University of Hull

600093 - Computational Science

Cellular Automata

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Contents

1 Introduction

This report shall show the steps taken to simulate the growth of cancer cells in a tissue using the Gompertz Equation to model growth.

Growth for individual cells can be modelled using a differential equation so that the number of cells is a function of time. The Gompertz Model of Cell Growth works well in this application because it can accurately model the non exponential nature of cell growth (Tatro n.d.). Once an area has reached it's capacity no more tumour cells can form, hence the cells must begin to move through a tissue. This movement can be simulated using simple random walk algorithm or more complex genetic algorithms.

This paper specifically shall analyse the computational complexity of such models and evaluate the differences between simulation techniques. The underlying implementation shall be investigated, including random algorithms and accuracy of simulations on computer systems.

2 Methodology

- Does the growth reach a steady state? (at t=1200) - Will the rate of growth reach a steady state or will the number increase as you keep increasing the size of the grid? - What will happen if the value of M is changed - pick two values on either side of the value given. - Comment on computational complexity of each method. (note you had been asked to locate common-points which both methods reach)

2.1 Cell Movement

5 marks for definitions of distributions and reasons behind the choice of distribution

The random movement of cells should be modelled using a probability distribution

There are several probability distributions that can be classified as discrete or continuous, we will analyse uniform, bernoulli and beta.

The uniform distribution is usually regarded as a continuous distribution but can also be used to model discrete variables.

Area under the graph is one

$$f(x) = \begin{cases} a & \text{if } x = 1 \\ b & \text{if } x = 0 \end{cases}$$

$$f(x) = \begin{cases} 1 & \text{for } 0 \leq x \leq 1 \\ 0 & \text{otherwise} \end{cases}$$

Uniform distribution Definition of distributions Uniform distributions Bernoulli Distribution

Bias introduced with different distributions

When all directions are equally probable a uniform distribution could be used.

If a Bernoulli distribution was selected, it would introduce a bias to the direction of movement This could be desired in a complex model where factors such as surface tension affect the direction of movement

Movement directions

'Complexity of direction methods'

