

NORTH-WEST UNIVERSITY

HONOURS THESIS

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# A cellular automata approach to model informal settlement growth

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*“The main problems in life can only be solved when you know what works, what doesn’t and why”*

Charlie Munger, American investor and billionaire

NORTH-WEST UNIVERSITY

# *Abstract*

Faculty of Natural and Agricultural Sciences  
School of Computer Science and Information Systems

Bachelor of Science Honours

**A cellular automata approach to model informal settlement growth**

by Affaan MUHAMMAD

Abstract will come here in the future.

# *Acknowledgements*

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# List of Abbreviations

<b>CA</b>	<b>Cellular Automata</b>
<b>UN</b>	<b>United Nations</b>
<b>StatsSA</b>	<b>Statistics South Africa</b>



# Chapter 1

## Introduction

### 1.1 Project description

The process of urbanisation has been a double edged sword whereby many a people have benefited from it while a lot more have not. The issue of informal settlements is one that covers areas such socio-economic, governance, climate, politics, healthcare, and resource management to name a few.

One of the few approaches to tackle these issues is through good modelling, and understanding the growth of such informal settlements.

This project will employ a cellular automata technique, specifically John Conway's 'Game of Life' to model informal settlement growth in South Africa.

### 1.2 Problem description and background

From the 1950s to the early 2000s the rate of urbanisation has increased 20%, however the amount of people living in inadequate housing, informal settlements, and slums globally is still about 1 billion.[7]

According to the United Nations (UN) the definition of an informal settlement is a dwelling with a lack of security, sanitation, water, living area, and housing durability.[2]

The UN also has a list of 17 Sustainable Development Goals of which number 11 is to create 'Sustainable Cities and Communities'. These goals are such that if even a few can be achieved the other will become easier to achieve as well. Discuss Informal settlement framework(what, where, when, how of informal settlements)

Cellular Automata (abbreviated as CA) is a discrete computational model which is studied in automata theory. The basic components of such a model is a grid which contains cells. Each cell can have a finite number of states it

can take on. An initial state at time ( $t = 0$ ) is assigned to the grid as a whole. For each time interval thereafter the cells change their states according to a predefined set of rules.[6]

Conway's *Game of Life* also known as *Life* was created by the British Mathematician John H Conway in the 1970s and first appeared in the *Scientific American* magazine.[1]

The states the cells in Life can take on are either alive or dead. The rules that govern the states of Life are as follows:

1. Due to underpopulation a cell will die if it has less than 2 neighbours<sup>1</sup>.
2. If a cell has 3 or 2 neighbours it will remain alive in the next cycle.
3. If a cell has more than 3 neighbours it will die.
4. If a dead cell is surrounded by 3 alive cells it will become alive in the next cycle.

Using such a set of rules this project will embark on creating a model that will accurately predict informal settlement growth in South Africa.

Some limitations have been noted in using CA to model urban growth. These include creating tradeoffs between flexibility and simplicity for the transitional rules. At the same time other opportunities in CA models also present themselves for study such as calibration, stochastic components, and cell types.[5]

## 1.3 Aims and objectives

### 1.3.1 Aims

- Create a sound mathematical and statistical model
- Apply model to Life to predict growth of informal settlements

### 1.3.2 Objectives

- Conduct the relevant literature reviews
- Get access to relevant maps needed regarding informal settlements

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<sup>1</sup>These are cell which are alive and are located around the current cell

- If above step fails, create own maps
- Create an application that allows a map to be added and a grid to be placed for simulating Life.
- Create a mathematical and statistical model to provide an initial state
- Apply initial state to the map
- Iterate and monitor growth output
- Calculate accuracy of model by comparing maps from different time periods

## 1.4 Procedures and methods

### 1.4.1 Paradigms

When a research project is conducted it usually fall under specific paradigms. A research paradigm is defined as "a set of commonly held beliefs and assumptions within a research community about ontological, epistemological, and methodological concerns." [4]

The research paradigms are as follows:

- Positivism
- Interpretivism
- Critical realism
- Critical theory

*Positivism* stipulates that reality exists independent of human experiences and actions. It further states that knowledge can be gained from experimentation and observation. Lastly, its strategy focuses on surveys and experiments.

*Interpretivism* stipulates that a 'social world' is created by humans who conduct social actions and give meaning to the actions. It further states that knowledge can be gained by actively partaking in the phenomenon and the people who create it. Lastly, its strategy focuses on ethnography, action research, and case studies.

*Critical realism* stipulates that science is not only about observation and there exist mechanisms that are not observable but generate observable behaviours and events. It prefers reduction which is a methodological approach. It begins from unexplained phenomenon and moves to proposing different mechanisms that explain the phenomenon.

