



# Cartography M.Sc.

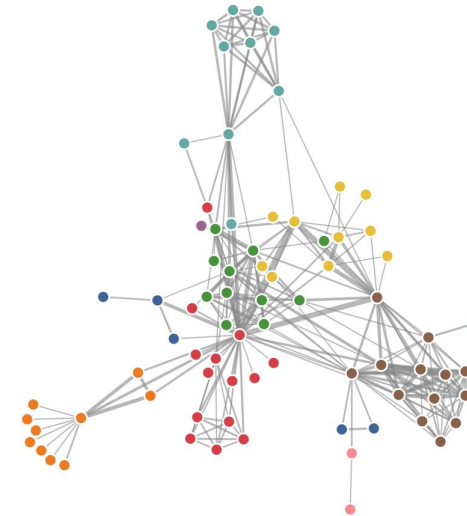
## Understanding Relevance in Maps through the use of Knowledge Graphs

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Advisors :

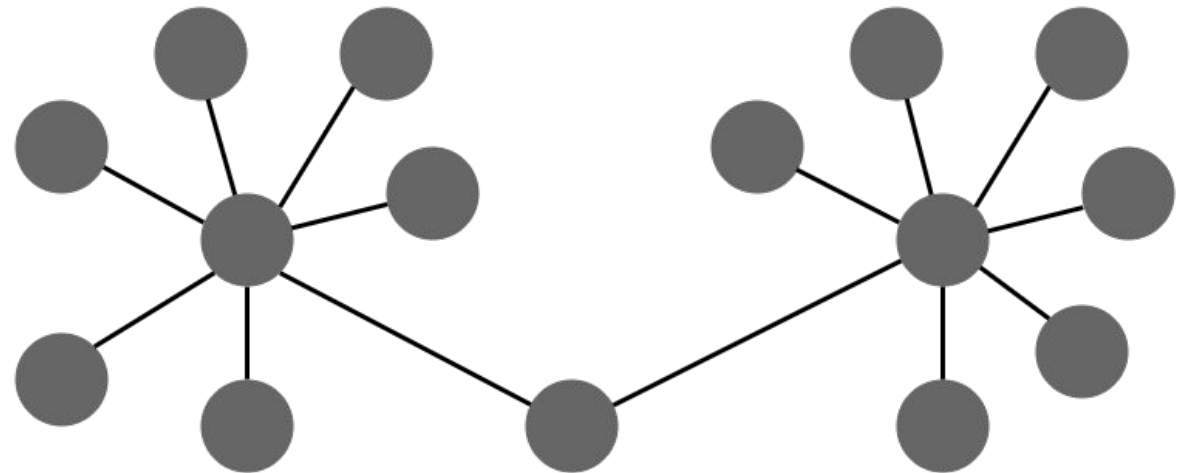
Dr. Georg Gartner , TUW

Dr. Markus Jobst , BEV



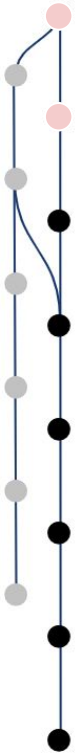
# Outline

- Relevance
- Types of Relevance
- Relevance in Cartography
- Knowledge Graphs & Knowledge Networks
- Research Questions
- Methodology
- Results
- Discussion / Conclusion
- Questions



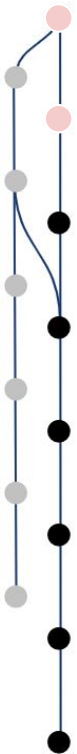
# Relevance

- The basic inner and outer human cognitive notion in constant use when we have a present matter. [Sar96b]
- Relevance is an action to **access, filter, infer rank, accept, reject and classify information**. [Sar96b].
- Relevance is still a not well-defined concept and it subdivides itself into many types [SMR15].



# Types of Relevance

- **Psychological relevance:** How people use the information and how their views change after such information has been received [Wil73].
- **Logical relevance:** The relation between an item of information and a particular individual's personal view of the world and his situation in it . A piece of information holds its **weighted relevance** proportionally to the probability of confirmation of the conclusion.[Wil73][Coo73]
- **Situational relevance:** based on situational concerns such as **preference, interests, time, degrees of relevance, and completeness.**[Wil73]



# Relevance in Cartography

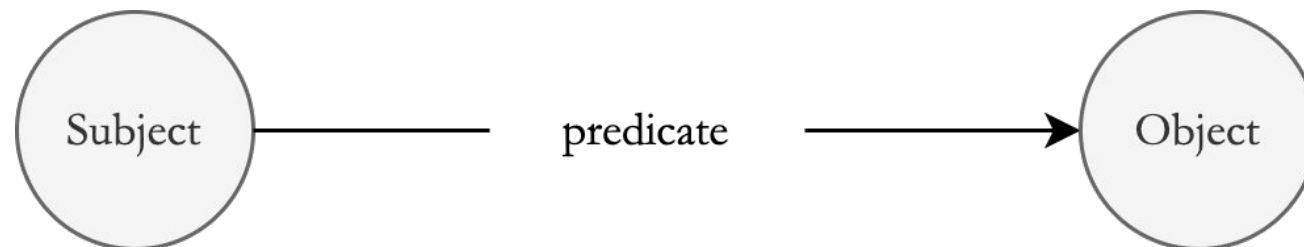
- **Geographical relevance:** all entities in a geographic space have a quality attribute. The quality is the **relation** between the **representation** of such an **entity** and the use **context**. [RDS11]
- Geographical relevance criteria
  - *depth*
  - *scope*
  - *specificity*
  - *availability of information*
  - *sources of information*
  - *effectiveness*
  - *accuracy*
  - *curiosity*
  - *validity*
  - *clarity*
  - *currency*
  - *tangibility*
  - *reliability*
  - *quality of sources*
  - *accessibility*
  - *novelty*
  - *familiarity*
  - *variety*
  - *co-location*
  - *spatio-temporal proximity*
  - *topicality*
  - *association*
  - *verification.*

[dSR12]/[RDS11]/[IS98]



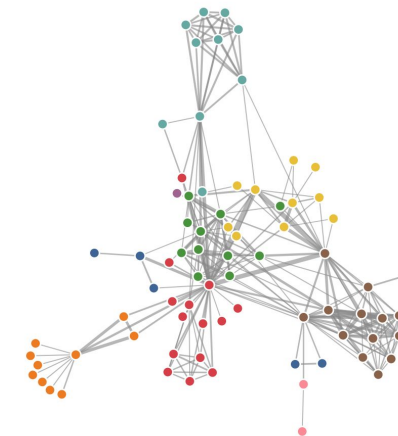
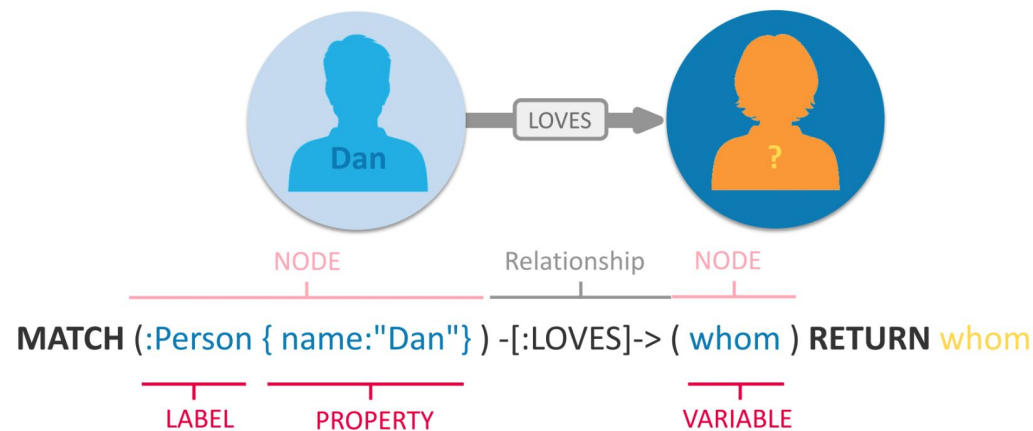
# Knowledge Graphs & Knowledge Networks

- Ontologies are the description of concepts and relations using deterministic structures. The construction of a determined semantic space is known as a domain. [MHC+ 22]
- Knowledge Networks(KNs) stem from decentralized linked data [Biz09]
- Statements in context can be expressed in the form of a triplets (h,r,t), the head entity (i.e., subject), the relation (i.e., predicate), and the tail entity(i.e., object). **SPO model**[MHC+22]



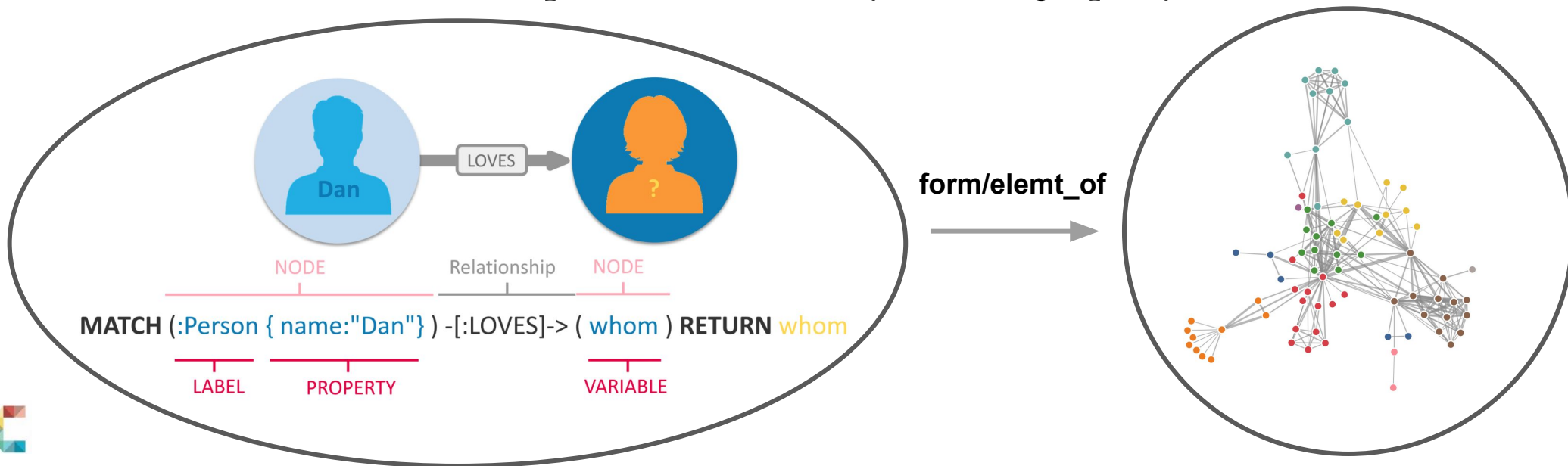
# Knowledge Graphs & Knowledge Networks

- Knowledge can be **surrogate** by a representation[DSS93], which helps us reason knowledge. In any given **knowledge graph** we can use a Node, Relationship structure. (**SPO** model)
- When various SPO triplets combine they form a graph system.



