Ellie Madsen

NetworkTopography

Timeline

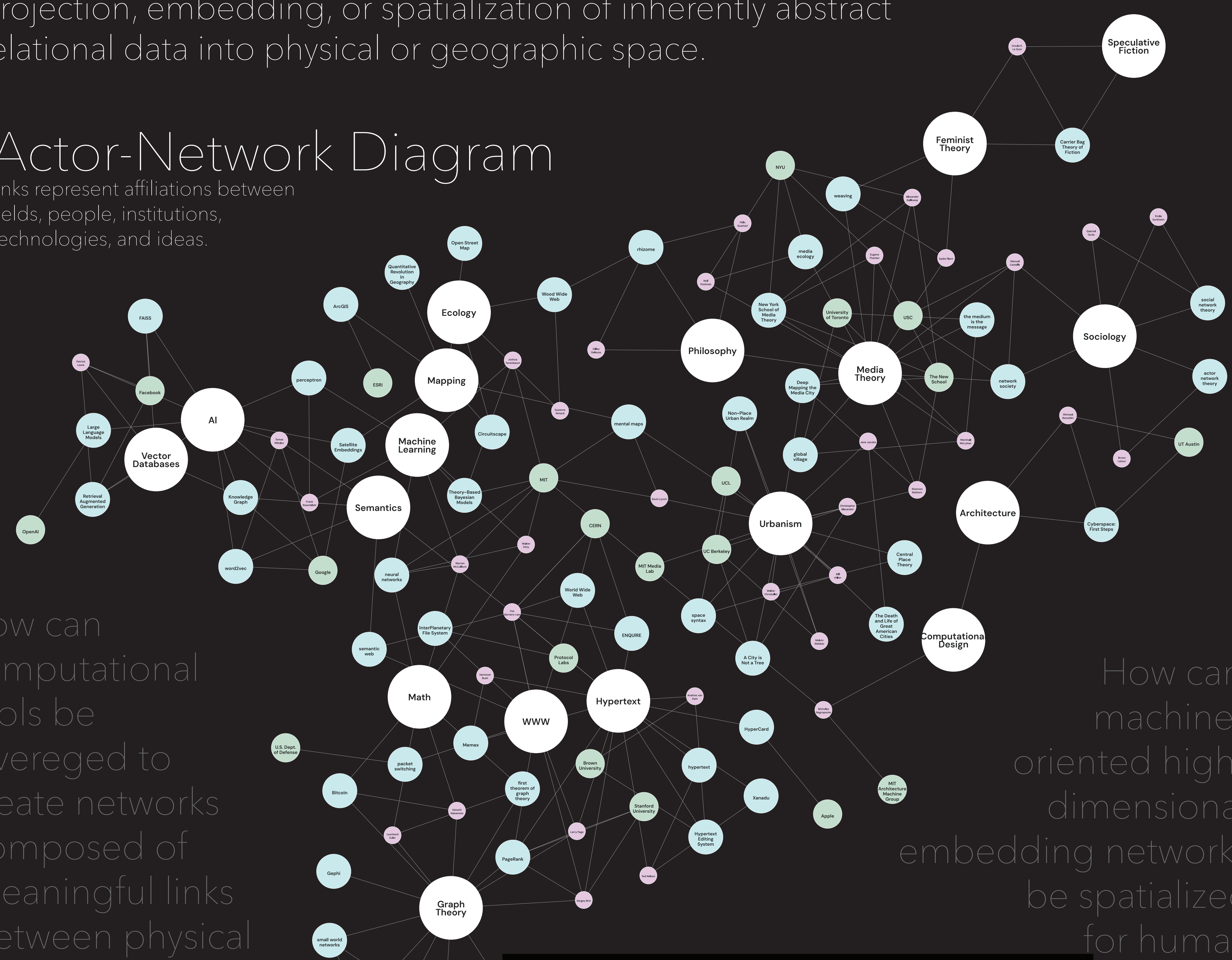
Developments in network theory & applications

