
  - 2 - the capability of a machine to imitate intelligent human behavior
- Many applications in business
- Few in urban and regional planning

- GeoAI

Main subdomains

- Knowledge management
- Machine learning
- GenAI = Generative AI

- Others
  - Multi-agent systems
  - Bio-inspired systems

Contents

- Definition of geographic knowledge
  - Geographic knowledge ↔ urban knowledge
- Rule-based systems
- Geographic Knowledge graphs (GeoKG)
- Deep learning
  - Large Language models
- Generative IA
  - LLM ↔ GeoKG

2.1 Definition of Geographic Knowledge

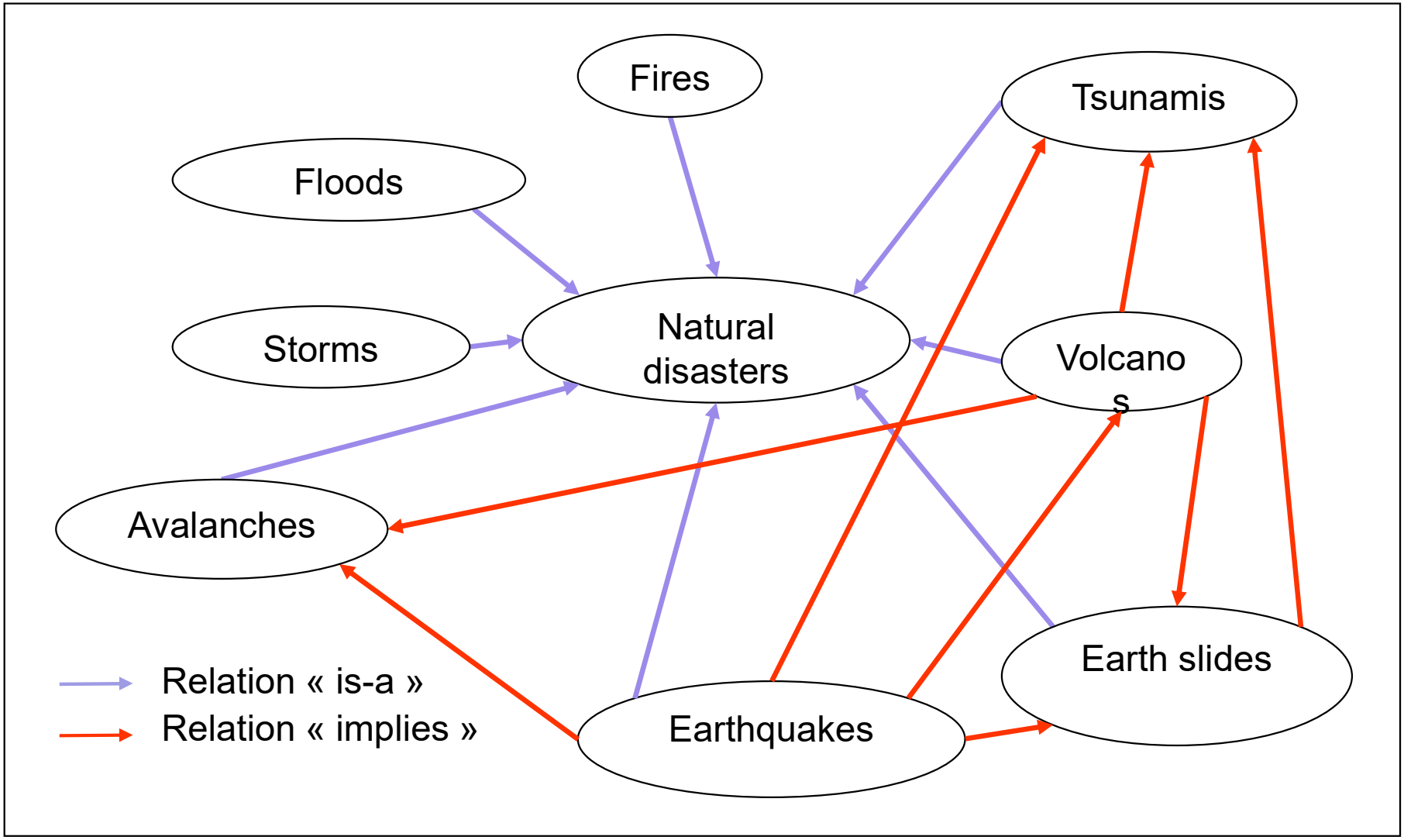
- Knowledge = information which can be used to solve a problem or to assist decision-making

- For a territory, geographic knowledge corresponds to information potentially useful to:
  - explain
  - manage
  - monitor
  - simulate the future
  - and plan.

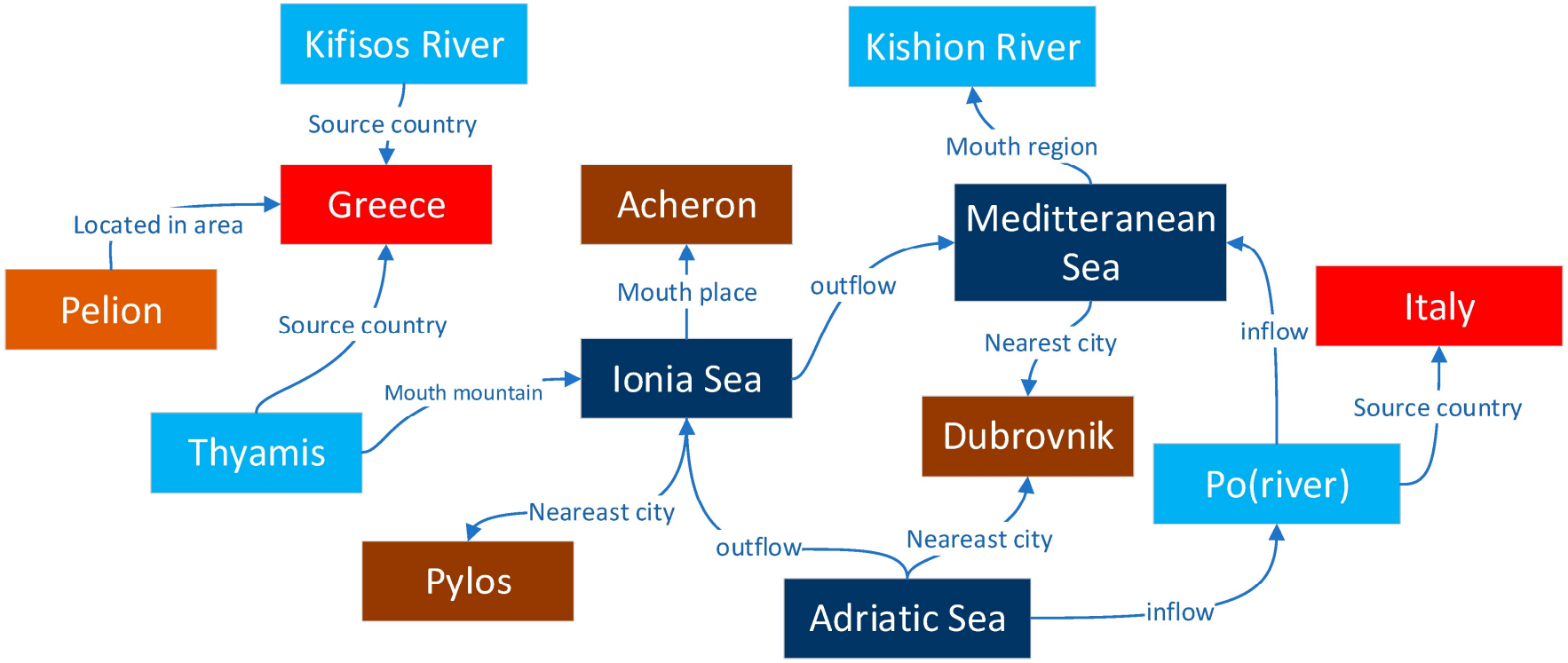
Knowledge management

- Several ways of knowledge modeling
  - Semantic networks (SOWA) ➔Graphs
    - RDF triples (Resource Description Framework)
    - Ex. <Athens, *is_capital*, Greece>
    - <Thessaloníki *belongs_to*, Morocco>
  - Ontology
  - Rules and constraints
- Document management

