Agent-Based Modelling And Simulation For The Geospatial Network Model Of The Roman World

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GEHIR
gehir.phil.muni.cz
GENERATIVE
HISTORIOGRAPHY
OF RELIGION PROJECT

Overview

Generative Historiography of Religion

GEHIR

- interdisciplinary project @ Masaryk University
- application of methods for modelling dynamic complex systems to historiography of ancient Greco-Roman religions

Working with historic data

- sparse and imprecise archaeological evidence
- modeling can help fill in the gaps

Input data

Geohistorical features

- documented roads
- estimated and documented maritime routes
- travel cost estimates based on terrain (elevation, climate, ...)

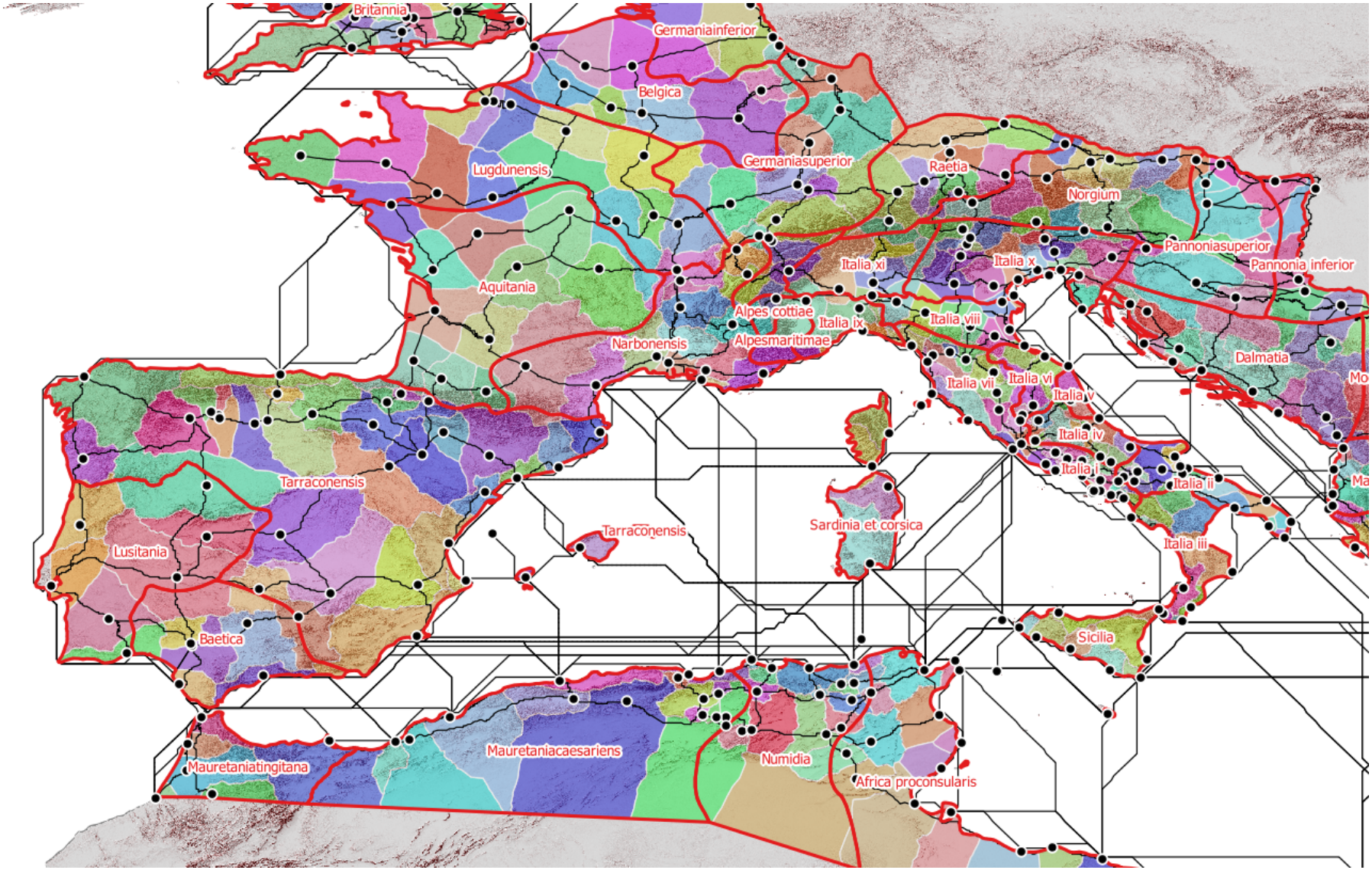
Archaeological evidence

- dated presence of phenomena of interest (e.g. religious practice)
- socio-economic evidence (e.g. coins, writings, etc.) as proxies for population sizes