1736	Leonhard Euler solves the Seven Bridges of Königsberg problem, founding graph theory.	Math Graph Theory
1890s	Émile Durkheim theorizes society as a structure of interdependent institutions while Gabriel Tarde frames social life as a network of contagious imitation—together laying groundwork for social network theory.	Sociology
1933	Central Place Theory is introduced as an urban geographical theory that seeks to explain the number, size and range of market services in a commercial system or human settlements in a residential system	Urbanism
1943	McCulloch and Pitts propose the first mathematical model of a neural network, using binary logic to simulate artificial neurons and laying a foundation for artificial neural computation.	Machine Learning Math
1945	Vannevar Bush describes the Memex, a proto-hypertext system based on associative trails, in the paper in "As We May Think."	Hypertext
1950s	The quantitative revolution in geography sought a more rigorous and systematic methodology, shifting the discipline from regional geography toward spatial science.	Mapping
1958	Frank Rosenblatt introduces the perceptron, an early algorithm for image classification supervised learning, inspiring decades of research into learning systems.	AI Machine Learning
1961	Jane Jacobs challenges top-down urban planning in The Death and Life of Great American Cities, framing cities as dynamic, self-organizing networks of interactions rather than rational machines.	Urbanism
1964	Marshall McLuhan publishes Understanding Media, theorizing the "global village" and media as networked extensions of humans.	Media Theory
1964	Melvin Webber introduces the concept of the "non-place urban realm", suggesting urban areas are held together by communication networks more than geography.	Urbanism
1965	Ted Nelson coins the term "hypertext" and begins Project Xanadu, a nonlinear, reference-rich digital text system	Hypertext
1967	Christopher Alexander writes "A City is Not a Tree", critiquing tree-like hierarchies in planning and advocating for semi-lattice structures.	Urbanism
1967	Andries Van Dam and Ted Nelson co-develop HES (Hypertext Editing System), the first commercially available hypertext system.	Hypertext
1969	Advanced Research Projects Agency Network (ARPANET), the first packet-switching network and precursor to the internet, goes live.	WWW
1970s	Bill Hillier and researchers at UCL concieve of Space Syntax, using graph theory to model the spatial connectivity and navigability of urban form to explain how built environments influence movement and social interaction.	Urbanism
1971	Inspired by McLuhan, Neil Postman founded the Program in Media Ecology at New York University.	Media Theory
1971	Nicholas Negroponte founds the Architecture Machine Group, precursor to the MIT Media Lab.	Computational Design
1980	Tim Berners-Lee develops ENQUIRE, an early hypertext system.	Hypertext
1980s	Bruno Latour and colleagues develop Actor-Network Theory, theorizing society as composed of heterogeneous networks of humans and nonhumans (technologies, texts, objects) that co-produce agency and structure.	Sociology
1986	Kevin Lynch publishes The Image of the City, a book about how observers take in information of the city, and use it to make mental maps consisting of paths, edges, nodes, districts, and landmarks.	Urbanism
1986	Ursula K. Le Guin publishes "The Carrier Bag Theory of Fiction," arguing for storytelling as a gathering practice focused on everyday life, relationality, and non-heroic narratives—offering an alternative networked epistemology.	Speculative Fiction Feminist Theory
1987	Apple releases HyperCard, a stepping stone to user-accessible hypertext systems.	Hypertext
1990s	ArcGIS becomes dominant in digital mapping and spatial data modeling, including topology and network analysis.	Mapping
1991	Tim Berners-Lee launched the World Wide Web, composed of HTTP, HTML, and hypertext links.	WWW Hypertext
1993	Benedikt's book Cyberspace: First Steps explores architecture of digital space as topological, networked, navigable.	Architecture
