# ODD – PolisABM: Modelling *polis* formation, urbanism and social complexity trajectories.

*Dries Daems – Middle East Technical University | KU Leuven*

## 1. Purpose

This model simulates processes of *polis* formation through fission-fusion dynamics in village communities, inducing energized crowding effects as postulated by settlement scaling theory and initializing processes of central place formation to generate settlement networks and hierarchies.

## 2. Entities, state variables, and scales

* One entity: communities.
* Temporal resolution: 1 tick = 1 year
* Length of simulation run can be defined by slider which is standard set to 1000 years
* Spatial resolution: 100x100 patches. Distances between communities are abstract but assumed to be easily bridgeable and no deterrent for inter-community movement.

State variables:

* Communities
  + community-id
  + community-size
  + scalar-stress
  + status
  + loyalty
  + nearest-neighbour

## 3. Process overview and scheduling

1. Communities created and positioned randomly
   1. Size defined by normal distribution with mean set by slider ‘community-size’ on interface (standard = 150 people) and 20% standard deviation
   2. Communities are given a territory with size defined by variable ‘buffer-zone’ set on interface. Standard value set at 30 patches radius
   3. Communities are initialized with ‘hamlet’ status
2. Population growth is calculated depending on population size of each community, population growth percentage and carrying capacity set by sliders (‘pop-growth’ and ‘carrying-capacity’) on interface.
   1. Population growth formula: δN/δt = rN (1-N/K)
3. Growing communities that match or exceed the village threshold (set by the ‘village-threshold slider on the interface, standard at 500) must either undergo fission, subdividing in two village communities, or fusion by absorbing a nearby community.

Process:

* Setup
* Fission-fusion
* Central place formation
* Reproduce
* Update visualization

## 4. Design concepts

*Basic principles:* The model is based on a model of *polis* formation posited by John Bintliff (Bintliff, 1982, 1994), generalized to be part of a broader model of community formation and social complexity trajectories (Daems, 2021). The model is based on fission-fusion dynamics, settlement scaling theory and central place formation.

*Emergence*: The interactions within and between communities through fission-fusion dynamics give rise to the emergence of settlement networks and hierarchies.

*Adaptation*: Communities adapt and set new properties when transforming from villages into polis communities, including scalar thresholds and territorial requirements

*Objectives*: The agents do not actively pursue any objectives.

*Learning:* No learning dynamics are included in the model.

*Prediction*:Agents do not predict future dynamics. Some degree of (bounded) knowledge of the environment is incorporated to facilitate interaction processes.

*Sensing*: Communities sense ‘scalar stress’ if their population size grows too much relative to the degree of social organization.

*Interaction:* Communities engage in competitive interaction over space and to settle in hierarchic relationships.

*Stochasticity*: Stochasticity is involved in:

1. The assignment of population sizes to a community
2. Probabilities of fission-fusion events

*Collectives*:Communities are represented as collectives of individuals.

*Observation*. The data that are generated by the ABM for further testing and analysis are population sizes and settlement patterns (in the form of rank-size distributions) that are collected at the end of the simulation run.

## 5. Initialization



A number of sliders are initialized on the interface with following settings:

* Time limit with standard setting on 500
* 1 community created
  + For each community, a population is created, based on a normal distribution with a mean of 150 set by the slider and standard deviation of 1/5 of the slider setting
* Scalar threshold for village communities is 500 persons
* Scalar threshold for polis communities is 1000 persons
* Population growth 10%
* Buffer zone for communities 30 patches
* Fission probability on 20%
* Innovation rate set to 10%
* Each community starts with:
  + status “hamlet”
* Patches within buffer zone of each community are assigned to that community
* The buffer zones can be visualized or not through the territory-viz switch
* The scaling exponent is implemented as a threefold choice (0.83-1-1.17) but not yet implemented in the code in the current version of the model

## 6. Input data

No external input data is used.

## 7. Submodels

* Setup
  + Create communities
  + Assign patches to communities
* Reproduce based on population growth formula
* If community reaches village threshold:
  + Fission if available space
  + If no available space: attempt at fusion
  + If not possible: community collapses