# Knowledge Graphs & Knowledge Networks

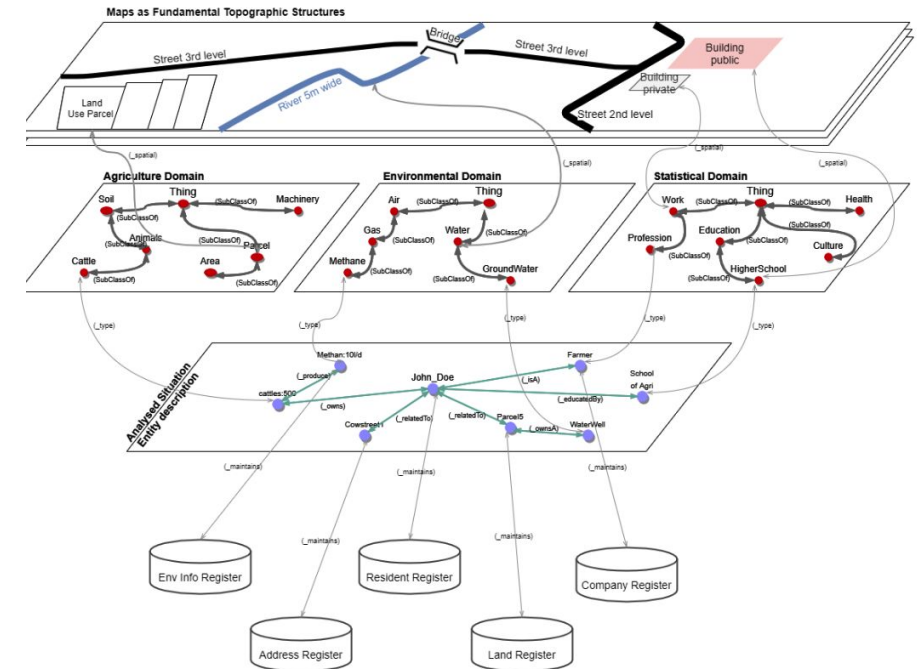
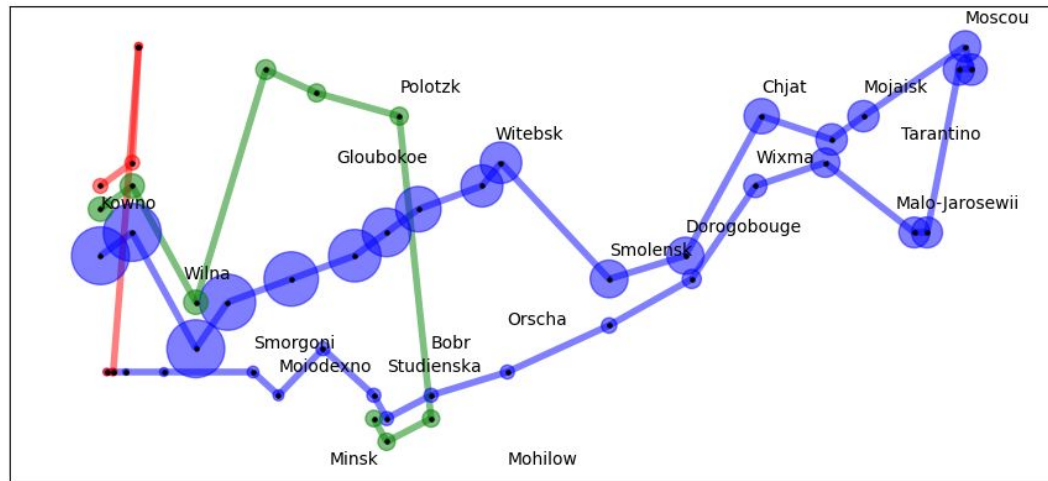
- Knowledge can be **surrogate** by a representation[DSS93], which helps us reason knowledge. In any given **knowledge graph** (KG) we can use a Node, Relationship structure. (**SPO** model)
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# KNs & KGs Cartography

- Three dimensions have been presented in KN cartography: thematic, topographic, and connection. [JG22]
- Narrative cartography (Mental semantics) [KF19] [MHC+22]
- Navigation (LBS)



\*\*Figure 5.1: Napoleon's Russian Campaign with NetworkX [HSS08]

\*\*Jobst, M., & Gartner, G. (2022). Accessing Spatial Knowledge Networks with Maps.

# Technologies [Graph Databases - GDBMS]

- GDBMSs which operate on a node-edge structure
- Query Languages
  - All operate under pattern matching and pattern navigation [FB18] [Akh17]
    - SPARQL [AllegroGraphDB]
    - Cypher [Neo4j]
    - Gremlin [OrientDB]
- Brazil's river network has been migrated from an RDBM to a GDBM to calculate upstream catchment areas. [DM16]
- Augmented reality navigation systems [ABG+15]

[RA97]

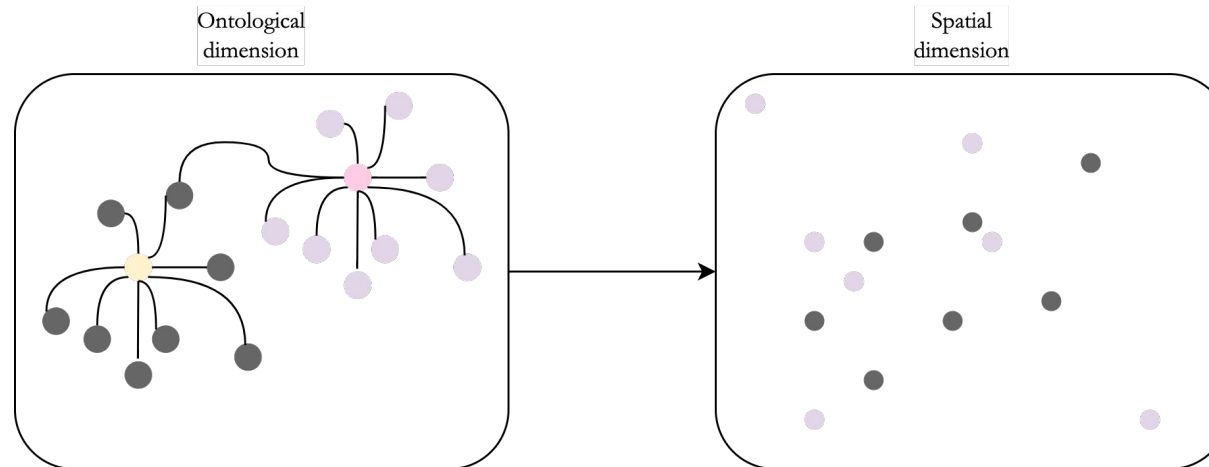


# Research Questions

- Does a **web-based map tool**, which contains a **linked ontological** and **spatial dimension**, enables **geographical relevance criteria to be identified** within in the ontological and spatial dimension?
- Which criteria from geographical relevance can be asserted from a web-tool which shows linked ontological (knowledge graphed space) and spatial dimension (map)?

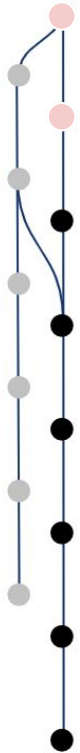
# Hypothesis

- The connection of the ontological and spatial dimensions, while displaying both spaces and adding based event interactive filtering features, will allow us to explore new ways to understand relevance related to spatial features.



# Contribution

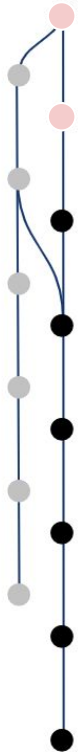
- a. Explore the use and combination of knowledge graphs in maps.
- b. Through the linkage and combination of these dimensions, see the unseen and bring relevance forward.
- c. Proof of concept that can be built upon to explore relevance that originates from the ontological space.
- d. Popular-themed cartography focuses on layered visual classification, where ontological relations can be overlooked.
- e. Understand the relevance in the ontological dimension and project such relevance into the spatial dimension.



