Modelling and Simulation
Practical Assignment 2: Percolation

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1. Introduction

Tijd over: Blaat over toepassing van model

This paper first presents and then discusses a percolation model. Section 2 presents the model we used and an implementation in pseudo code. In section 3 we discuss some of the experiments we have performed with the model and their results. Section 4 presents a summary of the findings of our experiment.

2. Method

Algorithm 1 presents our iterative growth process, the defined function expects three arguments `N`, `probability` and `mask`. Given the size parameter `N`, the grid used for the percolation is $(N+1)\times(N+1)$, since this causes the grid to have an uneven number of rows and columns its center is always clearly defined as (N, N). The parameter $p \in [0, 1]$ is the probability that a given site in the cluster becomes occupied if it is considered. The `mask` is a matrix with r rows and c columns that determines the used connectivity. In general four-connectivity is used. This parameter allows us to empirically determine the influence of the connectivity on the growth of the cluster in section 3.4.

Each iteration we remove the next `site` from the queue. We grow this point, using the function `grow`. This method considers

Algorithm 1: `percolation`$(mask, N, p)$

```
input  : N size
         p probability
         mask r × c binary matrix.
output : grid (N + 1) × (N + 1) matrix

center := (N + 1, N + 1)
push(queue, center)
grid := initGrid(N, N)
while not isEmpty(queue) do
    site = pop(queue)
    sites = grow(grid, site, mask, p)
    if onBorder(site) then
        break
    push(queue, sites)
```

all neighbors that are connected to `site` according to `mask`. For each of these neighbors we determine the value z, which is randomly sampled from an uniform distribution with the range $[0, 1]$. If $z \leq p$ we mark the neighbor site as occupied, otherwise it is marked empty. The method `grow` returns the neighbor sites that are occupied, these are added to the queue.

The model stops the growth of the cluster if it is finite or if it is percolating. A cluster is finite if all neighbor sites, according to the connectivity defined by the `mask`, of the cluster

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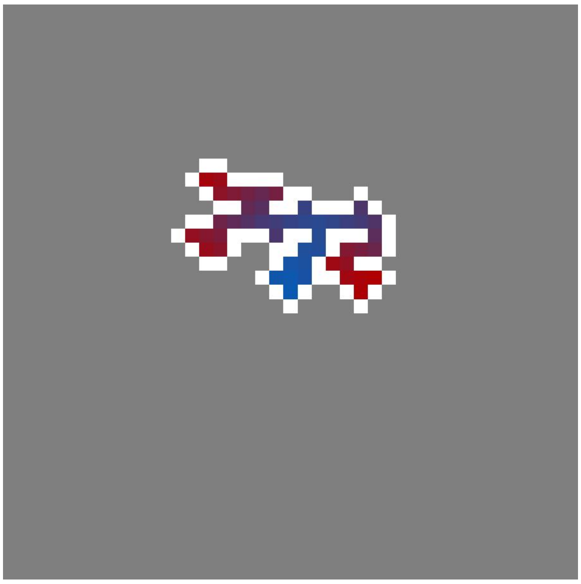
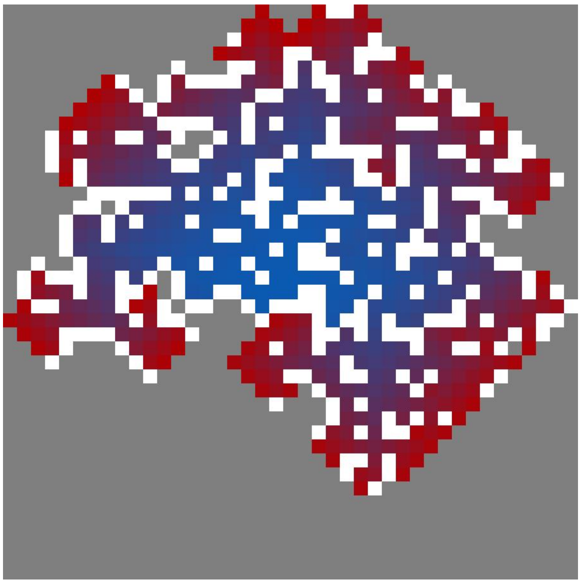
are marked as empty. In algorithm 1 we test for this condition via the guard of the loop, if the queue is empty there are no more neighbors to consider, consequently the cluster must be finite.

A percolating cluster is a cluster that has reached the border of the grid, i.e. if there is a occupied site with row or column number 1 or $2N + 1$. We test for this condition with the method `onBorder`. It should be noted that we only check if a site is on the border of the grid after we have already grown the site.