Written records

- e.g. descriptions of trade routes, naval navigation maps, ...
- variable reliability

Input data


Britannia
Germaniainferior
Belgica
Lugdunensis
Germaniasuperior
Raetia
Norgium
Pannoniasuperior
Pannonia inferior
Italia xi
Italia x
Aquitania
Alpes cottiae
Italia ix
Italia viii
Narbonensis
Alpesmaritimae
Dalmatia
Italia vii
Italia vi
Italia v
Italia iv
Tarraconensis
Italia i
Italia ii
Sardinia et corsica
Tarraconensis
Italia iii
Lusitania
Sicilia
Baetica
Mauretaniacaesariens
Numidia
Mauretaniatingitana
Africa proconsularis

Transport model

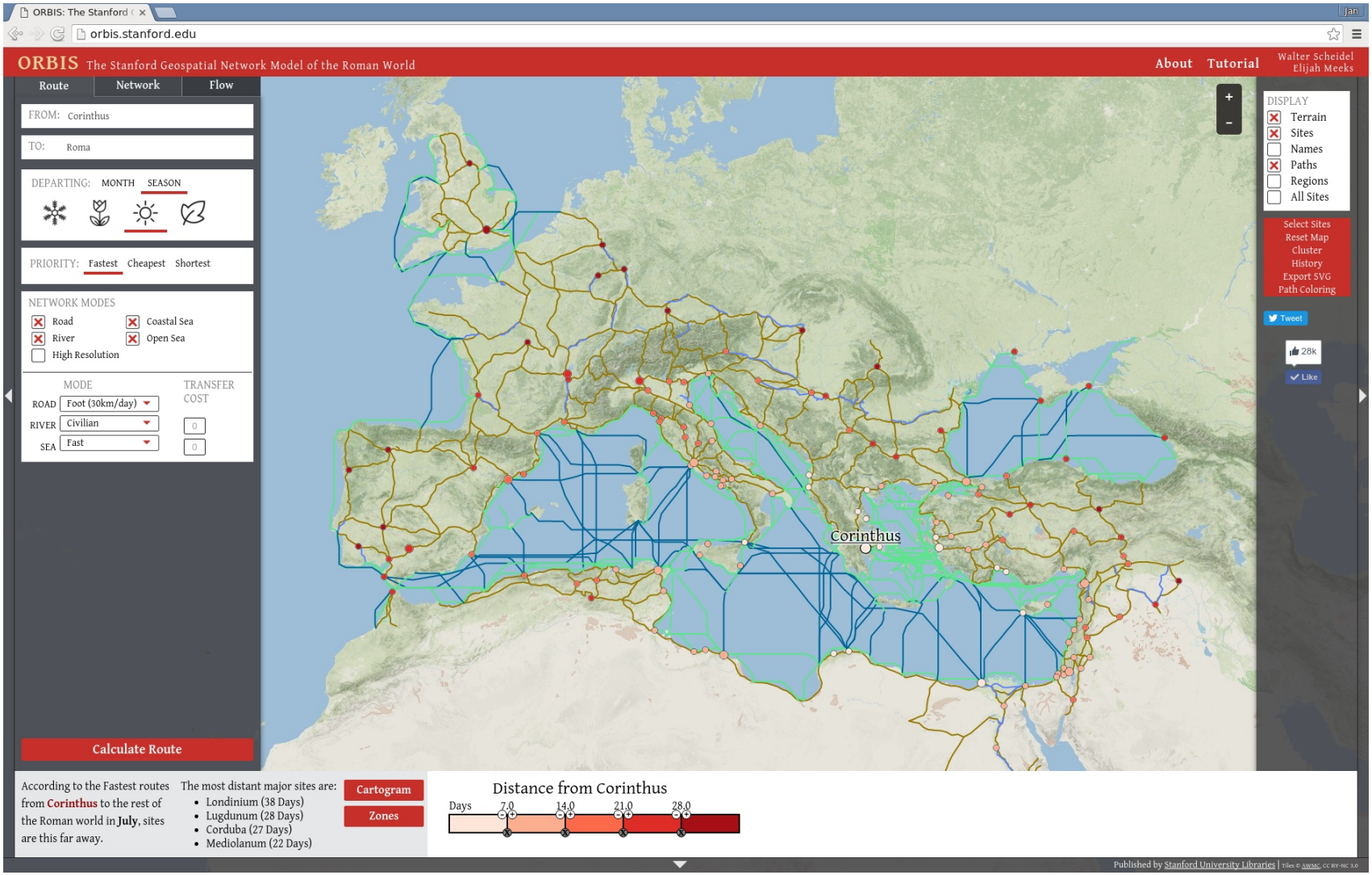
Building on the ORBIS: The Stanford Geospatial Network Model of the Roman World

