Utrecht University

Geosimulation using fields and agents

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Software for simulation modelling developed at Utrecht University

PCRaster (https://www.pcraster.eu, 1996 -)
- Continuous fields (rasters)

Campo (2021 -)
- Continuous fields and agents
- In development
- https://campo.computationalgeography.org

LUE (2019 -)
- Parallel computation (desktops, cluster computers)
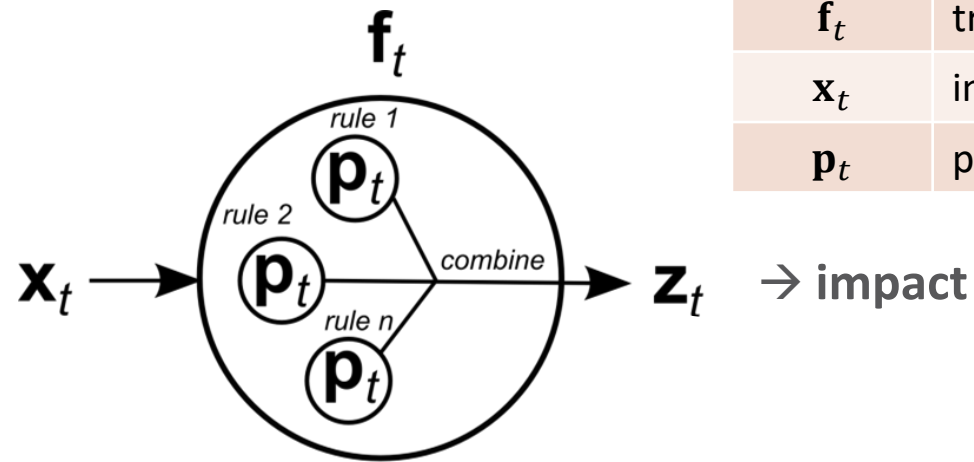- In development
- https://lue.computationalgeography.org

Tutorial Outline

- Introduction to Campo (Judith Verstegen)
- Hands-on Campo (Oliver Schmitz)
- Discussion and questions (team)

Motivation

irrigation → water shortage

ag. expansion → habitat fragmentation

air pollution → respiratory diseases

deforestation → carbon emissions

urban expansion → impermeability → floods

land abandonment → erosion

coreymondello.com

Defining Geosimulation

variable	description
t	time step
$\mathbf{z}_t$	system state at t
$\mathbf{f}_t$	transition function
$\mathbf{x}_t$	inputs/drivers at t
$\mathbf{p}_t$	parameters at t

$\rightarrow$ impact

| Data-driven	Spatio-temporal models	Process-driven
Start with empirical data		Start with a theory (system description)
Based on correlations between drivers and the system state		Based on known/assumed cause-effect relations between drivers and system state
Also called: empirically-based model, statistical model, machine learning model		Also called: process-based model, physically-based model, **geosimulation model**

Modelling paradigms

	Agent-based modelling (multi-agent systems)	Field-based modelling (cellular automata)
system state	Set of discrete objects	Continuous or discrete
attribute(s)	Is linked to the agent	Has a value everywhere
processes	Behavior of a single agent, potentially moving	Behavior of cells that remain in their location
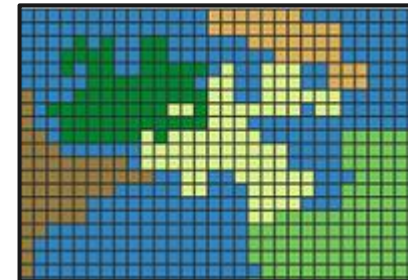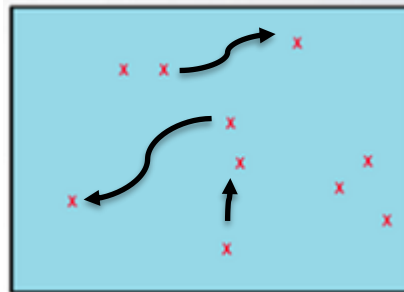
Systems have multiple phenomena that do not fit into one paradigm!

Example: Fields & Agents!