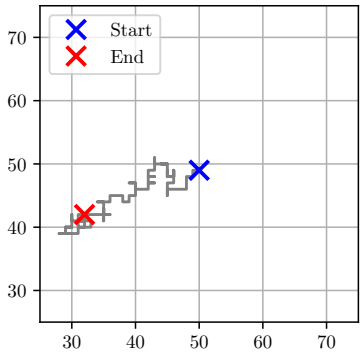

Figure 2.1: Square cell movement plot

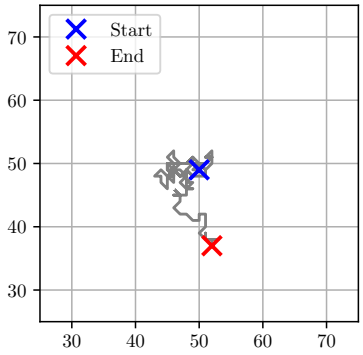

Figure 2.2: Diagonal cell movement plot

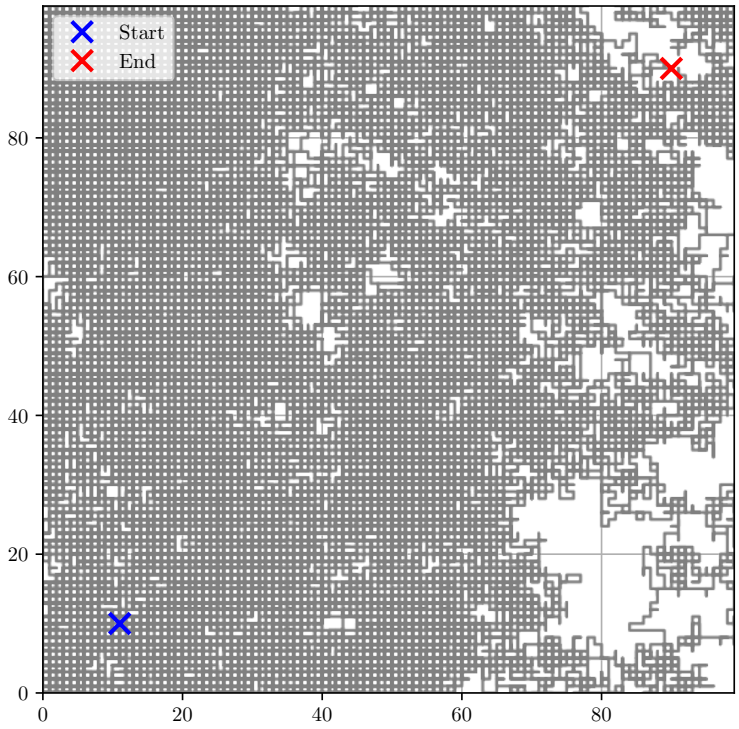

Figure 2.3: Square cell movement plot with fill

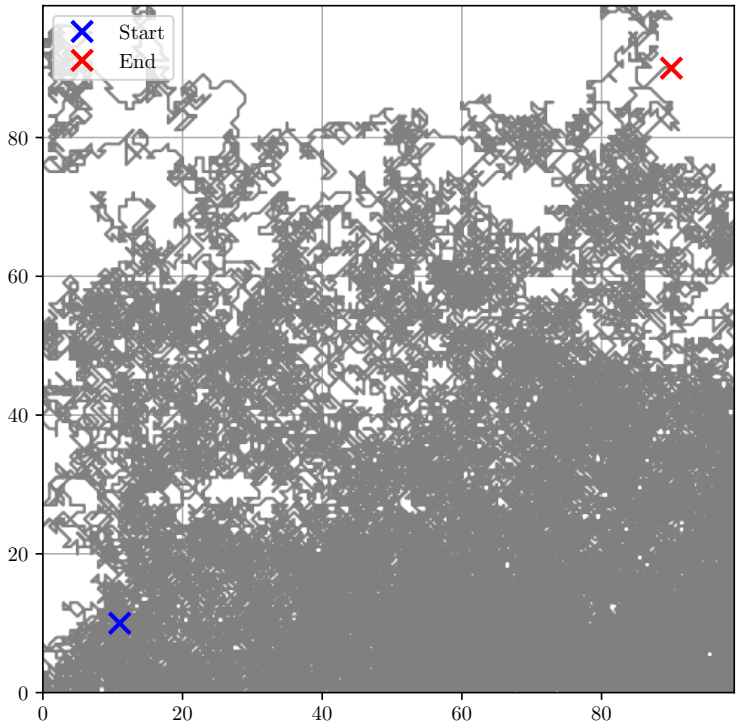

Figure 2.4: Diagonal cell movement plot with fill

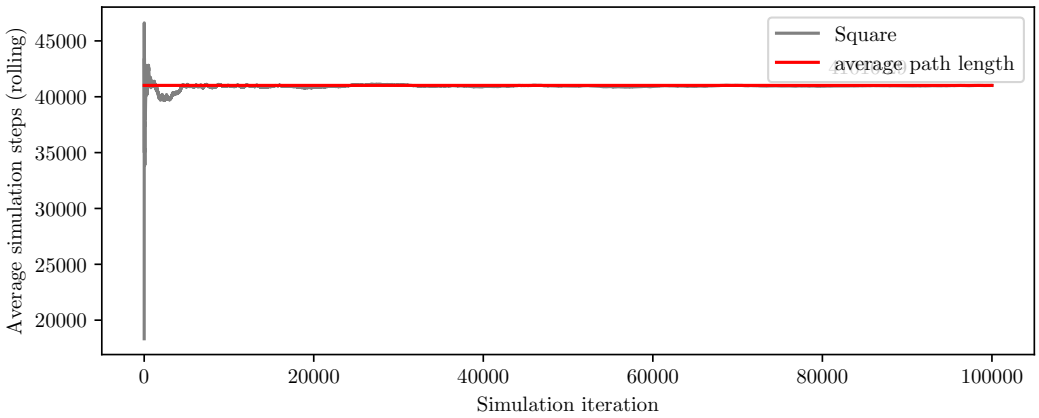

Figure 2.5: Square cell simulation steps