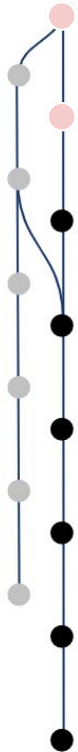
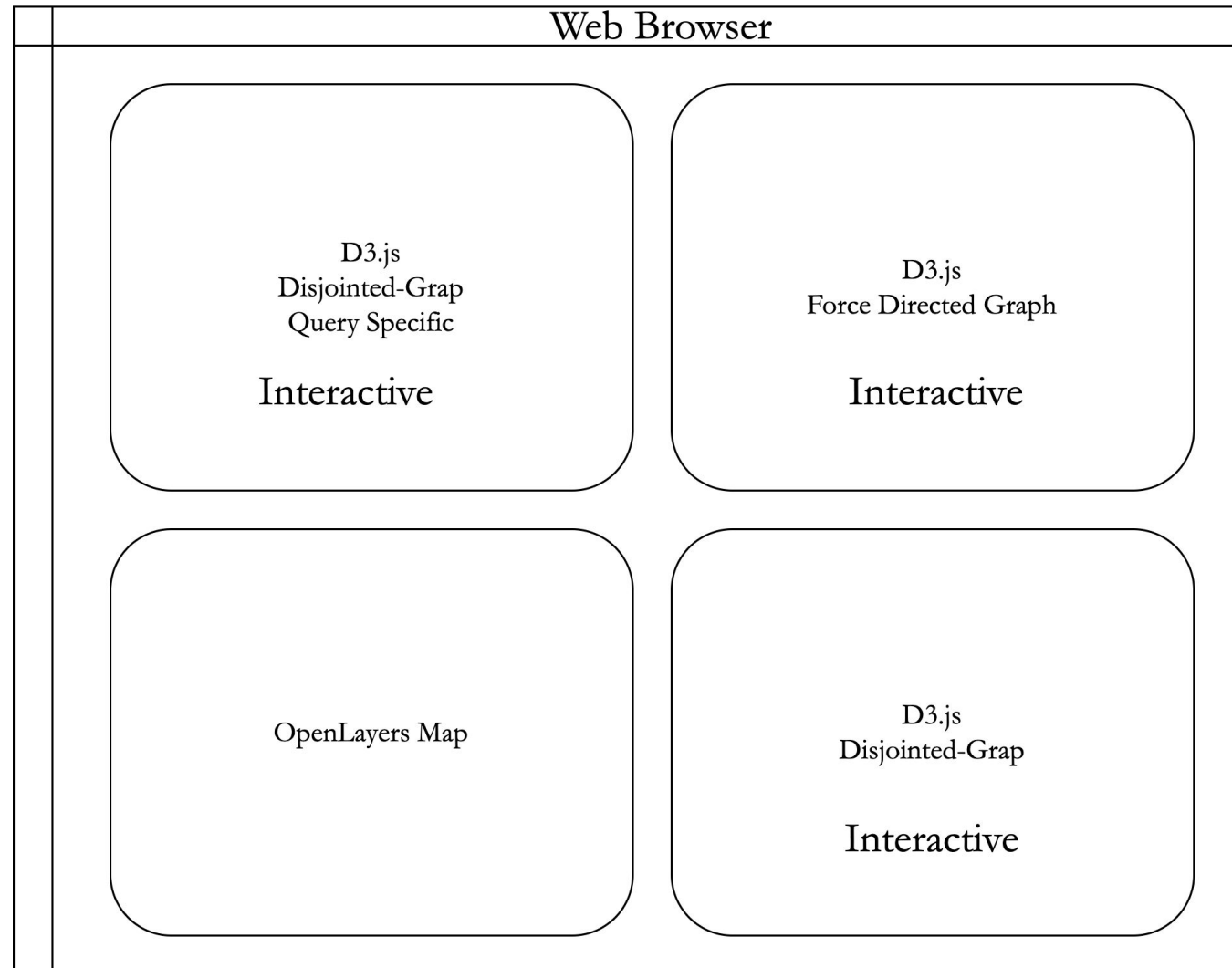
# Methodology

*SeMaptics* design follows a **conceptual design** and the 4 main steps of graph visualization. [GRMSOG18]

- a. Data retrieval
- b. Building
- c. Calculations
- d. Layout and rendering




# Methodology [Conceptual design]



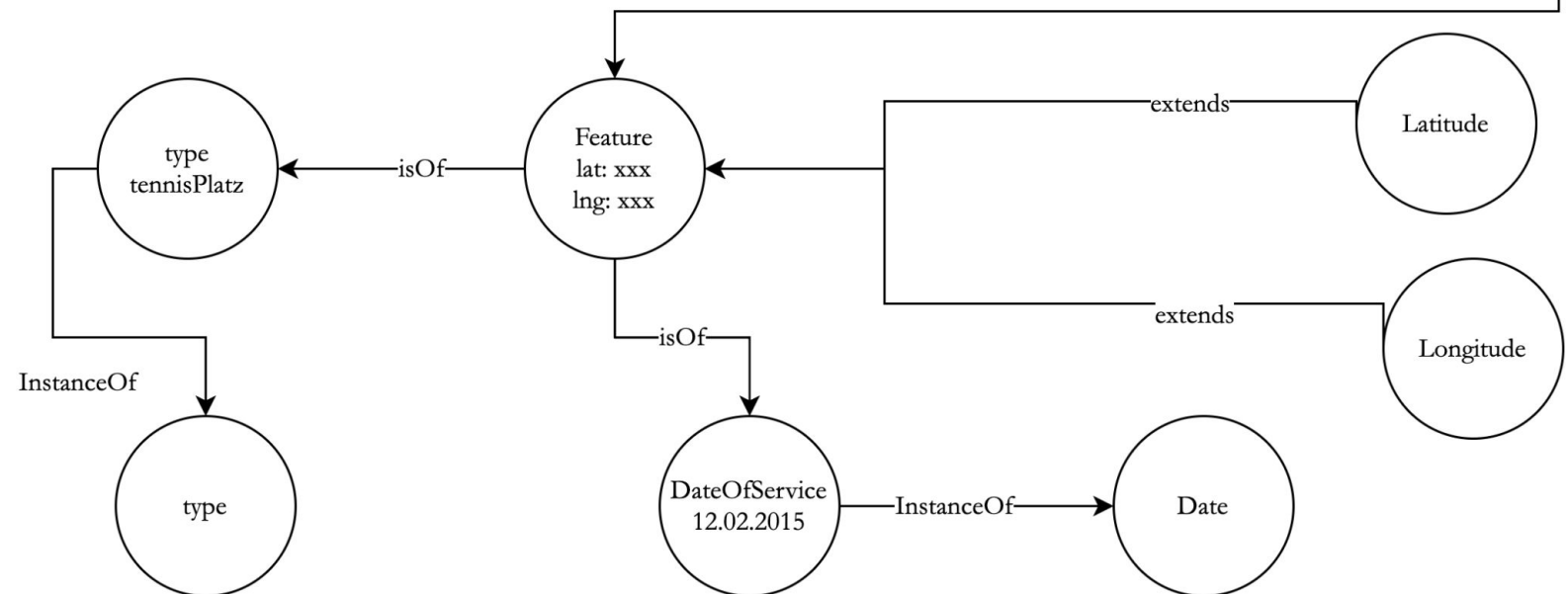
# Methodology [Data retrieval]

- Inspired on Nickel (2016) in his knowledge graph building methodology. [NMTG16]

	id	(...)	type	DateOfService	...
Feature	34364	(...)	TennisPlatz	12.02.2015	...

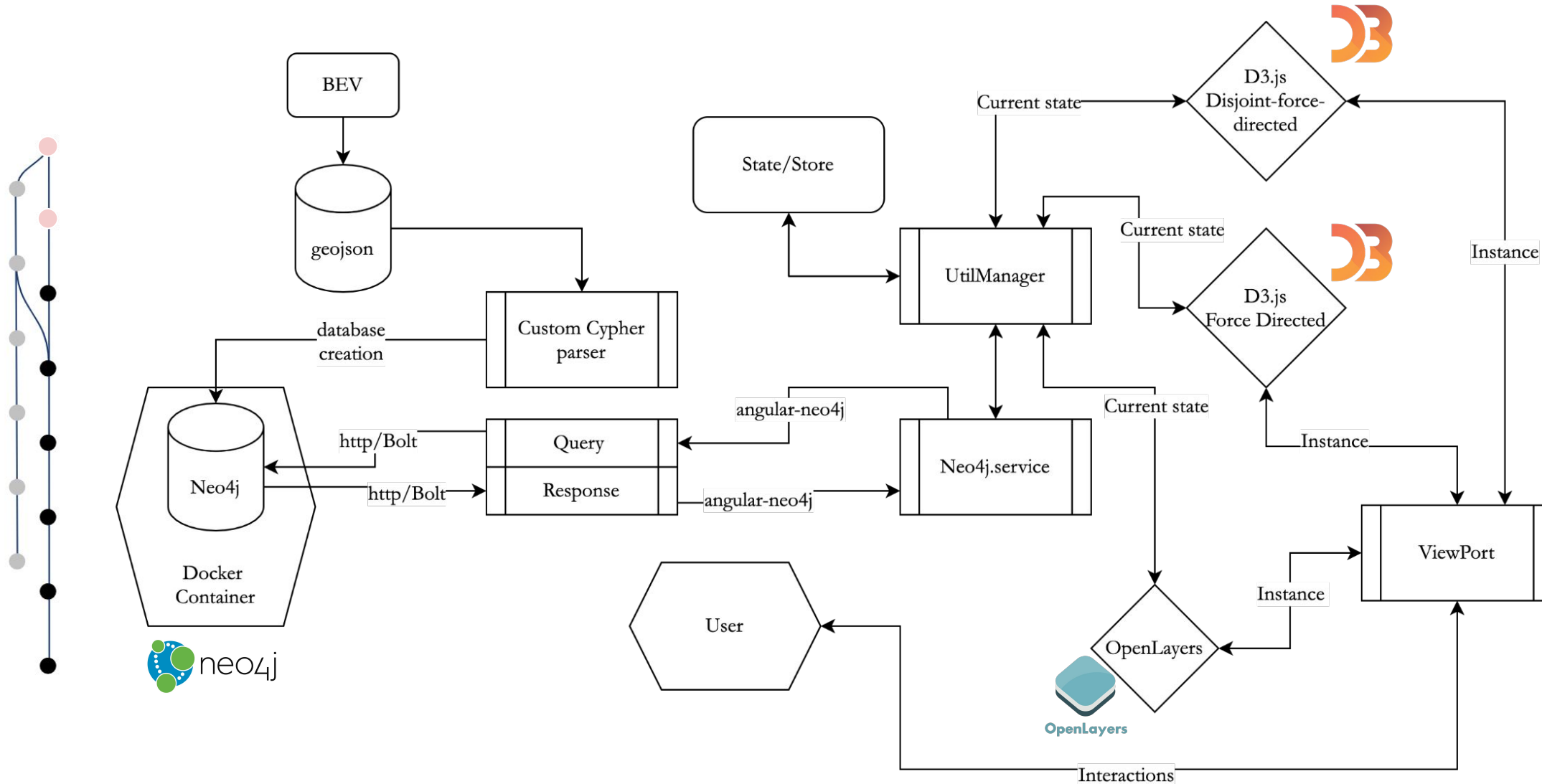
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(BEV)