- combines road network, sea routes and main rivers
- takes seasonal variation into account (e.g. impassable mountains in winter)
- provides interactive map, route calculations
- network visualizations: distance map and cartogram
- not possible to export data for additional analysis
- `http://orbis.stanford.edu`

Drawbacks:

- model not available for researchers directly
- not possible to use for systematic analysis and modelling
- not possible to modify (improve) the underlying data

ORBIS


ORBIS: The Stanford
orbis.stanford.edu
ORBIS The Stanford Geospatial Network Model of the Roman World
About
Tutorial
Walter Scheidel
Elijah Meeks
Route
Network
Flow
FROM: Corinthus
TO: Roma
DEPARTING: MONTH SEASON
PRIORITY: Fastest Cheapest Shortest
NETWORK MODES
Road
River
High Resolution
Coastal Sea
Open Sea
MODE
TRANSFER COST
ROAD Foot (30km/day)
RIVER Civilian
SEA Fast
Calculate Route
DISPLAY
Terrain
Sites
Names
Paths
Regions
All Sites
Select Sites
Reset Map
Cluster
History
Export SVG
Path Coloring
Tweet
28k
Like
Corinthus
According to the Fastest routes from Corinthus to the rest of the Roman world in July, sites are this far away.
The most distant major sites are:
Londinium (38 Days)
Lugdunum (28 Days)
Corduba (27 Days)
Mediolanum (22 Days)
Cartogram
Zones
Distance from Corinthus
Days
7.0
14.0
21.0
28.0
Published by Stanford University Libraries