1996	Larry Page and Sergey Brin develop PageRank, an algorithm that models the web as a directed graph of hyperlinks, revolutionizing search by ranking pages based on their network centrality.	Hypertext Graph Theory WWW
1997	In Zeros + Ones, Sadie Plant draws connections between women's histories of weaving, code, and decentralized epistemologies.	Media Theory Feminist Theory
1997	Simard identifies the Wood Wide Web, a network of mycorrhizal fungi that allows trees to exchange nutrients and chemical signals, revolutionizing ecological models with a biological network paradigm.	Ecology WWW
1998	Deleuze & Guattari use "rhizome" to describe a post-structialist assemblage that allows connections between any of its constituent elements	Philosophy
1998	Watts and Strogatz publish a paper introducing Small-World Networks, showing that many real-world networks balance local clustering and global reach.	Graph Theory
1999	Tim Berners-Lee propose the Semantic Web (web 3.0) to structure web data as machine-readable graphs by encoding semantics into data using RDF and OWL.	WWW Semantics
1999	Barabási publishes Linked: The New Science of Networks, introducing scale-free networks as a model for understanding web graphs, biological systems, and social networks, where few nodes (hubs) hold many connections.	Graph Theory
2000	Castells' book Network Society articulates how cities and social life are structured by information flows.	Sociology Media Theory
2004	Galloway and Thacker publish The Exploit: A Theory of Networks, theorizing power in decentralized systems.	Media Theory
2004	OpenStreetMap was founded, using a data structure composed of nodes and relations. It grew into a crowd-sourced geospatial dataset with global reach, used in urban planning, humanitarian response, and web cartography.	Mapping
2006	Joshua Tenenbaum proposes "Theory-Based Bayesian Models" — early steps in semantic graph-based reasoning.	Machine Learning
2008	Satoshi Nakamoto releases the Bitcoin whitepaper, proposing a decentralized, peer-to-peer network maintained via a cryptographic ledger known as the blockchain, effectively a graph of transactions and trust.	Math Graph Theory
2008	The open-source platform Gephi is released, offering an interactive visualization and exploration environment for all kinds of networks and complex systems, widely used in digital humanities, sociology, and web analysis.	Graph Theory
2008	Connectivity analysis software Circuitscape applies electrical circuit analogies to model landscape connectivity.	Mapping
2009	Google releases Knowledge Graph, a massive entity-relation graph that marked a major shift from keyword matching to semantic understanding.	Semantics AI Vector Databases
2012	Google Brain releases word2vec, a neural embedding model that transformed words into high-dimensional vectors, capturing semantic relationships through cosine distance and enabling graph-like reasoning in textual data.	Semantics AI
2014	Shannon Mattern publishes "Deep Mapping the Media City," a critique of how digital and physical infrastructures are intertwined, highlighting the layered, networked nature of urban media systems.	Media Theory Urbanism
2017	Facebook releases FAISS, an open-source library for similarity search and clustering of vectors across large embedding spaces.	AI Vector Databases
2019	Launches the InterPlanetary File System (IPFS), a peer-to-peer hypermedia protocol that maps and addresses data by its content (hash) instead of location, reshaping file storage as a distributed graph.	WWW
2020	OpenAI incorporates dense embedding models and vector search into its retrieval-augmented language model pipelines, improving fine-tuning and enabling semantic memory systems for large-scale language understanding.	AI
2020	Researchers at Facebook AI propose Retrieval-Augmented Generation (RAG), a framework that combines pretrained language models with external document retrieval to generate more informed and accurate responses for knowledge-intensive NLP tasks.	AI Vector Databases
2025	Google releases its Satellite Embedding dataset, a global, analysis-ready collection of learned geospatial embeddings.	Mapping AI