DaisyWorld was introduced by James Lovelock and Andrew Watson (1983), to illustrate the Gaia Hypothesis that organisms interact with their surroundings, creating a self-regulating system.
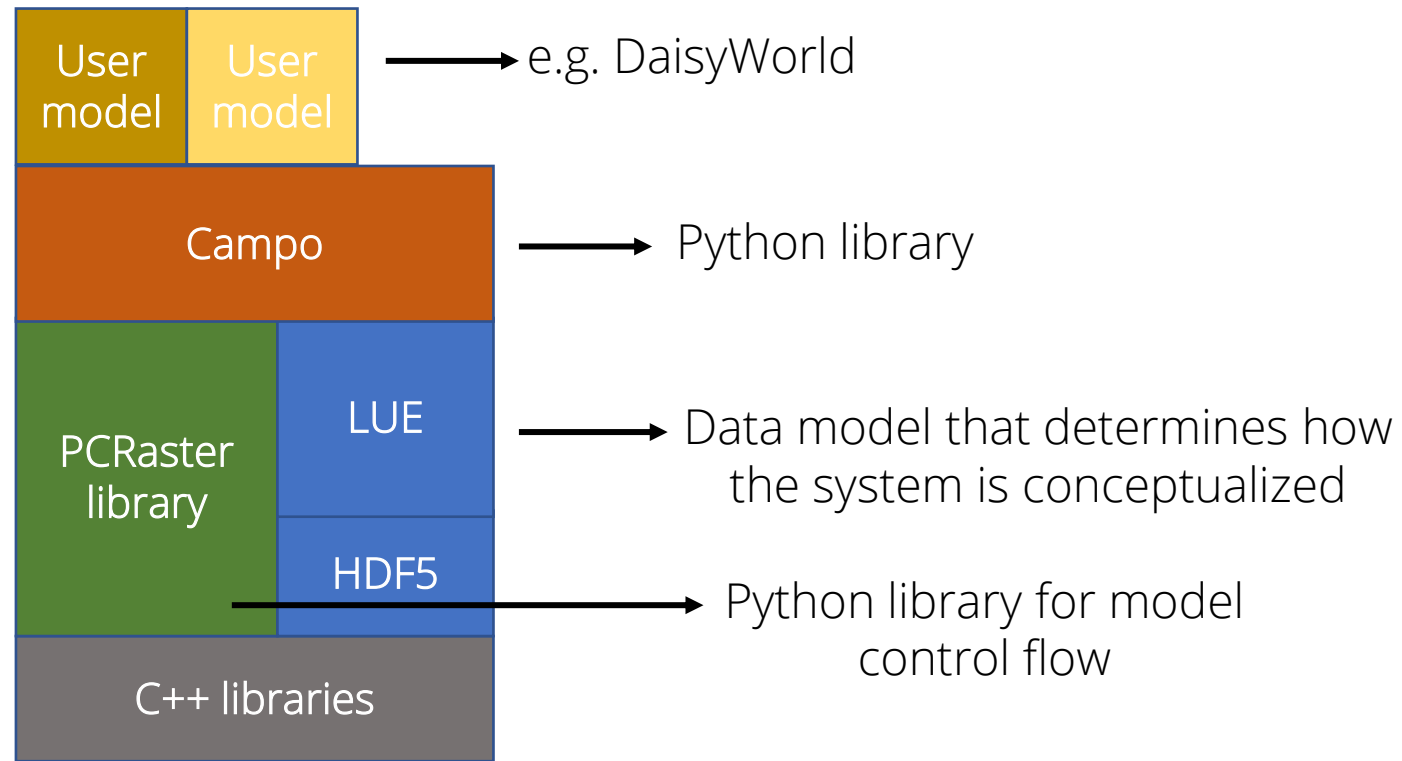
Daisy agent

Property, e.g.:
Breed (black/white)