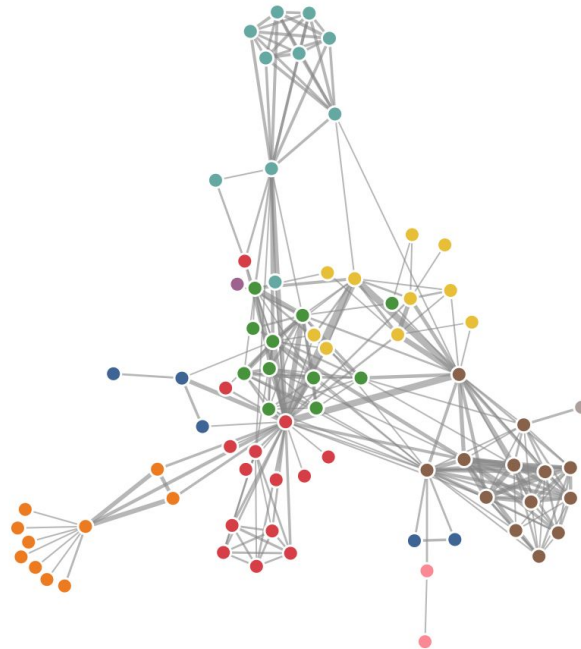
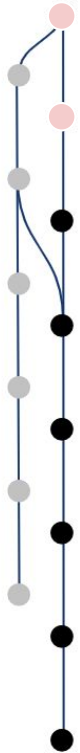




# Methodology [Building/Calculations]

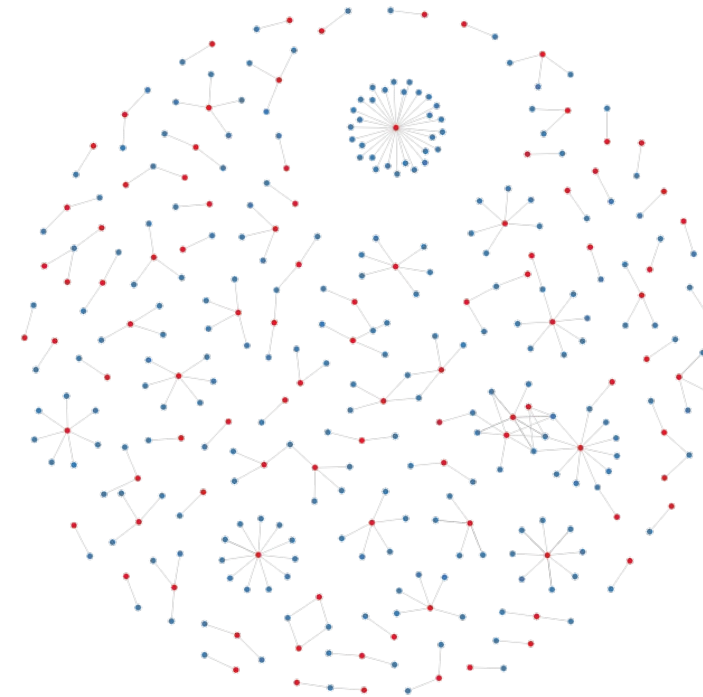


# Methodology [Layout and rendering]



Force-Directed

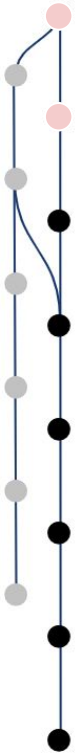
- ✓ Planarity
- ✓ Aesthetic rules
- ✓ Size predictability
- ✓ Time complexity[Her00]



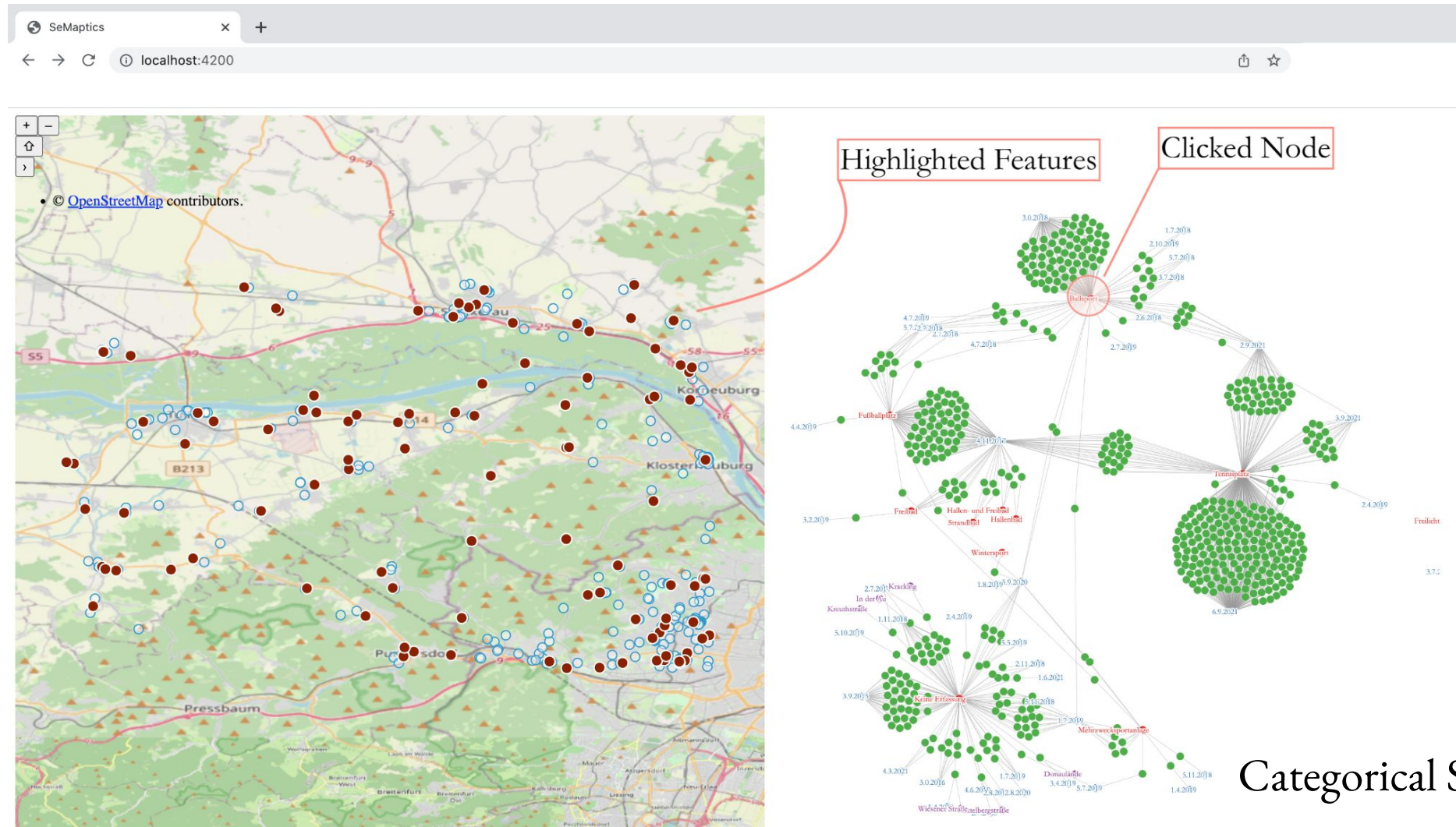
Disjoint-force-directed

# Results

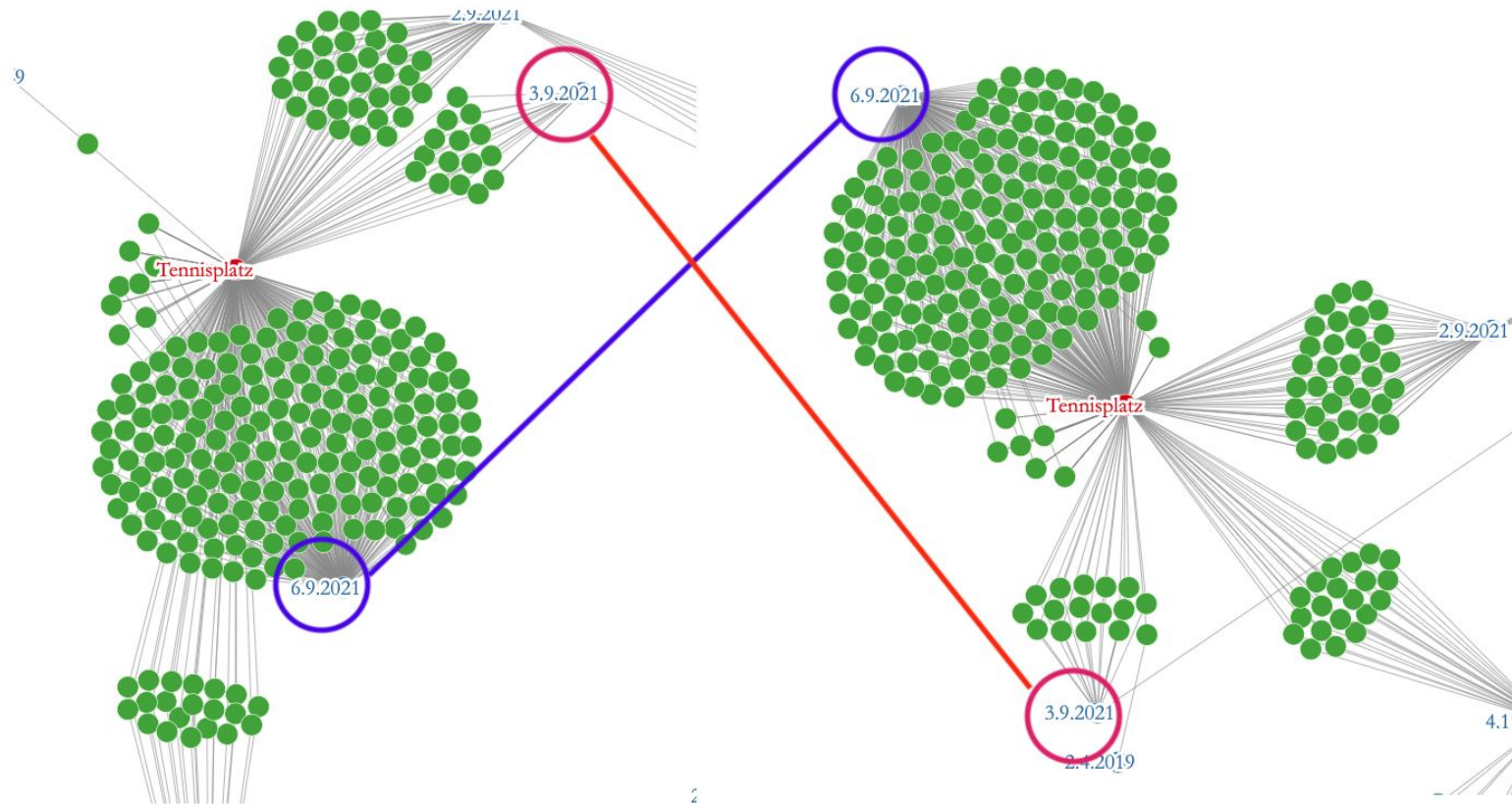
- BEV dataset is a 563 node graph that contains 528 feature nodes, 10 categorical nodes and 25 date of service nodes and 4 street name nodes.
- Demo