(a) *$N = 20$ and $p = 0.5$*



(b) *$N = 20$ and $p = 0.7$*

Figure 1: *Examples of a finite cluster (a) and percolating cluster (b).*

Verwijs naar dit figure. Fix betere plaatjes

3. Experiments

This section presents our exploration of the parameter space of the percolation model. In section 3.1 we discuss the influence of the probability parameter p. Section 3.2 explores the effect of the size of the system on the clusters. In section 3.3 we attempt to determine the fractal dimension of the finite clusters as a function of p. Finally, section 3.4 presents a short analysis of the impact of the connectivity.

3.1. Probability

Discuss cluster size statistics, mean cluster size M and sd as a function p for finite clusters

Determine some vague fraction

To investigate the effect of different p on a lattice with a constant size we perform the following experiment. We opt for a lattice size, with $N = 20$, which results in 41×41 sized grid. We calculate the mean and standard deviation of the finite clusters over $r_{max} = 200$ runs. The probability of growth p is incremented with 0.01 ranging from 0.3 to 0.7. The resulting statistics for all p are shown in figure 2.

We observe that the mean cluster sizes up to approximately $p = 0.55$ generally increase,

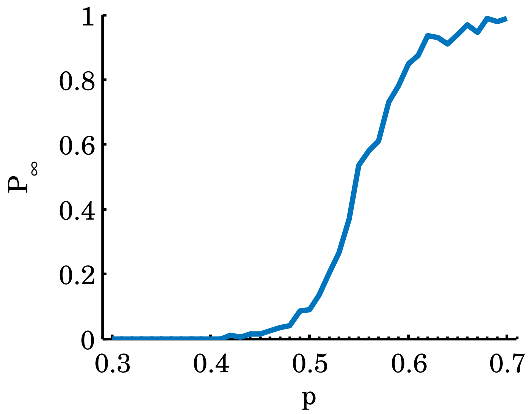


Figure 3: *Ratio of percolating clusters, P_∞, as a function of p. Ratios calculated over $r_{max} = 200$ runs on a grid size of 41×41.*

which is consistent with the definition of p. With $p > 0.55$ we see that the mean cluster sizes start do decrease again. This drop in mean cluster size can be explained with the plot shown in figure 3. Figure 3 shows the P_∞ ratio as a function of p, where the P_∞ is the ratio of 'infinite' clusters. Looking at approximately $p = 0.55$ we see that the number of finite clusters decrease...

Which is not as obvious, as I first thought so need to look at theory...

3.2. System Size

How do the results change when the system size changes. Experiment with different latice sizes

Wat could the behavior be in the limit of infinite lattice sizes

3.3. Fractal Dimension

Definitie van fractal dimension

Welke fractal dimension hebben anderen gevonden?

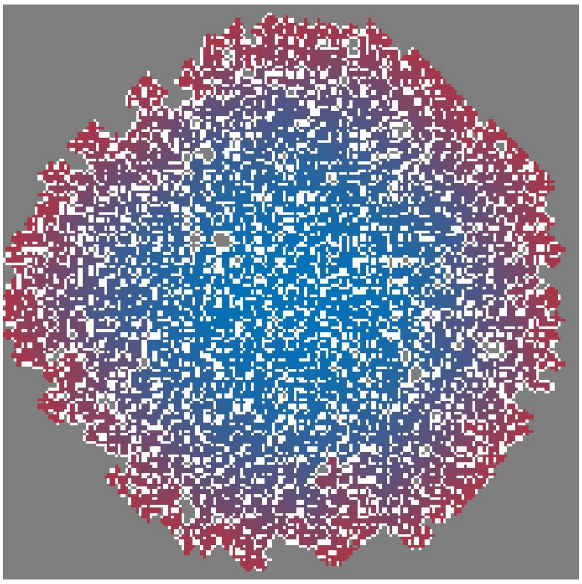


Figure 4: *The cluster used to determine the Minkowski-Bouligand dimension of clusters generated with percolation, the clusters was generated with $N = 80$, $p = 0.7$.*

Boxcounting = MinkowskiâĂŞBouligand dimension uitleggen met source

$$\dim_{\text{box}} = \lim_{\epsilon \to 0} \frac{\log N(\epsilon)}{\log \left[\frac{1}{\epsilon}\right]}. \tag{1}$$

We have used the function `boxcount` by Moisy [1] to determine the fractal dimension of different clusters. This method uses boxsizes that are power of two consequently $\varepsilon = 1, 2, 3, \ldots 2^Q$ where Q is the smallest integer such that $Q \leq (2N + 1)$. We have used the boxcounting algorithm on a cluster generated with $N = 80$, $p = 0.7$, the used cluster is shown in figure 4.

