Modeling and Simulating (the Spread of) Forest Fires

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Important

- You should **work in pairs** for this assignment.
- This assignment is significantly larger than the previous. **Start on time**.
- The point of this course and assignment is largely the experiments you perform. Design and do something interesting – be creative. The assignment is **not** a complete description nor a recipe for a guaranteed 10.
- This assignment changed from the previous year(s) so repeat students beware!
- You **must** use the GUI in a logical way and properly visualise your experiments.
- The report and experiments are important. Take them seriously.

Problem Statement

Forest fires are a serious issue and knowing how they behave is crucial in fighting them or at least minimising the consequences. However, now that the fire season in Australia has ended and California isn't on fire anymore we will have to figure out a different way of analysing forest fires. Seeing as the Rijksoverheid is unlikely to be enthralled at the idea of setting the Amsterdam forest ablaze however we must make do with simulations (please do not set the Amsterdam forest on fire). In this assignment you will create a two dimensional model that will simulate the spread of forest fires. You will use this model to perform experiments on, for example, the effects of different types of biomes or vegetation, the effectiveness of different types of mitigations, metereological factors or other interesting experiments you can think of.

The Model

One widely used way to simulate forest fires and their effects, as discussed in the lectures, is using cellular automata. The main difference between those cellular automata and the ones you implemented in the previous assignments is the fact that you have to add another dimension, making it a two-dimensional cellular automaton. Furthermore, to make the model more realistic, the notion of probability is introduced, making the model a non-deterministic two-dimensional cellular automaton.

The description below roughly states how you could approach the implementation of forest fires. Note that this is not the only option. You are free to choose whatever design makes sense to you as long as it is a logical model (and you explain it properly). Also, do keep in mind the points stated at the beginning of this document.

We consider a two-dimensional grid. A logical way to start is by populating this grid with objects. You can intuitively interpret each cell as a spatial region somewhere on a vegetation-bearing planet. You can populate this grid with e.g. regions of forests, other types of vegetation, winding rivers or even cities or towns, depending on the kind of model you choose to implement. Of course a 10 hectare forest is perfectly logical but a road that is several kilometers wide makes less sense. Think about a logical interpretation of your model that reasonably simulates reality and explain how and why you have made your decisions. Each cell could also have states: a healthy forest, a dry forest, a burning or burnt down forest for example would make sense for forest-cells. Think of other kinds of states for different types of cells.

A model shouldn't be static though; rather it should develop over time. For this you ought to define rules and behaviours: if a piece of dry forest neighbours a forest that is currently alight there could be a probability the fire spreads. Perhaps this probability is further influenced by mitigations you model such as firefighters wetting an area of a forest proactively. Perhaps your model includes a changing wind direction that influences the spread of fire as well. Which factors exactly you decide to model is up to you but note that your model **should not be trivial**. Think of something interesting and sensible!

Fitting a Model

In this case your will use your model to simulate reality. The parameters of your model should therefore be realistic and make sense. Adjusting the parameters to reality is called *fitting a model* and you should perform sensible fitting of your model.

To ease fitting you would do well to organise your parameters in a fitting data structure. A dictionary or a file would be logical options but make sure that your parameters are easily adjustable (i.e. via the GUI as well with the defaults set to your experimental parameters).

What makes a suitable value for a parameter is dictated in this case by reality: how does fire spread in real life. Luckily the emergence and spread of forest fires is well-studied and there is ample data available on your favourite search engine on the probability of forest fires emerging and spreading, the effects of roads and/or wind thereon, et cetera. Make sure to include proper references to what you based your parameters on! Failing to cite your sources makes your experiments untrustworthy and thus meaningless.

Eventually your model should yield a relatively stable prevalence state. This means that if a given region (in real life) sees a certain number of forest fires with a certain amount of land burnt per annum your model should match this stably. You should note the parameters required to reach this stable state and set them as the default values for your model (i.e. when the GUI is launched). A plot showing that your model settles on this stable state is very useful.

Note that this process can be done by hand or automatically. The first method is self-evident and for the latter method we present a limited overview of a way to automate *parameter optimisation*: random sampling. Start by defining a range of allowed values for every parameter and randomly generate sets of parameters. Then determine the "error" that your model has compared to your desired stable state (e.g. through the absolute difference).

Experiments and Analysis

The most important part of this assignment is the conclusions you can draw. To draw interesting conclusions you need good experiments performed on a solid model. Now that you have a model mimicking reality to a reasonable degree you can perform your experiments.

You are relatively free in the experiments you conduct, but make sure they are interesting. You should at least analyse different mitigation methods and the effects of some different objects or other new parameters in your model. Is there a way to never let any forest fires spread to destruction?

Critical Density Make sure to also analyse the critical density of your model. In a system there is a point where after a certain identifiable point the behaviour of the model is changed radically. With forest fires for example there could be a change in humidity that increases the likelihood of fire spreading throwing your model off balance in such a way that everything now burns down.

Bare Minimal Requirements Make sure your results contain at the very least two insightful plots that summarise your findings. More plots are welcome but it is also not desirable to just spam fifty plots that contain the same information. You should also write a report on your findings where you describe what you have done, how your model is built and fitted, and you should logically connect the figures and draw sensible conclusion(s) from them. Keep your report concise and make sure you cite all sources you used.

Assignment

Submit to Canvas at least the following:

1. A short written report with the following main headers (see above sections for details on their contents):
   (a) *Model definition and implementation.*
   (b) *Fitting the model parameters.*
   (c) *Experiments and analysis.*
2. Your implementation. The code ought to be functional and properly documented. Your code must run successfully without alterations and there should be a script to automatically generate your plots.

Deadline: Thursday, 27 February 2020, 23:59.

References

[1] Yuki Sugiyama, Minoru Fukui, Macoto Kikuchi, Katsuya Hasebe, Akihiro Nakayama, Katsuhiro Nishinari, Shin-ichi Tadaki, and Satoshi Yukawa. Traffic jams without bottlenecks—experimental evidence for the physical mechanism of the formation of a jam. *New Journal of Physics*, 10(3):033001, 2008.