Example of an ontology



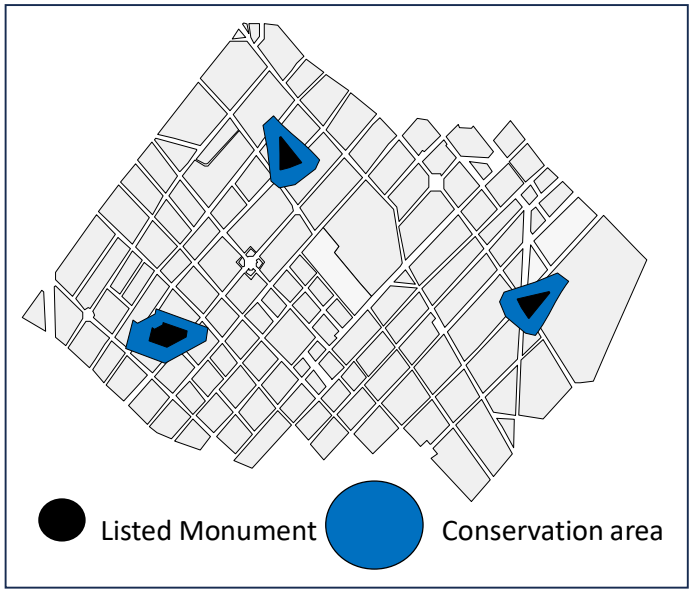
Example of semantic network



2.2 Rule-based systems

- **In business (only logic)**
  - “IF-THEN-Fact” and “IF-THEN-Action” rules
- **In Geomatics (+ topology and computational geometry)**
  - “IF-THEN-CreateZone”;
  - Co-location rule: “IF something here, THEN another thing nearby”;
  - Located rule: “IF in a place B, THEN apply RuleB”;
  - Bi-location rule: “IF something holds in place P, THEN something else in place Q”.

Examples: listed monuments



$$\forall\ T \in Earth, \forall\ B \in PROJECT, \exists\ M \in Geo\text{-}Objects,$$

$$\text{Type}\ (B) = \text{“Building”},$$

$$\text{Type}\ (M) = \text{“Listed\_Monument”},$$

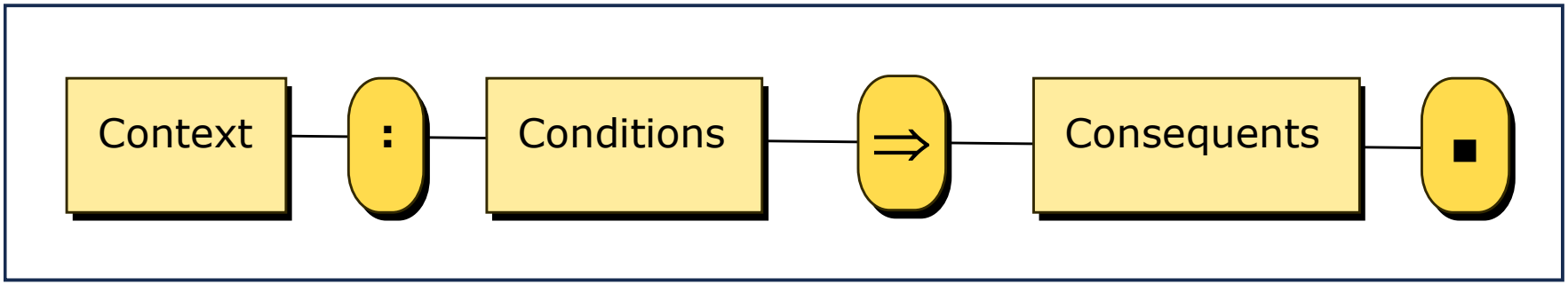
$$Inside\ (Geom\ (B), T), Inside\ (Geom\ (M), T)$$

$$:$$

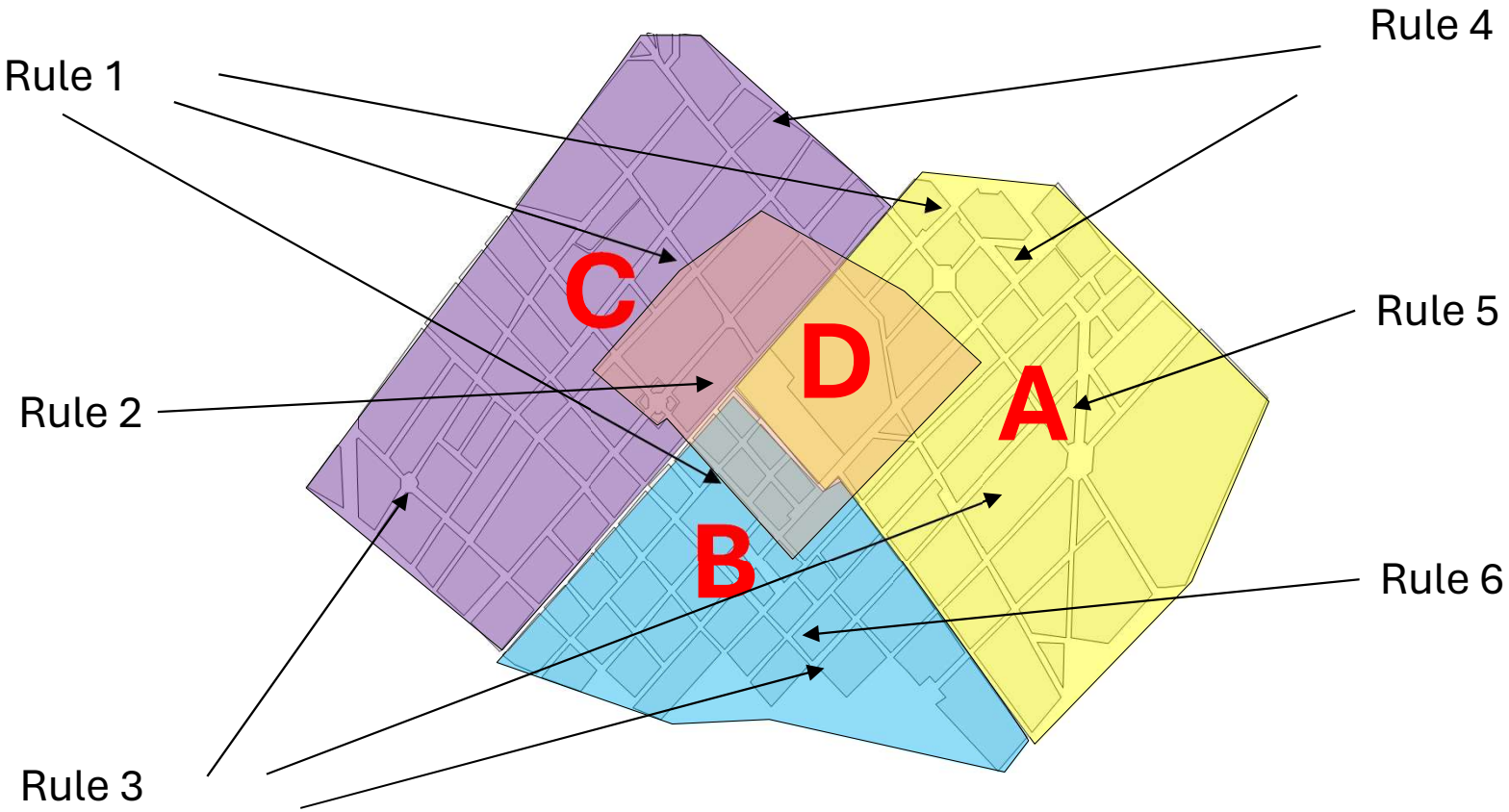
$$Disjoint\ (\text{Geom}(B), Union\ (Buffer\ (Geom\ (M), 100)))$$

$$\Rightarrow$$

$$State\ (B) = \text{“LM\_Approved”}$$



Located rules




```
IF Object Z Belongs to ZoneA
Then Apply Rules 1, 3 and 5
```