Network topography, a play on *network topology*, refers to the projection, embedding, or spatialization of inherently abstract relational data into physical or geographic space.

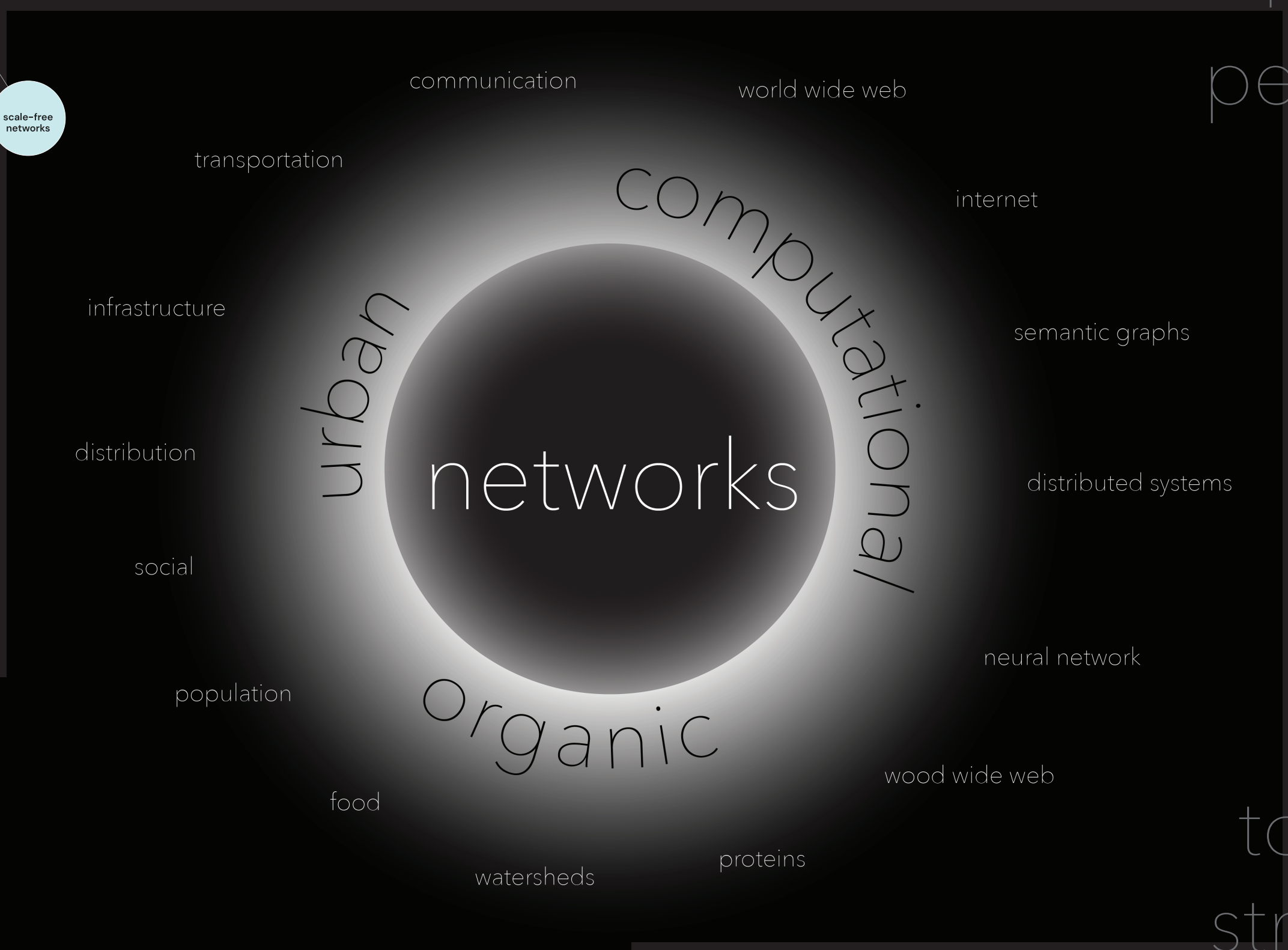
Actor-Network Diagram

links represent affiliations between fields, people, institutions, technologies, and ideas.



How can computational tools be levereged to create networks composed of meaningful links between physical and digital assemblages?

How can machine-oriented high-dimensional embedding networks be spatialized for human perception?



Spatializing Texts in Network Theory

I trained an embedding model on each text's metadata and reduced the vectors to two dimensions, producing a map where semantically related content is locatednearer in space.

How can topological structures of spatialized networks inform new ways of interpreting or designing geospatial systems?