Temperature
field
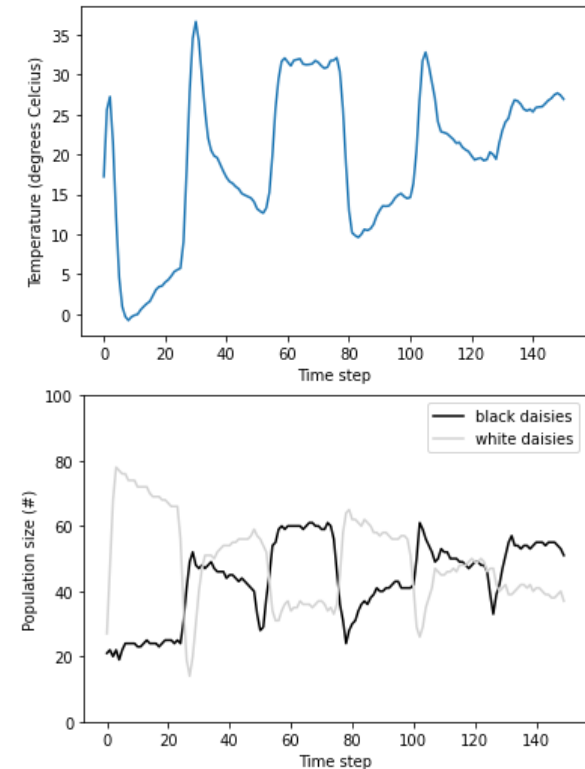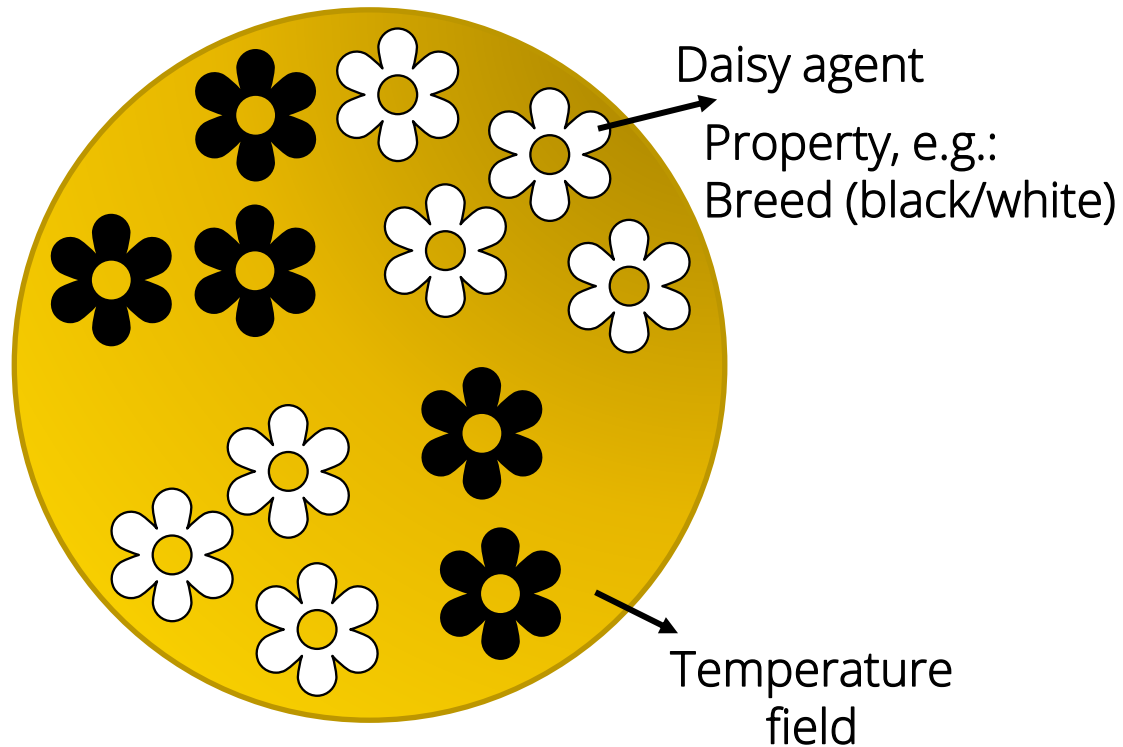
Problem statement

Current software:
• Often departs from ABM, and approaches fields as sets of square objects → computationally sub-optimal
• Has separate sets of functions for fields and agents