Prospect

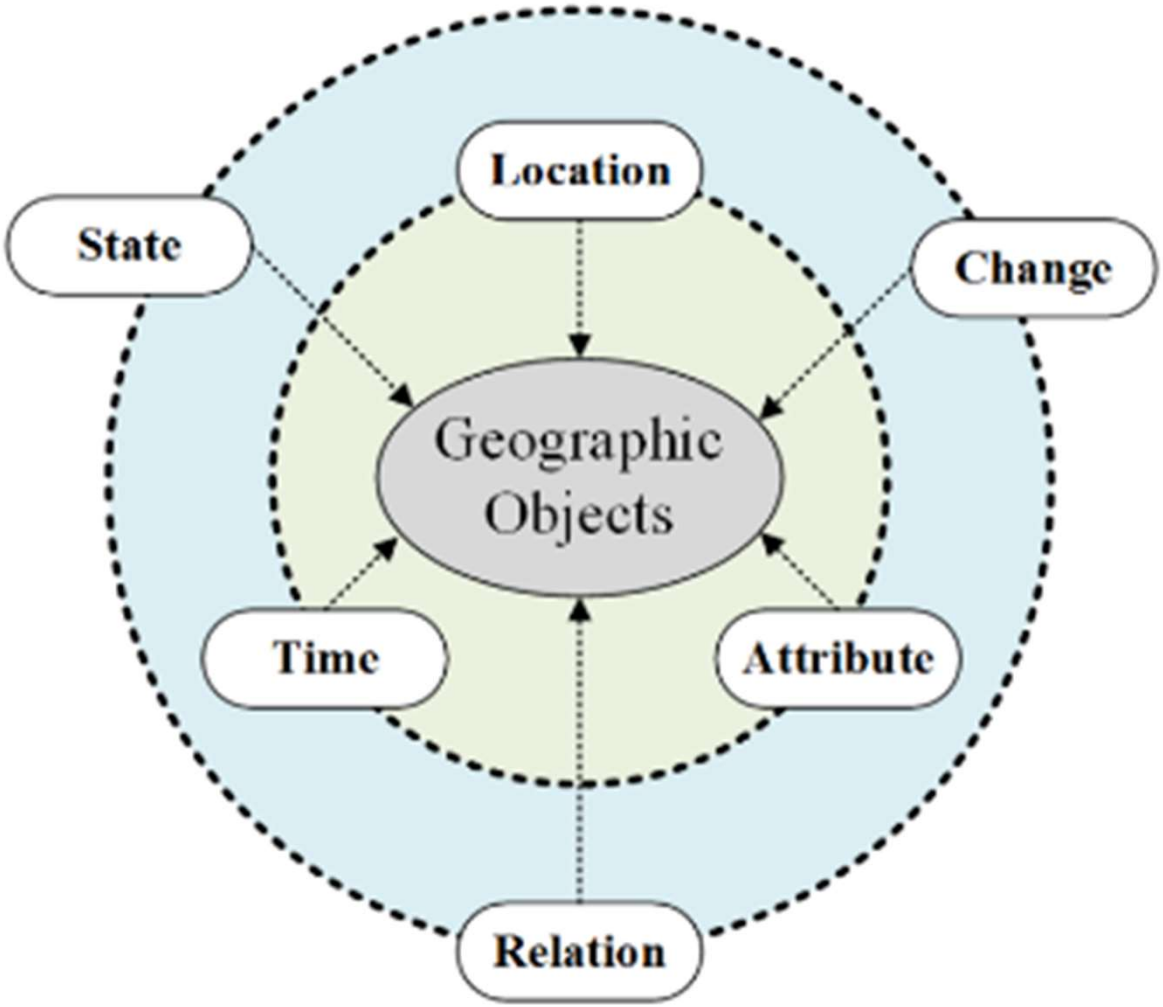
- Difficulties to model with the IF-THEN clauses
- Integration of operation research and multi-criteria decision-making
- Several hundred rules are already written

- Challenges
  - Writing a reasoning engine
  - Explanation of results
  - Coupling with geovisualization

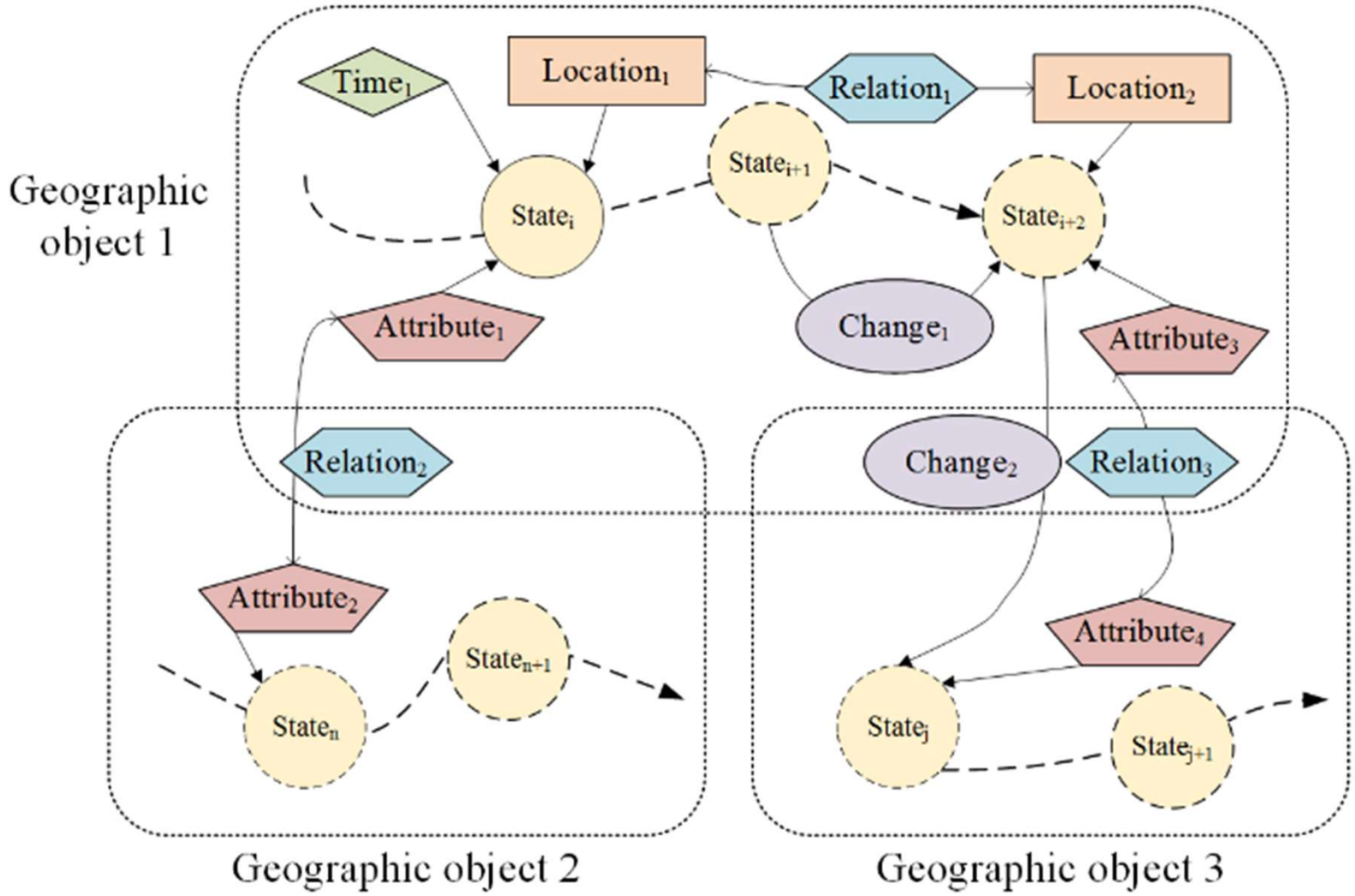
2.3 Knowledge graphs and Geographic Knowledge Graphs

- Where is it? → **location**
- What is it like? → **state**
- Why is it there? → **evolution**
- When and how did it happen? → **change**
- What impacts does it have? → **interaction**
- How should it be managed for the mutual benefit of humanity and the natural environment? → **usage**

Geo-KG (Shu Wang 2019)



Geo-KG (Shu Wang 2019)



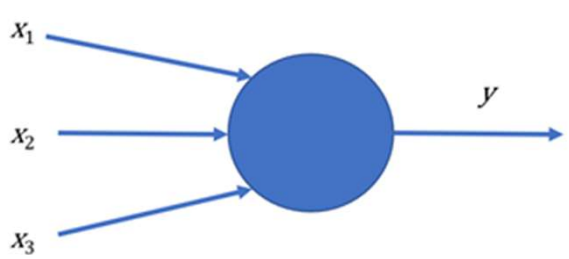
Prospect

- Interesting for the complete description of a place/district/precinct/territory/city
- Allowing spatio-temporal queries
- Navigating