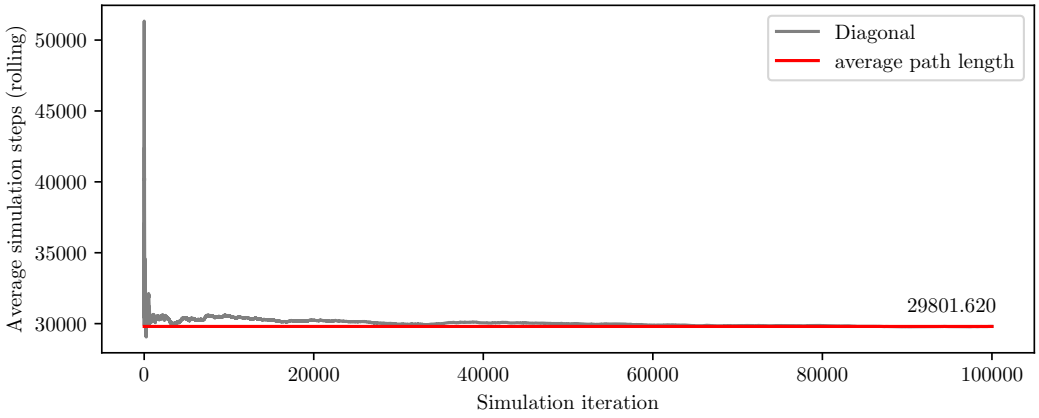

Figure 2.6: Diagonal cell simulation steps

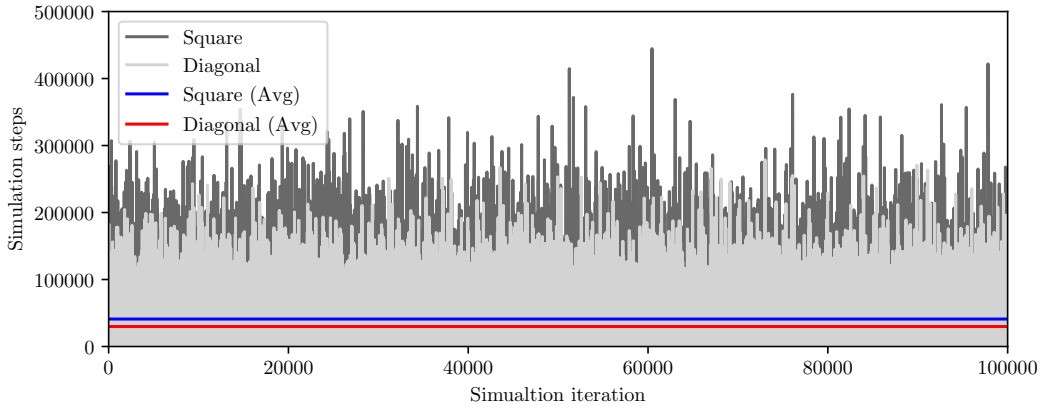

Figure 2.7: Comparison of square and diagonal simulation steps

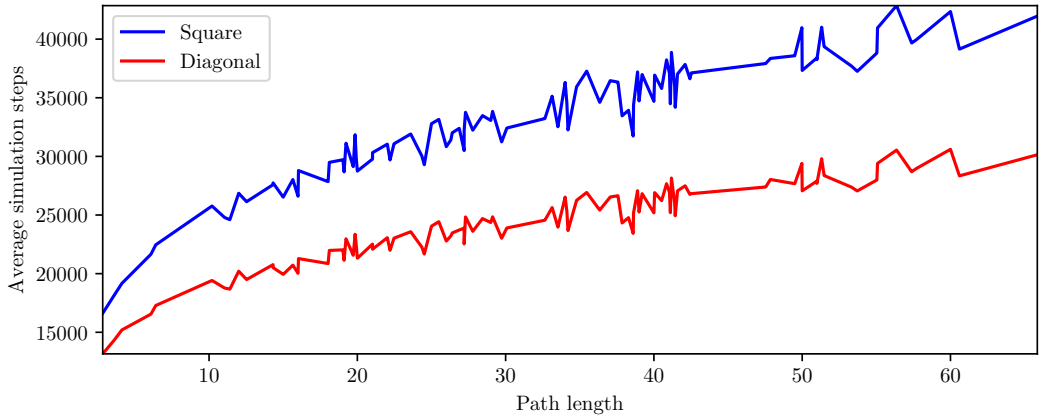

Figure 2.8: Comparison of multiple square and diagonal simulation steps

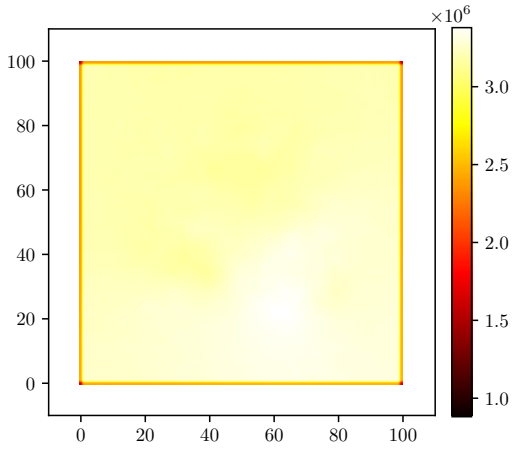

Figure 2.9: Visited cells in square simulation heatmap

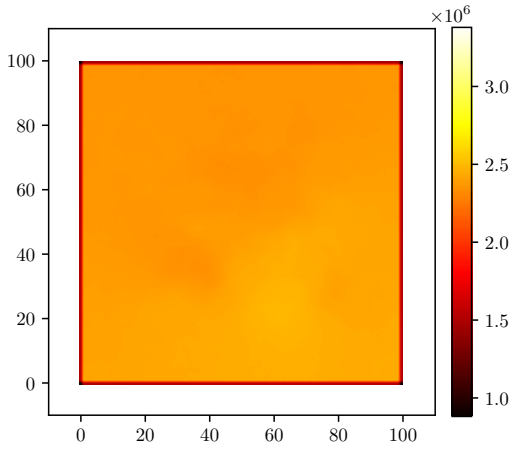

Figure 2.10: Visited cells in diagonal simulation heatmap

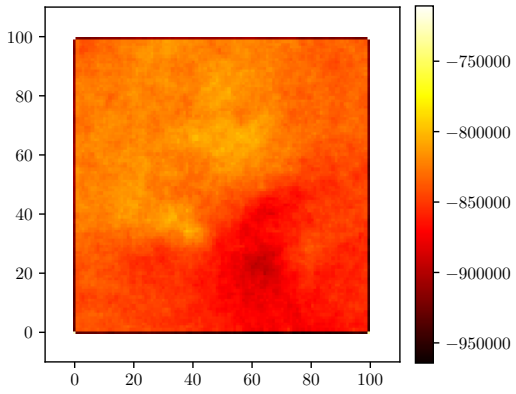

Figure 2.11: Difference in visited cells between square and diagonal simulation heatmap

2.2 Cell Growth

10 marks for basic simulation, 5 marks for showing time to reach final time You can also use analytical methods to do the same

5 marks for the part where you suggest what happens when the value of M changes, and why this is important