*Critical theory* stipulates that understanding should not be the only goal and human emancipation should be another driving force of research. It strives to expose oppressing effects of political ideologies, cultural practices, and academic theories.

This project will fall under a combination of Positivism and Interpretivism. The study will be on social factors combined with infrastructure and other related factors that will assist in creating a suitable or viable model.

### 1.4.2 Artefact Life Cycle Philosophies

When an artefact is developed it can take on different methodologies in its approach. Below is a table that has a few such approaches. The table is a modified example from another source[3].

Method	Description
Crystal Clear	Emphasis on 'osmotic communication'
Disciplined agile delivery (DAD)	Incremental and iterative
Extreme Programming (XP)	Concrete commitments
Kanban	Incremental improvements
Lean Software Development	Deliver value
Scrum	Feedback and self management, iterative
Rational Unified Process (RUP)	Iterative cycles. Each cycle has 4 phases Inception, Elaboration, Construction, and Transition.
Waterfall	Linear sequential phases
Top-down or Bottom-up	Composition and Decomposition

TABLE 1.1: Overview of development methodologies

The approach for this project will be Scrum. As it is perfect for incremental changes made to the model that will be created.

### 1.4.3 Collaboration

A comparative approach will also be taken by integrating work from a fellow student's project. The student will be focusing on CA modelling from a swarm intelligence approach.

## 1.5 Project management

### 1.5.1 Project Plan

Self management will be key in this project and all its endeavours.

Important dates include:

- 18 April: Submission of project planning and research proposal
- 13 June: Submission of literature study
- 21 October: Demonstrations of artefact and poster
- 1 November: Submission of complete documentation

A basic Gantt chart with overview of the project is shown below

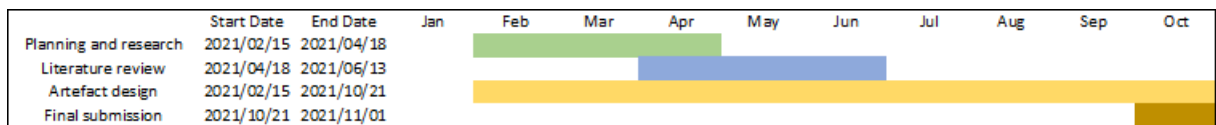


FIGURE 1.1: Project plan as represented by a Gantt chart

### 1.5.2 Scope and Limitations

The scope for this project is the creating, testing, and computing accuracy of the model. Further research will have to be done in other projects at a later stage. The current limitations for this project is time as the deadline for the final presentations and artefact design is in November 2021. No other limitations with regards to financing or resources exists.

Risk analysis was conducted and all the risks involved are listed below:

- Model is not viable
- Model is not accurate enough
- Time is not enough to conclude research

## 1.6 Development platform, resources, and environments

Datasets: Still under procurement from third parties (AfriGIS, StatsSA, GeoTerra Image).

Operating system: Windows and Linux

Programming language: Python will be used

IDE: No specific. However current tools include Jupyter Notebooks, Google Colaboratory, and basic text editors.

The reason why these tools were chosen is for their versatility, ease of access, plethora of libraries and additional packages that can be imported as needed.

## 1.7 Ethical and legal implications

The only legal and ethical implications for this project is in the form of third party data access. The ethics form is attached in Appendix [A](#)

## 1.8 Provisional chapter division

Chapter 1 - Introduction

This will cover the outline of the project.

Chapter 2 - Literature Review

The focus of this section is to delve deeper into the relevant literature for this project and give a thorough analysis.

Chapter 3 - Artefact Design

The focus of this section will be on the complete processes involved in creating the model for this project.

Chapter 4 - Discussion

The focus in this section will be to analyse the results gained from the model and compare them to the relevant literature discussed before. Further assumptions and claims are also discussed here. Lastly, comparisons with other students' work will be discussed.

Chapter 5 - Conclusion

The research project is closed off and further insights for the future can also be given. Aim and objectives are re-examined to ensure if they were achieved.

# Appendix A

## Ethics Form

ITRI 671 Research ethics form: Honours project

**Name:** Affaan Muhammad

**Title of project:** A cellular automata approach to model informal settlement growth

**Supervisor:** Prof Hennie Kruger

**Starting and end dates of project:** 15 Feb 2021 – 1 Nov 2021

1. Have you read the information available related to research ethics (Chapter 5 of Researching Information Systems and Computing; BJ Oates and Chapter 13 of Writing for computer science, J Zobel; Manual for post graduate studies, available on efundi)?	Yes ✓	No
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2. Do you make use of people as source of data in your project (for example the completion of questionnaires or evaluation of products)?	Yes	No ✓
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3. Are there any aspects of your research that you need permission from another party to use (for example use of property or tools)? If yes, provide more detail.	Yes ✓	No
---	-------	----

4. Describe your research question and give a short description of your plans for the collection of data.  <b>Access for maps from third parties such as AfriGIS, StatsSA, and GeoTerra Image.</b>
--

5. Describe how you plan to provide information about yourself and the goals of your research to participants.

**N/A**

6. Describe what methods you will use to get permission from participants in your study.

**N/A**

7. Will you be able to ensure that participants' information will be used in an anonymous, private and confidential way? How?