- Challenges
  - How practically help planning

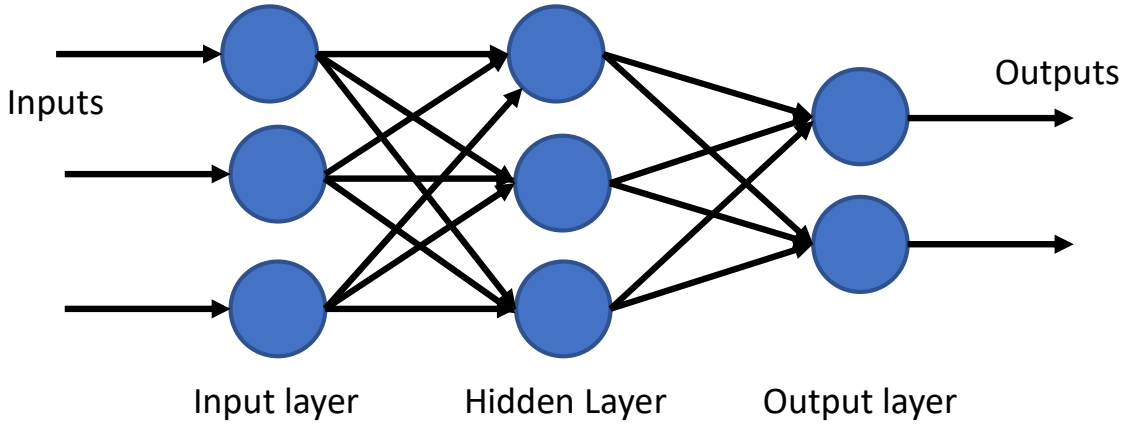
2.4 Machine Learning and Gen-AI

- Artificial neurons



$$y = \begin{cases} 1 \; if \sum_{i=1}^{i=n} w_i x_i \geq 0 \\ 0 \; if \sum_{i=1}^{i=n} w_i x_i < 0 \end{cases}$$

- Neuron networks



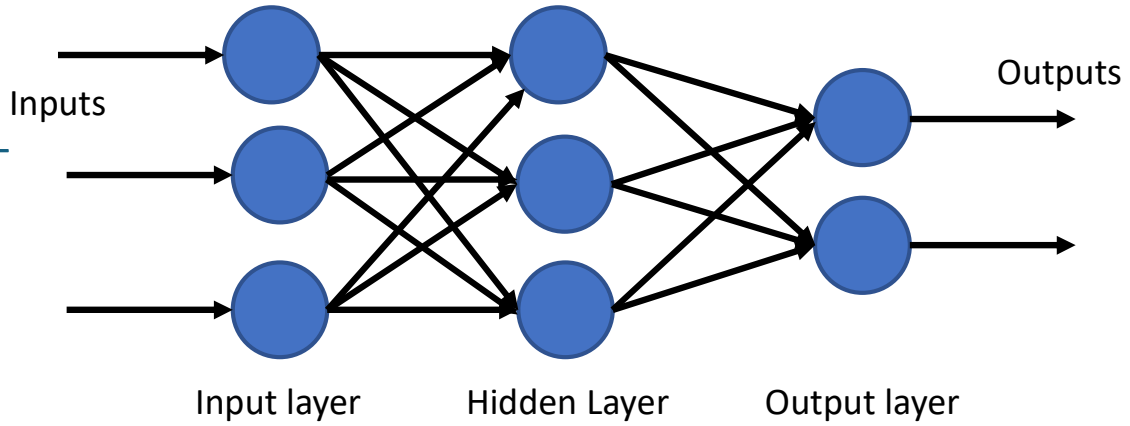
- Deep learning

- Generative AI

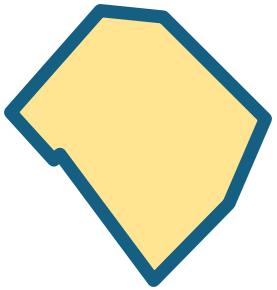
Application of deep learning

- Classification
- Clustering
- Predictions
- Domains: sat image processing, etc.

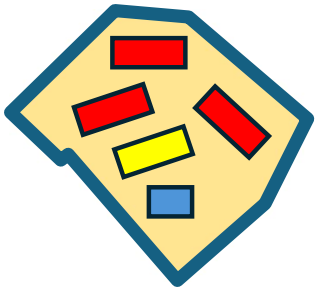
Learning
Ex: Ground plane



Query input
- Terrain shape
- Quantity of houses
- Other services



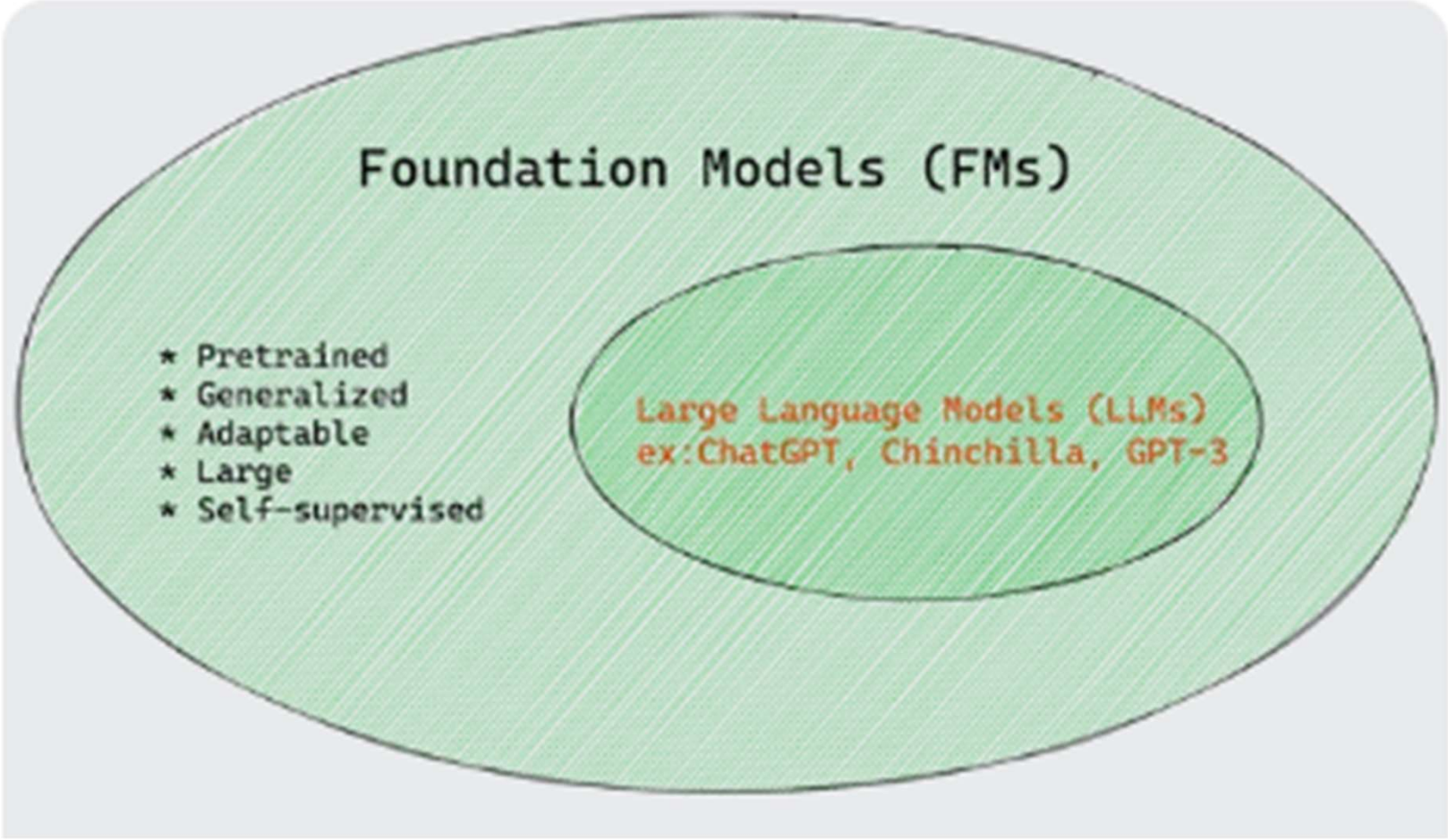
Query output
- Proposal of several ground planes