$$\frac{dN}{dt} = kNln\left(\frac{M}{n}\right)$$

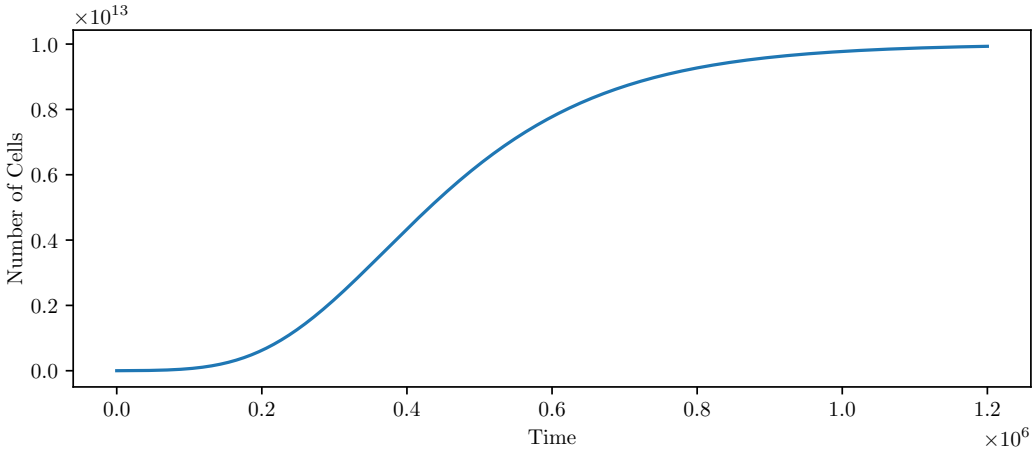

Figure 2.12: Cell growth simulation

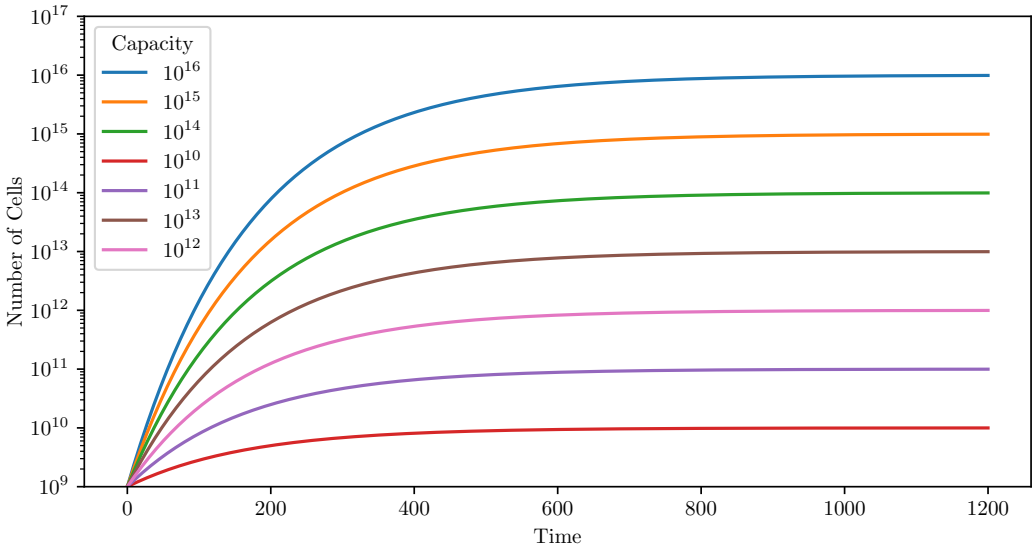

Figure 2.13: Cell growth simulation with different capacity values