LINUM: Transport model

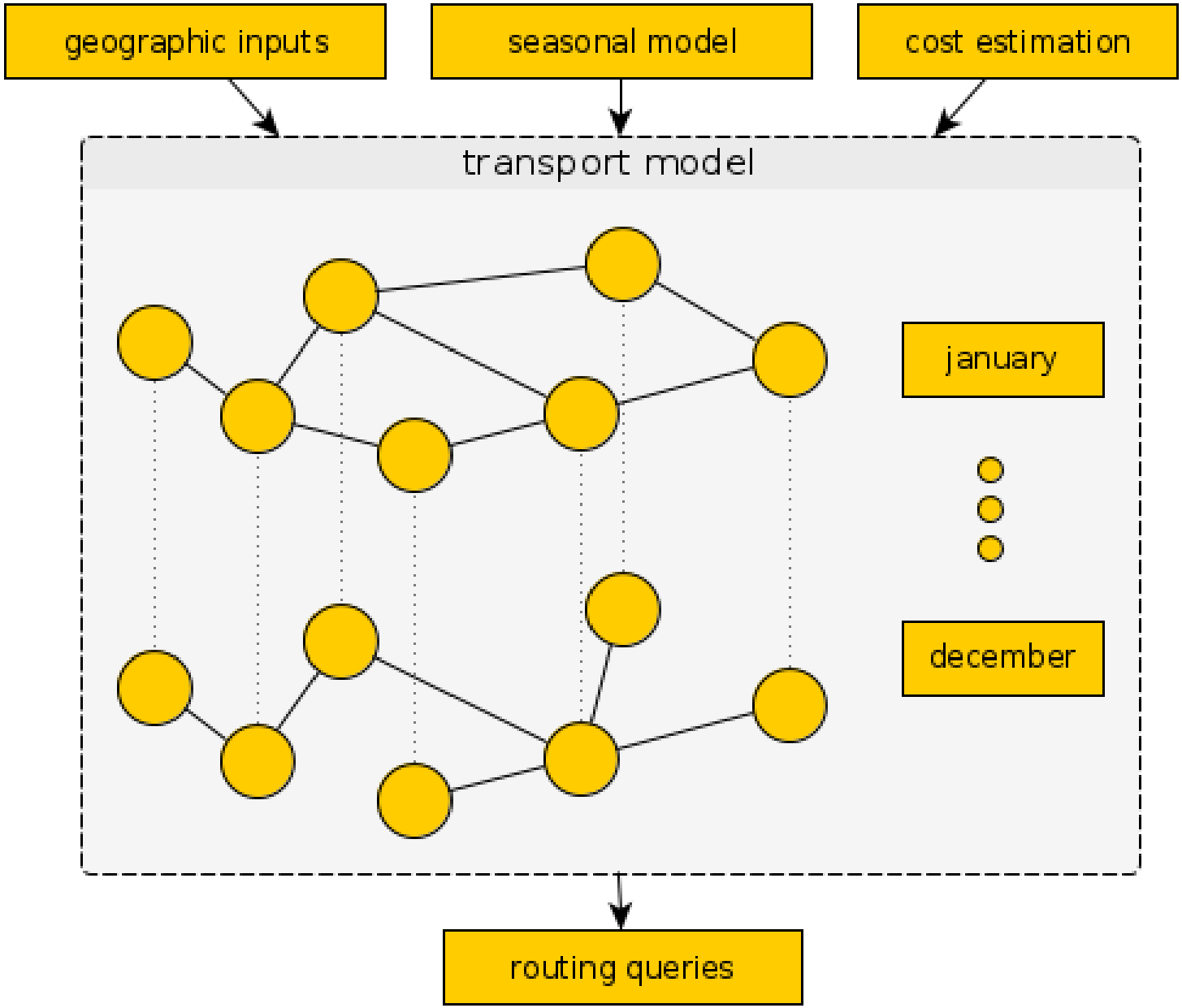
Our reimplementation of ORBIS core model

- multilayer transport network (layer=season)
- allows user to modify all model parameters
- can be setup with custom transport networks (roads, rivers, etc.)

The model

- nodes represent settlements and crossroads, connections roads, rivers, and maritime routes
- holds distance and costs for every connection
- connections can change costs or be disabled on seasonal basis
- provides means to calculate shortest or cheapest routes

LINUM: Transport model



LINUM: Gravity model

Gravity law in transport networks

- estimate of size of inter-city traffic
- $T_{ij} = \frac{P_i P_j}{d^2}$
- where P are populations and d is geodesic distance

Usage in LINUM:

- uses the transport model to determine the distance
- provides static approximation for intensity of information exchange
- guides the random walks

LINUM: Analysis and modelling

Agent based models

- collection of models of interest on the transport network
- spreading processes (e.g. innovation or information spreading)
- destination-driven random walks ("traffic"simulation)
- interacting random walkers

Complex network analysis

- aggregation of the model in time (export as static network)
- random-walk based metrics (e.g. random-walk betweenness)
- probabilistic analys: randomization over season or other parameter setting

LINUM: Computational environment

Building atop of existing packages from Python ecosystem

- `jupyter` notebooks for interaction
- `mesa` for agent based models
- `networkx` for network analysis and data structures
- `shapely`, `fiona`, and `descartes` for manipulation and visualization of GIS data
- `ipython` for distributed processing (parameter sweeps)

Accessibility of Python allows collaborators to easily extend the model and adapt it to their needs.