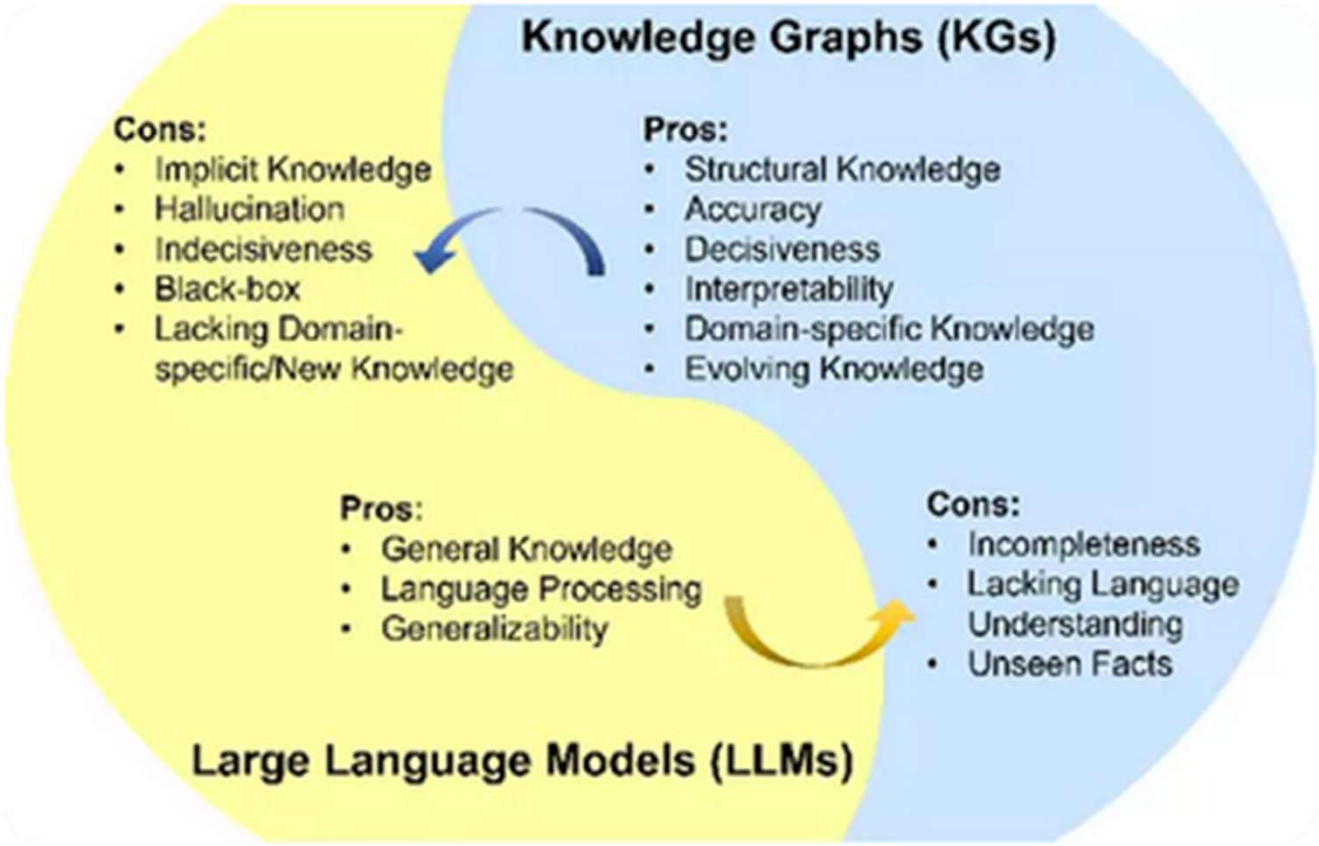
Foundation models

- Chatbots built on Large Language Models
  - Huge training text sets
  - Token (portion of a word)
  - Statistics between tokens
  - Well adapted for texts, images, etc.
- What about space?
  - Images ➔ aerial photos, sat images
  - Terrains
  - Cities ??

Foundation models



Unifying LLM and KG



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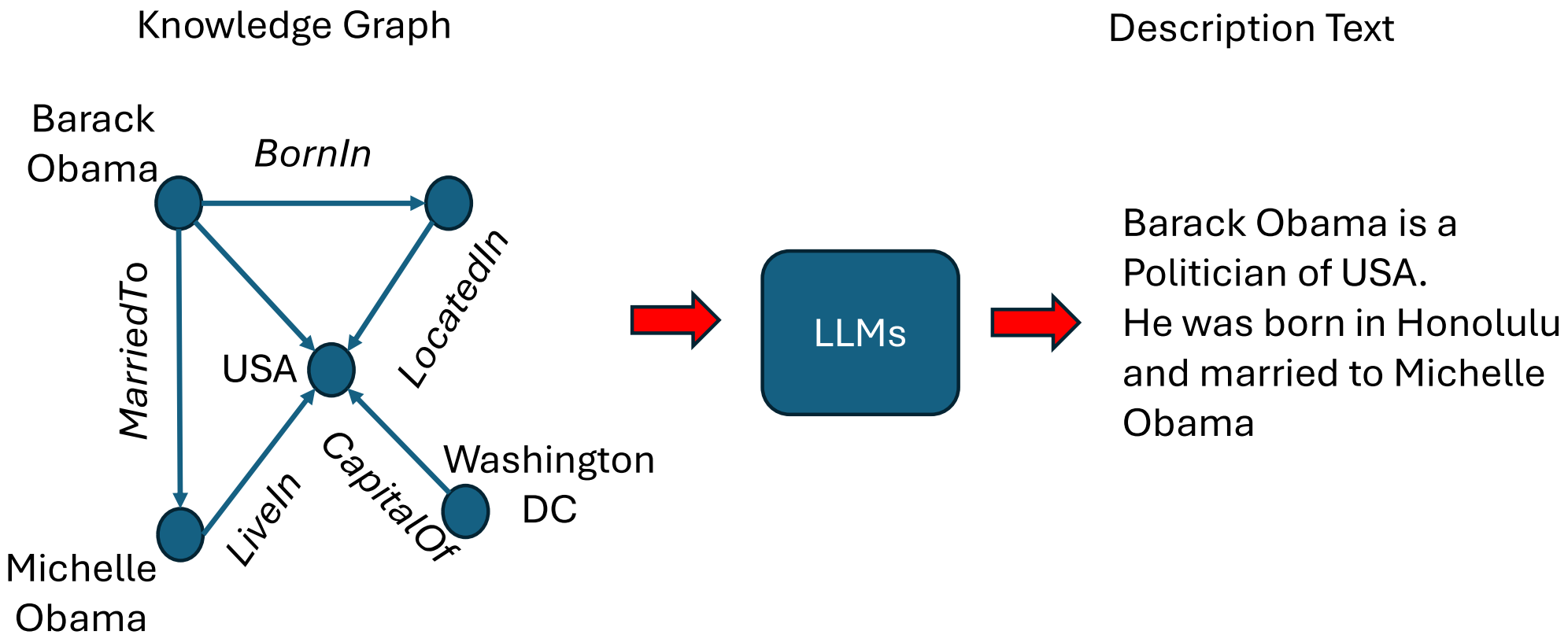