embedding space
semantic distance
n-dimensional
vectors & nodes

⟷

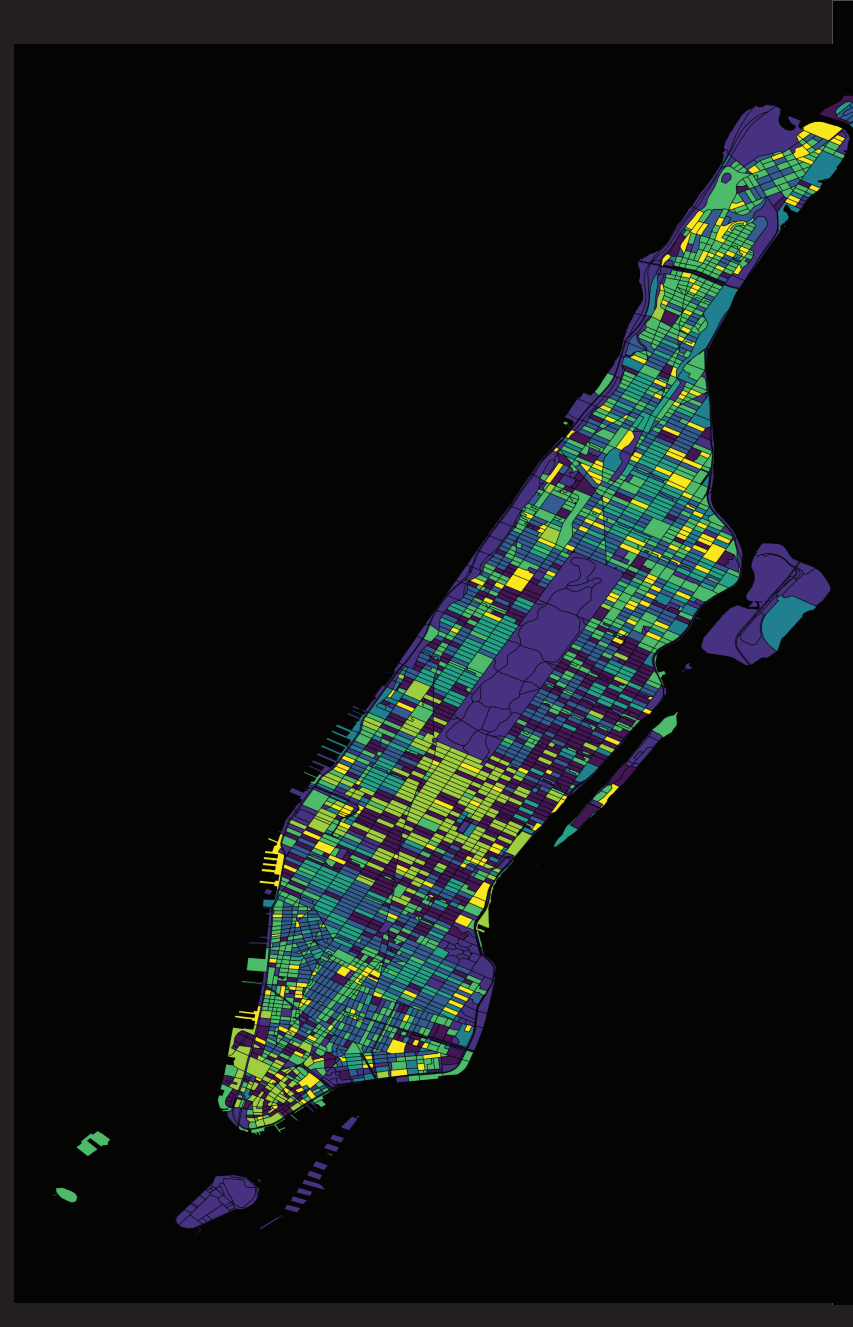
world space
physical distance
3-dimensional
paths & places