LINUM: Main components

Transport model

- main data structure: **multilayer network**
- allows queries for shortest paths at given season
- can be extended to incorporate changing seasons to path calculation

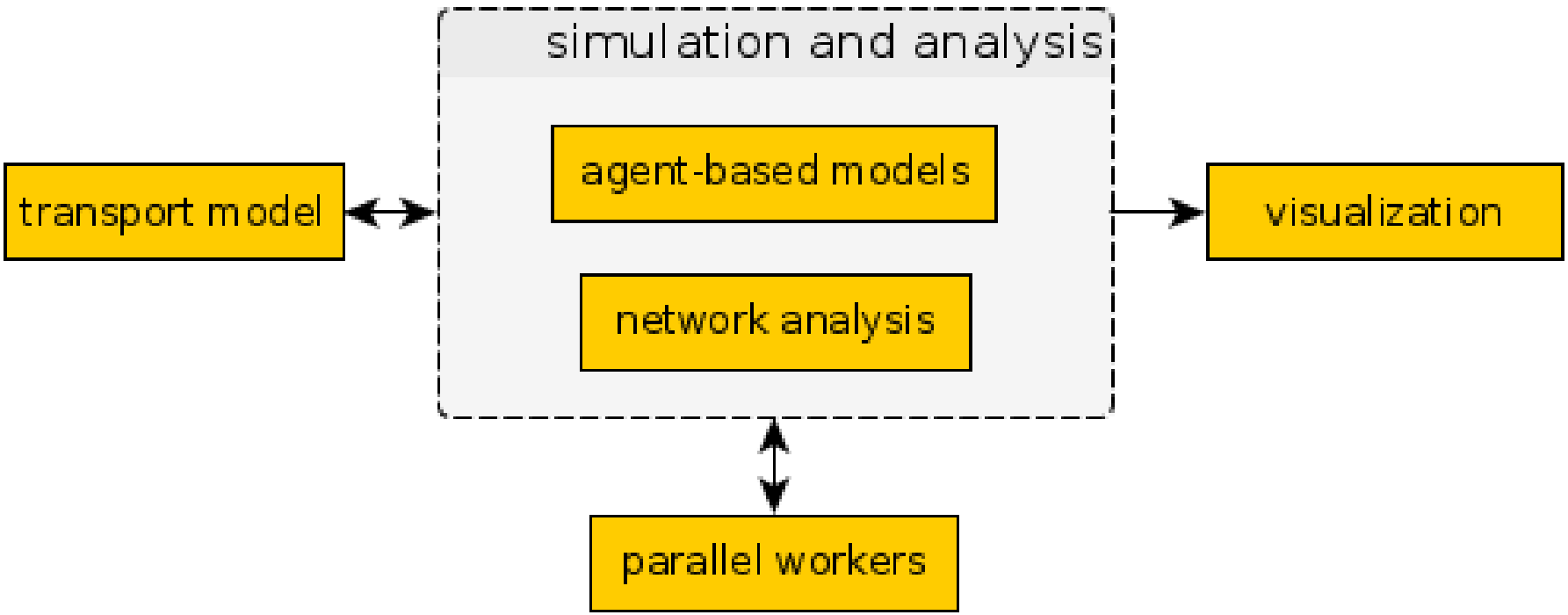
Simulation and analysis

- execution and analysis of agent based models
- uses transport model for routing and to determine neighbourhood
- responsible for orchestration of parallel processing

Visualization

- combines cartographic maps with results of simulation and analysis
- animations for dynamic processes

LINUM: Computational environment



LINUM: Parameter space exploration

Motivation

- both the transport model and the modelled processes have many parameters and uncertainties (historical evidence)
- analysis needs to be repeated for many different parametrizations to test robustness of the results
- exploration of large parametric spaces can become computationally costly

Solution

- parallel and/or distributed evaluation of the model instances
- master-worker architecture using `ipython`
  - provides backends for local, cluster and distributed processing

Pilot study: Christianization of Mediterranean Area

Problem statement:

- evaluate factors playing a role in the spread of early Christianity

Possible factors:

- distance from Jerusalem
- population size
- presence of Hellenic or Jewish culture

Result:

- Significant correlation with gravity model towards Jerusalem (combined population and distance).
- Other factors not significant.

Example study: Christianization of Mediterranean Area

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Thank you for your attention.