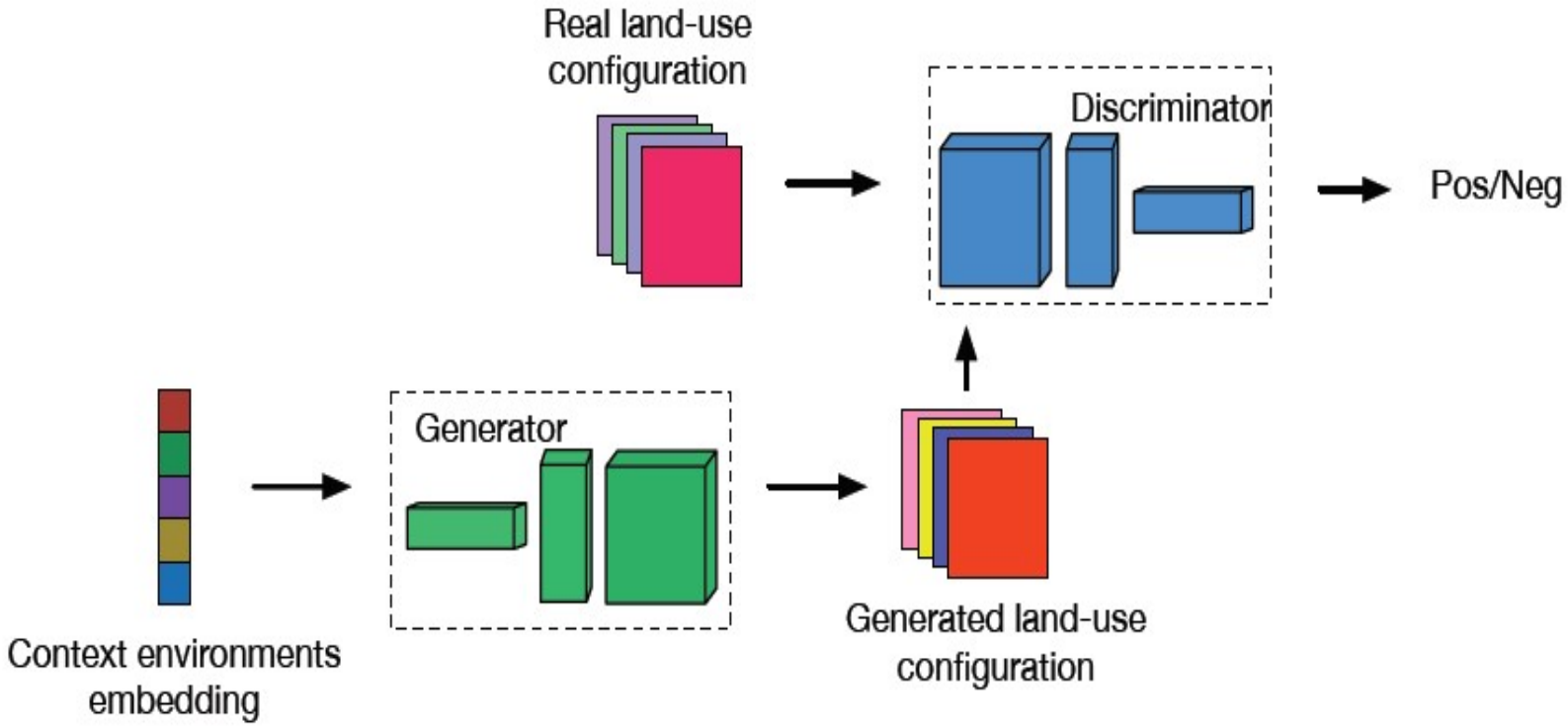
Possible roadmap

- LLM graph: relations between words/tokens
- Knowledge graph: relations between notions

- Geographic knowledge graph: relations between geographic objects

- Unifying ??

Automatic land-use configuration planner



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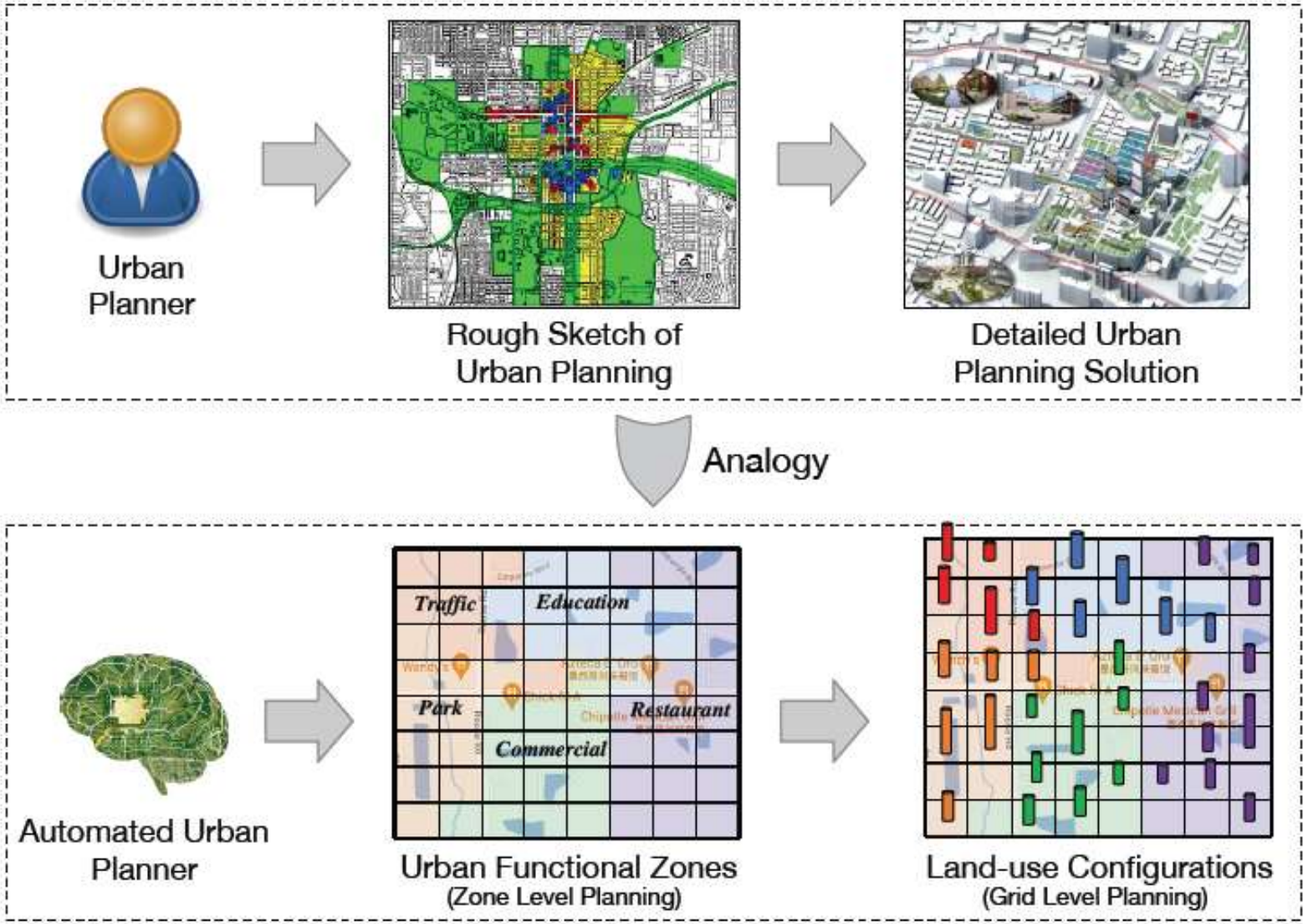
Approach from Dongjie Wang et al. (2023)

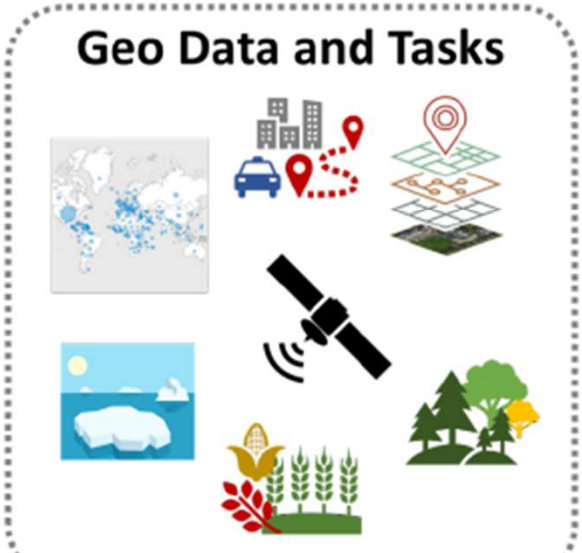


Foundation models (Xie et al. 2023)

Success Recipe:

- SSL aligned with real tasks
- Already human-generated data

- Broad population contribution



Do we have "geo"-equivalents?

- Loose task alignment
- Limited human annotations
- Spatial heterogeneity

Opportunities:

- Task-oriented
- Data innovation
- Bridge to LLMs
- "Language" tasks

Prospect

- Gen-AI/Geo- AI at its infancy
- Huge investments
- Few applications in smart cities
  - Applications of Gen-AI for generating answers to citizens' letters and e-mails

- Challenges
  - Applications to 2D and 3D spaces

2.5 Citizen participation

- Between NIMBYs and general interest
- Who is in charge of defining general interest?

- Yesterday: only information to the public

- To-morrow: decision in common

- Presently: concertation between local authority and citizens

After YOUSEF KHALILI, Tonomos

CCO / President Professional Services Unit

Prospect for participation

- Creating new participation procedures
- How to synthetize divergent opinions between citizens and stakeholders?

