Software Requirements Specification for Game of Continuous life: An Advanced Version of Conway's Game of Life

Baptiste Pignier

February 26, 2025

Contents

Revision History

Date	Version	Notes
01/02/2025	1.0	First release

1 Reference Material

This section records information for easy reference.

1.1 Table of Units

No special units will be used

1.2 Table of Symbols

No special symbols will be used

1.3 Abbreviations and Acronyms

symbol	description
A	Assumption
DD	Data Definition
GD	General Definition
GS	Goal Statement
IM	Instance Model
LC	Likely Change
PS	Physical System Description
R	Requirement
SRS	Software Requirements Specification
TM	Theoretical Model

2 Introduction

Conway's Game of Life [Gardner (1970)] is the result of applying simple rules of evolution. It allows the observation of an emerging phenomenon called cellular automaton. These cellular automata can be made more complex by making the rules of evolution more complex to observe more complex structure. For example, evolutionary rules can be more permissive by allowing the death or birth of a cell under several conditions. This section will develop the characteristics of the SRS document, more than those of the project itself.

2.1 Purpose of Document

The purpose of this Software Requirements Specification (SRS) document is to define the functional and non-functional requirements of the project in a clear and structured manner.

This document serves as a communication tool between stakeholders, including clients, developers, and project managers, to ensure a shared understanding of the project's scope and objectives.

2.2 Scope of Requirements

This project aims to develop a simulation in a simplistic artificial environment. As such, the simulated elements will not be governed by any other physical law than those implemented by the environment. No assumptions will be made compared to a classic physical simulation model. The presentation of assumptions is therefore not applicable to this project.

2.3 Characteristics of Intended Reader

Reviewers of this document should have undergraduate mathematical knowledge as well as a good understanding of the physical approximations that will be implemented. He will also need to know the graphics libraries used for this project.

2.4 Organization of Document

This document is structured as follows. Section 3 covers general information about the project. Section 4 explains this information in detail. Section 5 covers the project requirements. Section 6 lists the likely changes and Section 7 lists the unlikely changes. Section 8 presents the requirements traceability. Section 9 presents the project development plan.

3 General System Description

This section provides general information about the system. It identifies the interfaces between the system and its environment, describes the user characteristics and lists the system constraints.

3.1 System Context

- User Responsibilities:
  - The user's sole responsibility is to choose values for the parameters from those proposed by the interface.
- Game of Continuous life Responsibilities:
  - Provide the user with a simulation that faithfully matches the data the user has given to the system.

This software is intended for educational and/or artistic use. As such, its components must not be used for uses requiring security or critical requirements.

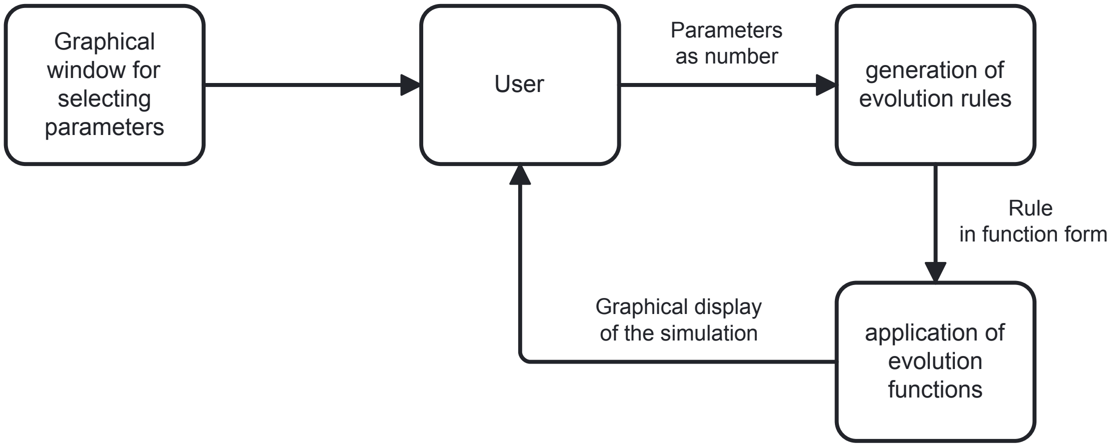

Figure 1: System Context

3.2 User Characteristics

The user does not need any special knowledge to use the program. All useful information will be provided by the graphical window for selecting parameters.