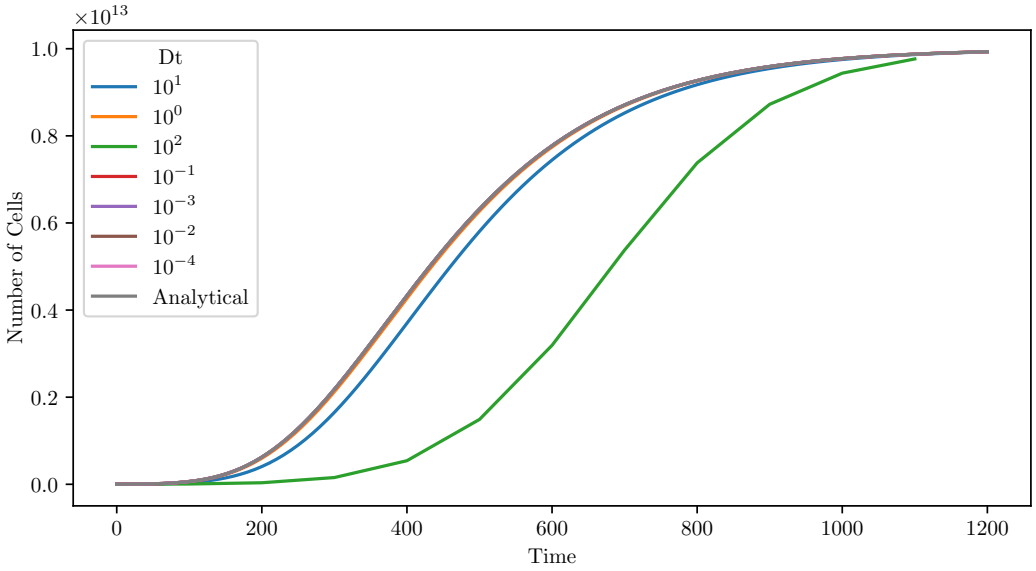

Figure 2.14: Cell growth simulation with different dt values

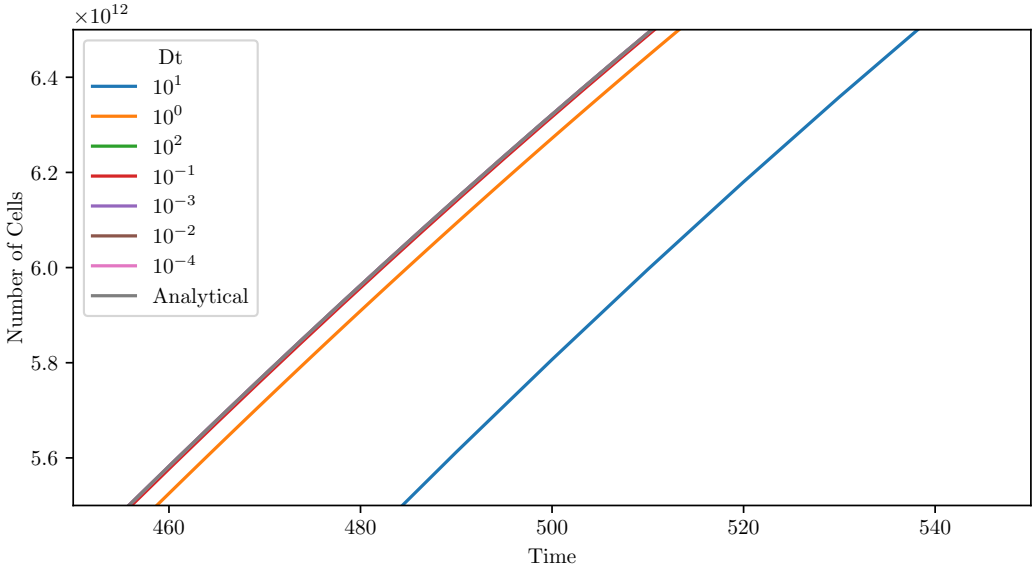

Figure 2.15: Cell growth simulation with different dt values (zoomed)