→ No full integration between fields and agents

Campo

User model User model → e.g. DaisyWorld

Campo → Python library

PCRaster library

LUE → Data model that determines how the system is conceptualized

HDF5 → Python library for model control flow

C++ libraries

Phenomenon: agents or field

'Agents': Phenomenon containing >1 **Objects**, areal coverage of each Object is where it has a value
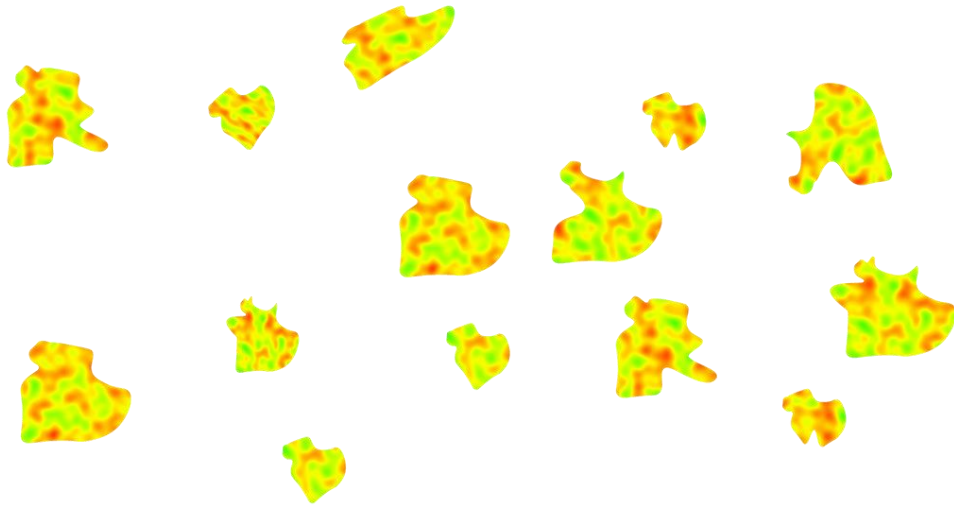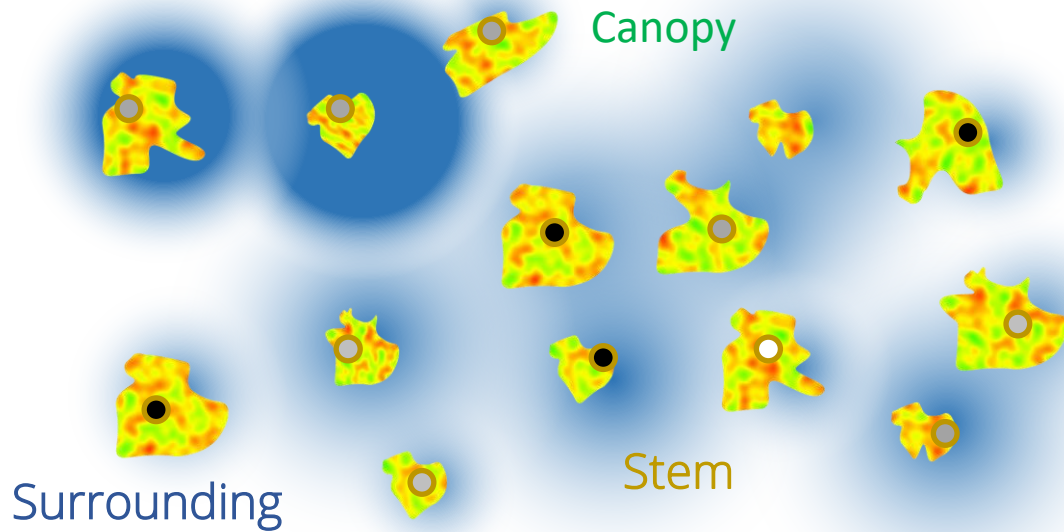
'Field': Phenomenon containing 1 **Object**, areal coverage is 'modelling area'

Phenomenon has Property Sets,
Property sets have properties

Forest system: trees, stems, tree canopy, seed dispersal..

Phenomenon **Trees**
    Property Set **Stem**
    Property Set **Surrounding**
    Property Set **Canopy**
        Property NDVI

Spatial *domain of each **Object**: point at stem circular centered at stem crown*

Canopy

Surrounding

Stem

Single Algebra for Agents & Fields

Syntax:

```
a = a_function(b)
```

Calculates for each Object its property a as a function of property b

Referring to phenomena, property set, for instance:

```
trees.canopy.lai = a_function(trees.canopy.ndvi)
```
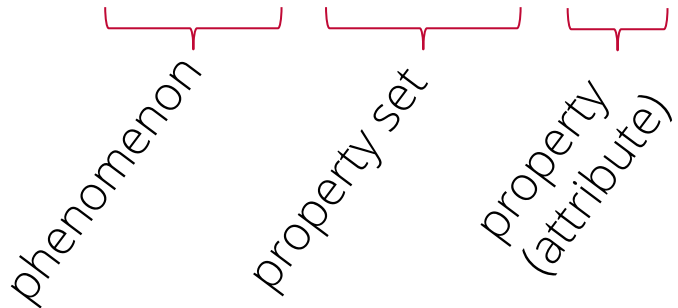
phenomenon   property set   property (attribute)

Framework for control flow

```python
class MyFirstModel(DynamicModel):
    ...

    def initial(self):
        # functions here are run once at start
        # create/modify Phenomena for initial state of system
        # I/O using framework functions

    def dynamic(self):
        # functions are run for each time step
        # program time transition function
        # I/O using framework functions
```

Hands-on Campo

https://github.com/computationalgeography/agile2023

Contact

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- 29-06-2023, 2-5 pm @UU and online: short course on LUE to develop scalable numerical spatial simulation models, info at https://lue.computationalgeography.org/blog/, register with Kor de Jong k.dejong1@uu.nl