- ➔ Territorial intelligence
- Mixing AI and human collective intelligence

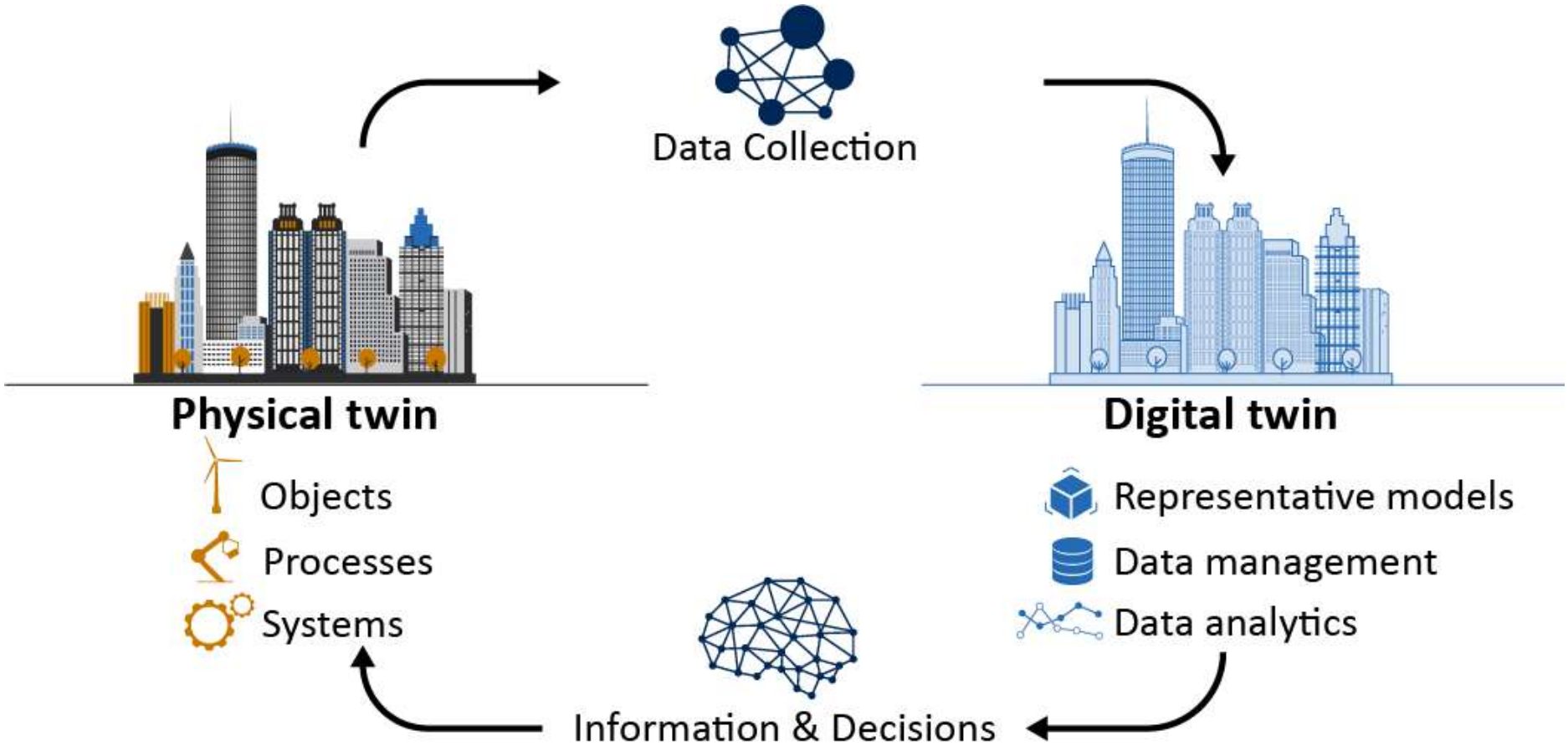
2.6 Digital twin cities

- A digital twin of a city is a virtual representation of the city's physical assets, processes, and systems. It is created using data, data analytics, and machine learning to help simulation models that can be updated and changed in real-time as their physical counterparts change
- Scope
  - Awareness
  - Response
  - Prediction by simulation

Origin

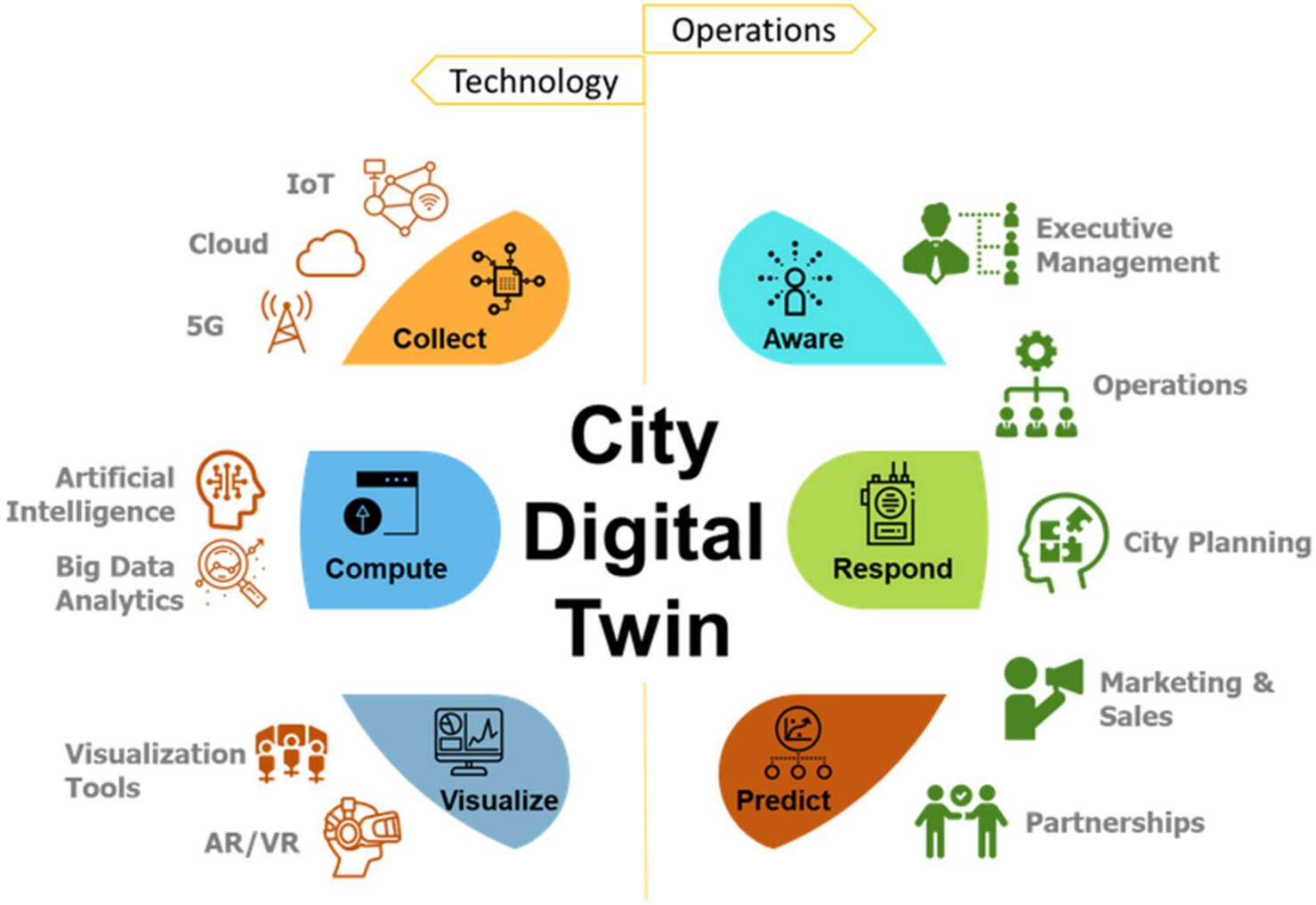
- A digital twin consists of three crucial parts: physical products, virtual products, and the connections tying them.
- A digital twin fully describes a potential or actual physically manufactured product from the micro atomic level to the macro geometric level (Grieves and Vickers, 2017).
- Digital twin technology deeply integrates hardware, software, and IoT technologies to enrich and improve virtual entities.