## Results [Interactions]



# Results [Interactions]

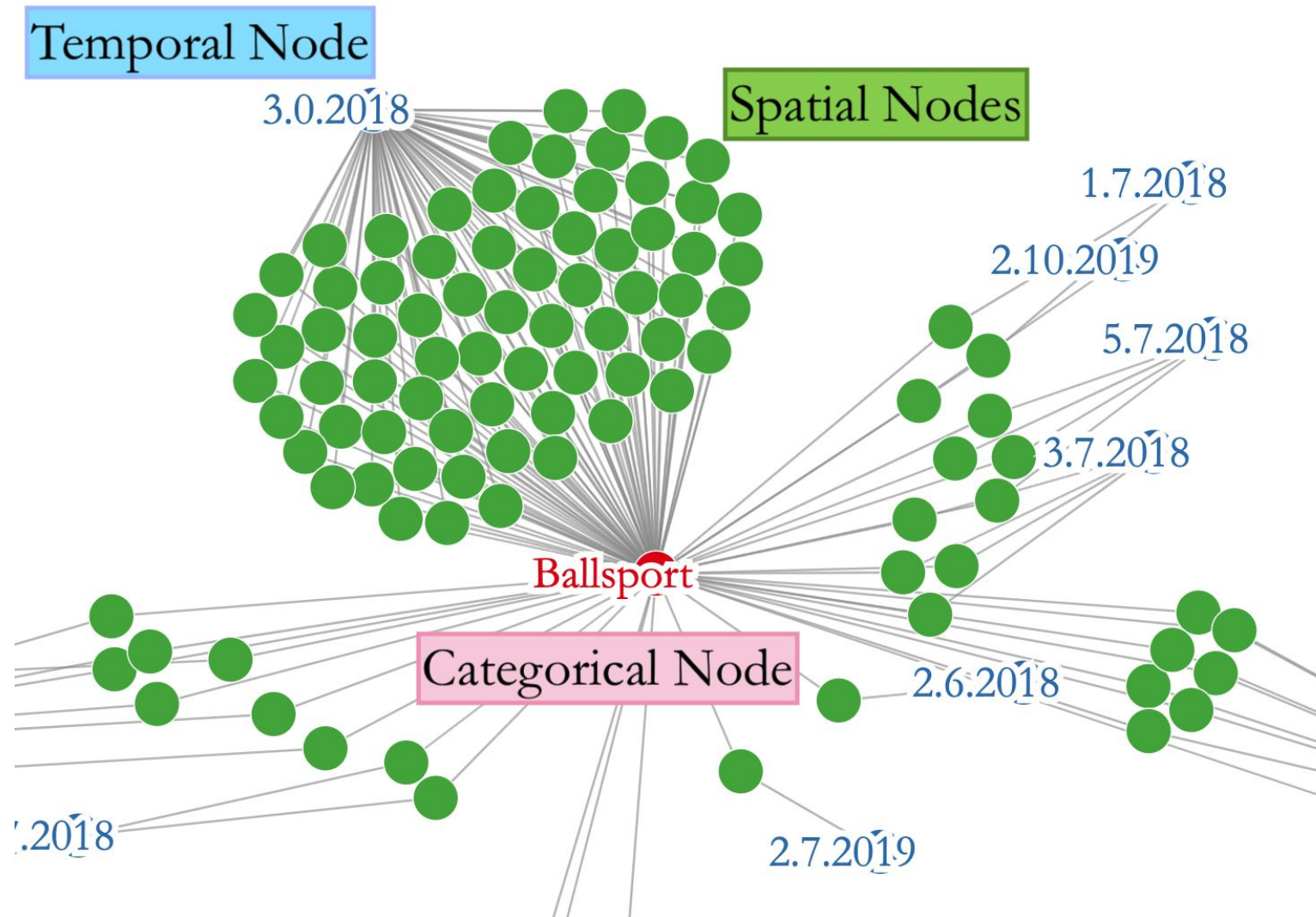


Before Drag

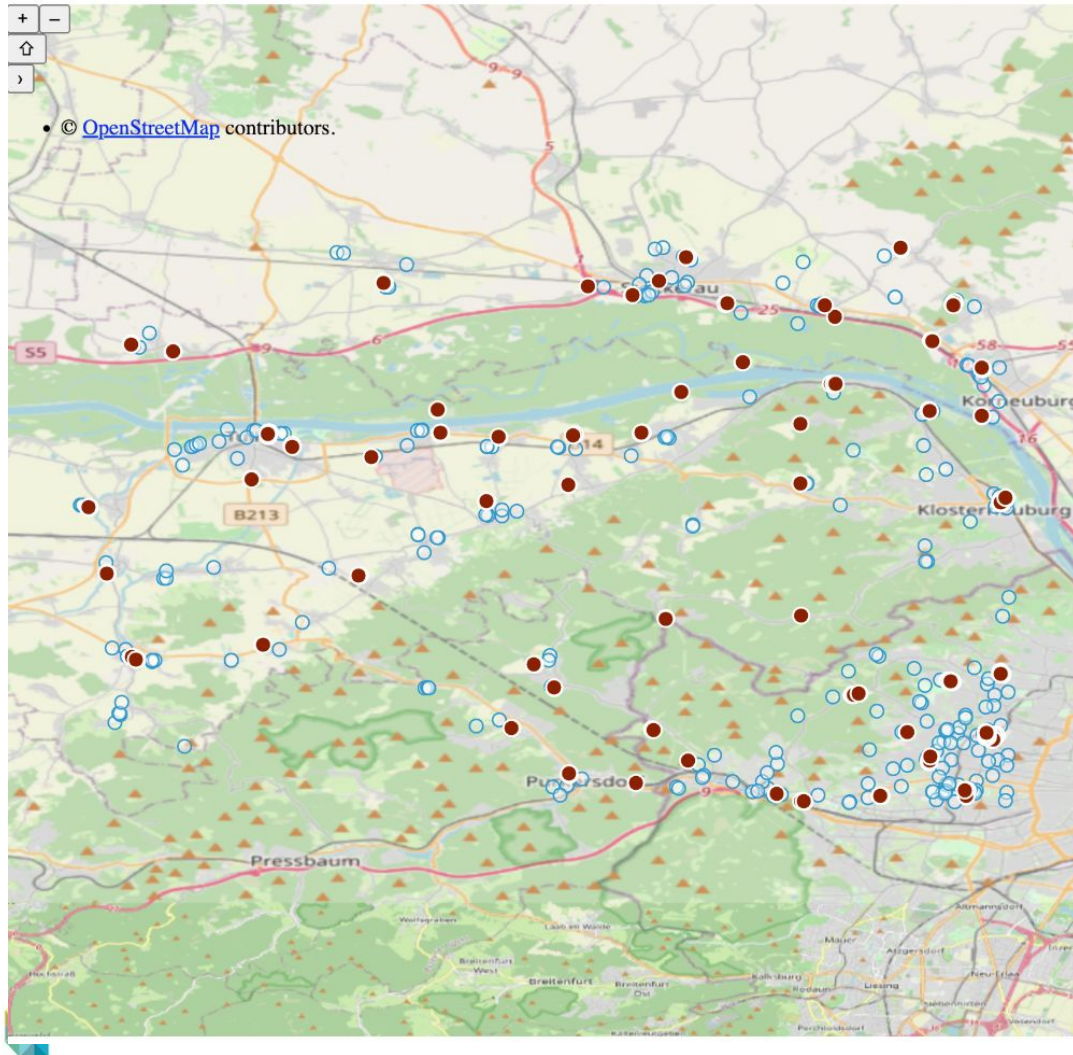
After Drag



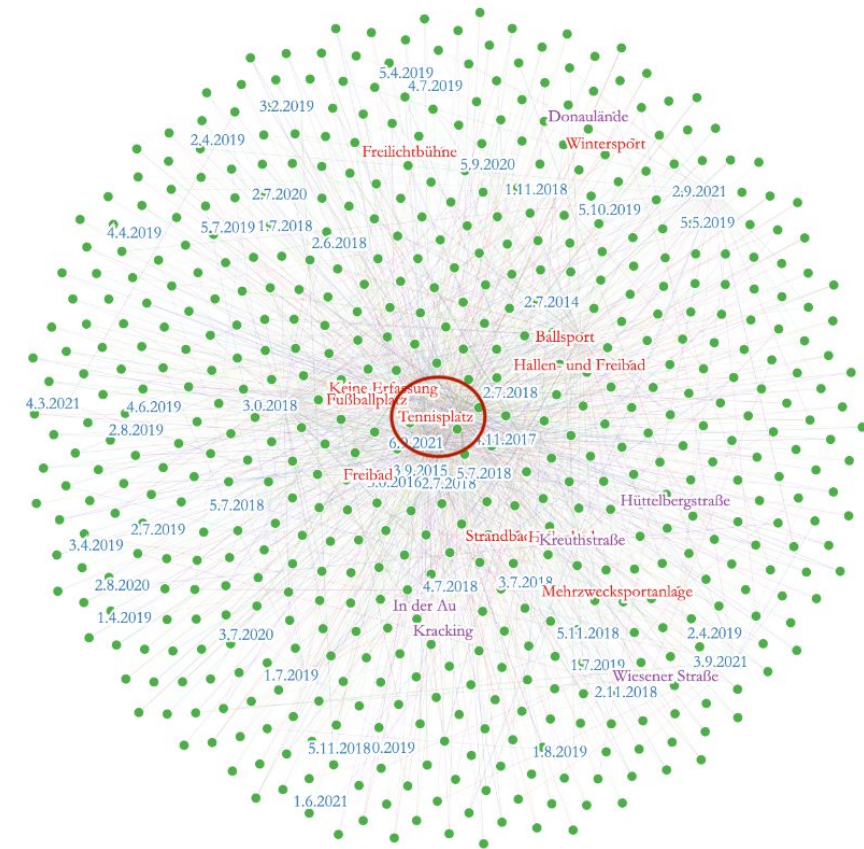
# Results [Node types]