Figure 5 presents the number of boxes as a function of the size of the boxes.

Observatie

Past de gevonden fractal dimension met de theorie?

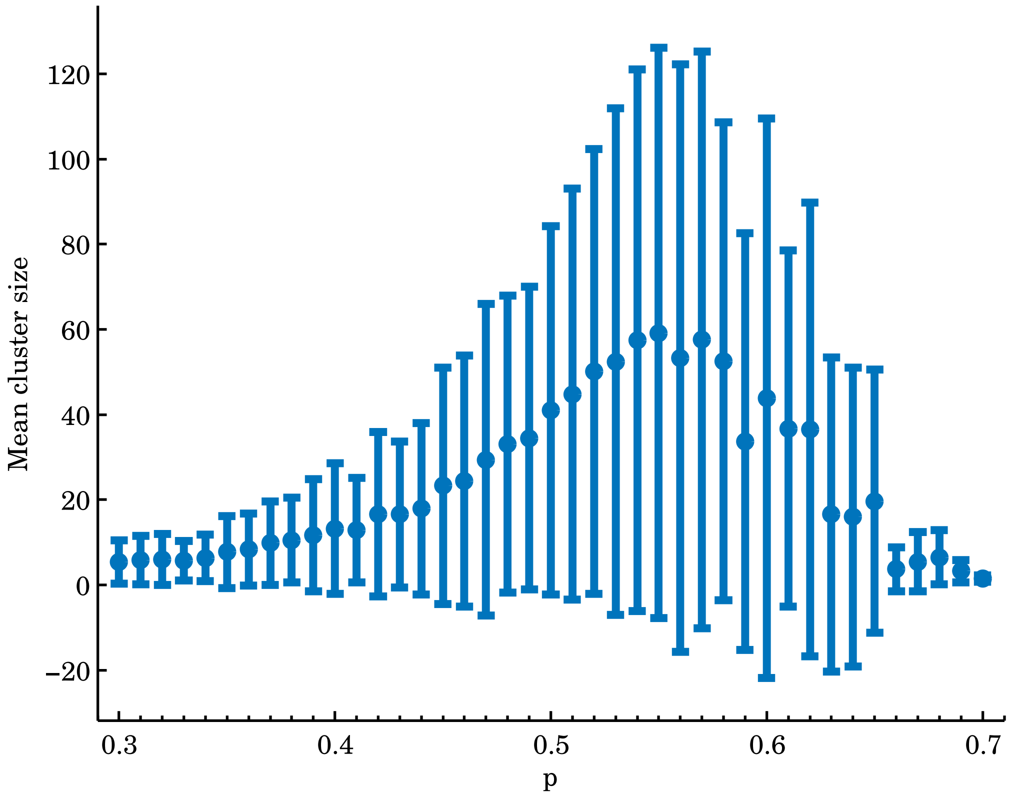


Figure 2: *Mean cluster sizes* μ *(indicated by the points) and standard deviations* σ *(vertical error bars) computed as a function of* p*, with a step size of* 0.01*. Values* μ *and* σ *were calculated over* 200 *runs with a grid of size* 41×41*.*

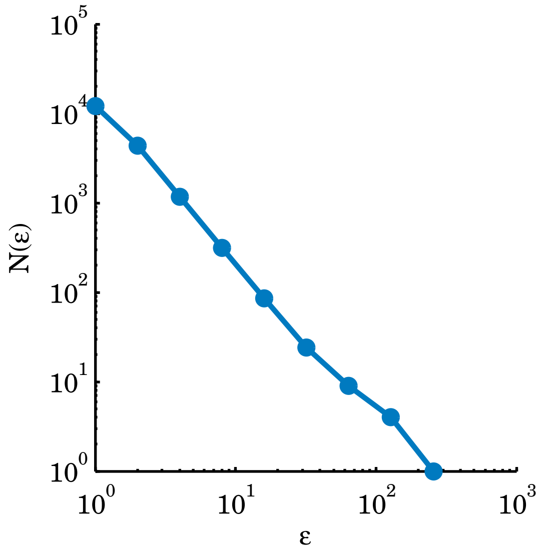


Figure 5: *The number of boxes used to cover a cluster ($N = 80, p = 0.7$) as a function of the box size for the cluster presented in figure 4.*

3.4. Connectivity

Present mask used previously, and 8-connected mask

How does the connectivity influence the final cluster

4. Conclusion

Vat bevindingen van experiment samen

References

[1] F. Moisy. *Computing a fractal dimension with Matlab: 1D, 2D and 3D Box-counting*. 2008. URL: `http://www.fast.u-psud.fr/~moisy/ml/boxcount/html/demo.html`.