**N/A**

Yes

No ☒

8. Are there any foreseeable risks of damage (physical, social or psychological) to participants or the environment? If you answer yes, give detail of the preventative measures you will follow.

**N/A**

Yes

No ☒



9. Are there any foreseeable risks to the NWU, for example lawful actions that may follow the research, or damage to the image of the university? If yes, give detail.  <b>N/A</b>	Yes	No <input checked="" type="checkbox"/>
10. Are there any other ethical issues that may occur during the execution of the research (for example conflicting interests)? If yes, provide detail and explain how you plan to handle them.  <b>N/A</b>	Yes	No <input checked="" type="checkbox"/>

I declare that the information contained in this form is accurate. I have attempted to identify the risks that may arise in conducting this research and acknowledge my obligations and the rights of the participants. I confirm that the research will be conducted in line with all University, legal and ethical standards.

**Name of student:** Affaan Muhammad  
**Signature:** *Signed Affaan Muhammad*  
**Date:** 18 April 2021

**Name of study leader:** Prof Hennie Kruger  
**Signature:**  
**Date:**

**Name of additional moderator:**  
**Signature:**  
**Date:**

# Appendix B

## Research Proposal

### SUBJECT GROUP COMPUTER SCIENCE AND INFORMATION SYSTEMS

#### Research Proposal for Honours project

The student and the supervisor must consult the *Manual for Postgraduate Studies* prior to writing the research proposal. The *Manual for Postgraduate Studies* explains in detail what is expected at each of the subheadings below. The proposal should not be longer than 5 pages.

The Subject Group requires that the research proposal will be submitted through the use of this form and in the format below. Please complete using a computer.

#### 1 Student initials, surname and student number

Initials  Surname  Student number

#### 2 Degree for which student is registered

#### 3 Name of supervisor

Initials and surname

#### 4 Proposed title

Title (preferably not more than 12 words)	A cellular automata approach to model informal settlement growth
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#### 5 Problem statement and substantiation

Provide the theme and link with gaps in the literature and recent research in the area. Indicate the research question, its actuality and how the research will endeavour to answer the question.

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#### 6 Research aims and objectives

Provide the different general as well as the specific aspects which will form part of the research.

<p>Aims are to create a sound mathematical and statistical model thereafter apply the model to Life to predict growth of informal settlements.</p> <p>Objectives are firstly to get access to the relevant maps and datasets. If this is not achievable other methods such as creating it ourselves will be employed. Thereafter creating and applying the model to the maps to predict growth. Lastly compare accuracy.</p>
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#### 7 Basic hypothesis (where applicable)

N/A
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## 8 Method of investigation

### 8.1 Literature study

Provide an indication only of which literature will be used in the study with a few key references. A summary of the literature is not required here.

### 8.2 Methods of investigation

The proposed design, data acquisition, procedures, data processing, funding sources (but not a budget), mathematical methods, computer methods, etc.

## 9 Provisional chapter division

Here it should be clear that there was proper reflection on the appearance of the final product (mini dissertation). Provide provisional titles of the various chapters, with a brief outline of the planned content of each.

1. Introduction
2. Literature Review
3. Artefact Design
4. Discussion
5. Conclusion

## 10 Literature references

Provide complete references to the literature referenced to in this proposal only.



Student

Supervisor

18 April 2021

Date

# Bibliography

- [1] Martin Gardner. "MATHEMATICAL GAMES". In: *Scientific American* 223.4 (1970), pp. 120–123. ISSN: 00368733, 19467087. URL: <http://www.jstor.org/stable/24927642>.
- [2] *Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable - SDG Indicators*. URL: <https://unstats.un.org/sdgs/report/2016/goal-11/>.
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- [4] Paul Johannesson and Erik Perjons. *An introduction to design science*. Springer, 2014. ISBN: 9783319106328.
- [5] Inés Santé et al. "Cellular automata models for the simulation of real-world urban processes: A review and analysis." In: *Landscape and Urban Planning* 96.2 (2010), pp. 108 –122. ISSN: 0169-2046.
- [6] Tommaso Toffoli and Norman Margolus. *Cellular automata machines : a new environment for modeling*. Cambridge, Mass: MIT Press, 1987. ISBN: 9780262200608.
- [7] *World Cities Report 2016 Urbanization and Development: Emerging Futures*. United Nations Pubn, July 2016. 260 pp. ISBN: 9211327083.