# Results [Force Directed]

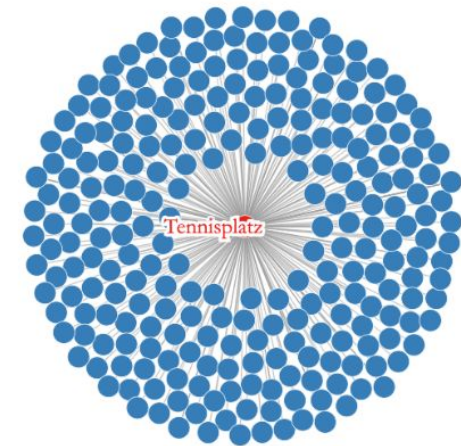
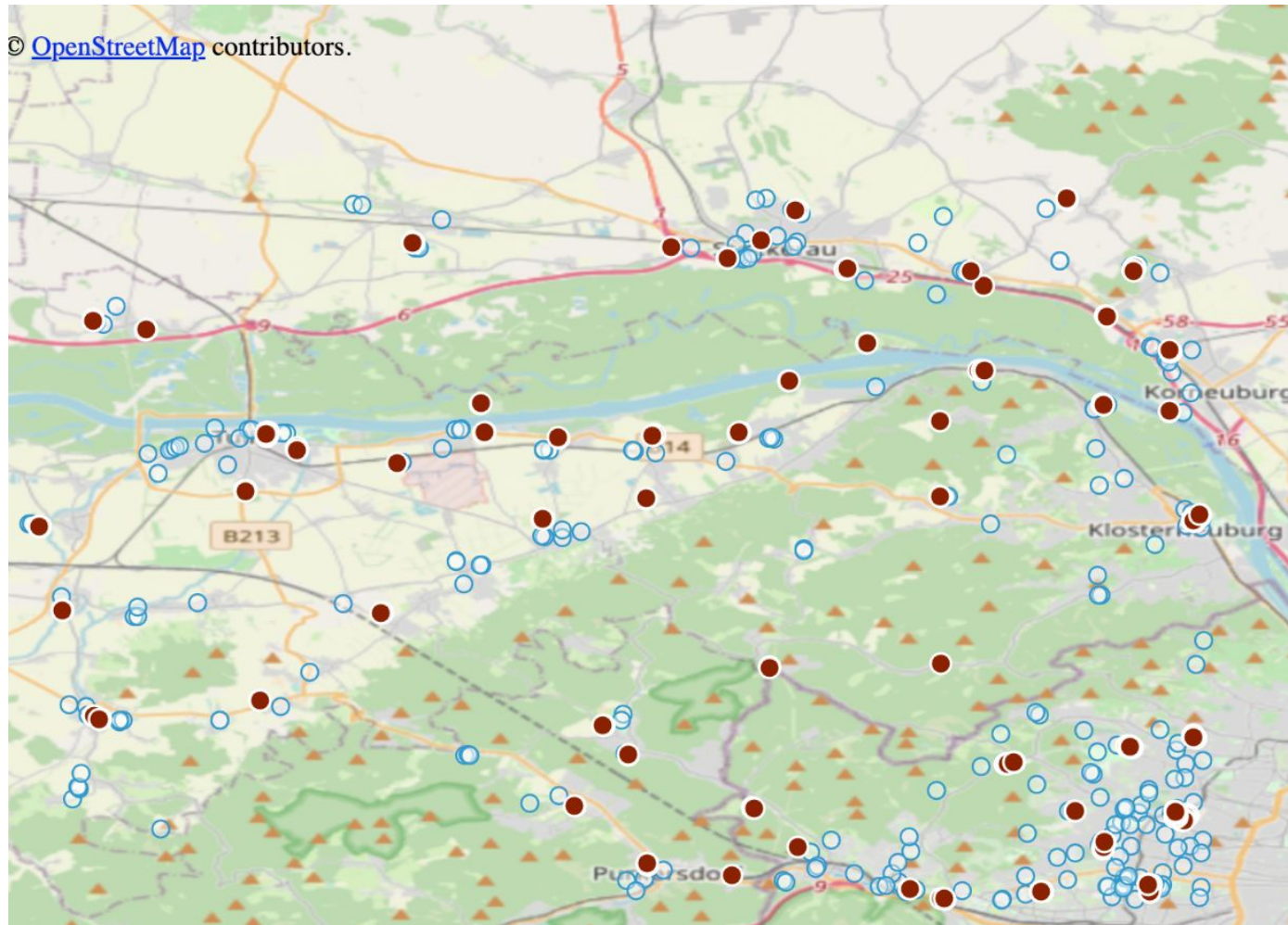


Tennisplatz - Categorical Node





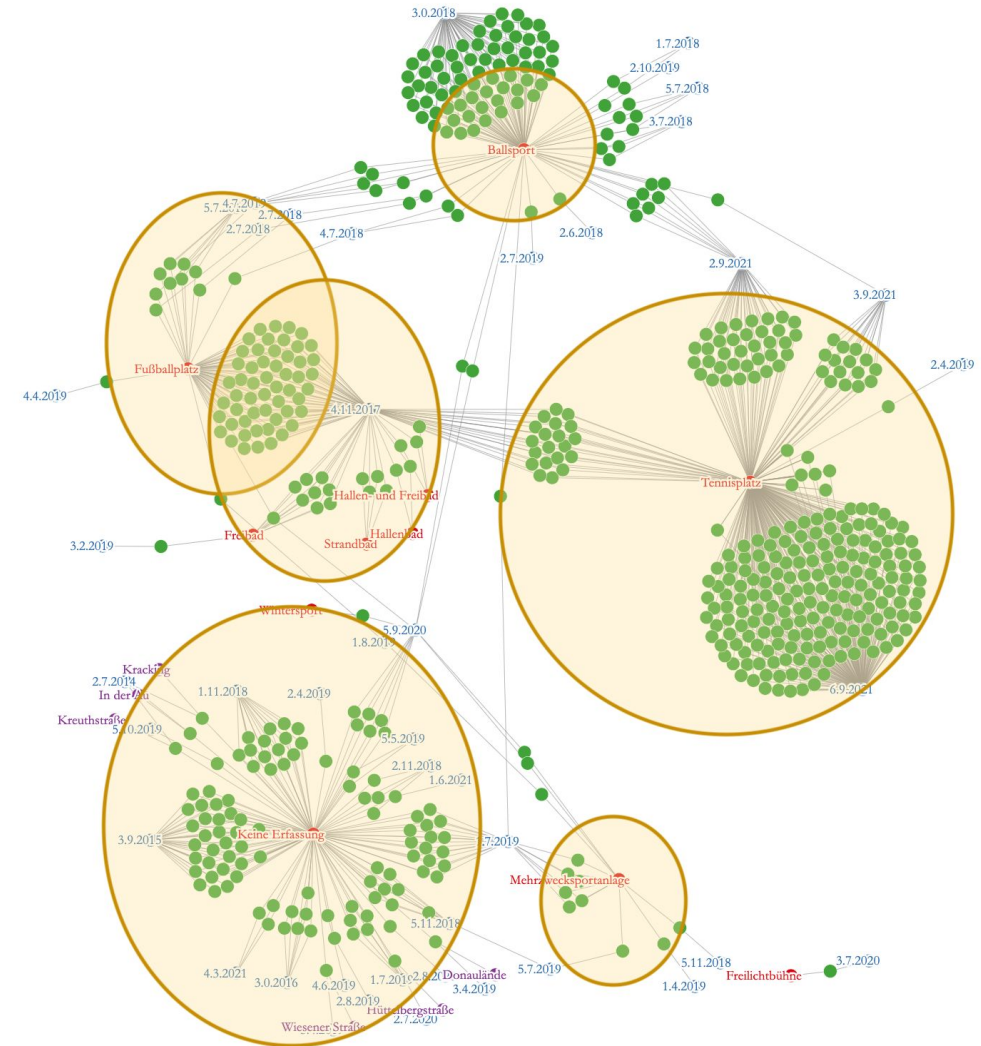
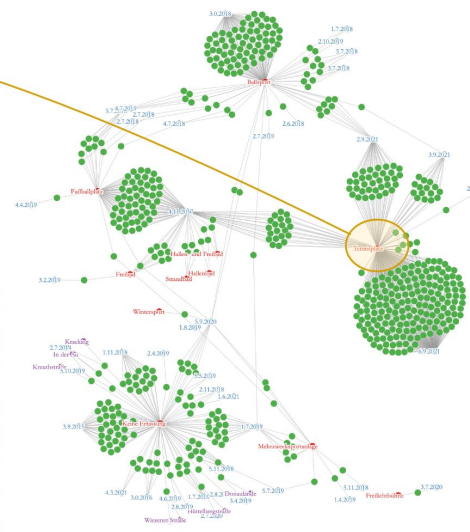
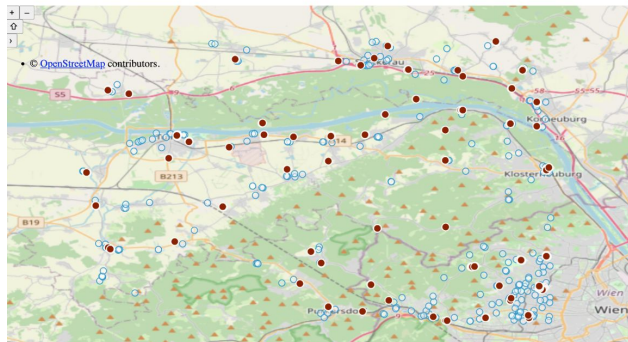
# Results [Graph Isolation]