3.3 System Constraints

No system constraints are identified for this project.

4 Specific System Description

This section first presents the problem description, which gives a high-level view of the problem to be solved. This is followed by the solution characteristics specification, which presents the assumptions, theories, definitions and finally the instance models.

4.1 Problem Description

Game of Continuous life aims to demonstrate the emergence of macroscopic behavior and structure from microscopic generation and evolution rules.

4.1.1 Terminology and Definitions

This subsection provides a list of terms that are used in the subsequent sections and their meaning, with the purpose of reducing ambiguity and making it easier to correctly understand the requirements:

- A cell : A portion of a display area that contains one or more numbers that represent its value(s).t

- The grid : A cell grid as small as possible to simulate a continuous space, such as a computer screen with pixel. The dimensions of this grid are as large as desired.
- Neighbourhood : Area around a cell, consisting of the cells in that area. This area is delimited by a neighbourhood function
- Neighbourhood function: Function that takes a cell as input and returns the cells in its neighbourhood.
- Growth function: Function that takes a cell as input and modifies the value(s) contained in the cell based on its neighbourhood.
- Structure: Finite set of cells in prolonged interaction.
- Channel: The definition is the same as in the context of digital images. If the cell has 3 independent values, it can be seen as a color, composed of three channels: RBG

4.1.2 Physical System Description

The physical system of Game of Continuous life, as shown in Figure 1, includes the following elements:

PS1 : Cells

PS2 : Growth function

PS3 : Neighbourhood function

4.1.3 Goal Statements

Given the input parameters defined in 4.2.6, the goal statements are:

GS1: Create the Growth function

GS2: Create the Neighbourhood function

GS3: Apply iterative evolution

GS4: Define interesting evolution

GS5: Find some interesting evolution

4.2 Solution Characteristics Specification

The instance models that govern Game of Continuous life are presented in Subsection 4.2.5. The information to understand the meaning of the instance models and their derivation is also presented, so that the instance models can be verified.

4.2.1 Assumptions

Since the project does not aim to model a physical system by simplifying it, no assumptions of physical simplification will be made. Therefore, this section is not relevant.

4.2.2 Theoretical Models

RefName: **TM:GF**

Label: Gauss function

Equation: $G(x) = A \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right)$

Description: This formula will be used for applying the growth and neighbourhood function on a cell. A is the amplitude of the curve. μ and σ define the shape of the curve.

Notes: None.

Source: https://en.wikipedia.org/wiki/Gaussian_function

Ref. By:

Preconditions for TM:GF: None

Derivation for TM:GF: Not Applicable

RefName: **TM:LO**

Label: Laplacian Operator

Equation: $\nabla^2 u_{i,j} = u_{i+1,j} + u_{i-1,j} + u_{i,j+1} + u_{i,j-1} - 4u_{i,j}$

Description: This formula is the discrete approximation of the second derivative. This model models the interactions between two concentration values. It will be used only if the simulation includes multiple channels.

Notes: None.

Source: https://en.wikipedia.org/wiki/Finite_difference#Multivariate_finite_differences

Ref. By:

Preconditions for TM:LO: None

Derivation for TM:LO: Not Applicable

RefName: **TM:NL**

Label: Reaction-Diffusion equation

Equation: $\frac{\partial u}{\partial t} = D_u \nabla^2 u + f(u, v)$

Description: This model models the interactions between two concentration values. It will be used only if the simulation includes multiple channels.

Notes: None.

Source: https://www.karlsims.com/rd.html

Ref. By:

Preconditions for TM:NL: None

Derivation for TM:NL: Not Applicable

4.2.3 General Definitions

No additional assumptions will be made to modify the equations used. As such, the models are described in section 4.2.2. This section is not relevant.