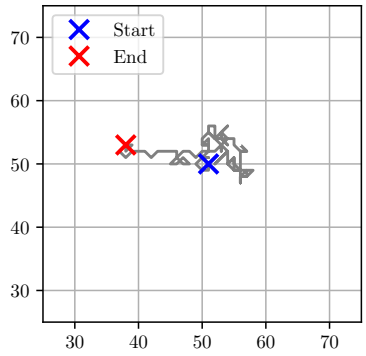

Figure 2.16: Cell growth simulation with diagonal movement

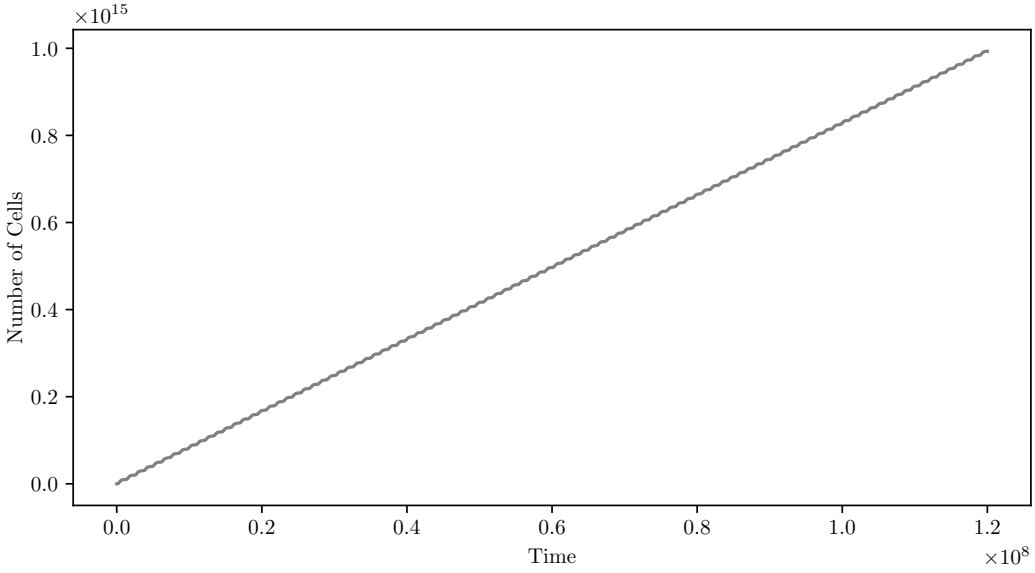

Figure 2.17: Cell growth simulation with diagonal movement (total cells)

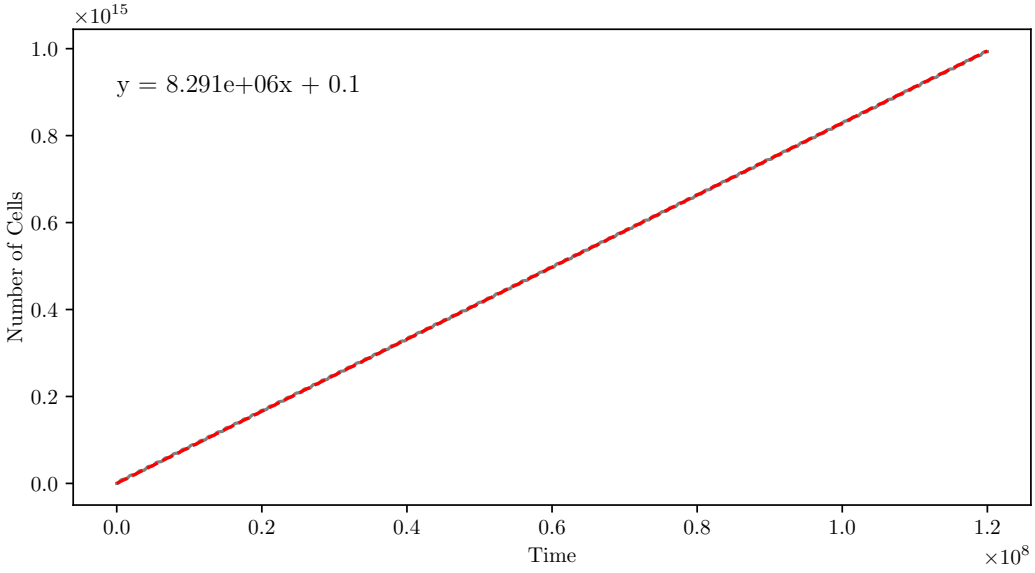

Figure 2.18: Cell growth simulation with diagonal movement (total cells) linear estimation

3 Conclusion

Some text

Also talk about edge processing and limited requirements

List of Figures

List of Tables

Bibliography

Tatro, Dyjuan (n.d.). “The Mathematics of Cancer: Fitting the Gompertz Equation to Tumor Growth”. In: ().