# Discussion [Hidden Patterns]

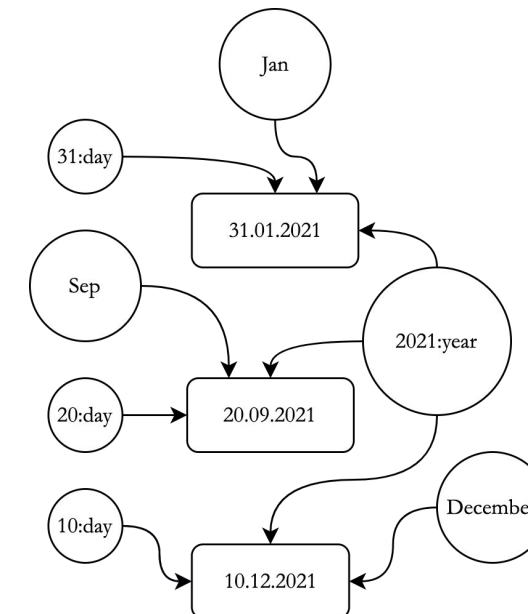
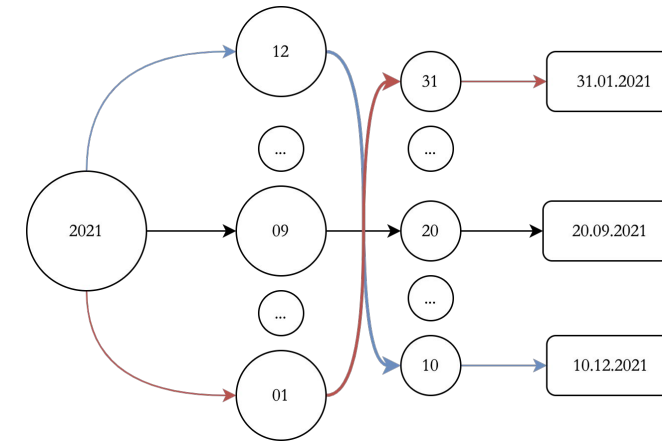
Ontological groups selected



Ontological groups (clusters)

# Discussion

- Ontology definition
- Data harmonization
- Query language selection
- Graph visualization selection
- Interaction design



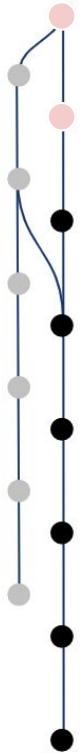
# Discussion

- *SeMaptics* has a role in **psychological relevance**, since every time the user interacts and explores spatial entities on the graph new questions arise that relate to the what, when, where, and who.
- Geographical relevance evaluates the object within the information system [dSR12] and *SeMaptics* allows for a visual evaluation of node relevance on any loaded information space. This includes a **dynamic state** which changes with any given **interaction**.



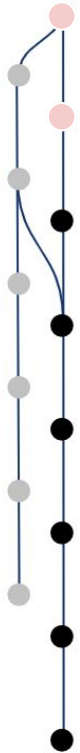
# Conclusion

- The visual and state connection of both the ontological and spatial dimension with event-based interaction allows us to explore hidden patterns and allows for **efficient semantic reads** where relevance is present.
- Mapping ontological spaces require to have a **discrete concept** definition. Existing vocabularies can serve as a guide to defining local ontologies. However, there are still no fixed methods for defining ontologies that stem from traditional tabular data.
- The geographical relevance criteria[dSR12] [IS98] [RSPF16] found in ontological mapping is the following:



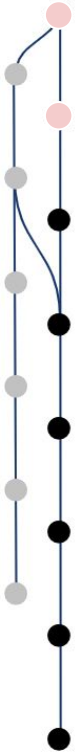
# Conclusion

- i) *depth* with the display of all data and how it relates to other ontologies, with the added visual navigation.
- ii) *specificity*, with well-defined ontologies that allow for the mapping of a discrete dimension that projects to a continuous dimension(space)[JT22].
- iii) *availability*, through state persistence and the presentation of the whole data set visually.
- iv) *accuracy*, since the ontological space is discrete thus accurate descriptions and data points can be derived. This of course is always dependent on the quality of the data source, which is also a criterion of geographical relevance.
- v) *tangibility* is another criteria that bonds well to a discrete mapped space.
- vi) *accessibility*, allowing interactions and data handling.



# Conclusion

- vii) *dynamism* since data in any graph visualization is flexible to change and recording change can be done within the same ontological dimension.
- viii) *curiosity* is fed through semantic mapping where creativity is stimulated[KAF14]
- ix) *spatial proximity* is seen directly on the map.
- x) *visibility* is present in both graph and map visualization and interaction services such as highlight and filtering.
- xi) *Cluster and Co-location* can also be derived from graph patterns.



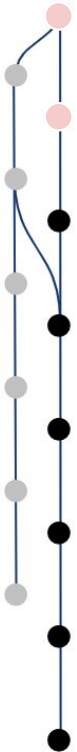
# Conclusion

- It is possible to make web-mapping tools using only GDBMS. However, much technology is already developed for RDBMS that benefits from GDBMS
- The graph visualization process proposed by Romero (2018) [GRMSOG18] serves as a good guideline to design ontological mapping as well.
- In this dataset, some ontological patterns do not translate to spatial patterns.
- The aesthetic design of both the map and the graph visualizations influence relevance perception.



# Conclusion

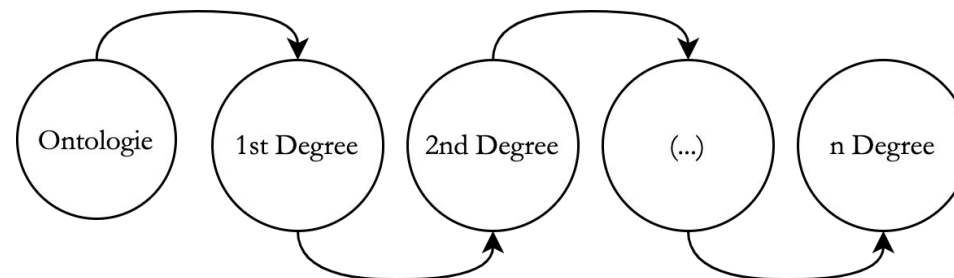
- Relevance is an elusive concept that changes scope depending on the who, where, what, how, and when the data is accessed. Graph mapping opens a door of possibility having multiple dimensions (time, space, methods, technology, and user) interacting in the same space.





# Future Work

- The presented exercise focused on the most simple spatial form (Point). However, ontologies are also embedded in higher forms such as **lines and polygons**.
- The type of relations used in *SeMaptics* where of type boolean. However, relationships can have other natures and carry meaning and weight to the link.
- Graph navigation patterns may be influenced by axioms of relevance, which may reveal the user's nature. A higher degree search should also prove important in finding underlying data semantics



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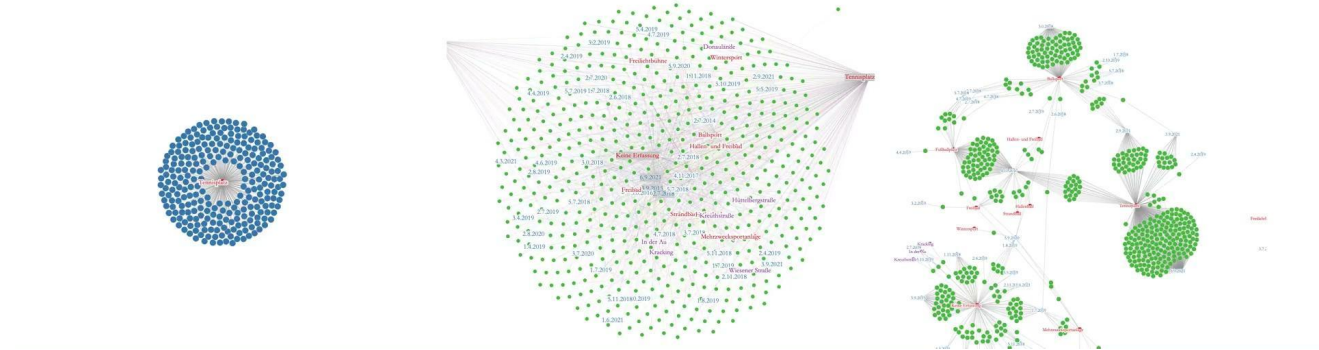
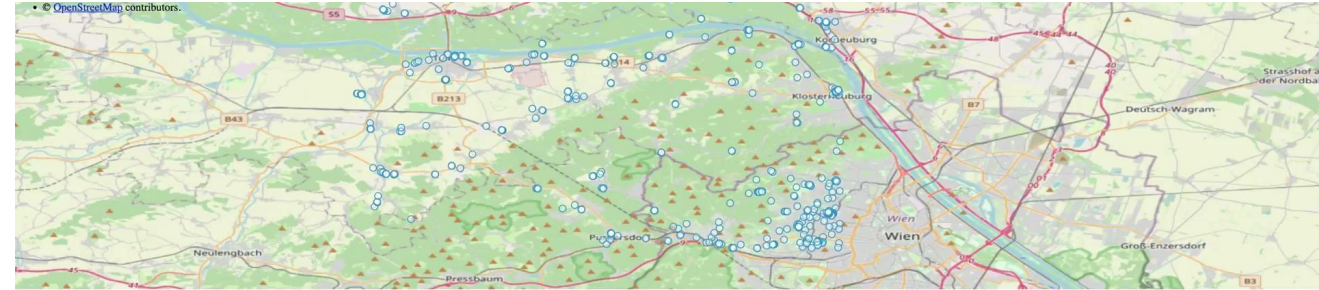
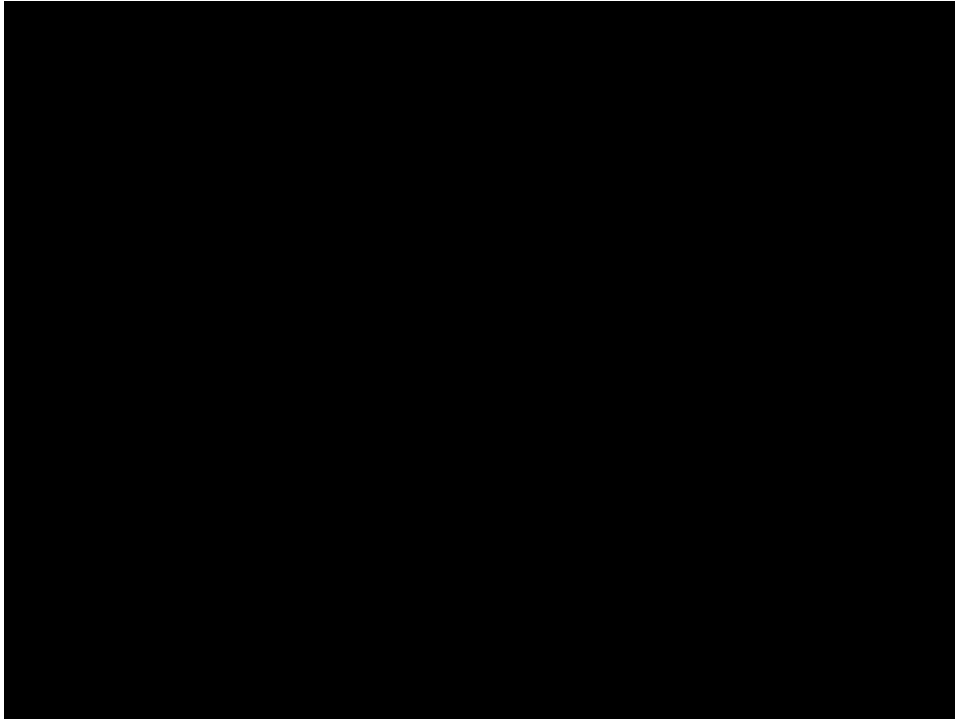
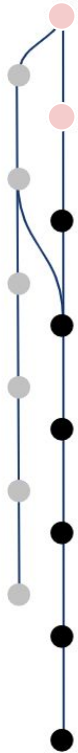


