Modelling the origin of *polis* in Anatolia. From conceptual to computational approaches.

**CAA 2019 - S11: Pre-Modern Cities and Complexity**

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1. The *polis* in Anatolia
2. Designing models: What, how, why?
3. Conceptual modelling
   A. Fusion-fission cycles
   B. (Urban) scaling
   C. Central place theory
4. From conceptual to computational models
5. Computational models: PolisABM
The *Polis* in Anatolia

Archaic and Achaemenid periods


Hansen & Nielsen (2004) Inventory of Poleis
Willett 2019 The Geography of Urbanism in Roman Asia Minor

Map made by Willett (2019)
Designing Models

• Model properties:
  • Representation (what?)
  • Simplification (how?)
  • Purpose (why?)

• **What?** Origin and development of *poleis* in Anatolia

• **How?** Focus on key properties:
  • Fusion-fission cycles
  • Urban scaling
  • Centrality

• **Why?**
  • Untapped potential of computational modelling approaches in Classical Archaeology
  • Testing existing hypotheses and exploring possibility space
Conceptual Modelling

“A model that is made of ideas or concepts is called a conceptual model” (Gonzalez-Perez 2018)

Focus on dynamics within and between communities:

1. Intra-community dynamics
   • Community fission
   • Urban scaling

2. Inter-community dynamics
   • Community fusion
   • Central places and networks

Gonzalez-Perez (2018) Information Modelling for Archaeology and Anthropology.
Conceptual Model: Fusion-Fission Cycles

- Bintliff et al. (2007) Emergent complexity in settlement systems and urban transformations.
Conceptual Model: (Urban) Scaling

- Population growth and concentration as one of main drivers of societal development
- Face-to-face interaction and information transmission
- Settlements as ‘pockets of interaction’ or ‘social reactors’
- As community sizes increase, ‘social outcomes’ grow as well
- Processes span urban-nonurban divide

Population growth & population density → Aggregation & urbanization

Demographic drivers

Increased face-to-face interaction (energized crowding)

Scalar stress → Community formation → Economic growth

Social outcomes:

Bettencourt (2013) The Origins of Scaling in Cities
Smith (2019) Energized Crowding and the Generative Role of Settlement Aggregation and Urbanization
Conceptual Model: (Urban) Scaling

\[ X = X_0 N^\alpha \]

Conceptual Model: Central Places

- Larger community ~ more diversity in activities/functions (Hanson et al. 2017)
- Spatial concentration of functions in settlement systems (Christaller 1933)
- Centrality in network hierarchies:
  - Qualitative and quantitative
  - (1) administration; (2) security; (3) craft and industry; (4) trade; and (5) cult (Gringmuth-Dallmer 1996)

Christaller (1933) Die Zentralen Orte in Süddeutschland
Hanson et al. (2017) Urbanism and the division of labour in the Roman Empire

http://www.ebah.com.br/content/ABAAABUCMAB/human-geography-leonardo
Conceptual Model: Central Places

• “Relative concentration of interaction”
  • Network approach: Places and flows

• Pulling factors for potential centrality
  • Population size, natural resources, strategic location, administrative institutions, cultural functions, high carrying capacity, ritual features, etc. (Knitter and Nakoins 2018)

Computational Model: Simulations

Conceptual phase
1. Identifying research questions
2. Finding most suitable method
3. General framework and resolution of simulation
4. Entities and rules of interactions

Technical phase
5. Coding and testing
6. Parameterising simulation
7. Running simulation
8. Analysis and recontextualization of results

Dissemination phase
9. Disseminate findings

Romanowska (2015) So You Think You Can Model?
Computational Model: Documentation

ODD protocol: standardize the published descriptions of individual-based and agent-based models (Grimm et al. 2010)