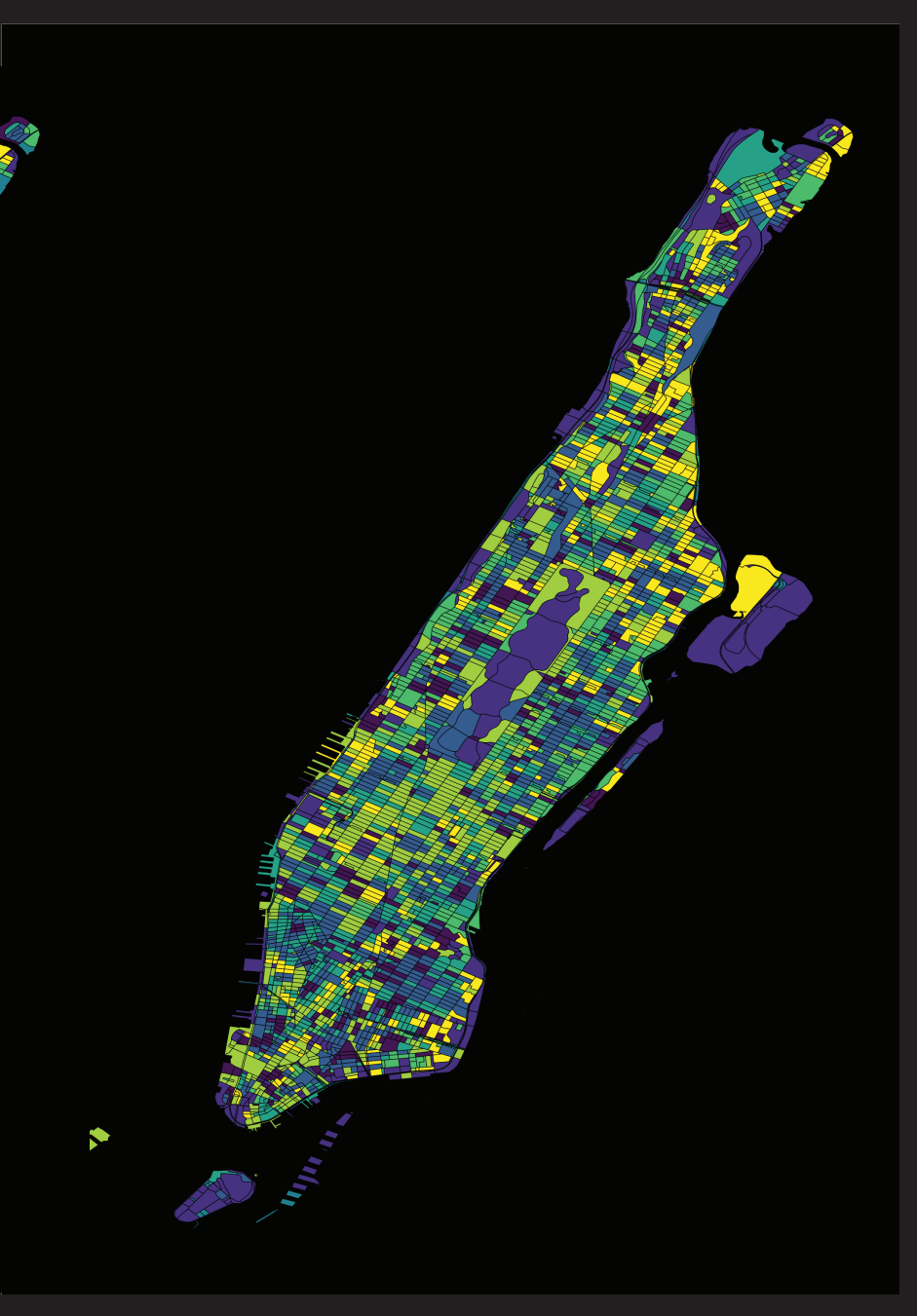
Urban Embeddings: Visualizing Semantic and Spatial Similarity in Manhattan

I compiled spatial and semantic attributes for each block in Manhattan, generated high-dimensional embeddings, applied k-means to clusterthe blocks by similarity, and mapped the results by visualizing each cluster as a layered network.