4.2.4 Data Definitions

Number	DD1
Label	**Concentration**
Symbol	u_t
SI Units	
Description	The concentration of species u in a given cell, at a given time t.
Sources	
Ref. By	IM2, IM1

4.2.5 Instance Models

This section transforms the problem defined in Section 4.1 into one which is expressed in mathematical terms. It uses concrete symbols defined in Section 4.2.4 to replace the abstract symbols in the models identified in Sections 4.2.2 and 4.2.3. The goal GS1 are solved by IM2.

Number	IM1
Label	**Reaction Diffusion**
Input	D_u,D_v, u_t, v_t, F, k
Output	$u_{t+1} = u_t + D_u \cdot \nabla^2 u_t + u_t \cdot v_t^2 + F(1 - u_t)$ $v_{t+1} = D_v \nabla^2 v_t + u_t \cdot v_t^2 - (F + k)v_t$
Description	D_u and D_v are the diffusion rate for u and v. u_t and v_t are the concentrations of elements u and v at time t F is a real number that represents the feed rate and k is a real number that represents the kill rate.
Sources	`https://visualpde.com/nonlinear-physics/gray-scott.html`
Ref. By	4.2.2

Number	IM2
Label	**Growth function**
Input	u_t, α, β
Output	$u_{t+1} = -1 + 2\exp\left(-(\frac{u_t - \alpha}{\beta})^2\right)$
Description	We'll use a Gaussian function to start. We want an amplitude between -1 and 1 to simplify the calculations.
Sources	None
Ref. By	None

4.2.6 Input Data Constraints

Constraints on the input data will be set by the program itself, via a selection interface. The input parameters are decimal numbers whose precision and limits will be determined in a future version of the document.

4.2.7 Properties of a Correct Solution

This program does not provide a "solution", but a visualization of the events induced by the parameter choices made by the user. This section is not relevant.

5 Requirements

This section provides the functional requirements, the business tasks that the software is expected to complete, and the nonfunctional requirements, the qualities that the software is expected to exhibit.

5.1 Functional Requirements

R1: The system shall accept input data from the user before the simulation starts

R2: The system must allow modification of input data during simulation

R3: The parameter selection interface graphically displays the impact of the entered values on the functions used by the simulation.

R4: The program must calculate step by step the results of applying the growth function to each cell.

R5: The output should allow the user to correctly distinguish between concentrations of value.

5.2 Nonfunctional Requirements

NFR1: **Accuracy** The accuracy of the simulation must be such that no display inaccuracy can be detected.

NFR2: **Usability** All users should be able to use this software easily.

NFR3: **Maintainability** The effort required to make any of the likely changes listed for Game of Continuous life should be less than ϵ of the original development time.

NFR4: **Portability** This program should run on all operating systems supported by the libraries used.

5.3 Rationale

It is clear that significant mathematical and physics skills are required to simulate a biologically accurate cellular automaton development environment. Not having such skills, I limit myself to a basic but correct and useful implementation of a cellular automaton simulation.

6 Likely Changes

LC1: Implementing multiple value channels

LC2: Stochastic equation implementation for the evolution rules

7 Unlikely Changes

None

8 Traceability Matrices and Graphs

The purpose of the traceability matrices is to provide easy references on what has to be additionally modified if a certain component is changed. Every time a component is changed, the items in the column of that component that are marked with an "X" may have to be modified as well. Table 1 shows the dependencies of general definitions and instance models with each other. Table 2 shows the dependencies of instance models and requirements on each other.

	GD??	GD??
IM2	X	
IM1		X

Table 1: Traceability Matrix Showing the Connections Between Items of Different Sections

	IM2	IM1
R4	X	X

Table 2: Traceability Matrix Showing the Connections Between Requirements and Instance Models

Auxiliary Constants	Values
ϵ	$\frac{1}{20}$

9 Values of Auxiliary Constants

References

Martin Gardner. The fantastic combinations of john conway's new solitaire game "life". *Scientific American*, 223(4):120–123, octobre 1970. doi: 10.1038/scientificamerican1070-120.