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# Results [Demo video]





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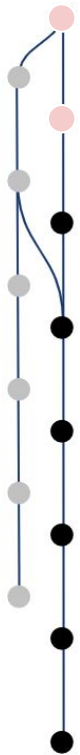
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WIEN  
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# Knowledge Graphs in Data Visualisation [Additional]

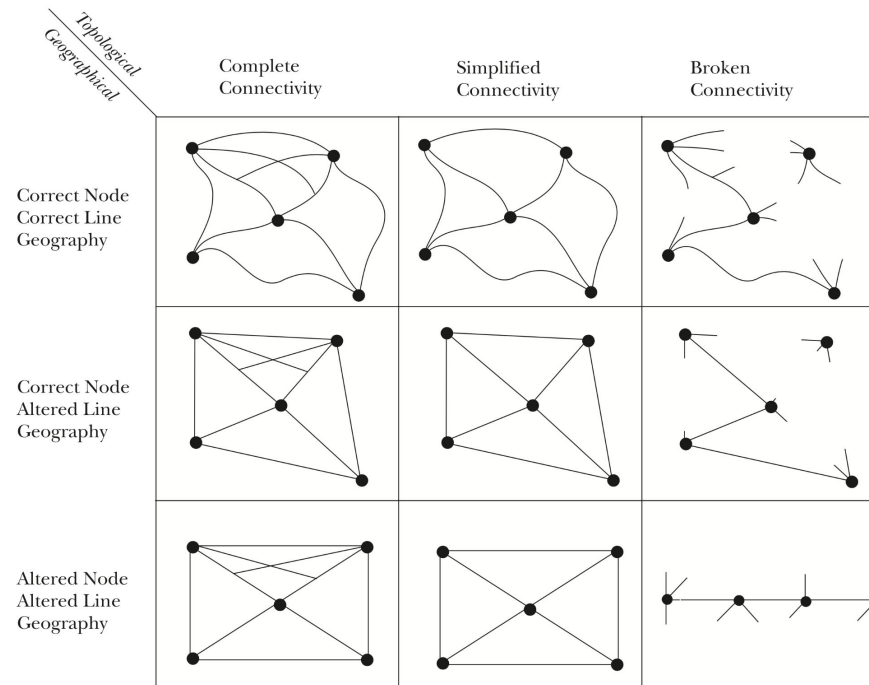
- Geovisualisations have 3 main variables:
  - interaction(I)[high(h)-medium(m)-low(l)]
  - users(U)[public(p)- specialist(s)]
  - task(T)[knowledge(k)-info(i)]
- 4 levels
  - exploration(I-h,U-s,T-k)
  - analysis(I-h/m,U-s/p,T-k/i)
  - synthesis(I-m/h,U-p/s,T-i/k)
  - present(I-l,U-p,T- i)

[MGP+04]



# Visual Knowledge Graphs & Cartography [Additional]

- Knowledge visualizations integrated into maps are flow maps, connection maps and sketch maps.
- A network is an organized collection of objects with cartographic nature, where degree, organization, flow-interaction, and contextual relationship influence their representation of such network. [RA97]

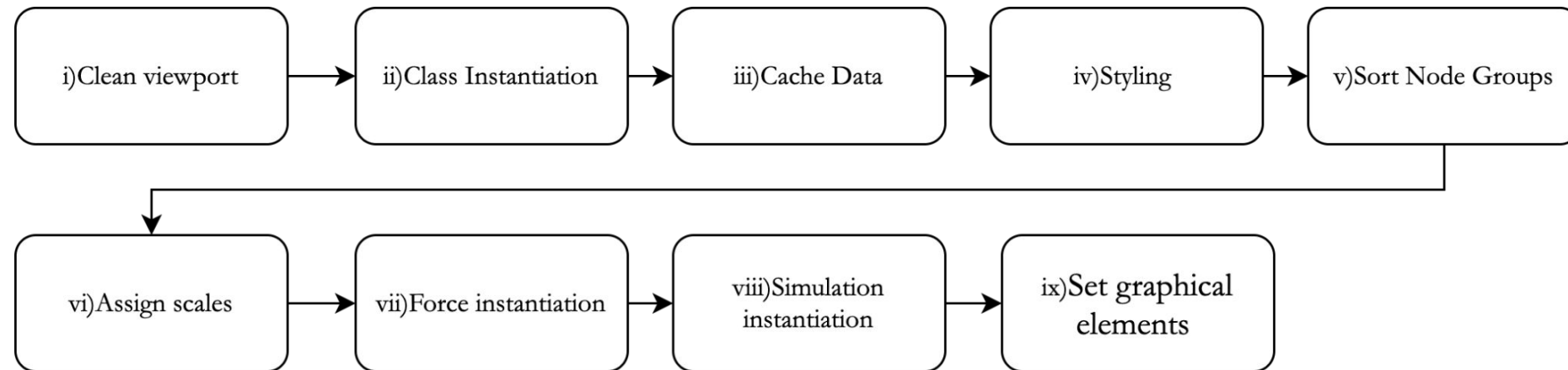


[RA97]



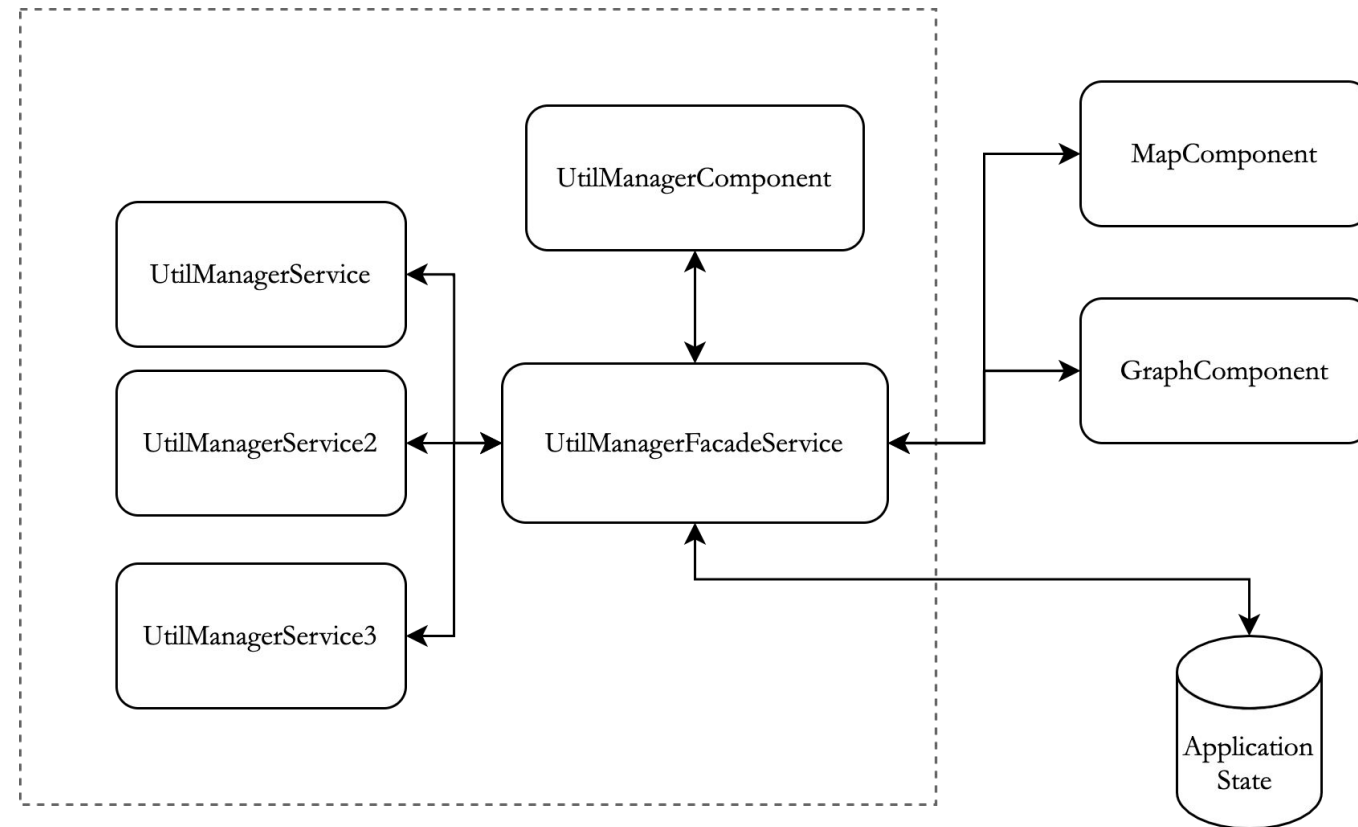


# Graph Build Process [Additional]





# Methodology [Layout and rendering][Additional]



# Methodology [Layout and rendering][Additional]