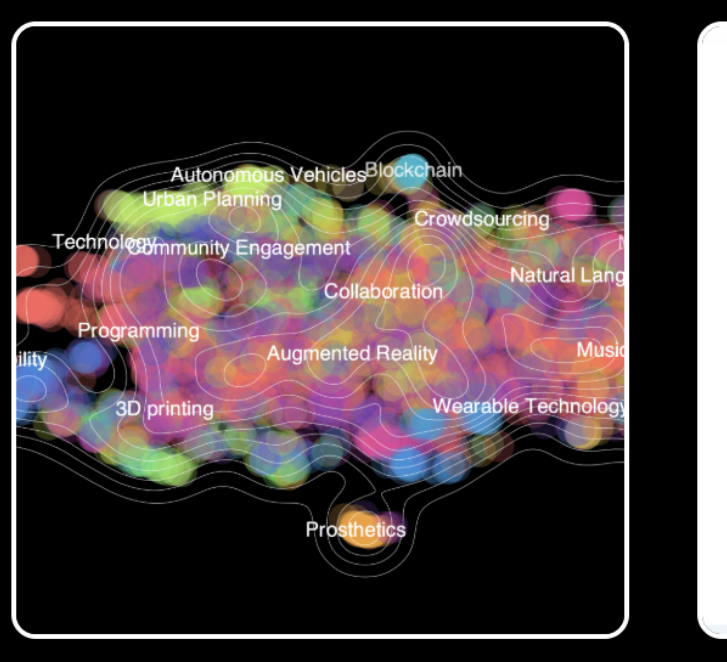

Network of Spatial Similarities

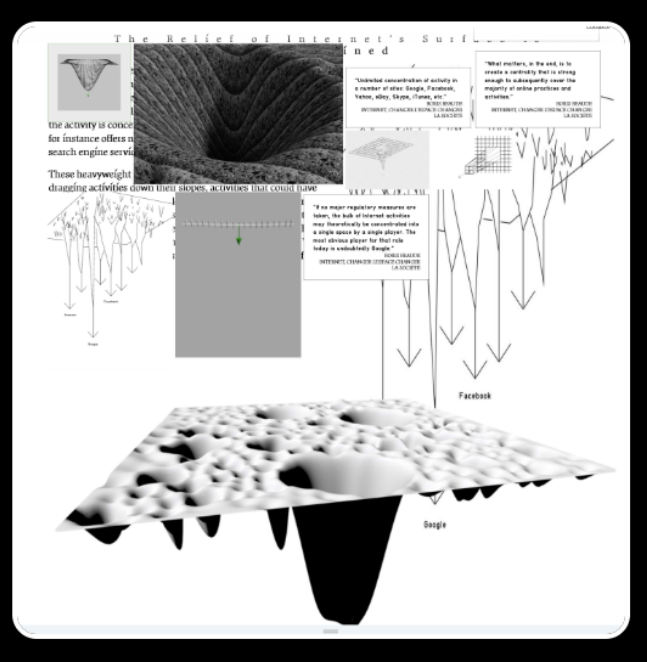

Network of Semantic Similarities

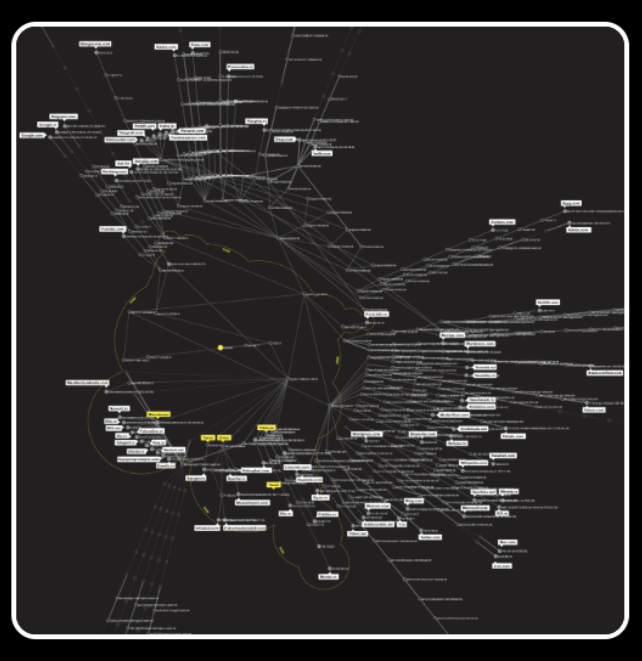

Spatial Clusters

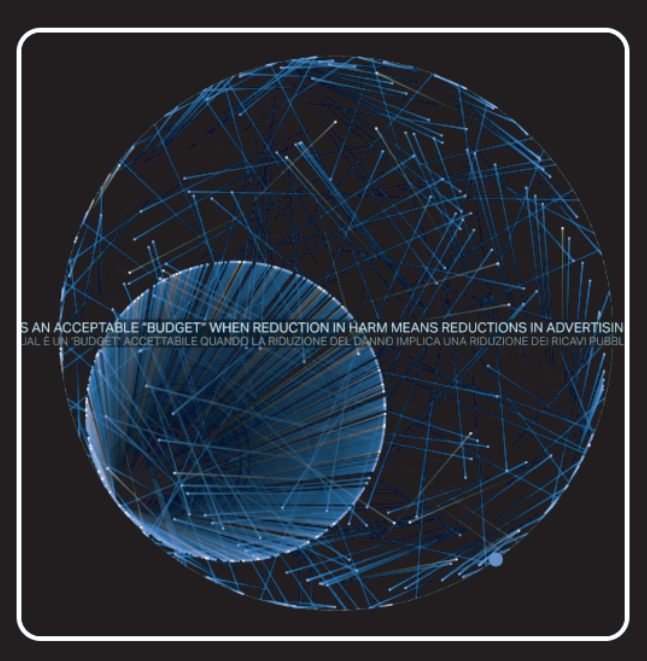

Semantic Clusters

Precedent References

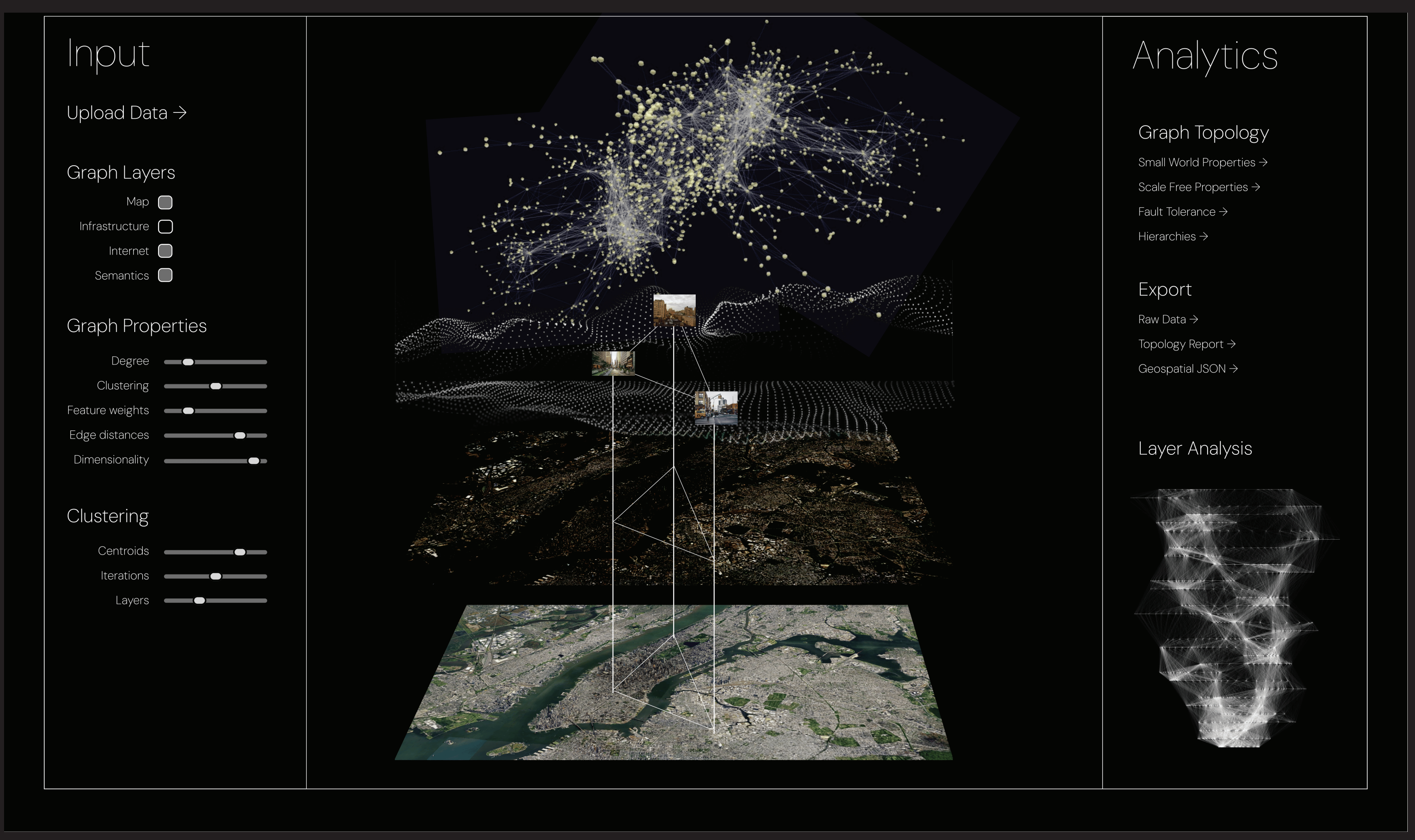

Latent Lab


Critical Atlas of Internet


Invisible Infrastructures


Curse of Dimensionality

Interface Prototype


Input

Upload Data →

Graph Layers
- Map ☐
- Infrastructure ☐
- Internet ☐
- Semantics ☐

Graph Properties
- Degree
- Clustering
- Feature weights
- Edge distances
- Dimensionality

Clustering
- Centroids
- Iterations
- Layers

Analytics

Graph Topology
- Small World Properties →
- Scale Free Properties →
- Fault Tolerance →
- Hierarchies →

Export
- Raw Data →
- Topology Report →
- Geospatial JSON →

Layer Analysis

Computational Design Practices   Methods and Practice   Research Proposal   Columbia University   Graduate School of Architecture, Preservation, and Planning   August 2025