handed out: June 9, 2020
handing in: June 18, 2020
presentation/discussion: June 19, 2020

Crucial parameters for the following exercises are not given. Choose them following your judgement and understanding of the system. The corresponding thoughts are part of these exercises. If needed, some orientation is available from the lecture notes.

For exercise 2 and 3, use the Utopia `ForestFire` model for simulations. Consult the `ForestFire` model's documentation[1] for information on configuration parameters and available plots. If necessary, implement your own plotting function.
Make sure to have pulled the latest docker image using `docker pull ccees/utopia:latest`. See exercise sheet 6 for Docker setup and hand-in information.

These exercises also require significant computational efforts. Since no parameters are given, you have to explore. Recall earlier recommendations and use very small grids, say 64×64 for exploration and only once you have found the desired set of parameters increase to what you are willing to spend, say 4096×4096 as many of the figures in the lecture notes. Notice that with this choice, 1 s of CPU time for the small grid translates into a bit over 1 h for the large grid. Take into account the docker preferences when it comes to the number of available CPU and memory.

1. **Utopia – Getting Operational II** present ☐

   Work through the remaining sections of the Utopia tutorial to familiarize yourself with *(i)* configuring the creation of plots, *(ii)* implementing your own plotting functions, and *(iii)* performing and analyzing parameter sweeps.

   Using a model of your choosing and following the instructions in the tutorial, implement one *universe* plotting function and one *multiverse* plotting function. Hand in your custom plot functions' code, the relevant configuration files, and two or more resulting plots.

2. **Percolation** present ☐

   Consider a uniform square domain with side length 2^n with the forest fire dynamics where connected clusters are burnt instantaneously. Assume an initially empty domain, a constant growth probability p, no lightning, and the lower boundary always on fire.

   (a) Describe the expected dynamics of this system. (No simulation required. You may still wish to produce a movie to verify your expectations.)
   (b) Draw time series of $\rho(t)$ for domains of increasing size with $n \in \{3, 4, 5, \ldots\}$.
   (c) Calculate and draw the asymptotic values of the temporal average $\overline{\rho}$ and of its variance σ_ρ^2 as functions of n.
   (d) What differences do you expect for simulations run with a 5- vs a 9-neighborhood? Think and describe first, then simulate.
   (e) Compare with the situation where one point is always on fire. First formulate expectation, then run simulations.

   Hint: To permanently ignite a single cell, use the entity selection mode `sample` with the parameter `num_cells: 1`. If desired, adjust the simulation `seed` in your run configuration such that the randomly selected cell is in the central area of the (periodic) grid.

3. **Forest Fire Model (FFM)** present ☐

   Explore forest fires in heterogeneous environments and ways to prevent large fires. Specifically consider the following cases:

   - The environment consist of randomly distributed rocky patches (i.e., cells that are inflammable) with density ρ_r.

[1] `https://hermes.iup.uni-heidelberg.de/utopia_doc/master/html/models/ForestFire.html`

- The rocky patches are regular, corresponding to fire lanes.[2]
- A mixed forest with some more fire-resistant trees: Study the role of (random) immunity g.

For all cases

- look at the dynamics by plotting some spatial distributions after selected times (a movie may be helpful)
- compare time series of the density $\rho(t)$ with that for the uniform base situation, specifically plot the asymptotic mean density and its variance as a function of the pertinent parameter(s)

[2]Selection mode `lanes`. For details and configuration parameters, have a look at the C++ entity selection documentation, `https://hermes.iup.uni-heidelberg.de/utopia_doc/master/doxygen/html/group___entity_selection.html`.