Relationship between a city and its digital twin



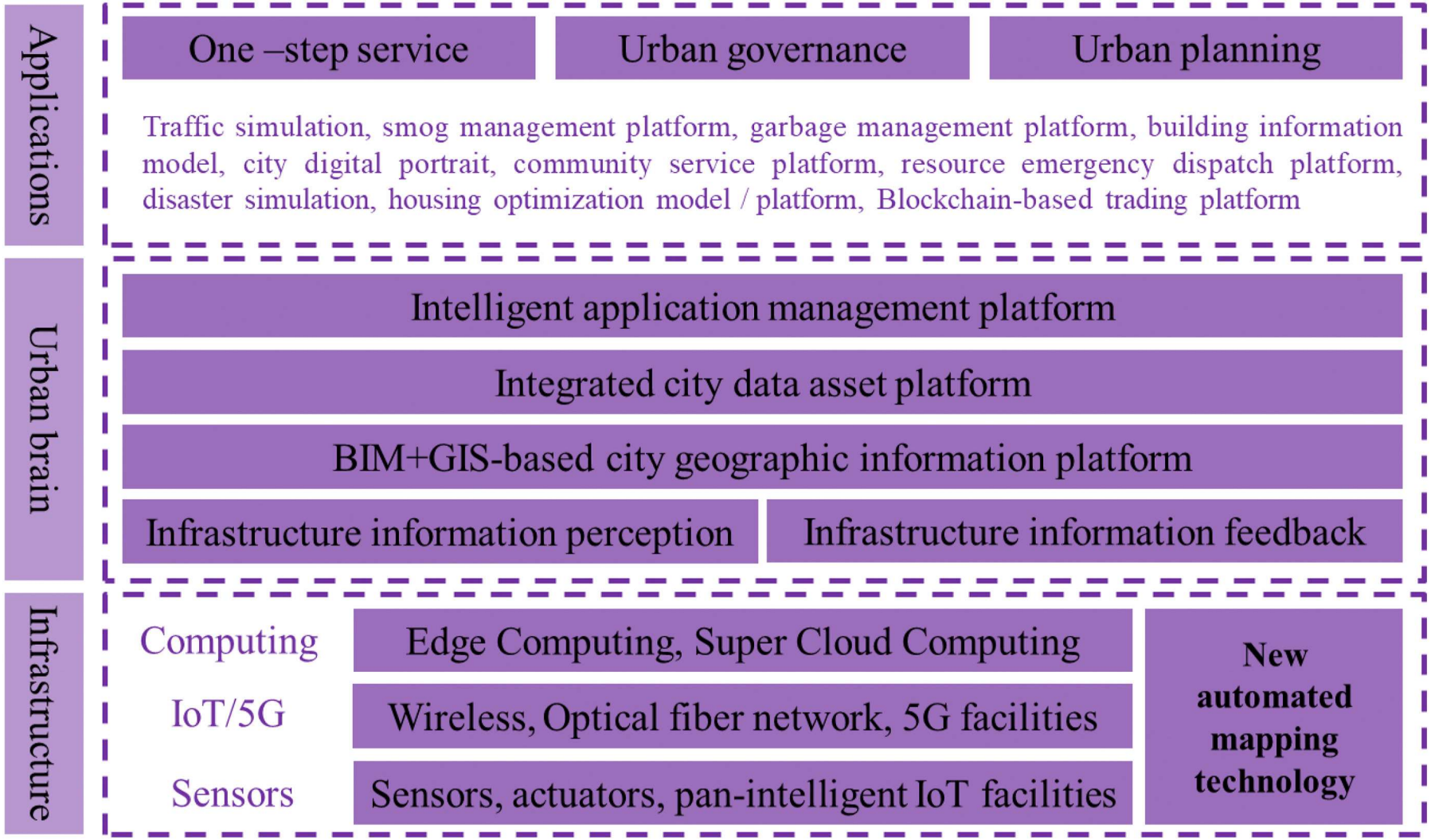
Sources: GAO; ladoga/stock.adobe.com. | GAO-23-106453

City Digital Twins: Benefits and Technology Enablers



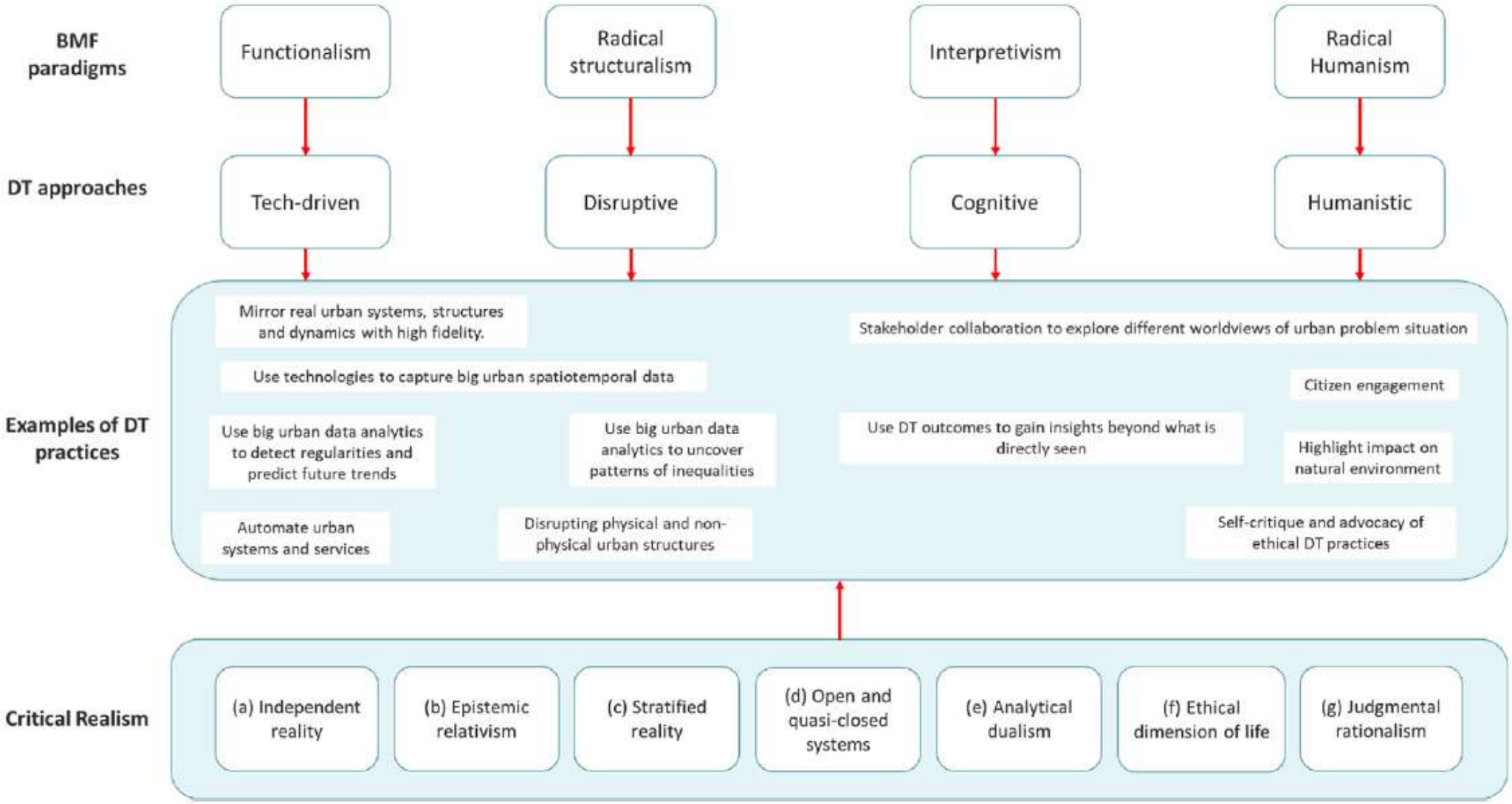
Source: IDC, 2020

Composition of digital twin cities. According to Tianhu Deng



The pluralism of digital twins for urban management: Bridging theory and practice

Ramy Al-Sehrawy *, Bimal Kumar, Richard Watson



Prospect

- Few cities have already developed their own digital twin
- Definition of objectives

- Challenges
  - Cost of maintenance
  - What could be the benefits?

3 – So what?

- Many novel applications everyday
- New technologies can appear
- Disruption
- What could shape the future ?
  - Balances between
    - ICT increase in lots of domains
    - Increase of ICT-based GHG and environment
    - Freedom – social control
  - Towards digital sobriety
  - Augmented humans
  - Territorial intelligence

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