Iterated process
- Structure thoughts
- Think through construction of the model

Purpose:
- Study the emergence of *polis* communities out of fusion-fission dynamics and urban scaling processes; and trace their development into central places through network formation
- “Agent-based models make possible the study of nonlinear cultural dynamics that emerge from the historically contingent actions of heterogeneous agents interacting in space” (Premo 2006)

Grimm et al. (2010) The ODD protocol: A review and first update
Premo (2006) Agent-based models as behavioral laboratories

Elements of the updated ODD protocol

1. Purpose
2. Entities, state variables, and scales
3. Process overview and scheduling
4. Design concepts
   - Basic principles
   - Emergence
   - Adaptation
   - Objectives
   - Learning
   - Prediction
   - Sensing
   - Interaction
   - Stochasticity
   - Collectives
   - Observation
5. Initialization
6. Input data
7. Submodels
ABM: Polis Formation

• Software: NetLogo (Wilensky 1999)

• From conceptual to detailed design:
  • Translating the conceptualised system into a set of entities and rules of interaction
  • Input and output information per component
  • Scale and resolution

• Operational design
  • Pseudo-code
  • Coding

Edmonds and Meyer (2013) *Simulating Social Complexity*
Gonzalez-Perez (2018) *Information Modelling for Archaeology and Anthropology*
Simulation Design

Class: community

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<th>Attribute name</th>
<th>Cardinality</th>
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<td>Connections</td>
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```
a: community
```

```
Community
```

```
a: Community
b: Community
```
Process overview

- Settlement dynamics
  A. Fission-fusion
  B. Energized crowding
  C. Centrality and network formation
Simulating Fission-Fusion Cycles

- Polities expand in size over time due to population growth
- Group fission occurs with certain chance once population threshold is reached and empty space is available
- If no space for expansion
  - Fusion process
  - ‘Conquest’
- Fusion can occur when adjacent polities of similar size come into conflict when no empty land separating them remained for expansion

Population growth:
\[
\frac{\delta N}{\delta t} = rN \left(1 - \frac{N}{K}\right) + W
\]

- \(N\) = population size
- \(r\) = population growth rate
- \(K\) = carrying capacity
- \(W\) = settlement pulling force

Griffin (2011) Emergence of fusion/fission cycling
Simulating Scaling

Original social reactor model:
- Number of people over a settled area
- Energetic constraints and costs of travel distance
- Probabilities they will encounter other people
- Average output or productivity per person
  (Bettencourt 2013; Smith 2019)

Parameters:
- Number of people
- Size settlement/territory
- Average settlement output

\[ A(N) = aN^\alpha \]
- \( A \) = settled area
- \( a \) = constant for benefit interaction / cost per unit time & space
- \( N \) = population size
- \( \alpha \) = scaling exponent (2/3 for sublinear output)

\[ X = xN^\beta \]
- \( X \) = aggregate of socio-economic output
- \( N \) = population size
- \( \beta \) = scaling exponent (7/6 for superlinear output)
Simulating Central Places and Networks

Pulling forces of a community (Wilson and Rihll 1987)
- Population size: larger communities exercise bigger influence
- ‘Weight’ of community

Network formation
- Neighbouring ties
- Production output as ‘capital’ to initiate long-distance connections and increase pulling power over other communities

Initialising Simulation

Entities = (corporate) communities

Initial state variables:
- Number of polities = 50
- Population size: Random in 250-750 range
- Territory: Voronoi Diagrams
- Connections = FALSE

- Scale
  - Patch size: 1km²
  - World size: 100x100 km
  - Time step: 1 year

- Network formation
Potential Future Development

Starting point for future development to extend/refine model:

• Micro-scale dynamics:
  • Generate energized crowding output from social interactions
  • Implement fission/fusion cycles according to scaling parameters

• Macro-scale dynamics
  • Royal policy stimuli

• Human-environment interactions
  • Energy capture and expenditure
  • Settlement chambers

• Code and documentation will be made available: https://github.com/driesdaems10/PolisABM
Thank you for your attention!

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